Tagging Amongst Friends: An Exploration of Social Media Exchange on Mobile Devices

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Abstract

Mobile social software tools have great potential in transforming the way users communicate on the move, by augmenting their everyday environment with pertinent information from their online social networks. A fundamental aspect to the success of these tools is in developing an understanding of their emergent real-world use and also the aspirations of users; this thesis focuses on investigating one facet of this: the exchange of social media. To facilitate this investigation, three mobile social tools have been developed for use on location-aware smartphone handsets. The first is an exploratory social game, 'Gophers' that utilises task oriented gameplay, social agents and GSM cell positioning to create an engaging ecosystem in which users create and exchange geotagged social media. Supplementing this is a pair of social awareness and tagging services that integrate with a user's existing online social network; the 'ItchyFeet' service uses GPS positioning to allow the user and their social network peers to collaboratively build a landscape of socially important geotagged locations, which are used as indicators of a user's context on their Facebook profile; likewise 'MobiClouds' revisits this concept by exploring the novel concept of Bluetooth 'people tagging' to facilitate the creation of tags that are more indicative of users' social surroundings. The thesis reports on findings from formal trials of these technologies, using groups of volunteer social network users based around the city of Lincoln, UK, where the incorporation of daily diaries, interviews and automated logging precisely monitored application use. Through analysis of trial data, a guide for designers of future mobile social tools has been devised and the factors that typically influence users when creating tags are identified. The thesis makes a number of further contributions to the area. Firstly, it identifies the natural desire of users to update their status whilst mobile; a practice recently popularised by commercial 'check in' services. It also explores the overarching narratives that developed over time, which formed an integral part of the tagging process and augmented social media with a higher level meaning. Finally, it reveals how social media is affected by the tag positioning method selected and also by personal circumstances, such as the proximity of social peers.

Acknowledgements

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Related Publications

Casey, S., and Rowland, D. Gophers: Socially Oriented Pervasive Gaming. GDTW '06 Games Design and Technology Workshop, ACM Press (2006).

Casey, S., and Rowland, D. Socially Promiscuous Mobile Phone Pets. Artificial and Ambient Intelligence Conference (2007).

Casey, S., Kirman, B., and Rowland, D. The Gopher Game: A Social, Mobile, Locative Game with User Generated Content and Peer Review. ACE '07 Proceedings of the International Conference on Advances in Computer Entertainment Technology, ACM Press (2007), 9-16.

Casey, S., Lawson, S., and Rowland, D. ItchyFeet: Motivations for Urban Geospatial Tagging. NordiCHI '08 Proceedings of the 5th Nordic Conference on Human-computer Interaction: Building Bridges, ACM Press (2008), 435-438.

Casey, S., and Lawson, S. Connecting with Gophers. Keho: The Place for Presence Research 4 (2008), 20-21.

Kirman, B., Casey, S. Lawson, S., and Rowland, D. User Powered Games for Research. GDTW '08 Games Design and Technology Workshop, ACM Press (2008).

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Additional Material

A number of definitions have been used throughout the dissertation. These are used to reference online appendix material and identify trial participants.

Online Appendix: An appendix of supporting documents is hosted on the web. Various URLs that relate to the site are referenced within the text, as defined below:

ID	URL	Description
	http://lisc.lincoln.ac.uk/sean/	Main appendix webpage.
A01	http://lisc.lincoln.ac.uk/sean/thesis/	Dissertation text and related publications available for download.
A02	http://lisc.lincoln.ac.uk/sean/code/	Application code available for download.
A03	http://lisc.lincoln.ac.uk/sean/screens/	Screenshots of the technologies that were implemented.
A04	http://lisc.lincoln.ac.uk/sean/photos/	Photos of the applications in use during testing phase and trials.
A05	http://lisc.lincoln.ac.uk/sean/trials/	Supporting trial documents, including disclaimers, original questionnaire texts, instructions and advertisements.
A06	http://lisc.lincoln.ac.uk/sean/analysis/	Documents that relate to the analysis of the trial data.

Trial Participants: Throughout the discussion users are referred to in shorthand using identifiers U1-16. Similarly, trial groups are referred to using G1-4.

1. Introduction

Mobile phones are emerging as the ubiquitous social tool of the 21st century. These devices have rapidly outgrown their primary function of voice communication and are being used increasingly as a platform to share social presence (and receive updates) whilst the user is mobile. In the past, technologies such as SMS text messaging offered an interim solution to providing this functionality, demonstrated by its use as a social coordination technology [130]. The desire of mobile users to share social updates can be measured by the extraordinary demand of consumers to use this once expensive technology. The recent evolution of mobile handsets into portable, multi-sensory computing devices which offer continuous mobile connectivity – in unison with a plethora of mobile social services on the horizon – suggest this technology is likely to be superseded in the near future by more socially aware computing tools, which will allow smartphones to become true mobile social networking portals. In recent years, a number of enabling technologies have entered the public domain which are also driving this change, such as location based services, GPS systems, geotagging, flat rate, ubiquitous mobile data access, Web2.0 computing and User Generated Content (UGC), combined with an explosion of popularity in social networking services.

The vision of a socially aware mobile handset is currently being realised by the downloadable mobile software or 'apps', offered by leading online social networking providers, that allow users to access and communicate with their online social peers on the move. The eagerness of consumers to adopt these new mobile technologies is clear and users are becoming accustomed to them through the massive popularity of smartphone and tablet devices, based on iOS and Android platforms [1]. This first generation of mobile social networking software offers a connection between a user's physical world and their digital social networks, but only a weak link, since it fails take into account the real-world context of users. In parallel to this, more pervasive mobile social networking tools are emerging, which are designed for mobile use from the outset. This is a diverse application area, which is only just becoming established. The tools, frequently referred to as Mobile Social Software (MoSoSos [194]), project a digital social layer over a user's everyday activities and offer a range of functionality, such as mobile presence updates, friend finders, opinion sharing, social reviews and information on local services. It is this new breed of tools that the dissertation research focuses on.

It is expected that future generations of these tools will exploit readily available mobile device data, to offer an approach much more ubiquitous to mobile communications and integral to the phones features; for instance, seeing the phone book replaced with groups of contextually relevant peers and the SMS inbox prioritised by real-time social and contextual relevance to the user. This concept has been demonstrated by research studies such as [160] and the seamless integration of social network data with mobile functionality is now starting to be showcased by mobile manufacturers, to varying degrees of success, for example in the HTC Sense UI and in Windows Mobile 7 devices [107][221].

Mobile social communications is evidently at a point of exceptional change. It is therefore vital that application designers understand the way users communicate using mobile social software tools in the real world and explore any issues around them, in order to inform this change. A key aspect to this communication is the exchange of social media. It is within this area that the thesis research questions are placed.

1.1. Motivations

The motivations behind the research progressed during the course of the trials. The first study was inspired by a number of pervasive mobile gaming studies that were utilising contextual data and compelling, real-world narratives to create engaging gaming experiences [15][24][148][153]. These were typically large, orchestrated affairs, that required significant effort to develop and host. In unison with this, the motivation of users to communicate via microblogging and tagging services, the emergence of web games for human computation [213][214] and improvements in mobile smartphone technology, highlighted a clear opening to encapsulate these trends in a mobile game. This informed the research aims defined in section 3.2.1, which were realised by the development of an exploratory game study; 'Gophers'.

During the course of this trial, a number of relevant developments took place, such as the emergence of mobile websites allowing access to social networking services on the move, the introduction of GPS-enabled smartphones and the release of social networking APIs that allowed applications to be developed for these networks of users (depicted on timeline in figure 2.1). It was clear these changes could have a significant impact on social networking and mobile communication practices and so, enhancing mobile social networking tools using geotagged social media felt like a natural progression. This led to refinement of the research aims to explore the more specific area of mobile semantic tag exchange; a particularly successful aspect to the Gophers study. The aims, detailed in sections 3.2.2 and 3.2.3, led to the development of another pair of studies; ItchyFeet and MobiClouds.

The research presented in the latter two studies was also motivated by the lack of understanding that currently exists in this changing sector and in how MoSoSos can be used in the real world. These applications are still an emerging area of technology and as such, a number of unexplored issues can be found. Firstly, new social technologies are being developed when research does not fully understand their real-world use, their effects on real-world interaction, or the aspirations of users. Also, there are questions of ethics, long term use and social exclusion. Finally, little is known about the type of social media exchanged in these scenarios, what influences user decisions when creating this media and how designers should utilise and present this to users.

If more was understood about these shortcomings, it is suggested that mobile social applications could be better designed in future to be more accommodating of them. It is the exploration of these factors that has motivated this research more broadly.

1.2. Research Question

The main research question addressed by this dissertation is based on the motivations for conducting the research in itself:

R01: *How do users exchange social media in mobile social software services and what are the factors that influence them?*

There are also a number of sub-aims that will be further defined in section 3. These relate to the individual studies that were developed for the dissertation:

Study 1: (i) *Assess the suitability of using mobile social games as a social platform for collecting useful, situated content about the world which bears a social and locative relevance.* (ii) *Evaluate the suitability of task based non-linear play and social agents as a way to direct the exchange of mobile social media.* (iii) *Measure the success of using gaming mechanics, credit-based economies and peer review as incentives to delivering good quality social media.*

Study 2: (i) *Devise a test framework based around mobile social geotagging that allows for logging and monitoring of user interaction.* (ii) *Discover typical usage patterns exhibited and* *document the effects of real-world influences on user interaction.* (iii) *Assess the relevance of peer tag sharing as a way to record semantic meaning for real-world locations.*

Study 3: (i) *Demonstrate the concept of 'people tagging' as a vehicle for positioning mobile social media and assess it's effectiveness in integrating with social surroundings and incorporating non-application users.* (ii) *Compare the use of Bluetooth people tagging with locative geotagging of social media.*

1.3. Thesis Themes

In addition to the overarching research question, a number of themes exist that are encapsulated by the research studies. Primarily, all of the studies are based around the *sharing and delivery of knowledge between users*. This initially comprises of text, photo and tag content, but this is refined to consider tags alone in latter studies. Another theme explored is *the mobilisation of social games* and social media is initially presented to the user via virtual social agents in an entertainment setting; latter studies focus on the exploration of a user's everyday environment through social tagging services. A final theme is the *promotion of discourse amongst friends*. This is realised in the studies through collaborative identification of social places, automatic sharing of user status and the exchange of mobile micro-blogs as a result of game interaction.

The studies feature other notable subjects not covered by the themes. Firstly, the verification of the social media generated by users; peer review, credit systems, use of existing online social networks, and competition are all explored as incentives to promote valid content. By doing so, users have a reason to create and maintain good quality social media, beyond the immediate utility of the applications. Secondly, a range of sensor methods are employed by the studies to position content; namely GPS, Bluetooth people tagging and mobile Cell-ID positioning. The unique properties and seams of each of these methods are shown to influence where and how a user will make use of the application. Finally, the emergence of ethical issues are important when facilitating mobile social media exchange in any of these settings and where applicable, these are identified in the thesis.

1.4. Overview of Approach

There are multiple disciplines that could contribute towards these aims and the research could be conducted from a design, art, sociological or psychological perspective. This thesis, however approaches the research from a computer science – and more specifically a Human Computer Interaction (HCI) standpoint, by developing a series of mobile software studies. The studies are based around social technologies that have been developed in the Lincoln Social Computing (LiSC) research centre, at the University of Lincoln and involve monitoring users in the real world via controlled experiments.

Contained within this thesis is the analysis of three such mobile social user studies: (i) a mobile, task-based game, (ii) a locative semantic tagging application and (iii) a social semantic tagging application. Each of these use social media in different ways to contribute to the research aims defined in chapter 3. These studies have all taken place in and around the city of Lincoln, UK. The following research approach was taken:

- **Software design and development:** Three unique mobile social software services were developed, based on mobile smartphone handsets and existing social technologies.
- **Design of research trials:** The trials were designed to assess the pre-defined research aims of chapter 3.
- **Execution of trials:** Trials made use of volunteer participants from the local area.
- **Acquisition of trial results:** A range of trial data was collected from users using various data collection techniques.
- **Analysis of results:** The data was analysed using bespoke analysis tools, thematic and quantitative analysis.
- **Trial findings:** Findings from this analysis gave an insight into the area of social media exchange.

All of the studies presented existed within a defined scope. Firstly, trial size was limited to a maximum of 16 users, so should not be considered a generalisation of population as whole. All users were volunteer recruits and were offered payment or prizes to reward effort. Also as the length of the trials was restricted, due to resource and device constraints, effort to orchestrate trials and cost incurred. Secondly, the social groups used for the trials were fixed groups of volunteers, so did not allow changing of their group by adding new friends, for example. The only social media formats studied were text, photo and semantic tag media; the discussion focused mainly on semantic text-based tags. All three studies used the Nokia series 60 platform and devices, supplied to the users and the option of deploying the applications to users' personal devices was not trialled. The timing of the trials means the results do not consider the effect on users of the latest generation of smartphones, such as iOS and Android devices, which are increasing the volume of mobile data services consumed by users. The trials are mainly based in same location, around the city of Lincoln UK, allowing for side by side comparison in a focused interaction area that was familiar to researchers; users were free to roam outside this area if they desired. Although significant, many other important issues such as security, are considered beyond the scope of the investigations, so will not be scrutinised.

1.5. Key Contributions

The thesis makes a number of important contributions to the area. Firstly, the open approach of the research has demonstrated the natural desire of mobile users to make use of social technologies as a method of updating their social network status via location-based semantic descriptions. This has now been commercially realised by the emergence of 'check in' services from commercial social network providers and the popularity of such services has further strengthened this aspect of the research. Another contribution is the discovery of high level narratives and themes that connect these status updates, both in a gaming and social networking context. The discussion in section 8.6 makes suggestions for how these could be utilised in social networking applications, for example to create novel methods of presenting social updates to users. Finally, the work has shown how user interaction differs depending on various circumstances, such as whether users are co-present or interacting at a distance.

1.6. Thesis Outline

The thesis is comprised of eight chapters. It begins with a literature review in chapter 2, which consolidates the essential literature based in the area of mobile social systems, the supporting technologies that enable these systems, the current state of the art research and how these developments have led to the creation of MoSoSo services. This is followed by a definition of the research aims in chapter 3, which the studies in this dissertation seek out to address.

The next chapter, 4 discusses Gophers, an entertainment experience based around a mobile social game, that places a variety of situated user-generated content in a mobile setting. The design and technological aspects of the study are overviewed, before discussing the wide findings discovered which reach beyond entertainment and relate to mobile social services more generally.

Using the results of the Gophers study, it was concluded that the remaining research would centre on the subset of semantic tagging and move away from gaming scenarios. Chapter 5 discusses the design and development of two, more focused mobile social services, ItchyFeet and MobiClouds, which are based around mobile social tagging. The ItchyFeet technology is a locative tagging and awareness technology, used to assess how mobile social services can be designed to take into consideration the user's real world social surroundings. MobiClouds trials a new socially-aware positioning system based around Bluetooth sensing and people tagging. Each of these applications was tested in formalised user trials and the results of these are discussed in the following two chapters, 6-7. The effectiveness of each of the technologies is assessed and the trial findings raise a number of points relevant to the design of future applications in this area.

Finally, from the results of these studies, a number of key findings are presented. The concluding chapter 8 discusses these findings in relation to the original research aims. In addition, it identifies how the technologies and study findings relate to the wider world of mobile social services and future improvements for the systems are suggested.

2. Exchange and Delivery of Content in Mobile Social Software

Mobile, social computing technologies have developed from the earliest days of bespoke research-led pervasive systems such as Active Badge [215], to today's consumer-oriented mobile phone based social networking applications, illustrated by recent studies such as Connecto, SpiderWeb and Cityware [14][188][120] and commercial systems including the Facebook Places service [69] and FourSquare [81]. This chapter documents this journey and provides the reader with a review of the current state of the art in mobile social software, focusing on the use of user-generated social media within these applications. To begin, it delivers a general introduction to mobile social applications and identifies the latest research in the area. It goes on to describe the more defined area of exchanging mobile social media within these services and identifies some of the challenges application designers are faced with. Next it discusses the different ways users interact with social media on their mobile devices and the motivations for doing so. Finally, it concludes that, despite recent developments, MoSoSos [194] are still in their infancy and identifies limitations of the technologies and the challenges that still prevail. These challenges have led to the three investigative studies which embody the research component of this dissertation.

2.1. An Introduction to Mobile Social Applications

Elements of social computing have existed in online web2.0 services for some time. These have facilitated the exchange of online social content, in the form of online blogs [146] popularised by Blogger [30], instant messaging and microblogging [2][211], photo sharing and tagging offered by Flickr [77], social bookmarking in del.icio.us [57] and even the tagging of music samples via SoundCloud [199]. The concept of social networking itself has also become increasingly popular in recent years with the launch of dedicated social networking websites, that facilitate management of social peer groups, communication between peers and sharing of social media online; sites such as MySpace, Twitter and Facebook, have witnessed enormous popularity worldwide. In addition, the recent availability of high speed, unrestricted mobile operator data tariffs and the increased popularity of smart phones led by Android and iOS devices, resulted in an improved acceptance of mobile data services by consumers. This is highlighted by a growth in mobile data of at least 4x from world regions between May 2008-2010 [1]. There has been both academic and commercial interest in the movement of social networking from the desktop to mobile platforms and as a result, most of the leading networks now offer mobile-optimised versions of their software, targeting smartphone handsets based on Android, Symbian and iOS platforms. Consumers have been equally keen to embrace these technologies; approximately 50% of total mobile web use is now on social networking sites [99] and in November 2010, there were 200 million registered users of mobile Facebook [67]. Many of these sites offer a user experience which is better tailored to the mobile platform, for example by offering network communication that is more tolerant to disconnects, or allowing users to upload camera phone photos for sharing with friends. However, besides these basic enhancements, mobilised social networking sites offer little consideration for the inherently social nature of mobile devices, the fact mobiles are invariably held on the user's person and the benefits that can be gained from these characteristics.

The first generation approach to social networking, described above, offers an online approximation of social interaction which is somewhat removed from the user's everyday environment. The alternative notion of layering these digital social tools over the physical environment through contextual awareness has been the focus of numerous recent studies; research platforms such as Social Serendipity [64], CenceMe [142], MobiClique [167] and CityWare [119], have successfully demonstrated this concept. Broad motivations for developing such tools include: (i) mobile awareness services: which inform a user of their friends' [216][14][5][220] or co-workers' [13] context and increase awareness of their changing social surroundings [163][147], (ii) contextual peer-matching services: which recommend relationships based on real-world social encounters [64][168][147] and (iii) contextual information sharing services: which allow for geospatial tagging of opinions, events and information of interest to others in their network [117][28][55] and offer ways to empower and harness community knowledge through crowd sourcing [222][28]. Many systems combine these motivations. These systems are classified under numerous terms, but are commonly known as Mobile Social Software, or MoSoSos [194], which is how this application family will be defined from this point onwards in this dissertation. The off-the-shelf availability of smart phones with integrated GPS and cameras, as well as cheaper data access has also allowed for companies to commercialise areas of this research and MoSoSos have even entered the public domain. Examples include Socialight [197], allowing locative 'sticky tags' to be authored, containing opinions, information and messages to be shared with the community, Plazes [169], offering tagging and sharing of socially relevant locations with

Facebook friends, FourSquare [81], a locative event and activity sharing system and Loopt [131] and Latitude [90], two popular peer finding services. Through using location awareness, these systems establish a link between online social networks and the user's day to day social activities.

2.1.1. Enabling Technologies

A range of technologies have emerged over the past ten years that have made the development of these systems possible. The most important of these are identified in figure 2.1, which gives an visualisation of the developments that were taking place alongside the research studies implemented in the dissertation.

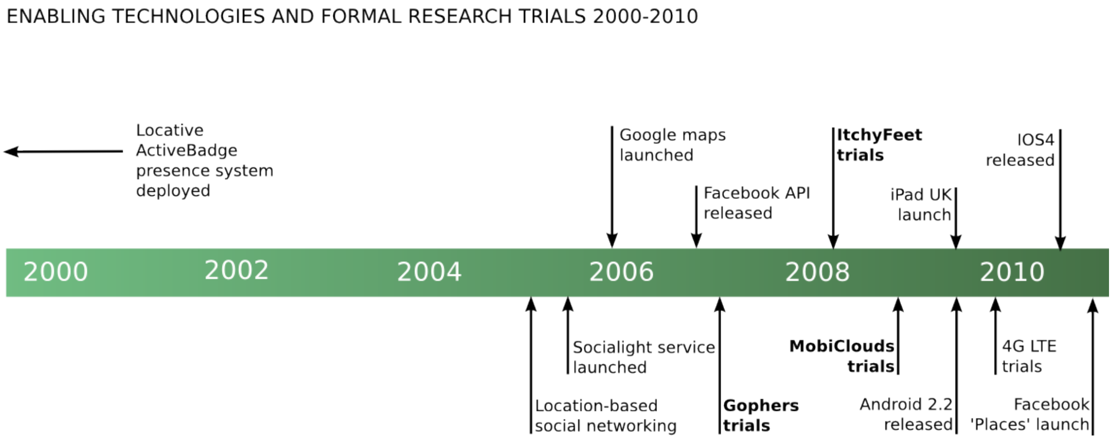

Figure 2.1. Toolkits, APIs and technologies that have assisted the development of mobile social applications

2.1.2. API Support

The release of accessible, well documented SDKs for mobile device development, APIs for accessing on-device sensors and frameworks for rapid development of social services have all assisted MoSoSo application designers. However, development on both mobile devices and social network platforms still presents challenges. Firstly, many technology manufacturers keep closed 'private' API functions to themselves [204], segregating third party developers from more advanced functionality. Furthermore, social network providers infrequently follow open standards; interoperability between these networks is badly supported at present and non-standardised, leading to developers having to write their own interfaces to adopt users from disparate social networks [173], or face being locked into a single platform and user base. It is hoped that this interoperability will improve in the future, perhaps taking note from

UK mobile operators, who allow users to piggyback on 3G infrastructure from competing networks. A similar situation confronts developers on mobile devices, who encounter difficulties in supporting many different device platforms, often using separate development SDKs; the current Nokia lineup alone contains literally hundreds of devices, supported by numerous versions of their software development kits [150].

2.1.3. Definitions

A number of terms are used to describe aspects of mobile social technologies during the thesis. Some of these have ambiguous meanings; table 2.1 defines the normal usage of these.

MoSoSo	Mobile social software service, used to connect people socially in a mobile setting.
Mobile social media	The content that is exchanged between users of MoSoSos
Peer group	The virtual social network that contains a user's friends
Social application	Application that takes social context as an input.
Locative application	Mobile application that takes location as an input.
Mobile	Something that is to be used in a handheld way in real-world scenarios

Table 2.1. Definition of terms used in the thesis

2.2. Mobile Social Media

One important facet of MoSoSos is Mobile Social Media. This is the means by which friends communicate amongst one another using these systems, such as publishing a restaurant dish recommendation [210], or tagging a rail station from the London Underground network [44]. Social media may be presented in various formats, including blog posts, tags, instant messages, geospatial data, photos, disclosure of user status and numerous other forms. In MoSoSos there is usually a way to *position* social media in the real world (such as geotagging for later retrieval) and mechanisms to *distribute* it to other users within their environment (for example transferring it via WiFi to proximal devices or a centralised server).

2.2.1. Design Considerations

The move of social media from the desktop to pervasive, always-on, mobile technology, introduces a number of design considerations that are still emerging. Many of these have been documented in social computing research studies and an overview of them is provided in this section.

Context: Social media gives users a real time communications channel wherever they are. One of the main differences when moving from desktop to mobile social networking is the fact that user context changes with a higher frequently [172]. Because of this, the content frequently relates to their changing surroundings. Application designers can take advantage of readily available information about the context of users, such as location, surrounding sensor networks, phone photos and commentary taken in-situ, to provide a strong link between social media and the user's everyday environment. Further to its usage in tagging social media, context can also influence the way users interact with the application; the Familiar Strangers, Hitchers and Feeding Yoshii studies exemplified the differences between urban and rural locations in application use for instance [163][61][19], whilst PePe showed different tagging practices were exhibited by users when away from the city capital where other peers were located [123]. This makes user context an important input to mobile social applications.

Appropriateness of use: Despite the fact mobile devices are always on and frequently carried on, or near the person, both social etiquette and personal factors, such as safety and security, still dictate where and when these applications can be used. This has been reflected by users of mobile systems, who relayed their apprehensions about using expensive devices in places perceived as unsafe [163] or prone to theft [19]. The Blowtooth study challenged the idea of using these systems in inappropriate situations, by giving passengers at airport security the chance to take part in a virtual contraband smuggling experience [129]. In hosting the game within a high security environment where certain behavioural expectations exist – particularly regarding the use of mobiles, the thrill of participating in the experience was enhanced. Also important is the context under which a device is being used; trends have been seen in an analysis of the risque practice of Bluejacking [206], which revealed the importance of location and appropriateness of use in the places enthusiasts chose to bluejack; predominately users selected public locations, away from the home where they would not be interrupted or discovered.

User availability: In addition to the usability issues typically associated with small screens and keyboards, user attention span is also a consideration when interacting with mobile handsets. Typically, users have been shown to hold their mobile devices within arms reach of their person 58% of the time [162], indicating the device location may not always be synonymous with user location and that availability for users to interact with their device cannot be guaranteed. Attention when interacting with mobile devices on the move has been observed to comprise of short, intense bursts, when the opportunity to interact arises and the suggested attention span for users is less than five seconds [161][159]. A user's ability to interact with the application also depends on external surroundings and personal context; this may be limited if the user is engaged in other activities [49], or if a more important application task takes precedence; demonstrated by users of the Biketastic route documenting system who implied that the main task of biking could collide with the secondary use of the media capture function to capture geotagged social media en route [175]. Because of this, mobile applications should be designed in such a way where they do not demand continuous attention from the operator in order to function.

Shared understanding: The use of social media is often associated with emerging application concepts, which may be unfamiliar to users. As a result, it frequently takes time for users to reach a shared comprehension of application rules and define an agreement of when, where and how the mobile application should be used and often these processes are developed by users as part of a shared learning experience [216]. This implies that applications where users are proximal to one another will develop in different ways to those where users are at a distance.

Technology availability: Sensor systems are not available, or accurate 100% of the time. Technology such as GPS can suffer from black spots and accuracy can diminish with environmental conditions, whilst the accuracy of mobile cell positioning varies according to the density of mobile phone masts and can suffer from technological quirks, such as mast flipping [61]. The availability of Bluetooth sensing is determined by how many choose to enable this feature on their handset and make their device visible. Similarly, mobile 3G data rate speeds vary significantly when close to the edge of cells and also suffer from connection outages, reflected by mobile gaming studies that relied on constant connectivity [79]. Another consideration is power consumption. The regular polling of sensors has a detrimental effect on the battery life of handsets, limiting the amount of time an application can be used in a continuous session and this has led to the development of energy-aware strategies for minimising power drain of devices, such as streamlining the number of requests sent from applications [225] and the development of sensing methods that can adapt to balance energy use against the context and target application [127]. Depending on the severity of availability problems, they can either cause partial or total failure of the application. As a result, social applications designers have learnt to either design around these quirks, by using technologies such as delay tolerant networking, exemplified by the sensor access points in BikeNet [65] and others [122], or deliberately expose them as an inherent part of the design, something that the concept of 'seamful computing' aims to achieve. This is demonstrated in the Feeding Yoshi game, which made use of otherwise redundant wireless networks in order to create pervasive game sprites [19].

Non-application users: Concentrating social application design solely around application users and friends is limiting and various studies have investigated the possibility of including outside users as part of the experience. This has the advantages of adding more depth to the experience, creating a more realistic model of a user's social surroundings and furthermore offering the ability to introduce users to new contacts. Stanley Milgram’s concept of the ‘familiar stranger’ described these familiar people that we regularly observe, but choose not to interact with; researchers have attempted to make users more aware of these individuals and our everyday relationship with them, by conceptualising an electronic mobile device known as 'Jabberwocky' [163]. In addition, the Wireless Rope study offered conference attendees the ability to make social exchanges with familiar users [147] and the InforRadar application provided a 'public messaging' facility to encourage users to engage with those outside their social network [174]. The orchestrated interaction with unknown strangers in a gaming setting has also shown to be an enticing element of play [24] and has been seen as a way to create more challenging social games [148]. Similarly, Insectopia [164] demonstrated the use of Bluetooth device scanning as another means to include non-player characters (NPCs) in mobile pervasive gaming experiences. In addition, the ongoing Cityware initiative [120] provides mechanisms to also include non-application users in social positioning, by linking anonymous Bluetooth addresses to Facebook profiles and is currently being used as a way to study real-world encounters in digital social networks. These examples demonstrate notable interest in facilitating exchange beyond the bounds of our predetermined social circle.

2.3. Mobile Social Media Exchange

The areas of MoSoSos and mobile social media have been defined in broad detail and some of the design considerations associated with moving social media to mobile platforms have been discussed. The review now moves to the main focus of this dissertation; that of 'social media exchange'. The same challenges identified in chapter 1 are also applicable to this research area.

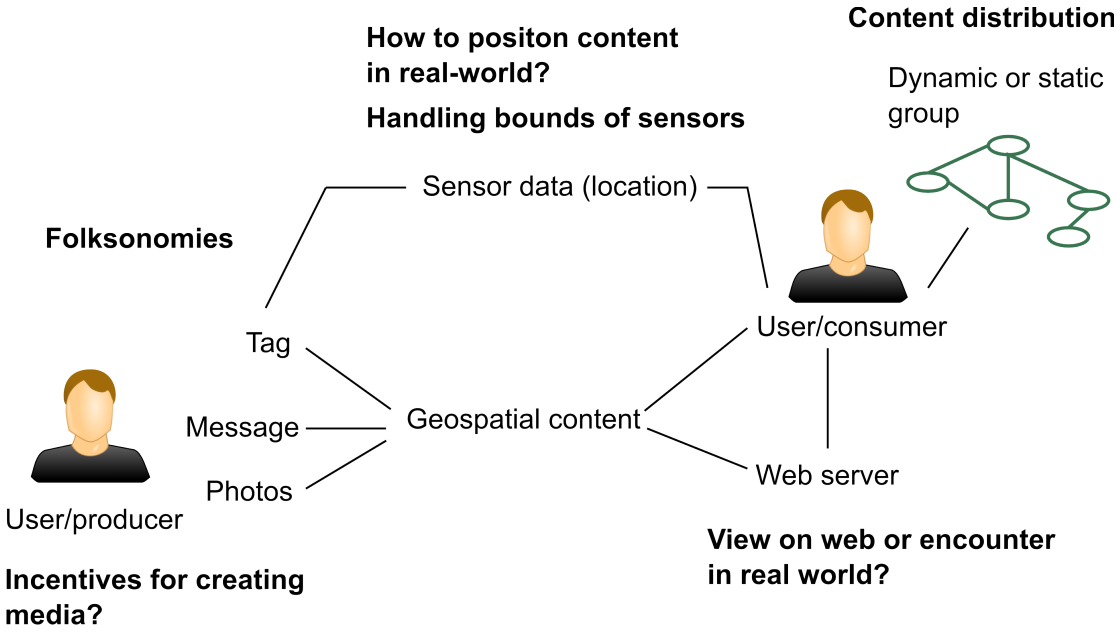

Figure 2.2. Considerations in designing the exchange of social media in mobile software

The exchange and distribution of social media between connected peers is a core element of mobile social services, which acts as a synchronous, or asynchronous channel of communication. This data may be exchanged directly – for example using ad-hoc connections to individual users [167][208], or indirectly by pulling from a centralised web server [14]; in addition it can be disclosed to individuals from a social group predefined by the user [142][14], or members of a dynamically generated group [100][168]; lastly it may be presented on a web server, for example in the form of a social web site, or made available for discovery in the real world by authorised users who enter a particular context or those that are proximal [28]. These parameters are dictated by the application design and all affect overall user experience. The diagram in figure 2.2 defines the research considerations involved in this process; the enabling technologies, methods of designing for this social interaction, limitation of sensor systems and how the peer groups are defined are all central to the design of this exchange and are each of these is now discussed in depth.

2.3.1. Enabling Technologies

The development of device and software technologies in recent years has made the transition of social media to the real world possible. The most prominent developments are discussed in this section.

Folksonomies for mobile tagging: The term 'folksonomy' refers to the dataset that emerges from collaboratively producing tags to classify pieces of arbitrary content [193]. Tag-based folksonomies are a key technology to support categorisation of mobile social media such as photos and real-world locations. They are further discussed in section 2.4.2.

Absolute positioning: There are numerous ways of locating mobile social media in order to give it a real-world bearing; each has advantages and drawbacks and the choice of location technology will significantly affect how an application is implemented. A common approach is to use absolute positioning systems, such as GPS or Cell Operator positioning [123]. This may be used to connect social media to real-world coordinates, allowing it to be represented on a map [175], shared with a user when they visit a particular location, or discovered via localised search terms [81]. These technologies are best suited to social applications based upon contextual information sharing, such as recommenders. It may also be used to represent the position of the user themselves in the case of map-based interfaces [154]. By inferring meaning from positions they can also be used in more subtle ways, in order to give semantic or social meaning to a place using comments provided by friends or other community members [28]; such as “people think this is a dull place”, or measure trends and infer patterns over time [97]; for example “your friends frequently go to this cinema”. Although GPS positioning offers a powerful and fine-grained connection to the real world (to an accuracy of a few metres), it is only available on relatively modern handsets, can have privacy issues due to the potential of 'tracking' users and current mobile GPS chips suffer from high power consumption and do not work indoors. An alternative option is cell-ID positioning which does not suffer from these issues and is available on a wider range of devices, but only offers a rough approximation of user location (between 100 and 200m in urban and suburban settings [196]) and the software support to access this sensor data is poor, relying on hacks and ageing third party applications [196]. Furthermore the mapping of cell masts to a real-world location relies on expensive operator positioning or incomplete third party databases, e.g. [40].

Relative/Social Proximity: An alternative notion of locative context is offered by relative positioning. A founding example is the Relate system, which demonstrated an indoor, infrastructure-free positioning system for mobile devices. Using bespoke USB dongles that employed ultrasound context sensing and RF communication, co-located devices could determine their relative position from one another in a finely grained manner [104]. By employing signal strength measurements, both quantitative relations, such as distance, and qualitative ones, such as *moving_towards* or *left_of*, could be determined by co-located peers to an accuracy of around 8cm. A service layer and API to access these measurements was created for application developers; an example ad-hoc spatial file transfer tool was built upon this to demonstrate the technology features, by allowing file communication between co-located devices in a visual manner.

A similar study offered an early evaluation of using Bluetooth sensors to form ad-hoc sensor networks, by installing them into prototype *Smart-It* nodes [113]. It highlighted limitations of the standard, namely its reliance on Piconets, which limit the scalability of ad-hoc discovery and communication. Despite this, the technology was regarded the best 'readily available' solution for this domain (versus bespoke solutions), due to its integrated power adaptation, QoS and error correction.

Bluetooth represents an ideal sensing technology for mobile social applications for many reasons. Rather than being used as a location sensing technology that determines spatial relations between peers, it is essentially a ‘presence’ technology which is able to identify proximal devices and the users who own them (using a unique 12 digit hex hardware address). It has the added ability to make ad-hoc data connections between paired devices; Bluetooth range is typically 10m on smartphones, but can vary between 1 and 100m, depending on the power configuration used [177]. In addition, the technology has been pervasively available on mobile phones for some time and now an increasing number of non-phone devices, both mobile and static, are becoming Bluetooth enabled. This gives application designers a sense of both the changing static surroundings as a user moves through their environment and returns to locations, as well as the changing social landscape around the user as people enter and leave their Bluetooth range. Bluetooth is considered a partially embodied physical and social medium; disembodied in that users can communicate virtually with strangers and remain anonymous, or embodied when users interact with device names belonging to peers who are known to be present [114]. As a result of these distinctive properties, Bluetooth technologies are ideally suited to peer matching applications, which rely on impromptu meetings [170]; further examples of applications are identified in section 2.4.

Because of its unique technical characteristics, Bluetooth has been used in social computing research as a way to study the dynamic nature of our social surroundings, in order to design mobile social systems which are a better 'fit' for these environments. Examples include studies of our relationship to familiar strangers [163] and the Cityware initiative [120], which took an alternative approach and exploited Bluetooth as a way to embody people's digital social networks that already exist online. The project paired users' unique Facebook IDs to their (also unique) Bluetooth mobile addresses and utilised static and mobile scanning nodes to monitor their physical presence, by allowing users to ‘tag’ Facebook friends when they were physically proximal. The study aimed to collect a dataset that both users and researchers could make use of to analyse their online and physical social worlds. Bluetooth has also been used in contextual information sharing services as a way to introduce users to each other by exchanging personal ‘profile’ information with peers [64][166]. Further demonstration of using these sensor networks for peer recommendation is evidenced by the Serendipity system, which was able to detect social dynamics between peers and using these, automatically infer whether to exchange profile information [165]. Rather than focusing on the proximity of individual peers, the Wireless Rope study [147] analysed the dynamic social change of surrounding peer groups as a whole over time; through logging a user’s surrounding social situation using Bluetooth proximity data and analysing the frequency of appearance and familiarity of peers, the systems were able to infer meaningful relationships, such as relevance of peers to user. This was taken further in Friendsensing by using social network theories, such as link prediction to analyse proximity logs and from these, automatically generate friend lists [170]. An alternative approach is seen in the Mobitip study [181], where rather than acting as a simple social proximity measure, Bluetooth is employed as a ‘social positioning’ technology; a multi-faceted contextual indication that positions users in a physical, geographical and social space. By visualising the social position of a user and their peers, the system allows users to place digital ‘tips’ within their social context and visually share these in an ad-hoc manner amongst proximal peers.

Another presence technology offering similar properties to Bluetooth is WiFi, which is now available in many mobile devices. It has been suggested as a higher performance alternative for mobile presence studies [188]. However mobile handsets rarely advertise their WiFi presence by default, making these sensor signals less ubiquitous at present.

Inclusivity of Technologies: It is questionable whether sensor technologies such as Bluetooth, WiFi or GPS can ever give a true representation of social encounters. Take

Bluetooth, for example; many mobile phone users will own older, non-Bluetooth enabled models and additionally, are routinely shown to disable ‘discovery mode’ on their mobile devices, or turn Bluetooth off completely [114]; recent research shows that only 7.5% of pedestrians in the city of Bath were found to leave Bluetooth ‘on’ and ‘discoverable’ [119]. This may result in a skewed representation of an individual's social surroundings. As with many sensor technologies, one needs to question the inclusivity of such technologies before using them to represent a generalisation of society as a whole and application designers should be extremely cautions not to imply any serious sociological conclusions, since any findings will consider only those individuals with access to [180] and desire to use modern handsets [205].

Alternative Sensing Methods: Research studies have investigated methods to move beyond static coordinate pairs and proximity data from fixed points in time and instead, extract more meaningful inferences from this data. One way this being done is through considering trails of points that a user has encountered over time, as investigated in Hermes [60], which looks to investigate adaptation of GPS trails left by users, depending on real-time environmental and contextual properties. It suggests trails should be generated depending on user preference and knowledge gained from prior users. Through monitoring and analysing the trails of users, this could provide a more effective way to sense user activity in social networking applications. Another method of representing user context is to create deeper multi-contextual indications of a user's activity. The CenceMe study [143] for instance, allows social networking users to share their 'sensing presence' (a combination of activity, disposition, habits and surroundings), with their friends. This offers a way to replace the meaningful contextual information that is normally lost when communicating using social media, by injecting this back into social channels. To exemplify the technology, various services have been built, including a 'significant places' application, used to detect and share meaningful locations with peers. Other 'alternative' sensing methods deployed in mobile social applications include physiological sensors for measuring participant exertion [135] in order to generate evolving virtual environments for mobile social gaming experiences [33] and also as an additional contextual input into social sport products [200] and RFID/QR-codes, used to rapidly create a pervasive social infrastructure at low cost [201]. These technologies are less widely supported by current off-the shelf mobile handsets, so often require a third party sensor to be carried. At present, few applications that exploit the properties of these sensing technologies have been developed and these should be realised in next generation mobile social applications.

2.3.2. Supporting Social Interaction

One way that users interact with each other in MoSoSos is through the exchange of mobile social media. This section looks at ways systems can manage these exchanges in meaningful ways.

Encouraging content producers: As is the case with Web2.0 systems generally, the creation of relevant social media is vital to the success of a MoSoSo. Research shows that in public online systems such as Micro-blog [84], the act of receiving social responses from readers of their content (in this case, blog entries) can be sufficient to encourage producers. However, to further encourage social media in systems where this may not be the case, another option is to offer incentives for producers. Two broad methods have been proposed. Firstly, systems can make use of pre-established social networks where users are already members. Creating good content helps develop their personal profile on the social network, which encourages users to produce content in order to benefit their social group as a whole. The drawback of this is it deters communication with strangers and those outside the existing network [205]. A second option is the use of artificial mechanics to encourage good content, for instance a credit-based system, where queries cost and responses earn credit [84], or use gaming mechanics, where providing good content furthers a user in a game. Each of these systems are assessed in the three research studies. A more general problem associated with content production is reaching a critical mass of content before a system can become useful. This is of particular relevance to short to medium term research studies [103]. One way of improving the time taken for these services to develop is through bootstrapping systems with content prior to users trialling the system; this approach has been employed to populate the geographical locations of beacons in the Placelab system [196], where the locations of 802.11 access points and GSM masts were initially bootstrapped by online databases. Another method might involve mining and processing UGC from an existing social network in order to populate the world.

Controlling exchange and flow of social media: In order to exchange social media in meaningful ways between users, it is important to maintain up to date information on the context, status and social networking profiles of users within the mobile social network. The difficulty of extracting semantic information from online social networking users is highlighted in [173], which identified the closed APIs and poor interoperability across existing digital social networks as some of the main challenges when mining user data. Accessing the more localised data stored on the user's mobile activities, such as call logs, is a further challenge; additionally, collecting information from the handsets of proximal users may also be desirable, but these techniques normally require use of preinstalled server software, such as [171]. Another less challenging way to control the exchange of social media between users in the real world is based on context. User context can be sensed through use of a wide range of personal sensor systems, such as GPS, Bluetooth, cell operator positioning, WiFi and physiological sensors [33][135]. These sensor systems allow MoSoSos to form an intrinsic link with a user's everyday behaviour and the social spaces they frequent. Many MoSoSos centre their functionality specifically around locative data, either through use of absolute positioning or their relative proximity to other users; the merits of each and associated studies are overviewed in section 2.3.1. These technologies are readily available on modern handsets and so are familiar to most users. Because of this (and the current difficulties associated with mining user status and profile data), the focus of the dissertation research is limited to exchanging social media based on user context – using both absolute and relative positioning systems.

Exploiting current social exchange technologies: Traditionally, mobile users utilise SMS and MMS messages to engage with peers and exchange content, but more recently social technologies such as Bluetooth have also been used for these purposes. It's primary use is for exchanging content (music, photos, etc), from one device to another, but Bluetooth use by smartphone owners has emerged as a form of social interaction in itself. One example of this is the use of human-readable Bluetooth 'friendly names' by users as a means to communicate with peers. A study, which using a single mobile handset, scanned and logged the presence of surrounding Bluetooth devices over a period of 7 months [114] found that the most common use of friendly names was to relay a person's name or device name, but the use of explicit names, personal names, statement about themselves or ‘graffiti’ type tags were also apparent. The use of text or mobile numbers as a means to encourage or discourage social interaction; in one example asking for adult material, was also noted. Further evidence of social discourse and interaction through Bluetooth is seen in the practice of Bluejacking [31][206], which plays on our fleeting, anonymous encounters with strangers to engage in illicit communication; a user sends unauthorised messages, via electronic vCards to the handsets of close proximity strangers. These natural emergent uses of Bluetooth as a socially enabling technology demonstrates its importance in the domain of mobile social systems and more generally, highlights the desire of users to interact in novel ways using their phones. Numerous research studies, depicted in section 2.3.1, have also worked to exploit the use of Bluetooth as a social ‘glue’ between mobile users. By utilising the exchange technologies already used by mobile users, it is expected social applications are more likely to gain user acceptance and retention.

2.3.3. Sensor System Limitations

The sensor systems that are used to feed mobile social systems with data on user context are imperfect. Limitations in these might affect the accuracy or functionality of a service and these are discussed here.

Space & place: One limitation of social media exchange is that designers overwhelmingly rely on location or proximity awareness as a vehicle for positioning content. However, our everyday physical world is a rich communications space of contextual cues and information; Harrison and Dourish [102] for example, argue that there is more to 'place' than just spatial measures – and indeed, the less measurable elements of "…the shared understandings of appropriate use and the social interpretation of cues in the physical environment" are equally important for defining place. Further research leads us to believe that there are other important influential factors to be considered during the authoring and interpretation of user-generated content in mobile settings more generally [195][123][20]. The importance of human factors in location aware computing are also identified by Schmidt et al. [190]. When human factors play such a central role to social computing systems, it is crucial that these are also taken into consideration during the exchange of mobile social media.

Boundaries & the edges of sensor systems: No sensing technology is perfect. The availability of mobile devices was identified as a design consideration in section 2.2.1. Problems with sensor availability often occur when the limits of these technologies are reached, which can also cause them to function in unpredictable ways. Depending upon the sensor accuracy required by the application and the ways this data is represented, this may or may not be perceptible from the user's perspective. The effects of clearly erroneous sensor data can obscure the user's view of the association between application and the real world context, alert them that the application is working incorrectly causing frustration [22], or cause them to resort to evasive tactics to try to repair the problem [26]. In other circumstances the technology can become completely unavailable, for example if a user walks indoors, or enters an 'urban canyon' and loses GPS signal. Good applications design around this and incorporate these failures into the design [22]. Striving for a perfect sensing technology is a futile goal as it is unlikely to ever happen and even if this was achieved, the consequences of an unforeseen failure could have a much bigger impact on the user experience. An alternative viewpoint has been developed with the concept of seamful design [181][41], which exploits these sensor failures as an integral part of the application design. This was demonstrated in Feeding Yoshi, which made use of secured wireless access points that could not be employed for their primary purpose of exchanging data, as artefacts in the game landscape [19].

Behaviour sensing: One way that research is moving beyond location sensing is by offering a richer indication of user activity. Through use of personal sensor networks, recent studies have provided ways to infer user behaviour and offer an indication of user activity, such as walking or running, their emotional feeling or current environmental conditions and autonomously share this enhanced status with friends across a range of social networks [187]. Behaviour sensing and sharing systems have additionally been proven as a way to increase user activity for health purposes [48], but their real use in mobile social services have not yet been revealed.

2.3.4. Disclosure of Media to Groups

A final consideration for researchers is how to disclose the content that has been generated to a user's peer group. The distribution group is the defined set of users that are eligible to receive the social media and this can be be statically or dynamically stipulated.

Static definition of groups: Static peer groups can be defined manually, or automatically. The simplest approach is to allow users to add peers to their network by exchanging a friendship request, or meeting them in person. This can take time and requires effort on the user's part to manage these groups. One method of gathering this information automatically in order to create a 'contact list' of peers is by making use of existing social network ties from a user's online social network profile. This has been exemplified in research studies such as [173][14] and has the advantage of being able to immediately bootstrap the network with a social network for immediate use – making this an attractive option for short-term research studies. The drawbacks of such an approach is that interoperability between social networks is currently poorly supported [172], data mining from most of these requires authentication and presence of ambiguous user names causes difficulty [173], not all networks are accessible via a documented API and finally, this approach constrains the diversity of the users involved in the trial and the contacts they can communicate with. An alternative approach is to automatically define these groups. By analysing which mobile devices are proximal, using either WiFi or Bluetooth traces and using measures such as distance and population density, prediction algorithms are able to determine which mobile encounters are relevant ones [170].

Through logging these encounters, the system can then make appropriate friend suggestions to the user, which they can choose to accept or reject.

Dynamic definition of groups: Another method is to determine the social group dynamically by monitoring proximal users [172], or building communities of otherwise unknown users that share interests [125]. This method is advantageous as it removes the burden of maintaining an up to date contact list from mobile users and instead, the list is built in an ad-hoc manner as friends come and go. This also offers a social network that is more current and arguably more relevant to a user's surroundings. Systems such as Dodgeball offer a way for users to create dynamic peer groups using the people that exist around them [59][108]. Research has shown how spontaneously generated social groups can be used to offer a shared, dynamic communications space, by generating a dynamically changing social network as a user moves location; visualised in SpiderWeb as a virtual world [188]. This can have the benefit of empowering users to communicate with those individuals beyond their predetermined digital social networks who might normally be ignored. However, Spiderweb suggests that filtering users on a per-profile basis is nevertheless desirable to avoid flooding the user with irrelevant content. An agent-based architecture to support ad-hoc group discovery and automatic media exchange is proposed in [172], which similarly aims to reduce the reliance of manual intervention by automating many common mobile social networking tasks. Research suggests that use of these systems can alter a user's experience of a social space [108].

User identification of locations: Ultimately users themselves select which locations are socially relevant, which will indicate where social media should be placed, or their user location disclosed. For example, the type of locations disclosed by users of the PePe mobile presence system included generic locations, points of interest and geographic areas [123]. Identification and disclosure of user location is an important aspect of human communications and this is emphasised in the Reno study [195]. The application allowed users to both manually or automatically (through cell-id) disclose their location in the form of personally defined semantic labels to others in their social network and furthermore, request locations of their peers. Similarly, the user definition of place is investigated in PePe field study [123], which offered a way for users to individually identify meaningful locations either using cell-ids or user-defined text and image data, so their mobile status could be disclosed to their friends as a representation of their current context. It showed automatic location disclosure to be a useful tool for enhancing communication in many circumstances, but on the contrary, this could be problematic when automatically disclosed locations lost meaning due to the differing context under which they were interpreted. In a similar way, ‘context cues’ have been successfully deployed in CSCW environments as a method of indicating co-worker status with the intention of minimising inappropriate interruptions [13] in a busy hospital setting. These systems did not socially share location placemarks, so each time users must manually enter a location description. Systems such as Connecto [14] capitalise on this by sharing placemarks between users in a social group and automatically reveal locations of group members that relate to a tag location and similarly MMM2 reused contextual image tags by sharing them amongst the community [55]. This demonstrates a more collaborative approach to generating locative content, better matched to social systems and again, reduces burden on users to manually interact with the systems. Recently, online social networks have commercialised on this and manual disclosure of a user's mobile status to their friends is now possible using Facebook's Places tool [69].

Distribution of content to peers: There are a number of ways the distribution of social media to a user's friend groups can be controlled. Another important aspect of distribution is synchronisation of this data. Social content can be pushed to peers real-time, in systems such as Connecto and Dodgeball [14][108], where information is automatically distributed to peers in the social group. It may also be pulled asynchronously, for example in a geoblogging system, where blog entries are tagged to a map and peers encounter this information only when they read the blog [11]. The former system is more instantaneous, so preferred by real-time mobile awareness applications, where the usefulness of data degrades over time and the latter chosen when timeliness is less important and it is desirable to read entries together as a continuing narrative, or when convenient for the reader, for instance in mobile blogging [84], or mobile recommender systems [97].

Serendipitous encounters: An alternative way of distributing information asynchronously to users is advocated by the concept of mobile 'information encounters' [46]. This is a method of revealing information in a serendipitous manner as users explore their environment and its attributes. In doing so, content is interpreted by users in the same context as it was recorded. The user can take a more passive role, as they are free to explore the environment and have information presented to them where relevant. Additionally, it allows users to gain knowledge in a more natural exploratory way that embraces the random encounters of life, rather than the rigid hierarchies and search terms that govern online content. This type of experience is ideal for distributing information in tourist applications [9] such as mediascapes [176], where the user should primarily be focused on their surroundings, with the mobile device augmenting this experience. Another interpretation of exploratory information finding is demonstrated in the Sweep-Shake system [179], which combines location-based input with haptic interaction to provide an engaging way to explore more specific targets in a user's environment. The concept of serendipitous information encounters has also been applied to mobile social systems as a way of discovering nearby users to chat with [168], encountering a virtual gun fight [47], or finding tips and routes to better explore your current surroundings [28].

High level inferences: In the systems discussed to this point, the disclosure of social media to peers mostly relies on simple, location-based rules. Moving beyond this, more meaningful queries could be handled if it were possible to automatically infer higher level themes that relate to the social state of persons, sub-groups and locations and determine the trends that are occurring in these over time [172]. The Mobisoc middleware [97] aims to support the type of high level questions we might want answers to when shifting from physical to virtual communities, such as "Can someone show me what is on the menu at the cafeteria today?" or "How busy is this park on a Sunday?". In time, this could lead to a powerful new generation social applications.

2.4. User Motivations & Interactions

This section summarises some of the key motivations for producing social media as a way to interact with peers, focusing on the areas that are used in the three research studies. As this field grows, the range of applications available becomes increasingly diverse; an overview of application genres and some example applications is provided in table 2.2.

Many social applications encapsulate a number of these genres. Users are motivated for many reasons and not always for the primary intended application use. Numerous motivations can play a part in creating mobile social media and these reasons are often application specific, such as being mischievous [183], bragging to friends, artificially generated credit systems and personal benefits, such as self-organisation [4]. A number of these application themes are examined by the three research studies and these are highlighted in the table. As introduced in section 1.3, the studies explore three key themes: (i) the mobilisation of social games, (ii) the sharing of real-world social knowledge using paradigms such as folksonomies and finally, (iii) the promotion of discourse between peers using mobile social technologies such as microblogging. These broad themes also encapsulate some of the main foci of the research area; the section now goes on to investigate each of these in depth.

Application Genre	Example Applications	Typical Social Media Exchange
Geospatial tagging & sharing content (tags, photos, text)	Flickr, Plazes, Google Maps Mobile, MMM2	“This is my home town”
Social check-in	Facebook Places, FourSquare	“Sean has checked in at...”
Social awareness & micro-coordination	Latitude, Connecto, Hummingbird, ContextContacts	“Someone is near you”, “I'm on my way back”, “Friend *f* is travelling”
Microblogging, context-aware moblogging	Twitter, Locoblog, Festival-Wide Social Network Interaction	“My holiday in Berlin”
Crowd sourcing & group organisation	Mcrowd TXTmob, FlashMobs	
Route sharing	Geoladders, Biketastic	“This is a common mountain biking route”
Social review, recommendation, city guides	Mobisoc, Socialight	“Where is there a good park around here?”, “This is a great restaurant”
Peer matching & recommendation	Dodgeball, Digidress, Familiar Strangers, Wireless Rope	“Is there anyone to chat to...”, “we suggest these persons as new contacts”
Social gaming & entertainment	Pirates, Hitchers, CYSMN, Savannah	“Find me the treasure!”
CSCW scenarios	AWARE	“Is my colleague busy - can they be interrupted?”
Study of digital social networks	Cityware, Familiar Strangers	“Which of my peers have I encountered?”
Urban design	Urban Tapestries	

Table 2.2. Examples of current mobile applications and the ways they exploit social media. The application genres highlighted were an influence to the three dissertation studies

2.4.1. Mobilising Social Games

Social computing has recently entered the field of entertainment, with the launch of social games. These are games which are set apart from usual online games, as they offer an intrinsic link with a user's social network to create novel gaming experiences. Many of the most popular games are commercial offerings, designed to integrate with a user's existing online social networks, such as Farmville and Mafia Wars [72][134].

A subset of social games[1] which have emerged are mobile-social games. These are games designed for mobile devices, which in addition to interacting with social peers, invariably make use of contextual data to better place gameplay in the real world and exchange social media which is more contextually meaningful. This section summates these studies and discusses aspects that are relevant to the area of social media exchange.

In addition to advancing the field of computer entertainment, pervasive gaming research has also provided a rich test bed for emerging ubiquitous computing technologies and allowed in-depth study of users interacting with these technologies 'in the field'. To facilitate this research, developments have been made in research methods, ethnographies and design methods for ubiquitous computing. One area these games have assisted with is how to best make use of imperfect location-aware sensor data in social applications and the ways in which users make allowances for this. Many mobile social experiences make use of cartographical maps in order to locate players. Can You See Me Now? for example, was a mixed reality experience focused around a city-wide game of ‘chase’ [209]. By combining online players and ‘street’ players, to create a shared social gaming experience between a digital and physical world, it revealed how inaccuracies and uncertainties in technologies such as GPS could affect gameplay and how designers need to consider this. Following this, Uncle Roy is All Around You [24] offered a similar performance where GPS systems were replaced by self-reporting methods and showed that these lower-tech methods could be just as effective as automated sensors when used in a non-casual format. Sensor data uncertainties were further explored as part of the CatchBob! [153] mobile game platform, which looked to assess how these uncertainties affect collaboration in a quantitative way. These systems offer a highly orchestrated research experience, which although social, are short lived and therefore cannot explore longer term integration with a user's social life.

As an alternative to on-screen maps displaying the location of players, it is also possible to make more subtle use of location, for example to infer proximity of social peers, or to position in-game elements. Games such as Insectopia [164] make use of ad-hoc Bluetooth connections and unique IDs associated with devices to determine social presence and then use this data to dynamically generate in-game artefacts. In the game, each Bluetooth device is assigned an insect type, depending on the hardware address range it falls into; the aim being to ‘collect’ these insects and score points, relative to their rarity, as the user explores their

1There are many further important pervasive gaming studies that do not feature a social element; these will be excluded as they are beyond the scope of the thesis.

social surroundings. Similarly, 'Ere Be Dragons [33] exploits user location and emotive response as an input to generate an evolving game landscape. By generating content on the fly from user surroundings, these games have the potential to reduce the expense and time of creating and updating in game content. This has allowed more casual social games to be explored, as a way to more effectively match the interaction methods typically favoured by mobile phone users and adapt to the rapidly changing social environment that users inhabit. Further examples include Hot Potato and the Mobslinger game [148][47], both which made use of Bluetooth social surroundings to influence game content and engage users in rapid, turn-based play; the Mobslinger game for example, used social encounters as the basis for a serendipitous gun fight game. The main limitation of these games is their simplicity, usually being based around a single game mechanic, thus limiting replay value and user retention and reducing the potential for the games to form part of a user's everyday social life.

Numerous studies have explored the opportunities of using lower tech approaches to hosting mobile application trials. By exploiting technologies and functionality which are readily available on the majority of devices, possessing state of the art phones and the financial and technical means to install applications are less relevant. This has the potential to increase participation and bring a more varied trial group by reaching a larger demographic of users. One example demonstrated by early location-aware games such as Botfighters [178], was the use of SMS as an alternative technology for social exchange and game interaction. Not only does this have the advantage of a lower technical point of entry, but as discussed in section 2.3.2, by piggybacking onto a technology that is already highly successful as a social micro-coordination technology, interaction can appear more natural to users. In the text-based adventure experience Day of the Figurines [80], which has been inspired by legacy MUD games, the physical location of a user is not seen as important and instead, players interact using SMS-based commands to control their on-board avatars. The game illustrated that by using these technologies, in-game player narratives are able to speed up/slow down/change trajectory depending on regularity of player interaction with their mobile device. As a result the speed of the gameplay would match the user's natural mobile interaction style well, rather than constraining them to use their device in a predetermined style or speed; largely positive results suggest this to be a successful format for a mobile social gaming experience. Many other games designers have also implemented low-tech approaches to mobile social gaming. Two recent examples of games hosted in the capital city of London are Chromaroma [44], which makes use of task based play and 'Oyster' public transport smart cards to enhance users everyday commute to work and Nike's 'The Grid' [149], an asynchronous multiplayer running game based around London postcodes; the game utilised public phone boxes to denote the start and end of races and track player performance. Both these examples demonstrate that use of everyday technologies can create experiences which ubiquitously enter a user's lifestyle and furthermore offer the ability to interact in places where many sensor technologies would be unavailable (i.e. the London underground network).

As well as social gaming with friends, the concept of gaming with the strangers and unknown peers in our environment has also been experimented with; the ‘You-Who’ game [224] for example, took advantage of the anonymous rapport that can exist over Bluetooth communications, which was introduced in section 2.3.1. The game allowed two strangers to pair up and play a game of ‘guess who’ in a public place, in which one would ask questions about their appearance and the other would make yes/no responses, with the aim being for the first player to guess the identity of the second; at which point the virtual game would spill from the digital world into the physical embodiment of the Bluetooth user [114]. Similar technology has been used to take advantage of the serendipitous, fleeting encounters that form part of our changing everyday social surroundings as users move around the world [47][164]. These games make powerful use of everyday social surroundings and importantly make social gaming and interaction an occurrence that does not need to be organised in advance with friends, but can occur casually, on an ad-hoc basis with any proximal players.

Limitations of Previous Work

Although the aforementioned games offer the exchange of basic social data, for example presence information, location or player moves, they do not support exchange of the type of rich, user generated social media that are commonplace in mobile social networking applications, such as contextual semantic tags, geotagged mobile photos, and status updates. This limits the depth of the in-game content that can be generated and whilst they may offer an engaging gaming experience, most of these experiences do not offer a way to engage with the everyday real world activities and experiences of social peers in a direct and meaningful manner. In addition, the mobile social games discussed are mainly niche, often orchestrated formats. These concepts cannot be extended through user generated content, by offering for example, the introduction of new gaming themes, the exchange of social media and contribution to ongoing social narratives, as is possible with most online social networks. This limits their re-play value. Despite their popularity and widespread deployment in other application areas, few studies have explored the use of web2.0 technologies such as blogging, or geotagging as part of a mobile social gaming scenario.

There are some notable exceptions to this. The Hitchers framework [61] (and later followed by Mobimissions [94]), was developed at the University of Nottingham's Mixed Reality Lab for use as a social gaming platform. It exploited readily available location data provided by the GSM cell phone infrastructure to situate content and in-game players in the real-world. The study introduced the concept of task-based play, to create a digital hitchhiking experience and the platform itself aimed to act as an extensible framework from which to develop future location aware cell phone games. In addition to this, the power of social games based on UGC has been realised in the field of human computing research discussed in section 2.4.2. By introducing a competitive element into a web2.0 system, these systems aim to create meaningful data as a product of play and the ability to generate useful geospatial content using similar mechanisms has been proven in recent studies [138] and commercial systems such as FourSquare, where 'badges' are earned as a result of interaction in the real world [81]. The Hitchers framework, along with the concepts of social and human computing have formed the basis to develop the pervasive game 'Gophers' [38], described in chapter 4.

2.4.2. Sharing Real-World Social Knowledge

In mobile systems, social media can be exchanged in numerous ways, but this knowledge must be encapsulated in a format that allows: (i) users to record whilst mobile, (ii) association with real-world contexts (e.g. social and locative semantics), (iii) convenient exchange between servers and mobile devices and (iv) presentation in a format easily inferred by mobile users. Two technologies that are commonly associated with this process are tagging and blogging. This section overviews recent research in each of these areas and exemplifies mobile social research studies where they have been utilised.

Tagging

A tag is a method of classifying media using a free text semantic descriptor, which does not conform to any strict ontology. A geotag (or *machine tag*) is an alternative form of tag which also contains locative data to give it contextual meaning. Other domain-specific tag variations also exist for example hash tags and author tags and these are usually specific to particular social software services.

Tagging originally acted as an alternative to the hierarchal organisation favoured by websites in the past and offered clear advantages to emerging Web2.0 services such as Flickr [77], including the ease of representing content in multiple categories, the ability to create new categories and the categorical evolution over time through social interaction. This social technology is now widely associated with most UGC applications. A taxonomy of architectures has been devised as a way to categorise the diverse range of social tagging systems that currently exist [137], it implies that the design choices of a tagging system will significantly affect how end users interact with it, so must be carefully considered. It indicates the motivations for tagging are much the same as those for creating social media more generally and tags may be generated for both personal or group gain, for the purposes of entertainment, personal interest in content (such as applications above), to gain points in credit-based systems (where tagging earns points towards additional functionality), for contribution towards a wider community (e.g. on a social networking site) and for personal organisational means (bookmarking systems). Sometimes these motivations are more domain-specific, for example fitness/health gains and bragging rights are common motivations in sports applications [65].

Often these motivations are insufficient to generate adequate tag pools and one way of improving the frequency and quality of tags is through tag suggestions. These have been used to assist with applications such as search and retrieval of photos [137] and user film tagging for the online 'MovieLens' service [191]. One potential drawback of tag suggestions, as with automated peer recommendation, is that the diversity of tag content could be affected. Another facet to tag generation is the balance between good and bad tag content; usually as the tag pool grows, it stabilises, making it trivial to select the useful tags from the noise[182].

The tagging metaphor has been applied to a range of mobile, real world settings. Context, or more specifically, location is used by geospatial tagging systems to associate social media with physical locations (via a coordinate tuple), for instance when geotagging photos on Flickr, creating mobile blog entries in Micro-blog [84], or leaving sticky notes at physical locations in Socialight [197]. Semantically tagged locations are frequently used in mobile awareness systems to indicate a user's contextual status, through either manual or automatic disclosed updates [123][14][69]. Another real world setting where knowledge is shared through tags is in tourist applications. One such example is the indoor, information-rich environments of art galleries and museums, where the quantity of information can be difficult for users to process and interpret as an individual. Proximity sensors, such as RFID and QR codes can be used to identify artefacts indoors. In the steve.museum study [207], a collaborative tagging system was deployed in the Metropolitan Museum of Art, New York, allowing visitors to apply social tags to gallery art pieces, with the intention of building an accessible collection of visitors' opinions, providing the type of accessible user-focused content rarely divulged by museum descriptions.

Another potential research area for social tagging is the realm of human computing, where networks of humans collaborate on jobs that computers cannot do well, for example computer vision tasks. By combining these techniques with social games, it becomes possible provide potentially useful data as a product of play. This has been realised by Von Ahn in the asynchronous social ESP Game [212] and more recently the head to head collaborative game Peekaboom [214]. These studies are based upon online casual games; as users compete in the games, their responses help to produce accurate labels for large databases of images and parts of images. The release of Google's *Image Labeler* [89] further highlighted the potential of this concept. Non-gaming scenarios can also elicit creation of accurate tags, such as Tagpuss! [203] where the images of cute cats on Facebook provided adequate incentive for cat lovers to create tags and ultimately identify and log cat emotions for animal research purposes. The output of these applications is not only relevant for solving computing problems, it can also have human outcomes. For example, it has been suggested as a way to promote healthy eating through analysis of socially provided food tags in the Tag-liatelle application [128], or as a way to share social bookmarks in an enterprise setting using the Dogear Game [63].

Tagging is a technology widely used in mobile social applications, yet little has changed from its deployment on desktop systems to adapt to the constrained input techniques, screen sizes, context changes and availability issues commonly associated with mobile devices. As a result, there is a significant research effort to refine these methods and improve the user experience of tagging on mobile devices. One way that researchers are attempting to do this is through real-world tag suggestions. The MMM study [54] presents a metadata annotation system for camera phone images, which aims to exploit tag data shared by the networked local tagging community in order to simplify the process. The system allows users to tag photos alongside their 'spatial, temporal and social context' – indicated mainly by Cell-IDs and by using a simple algorithm ruleset the system can then make tag suggestions to users that take photos under similar contexts; users can either accept the suggested tags or modify them before submitting the photo. Trials proved the capability of tag suggestion algorithms and demonstrated they could improve tag responses overall. Extending this concept, MMM2 [55] collected additional Bluetooth presence data at time of capture to give an indication of social context and later utilised this to ease sharing between friends online. The study demonstrated that Bluetooth presence data is an accurate method of determining which peers share social media most of the time and could therefore be utilised as a way to automatically share social media between peers. To formally test the effectiveness of mobile tag sharing techniques, the difference between online and mobile tagging is investigated in [4], which compared the default tagging in Flickr with the mobile 'ZoneTag' system, which is derived from MMM. The study found that when using a mobile system, participants were more likely to tag than when exclusively online. It makes suggestions for the design of mobile tagging systems, namely not forcing users to tag in-situ, allowing tagging in both real-world and online settings and finally, that tag suggestions should be used with caution, since they may be misunderstood by users and may lead to incorrect tags being accepted to reduce effort. Importantly, the study identified that in the real-world at point of capture, users have more incentives to tag their data and *social incentives* were of particular importance. This suggests a user's real-world tags are affected by their context and surroundings in addition to their location. Another important consideration when interpreting content in a mobile setting is the time it takes to reach the reader. If the contextual cues that were present at the time of capture are lost, then the content is reinterpreted depending upon user context and interaction time, something that affected the experiences of gamers in Day of The Figurines [80].

Visualisation of Tagged Data

Visualising tags so they can easily be accessed, browsed and retrieved by users is an active area of research. In a tag cloud, tags are arranged alphabetically and tag size varies relative to frequency. Despite their wide deployment in web2.0 services, tag clouds are shown to be less effective than traditional key word searches when searching for specific information, but nevertheless effective for general browsing and discovery of information [193], with visible tags acting as inspiration to users while browsing. In more demanding circumstances, standard tag clouds are less suitable; the exploration of large communal clouds, for example is limited due to the fact that people create tag content in different ways, depending upon their background and experience of an item [18]. This results in a very noisy data set and an unorganised mass of tags which is difficult to navigate. Proposed solutions to these problems include the clustering of semantically similar tags to offer improved browsing [18][192] and the creation of novel visualisation techniques that ease browsing of very large data sets [83].

A unique property of tag clouds is that they represent non-static data sets, which may dynamically evolve over time and this change has been highlighted in the study of tag pools for del.icio.us URLs, which were shown to eventually stabilise [182]. Researchers have proposed extending the tag cloud paradigm to visualise tag evolution over time; visualisations such as ‘waterfall’ and ‘river’ have been developed to these ends [62]. Despite these developments, research shows that standard tag clouds remain effective for the visualisation of less demanding tag pools containing small, broad, non-specific categories [193].

Limitations of Tagging Systems

Some of the key limitations of tagging systems stem from the fact these were designed for use on non-mobile platforms. Research has shown that tagging methods need specific refinements to improve their effectiveness and usability on mobile devices, for example not forcing users to tag content in situ and the use of tag suggestions. Tag suggestion systems are emerging as a promising way to improve interaction times with mobile devices, making users more likely to create good tags, but it has been revealed that the current generation of these systems have a tendency to direct users down one particular path, limiting the heterogeneity of content that is produced. Improvements should be made to these systems to make them a viable option for publication of mobile social media.

The studies discussed have shown tags are often quite subtle, short messages, can be difficult to understand alone, with users being influenced by multiple factors when creating them. But tags need to be intelligible in the field as well as on the web. One way this could be improved is through use of 'meta tags' that supplement tag data leading to more meaningful descriptions, or used as tags in their own right. These could be sourced from auto-generated semantic tag data using contextual information, for example geospatial semantic data generated via reverse geocode lookups, or user behaviour cues. These enhancements could create tags that are more meaningful to a user who is 'out of context', or outside their social circle, could reduce the burden of users creating tags in terms of time and effort and finally, might promote tag creation in situations which would otherwise be ignored.

2.4.3. Promoting Discourse with Peers

There are many paradigms that facilitate the ongoing exchange of social media between peers and include moblogging, microblogging, presence sharing and 'check in' services. Some of the key research studies based in these areas are overviewed in this section.

Mobile Status

The time and author-stamped entries in online blogs have been shown as an appropriate format to represent ongoing narratives between users and have been utilised in many of the social computing studies already discussed. Effort has been made to move blogging onto mobile platforms, allowing the recording of everyday activities in-context, rather than online after an event. The increase in smartphone owners and in-built 3G data, cameras and GPS has led to increased popularity of the practice known as 'moblogging', which makes it easier to create blog entries which are rich in media. It also has the advantages of offering current, relevant information, the ability to get instant responses and discourse from other social peers. The use of geospatial data to tag these entries has been promoted by studies which link blog entries to the situations they were recorded in. One example is LocoBlog [11], which organised entries on a hierarchical map interface, to separate the broad location of blog journeys from the specific timestamped entries contained within. The spatiotemporal life and travel blogging service, demonstrated the early feasibility of releasing a location based service for mobile handsets which made use of Bluetooth GPS units. Emerging use showed how users adopted varied styles of blogging for different contextual situations and emphasised that privacy was not considered an issue by the majority of users, who were typically subscribers to an open minded blogging philosophy. Life is Sharable [42] envisaged an architecture for a peer to peer blogging system, where users were able to publish or modify blog posts, before attaching these to real-world locations using in-situ RFID tags. Patholog [36] extended this concept into a GPS-based community blogging system, which aimed to use blog entries as a way to inspire others, rather than simply record where a user had been.

Lower tech approaches to context-aware blogging have also been investigated. In [201], a music festival wide social network was deployed that made use of 2D barcodes on wristbands and low cost handheld scanners to identify peer presence. Users of the system could mark their presence and make microblog entries and photos linked to their context via SMS, which were later shown on public displays, thus providing a much wider audience for the social media. Messages relating to environmental statements, festival commentary and weather updates were common tag themes. Users of the system were enthusiastic about the concept of using physical barcodes for social networking and in addition were very open about revealing personal details in profile creation. As well as the low cost to deploying these systems, anyone could participate in the network without owning special hardware or installing applications.

A technology more synonymous with the frequent, short bursts of activity associated with mobile discourse is microblogging [84]. This more minimalist system offers a convenient way to communicate a user's status with their peer group. It is designed for mobile interaction and was made popular by the Twitter service [121], which allows for 140 character messages to be posted from a users mobile device to their Twitter feed, acting as a convenient channel to multicast many short SMS-style messages to contacts who are subscribed to their feed. Micro-blogging services such as Jaiku and others [110][84] now offer a combination of locative networking and blogging. Jaiku users post blog updates of their activities in an activity stream, along with their current location. Users are able to view updates and locations of their Jaiku contacts via their mobile phone. The Fatdoor service [74] took an alternative approach by allowing networking on a much more localised level, being designed to encourage users to meet and communicate with neighbours, who they may not normally have the opportunity or inclination to communicate. Similarly, knowledge sharing systems such as CityFlocks have investigated ways to tap into local knowledge [28]. Using this, local businesses and residents were able to pinpoint their premises and add a profile of interests, which were then accessible to localised users. However these technologies require that users manually post activity updates in order to keep their profiles up to date and change their status.

An alternative to these systems are awareness tools which automatically disclose user context. These normally require a user to identify key areas of their environment using semantic descriptions and on returning to these areas, the system will update their status to reveal their current context. One example of such a system is Dodgeball, which will relay a user's presence autonomously, leading to exchange of social information in real-time [108]. A user must be signed into these systems in order for their status to be disclosed, but regardless of this one of the main criticisms of these systems are the privacy implications they create, with users reporting discomfort in being 'tracked', concern about sensitive location data getting into the wrong hands [118] and desire to clearly define recipient group [49]. This has been reflected by users of a location disclosure system who intentionally masqueraded their context by using generic location as a way of concealing their whereabouts, or reducing accuracy of the indicators [123]. Despite the massive increase in social networking use in recent years, location is still considered valuable personal asset, with GPS sensor data being considered particularly sensitive [118]. Another problem of such systems is that most rely on a user manually identifying locations in the first place and there is little consideration for sharing the burden of labelling these locations amongst their peer group. Some research effort is going into identifying these 'socially meaningful' locations automatically, for example using Markov models [124]. This is currently achievable to varying degrees of accuracy and offers a promising way to suggest potential social tag locations to users. When recording social locations, research suggests that the primary importance is the defining of the location itself and secondary to this is recording associated data, such as images or text. Users of the PePe [123] and LocoBlog [11] studies saw defining locations to be the primary aim, even if they were unable to supplement this by adding content to the entry, or were forced to do this at a later time.

Another use for awareness systems is their potential to create impromptu meetups between social peers. This was demonstrated in [220], in which mobile users could advertise rendezvous points that their friends were navigated towards using tactile feedback. In doing so, the system maintained the privacy of users and offered a non-intrusive way to navigate users to these events. Other important facets of awareness tools are the shared narratives they encourage and the combined user agreements of how the applications should be used. In [183] users demonstrated the group creation of mobile social media and showed an important aspect of this was the collective sense-making of the content in terms of shared intertwining narratives between users and how these could be utilised for coordination purposes. Similarly, the collective use and understanding of technologies by users was demonstrated by the HummingBird trials [168]. The shared knowledge between friends has been shown as an important cue to interpreting tags in awareness applications [14]. Because social discourse in mobile awareness tools can occur in near real-time, social narrative can emerge as a natural part of interaction. This was demonstrated by the social location sharing system Connecto [14], a system which offered a way for groups of friends to tag locations and automatically share updates of their context. The study found that in use, the application moved beyond its primary use as a mobile awareness tool to report individual locations, towards supporting an ongoing social group repartee or narrative, which evolved as users moved around.

The next generation of these technologies now allow users to publish contextual 'check in' updates directly on their social networking page, demonstrated by Facebook Places [69] and FourSquare [81]. These applications allow users to define key places in their environment, that others in their social network can 'check into' next time they visit. On manually checking in to a location using their GPS mobile phone, a user's social networking status is automatically updated to reflect this context, but an important addition that the tools offer is an insight into which other people in their social network have visited the same locations as themselves.

Limitations of Social Awareness Applications

Many benefits are offered by sharing knowledge between users through social awareness applications, but the flow of this social media cannot be easily managed, with most systems relying on simple location metrics and social network status to do so. Additional considerations of automatic disclosure systems are ethical issues such as privacy. Better ways to define the disclosure group of social media, improved ways to define social locations and a deeper understanding of the social narratives that often ensue must all be considered to improve these tools.

2.5. Ongoing Challenges for Researchers

MoSoSos are still an immature area of technology. Some of the current considerations of applications designers have been summated in sections 2.2-2.4, but research suggests there are still a number unresolved issues when designing for these systems, some of which are only beginning to emerge. Energy-aware application design, incentives for creating content, privacy, spam and content inaccuracy have all been identified by academics as potential future challenges for these services [84]. This section defines what are believed to be the broad challenges of MoSoSos and in addition, the more specific challenges of social media exchange are discussed.

2.5.1. Grand Challenges Faced by Community

MoSoSo research is still an emerging area and currently offers a somewhat niche market of applications with many problems yet to surface, but some major challenges have already been identified by research trials in the area. Building upon these, this section summarises what are considered to be the grand challenges for researchers as the software matures:

Increased societal homogenisation: Through emphasising the strong ties that already exist in a user's social network, these applications risk ignoring the weaker ties on the edge of a user's social circle. At its most extreme, this also risks increasing the digital divide that already exists in today's society; those individuals who have no access to the prerequisite technologies are excluded from the enhanced experience afforded by shared social spaces.

These fears have been highlighted by a critique of the real-world social networking, which envisages a homogenous representation of the city being created over time, as users are encouraged to socialise with those they already know [205]. The paper argued for a more 'inclusive' view of the city. Ignoring this issue could fail to portray the niche aspects on the edge of society that make everyday interaction interesting. In addition, location-based systems are at risk of isolating peers from one another who dwell in different locations. A question for researchers is how to minimise the potential for social isolation and also allow these systems to scale between highly localised and more spatially distributed social networks.

Lack of openness: As social networking has become more popular, an increased amount of social media is becoming locked up in social network servers and their associated applications. The isolation of this content in silos of closed information such as Facebook and its associated applications, leads to this data being closed off to application developers and some argue that over time, this could challenge the open nature of the internet and limit adaptation, potentially posing a “threat to the web” [70]. If the same were to happen to mobile social services, this risks locking up mobile social media and the option for users to move their data to other web2.0 platforms as they please. Furthermore, this could limit any future applications that might build upon this media, restricting innovation. It is therefore desirable to keep mobile social applications as open as possible. The difficulty of achieving interoperability between existing social networks is an additional challenge for mobile application designers, discussed in section 2.1.2.

Threats to privacy and security: The privacy implications of always-on mobile social applications is an important area of research that must be addressed before use of MoSoSos becomes more widespread. Investigations have shown how maintaining control over the disclosure of a user's personal status (such as locative context) and the content they produce is a vital part of this; as is defining access profiles to clearly stipulate what peers can view. However, social networking research shows that users are more likely to restrict access to their profile, or obscure information using nicknames, rather than use inbuilt social network privacy controls to manage individual items of social media [209]. One proposed solution to the problem of privacy is the decentralisation of content, which allows users to be in complete control of the content they create and its release [53]. In this setup, to exchange information a user peers must communicate with and be authorised by the publisher themselves. Social networks such as Diaspora [58] are now realising this architecture online and similar architectures are being trialled by mobile researchers [168]. Another security issue that exists in MoSoSos is the k-anonymity problem [17], where if sufficient user data is exposed a user's identity can be revealed through amalgamation of these data sets. The security and privacy of users is often further compromised in these systems, since exchanged social media is linked to non-anonymous user-IDs, which leaves systems open to potential spoofing and eavesdropping attacks. Some solutions to this problem have been proposed, such as the use of internet-style client side certificate authentication to control content exchange, or the use of hashed anonymous IDs and a peer to peer architecture where only trusted peers would be allowed to communicate over encrypted connections [17]. Similarly the Smokescreen study added a privacy layer for mobile presence sharing apps [51], relying firstly on 'clique' signals to control the range of sharing amongst known peer groups and secondly, employing 'OID' identifiers to advertise presence to strangers; any exchanges had to be made via a trusted broker, ensuring the two parties' permission before an exchange could be made. These current solutions all require some effort on the user's part and future systems could make use of learning algorithms that operate in a similar way to spam filters, in order to automatically identify which communication will be undesirable to the user and in doing so, minimise the burden on users.

Ethics: Ethical considerations are an important aspect of mobile social applications and the concerns of users have been conveyed by numerous research studies [49]. One aspect that raises ethical questions is the use of non-consenting third parties as an input to applications, a technique used used to great effect by the Uncle Roy study in order to engage anonymous strangers in the experience [24]. Research shows that privacy concerns are held by users when adding real-world non-player characters to a series of pervasive game concepts [148], particularly when they have not given informed consent. This may be done unintentionally, for example disclosing the location of an individual through their inclusion in a geotagged photo, or intentionally as an inherent part of the application design, for example by exploiting the sensor signals that user's mobile handsets broadcast [168]. In either case, understanding these aspects is critical to mobile application design, as they could influence user decisions when interacting with mobile social applications, in terms of what is acceptable to share and whether it is appropriate to use an application, thus influencing the range of social media that is published in the network and what social ties are created. As mobile social applications become more established it is likely a wider social etiquette will develop, in terms of when it is socially acceptable to use these applications, as has become the case with mobile device use more generally.

2.5.2. Specific Challenges of Mobile Social Media Exchange

The critical challenges of mobile social systems in general have been defined and clearly this a wide area; many of these are beyond the scope of this dissertation. The research studies in this thesis instead explore the challenges associated with the exchange of mobile social media itself and these are defined in this section:

Space and place: Many MoSoSos centre their functionality around locative context of users; either through relative proximity to other users, or via absolute positioning technologies. The merits of each sensor system were deliberated in section 2.3.1. Large scale studies of mobile social networking users has shown that the same social message can be interpreted differently by readers depending on their current context [172]. The definition of 'place' is therefore seen as an important consideration in the design of mobile social systems and this has motivated further investigation of the factors that illicit users to share content in mobile social services; something that the studies in this dissertation seek to accomplish. However these systems are not only challenged by the physical and digital interactions of individuals and social factors are also important. Early mobile locative computing studies, particularly regarding collaborative systems, recognised that social interaction was an important area of research and vital to the success of such systems. Gellersen et al. [190] considered social and human computing factors to be an equally important metric for context awareness. Systems such as Hummingbird [216] identified social awareness as a user's position in a group in relation to proximal users. This was explored further in the MobiTip system [181], which identified 'social positioning' as an alternative and often more valid approach to situating users in a mobile social setting. Regardless, most current social exchange systems place emphasis on situating a user and their social media using location alone and frequently social position is disregarded as an indicator of context.

Further to this, the concept of urban computing relates to situating computing and sensing technologies within our city environments and through doing so, incorporating them as a part of everyday urban lifestyles. It is an emerging area, which demands new design principles to embrace it. An ethnographic study investigating ways that social technology could enhance urban experience on the London Underground rail network [16] highlighted some of the subtle interactions, unspoken etiquettes and relationships that need to be considered when prototyping an application for this specific setting, all influencing user interaction. Positioning and interpreting social computing technologies in urban environments is clearly a non-trivial matter and using location data alone would limit where they could be used in these challenging environments and furthermore, much of the human and environmental aspects of interaction would be lost.

At present, despite the wealth of interest and developmental activity in areas such as MoSoSos, mobile social tagging and urban computing, there still remains a lack of understanding of how environmental and human cues motivate users when using mobile social services to tag their everyday surroundings. It is to this aspect of mobile social applications that the research studies are directed. Through analysing experimental data from trials of three experimental MoSoSos, one intent of the dissertation is to better understand social interaction in these environments and identify the factors that encourage users to exchange geospatial information.

Considering non-application users: An additional challenge concerns the non-application users that frequently form a part of the application experience. These include friends, bystanders and complete strangers that do not use the application, but regardless become involved in a user's application interaction. This may occur in a passive way, for example if a person is caught in the background of a mobile photo, or their presence may be more explicitly used, by sensing it and using this as an input into the application.

This issue of non-application users is intrinsically linked to the matter of inclusivity. If mobile social applications reach ubiquitous deployment, these could augment our physical environments with a continuous backchannel of social data layered over reality [50]. An ethnographic study of user data from the Dodgeball network suggested that social networks change users' experience of a place, particularly where social information can be defined in an ad-hoc manner, creating a 'third space' where local community knowledge is current and available without asking [108]; something that was made possible by the automatic status updates of Dodgeball. The danger is that these type of services offer a restricted and generalised view of society; firstly of social networking as a whole (the paper notes that Dodgeball content is not equivalent to that of networks such as MySpace, for instance) and secondly of the environment itself, emphasising that not everything in the world can be sensed so our environment will never be a complete real-time system, however hard designers try. Similarly, when 'check in' systems like Facebook Places [69] are considered, many factors such as device type, social network membership, social peers present, sensor availability and mobile reception dictate the range of places that can be checked in to, potentially resulting in a skewed perspective on society, with iPhone users checking into city pubs expected to be the stereotypical use case. This is an important consideration as the deployment of such applications becomes more widespread, since the great danger in this is that this could lead to a more homogenised society.

Previously, this chapter identified the technical ability to sense the presence of non-application users, proven by applications such as Cityware, Familiar Stranger and Blowtooth. To provide additional meaning from these users, systems would need to data mine their social networking profiles. However, providing this information about non-application user status is an ongoing challenge, which currently requires installation of customised client software. A further challenge that exists is how designers can make use of these non-application users in order to create systems that consider the social fabric of the world as a whole, rather than the subset of individuals that make use of the application. The benefits of doing so could include more accurately positioning content and detecting social context in these systems, becoming more inclusive of users and allowing interaction with users who would otherwise be excluded due to failing the technical barriers to entry, for example by not possessing a mobile device adequate to run the application. This could also offer a more accurate representation of a user's social surroundings by providing a representation of these even when away from their usual peer group.

Nonetheless, many of the ongoing challenges associated with this area relate to societal acceptability as well as technical implementation. There are ethical considerations of using these people, both as direct input to system, or less explicitly in the 'background'. It is important to explore and understand users' current perceptions of doing so, as a guide for designers, before these applications are more widespread. Beyond this there are ongoing legal and privacy challenges that may dictate deployment of applications using sensor systems in urban settings, due to the difficulty of making personal data such as Bluetooth addresses anonymous [184]. UK and EU law will need to develop to consider these new use cases for mobile technologies.

Exploiting user generated narratives: Narratives are an important aspect to human communication and the desire of users to communicate in the form of stories has been exemplified by numerous mobile technology studies [11][14]. This is further proven by the recent trend for mobile microblogging, highlighted by the growth of services such as Twitter

[121] and the storytelling that exists on social networking sites. However, these examples of narrative exchange are constrained to the fields of blogging and microblogging applications, but examples of narrative exchange also exist in mobile social networking.

As social media use becomes more familiar to users, studies have shown how narratives are used as a way of discussing social media [155] and have also been seen in the wider area of MoSoSos, exemplified by studies such as Connecto [14]. In this, geospatially tagged content was exchanged between users in the form of status updates; a series of repartee was found to naturally emerge amongst users, in which updates were linked by a central thread and spanned across space and time.

No support currently exists for encouraging and allowing these narratives to exist and develop as part of mobile social media exchange. One way this could be achieved is by exploiting the higher level themes as a way to intelligently link streams of related media together and describe them using some thematic metadata. A social application would be able to automatically identify entries that form part of a narrative by clustering any social media that algorithms deem to be closely related; this could be achieved, for example by exploiting the contextual data collected around the time of capture (locative and camera phone data) with a semantic analysis of the social media itself. As well as clustering entries, an overarching meta-theme for the stream could also be defined. In order to support real-world social narratives, standards should be developed for representing and easily querying them, for example via an extensible social narrative API; this would allow new narrative-based social applications to be more rapidly developed.

There are numerous ways that narratives could be exploited by application designers to provide benefit to mobile social applications. At their most basic, they could be used to present related comments on the web as a coherent thread; for example using a blog-style format which displays comments in a chronological order and allows the streams to be modified by the reader, in order to append to the narrative. This has the advantages of being easier for the reader to explore, easier for them to interpret and of presenting comments together in the context they were intended – essential if these are stateful entires, where interpreting one comment relies on the reader being aware of narrative history. Also, the narrative-based organisation of data makes the very large data sets that could emerge over time in a MoSoSo easier for users to handle. One way narratives could be found by a user is by filtering those that might be relevant to them from those that are not, using either spatial proximity measures or the history of narrative themes a user has engaged with, in order to measure their relevance. Using these techniques, applications would be able to make powerful inferences about narrative data and present them to the user at the appropriate moment as they explore their environment, for example “your peers exchanged these comments and took some photos whilst exploring this historical site: do you want to subscribe to this stream?”.

Another use for narratives is as a way to create new, engaging social gaming scenarios, with users contributing to narratives, or revealing narrative content as a result of play. Massively multiplayer online role-playing games (MMORPGs) for example, have a strong narrative element to guide user collaboration and interaction, using these create endless gaming scenarios. By using these in real-world settings, they could have the added cultural and health benefit of encouraging users to explore lesser known parts of their environment and learn more about their local area. Furthermore, they could exploit the concept of crowdsourcing as a way to gather data about the local environment for example. A final way of using them would be to allow their elements of a narrative thread to be revealed as users experienced similar contextual or social conditions, for example “your friends know these interesting routes to explore the city”. These contextually linked 'Social journeys' would allow peers to stay informed and be guided along the route. Revealing them in this exploratory fashion would have the benefit of allowing the user to explore the social narrative within the real-world context that it was recorded and also contribute to discussion topics that were held along the route in an asynchronous manner.

Exploring better incentives: Incentives are a powerful method of encouraging users to create social media that is good quality, relevant and up to date. There are multiple examples of incentives that are used to encourage user interaction in social computing studies, such as social gain (the use of existing social networks encourages responses which benefit community as a whole), personal gain (the organisational benefits that come from social bookmarking or the interest gained through receipt of blog responses) [4] and reputation systems (which reward members of a social community that provide 'good' content) [84]. A challenge is to identify the best way of offering similar incentives that will entice users to create and maintain good content in MoSoSos. One option is the use of competitive, gaming-related incentives inspired by the web based human computing games created by von Ahn [213][214], which demonstrated gaming could be used to encourage useful, accurate tag creation. Another is to investigate the reward of serendipitous receipt of real-world content as a way to encourage social media publication. By focusing research on this area, it has potential to inspire: greater quantity of more interesting content, more accurate content and content that is more likely to be kept current by the user community.

2.5.3. Challenges of Experimental Methodologies

Selecting appropriate methodologies for evaluating research studies based around mobile social media exchange is a challenge in itself. In order to sense user location, Wizard of Oz (WoZ) methods have been utilised in past pervasive computing studies [43] as a way to simulate a user's real-world location without the problems commonly associated with these technologies. However, more recently the ease of accessing sensor data through freely available SDKs and cheap off the shelf devices has made conducting field trials of applications using real locative data trivial. There is the question of whether to make use of pre-established social networks or to create isolated social networks for trial purposes. In addition, tools are required to log, monitor and replay user interactions in these environments; for example visualiser tools have been developed to support field trials of CatchBob, Uncle Roy and Savannah. These are mainly limited to absolute locative data and are not designed to handle dynamically generated social content, so would need to be extended for the study of mobile social media exchange. Finally, methods are required to collate qualitative user experience data; a common method of doing so is through completion of 'study diaries' to monitor their usage; a technique that achieved a good range of responses when assessing Feeding Yoshi [19].

The emergence of sensor-rich smartphones more recently has led to an improvement in evaluation techniques specifically designed for these devices. One continuing challenge is obtaining a trial group that is a representative cross section of society, when smartphone users are such a specific group. In [45] beta-testers of new products are loaned smartphones over a long term period and this ensures they are familiar with the devices by the time of the trial. An example of evaluating and logging of general smartphone usage over time is shown in [71], which automatically monitors on-device events to file and this is used to study users' real-world high level interactions with their devices and applications, the data traffic and energy use consumed. Alternative approaches for testing prototypes of new applications before they are even created have also been proposed [56]. A framework for evaluation of lower level application interaction in the real world is demonstrated in [8], which can be used to evaluate modern Android-based applications in terms of usability before being trialled. Using an on-device utility, the tool can collect, log and analyse interaction data to file by watching for in-application interaction events. Other tools now allow for user experience of smartphone applications to be evaluated. Systems for capturing objective and subjective user feedback in-situ on smartphones have begun to emerge, for example [45] uses two way SMS-based experience sampling, combined with online web diary responses and the gathering of on-device data such as call logs, while [82] incorporates a combination of logged device usage and user experience sampling through on-device feedback requests (scripted in XML and triggered by application or other events, e.g. locative context), to provide a rich summary of trial application usage. The application allows researchers to monitor logged trial data at a distance and can be used either stand alone, or as a library included from the application. These tools were not available at the time of the dissertation trials, but similar techniques were manually implemented in the studies as a way to log in-application user interaction, contextual status and events.

The recent emergence of smartphone 'app stores' has made the large-scale trial of applications a reality, by distributing the software directly to the personal smartphones of users; something that could not be easily attained at the time of the trials. In one study, the aforementioned Feeding Yoshi game was re-trialled using an app store distribution, as a way to inform a re-design of the game [142]. By using this technique, the trial maximised the number of potential participants, whilst maintaing a sound quantitative and qualitative research process. Trial data was collected firstly, by performing quantitative logging of user interaction on-device, through the use of in-game 'token earning' that allowed users to respond to specific questions from researchers, by acquiring more detailed qualitative data using existing Facebook messaging services and finally, by holding further VoIP interviews with selected participants. This new research methodology had a number of advantages including reduced effort and trial cost, increased user base and geographic spread. The study also highlighted a number of challenges with the technique, such as making the trial inclusive of users, being multilingual and handling communication across different time zones.

2.6. Summary

To summarise, this chapter has provided an overview of Mobile Social applications and the key technologies that have made these possible in recent years and has also focused on the more refined area of social media exchange. It has looked at the various motivations for use of social media in mobile applications and some of the latest applications that are emerging in the area. Finally, the chapter has summarised what is believed to be the great challenges of mobile systems generally and the more specific challenges that affect mobile social media, namely considering the: external factors that can influence user content beyond location, ways that non-application users can be used in designing mobile social applications, exploration of user-generated narratives as an element of these applications and finally, identification of the best ways to offer incentives to application users to encourage creation of high quality social media.

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The next chapter elaborates upon these social media challenges and discusses the research aims of the three studies contained in this dissertation.

3. Research Aims

This chapter defines the experimental technologies that were developed and trialled as part of the research. These are all based in the field of mobile social media exchange. In addition, it identifies the overall research question of the dissertation and the individual aims that each trial set out to address. The aims are based on the specific challenges associated with mobile social media exchange that were identified in section 2.5.2. These aims are also set in the context of the three themes outlined in section 2.4: *mobilising social games*, *sharing real-world social knowledge* and *promoting discourse with peers*.

3.1. Overall Questions

The three technologies contributed to a single overarching research question:

R01: *How do users exchange social media in mobile social software services and what are the factors that influence them?*

The social computing studies discussed in chapter 2 identified that many factors influenced users when creating real-world content, such as geotagged photos and semantic tags. It is proposed that an improved understanding of these factors will allow MoSoSos designers to be more accommodating of them and explore new ways to position real-world media, beyond locative context. One facet of this investigation will be to identify any overarching themes or 'narratives' that occur in the real-world as users interact, both as an intrinsic part of the application design and as a naturally emerging characteristic. This process will focus on how the utilisation of narratives could enhance mobile social tools, for example by offering improved ways to associate social media entries bound by an overarching theme. It is this pivotal question that led to the development of the initial study; an experimental mobile social game known as *Gophers*, which later informed the design of two MoSoSos; *ItchyFeet* and *MobiClouds*.

3.2. Experimental Investigations

The experimental investigations comprise of three investigative studies, each with its own specific research aims. These involved the development and user trials of three mobile social services: Gophers, ItchyFeet and MobiClouds. These were trialled by groups of volunteer users in their everyday environment, in the same way a real MoSoSo would be used. The trials ran over a sustained period of time and used the testing methodology that is defined in sections 4.5.3 and 5.4. Through the analysis of data from the trials in the form of log data, daily diaries and interviews, the research seeks to better understand social interaction in these environments and identify the factors that encourage users to share social media. There were a number of defining features of the technologies that made each of them unique:

Different methods of positioning social media were used: Gophers made use of coarse GSM Cell ID positioning as a way to calculate relative distance between in-game characters, elements and players. This was replaced with GPS positioning for ItchyFeet, which was used to precisely position the geotags that represented user context. Finally, Bluetooth was used as an input to MobiClouds, as it allowed the monitoring of a user's social environment and was also inclusive of non-application users.

Different incentives were used: Gaming-related incentives were used by Gophers, which intended to maintain a good range of user generated content as a result of the enjoyment of players engaging in the game and the competitive ecosystem that was created meant that by supplying relevant social media, players would score more points in the game. ItchyFeet and MobiClouds did not introduce an artificial incentive and instead relied on becoming an integral part of a user's existing online social network; something that users like to supply with good social media to maintain their online profile, due to being an active member of an online community.

Different social networks were used: The social network created in Gophers was simply the pool of all trial users, all of whom could interact with one another. The service did not integrate with any existing online social network; at the time of the trial there was no simple way to do so. In ItchyFeet and MobiClouds, the services integrated with users' existing online social network accounts (Facebook) and each group of users were already friends on the service and so were used to interacting through electronic social tools.

At the start of the PhD, the research focused on investigating social games and the research questions in section 3.2.1 were formed. A number of notable findings emerged from this exploratory study, for instance the importance of narratives when players were interacting in tasks, the appeal of social agents and also the popularity of semantic geotagging in the guessing game. Following this study, the research topic needed to be refined. The research could have focused more closely on any of these individual areas, all of which could have made valuable contributions. However, the importance of mobile social networking was becoming increasingly clear around the time of these trials and there was a notable lack of academic research tackling this. As such, it was decided that the remainder of the research focus more closely on the subject of social media exchange. The implementation of another gaming study was an additional time burden which was unnecessary to investigate this area and hence the remainder of the research focuses on a pair of status sharing applications. This led to the development of the research questions in sections 3.2.2. and 3.2.3.

3.2.1. Specific Aims of Gophers

Gophers was an experimental mobile social game, based around user-generated social agents known as 'gophers', that were assigned real-world tasks. Players interacted with these agents in their everyday environment, by providing multimodal social media, in an effort to help complete their tasks. There were a number of aims to trialling the technology:

G01: *Assess the suitability of using mobile social games as a social platform for collecting useful, situated content about the world which bears a social and locative relevance.*

As a product of Gophers play, the system was designed to collect large quantities of verified, contextually tagged social media and this could have other useful applications beyond the field of entertainment. This aim assesses the ability of real-world social games like Gophers to collect this data automatically.

G02: *Evaluate the suitability of task based non-linear play and social agents as a way to direct the exchange of mobile social media.*

The design of Gophers incorporates task-based narrative play and social agents as inherent parts of the game design. By studying the ways that users interact with this experience via social media, the study will measure the success of a game designed around these elements.

G03: *Measure the success of using gaming mechanics, credit-based economies and peer review as incentives to delivering good quality social media.*

A peer review system is used to determine success of completed tasks in Gophers and users are scored depending on the quality of the social media they have published. The ability of this setup to generate high quality social media in a self-sustaining manner will be measured by the trial.

3.2.2. Specific Aims of ItchyFeet

The Gophers trial provided important findings relating to semantic geotagging as a community in particular. A more focused investigation of this area would be tackled by the subsequent technology, ItchyFeet. ItchyFeet was a community geospatial tagging and presence sharing service, based on GPS enabled mobiles, that allowed users to tag socially important real-world locations, which would be used as contextual indicators for members of their peer group. The service integrated with a user's existing online social network and contextual updates were posted as status updates on their social networking profile. There were a number of aims to the study:

I01: *Devise a test framework based around mobile social geotagging that allows for logging and monitoring of user interaction.*

ItchyFeet itself is designed as a testbed that incorporates these features. The trial of the service aims to collect detailed information on user interaction with the service, which will later be analysed to provide an insight into typical usage of a mobile social tagging service.

I02: *Discover typical usage patterns exhibited and document the effects of real-world influences on user interaction.*

Using analysis results from the ItchyFeet trials will provide an insight into how users interact with the service, for example providing data on the locations they choose to interact, the social media that is created and which other users are around at the time of tagging. It is also expected the combination of log data, daily diaries and user responses will give information on the real-word factors that influence users when interacting.

I03: *Assess the relevance of peer tag sharing as a way to record semantic meaning for real-world locations.*

Tags are shared between users and reused to represent user context, each time any of the peers become proximal to the tag and in addition, they can be reused by users wishing to reuse them at another location. The study measures the effectiveness of this tag sharing to meet this aim.

3.2.3. Specific Aims of MobiClouds

A user's social surroundings were identified a major influence to tagging in ItchyFeet, which meant the next study would aim to investigate how a these could be used as an input to a mobile social service. Further investigation into the the influences of social surroundings on user interaction was also warranted. This was realised by the final study: MobiClouds. The study extended the technology used by ItchyFeet, but this time made use of experimental 'people tagging' technology to allow users to tag elements of their social surroundings and use these as contextual indicators for their peer group. Again, the service integrated with a user's existing online social network. There were a number of aims investigated by the study:

M01: *Demonstrate the concept of 'people tagging' as a vehicle for positioning mobile social media and assess it's effectiveness in integrating with social surroundings and incorporating non-application users.*

One of the arguments for using people tagging is that it intends to be more representative of recording what is happening socially around a user. The trials assess how effective the technology is in meeting this aim.

M02: *Compare the use of Bluetooth people tagging with locative geotagging of social media.*

Because both MobiClouds and ItchyFeet share the same underlying platform, with the exception of the tagging method used, this allows the two tagging methods to be contrasted. Through doing so, the suitability of each tagging method for recording real-world status in different situations can be assessed.

3.3. Summary

This chapter has summarised the main research studies of the dissertation, entitled Gophers, ItchyFeet and MobiClouds and outlined the aims of each. These technologies were each trialled in order using formal research studies. Chapter 4 discusses the design of the Gophers technology and an analysis of trial results, followed by chapter 5 which discusses the design of the platform shared by ItchyFeet and MobiClouds. Following this, chapters 6 and 7 analyse the results from these study trials. Finally, a detailed summary of the findings from all three trials and a critique of the studies is provided in the conclusion, chapter 8.

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The next chapter discusses the design and trial of the first dissertation study, Gophers.

4. Gophers: Social Gaming in the Real World

The aim of the first study was primarily to explore the application of mobile social services in mobile entertainment experiences and the potential these have in generating real-world social media that is relevant to a small social network. Specifically, the study focused on evaluating the concepts of task based play and social agents as ways to direct this media exchange and the benefits of using gaming mechanics to reward users for generation of this content. To meet these research aims 'Gophers' was devised; a social game for mobile devices that utilised these concepts to create a novel entertainment experience [37][38]. The study was designed as a wide, exploratory investigation into how users could interact using social media and was assessed in user trials over an 18 day period. It was devised around virtual agents, which players interacted with to assist in real-world tasks and through doing so, this facilitated the exchange of social media. A number of broad research themes were explored in the study that relate to those specified in section 1.3.

This chapter summarises the experience of trialling such a game in the real world, assesses the interactions that users made and makes observations on the gameplay that occurred and the social media produced as a result of social play. It begins by introducing the concept of using games to facilitate real-world social networking and summarising the aims of the research. Following this, the game is discussed from a user perspective, the key elements of the game design are summarised and it goes on to identify some of the technical aspects of implementing and hosting the game trial. Next, the results of this trial are discussed and some of the main findings are identified. Finally, it summarises the key findings of the study in relation to the original aims and how this led to the development of the mobile presence sharing system, ItchyFeet which follows this study. It is intended the results of Gophers will inform the creation of real-world games which are inherently linked into a user's social network. The experience of trialling the game in the real world is discussed and the findings from the study are presented.

4.1. Introduction

The area of pervasive gaming is one way game designers have started to explore the opportunities afforded by mobile smartphones. These experiences offer gaming environments that integrate contextual information from a user's everyday activity, for example locative data, in order to create a more immersive gaming experience. In the past these games were limited to orchestrated, short-lived experiments based on bespoke hardware, but more recently the wide availability of off the shelf smartphones, with integrated sensors, cameras and inclusive data tariffs, has allowed these applications to be deployed on more mainstream devices. As a result, they have a lower point of entry, are open to more users and can be played over longer periods of time. Likewise, online social network games have become increasingly popular, which make use of a user's social network connections as an input to the game. Mobile social games represent a subset of these genres and utilise both the interactions made between players and their relationship with the physical world to provide an entertaining experience.

This suggests an appealing platform for investigating the area of mobile social media exchange. It is proposed the gaming element of these studies provide adequate incentive to create good mobile content, whilst revealing how users socially interact in these systems.

It is these intentions that led to the development of Gophers. Gophers is an experience designed to incorporate the type of features seen in mobile social software services into a gaming setting. It was envisaged that this could provide an inspiring environment for users to explore this new type of social communication and from a research perspective, allow an insight into how these applications are used as part of a social group's daily routine. In addition, by doing so it also allowed the introduction of users to a concept which, at the time was unfamiliar to most.

4.1.1. The Gophers Concept

Gophers is a social, locative game developed for Nokia Series 60 camera phones. It combines user created social media, narratives and pervasive task-driven gameplay, to create an enticing social gaming experience. The game uses cell positioning in order to supply coarse, relative positioning information which is used to geospatially tag in-game social media, characters and players. It is not based on existing social network (unlike latter studies), due to lack of APIs available at time and also the disparate social network membership that existed amongst users of this age. Instead the social network is a fixed group of friends, defined by the trial group. The game uses indirect, non-real time exchange of social media between players using in-game characters (social agents) as proxies to carry this information.

Gophers are in-game agents that act as carriers for tasks and proxies to carry information from one player to another. Tasks are devised as a thematic way to encourage content authoring and mobile communication. The nature of a task is completely open-ended and predetermined by the player who created the gopher. As they move around their physical surroundings, players encounter new gophers. If any gophers of interest are found, a player can pick them up using their phone. Once acquired, a player can help a gopher complete its mission by interacting with it through the supplying of social media, such as camera phone images, textual content and geospatial tags. With each interaction, gophers collect situated content [176] that is used to generate an evolving narrative relating to their game tasks.

Once a gopher is acquired, it resides on the player's phone and is visualised in their list of current gophers. While present on the phone, it is not discoverable by other players. A gopher remains on a phone until the player decides to drop it, or it becomes 'bored' and leaves of its own accord (gophers possess a boredom timeout, which causes them to automatically drop from the handset after a sustained period of no player-gopher interaction). When dropped, the gopher remains at the current physical location, (defined by the identifier of the nearest cell phone mast), and stays there, in a dormant state, until being picked up by another player.

Tasks often require the cooperation of numerous players. When a gopher has completed its task, a player can submit it for trial by jury. Here, the gaming community judges whether the mission was a success by reviewing the blog information. After the trial is complete, the gopher is returned to the player who originally created it. This player is then able to assign the gopher a new task and re-release it, or retire the gopher and thus, remove it from the game.

A player's performance in the game is dictated using points (with more points being better) and these are displayed on a web-based leaderboard. The points also act as the in-game currency and can be invested by the player to participate in the game's activities (for example, creating a new gopher, or participating in the Guessing Game, cost a certain number of points). The game explored three key themes that relate to those specified in section 1.3:

4.1.2. Theme 1: Mobilisation of Social Games

The Hitchers framework [61] was developed at the University of Nottingham's Mixed Reality Lab for use as a social gaming platform. It exploited readily available location data provided by the GSM cell phone infrastructure, to create a digital hitchhiking experience. It aimed to act as an extensible framework from which to develop future location aware cell phone games. This framework was used as a base to develop the pervasive game Gophers, described in this chapter. Gophers furthered the concept of digital agents to allow for more in-depth interaction and although the client side code was loosely based upon the original Java ME

Hitchers classes, it greatly extended these, introduced a new custom UI implementation, photo capture capabilities and many new gameplay features.

4.1.3. Theme 2: Sharing Real-World Social Knowledge

The use of gameplay for gathering potentially useful knowledge has recently been employed by several popular games (notably the ESP game [212] and Peekaboom [214]). These studies were based upon online casual games and made use of human responses to label databases of images. The release of Google's Image Labeler [89] further extended the popularity of this concept. Gophers was designed to produce geospatial labelling information from player interaction with a view to using this in later locative applications.

4.1.4. Theme 3: Promotion of Discourse Amongst Friends

With the advent of Web2.0, user generated content is shared in an increasing number of ways. Contextual updates are sent through SMS/MMS messages and individuals blog their daily lives, sharing personal photos and videos with the rest of the world. Such content is becoming ever more popular on the Internet, with the convergence of mobile, blogging and geo locational technologies. Gophers made use of this information by incorporating automatically created blogs (that record game activity) into the gameplay. An additional research aim in Gophers was to make use of this content to promote mobile 'information encounters' [46], with players being presented with situated information as they played the game, explored and made use of their environment and its attributes.

The exchange of social media online often results in the creation of ongoing narratives that emerge over time from a series of connected events, a good example is the updates frequently posted by social network users as part of documenting their holiday travels and the responses these generate, adding to the story. Gophers encouraged the creation of ongoing narratives by design, allowing exploration of how these could control the flow of social media amongst users.

4.1.5. Research Aims

A number of research questions exist that the study of Gophers and the Guessing Game aimed to investigate:

G01: *Assess the suitability of using mobile social games as a social platform for collecting useful, situated content about the world which bears a social and locative relevance.*

G02: *Evaluate the suitability of task based non-linear play and social agents as a way to direct the exchange of mobile social media.*

G03: *Measure the success of using gaming mechanics, credit-based economies and peer review as incentives to delivering good quality social media.*

G01 aims to assess the use of mobile social games as a human computing platform and determine the usefulness of the content that can be collected as a by-product of gameplay, in terms of social and geo tagged data and whether this can be reused elsewhere. G02 examines the unique play style in Gophers, which makes use of pervasive, task based play and in-game social agents, to create exciting, non-linear gaming experiences; in the game, user-generated situated content is collected by the game agents (or gophers) and delivered to other players. Furthermore it measures how successful this technique was with regards to encouraging social exchange between users. Finally G03, assesses how well the game's in-built user moderated content verification works for assessing the quality and validity of content, in terms of both jury service and the gopher Guessing Game.

4.2. Game Design

It is with these research questions in mind that the user experience was conceived. The player experiences two distinct modal experiences of the game world: the mobile mode and the web mode. In order to be as pervasive as possible, the majority of interaction is kept on the mobile client, but user interaction restrictions on the devices, as well as the desire to give gopher agents an online presence, mean certain functionality has been restricted to web access. Mixed reality studies such as *Uncle Roy All Around You*, show that it is possible to combine these experiences in a carefully designed game [78]. Figures 4.1 and 4.2 illustrate an overview of the game from a real world perspective; figure 4.6 shows a web interaction view.

4.2.1. Gameplay

One of the major challenges of the technology was in devising gameplay that would encourage social exchange and social media generation, whilst capturing and maintaining the users interest. In this section the game design is described from the perspective of a player.

There are three modes of communication a player and gopher can have; *photos*, *short messages* and *semantic tags*. Each of these are described in figure 4.4.

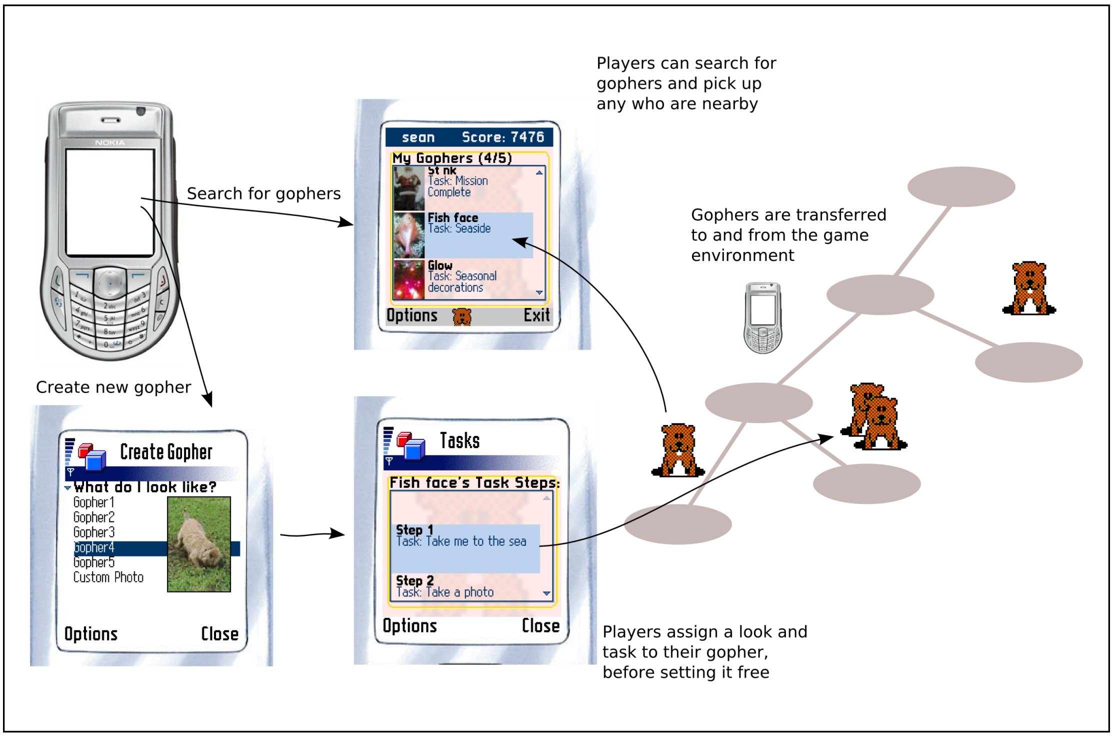

Figure 4.1. Real world experience, showing lifecycle of gophers, which can either be acquired through searches or created from scratch

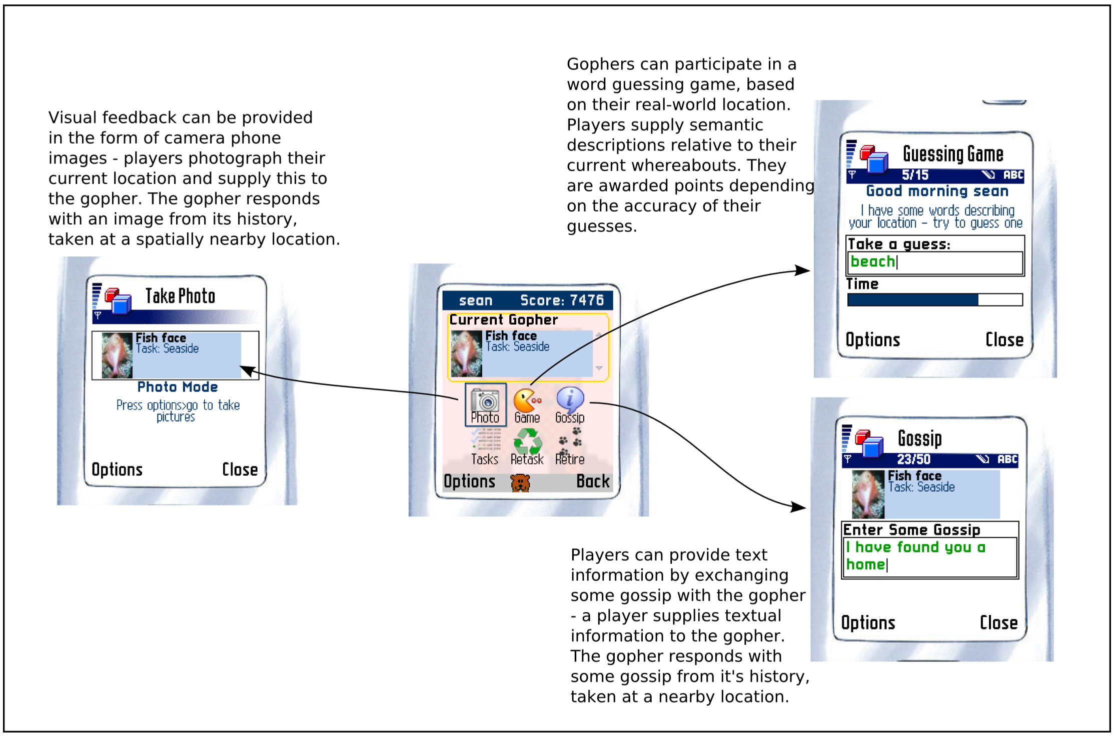

Figure 4.2. Real world experience, depicting different methods of interacting with gophers

Location based information in the game is provided by mobile cell-id information, via Placelab software [104]. This provides an approximation of the relative positions of in-game objects. When not currently possessed by any users, gophers are assigned physical locations in the real world. As players move around their everyday social environment they encounter new gophers which are proximal to them. If any gophers of interest are found, a player can pick them up, moving them from the physical world onto the mobile device.

Once a gopher is acquired by the player, it resides on their phone and is visualised in their list of current gophers (see figure 4.1). During this time, no other players are able to see the creatures. Players are able to interact with any gophers that are present on their phone. The gophers remain on the device until a player decides to drop them or they become bored and leave of their own accord (a boredom threshold was introduced at an early design revision of the game, to discourage players hoarding large numbers of gophers on their phone, in effect trapping them). When dropped from the device, the gophers will reside at the player's last location and remain dormant until another player picks them up. For more information, see the gopher lifecycle diagram in figure 4.1.

Figure 4.3. A player interacts with their collection of gophers

Tasks are intended to be social activities and their successful completion will often require the cooperation of numerous players. When a player deems a gopher's task to be complete, they can submit it for assessment in a unique peer-review system known as 'jury service'. During jury service, a panel of judges are selected from the gaming community (randomly selected from the pool of players who least recently acted as judges). It is their job to judge the success and perceived difficulty of the task, by reviewing the gopher's blog information. Depending on the panel's decision, the gopher is either returned to the original player (if the task was deemed a success), or alternatively released back into the game to complete the task (if the task was considered unfinished). This allows the game community to be self-sustaining.

Gossip Mode

User supplies a short line of text to the gopher, intended to help in the completion of it's task. The gopher responds with some gossip collected at a nearby location.

Photo Mode

User takes a camera phone image which may be of use to the assigned task and supplies it to the gopher. This is geotagged and stored in the gopher's blog. The gopher responds with an image taken at a nearby location.

Guessing Game

User participates in a geospatial word guessing challenge. The user supplies a semantic tag to describe their current location, which is compared with tags that have been left by previous players to describe the current mobile cell. If the tag matches, the player receives points as a reward.

Figure 4.4. Overview of the three main player-gopher interactions

Success in the game is measured by a points based scoring mechanism, where players are ranked on an online leaderboard. Points act as an in-game currency and are awarded for participating in a gopher's tasks and various other activities. They can also be spent/traded to perform certain actions in the game (for example, creating a new gopher, or participating in the Guessing Game cost a specific number of points). In this way, the scoring mechanics are designed to offer incentive to players for supplying good, relevant social media to the system. The design of each of these game concepts are now discussed in further detail.

4.2.2. Exchange of Social Media

Social media is exchanged and consumed by players in a number of ways, described in figure 4.4. These were: Creating text, photos, tags; Receipt of photo or text from recent point in narrative; Reading a gopher's blog out of interest, or as part of jury service.

4.2.3. Task-based Play

Tasks are a key element to gophers, as they initiate the creation of social media by users. When creating a gopher, the player needs to specify a task title and can add any number of task steps, depending on the complexity of the mission (the option to attach multiple steps was added in an early revision of the game design to allow for more elaborate tasks). Examples of tasks that were created during the testing can be seen in section 4.6.2.

Figure 4.5. Creating a gopher and assigning a series of sub-tasks

The gopher's blog narratives are also an important element to task based play, as they provide a current overview of the task progress. Blogs are used by players to determine which parts of the task have been completed, what still needs to be done or whether it is already complete.

4.2.4. Peer Reviewed Content Assessment

After a player reports a gopher had completed it's task, there is a need to independently verify this claim. Through analysis of the gopher's blog narrative, it is possible to confirm whether the task had been properly completed, assess the difficulty of the task and identify the players which helped most in the completion of the task. Because this is a contentious and highly subjective process, the system borrows from the concept of human computing [213] to achieve this. A unique peer-review system known as 'Jury Service' was developed to allow members of the gaming community to review the tasks. The system is a key element to creating a self-sustaining gaming community and serves two main purposes in reality: (i) to determine success of task (ii) to verify the quality and accuracy of social media. As a result of the jurors participating in the review process, the system also acts as a method of assessing the quality of social content submitted to the game. Through the outcome of jury service it was possible to assess the validity of content participants were submitting to the system, acting in effect, as a social moderation system.

Here, the operation of the Jury Service system is discussed. A gopher is submitted to Jury Service when a player selects 'Task complete' from their mobile client. This initiates a new task assessment or 'trial' being initiated for the gopher and a panel of 'jurors' are selected to take part in the reviewing process. Jurors are invited via an email notification and are made up of the 5% of players who stood on a trial panel least recently, or have never taken part. Participation in jury service is not strictly compulsory, but is worthwhile to players, as they are rewarded with points for their contribution.

To participate in the trial, jurors are given a 24 hour window to login to the Gophers websites to cast their votes. On this site they are presented with the gopher's blog narrative and a web interface from which to input their responses. An example of this can be seen in figure 4.6. Presuming a sufficient number of jurors participate in the trial, it is closed after 24 hours and the results calculated. Using the mean responses from the jurors, the following are decided: (i) has the task been completed? (ii) how difficult was the task? (iii) who were the key individuals who helped the most? If the mission is deemed by voters to be complete, points are then calculated based on these outcomes and distributed to the following parties:

- The player who originally created the gopher is awarded points relative to the perceived difficulty of the mission.
- Individuals who helped the gopher complete its task are rewarded with points depending on the amount they were perceived to have helped in meeting the mission goals.
- Jurors on the trial are rewarded for their participation in jury service, with the number of points awarded to them being relative to the closeness of their responses to the

median (used as a measure of reviewing accuracy) and thus rewarding for honest voting.

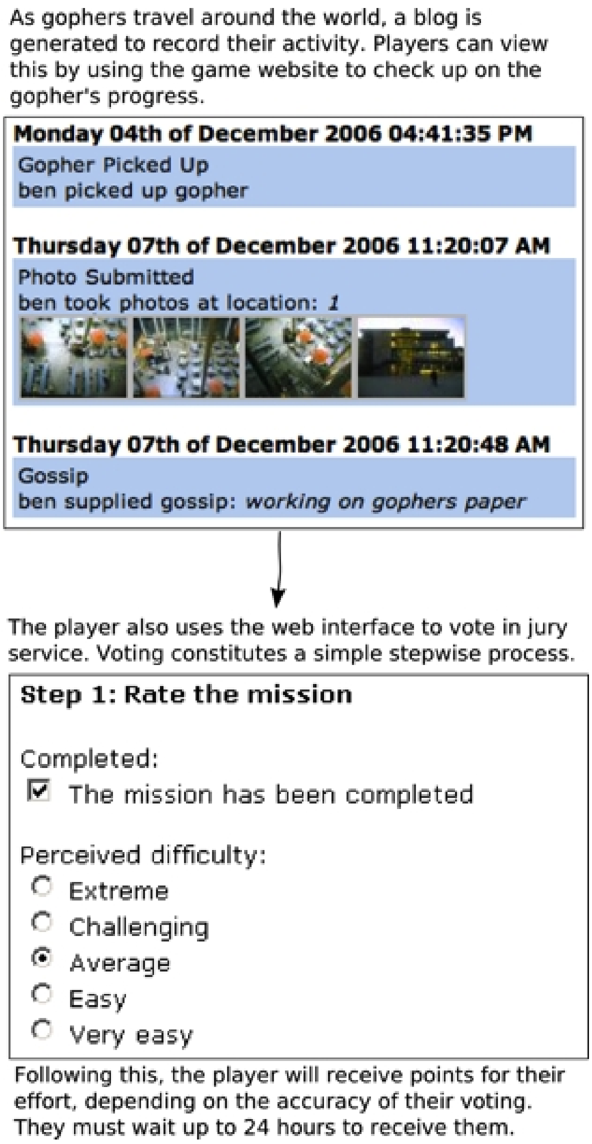

Figure 4.6. Depiction of online web review system

Alternatively, if the mission is considered incomplete, the gopher is re-released and returned to its last known location, where it would remain until a player picked it up to help complete the task.

Because there are many different factors which need to be considered when distributing points, the scoring system is complex. To mask this complexity from players, information about in-game scoring is released in small snippets, via in-game popup messages, for example after participating in jury service, players would be informed “you received *n* points for your effort”; this way enough of the system is exposed to let players learn over time what actions benefit them and which ones penalise, without overwhelming them with information. An additional challenge in developing the scoring system was optimising the point distribution for the various activities. All of the scoring logic is kept on the server side, so that this could easily be fine tuned during the testing process.

4.2.5. Photo and Text Exchange

Two ways a player can communicate with gophers is through the exchange of text and photo-based social media. The player can supply photographic content to the game by taking camera phone images on their mobile handset. Photos are used as a way to provide information that can help with a gopher's task. Images supplied are time and geo tagged with the user's current location and appear as a 'photo' entry in the gopher's blog. In a similar way, the player can supply a single line of text known as 'gossip', which is of relevance to the gopher's task. Again, this information is geo and time stamped before being added to the gopher's blog.

As a way of providing indirect social exchange between similar players and also acting as a reward for participation in the task, the gopher responds to content by showing the player some content (photo or message) from its historical knowledge, which it has collected from a previous player at a spatially nearby location (and not already shared with the current player). This acts as a way to pass social information from one player to another, through the medium of gophers and similarly to the way users of similar interests might exchange information on a social networking site, players with interests in similar gopher tasks and frequenting similar locations also exchange information, with the gopher acting as a *social and locative recommender* between peers.

Giving the player the option of different communications mediums allows the game to be used in a wider range of circumstances and for a more diverse range of tasks, for example, in certain situations a user may find it quicker to take a photo, while in others (such as a crowded place), it may be inappropriate to use a camera and a more subtle text message can be written. Furthermore, it has the potential to generate more interesting blog-style narratives and makes it possible to study the exchange of disparate social media formats.

4.3. A Geospatial Folksonomy Game

A common feature of mapping systems such as Google Maps [92] is that they allow users to tag locations of interest (using pushpins in this example) and to provide some descriptive content relevant to the area. The Gopher Guessing Game was an early concept prototype that aimed to tag locations in the real world through gameplay. This separate mini game was a transparent part of the Gophers experience that allowed the concept to be tested and offered an alternative play style to the main game, by focusing on casual, short interactions, rather than long term task-based play. The game focuses on using human computation to collaboratively generate a semantic tag map over the everyday landscape frequented by a group of users. It was inspired by non-mobile tagging games, such as the ESP game and Peekaboom, which pit players against each other in a game where they must agree on a descriptive word or salient areas for a particular picture. As an outcome, accurate labels and marked areas of interest for images are produced. In a similar fashion, the gopher Guessing Game aimed to extended this idea to label physical locations and words are verified by the game mechanics themselves, rather than being incorporated into a separate review process. This also gives players immediate feedback to the tags they supply, resulting in a more rapid 'mini game' play style.

4.3.1. Game Logic

Because of the unique situation the game would be played in, the design of the game needed to overcome a number of potential problems: (i) allow players to make asynchronous guesses, so they do not have to be playing the game concurrently, since users would be playing the game at unpredictable times in mobile situations and there would be no time to match players (ii) discourage cheating, which could occur through 'pairing up' and tactically copying content from co-located peers and (iii) encourage the supply of accurate, contextually accurate information. The essential game design adheres to the following logic:

Players enter words to describe their current location and are rewarded for guessing the same word as other players.

In early iterations of the game design that were informally trialled, only the player's current mobile cell was considered for matching guesses, which resulted in a very low number of matched guesses and as a result, low participation from users. Phenomena such as mast flipping [61] and the high density of mobile masts in urban environments [105] meant that two guesses could be made at the same physical location and still be tagged to different cells. To counteract these problems, the initial simplistic scoring mechanism was modified to offer a more fuzzy approach to semantic matching; reducing the accuracy of guess required, whilst still rewarding appropriate guessing. Points were awarded following an 'archery target' analogy, where a 'direct hit' received the most points and points were awarded on a decreasing basis depending on how many cell hops the guess was made away from the match.

In the final version of the game, two further revisions have been made. First, to encourage original guesses, points are awarded on a decreasing basis relating to the number of players who have already guessed the same word at that location. A maximum of five players is set, at which point players are asked to guess again. Second, to discourage players from ‘pairing up’ and intentionally entering the same words into the game, each time the same two players are matched, the points awarded diminish. Taking these issues into account, the final set of Guessing Game rules were as follows:

A player enters a word to describe their current location. If other players have previously entered the same word at this location, this scores a direct hit – and both players are rewarded with maximum points (reduced if the same players have matched before and depending on whether other players have already matched with the word at that location). If the word matches with a nearby location, then points are awarded decreasing with distance (up to a maximum of four hops). Otherwise, if no match occurs, then their current cell id is tagged with the new word in the node database, and points are awarded for any future hits.

These (admittedly complex) rules are not made explicit to the players; rather they are suggested through subtle messages when guesses are made.

4.4. Gophers Technologies

This section describes the technical implementation of the game. The overall architecture was broadly an extension of Hitchers and feature a Java ME client application, communicating with a PhP backend and likewise supported by an interactive web site. A high level overview of the application architecture is provided in figure 4.7. The full code for Gophers is available for download at A02.

The server side contains two main elements. Firstly, the general Gophers website is hosted, which features cookie-based password secured sections, offering players access to interactive HTML forms displaying the leaderboard, peer review system and blog viewer. These can all be accessed using a desktop web browser. Secondly, a web API has been developed using PhP scripts, within which the game logic is persisted. This can be called by the mobile client and web interface to query and update the game state of players and gophers and likewise, to post new social content. These two elements communicate with a centralised MySQL database, describing the overall game state for all players, active and retired gophers, individual player status and scores. In addition, the current and past locations of both players and game elements are logged as a location graph, represented in a flat database structure. Any social media supplied to the game is tagged with author ID, gopher ID, timestamp, location of interaction and stored. Finally, all interactions with the API are logged for debugging and security purposes.

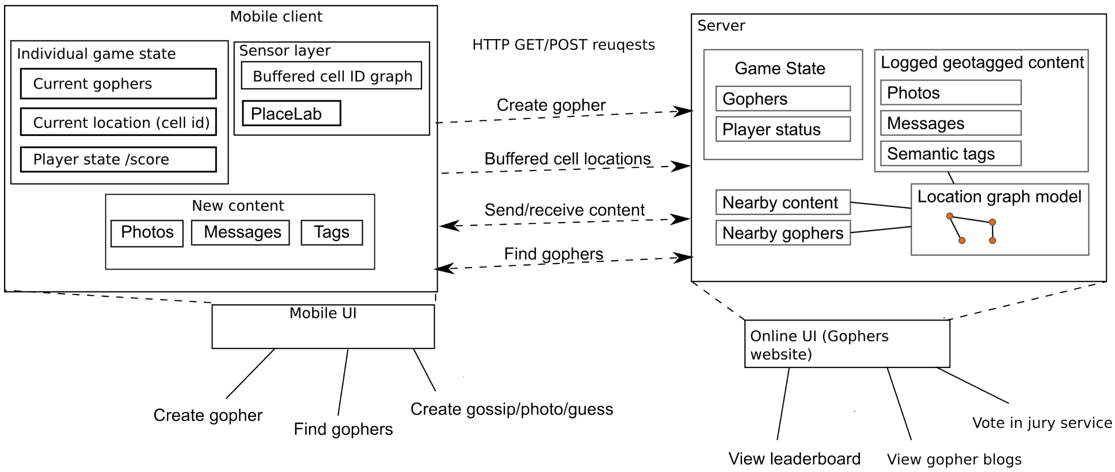

Figure 4.7. A high level architectural overview of the system

The mobile client device acts as a thin UI to visualise the game to players and allow them to interact with gophers in a graphical manner and supply content to the game. A small amount of current data is held on the device such as which gophers were currently held, the number of points the player has acquired, a cache of recent thumbnails and cell locations the player has visited. The client communicates with the server API via HTTP POST and GET requests, each time a user performs an interaction with the device. With each request, the local game status is synchronised with the server in order to update the shared database.

Because of the limited distribution and knowledge of the trial, application security is kept to a minimum, with a user name and pin combination of each player being passed with each request to authenticate the player and all requests being sent as non-SSL HTTP. This proved adequate for the scope of the trial, but would be re-assessed in a larger scale distribution.

4.4.1. Determining Location in Gophers

In many pervasive games, physical location is used to directly map a player's location onto the game world (for example, the player's position in CatchBob! [153]). Gophers takes a different approach by using location data as an indirect aspect of the gameplay. In doing so, the effects of the inherent instability and errors associated with positioning systems can be alleviated and the system is more privacy sensitive than some, since the absolute location of players is not revealed. GSM cell ID positioning[2] was chosen to determine relative position of gophers, social media and events that occur in the game world. This offers high availability and reduced power requirements compared with GPS and meant that additional GPS receivers did not need to be carried by users (internal GPS was not available at the time of the trial). Another unique property of the technology is that the density of cell masts varies between most dense in urban environments to sparse in rural landscapes – and this scales well with the probable distribution of content around the environment.

Mobile cell IDs were acquired by using a portion of the Placelab software. As users explore their environment, the unique identifiers of the mobile cell masts they encounter are recorded. These are held in a buffer and synched with the server with each client-server request. Utilising these, the server dynamically builds a global connected graph of cell data and social content. This graph comprises of 'node' objects which represent cell masts and 'edges' that describe the relationships between them. A new graph node is added each time a unique cell ID is discovered and an edge is created between two cell IDs when a user physically travels between them. Server side scripts can query the graph in order to determine the relative distances between gophers, players and geolocated content.

Gophers could be assigned localised missions, for example, that could only be completed at a particular place. Because of the intrinsic link between many gopher tasks and the area in which they are found, players were encouraged to pick up nearby gophers as opposed to those further away. In early iterations of the game, only gophers within a player's current cell were discoverable. This was playable when tested locally with a number of highly motivated players, but in an environment that was not densely populated with players and gophers it presented a less rewarding experience. If searches regularly returned no gophers, players simply stopped participating. A revised search mechanism that encouraged players to pick up

2 At the time of the study, there was no free, reliable method of connecting mobile cell masts to physical locations and this was another reason for utilising relative positioning; this situation has now improved with the help of online initiatives such as opencellid [157].

nearby gophers, yet scaled between sparse and densely populated gaming communities was implemented, using a node graph based on the connections between cells.

In this system, each vertex, or node on this graph represents a mobile cell mast with edges connecting masts that are physically adjacent. When a player searches for gophers, the game returns a distance ordered list of the nearest 16 gophers. This distance is calculated using the network distance between the player and the gopher (calculated using Dijkstra's algorithm). When a gopher is in the player's current cell it can be picked up immediately, otherwise the time it takes the gopher to arrive at the player's phone is set proportional to the network distance (10 minutes per hop). Players also pay an additional transportation fee (equal to the number of hops) and this is deducted from their point total.

4.4.2. Acquiring Situated Content from Play

As players participate in the game, a byproduct of the gameplay is that a collection of verified, situated content is built. Content supplied by players is geotagged using cell-id and timestamped. This social content is used to facilitate social media exchange between the players, in an indirect manner. This can be consumed by players using two methods:

- Content is passed between players in response to gopher exchanges; for example on giving the gopher a photo, a player receives one in return.
- Players can keep up on real world activities by subscribing to gopher blogs and seeing where they travel.

4.5. User Trials

Gophers was assessed in two separate user trials; an exploratory study to prove the game concept by six university students over 8 days and formalised trials, where 13 6th form college students played the game over an 18 day period.

During the trials of Gophers, each task resulted in a mean of 5.07 responses from players. While exploring, players encountered 430 unique mobile cells in and around Lincoln and travelled between these cells in 2,218 unique hops; some of these cells were encountered only in passing (for example a car journey), while others formed central hubs of interaction with the game (for example the school attended by players in one of the trials). The mean travel distance for a gopher was 3.96 cells, calculated from the number of unique locations within which user-gopher interactions occurred.

Nokia series 60 2nd Edition mobile phones were distributed to players, mainly 6680 smartphone devices. The devices were on pay as you go data contracts and supplied with sufficient credit for the duration of the trials. In addition, the players were free to access the web elements of the game via the Gophers website, which was available from any web connected computer.

4.5.1. Player Recruitment

The game was initially downloadable from the Gophers website, using a mobile OTA installer. In this first attempt, players used their own personal phone to run the game and the intention was to allow the trial to continue for as long as active players existed. It was envisaged that this method would have the advantage of achieving a sparse distribution of a large numbers of players. Additionally, through using their own phone, already a part of their daily lives, players would receive a more natural experience utilising technology with which they were already very familiar.

The game was advertised on relevant mailing lists, blogs and websites, but limited recruitment success was achieved. There are a number of factors that could have discouraged individuals from participating. Since the game was experimental, no guarantees could be given regarding the effects of running it. So, players may have been reluctant to play using their own phone since the cost of data transmission could not be assured and there was the possibility of the corruption of personal data, or even damage to their handset. The principle of informed consent required that players be aware of these potential issues before joining the study; a click-through disclaimer was used before the game could be downloaded and this can be seen at A05. Additionally, players could have been discouraged by age restrictions. Because the game contained large portions of user generated content that was not moderated, players were restricted to being over 17 years old (and later over 15 with parental consent). A final cause for poor uptake was the very specific hardware requirements. The game utilised the PlaceLab toolkit for location data and this was limited to running on a particular subset of Nokia Series 60 2nd Edition cell phones.

4.5.2. User Demographic

Due to the difficulties described above, the studies were conducted using organised trials in and around the City of Lincoln. The trials acted in a more formal ethnographic style, where players could be more closely monitored in the field. Two trials were held; the first was a preliminary trial used to assess the functionality of the original game concept. Players were introduced to the game during a university lecture. The trial involved six university students who played the game over a period of eight days. The second game trial involved 13 A-level students from a local 6th form. This ran over 18 days during the school Christmas holiday. Although the players were not necessarily social network friends, they were all familiar to each other.

Although a group of this size was not large enough to act as a generalisation of the population as a whole, it would allow for highly in-depth and focused individual analysis of a subset of the population. A combination of trial cost, administrative time and amount of hardware required, limited the size of these studies.

4.5.3. Methodologies

In the trials, players were recruited to participate and supplied a phone with the software preinstalled. In each case, a Nokia 6680 phone was provided, with sufficient credit for the duration of the game and given a brief printed synopsis of the rules (which can be seen at A05). To assess the effectiveness of the game concept itself, a post-trial interview was held after the first trial and responses filmed. In the second trial, users' play activity was monitored through log data and with self-documented daily diaries.

Monitoring User Experience: Players were asked to complete a 'game diary' over the first seven days of the trials, to monitor their play; a technique that achieved a good range of responses when assessing Feeding Yoshi [19]. In addition to the qualitative content supplied in the questionnaires, all game interactions were automatically logged on the game servers. Combining these data sources provided an accurate depiction of game activity. On the last day of the trial, a more general questionnaire was completed by the participants that was designed to investigate player opinion of the trial as a whole. Post trial, the groups were interviewed and debriefed.

An example of the questions used can be seen in the appendix at A05. To extract from the response data, the completed questionnaires were manually read and results inputted into a spreadsheet. Quantitative responses were then summated and qualitative ones themed before summating. Trends in these results provided an insight into the experiences of users, which could then be applied to the discussion.

Graph Visualisation: In order to provide the high resolution individualistic analysis, the development of a visualisation tool was necessary. The visualiser, shown in figure 4.8, rendered a graph of encountered cell mast locations and the social media provided at each, built from user's interactions with the game. Each encountered cell mast was represented as a unique graph node and the connecting edges were built from a user travelling between one cell mast to another. The visualiser could be used as a method of plotting the social media they provided to gophers at different locations in the game. It was later revised to include timestamp data to allow for better analysis of how the user's use of the application deviated and changed over time.

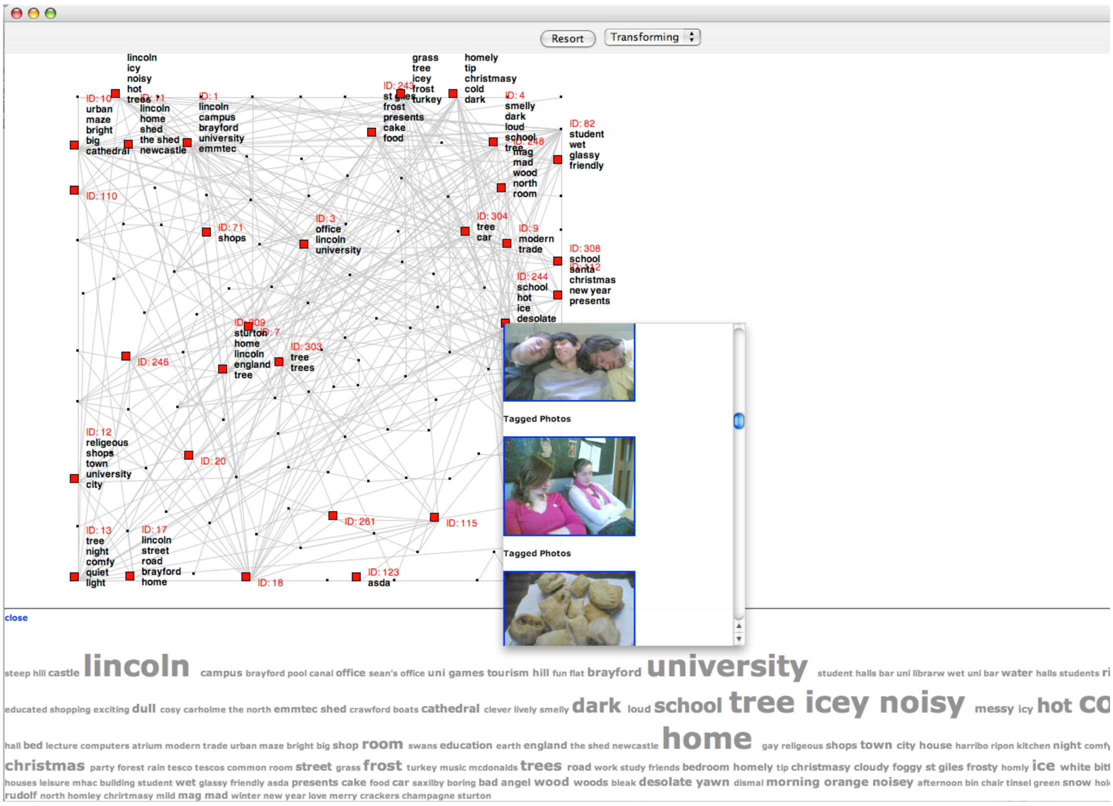

Figure 4.8. The Gophers visualiser, which was enabled detailed analysis of user interactions

Interaction Logs and Gopher Blogs: One valuable source of user interaction data were the gopher's blogs themselves. Through playing the game, the players had generated a self-documenting diary, which provided a useful insight into the way social media was exchanged. Furthermore, an online interaction log viewer allowed for more detailed analysis of user interactions.

In order to analyse these blogs, it was possible to log in to the Gophers website using a special 'admin' user. This allowed a review of the blogs of all gophers a player had interacted with. It also made it possible to more closely inspect the most interesting tasks that were previously identified in the analysis process, described in section 4.6.2, and also view the social media exchanges that were partaken. By visually reviewing and noting the social media interactions a player had made with each gopher, it was possible to build an insight into the typical interaction styles adopted by users. These insights assisted with the analysis in section 4.7.

Bootstrapping: Because of its dependence on user generated content, Gophers relied on a certain level of deployment for its operation. In order for the game to function, a 'critical mass' of participants needed to be reached. A sufficient number of dedicated players were needed to supply content in order for the game to become interesting. To encourage users, the game was initially bootstrapped with a number of sample Gophers players could interact with, to act as a guide into what was possible and inspire users to create their own. In addition, players were given enough points to create two gophers each.

4.5.4. Scope

The literature review identified many social gaming scenarios. The Gophers study looks specifically at games based on user generated social media for in-game content and task-driven scenarios. Furthermore, it focuses on three pre-defined formats of social media where exchange takes place via indirect proxies. The study considers a fixed social network that has been constructed specifically for purpose of the trial, mainly within the spatial bounds of the city of Lincoln, UK. The social media is positioned in a coarse way using cell id positioning, so only the approximate area of users is considered in the analysis. Overall, the scope of the content itself was left quite open since Gophers was an exploratory study to investigate how users would make use of the technology; as a result users were allowed to theme the tasks and content as they wished, within the boundaries of the game mechanics.

These findings have been applied to the wider area of mobile social content exchange, where more accurate positioning and a wider degree of freedom to communicate with other social peers is normally possible.

4.6. Overview of User Behaviour

This section provides a general overview of how users interacted with the application. Firstly, figure 4.9 compares the different genres of social media that was created for each social media format that was exchanged. In addition, a number of different categories of task were set by users during the trial and these are identified in figure 4.10. Finally, an overview of questionnaire responses are summarised, summarising the trial from a user's perspective.

4.6.1. Social Media Categorisations

Social media was created by participants in the form of photos, text-based gossip and tags in the Guessing Game. The content supplied to each of these was analysed and thematically categorised according to subject matter, using the following process. Firstly, all relevant data was extracted from the database of interaction logs using an SQL call, which captured any user interactions that were implicated in the creation of a photo, gossip or tag. This data was then imported this into spreadsheets, using a separate table for each. Each of the interactions was then coded (in terms of content), using identifiers to group similar themes. The codes were then given an appropriate theme to describe them. In order for photos to be analysed, a script was created to extract all photos stored in the interaction logs and display the images on a web page (see 'Photo Tool', A02), thus allowing photos to be thematically analysed by sight and the results also recorded in the spreadsheets. Finally, graphs were created for photos, gossip, guess interactions, that quantified the themes for each, which can be seen in figure 4.9. The graphs could then be used as an indication of typical subjects of discourse.

In terms of the stand alone Guessing Game, tags mainly focused on descriptions of the player's surrounding environment. Trial analysis showed that certain users created significantly more tags than others. The tag pool generated by the game was therefore biased towards those users. In building applications upon the semantic output from the tag game, an important consideration is whether to accommodate for tag frequency to ensure the tag pool is not overridden by a single user; for example by giving large numbers of (possibly similar) tags from a single user less weighting than an occasional tag from another. Many of the environmental descriptions were concerned on what the weather conditions were like in their area – a very changeable and transient subject that users were not expected to comment upon; this suggests that through using semantic analysis, the outcome from the game could be utilised as a social weather tool for gathering highly localised, up-to-date reports.

Most gossip created by players was used to provide responses to the task at hand, showing the game itself to be the primary driver. A significant amount was also humorous or focused on christmas festivities, showing that gophers could be used as a way of distributing jokes and festive feelings associated with this time of year to peers. It was also common for players to communicate general chat messages to social peers via gopher gossip. It is suggested that through use of in-game agents acting as an indirect broker for social media exchange, this may offer an appealing alternative for users to share more emotive social responses that might not be otherwise be exchanged when communicating with friends directly on social networks.

Further to this, players showed a desire to communicate with the trial moderators using these indirect social tools, asking trial-related questions; for instance, requesting extra credit and issuing technical and gameplay questions (see below). This is despite the fact participants were explicitly given more direct methods of communicating with the moderator at the start of the trial, in the form of email and phone contacts and also the shared support network that existed amongst the users themselves. One enhancement to support users when hosting such trials, would be to employ an additional communications channel that would allow them to make these queries more easily from the device and issue additional comments about the trial, represented as a new gopher interaction, such as “*leave this gopher a tip*”.

> “can i have some credit please and thankyou” [U18]

Photos were also closely related to the overarching task; photographic evidence was often favoured as evidence for tasks being completed – whereas gossip could not always provide sufficient proof, for example when a lecture needed to be photographed in figure 4.12. Despite this, the reuse of existing media remained a common way to complete some of the more taxing 'collection' themed tasks, from the internet, books and magazines, demonstrated by the *man with the giant cookie* seen in figure 4.12. It was much more common to use photos as a way to represent a user's outdoor context; something that was rarely disclosed in gossip. A large amount of christmas related imagery was also present.

Overall, only a small amount of meaningless noise was perceived in the responses, showing that the peer review system and game mechanics were adequate incentives to provide good social media. The analysis suggests the type of social media used closely related to the role and situation of the player, with photos being more convenient for recording task-based evidence; gossip useful for other task-based information and chat; and tags most useful for providing rapid updates of emotive feeling and weather reports.

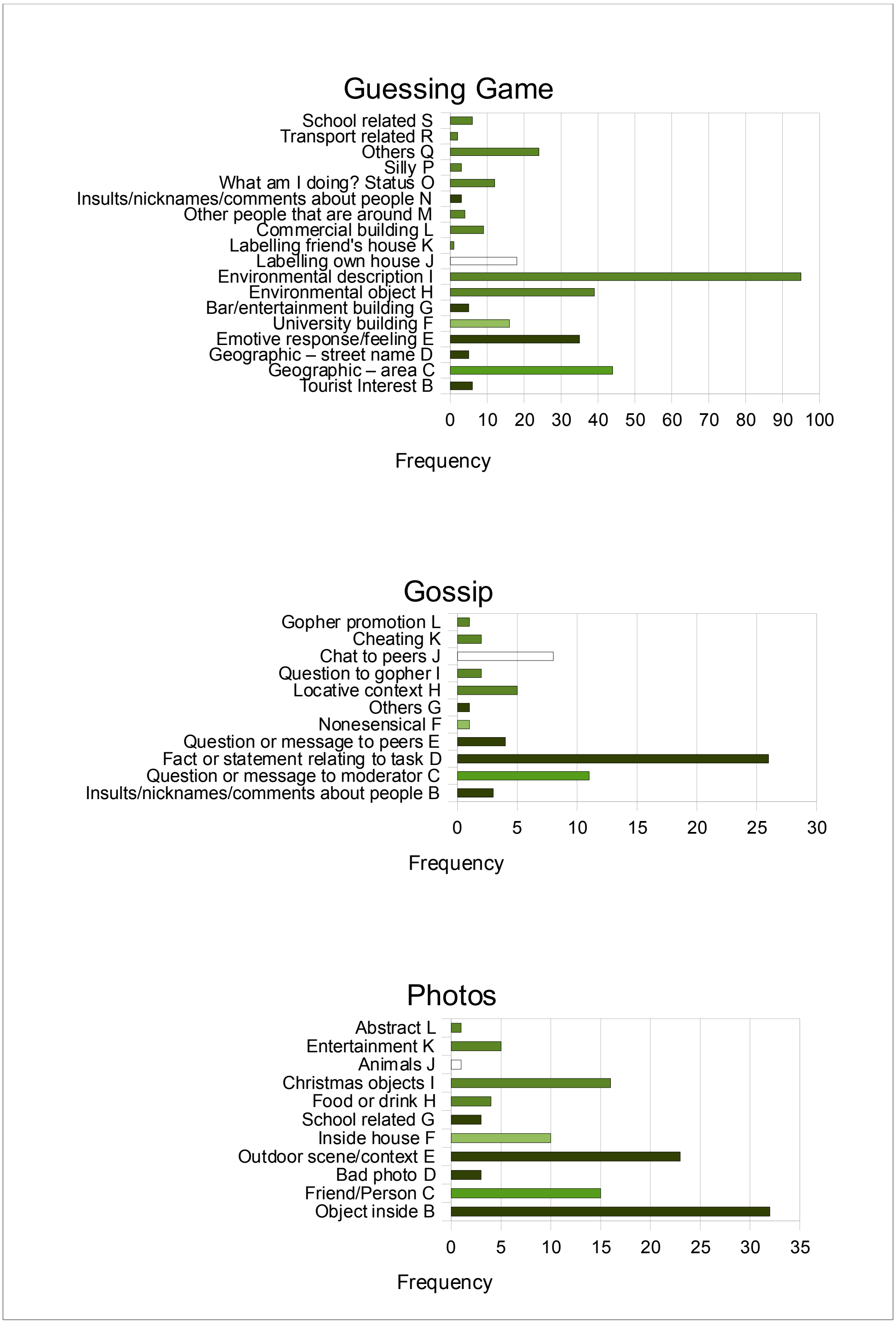

Figure 4.9. Thematic categorisation of the three social media styles submitted to the game

4.6.2. Task Genres

The type of tasks applied to gophers determined the social media that would be created by players during interaction, so were also an important element to user interaction. In order to provide an overview of the style of task the players were participating in, the range of gopher tasks have been thematically analysed. The process for theming the tasks took the same approach as determining the tag themes in section 4.6.1. The results can be seen in the graph in figure 4.10. A selection of tasks for each of the popular themes were identified for further discussion.

The most utilised of these were *collection* based tasks. These challenged players to collate a number of objects from the real-world and post evidence of locating them, for example by providing photographs.

> "Herbertico - Consoles: Find a psp/find a wii/find a ps2/find a dreamcast [U13]

Social interaction tasks which explicitly encouraged social interaction between users were also commonplace. These either required players to find other players, non-players or strangers (frequently they would also be asked to pass on a message or insult), or to interact with other people's devices (for example, finding a specific phone model). These tasks demonstrated that the role of gophers moved beyond that of a game character, toward acting as a social mediator between peers and non-players.

> "LOL - Laugh out loud: Photo someone lolling!/Photo something that will make me smile!" [U16]

Other tasks, such as *travel* or *explorer* tasks exploited the locative properties of the game. These required the users to get to a particular place and either retrieve some information or take a photo to prove their presence.

Finally, *information finding* tasks saw the application being used for localised human computation services. These often required users to answer specific questions or gain information about local services, such as which shops or businesses could be found for a particular product or service. The responses received by these tasks clearly demonstrates gophers being used as a useful localised information finding scouts, showing great potential for human computing.

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"Apple Pie - Ice cream: Take me somewhere I can buy my
favourite ice cream" [U9]
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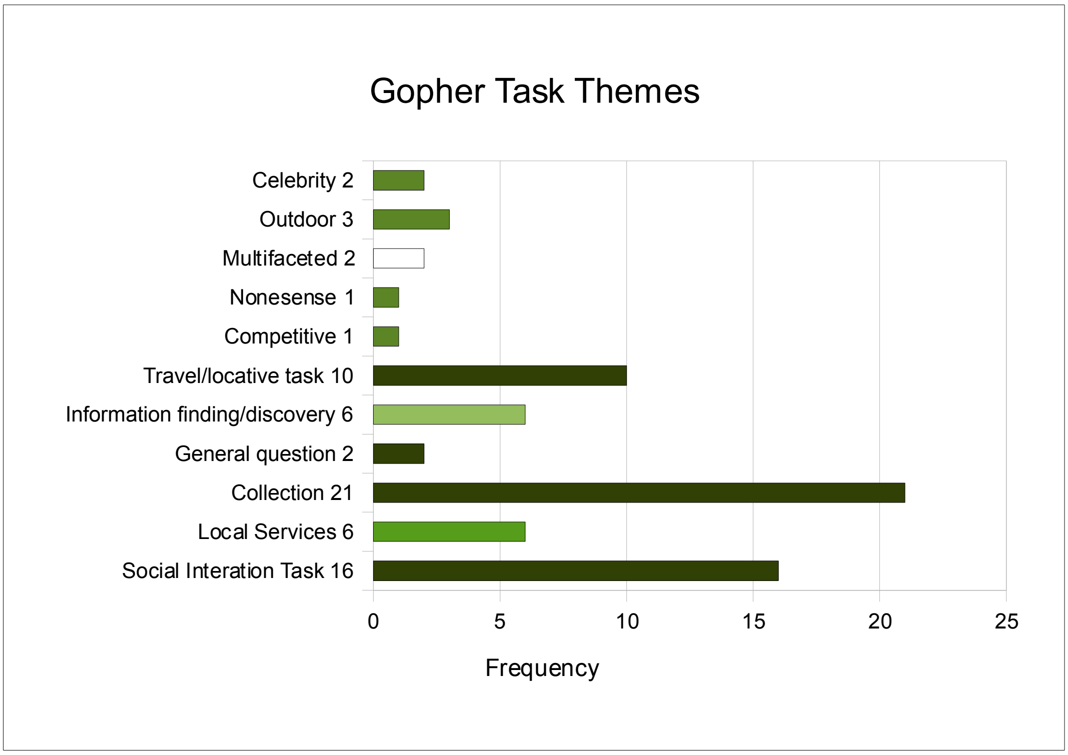

Figure 4.10. Categorisation of the task themes applied to gopher agents

The main task genres are overviewed in this section, but because tasks could contain multiple subtasks and were modified by multiple players over time, this often resulted in multifaceted missions that required social media from various sources to be collated. In addition to defining the task in question, the task descriptions were also used to define the scope or rules of the challenge, for example, "find me 3 items", "Task ends tuesday", with the moderators deciding whether this criteria had been met in peer review. Through defining the game rules ad hoc, users were able to increase the variety of tasks that were permissible. Many social tasks were also insults and many took on a cryptic/ambiguous tone, reminiscent of *riddles*, in which the immediate task was not obvious to those outside the game. Finally, a few tasks were of dubious ethical nature – although the game was self-moderating to an extent, the overall task-based interaction was also closely monitored in case intervention was required. Most of these tasks were mischievous at best, but it suggests given a more volatile group of users, there is potential for task based social exchange to cause ethical concern, especially in a competitive scenario.

4.7. Trial Outcomes

This section provides a detailed analysis of the social media that was supplied to the application. Firstly, three main styles of users interacting with the application are identified. Following this, observations are made about the style of gameplay that emerged as the trial progressed. Next the outcome from the stand alone Guessing Game and the naming conventions adopted for tags are identified. After this, the social media that was supplied as gossip and photos and some of the issues that emerged are discussed. Following this, the discussion looks at how narratives emerges as part of play and finally, any ethical and cost issues associated with taking part in the trial are identified.

4.7.1. User Interaction Styles

From the analysis of content received for tasks, a number of general ways the game can be played can be identified, demonstrated by a number of distinct play styles adopted by players:

(i) Individualistic: Held onto gophers, supplying all the content themselves and rarely released them for others to interact.

(ii) Social: Used the game as a social tool and just enjoying the overall experience, giving gophers information and dropping them in order to pass on to others, creating large quantities of gophers despite the cost.

(iii) Playful: Gave the gophers content, which did not necessarily relate to task at hand. Joke/chat responses.

(iv) Competitive: Gained most possible points in any way they could, 'gaming' the system, creating gopher tasks they can easily win, repetitive gambling of points on the Guessing Game. Making great effort to complete the tasks as well as possible, possibly going outside their daily routine to do so.

(v) Armchair: Engaged in tasks in a traditional gaming way, as indoor players, in a non-pervasive way, often relying on content that was at hand. Questionnaires show that this was a common way to interact.

(vi) Real-world: Engaged with the application in a more pervasive way, interacting while in their surroundings, photographing and commenting on real-world locations in order to complete tasks. Questionnaires revealed that it was less common to interact with the game while moving.

4.7.2. Questionnaire Responses

There were a number of important findings to note after reviewing the questionnaire responses from the second participant group. The group as a whole were already familiar with the capabilities of mobile technology as a social tool. Eight out of the ten respondents from the school trial group reported they used social networking sites and regularly played computer games. All of those that responded reported that they considered themselves good team players. An interesting observation concerned the way that players acquired an understanding of a distributed game's rules. The rules were not known in advance, and players were seldom co-located (where they could share their understandings). Each player therefore had to discover how to play the game for themselves. This could have actually encumbered competition, since to play most effectively players required a shared knowledge of rules and the play gestalts. This illustrated a problem for mobile and distributed games more generally.

Overall, player feedback showed that the game was interesting to play. All respondents bar one, reported to have enjoyed participating. However, initial responses indicated that a significant number of players (four) did not fully understand the game's mechanisms, which gave the impression that, although some aspects were successful (the Guessing Game and photo modes were amongst the favourite features), the game was too complex as a whole. As the trial continued, comprehension of the game increased; this highlighted a noticeably steep learning curve for new players.

The movement between cells gave the impression that movement was an important element of task completion in Gophers. Within the group of A-level students, the school became a focal location of the game. Players used breaks and other free periods during their timetable to interact with the game and discuss it with other players and spectators. Although the game was pervasive, most people preferred to play at static locations: watching TV, in the school common room or on the computer. Players were less keen on interacting when walking about; possibly because the length of interaction time (delays due to HTTP communication speed over GSM were significant).

Willingness for players to supply user-generated content was paramount to the game's success. As discussed previously, it was vital that players provided sufficient quantities to maintain interesting and varied gameplay. Trial results have indicated that players were willing to supply this information for at least the length of the trials.

4.7.3. Guessing Game and Geospatial Tagging

The words supplied to the Guessing Game were geospatially connected to their associated locations. Words for a particular area could be graphically displayed using a visualisation tool (see figure 4.11). This representation was designed to highlight spatial patterns in the data set and through doing so, allow the game's ability to collect worthwhile geospatial information to be assessed. The visualisation organised the nodes using a non-weighted spring algorithm. Active nodes, where interactions between player and gopher occurred were coloured red. Next to each, ranked lists of the five most popular tags for the cell were indicated. Without the geographical coordinates of the actual cell masts, there was insufficient data to connect these nodes to precise physical locations. The resultant graph simply showed a set of cell masts, organised in a fashion that balanced their interconnecting edges. Spatial relationships between these graphs and the physical world were clear when compared to a cartographic map of the area.

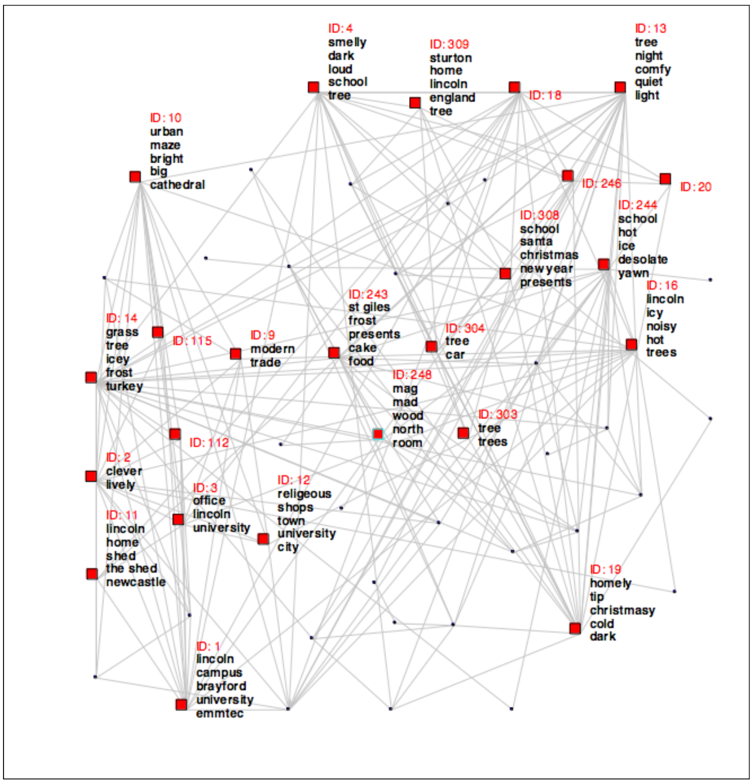

Figure 4.11. A connected spring graph depicting semantic terms supplied to the Guessing Game. Each node represents a unique cell ID location and a vertex indicates that users traveled between two nodes. Spatial similarities exist between the graph and a cartographic map of the area.

For example, when the graph in figure 4.11 is compared with the geographical area, a number of similarities could be identified. Ids 1, 13 and 3, at the bottom left of the graph were associated with the university campus; words such as *campus*, *university* and *Brayford* were listed; these corresponded to the Brayford Pool university campus, in the southwest of the city. Id 10 contained the descriptors *big* and *cathedral*, mapping to the cathedral quarter and ids 308/244 both contained *school* tags, connected with the secondary school in the northeast of the city.

It was only possible to see any relationship between visualised graphs and physical topology in the heavily played urban areas, such as central Lincoln. This was due to the more established links between nodes in these areas. Similar comparisons in less well travelled areas produced few relationships between node layout and spatiality, as the graph had insufficient information to converge in an organised fashion. Despite this, there were always strong semantic links between content and the cell mast to which it was tagged.

The design of the Guessing Game did not attempt to impose a naming ontology [105] on players. As a result, descriptive location tags were not the only words supplied. It was common for players to supply 'feelings' or emotional words to describe an area. In the vicinity of the school, for example, words like *ice*, *desolate* and *yawn* were included. This was interesting, as it could indicate a 'social vibe' for a particular area. In the right context, emotive descriptions like this could be as informative as place names. Also common were descriptions with personal, but little group meaning (such as *home*), fun and seasonal words with little spatial relevance (*jelly*/*christmasy*) and the inevitable juvenile humour (*gay*). This provided an interesting insight into the naming conventions that people intrinsically associated with their everyday location and context.

4.7.4. Text and Photo Gossip

Text and photos supplied to the game were manually reviewed by sight. A randomly selected set of gossip and photo entries has been produced to demonstrate a sample of this content (figure 4.12). Most of the supplied photos were connected with the gopher's task (two thirds of users claimed to try and supply task relevant content), suggesting that the presence of jury service was successful in promoting good content. However, it was also noticed that a large portion bore no relevance. This was supported by player comments, who reported to enjoy "taking photos of random rubbish".

Another unforeseen feature of the photos was that the content did not necessarily reflect the location in which they were taken. The social media examples in figure 4.12 demonstrated that some of the more unusual images supplied to the game (e.g. man with giant cookie) were taken from the Internet, television or printed images. These images were associated with the 'armchair' players identified in section 4.7.1, who preferred playing the game at a static indoor location.

"skegness is an hour away by bus"

"the football pitch is next to the sports centre"

"there are some good takaways on the high street."

"ive found santa hes down town"

"beer is good :-)"

Figure 4.12. Examples of photos and gossip supplied by players while interacting with gophers

Overall, questionnaire responses gave the impression that players enjoyed being exposed to new locative photo and gossip content supplied by gophers. Unfortunately, reduced gopher sharing in the second trial, due to the hoarding of gophers; seen in the individualistic play style identified in section 4.7.1, limited the amounts of content players were exposed to (a gopher only replied to a player with content that the player had not themselves supplied).

4.7.5. Use of Narratives

Narratives emerged as an important part of task engagement and evolved as tasks were completed. Elements of the narrative were revealed to players in a subtle manner as they participated in elements of the game; for example when supplying a photo, a gopher would respond with a photo it recently received at a nearby location. By doing so, the game strived to generate interest and create a unique framework, within which players can exchange social media. Three example narratives are graphed in figure 4.13.

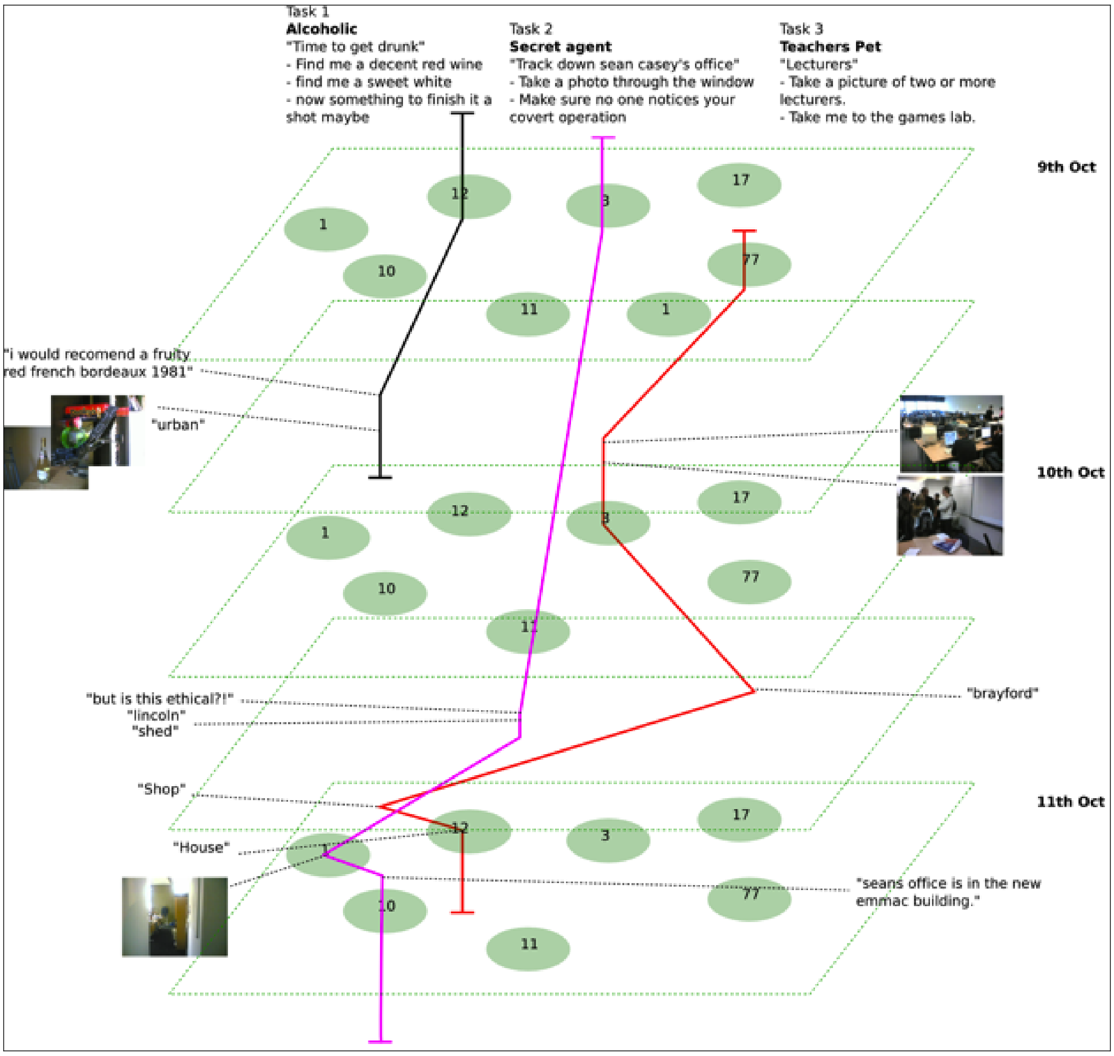

Figure 4.13. Examples of three narratives that emerged as part of the gameplay

4.7.6. Ethics

The raw location data collected by the system was not seen as a problem ethically; as discussed in section 4.4.1, this data was coarse, not absolute and never persisted on the mobile devices. However, because the social media in the game was not moderated and could be communicated to other players, there were other obvious ethical considerations to be addressed. One player reported this in a questionnaire "*Tasks involving the photographing of a third party…are causes for concern*". Another showed concerns about an investigative task that required players to find and photograph a certain member of staff's office, reporting in a piece of gossip "*but is this ethical?!*" These are certainly concerns that are warranted and would need to be safeguarded against if the game achieved wider distribution. It is because of the potential for ethical problems that disclaimers were created, stating the risks of UGC to users and enforced a minimum age (see section 4.5.1).

Gophers gameplay routinely featured non-players and strangers. In some instances these individuals featured in social media, such as bystanders in photos, while in others, game tasks actively encouraged players to engage with them. As a result, Gophers has provided a vital testbed for exploring these issues and through doing so, opened up large ethical questions associated with task-based games and the exchange of social media more generally. Certain tasks brought up ethical questions, for example the "take photo of lecturer" example below. At times, responses were grounds for ethical concern and users questioned ethics in questionnaire responses and the social media they supplied. Gophers had no concept of secrecy or privacy and could chat and distribute any gossip or photos in a viral manner; any players who were part of the ad-hoc peer groups that built up around gopher interaction were eligible to view all blog entries.

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"ANON NAME - Find Me: Snap a pic of ANON NAME" [U2]
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To improve the control of privacy in the game, numerous techniques could be borrowed from commercial social networks and web2.0 systems, for example the ability to report inappropriate content, block problematic users, profile for specific content and create game groups consisting only of known players in order to limit the social distribution of content. However, any of these solutions would inevitably affect the 'open' feel of the game play and could lead to a drastically reduced breadth of social media, decrease potential for human computation and domain 'experts' that could respond to specific tasks. In addition, future systems could make harmful content anonymous, using techniques such as semantic detection and substitution of names and pixelation of faces via image processing. There is a clear conflict between a safe game environment and varied gaming experience, which will need to be assessed in future task-based social games.

4.7.7. Playing Cost

Cost of play is an important factor for users of connected mobile games, especially when the end user demographic is likely to be using costly prepay data tariffs. Querying location via cell ID is cost free, so the only cost involved in Gophers was data transfer. These transfers were logged, allowing for easy analysis of the play cost. During the school trial 5,632 server requests of varying length were made from the 13 client devices. The mean cost of a single transaction was calculated to be £0.029GBP.

4.8. Summary of Findings

Mobile social networking is quickly becoming an accepted way to exchange media whilst mobile, but at the time of the study many users were not familiar with such concepts. Previous pervasive gaming studies have either been based on strict game rules or heavily orchestrated experiences. Gophers demonstrated that by exploiting the desire of users to exchange social media whilst mobile it is possible create new entertaining experiences that engage users and entertain, whilst also providing (indirect) micro-exchanges between social peers. In general, it was clear that players were willing to supply social media to this type of experience for the trail duration. Players indicated that they enjoyed participating, but the learning curve of the experience as a whole was steep.

Over an 18 day period, the study showed task based play to be an effective way of encouraging social media exchange between users. A range of gopher tasks were created during this period and these commonly focused on *collection*, *social interaction*, *travel* and *information finding* themes; from these, the potential for Gophers-like technologies to both collect useful information and elicit social exchange is clear. Another trial outcome was the potential for these social games in human computing, highlighted by the clear similarities revealed between graphed semantic tags from the Guessing Game and their relevance to real-world locations. Through visualisation of this content, the study has suggested potential for exploiting this concept for usage reaching beyond the field of entertainment. In their most basic form, these results could feed into online user generated collaborative map sites, such as Google Maps, but further uses are also discussed in Chapter 8. Likewise, the tagging of feelings and emotive content in the Guessing Game make it possible to represent current 'social vibe' of different cell locations. One aspect to ensuring that social media was of good quality was via the unique peer review moderation system and the effectiveness of this was proven in the quality of both text and photo gossip and the relevance of this to the tasks at hand. However it was found this mechanism did not prevent mocked up phone photos, copied from other media sources, meaning that the contextual origins of social media could not be guaranteed; regardless, users were never instructed against these techniques and they quickly became accepted as a valid gameplay technique by the community.

Users interacted with the application using distinct styles: *individualistic*, *playful*, *task-oriented completist*, *competitive*, *armchair*, *outdoor/pervasive*. The task-oriented game design was designed to be pervasively integrated into players' lifestyles by making use of location to place social media and gameplay; this was reflected in some text and photo gossip which had been taken in-situ, but most players interacted from the static, indoor locations typically associated with console play and most gameplay focused around a single set of cell IDs (around the school). Reasons for this were the user demographic, who mainly played in school breaks, the poor weather and the indoor family events typically associated with the time of year in the UK (reflected in the media), which all led to decreased outdoor activities; these methodology factors could be tuned in future trials. More fundamentally, it is suggested users were still learning how to make best use of these unfamiliar technologies and the experiences they afforded. Contrary to this, the stand alone Guessing Game responses were found to be more pervasive in nature and suggest a more mobile, outdoor focus, reflecting a user's contextual surroundings and the current environmental conditions, such as the weather. The analysis suggests that overall, the type of social media selected broadly depends on user situation and the type of information players wished to convey.

The concept of using gopher agents as mediators to indirectly exchange social media between users was received positively by users, reflected by the rich social media exchanged and results suggest that the 'personalised' nature of gopher creatures could potentially give players a more accessible broker through which to exchange personal social messages. This suggests that gophers might be an appropriate transport mechanism for distribution of other types of media to users. A unique property that emerged during analysis of these universally accessible characters was that they led to the creation of dynamically generated social groups, comprising of those that chose to engage in a task and physically crossed paths with the gopher.

Finally, there were a number of problems with these social gaming experiences which should be highlighted. Gophers were hoarded, limiting content exchange. Clear ethical issues were identified by users, mainly involving non-players becoming targets of tasks and also being encapsulated in online social media. Suggestions have been made to accommodate these problems, but they need to be explored further. Combined with play cost, these could present barriers to entry for the intended user demographic. Also, although possible to play such experiences in a pervasive way, analysis indicated that users will not necessarily do this. In addition, a steep learning curve existed and this was solidified by the lack of distributed learning between users. The main drawback of the Gophers trial in particular, was the lack of data describing user context and phone activity, making it challenging to analyse user exchanges in great depth and identify when users shared a context. These issues are explored in the three research studies and section 8.5 of the conclusion.

To summarise, the trial of Gophers showed mixed success. It presented an exploratory, small-scale study of a mobile social game that successfully incorporated spatialised, user generated social media and furthermore, demonstrated that gameplay based around pervasive, real-world tasks can create an engaging and fun experience over a sustained period of time. The chapter should be considered as a demonstration of how to design a social game based on these concepts and some of the pitfalls of mobile games development, particularly concerning the shared comprehension of a set of rules between isolated players. The study also allowed the trialling of a number of new game concepts, that individually showed promising results. Peer review showed it is possible to collect verified, user generated social media as the result of human computation and gameplay. Likewise, the standalone Guessing Game demonstrated the importance of semantic tag based labels in recording context in mobile settings and the amount of time players participated in the game was particularly encouraging. Results from the game suggest that cues in a user's environment are crucial to tagging in social apps – and hence, future studies aim to look in more detail at the location, time and social contexts under which this tagging takes place.

In response to the original research aims (G01), Gophers demonstrated great potential for human computation in mobile social games, with the user-assigned tasks being found to output useful data based on a number of themes. With respect to (G02), the task based play was found to offer an engaging experience for users over a sustained period of time and the gopher agents acted as effective social mediators to exchange social media between peers and acted as a conduit for ad-hoc peer groups. Finally (G03), the gaming mechanics and review system successfully enticed users to supply good content and as such, the social media generated by players was overwhelmingly valid and relevant to the task in question.

Research shows that games are undoubtedly an engaging way for participants to take part in mobile research trials [80][164][153] and the Gophers study indicated this is also the case for the subset of mobile, task-based experiences. However, designing studies as games presents challenges; the game mechanics were difficult to design, the orchestration involved in hosting a game nontrivial and there are certain expectations from users for highly polished interfaces and usability. Furthermore, considerable time in Gophers was spent on iterative design, involving fine-tuning aspects of the gameplay, such as scoring mechanics, graphics, which were not necessarily an immediate benefit to the research aims. For all these reasons, it was decided that future studies would move away from games. The mobile geotagging featured in the Guessing Game is also the primary method of recording situated social media in many other MoSoSos and as such, was a critical outcome of the research. Findings from the trial have motivated further development of this concept into a more mature, stand-alone format.

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Chapter 5 will now discuss the design of two subsequent mobile social network studies that focus on mobile semantic tagging; firstly using geotagging and secondly, an experimental people tagging concept. Results from these studies are later analysed in chapters 6 to 7.

5. The Design of Two Social Tagging Experiments

A particularly promising element of the Gophers experience was the semantic tagging that featured in the Guessing Game and, with the addition of gossip content, this resulted in a large amount of useful semantic data being generated for popular social locations. A powerful use of this social media is in representing the social context of peers in a tight knit digital social network. As such, this feature was selected as the focus of two further social media technologies, which use semantic tags as a way to microblog status updates, as well as to collaboratively tag and share social locations amongst the user's social network peers.

The possible range of mobile social software services is extremely wide, but at their core lies the ability for users to communicate in various ways, using input from their everyday contextual surroundings to enhance this experience. The main method of linking surroundings to user interactions is via user location, as demonstrated by the first study, 'ItchyFeet'. Complimenting this is the 'MobiClouds' study, which focused on the use of Bluetooth-based 'people tagging' to provide this link. The aim of creating these applications was to contribute towards the research aims defined in chapter 3. In relation to these, ItchyFeet aimed to; investigate the real-world influences behind social media creation and assess the effectiveness of tag sharing as a way to record real-world semantic descriptions. MobiClouds aimed to extend this research by testing the effectiveness of experimental people tagging technology as a way to be more inclusive of non-application users and integrate better with the user's social surroundings, in the process of doing so, it contrasted the use of people tags against those found in more commonplace locative tagging.

Because these applications shared a common underlying architecture, the implementation of the two software studies is discussed simultaneously in this chapter. It begins with a brief overview of the two application concepts. Following this is a discussion of the design design decisions that influenced the software and an overview of the typical ways that users interacted with the technologies, both whilst mobile and online. Next, the technical implementation is discussed and the most important components of the software and key decisions are discussed in depth. Finally, the applications were trialled as part of a formalised trail process and the methodologies and data collection methods are discussed. The detailed analysis of each study follows in subsequent chapters.

5.1. Introduction

Status disclosure is seen as an important communication resource by mobile users, who typically update their social networking status and microblog their surroundings whilst on the move [69][121]. As a result of the Gophers findings and the semantic tagging successfully explored in the guessing game, the final two dissertation studies continue this investigation by focusing specifically on collaborative, text-based semantic tags. To facilitate this investigation, the ItchyFeet application was designed as a simple mobile social service, through which users could author situated content applicable to a range of real-world situations and share this amongst their social network friends, for later use as context aware status updates. Similarly, MobiClouds was another social service, that allowed users to author situated content, only this time in relation to their real-time social surroundings (dictated by proximal Bluetooth devices); again sharing these with their online social group for use in future contextual updates.

Figure 5.1. Authoring a social tag in ItchyFeet

A number of developments were made in the area of mobile technologies since the ItchyFeet and MobiClouds trials were partaken. Mobile smartphones are now much more commonplace and mobile usage has matured, with users embracing new functionality such as internet browsing, microblogging, mobile Location Based Services (LBS) and the installation and use of third party applications. Mobile UI design has also greatly matured, with the introduction of multitouch interfaces and better design guidelines. Likewise, sensing technologies such as GPS have improved vastly through the enhancements brought by assisted A-GPS technology [152]. These changes make the research findings even more important for the mobile connected world of today. More complete information on the technological developments that have taken place during the thesis are summarised in section 8.3.

5.1.1. ItchyFeet

The social awareness and tagging application ItchyFeet, was devised as a means to investigate geotagging within the MoSoSo domain. The concept behind the application is to allow users and their direct social network peers to identify, share and manage locations they consider socially important to their group through the use of collaborative tags. Over time, ItchyFeet allows a dynamic, social landscape of tags to be built over the city, which is unique to the peer group. The tags attached to locations are then used as indicators of each user's current and past social context. This moves beyond the idea of 'friend finder' applications, which indicate context based on location coordinates or discrete contextual descriptions [5] towards a dynamically evolving, socially generated, meaningful commentary that strives to be of relevance to every member of the social group. The specific design of ItchyFeet is discussed in section 5.2.2.

5.1.2. MobiClouds

In a similar realm, MobiClouds was devised as a method to investigate the more experimental concept of real-world 'people tagging' in MoSoSos. The application allows users and their direct social network peers to identify, share and manage social peers they consider important to their group, by labelling their Bluetooth devices using collaborative tags. Rather than a fixed tag landscape layered over the city, MobiClouds usage produces a constantly moving tag landscape that dynamically changes with social surroundings, as the users who retain those tags move in and out of scope. A user's tag surroundings are visualised for use as indicators of their current and past social context. People tagging offers numerous potential benefits as tags are socially generated and highly meaningful to the social group as a whole, but also provide a contextual disclosure which is inclusive of non-application users. The design of MobiClouds is discussed in section 5.2.3.

5.1.3. Themes

The applications further explored two of the themes identified in section 1.3. Firstly, *sharing and delivery of knowledge between users* was offered using semantic free text that was tagged to both locations and people. In addition the systems promoted *discourse amongst friends*, by supporting automatic exchange of status updates via participants' social networking profiles. Furthermore, they allowed pools of tags to be created and shared amongst peers in a collaborative way.

5.2. Application Design

In both applications, users interacted with the service whilst mobile using Nokia N95 smartphone handsets and online, through the Facebook application and profile widget. The Gophers trial had shown what was possible in a fun, novel application, but these trials aimed to create technologies that would become an integral element of a user's social software toolset and could be ubiquitously accepted into their everyday lifestyles as much as possible. This section summarises the considerations that directed the design of these applications and provides a walkthrough of the main features of each, in both mobile and web modes.

5.2.1. Design Considerations

Working with immature technologies, such as mobile social services, mobile devices and Web2.0 services, combined with the generally unpredictable nature of mobile users and context aware computing, led to a number of unique design considerations. Below, these considerations are identified, along with discussion of how they were overcome in the design of the applications.

Ability to socially tag: Users should be able to tag their surroundings and communicate this data amongst their social peers. This tag knowledge should be shared and built upon in a collaborative manner. They should also be given the ability to explore these locations in real world and reuse previously tagged entries.

Disclosing user context: The applications aim to bring social networking practices into the real world it was decided at an early stage this would be achieved by GPS location awareness in ItchyFeet and user Bluetooth proximity in MobiClouds. It was decided that, instead of explicitly disclosing the position of users, which can be associated with fears of being tracked, it would be more useful to extrapolate meaning from this [119]. Context was therefore recorded in a way that was meaningful to users and provided utility in the target domain of online social networking. Gophers demonstrated that this type of approach could help smooth out the inherent instabilities associated with location technologies.

Gentle learning curve: The limited trial resources, including length of trials and number of available devices, meant that for maximum trial benefit, users should begin using the applications as quickly as possible. The trial itself meant many participants were already learning how to use new and unfamiliar technologies and at the time of the trial, mobile internet browsing, location based services and use of complex mobile application UIs were still unfamiliar concepts to many users (see questionnaire responses in sections 6.3 and 7.4). As a result, the application design needed to be as intuitive as possible. In order to ease users into the application use, multiple forms of support were made available, in the form of click-through installers, step-by-step online and printed introduction to applications, an online help form and email/phone support.

Integration with existing digital social practices: It was desirable to make use of technologies that were close to users' everyday social and mobile technology practices, meaning familiar web2.0 technologies such as Google Maps would be used wherever possible and common paradigms, such as tagging and blogging would also be employed. Utilising too many unfamiliar technologies could result in a steeper learning curve for users. Rather than electing to create a new isolated social space in which for friends to interact [143], the use of the popular social networking site Facebook (an established social network which has seen massive take-up by university students and a mature API for developing 3rd party applications), meant that the applications could build upon a user's pre-existing digital social relationships. This approach has been proven as a powerful way to execute social networking research [14]. Since users already had experience interacting with existing Facebook and mobile applications, there would be preconceived expectations of how these applications should be accessed and the functionality available; accordingly, popular social networking practices were integrated into the application design, for instance, status updating and checking, profile browsing, and application invites. Furthermore, there were certain expectations of what any new Facebook application should include. The online application interfaces followed design practices seen in existing applications, by incorporating appealing graphics, clean interfaces, help pages, discussion boards, profile settings, 'wall' widgets and other common UI features. Besides offering a consistent experience for users, this also helped distance the application from the typical 'research' look and feel of many academic studies and again, this intended to increase the probability of the applications becoming ubiquitously accepted into users' everyday lives.

Support for emerging application use: A number of user interaction styles emerged from the trial of Gophers, for example the differing play styles that resulted from open-ended tasks. To reflect this, emerging usage was also promoted in the design of ItchyFeet and MobiClouds. The choice of free-text semantic tags, which could be created at any time, meant the applications could be flexible to different interaction styles and usage scenarios;

effectively there were no restrictions on what the application could be used for and users were left to make this decision as a group.

Adaptable to change and scalable: One aspect of interest was how the application tags would adapt over time as group circumstances changed. The applications were therefore designed to be capable of adapting to tag modification. In addition, tag density and group size were liable to change over time and depending on location, so the applications were able to scale in accordance with these properties.

Support for typical mobile interaction styles: Considering the minimal interaction times typically associated between users and mobile handsets [159], mobile user interaction with ItchyFeet and MobiClouds was designed to be as ‘casual’ and unobtrusive as possible. From an interface design perspective, this meant minimising the number of screens a user must navigate and the number of clicks required to perform tasks. It also meant that the application should support rapid change of states between interactive state and background state, as users dipped in and out of the application experience. Research also suggests that users would be unavailable for much of the time, due to engagement in other tasks, not carrying their phone with them, or leaving it turned off, for significant periods of time [162]. As a result, the applications were designed to also operate autonomously, without intervention from the user.

Resilient, Seamful design: The applications needed to be operational at the edges of sensor technology; context might be unclear at the edges of sensor boundaries and situations could occur where sensor data disappears completely, for example when an urban canyon is encountered, or when no mobile data signal is available. In these cases the applications were designed to degrade in an elegant fashion. In addition, the applications needed to be resilient against crashes and protect valuable user data in these cases.

Mobile device considerations: By the time of the trial, the easy availability of GPS and Bluetooth-enabled smartphones with mobile data services were becoming possible (namely, the Nokia N95). This allowed for a familiar, personal platform onto which to deploy the application, similar to the devices users interacted with and carried on a daily basis. Ideally the applications would be installed on users' own personal devices, but specificity of device type meant this was not possible in the trials. Another advantage of an off the shelf device compared with the bespoke hardware proposed in early presence sharing studies [215][216], was that it minimised any skewing of data that could result from using a 'novelty' technology and reduced the learning curve for users. However, there were also drawbacks, unique to mobile phone handsets, some of which are overviewed here.

Firstly, it was clear that sensor data would be intermittent in ItchyFeet; self-experimentation with the GPS sensors on these devices showed that it could take up to 2 minutes of clear line of sight before a lock was acquired. Due to the antennae positioning, the optimal signal was achieved when the device was left open and handheld and not when closed in the bottom of a bag or pocket – a probable way of retaining the device when running in 'background' mode. Secondly, mobile networking over GPRS services was not guaranteed to be always-on and this could be expensive. However, maintaining a consistent, shared social experience across mobile devices in the trials was a necessity, so device synchronisation needed to be achieved in a way that minimised data transfer, whilst keeping the locally held data as current as was necessary for the applications; a carefully designed communications strategy was implemented to make this possible, discussed in section 5.3.4. Finally, development and debugging was a challenge in terms of development tools available the time of the implementation and this was magnified by the difficulties commonly associated with the testing and prototyping of contextual aware applications more generally [126]. The server-side logging described in section 5.3.13 assisted with debugging these real-world problems during development.

Moderation of Social Media: Typically, noise and inaccurate data exists in user contributed social media systems. One way to overcome this problem was through a peer review system, as demonstrated in Gophers, or by voluntary reporting bad or offensive content, as seen in online message boards. In the ItchyFeet and MobiClouds applications, users were all part of the same closely knit social group and adding worthwhile data offered a personal gain to participants, since it enabled an up to date status on their social network profile and also enhanced their experience of the applications over time as the tag landscape improved. As a result, it was decided that an artificial moderation system did not need to feature in the applications.

Ethical concerns: The automatic disclosure of user location, potential for 'tracking' users, the risk of hackers stealing logged data and the issues surrounding monitoring devices of non-consenting users, were all potential ethical concerns in the applications. These concerns were addressed in the application design in a number of ways. Critically, users signed a disclaimer, shown at A05, which made clear the type of data that would be logged and the precise nature of the applications. Users were able to exit the application to control the release of their context and logging of their position. All logged server data was made anonymous. Standard Facebook application privacy settings could be used to control which members of their social network could view their online status. Furthermore, only coarse semantic descriptions of user status was ever published, far less revealing than use of absolute locative data. Weak data security has been one of the criticisms of networked Java ME applications generally and efforts have been made to enhance this with new APIs [6]. Only basic security was provided in the ItchyFeet and MobiClouds software, with users authenticating themselves using a username and PIN login, after which the application was connected to the user's social network profile and further communication was sent over unencrypted HTTP requests, using plaintext tokens for authentication. Since the applications would not be receiving widespread exposure, this was deemed to be adequate for the small scale trials, but a more secure approach might have employed encrypted, timed sessions over SSL.

5.2.2. ItchyFeet Interaction

Based on these considerations, the first application, ItchyFeet, was designed. To introduce the application, this section provides an overview of its use from a user perspective. Mobile interaction in ItchyFeet was provided by a Java ME application that ran on their mobile handset. The application was able to silently run in the background, or take input from the user.

5.2.2.1. Mobile

Figure 5.2 illustrates some typical interactions between a user and the device. The first time a user starts the application, they are prompted for their login credentials. These are supplied to the user when they first register and are then linked to their Facebook account. The application authenticates these details and shows the main screen. The interface displays amount of data transferred, GPS lock status, a list of all tags and the current user status. The tag list is an amalgamation of all tags created by the user and their Facebook peers, as described in section 5.3.9.1. From this main screen, the user is able to view their current status, select a different tag to represent their status, or author a new tag. There are three main methods of interacting with the mobile system: (i) Tag creation, (ii) Automatic status disclosure and (iii) Status browsing and these are described below.

(i) Tag Creation. Users can select a tag at their current GPS location which describes their situation. Because certain tag types are applicable to more than one location, a user can reuse a tag from the list of all tags previously created by themselves and their social peers, as shown in figure 5.2. A user can browse this alphabetically ordered list of tags and select the one that best matches their context. The selected tag will be 'reused' and attached to their new location. Sometimes there are no appropriate tags to reflect a user's context, for example when a user begins making use of the application and few previous tags exist, or if they feel no appropriate tags have been created that match their current context. In this case, the user is able to author a new one by selecting the 'Tag this location now!' option. They are then prompted to enter a text description of the location (up to 50 characters). A tag is created at their current location, which is added to the server side model and their new status posted to their Facebook profile to reflect this (as shown in figure 5.6). Any tags are held at their location indefinitely and will later be used to indicate status of the users, or their social peers on returning to the location. In addition, when a tag is created it is automatically distributed amongst a user's one hop friends (those who have a direct 'friend' relationship in the existing social network). This allows tag models to be collaboratively shared amongst social peers, so all those in the same social network group will share the same social tag lists.

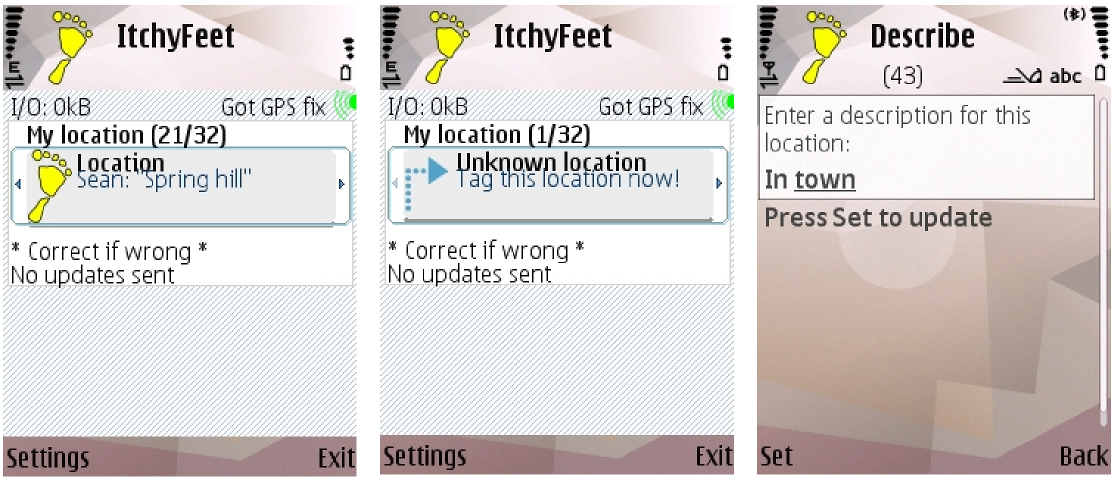

Figure 5.2: (i) A tag representing the user's current context is displayed, (ii) No tags exist for this location, user is prompted to author a tag (iii) User enters a tag descriptor to identify their current location.

(ii) Automatic status disclosure. Once the application receives a GPS fix, the application will look in the local tag model and select the tag that is most proximal to the user's current GPS coordinates, which is then shown under 'Location' in figure 5.2. The user is informed of this change with some tactile feedback from the device, to encourage them to check the screen. After 20 seconds of inactivity (ie. no key presses), the application automatically sends the selected status to the server, which then posts an ItchyFeet status update to their online Facebook profile. In this sense, the application manages to continue reporting social status without manual intervention from the user [108]. Alternatively, if the user feels the selected tag is not indicative of their current context, they are able to manually select a more appropriate tag or create their own, as described above. The newly selected tag will be updated to their Facebook page and additionally, their GPS coordinates will be permanently connected to the tag, so next time a user is in a similar context, the new tag will be automatically selected. To keep an up to date user status, the application continues to monitor the user's GPS state and will autonomously update this if they become more proximal to a different tag. Gradually, as users correct tag locations over time, the autonomously tag selection becomes more refined and accurate at predicting the contexts of group users, as depicted in figure 5.8.

(iii) Status browsing. The status review feature allows users to view the current and past status of their Facebook friends online. This feature capitalises on the popularity of 'social network surfing' [112]; the act of browsing friends profiles to check up on them. Status checking must be done online using either the ItchyFeet Facebook application to browse the status of their friends together, or by viewing their friends profile walls directly, on which their up to date ItchyFeet status is displayed, described below.

5.2.2.2. Online interaction.

Online interaction with the service is handled by the Facebook application. This links the group's semantic tags with their existing social network. Online access to ItchyFeet is made available from a user's Facebook account in two ways: the profile page box and application interface. A status box is displayed on a user's Facebook profile page, which indicates their current context to friends, along with time of last update, as shown in figure 5.6. This is visible to any friends visiting the page who do not need to be users of the application. By expanding the view, registered users are also able to see the full application interface, seen at A03. This shows last 5 tags encountered by the in question. In addition to this, the profile owner is able to see a breakdown of their friends' current and past contexts, browse and amend any social tags they have created using an interactive map, register and install the mobile client using a step by step interface and finally, receive online help and post questions.

5.2.3. MobiClouds Interaction

This section goes on to discuss the second application, MobiClouds, from a user's perspective. Mobile interaction is achieved via a client application with similar properties to ItchyFeet. Similarly, it was able to run autonomously, or take input from the user.

5.2.3.1. Mobile Interaction

Figure 5.3 depicts a walkthrough of the main MobiClouds application screens. As with ItchyFeet, a user supplies login credentials on first accessing the application, which then associates the application with their Facebook account. The main application screen is shown in the second figure. This is split into two main parts: the *tag visualiser* and *device display*.

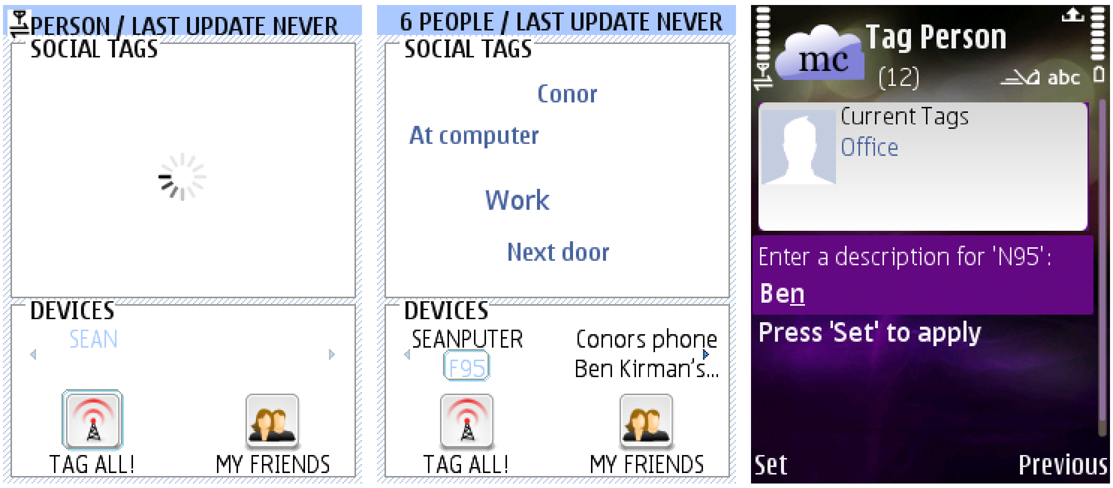

Figure 5.3: (i) A list of tags and devices surrounding a user (ii) A user tags one of the Bluetooth devices in their surroundings (iii) User views the social contexts of their friends.

In the bottom half of the screen, the device display is shown. This lists the 'Friendly Names' of the Bluetooth devices currently proximal to the user. The application updates this list in 30 second periods and any newly detected devices will appear in the device list. Users are able to select individual devices from this list in order to tag them. The top half of the screen shows a visualisation of the tags currently in the user's proximity, which relate to the currently present devices. This animated social tag cloud provides an aggregate social indicator of the user's current social surroundings and is also used to depict the user's status online and in the web application. If repeated tags are present, these are indicated by a larger tag size; a more detailed description of the tag visualiser and people tagging is provided in section 5.3.9.2. Also visible on the interface are two buttons; 'tag all', which allows the user to tag all detected devices with a tag simultaneously and 'my friends', which looks up the current social contexts of the user's Facebook peers. There are three main modes of interaction with the system: (i) Tag creation, (ii) Automatic status disclosure and (iii) Status browsing and these are described below.

(i) Tag creation. In order to better describe their social surroundings, users are able to tag the devices that surround them. Devices in the list that have previously been tagged are shown in black, whereas new undiscovered devices are highlighted in blue, prompting the user to tag them. To do this, the device friendly name is selected by the user. They are then prompted to enter a semantic free text tag of up to 20 characters, to be associated with the device (this is significantly shorter than the length of tags associated with locations in ItchyFeet – the change was necessary to allow tags to be visualised effectively). A tag is then created and added to the visualiser. The user's new tag cloud status is uploaded to their Facebook profile, as way of indicating their current social situation. The new tag is also added to the server side model and will be associated with the selected device when the user or their Facebook peers next encounter the device. Another method is *group tagging*, which is intended for users to label groups of related people simultaneously, for example a user might tag a crowd at a music concert with the label 'rock fans'. A user can create a group tag by selecting the 'tag all' button and creating a tag in the same way. Group tags will be tagged to all devices present.

(ii) Automatic status disclosure. If the device list changes, the tag visualiser is automatically updated to reflect the current state. As they explore their everyday environment, the user is informed of any changes to their social surroundings by tactile feedback from the device and presentation of their current social tag cloud. The application therefore provides automatic disclosure of user status, as was the case in ItchyFeet. Each change to a user's tag cloud surrounding the user is considered a change in personal context and will be recorded, timestamped and uploaded to their Facebook profile. Lists of recent user clouds are periodically uploaded to the server and their Facebook profile updated to reflect this. In keeping with the ItchyFeet design, possessing 'no surrounding tags' is not recorded as a possible social context.

(iii) Status browsing. Unlike browsing the status of ItchyFeet friends, which is limited to online access, MobiClouds adds the ability to view the status of friends on-device. A complaint from the ItchyFeet users was the lack of a mobile way to check their friend's contexts. To address this in MobiClouds, an option was added to load a list of their Facebook peers, which a user can do by clicking the 'my friends' button. The current context of each friend is represented by the social tags that surround them, as shown at A03. In addition to this, friends' contexts can be browsed online in detail via the Facebook application, or through the MobiClouds status box displayed on each user's wall, described below.

5.2.3.2. Online Interaction.

Online access to the MobiClouds application is provided in a similar way to ItchyFeet. A status box sits on the user’s Facebook ‘wall’, with an application page providing more in-depth information. The status box depicts an overview of the user’s most current social surroundings, represented by a tag cloud, as shown in figure 5.7. The application page shows contextual tag clouds detailing the current and past social contexts of the user and their friends. It also allows the user to see an anonymous collection of tags that others have tagged them with, what tags the user has assigned to others and, (if GPS information was available) the approximate location of these. This gives an insight into the role the user plays in their everyday social group.

5.3. Implementation

This section provides an overview of the software used to implement ItchyFeet and MobiClouds from a technical perspective. The vast majority of implemented functionality was shared between the two technologies, but some aspects were project specific. An open source version of the complete software repository is available for download at A02 under a GPL3-license. The code is modularised and intended to be reusable by other mobile social services.

5.3.1. Shared System Architecture

An overall system architecture was devised that could be shared by the two applications. The application consisted of a mobile client and server-side back end. The client was written in Java ME and runs on Nokia N95 handsets, which access either GPS location data via the JSR-179 location API, or Bluetooth proximity data via the JSR-82 API. The server code was based in PhP, with a MySQL backend and this integrated with the user’s Facebook account via the Facebook API [68]. A high level overview of the architecture is shown in figure 5.4.

This architecture comprises of a number of generic software components that were also shared between the two applications. These have been made available with the view to also be reusable by future software projects. This section overviews the fundamental aspects of this functionality.

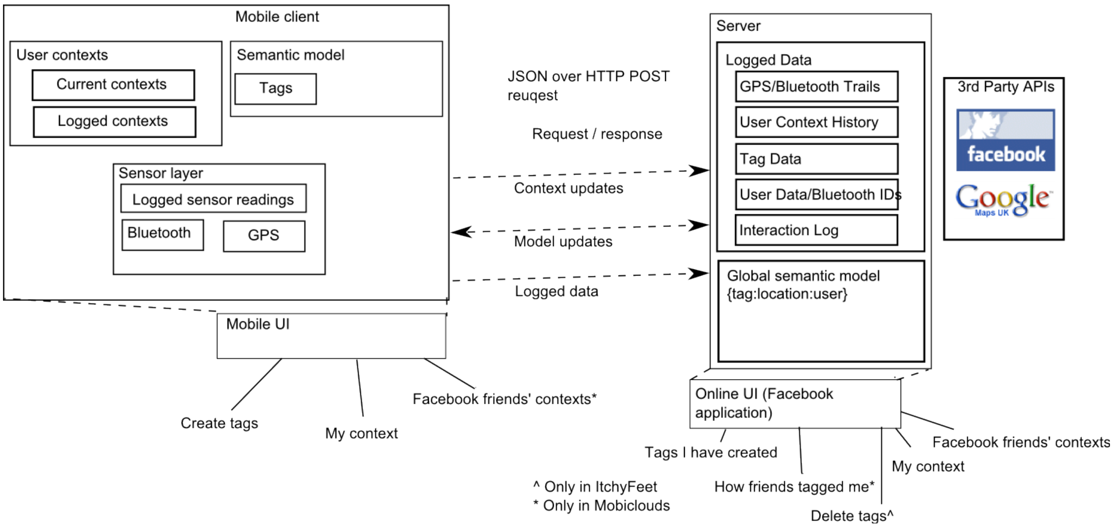

Figure 5.4: High level overview of the system architecture shared by ItchyFeet and MobiClouds

5.3.2. Registering and Identifying Users

In order for users to make use of the application, a step by step registration process needed to take place. This served a number of purposes: (i) it added the application widget to the user's profile (ii) it granted the application 'offline access', in order for the widget to be updated when they are not logged into application page, (iii) it generated a user ID/PIN pair for the user to authenticate and identify themselves to the application, as discussed in Section 5.2 and (iv) in MobiClouds only, it prompted the user for their mobile Bluetooth address, which allowed them to automatically identify their phone using it's internal address (and also monitor tags that others had created for them). Internally, the user ID was linked to the user's Facebook profile ID, which could then be used to allow server side application code to autonomously update the status shown on their social network profile. Registering users in this manner meant their logged data was connected to their personal details indirectly, via their social networking profile; it may be possible that an amalgamation of this profile information any tags associated with that person's device could lead to their real-world identity being compromised, something that k-anonymity techniques seek to address [17]. It also suggests that sending this ID in plaintext is a personal security risk, but this is a flaw of self-updating applications developed under the Facebook API in general and hence, not something that could be easily avoided in the application design.

5.3.3. Network Communications

Network communications took place between the mobile devices and server and are handled using HTTP POST calls over mobile GPRS connections. Data was packaged using JSON encoding, communication calls were frequently amalgamated (with, for example, trail log data or model updates) and if calls were not acknowledged, they timed out and were re-sent. This strategy ensured network traffic was minimised and offered verified, reliable delivery.

5.3.4. Shared Data Models and Synchronisation

The applications incorporated a shared tag landscape, which would allow sharing of semantic tags between users and so accordingly, a distributed, shared data space was needed that could be accessed by the applications. This was used to store a representation of all GPS and Bluetooth tags created in the applications. Two data model classes are maintained: a remote, *server-side model* and a *local model* that resided on each phone and was personalised to the user.

The server-side model acted as a main, global tag database, which recorded all tags created for the duration of the application, from all users, along with the ID of the user who created them, the time and context (GPS location, Bluetooth tag) with which they were associated. Each time a new tag was created by a user, this was committed to the global database, implemented in MySQL. In addition to this, a local semantic tag database was stored on each client device, which was a subset of the global database. This was personalised for each user and contained any tags created by the user and their one-hop social network friends. It was stored on-device using the Java ME record media store, or RMS.

To ensure each local data model maintained a current representation of the tags in the user's social group, a synchronisation with the server was routinely performed, where any new tags were downloaded to the device. The constraints of mobile networking meant that client-server communications had to be kept to a minimum and this inevitably lead to some delay between a user creating a tag and these updates being fed through to friends. To achieve this, a timestamp-based approach was taken. With each client-server call, the client passed a timestamp indicating the age of its current data model. Using this, the server generated a current tag model for the client, which contained any tags newly created by the user and their one hop social peers (ie. after the supplied timestamp) and returned these to the client, which then appended these to its local model. It was decided that periodic updates should be more frequent for users who were on the move than dormant ones, since those with changing context were more likely to encounter tags. The device could easily be shutdown by the user or phone at any point. A function listened for these termination events and attempted to synch the system state (eg. sending unsaved trail data) on a best effort basis before exiting.

5.3.5. Mobile UI Components

Due to the lack of mature UI frameworks at the time of the studies, the unpredictable nature of default Java ME 'form' interfaces and in order to ensure a consistent experience across devices, a number of low level custom UI components were implemented. These graphical components were developed to support the mobile interfaces in ItchyFeet and MobiClouds and are described below:

Bluetooth tag cloud (MC): Provided an animated visual representation of the dynamic change of the social tags that surround a user.

Scrollable tag list (IF): Displayed an alphabetically ordered list of the location tags associated with the user's social group. The list could be rapidly scrolled through and each distinct tag was labelled with a description and author name.

Friend Status (MC): Indicated the current contextual status of the user's friends, represented by their surrounding tag clouds.

Custom buttons (IF+MC): Arrays of graphical UI buttons, that provided access to application functions.

5.3.6. Social Sensing Logic

Social sensing occurred as a background process when either application was left running. This allowed the application to function in an semi-autonomous way, without intervention from the user. The tag sensing in ItchyFeet was designed to ensure a stable indication of user context was made and it adhered to the following logic:

Stage 1:	Periodically poll for GPS coordinates every 15 seconds
Stage 2:	When a new GPS reading is received, add this to location buffer and trail log
Stage 3:	Lookup corresponding tag if there is one in range (<500m), otherwise report 'no tag'

Stage 4:	When four matching readings are received, update tag in client UI to reflect this and inform user
Stage 5:	After tag has been displayed for 120 seconds without intervention, post tag to update user's online status; at the same time upload log data

In MobiClouds, a slightly different approach was adopted. Since the Bluetooth presence was a binary value and encounters were regularly fleeting, the client tag UI updated as soon as new devices were detected:

Stage 1:	Periodically scan for proximal Bluetooth devices every 30 seconds
Stage 2:	When surrounding devices differ from the currently displayed set, display these in *device display* UI and add to trail log (+ GPS data if available)
Stage 3:	Lookup tags corresponding to devices if available and render these in *tag cloud visualisation*; unlike ItchyFeet, tag results shown immediately
Stage 4:	If tag cloud has changed, add this to encounter log
Stage 5:	Once encounter log holds 5 encounters, or 10 minutes elapse, post tag cloud to update user's online status; at the same time upload log data

There were a number of adjustable application parameters that affected the above logic, for example the tag accuracy and boundaries; the defaults are defined below.

```
ItchyFeet
GPS Scan frequency: 15sec
Spatial accuracy: < 400m
Auto-sync: 10min

MobiClouds
Bluetooth scan frequency: 30 sec
Sensor proximity/accuracy: ~10m
Auto-sync: 10min / 5 changes
```

Figure 5.5: Summary of Application Specifications (some adjustable via constants in code)

It was also possible to manually intervene with this process by either manually selecting, or creating a new tag, as discussed in section 5.2.3.11.

5.3.7. Stage 1-2: Sensing Context

Context was sensed in the applications using GPS in ItchyFeet or Bluetooth sensor data in MobiClouds. Since these sensors are now inbuilt into many new mobile handsets, they are a useful basis for the development of mobile social applications. The technologies are also becoming increasingly familiar to users, with many of the UK population accessing GPS technologies via satellite navigation systems and the vast majority of mobile handsets being Bluetooth enabled. These trends were reflected in the questionnaire responses of trial participants, many of whom used these technologies on a regular basis (see section 5.2.1) and as such, would be familiar with the characteristics and limitations associated with them.

GPS and Bluetooth readings were easily obtainable by using the Java ME JSR-179[3] and JSR-82 APIs. These sensor readings were collected by the location or Bluetooth tracker processes, which continuously polled the APIs for context updates, using the parameters in figure 5.5. This contextual data was connected to newly created semantic tags to give them a real world bearing and these tags would later be triggered when a member returned to a contextually similar situation. Each time a new reading was received, it was added to the trail log, used for post-trial analysis and potentially human computing applications.

5.3.8. Stage 3: Semantic Tag Model and Tag Activation

Unlike Gophers, in which players actively searched for social media, ItchyFeet and MobiClouds users received information using a passive *information encounter* approach, in which semantic tags were pushed to their mobile device (using an HTTP mobile network call), simply by moving around. This offers a more pervasive way of interacting with the environment and can present a fun element of surprise when information is serendipitously encountered [176].

The semantic tag model was a locally held data model depicting the user's social environment and the tags that it contained; including the spatial areas the tags related to, the user who created them and the timestamps at which they were authored. This was tailored to the user and their peer group and regularly synchronised with tags held on the server, as described in section 5.3.4. The tag model returned a current tag descriptor when supplied with raw sensor data. In ItchyFeet, these tags were activated when a user passed into their activation boundary; a 500m radius circle which surrounds the centre of each tag. In MobiClouds, tags were activated when a device connected to them became proximal to a user; effectively a 10m radius boundary.

3 The code contains legacy support for reading from Bluetooth GPS devices using serial communications, but this support became less necessary with the wide availability of GPS enabled smartphones during the course of the trial.

In ItchyFeet, once 4 consecutive, matching tag readings were returned, the user's context was considered stable and the client tag display was updated to reflect the currently active encounter, while in MobiClouds the client tag visualiser was immediately updated. By waiting for a stable user context in ItchyFeet, this reduced the possibility of fluctuating context caused by multiple nearby tags, but ignored the rapid changes that occur in context when passing locations at speed (eg. when testing on public transport or in a car); additional logic was later added to handle these circumstances. Tactile feedback notified the user of a new tag encounter. This not only notified the user when they had stumbled upon a tag boundary, but also subtly informed them of how socially active an area was through the frequency of this feedback – and without physically checking their device.

If no active tags were found, the UI prompted the user to select a pre-existing tag or create their own, described in section 5.3.11.

5.3.9. Stage 4: Tag Visualisation

Tags were visualised on the device screens using a real-time visualiser, which indicated their current social surroundings. These same visualisers were also re-implemented as a way to present current and past user status on their web profile. Each application's visualiser is described below.

5.3.9.1. ItchyFeet Tag Widget

The social tags in ItchyFeet were used to indicate current and past context of users. These tags comprised of three parts: a *description*, *author name* and *timestamp*. An example of the web widget is shown in figure 5.6.

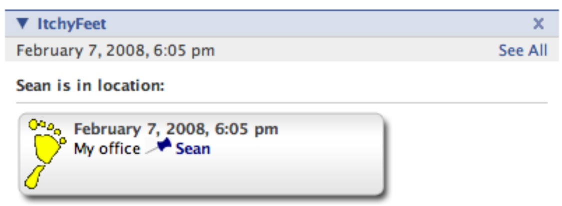

Figure 5.6. ItchyFeet location was represented using a semantic description, name of tag author and time of last update.

The descriptor was a single 50 character semantic tag or description, which represented a real-world location. The character limit was less than that imposed by many other microblogging systems, such as the 140 character Twitter limit. This was due to interface size restrictions, to encourage use of shorter tags that could apply to multiple social situations and finally to reflect the short, rapid device interactions that users typically make while exploring their surroundings. The use of free text in the descriptors allowed users to control their privacy through obfuscation of the tag content, e.g. users could enter generic, wide-ranging tags, or more precise ones, depending on how much they wish to reveal to others [123]. The author name showed the real name of the user who first created the tag. This was added during the design phase as a result of the ambiguity that arose from the use of common tags ('home' for example); adding this additional metadata made tag interpretation more meaningful to users. Finally, the timestamp revealed the time at which the social encounter took place and acted as an indication of the age of the reading; often useful as an additional contextual indicator (indicating for instance, if the tag was created at day or night time).

5.3.9.2. MobiClouds Tag Widget

An alternative tag widget was adopted by MobiClouds. In the trial, users could tag any Bluetooth devices that constituted to their social surroundings. Because of this, social tags were not necessarily encountered individually and instead, a user's social surroundings often constituted of a cumulative set of tags. The dynamic cloud of tags that surrounded each user would change as social peers entered and left their Bluetooth range. Early in the design phase it was decided that the additional cues offered by multiple tags negated the need to include an author name with each tag. By visualising tags alone, it was possible to generate a tag cloud that was analogous to the Web2.0 clouds, predominantly favoured by modern websites as a method of organising non-hierarchal information [193] and thus familiar to the user base. In order to achieve this aim, a much shorter 20 character limit was imposed on tag length, due to screen size restrictions. An example of the web widget is shown in figure 5.7.

The tag visualiser acted as an animated, dynamically changing indication of the user's social surroundings. Any tags that were associated with currently proximal Bluetooth devices were shown as individual entities in the cloud. Each tag description could be associated with multiple devices, so tag size was set relative to the number of tagged devices present. As a way of visualising the dynamic, changing nature of the user's social surroundings, on the client widget the tags were subtlety animated. Tags slowly floated around the window and when a device left the user's presence, any tags associated with it would gently faded away before disappearing, giving a subtle indication of temporal social change.

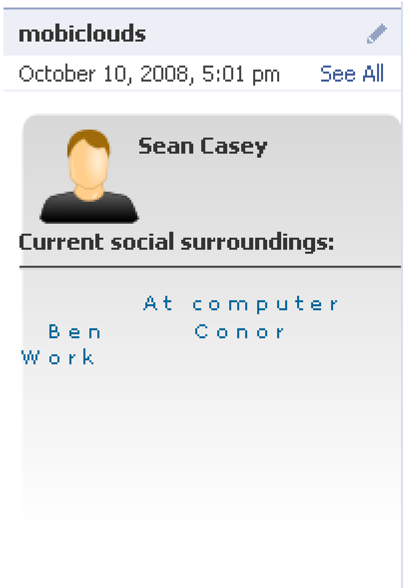

Figure 5.7: MobiClouds social context was represented using a dynamically generated social tag cloud

5.3.10. Stage 5: Updating Online Status

The user's context was initially displayed in the client interface and in ItchyFeet an intentional delay was induced before this was communicated to the central server. As described in 5.3.6, a monitor ran every 120 seconds to check the currently selected tag in the UI. If this had recently changed and the user was not interacting with the device (indicated by key press timeouts), an update was sent to the server, which would update the user's online status autonomously via the Facebook API. In MobiClouds, this update occurred after 5 tag cloud changes or 10 minutes. This ensured operation even when the device did not have the user's full attention. In order to override an automatic profile update, the user was given ample time to manually update their status by selecting a tag which better represented their context, described in section 5.3.11.

5.3.11. Creating and Reusing Tags

Users could interrupt the autonomous sensing process described in sections 5.3.6-10 and manually select their own tag, either by reusing an existing tag, or creating a new one.

The ItchyFeet UI, shown in figure 5.2 allowed users to manually select tags from a list of all available tags contained in the semantic tag model. It also allowed the user to create a new tag, after which they were prompted to enter a 50 character tag descriptor. When this was done, the visualiser updated to select this new tag and the device immediately sent an update request to the server, which updated the user's social network profile status and added the tag to the server-side global tag model described in section 5.3.4. This process served two purposes: it updated the user's current status and linked a tag to their location, which could be encountered by future users.

In the MobiClouds UI, shown in figure 5.3, users could select a device to tag from the Bluetooth device list, or choose to tag all to apply to all devices. In the same manner as ItchyFeet, the user could reuse a previous tag, or create a new one, instead using 20 character descriptors. This updated their profile and the server-side global tag model in the same way.

5.3.12. Tag Evolution in ItchyFeet

ItchyFeet tags were likely to be applicable to more than one location and the locations they represented were expected to change over time, as elements of the environment, or the group's interpretation of their environment changed. As such the spatial positions of a tag's boundaries were designed to evolve over time, adapting to future change. This was achieved by allowing tags to be deleted altogether when redundant (by the original author) and also offering the ability to modify spatial tag placement. Social tags could have multiple sets of coordinates associated with them and this meant a tag could represent more than one location and also allowed accuracy of tag locations to be improved collaboratively over time. On manually reusing a tag, the user's current GPS coordinates were added to the set of locations associated with it, effectively expanding the elastic activation area that surrounded the tag to include this new location [26], as depicted in figure 5.8.

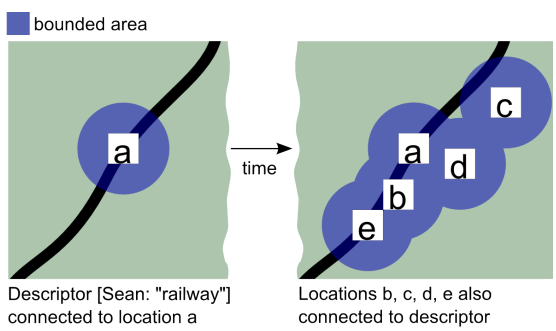

Figure 5.8. Over time more locations were associated with a description, expanding the bounded area.

5.3.13. Logging

A variety of logging was performed by both applications. Data was time and geo-stamped and logged on the server each time a user interacted with the services, for example authoring a tag, entering a new area or social surroundings, or manually disclosing their location. In addition to this, the user's GPS or Bluetooth traces were recorded as a way to monitor behaviour over time; something that was not available in the Gophers trials. A server-side database held the data, which was used for debugging problems and analysis purposes post trial, as well as supporting certain application functionality. Four types of log data were collected:

(i) User interaction log: When a user executed an application function on the device, such as logging in, shutting down the application and checking the status of friends, these were logged. This gave an indication of the type of situations the application was used in and helped with problem solving.

(ii) Contextual history log: Each time a user's contextual state changed on their mobile, this new tag or set of tags was logged.

(iii) Trail data log: Users built up trails of GPS coordinates, or Bluetooth device addresses, as they explored their everyday environment.

(iv) Tag data log: Each time a new semantic tag was created by a user, this tag data was logged.

5.3.14. Trail Logger

A particularly important source of log data was the trail log, which in itself was a useful source of human computing data. The primary purpose of the data was to allow analysis of user behaviour patterns post trial, making it possible to create the tag graph visualisations shown in section 6.3.3 and feed data to the visualiser tools described in section 5.4.4. GPS and Bluetooth sensor data was logged and buffered on the client until the buffer became full or any POST server call was made, when they were uploaded to the server by piggybacking on to the request. The data was sent as an encoded stream of timestamped deltas, to minimise data transfer. The timestamped entries were then held on a server side database table alongside the users' anonymous IDs. On receiving an acknowledgement from the server, the client emptied its buffer. This log data was stored on the client in a persistent manner, to protect from application crashes and shutdowns.

5.4. Trial Methodologies

The applications were trialled in two separate user studies and this section outlines the methodologies that were followed when hosting these.

5.4.1. ItchyFeet and MobiClouds Trial Design

ItchyFeet trials ran for a four week period between 8th February and 7th March 2008. MobiClouds trials also took part over four weeks between 17th October and 28th November 2008. The study method used was identical for each of these.

5.4.2. Trial Hosting

At the time of the trials, the ItchyFeet application offered a novel addition to Facebook users, so the service was made available to public users through the Facebook application repository in December 2007. Any interested parties could log into the page, anonymously register and download the application to a GPS-enabled mobile phone. In addition to this, the client application was available for download through Nokia's MOSH 'Mobilize and Share' service (now Ovi store) [151].

Following the public release of ItchyFeet, more formalised user trials were conducted between 8th February - 7th March 2008 and between 17th October - 28th November 2008, for ItchyFeet and MobiClouds respectively. It is from these trials that experimental data used in the analysis was collected. Participants were members of the university, who were voluntarily recruited in groups of four through use of the university mailing list and an advert posted on the University of Lincoln Facebook network, both of which can be seen at A05. Because the trial was, in part, concerned with how group dynamics influenced use of the system, prospective group members were required to be local residents based in Lincoln and also have existing friendship relationships on Facebook. A set of four group trials was hosted for each application and these ran in sequence over a duration of four weeks. Each application was therefore trialled by 16 users in total, with each group using the application for 7 days. During this period, users were free to interact with the application wherever they were located. To reimburse them for their time, each was paid a participant fee of £20.

At the start of each trial, users were verbally briefed about how to use the application and given the opportunity to ask questions. They were informed that they were able to create tags relating to their social activities, but to keep the trial as open ended as possible, were not explicitly told what these tags should contain, or were they should be created. Similarly to Gophers, the applications contained unmoderated user generated content and trial participants needed to be made aware of this in the form of ethical approval forms; after reading and signing these, each user was loaned a Nokia N95 handset with the application pre-installed and sufficient credit for the trial. They were also given a brief set of instructions describing how to setup and use the application and a daily diary questionnaire. The pervasive nature of the applications, the short, sparse bursts of interactivity, distribution of users and length of time of the trials meant that the type of full blown ethnographic study favoured by many field trials, which combine mobile video and audio feeds to supplement the log data [52], would be unsuitable. Instead, experimental data was collected from a combination of three sources; a *daily diary* where users recorded their daily experiences of using the application, *server logs* that were built from user interactions [82] and *post-trial discussions*. Each of these is now described.

5.4.3. Daily Diaries

Following the success of the 'daily diaries' issued in the Gophers trials, participants were required to complete similar diary style questionnaires for the ItchyFeet and MobiClouds trials on a daily basis. These aimed to give an indication of user perspective. Each page represented a different day and consisted of Likert scales, simple yes/no answers and open-ended text responses. An example of the questionnaires can be found at A05. Likert and binary responses were assessed quantitatively, whilst recurring themes across open text responses were identified and quantified. This statistical data was later used in the analysis.

5.4.4. Interpreting Log Data

The need for fine-grained analysis of the log data introduced in section 5.3.13 led to the development of visualiser tools for the two applications. In the ItchyFeet trials, the data set spanned over a four week period of interaction, but within this, subtle interactions were made in time periods as small as a few minutes. These rich periods of interaction could be sparsely distributed, so the ability to scale in terms of time and space were vital for evaluation. The Java-based replay tool developed is shown in figure 5.9. The tool employed the SwingX JXMapViewer component [202] to allow Google Maps [92] tiles to be accessed via the interface. Using the tool, it was possible to select a time period and location and it would visually depict current user contexts and locations, past GPS trails in the form of coloured paths, in addition to any interactions users has with the system, to varying levels of detail. The system builds upon the video playback-style controls employed in other replay systems [52] [153], which allow for real time geospatial user movements and system events from the selected time period to be replayed at varying speeds. In addition to being able to scroll and zoom around the world map spatially, by adding the ability to zoom to the required time range, it was possible to focus in on periods of interest and play back a series of events second by second. Specific subsets of users could be monitored by selecting their user IDs, along with the type of interactions to monitor. When a specific time and place of interest is pinpointed during analysis, this can be bookmarked for later retrieval.

In addition to this tool, a heat map generator was created, which extended the application to create heat maps for each group, superimposed over a real world map of the trial location. These maps could be used to indicate trends such as average number of tags created for the different locations.

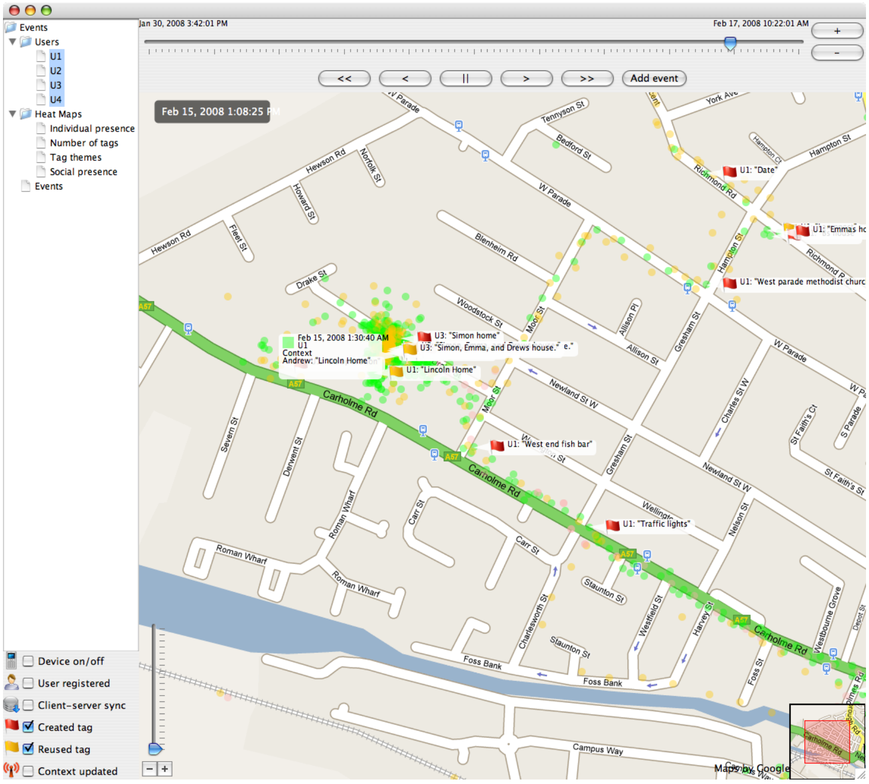

Figure 5.9. ItchyFeet replay tool plotting the GPS coordinates and interactions of four users over time

Based on the previous replay application, a similar tool was developed for MobiClouds. Using the same Java-based interface, this performed the same job for Bluetooth tags as it did for geotags previously. The MobiClouds replayer made it possible to select a specific time period and user(s), then visualise and playback the Bluetooth traces and associated tags that a user encountered over time, as exemplified by the screenshot in figure 5.10. The example shows three Bluetooth devices were in proximity to the user and for each of these people, the tags that have previously been assigned to them are shown. In addition, interactions that took place between the user and application at that time (for example the creation of new tags), are also indicted; as shown by the red flags in the screenshot. Because this Bluetooth data was sparsely distributed and interactions took place in small windows, the application looked for the nearest encounters that took place during a ten minute window either side of the selected temporal period.

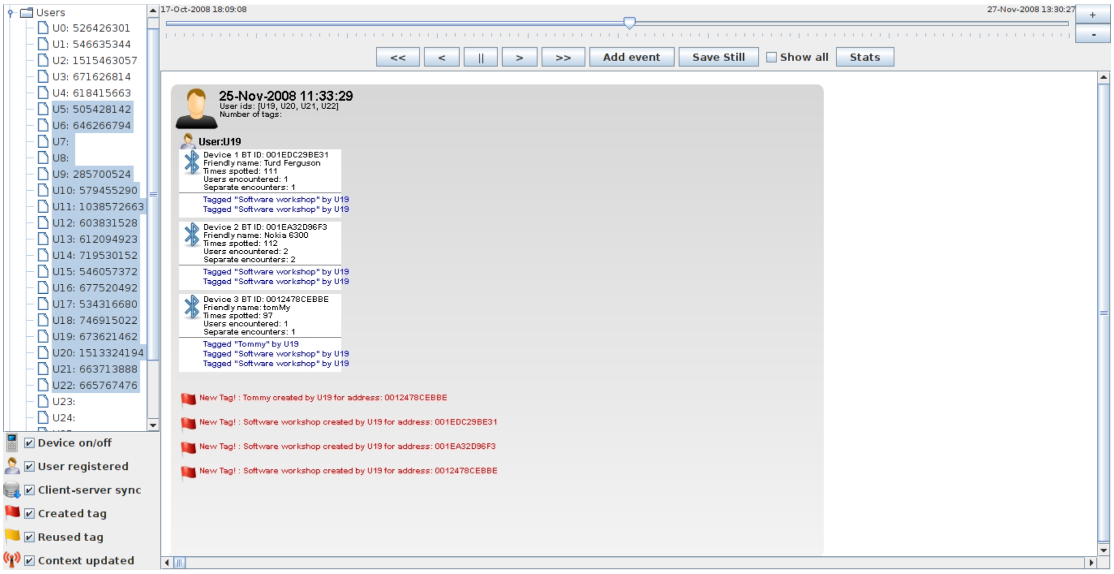

Figure 5.10. The MobiClouds replay tool showing the tags devices and tags encountered by a user at a particular time period and the creation of a number of new tags

In addition to the main replay tool, other visualisers were created for MobiClouds. Firstly, a tag cloud generator, which generated tag clouds showing an average of all encountered tags for each user (the results can be seen in figure 7.10). Secondly, a Flash-based social mapper was devised in order to give an indication of social relationships that built up during the trial. This generated an evolving connected graph of users and the Bluetooth devices encountered over time, along with any tags that had been created for that relationship (examples from this tool are shown in figures 7.7 to 7.9).

5.4.5. Post-Trial Discussions

Post trial, participants in each trial were debriefed and invited to discuss their experience of the trial as a group, in semi-structured discussions. The common ideas and themes, which emerged from these discussions reinforced and elaborated on many of the diary responses and allowed the users to articulate any ideas that were not documented.

5.4.6. Ethical Considerations

Ethical considerations were one outcome from the Gophers trials, particularly where non-consenting users were concerned and the issues surrounding this use case have also been the focus of related research studies [144]. A number of steps were taken to alleviate these problems. Ethical approval forms were completed in accordance to University of Lincoln policies and approved in advance of the trials. Furthermore, users agreed to formal disclaimers before participating, which stated exactly what data would be collected by the applications. Finally, any results discussed from the trials have been made anonymous, with names (excluding those encoded into tags), user IDs and Bluetooth addresses removed or obfuscated, to hide the identity of users.

Ethics were not a significant issue of ItchyFeet, since it did not break any ethical boundaries beyond those already crossed by existing applications in the mobile community. However, the experimental study conducted with MobiClouds was potentially more risqué despite the precautions taken, since it included monitoring and tagging non-application users as an intrinsic element of the application design. MobiClouds can be considered an exploration into the use of an invisible infrastructure of sensors that users freely advertise, but this will invariably be on the edge of what is considered ethically appropriate to some [32]. Related work has explored the reactions of users to similar infrastructures involving Facebook users in a discussion board on Cityware [120]; those supporting the research argued that users could 'opt-out' by switching Bluetooth to invisible, that the application never revealed 'real' user location, that authorities could track anyone using a mobile phone anyway and finally that the system only exposed information that people had already freely disclosed on their social network profiles. By contrast, MobiClouds does not mine social network profiles, so should be considered a less invasive system. Regardless, ethical considerations should be considered one of the prevailing issues with people tagging technologies in general.

5.5. Summary

This chapter has outlined the design and implementation of two social tagging technologies: ItchyFeet and MobiClouds. It has also endeavoured to justify the design decisions that were made during this process. Finally, it has overviewed the trial methodologies that were used to assess the technologies in two formalised user trials based in and around the city of Lincoln, UK.

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Using the results of these trials and processing them with the two replay tools has allowed for a detailed analysis to be performed. The analysis involved focusing on the periods of user interaction and also the preceding and subsequent moments that occurred around a user creating a tag. This has made it possible to provide an in depth interpretation of the type of content that users tagged, how this varied between social groups and the environmental influences that drove this process and these findings are discussed in chapters 6 and 7 for the two applications respectively. Using qualitative and quantitative analysis of the diary entries and discussion transcripts from interviews, has made it possible to further supplement these findings. The results from this analysis have allowed the original research aims to be assessed by the conclusions, found in chapter 8.

6. ItchyFeet: A Mobile, Social Tagging Service

This chapter analyses the first of two application trials from pair of mobile social computing studies, designed to explore aspects of real-world presence sharing between members of an online social network through use of semantic tags. This first study aimed to devise a general test framework, based around locative tagging that would allow for detailed analysis of user interaction, discover the typical influences that dictated the tag creation process of users when using these applications and finally, it intended to assess whether the meanings of the tags could be used as a way to provide deeper meaning about real-world locations. The mobile application *ItchyFeet*, introduced in chapter 5, was designed to meet these aims [39]. Part of the Gophers study investigated the collaborative generation of real-world social tags as a result of gameplay and ItchyFeet continues this exploration but in a non-gaming context. ItchyFeet is a mobile tagging and status update service that can be used by members of the popular social networking site Facebook, as a way to geotag real-world locations that are of relevance to their social peers. By utilising tag sharing, all related peers share the same pool of tags, in effect being collaboratively created by the group. When a user returns to a tagged location, the description is used as a real time indicator to imply context and their online social network 'status' is updated automatically to reflect this.

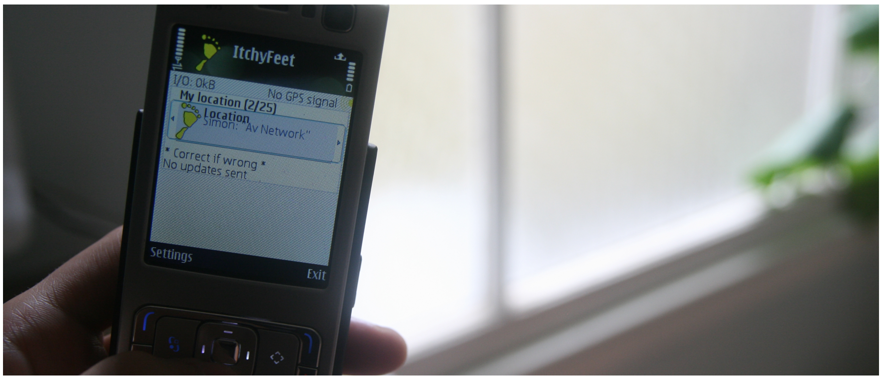

Figure 6.1. A user marks their status in ItchyFeet by entering and sending a tag from their mobile device.

The ItchyFeet application was assessed in formalised user trials conducted between 8th February and 7th March 2008 and this chapter provides an analysis of the results. It begins with an overview of the research aims and participants that took part, followed by a summary of how these users interacted with their environment when using the application and a discussion of the questionnaire responses supplied by the users. The chapter then concentrates on providing an in-depth analysis of the application data that was logged during the trial, which gives a detailed insight into the behaviour of trial participants. Next, the main factors that influenced users' interaction styles are identified and finally the key findings of the study are summarised. It is intended that these findings begin to contribute towards a general model for mobile social application designers.

6.1. Research Trials

The ItchyFeet service was initially offered to the public as a free download from a Facebook application webpage and the Nokia MOSH Mobile and Share service [151]. This provided a way for the core application functionality to be assessed and any technical issues to be addressed before conducting more formal trials. Furthermore, it demonstrated that the application proof of concept was of interest to the social networking community in general. Between its release in December 2007 and November 2008, ItchyFeet was downloaded and registered by 78 people, with 36 going on to make practical use of it. A total of 223 tags were created by users, across 15 international countries. During this period, 1,056 context updates were disclosed and 17,578 GPS trail points logged.

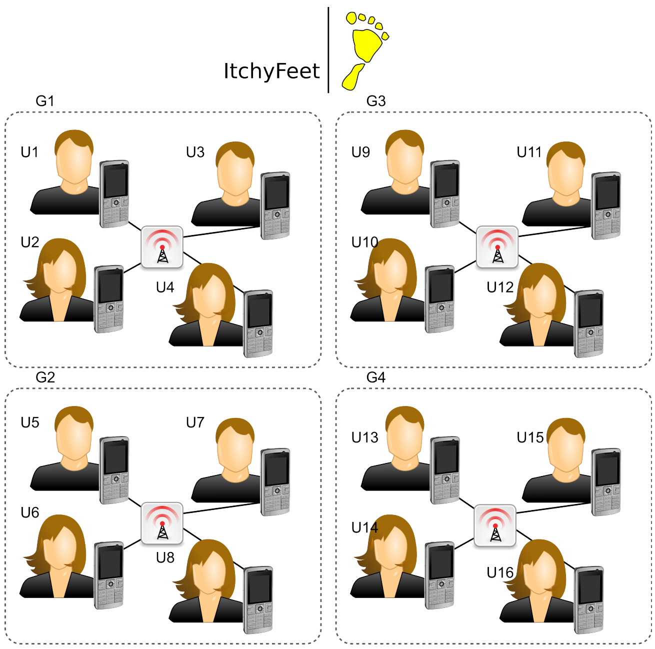

Figure 6.2. The experimental setup. 16 users were selected and each assigned a UID. Each trial group consisted of an individual network of users, connected by their social network.

In addition, the application was trialled over a four week period using 16 people, formed of four groups of volunteer Facebook users from the University of Lincoln. For the sake of consistency, only experimental data from the formal trial period is presented in the analysis. Throughout the discussion, real user names have been replaced with fictitious counterparts where appropriate; otherwise, individual users are referenced using identifiers [U1-16] and trial groups are defined using [G1-4].

6.1.1. Research Aims

As mobile social services become more mature, the range of social media that can be shared and the complexity of underlying systems is growing. It is unrealistic to attempt to recreate a fully-fledged mobile social service for the purposes of a short term research trial. A more practical approach taken by ItchyFeet, was to layer the experimental system on top of an existing commercial social network framework (Facebook API [68]). Also, to restrict the scope of the application trials, the study explored geospatial tagging in a predefined spatial area (city of Lincoln, UK). The ItchyFeet study investigated a number of research aims:

I01: *Devise a test framework based around mobile social geotagging that allows for logging and monitoring of user interaction.*

I02: *Discover typical usage patterns exhibited and document the effects of real-world influences on user interaction.*

I03: *Assess the relevance of peer tag sharing as a way to record semantic meaning for real-world locations.*

The main aim, I01 was to devise a test environment that could allow social networking users to exchange social geotags, whilst their actions were logged and monitored in a realistic everyday setting "in the wild". I02 aims to define the typical usage patterns exhibited by users accessing mobile social services and identify the factors that influenced them, in an effort to inform the wider design of such services. Finally I03, assesses whether the tags created by users to provide social networking status updates could be exploited to provide deeper meanings about real-world social locations.

6.1.2. User Demographic

The ItchyFeet participants were volunteer social network users who were recruited after responding to an advert posted on the university Facebook group. Prior to the trial, the participants were found to be heavy adopters of social technologies, with over half using additional online social networks (other than Facebook) and 14 being members of regional and academic networks within Facebook. All participants owned their own mobile phone, but more surprising was the state-of-the-art nature of these, with over 80 percent of respondents possessing a handset that was less than two years old; one user even owned multiple devices. Despite this, only one of the users currently made use of mobile Facebook services on a regular basis, showing this still to be an emerging area at the time of the trials. None of the users' current phones contained integrated GPS receivers. However, three users made use of other GPS devices and one actually developed his own GPS-enabled applications. From this, it was clear that users ranged from very technical to less technologically informed; furthermore the majority of users were uninitiated to the technologies used in the study and it was reasoned that this could pose a significant learning experience for them.

6.2. An Overview of User Behaviour

In order to review the way users interacted with the application and their environment over the trial period, a number of spatial 'heat maps' were generated, shown in figures 6.3-6.5 highlighting the key points at which interaction occurred. Heat maps offer a method to visualise mobile interaction data in ubiquitous computing studies [136], although in the ItchyFeet study they have been extracted from in a novel way, explained below. They have been selected as a technique to outline group tagging trends, as they are able to offer a static cartographic overview of group members interacting with the application over a one week period. The maps are generated using the server log data accumulated during the trial as users interacted with their mobile devices. This was inputted into the visualiser tool, discussed in section 5.4.4, which was adapted to enable it to render heat maps. Points of interaction are plotted using alternating shades of coloured blocks, superimposed over cartographic map data.

A static geographic area was selected for producing the maps, which spanned a surface area between latitude (53.221 : 53.249), longitude (-0.567 : -0.509) and this is shown in figure 6.3. This was the area of central Lincoln, which contained the university campus. Although the majority of participants left the boundaries of this area during the trial, their usage patterns in these more spatially distributed locations were sparse and infrequent, making them difficult to depict. Defining a fixed area of study, where all participants had spent time, allowed for direct comparisons between the way different groups interacted in a shared environment.

Cartographic street map tiles of the area were loaded from Google Maps [92] data and plotted using the Java SwingX/SwingX-WSs APIs [202]. Superimposed over the street map is a 100 x 100 cell grid, which aligns to the borders of the area. Each of the cells is coloured with a value from a gradient range, which corresponds to the frequency of a particular occurrence in that area. On each map, a key is displayed which describes the meaning of the colour range. Heat maps have been created to show three aspects of user behaviour:

(i) Individual interaction locations: Shows a map of all locations where the application was accessed by individuals. This shows the most and least popular places for using the application across groups.

(ii) Social interaction locations: Indicates the locations where the application was accessed by groups of users, i.e. those areas where at least 2 users shared presence. This highlights the most, and least social places to use the application across groups.

(iii) Tagging locations: Using data from the tag log, this shows locations for every unique tag created by users. It indicates the frequency of tag generation for different locations. This shows the most and least popular locations to tag across groups.

After plotting these heat maps, the data was analysed and extracted from in a novel manner, to determine if any 'hotspots' of tagging that existed. Firstly, the graphs of a group were squared off into a number of equal sized quadrants. This allowed the number of interactions or tags created to be manually totalled for each quadrant. It also made it possible to assess whether each quadrant was 'social' or not by visually determining whether social interactions between two or more users occurred in each. This analysis was logged to a spreadsheet and the process was repeated for each of the four groups. Next, the areas of tagging that were common between groups were visually identified; this allowed the most popular tag areas to be determined. The quadrants where tags existed were visually compared with the quadrants which were considered 'social', in order to identify whether a relationship existed between these. Finally labels were created for common quadrants to reflect the characteristics of the area, so that the interpretation could be referenced in the text. The results of this process are visible in the appendix, at A06.

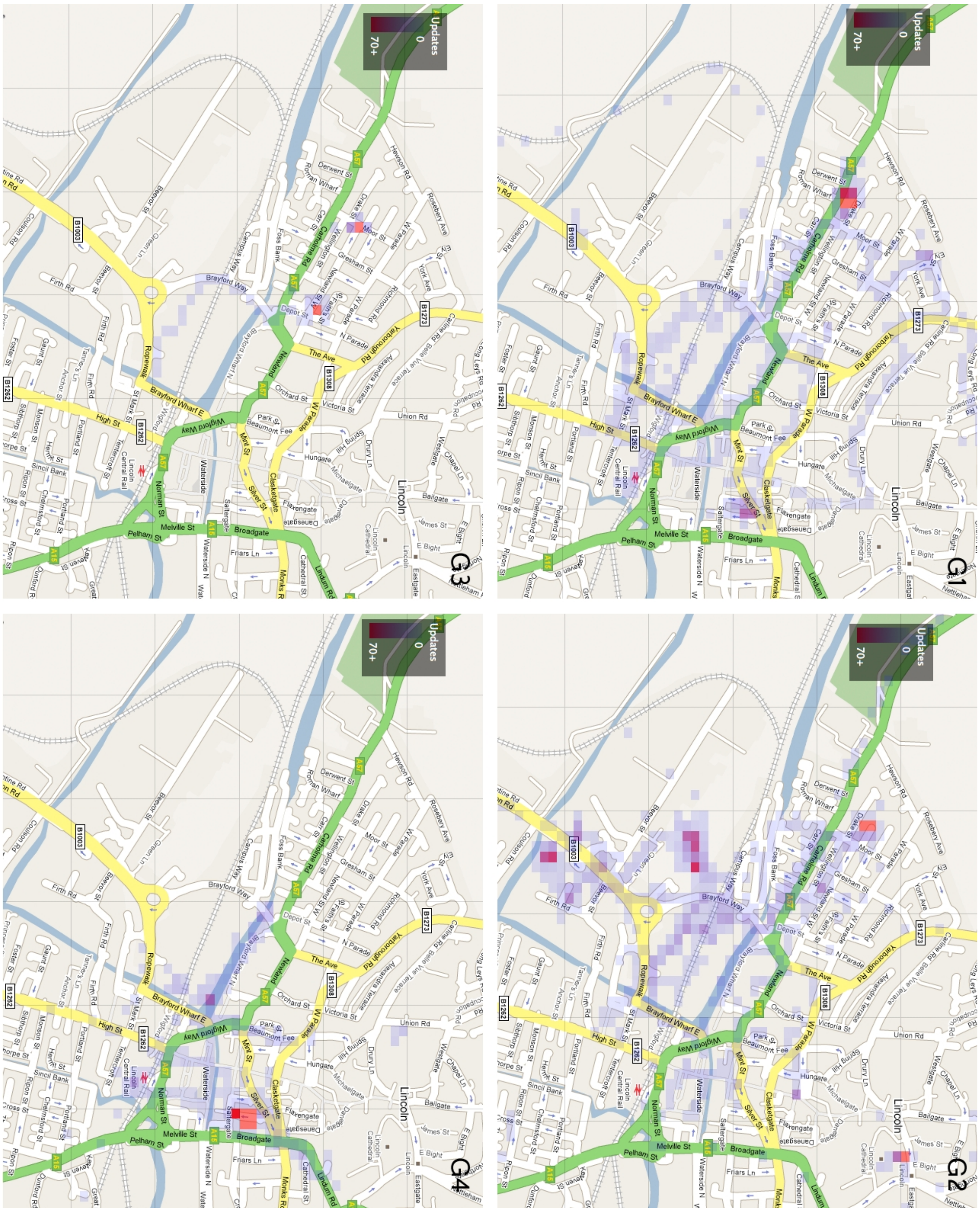

Figure 6.3. Individual interaction locations. This shows the frequency (measured by number of GPS updates) at which the application was accessed by users at different locations, overlaid on top of a map of the main trial area. One map has been created for each trial group. Translucent blue indicates few interactions occurred there, through to red, indicating 70+ interactions occurred.

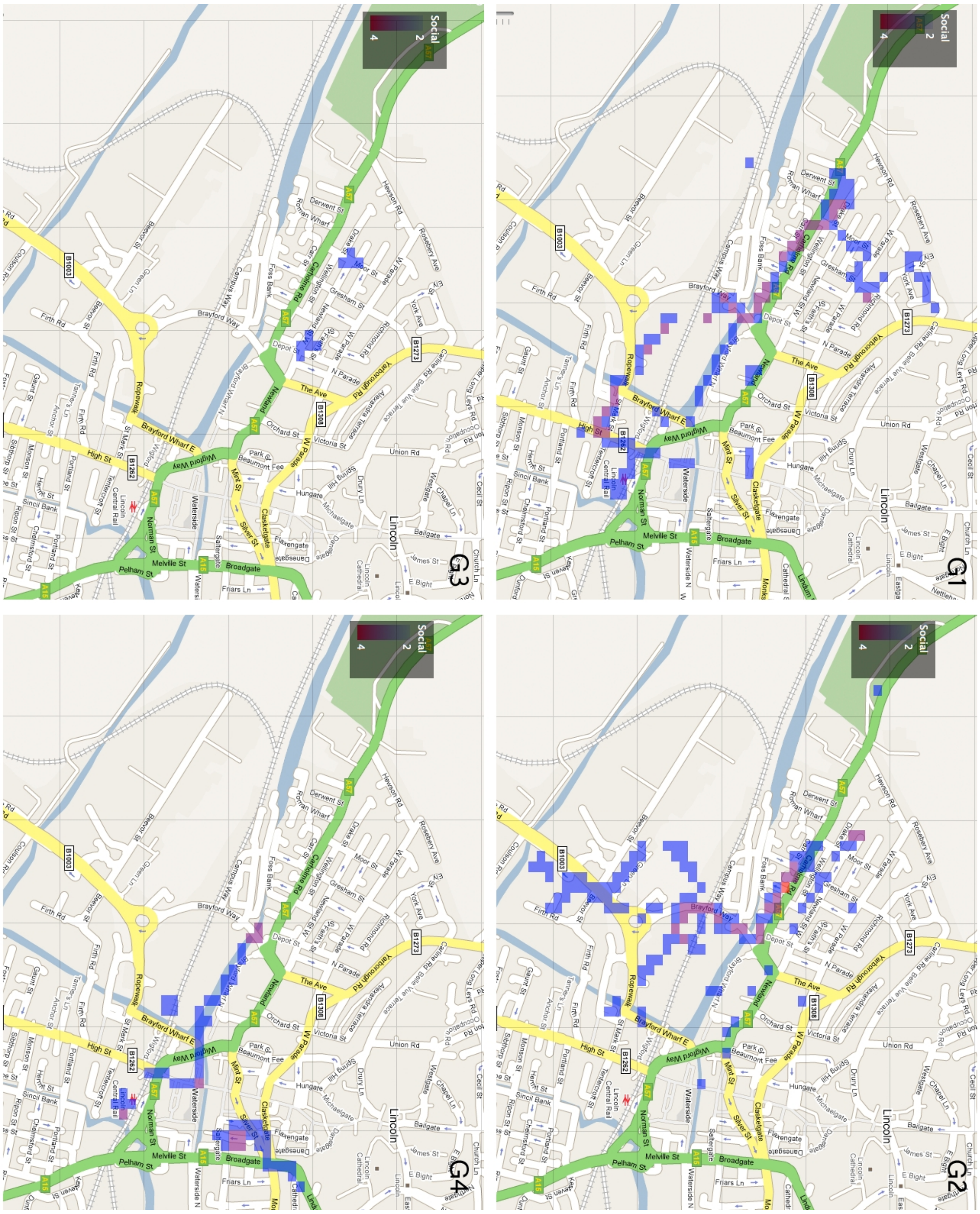

Figure 6.4. Social interaction locations. This shows the locations at which two or more ItchyFeet users accessed the application in parallel. One map has been created for each trial group. Blue markers implies a group of two, through to red indicating all four group members collaborated at the location.

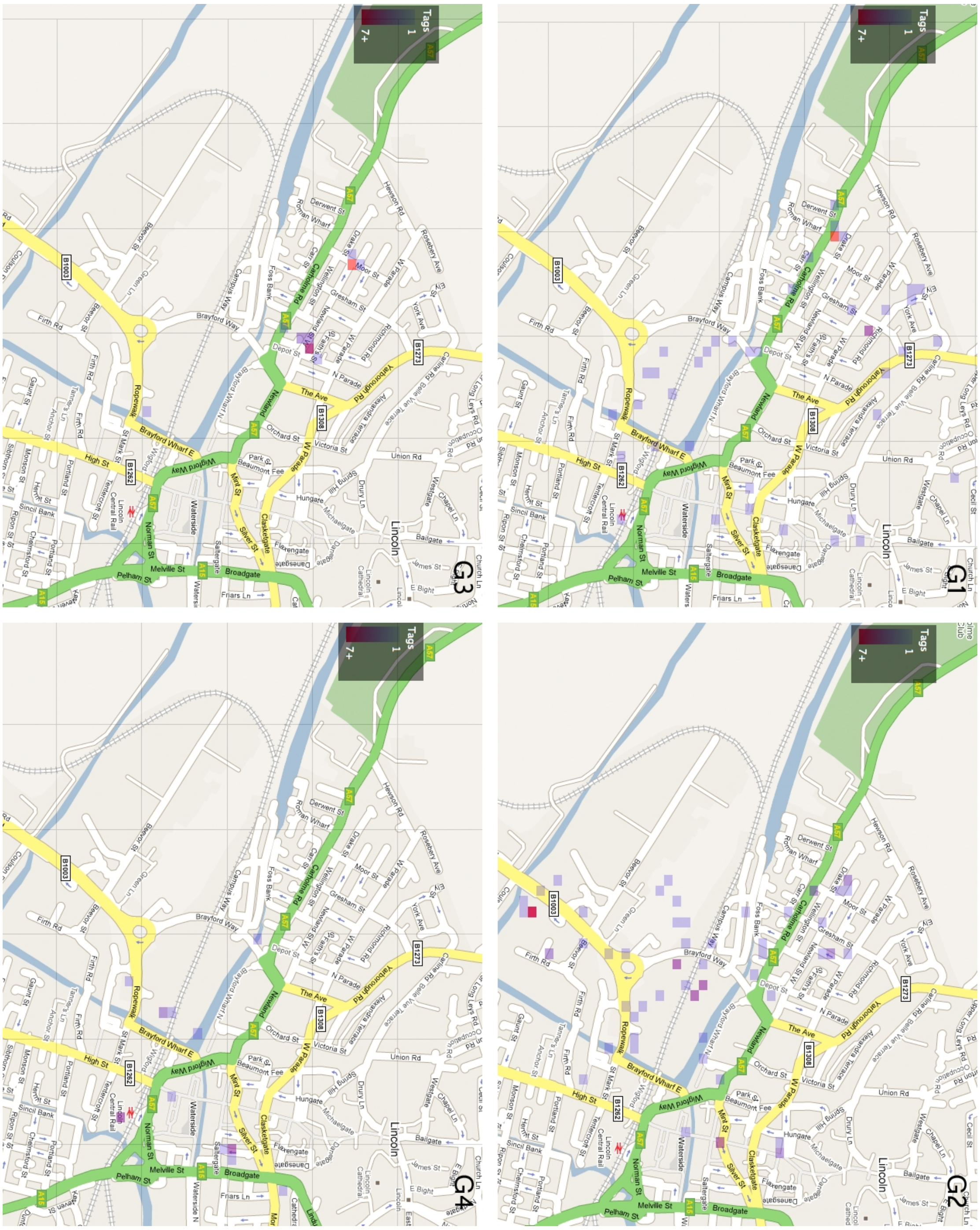

Figure 6.5. Tagging locations. This implies the most popular locations to create new tags, with blue markers indicating few tags were created, through to red, where 7 or more tags were created at the location. One map has been created for each trial group.

6.2.1. General Trends

Analysis of the heat maps shown in figures 6.3-6.5, reveals a number of inter-group trends and disparities regarding the most common places to tag. Figure 6.3 shows that specific areas of interaction were common across all but one of the groups (G3). These corresponded to the typically social areas in the city, namely the high street (main retail area, where the label 'waterside' is seen), the university campus (area south of the railway line and central) and the Brayford Pool area (an area filled with a range of bars and restaurants, seen immediately north of the river).

In Group G1, the most popular tagging locations (shown in figure 6.5) clearly correlated with the most social areas to use the application (from figure 6.4). These included the university campus, train station and residential areas in the west of the city, where many friends houses were tagged. In G2, again the most common tag locations corresponded to 'social' areas; for example the university campus and some of the commercial shopping areas in the south of Lincoln. A different pattern can be seen from the users in G3, who displayed a very compact spread of data right across figures 6.3-6.5. Overall, the density of tags placed for G3 was also very low. The lack of GPS traces in figure 6.3 suggests they users only briefly made use of the devices when they needed to create a tag, rather than leaving the application running, showing the group did not adopt the social tool to the same extent as the others. In the final group, G4 highly cooperative use of the application is seen around an off campus area of university buildings in the east of the city and this was unique to the group. The train station and main university campus were additional areas where the group's social activity and tagging occurred.

It is clear from the results that tagging was closely linked to social popularity of locations in the majority of cases and this reflects one of the key aims of the application, which was to create a framework that supported social tagging between friends. In addition, there were many similarities in popular tagging locations across groups. Some tagging locations appeared to be repeated across groups (such as the university campus and residential areas in the west of the city), while others were unique to individual groups.

The aforementioned group trends are important to the concept of geospatial social media sharing across user groups. It demonstrates that semantic tags can possess varying degrees of social relevance, with certain tags being more suited only to a user's immediate social network, whereas other content may have wider implications, being applicable to users from other related peer groups – for example peers that are members of the same Facebook 'group' who may be interested in events and information posted around campus. Other tags may even be of interest to the wider city population as a whole, for example geographic names and tourist sites.

6.2.2. Tag Categorisations

The preference of human-readable semantic tags over more formal naming methodologies (e.g. latitude and longitude, or map positions) has elsewhere been favoured as a way to allow users to create location identifiers that are more meaningful to them [195]. Such tags are closer to the spatial reasoning schemes we naturally create when communicating with one another, for example when conducting phone conversations [217]. The categorisation of the tag patterns recorded by users in mobile social systems is an area covered by numerous previous research studies [14][123]. However, the systems used in such studies were isolated from existing online social networks, the focus for tagging varied and much of the research did not take advantage of high-accuracy location tracking now afforded by GPS, instead focusing on general tag themes. In contrast, ItchyFeet users were social networking friends prior to the trials, labels were created for the sole purpose of exchanging social information, and the availability of high-accuracy GPS data offered a method of studying the precise interaction locations of users.

In order to manually analyse and extract the semantic tag themes from the data set, the same process described in section 4.6.1 was followed. The resulting graph in figure 6.6, shows a summary of the tag themes favoured by participants in the trial. This can be used as an indication of the most popular subjects to tag, across groups.

Many tags focused on major buildings, which users utilised as social waypoints, tagging them to indicate social context; the most popular places to tag were commercial buildings and areas of the university campus (tagged in terms of buildings). The houses of friends and the homes of users were also popular targets for tags, showing that users also considered these to be key hubs of social activity and ignoring any ethical issues that might emerge as a result of doing so. Another unexpectedly popular theme was the tagging of transport hubs, such as train stations, road-based service stations and major roads; tagging on transport systems and journeys was a recurring use for the application throughout the trial, interpreted as a way for users to post updates on their journey progress. Finally, the tagging of more explicit geographic descriptors, for example geographic areas and street names was also observed, seen as a way for users to report on their real-world location in areas where the rest of the group might not be familiar with, either to a fine or coarse degree of accuracy.

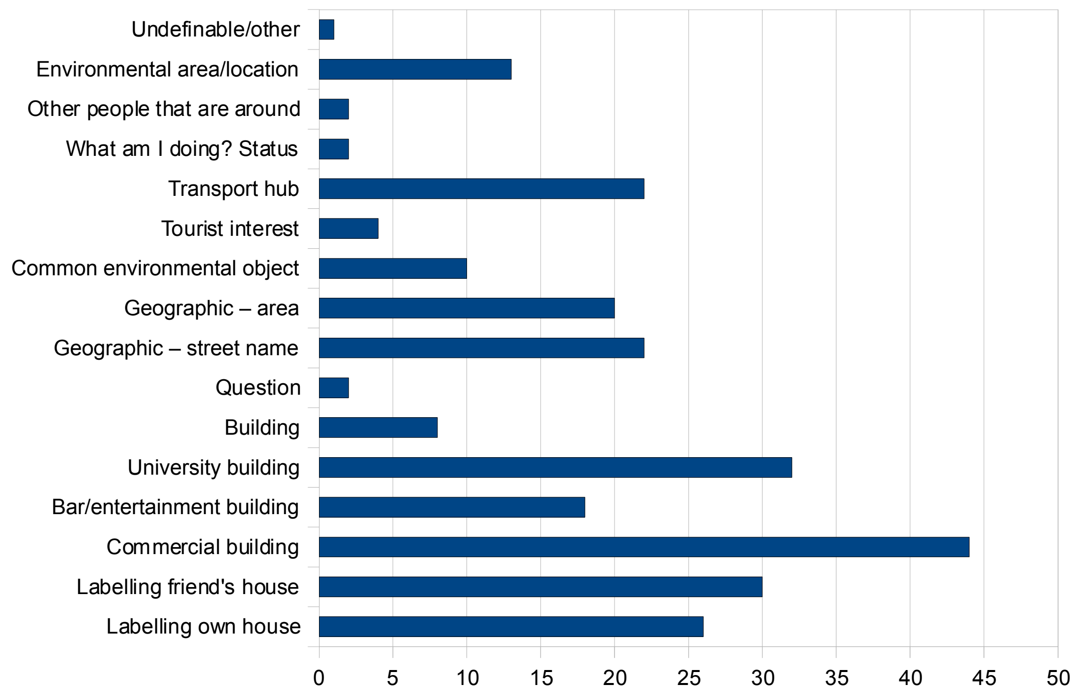

Figure 6.6. Prevalent tag themes employed by ItchyFeet trial users. Tags were thematically analysed and the number of instances of each theme recorded. The most popular tags focused on labelling buildings, friends and own houses, transportation and geographic areas.

Now a general overview of the application usage has been established, the next section summarises trial usage from a user perspective, by analysing responses from the questionnaires.

6.3. Questionnaire Results

The 'daily diary' questionnaires described in section 5.4.3 were given to users to complete during the course of the trial and the results of these were analysed, as a way of monitoring a user perspective on trial progress. Through qualitative and quantitative response data in the form of Likert scales and themed text responses, these provided a valuable insight into how the application was interpreted from the user's point of view. An example of the questions answered by users is provided at A05. In order to abstract from this data, the same technique described in section 4.7.2 was followed.

All the participants completed the questionnaires in full and answered each page of the questionnaire on a day to day basis. The opinions of all group members are therefore equally considered and responses have been acquired at periodic stages through the trail – collating user thoughts from early first impressions, to becoming an experienced user. Below, the main questionnaires results are summarised into sections and these are later referenced to corroborate findings in the subsequent discussion.

6.3.1. Real-World Usability

To assess the usability of the application and the success of the interface in real-world circumstances, users were prompted to provide feedback on how well the application and interface functioned. The general consensus was that the user interface was easy to use and the application functioned as designed. For example, only two users had difficulty selecting the tag required and 13 users reported the tactile buzz from the phone would cause them to check the application, but this only interrupted a user's personal activity in five cases. Furthermore, the application was seen as a pervasive part of users' lifestyles; participants 'rarely' found the application distracting to use and only three reported the application making them change their normal routine. The intentionally limited scope of the application functionality was seen as too restrictive for some ItchyFeet users, with 11 showing desire to tag information other than text, showing potential for extending the technology. Finally, 13 had seen labels that could be merged into a single tag, something that the application did not support.

6.3.2. Tag Sharing

When asked who they would be prepared to disclose tag data to, users reported they would be 'likely' to share this data with direct Facebook friends, but 'undecided' on whether they would share this with family members. The chance of them sharing data with unknown people in their Facebook network and strangers on Facebook were both considered 'very unlikely'. This shows a distinct desire to protect the social tags they had generated, only being willing to disclose this information to very close friends. It shows that issues of accountability and disclosure of location based information, raised in previous mobile computing studies [195] [160], are still a relevant issue today; even for users in a social networking environment where phenomena such as peer surveillance and social network surfing [112] are common practices and location 'check in' services such as Facebook Places and Foursquare are becoming established [69][81]. Many users also have a tendency to make their walls visible to unknown members of their Facebook networks, or to allow applications access to their profiles [198] (which can contain large amounts of potentially sensitive personal data including date of birth, place of work, sexual preference, photos). Despite these reservations, all 16 users felt in control of their information whilst using the application, indicating that the automatic disclosure of information to their immediate peer group was not an issue. Finally, no users shared the application (via Facebook invites, or otherwise) with those outside the trial group.

6.3.3. Tag Decision Making

When articulating the main factors that influenced users to create or reuse a tag, the most common reason was familiarity of the location, reported by 6. This is unsurprising, as familiar places are most likely to be of relevance to the peer group and also have a high probability of being revisited by the user and their peers during the trial. Another common driving factor was opportunity for a user to interact and availability of the technology, indicated by 5 respondents. This demonstrates that personal factors, such as cognitive or physical availability to interact with the device were essential perquisites to leaving a tag. It also suggests that blackspots of human cognition and technological activity may exist and when working close to these, application use would be limited to short interstitial bursts of interaction [161] as users work around these seams. Furthermore, implementing a tag system using a sensing technology with different limitations might forge a divergent tagging style. Other notable influences to tagging included time spent at the location (4), significance of the location to the group (3) and personal interest in the location (1). Finally only 6 users felt a 'responsibility' to tag their location at the start of the trial (and 5 by the end), showing the application was used mostly out of personal choice, rather than trial or peer pressure.

6.3.4. Group Proximity and Social Influence

Users were asked whether they travelled away from the trial group for a significant period of time and if so, how this affected their interaction experience. Of the respondents, 8 adapted the way they used the application and for four of them, differing social circumstances were the main factor of change. This shows that the social group had significant bearing over how a user interacted with the application. Two users mentioned an increase in technical difficulties, which could be caused by the lack of group knowledge at hand to help them solve problems.

Conversely, the effect of being in close proximity to group members during the trial also affected application use. This again highlighted the influence of social surroundings on interaction style, but rather than promoting use, in many cases it promoted discourse and a group learning process. A number of users (6) reported increased discussion around the application at these times, providing an opportunity to exchange ideas on where and how the application should be used and thoughts on the trial itself; this mirrors findings evidenced in related mobile awareness trials [216]. In addition, three users reported reduced application use in these circumstances, since their close proximity to the users rendered ItchyFeet redundant for the purposes of sharing status. Two participants also cited social differences explicitly.

In total, 14 users had been away from group for a sustained period of time and 14 had been in very close proximity to trial users at some point, showing a dynamically changing social group. By the end of the trials 10 users discussed with their friends which areas to tag and 14 felt they had reached a consensus on where/how the application should be used; this feedback suggests that a learning process occurred between users during the course of the trial.

6.3.5. Accuracy of Tags

Overall, the accuracy of tagged content was believed to be representative of the geographic locations at which it was placed, with users indicating accuracy was 'often' correct and only three reporting seeing incorrect looking tags. Additionally, ItchyFeet would 'rarely' select the wrong location for a tag (ensured by the prerequisite accurate GPS lock) and only four users saw the location of the tags they placed change unexpectedly. All 16 participants thought the meaning of the tag content was easy to understand. This all fostered an environment of accurate and meaningful social tags, assisted by the elements of competition and accountability associated with social networks [14] and so did not suffer from the noise generated by 'junk' content often associated with UGC systems. However, users divulged that one trade off of enforced high accuracy was that there were 'too few' tags around.

This concludes the summary of trial behaviours and user opinions and subsequent sections provide an analysis of these results.

6.4. Trial Outcomes

This section analyses the tagging behaviour of the ItchyFeet users in depth. The analysis is predominantly based on data from the server logs generated as users interacted with the system. Using the visualiser tool, an in-depth study of the creation of the social tag network, the movement of users through space and time and the changing group dynamics was performed. During the trials, users were able to tag in an open and unrestricted way and a discussion of the outcomes of this approach are also given; emergent interaction styles are discussed and notable tagging styles are identified. Following this, the discussion focuses on some of the main factors that influenced user tagging and the tag content that was created. Finally, the main findings of ItchyFeet are summarised and key factors of interest to the wider area of mobile social systems discussed.

After loading the log data in the visualiser, the following process was used to analyse the data. After selecting the first group of users, the timeline was manually dragged to identify points of interest (ie. the points at which tags were being created). The bookmark function was then used to record the position of these events. Next, an in-depth browse of the interactions that took place immediately preceding and following these events was performed and any pertinent characteristics of user interaction were noted, for instance, how users were interacting others, where they were located and how sets of tags related to one another. Some of these characteristics were taken from the original research aims in section 3.2.2, whilst others were not predetermined and instead, were revealed as part of this exploratory process. Screenshots were taken at these points to act as supporting evidence and the user and group these interactions concerned were noted; the most relevant have been included in the subsequent discussion. This process was repeated until the entire trial period has been covered for all four groups. Using this analysis, it was possible to make the observations on the user interaction contained in this section; applicable questionnaire and interview data has also been appropriated to reinforce these observations.

6.4.1. User Interaction Styles

The interaction styles adopted by users of ItchyFeet can be separated into three broad categories: individual (tagging independently), social/cooperative (tagging around/with others) and non-cooperative use (tagging in competition with others). These styles are typified by the examples below.

(i) Individual: The most basic level of application use was as a location-aware replacement to the personal 'status updates' commonly offered in social media applications such as Twitter and Facebook. One particularly individualistic form of tagging was seen when a user walked across town on his own and, over a 25 minute period, created tags for 13 different locations, shown in figure 6.7. This example occurred 3 days into the trial, during which the user's attention was particularly focused on marking his surroundings via tags.

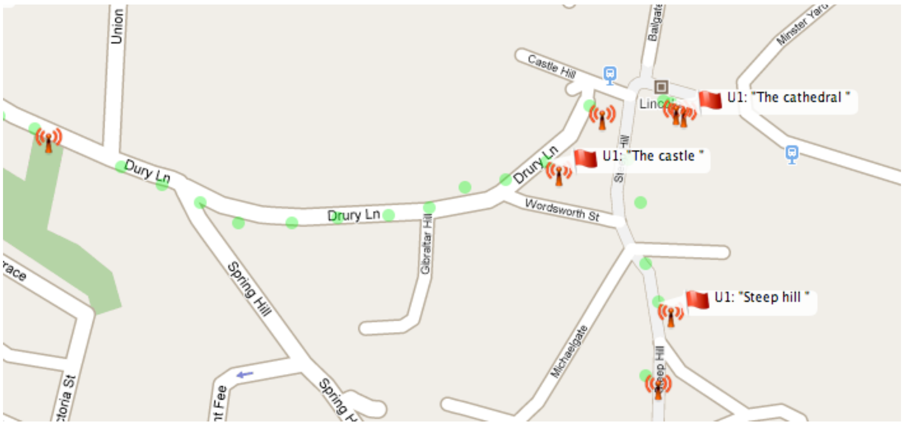

Figure 6.7. A user interacts with the application purely on an individual basis, creating status tags en route.

(ii) Social/Cooperative: Tagging developed into something that was not wholly an individualistic task, but something that could be performed as a social activity. This occurred in a number of ways. Firstly, through using the application the group collaboratively built pools of tags that were shared amongst the user community. This style of tagging moves beyond the individually generated locations offered in systems such as PePe [123]. By laying a tag, a user is doing more than disclosing their current presence, but also indicating a point where future presence of their peers will be disclosed – in effect, registering for location-based status updates from their peers. Users reported they would usually tag places that were familiar and important to their social peers (see section 6.3.3), showing a desire to build a tag network that would bear group relevance.

Secondly, participants shared social narrative-based events, examples of which can be seen in section 6.4.7. Unlike the static event reporting seen in many social services such as Facebook and Socialight [197], which usually occurs as a set of photos or comments, social events in ItchyFeet were instead recorded as live activities that were reported in real-time. Peers were co-located during these social experiences, but instead of sharing a single mobile device for recording social context and authoring tags, it was common to see them synchronously running and interacting with the application on their individual devices, as depicted by the example in figure 6.8. One reason for this could be the individual's desire to record their part in this shared experience; by using their personal device to make a digital mark of their presence acts as a way to show that they personally were an active 'part of it' or a method to leave their personal mark on an area [85]. In addition, personal experience was not necessarily equivalent across the group experience; users frequently made use of tags in these situations to record their own personal perspective of their surroundings for example (seen in figure 6.9).

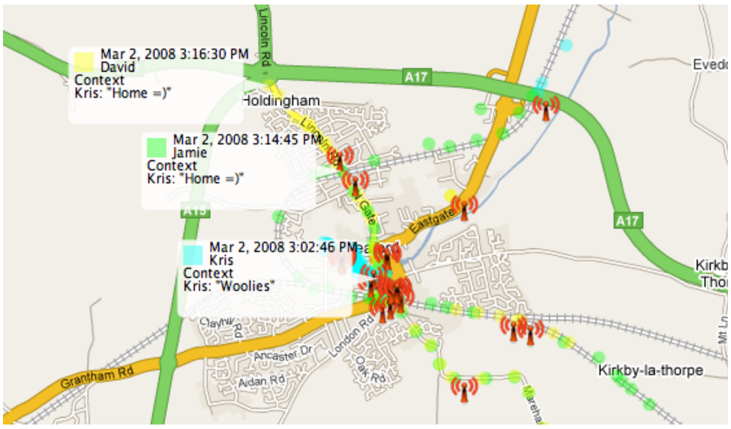

Figure 6.8. Users synchronously run ItchyFeet on their own devices. This provided a way to achieve a co-present social state.

There were also instances where social co-presence would clearly affect the tags which were left. A common occurrence was for one user to leave a tag, and for another user to observe the recorded tag and lay their own tag in the same position in order to elaborate upon, or change, the tagged information in some way, for example:

```
"Niks house" [U3]

"Best house ever" [U2 | 2 mins later]
```

Social use of the application often occurred naturally as users began to integrate the application as a ubiquitous part of their everyday social life. Often this was a conscious decision, typified by group members intentionally logging into the application together and using the application for the course of a journey as a shared experience (as in figure 6.8). During this coordinated application use, each member would encounter the same locations and a shared blog-style narrative would be built across their profile pages, combining to form a single record of their shared experience. Coordination of social actions has been evidenced in studies based around orchestrated social collaborative gaming, where coordination was a key aspect to game success [26] and players worked to overcome technical issues that stifled this coordination. This example shows that users exhibit similar coordinated application use in real-world tagging scenarios.

(iii) Non-Cooperative: Groups were also seen to use the application in a non-cooperative manner. This was typified by conflicts between users when deciding which areas to tag and how to describe them. In one case, a user thought the location of an academic building should be described as 'Architecture building', while another preferred to label the area in a more humorous way as 'By the mud' (e.g. in Figure 6.10). An element of competition was also reported to have taken place amongst participants. This emergent behaviour was revealed during post-trial interviews when a user described competing in a 'race' to label certain areas first, whilst another envisaged a 'treasure hunt' scenario:

> "it's good that it's almost like a race to get to the main places. Before we got to Thomas parker house...we knew that xxx had got there first and as soon as you get there it tells you that he got it! " [G4]

> "I looked at it from a gaming point of view. I thought you could add a bit that kind of...measures people's tags and tells you these tags and you almost have to go hunting for them. It will give you clues for the tags and you have to go on a treasure hunt to find them..." [G1]

Mobile social gaming research, as well as commercial projects, have exploited this competitive streak in the past by making GPS-enhanced competition an inherent element of application design [15][145][154][33]; the occurrence of these elements in ItchyFeet demonstrates both the ability for competition to flourish without directing users towards it and the importance of supporting play in mobile social application design.

6.4.2. Evolution of Tag Content

Until now, tags have been discussed as static markers, permanently attached to a location. In practice, tags were often treat as dynamic entities that could be revised over time as new knowledge became available or the meaning of a place changed. The tag space evolved most dramatically around the areas often frequented by users (indicated by the red parts of the heat maps in figure 6.3). These areas fell into two categories: *fine-grained locations* (for example a friend's house) and *distinguished areas*, (for example the university campus).

Evolution around fine-grained locations: In the fine-grained locations users were seen to build upon the tags created by others, by adding new tags that reflected their own personal perspective or feelings. User or group interpretation of places changes over time and this can be affected by many factors such as the time of day or event that is occurring [102][176]. If this is a tagged location it may necessitate a change of tag. Reasons for this could include a user discovering some new information, disagreeing with the original tag, or experiencing something new there since the last tag was created. Again, the evolution of tag content over time can also be seen as a way of users leaving their 'mark' on a place. Typically, the first tag left at a location would be fairly generic, but as time went on, the meaning of a place became more refined, resulting in more finely grained location tags that were more personalised to the social group. This common behaviour is illustrated in the example given in figure 6.9. In this example, a user initially placed a tag at a residential building – the house of a group member (the tagging of houses, central social hubs to the group, was, in fact, an emergent theme in the trials). Initially, the building was tagged using its street name 'Woodstock Street'. As time went on, more group members visited the location (depicted here by the different coloured trails), leaving their own personal mark on the tagging process. The users lay more precise tags, such as 'Woodstock sofa' depicting items and even their personal context within the building. Tags later become even more fine-grained and personalised, with participants labelling individual rooms: 'Jimmy's room', 'Tom's room'.

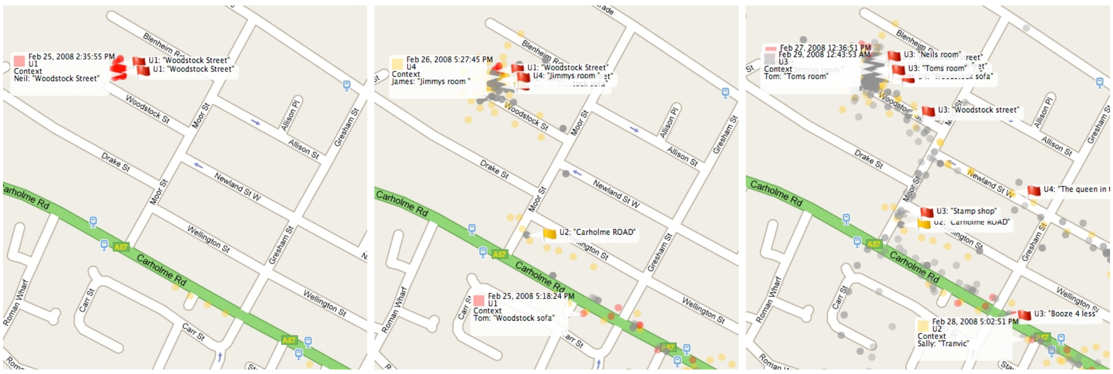

Figure 6.9. Tag content evolves around a specified location – a friend's house. Tag content was refined as users left their personal log on the area. Over time the tags changed from generic tags, through to more specific, personal tags.

A problem with this tagging style was that the application logic was not particularly accommodating of it, causing frustration for some users. Although the open application design meant that tags could be replaced by users when they wanted to alter the way context was reported by a location, the replacement tag would not necessarily take precedence over the original one. Instead, both tags would remain active and for future users passing the location, the proximally closest tag would be selected; an ineffective criterion when the minimum acceptable GPS accuracy was capped at 50m[4]. This limitation meant old tags would never expire and users reported this issue in the focus groups that followed the trial:

> "'Drew's house', 'top of hill' at same location – leads to flipping. Merging of nearby tags?....'Nick's house', 'best house in world ', all at same location. Yet 'nick's house' tag seemed to have preference." [G1]

Evolution around distinguished areas: In the geographic areas that covered a larger region, tag density across the area built up throughout the trial. Tag content varied in relation to the density of tags, with early tags differing from latter ones. These characteristics are depicted by the social tagging that occurred around the university campus area, shown in figure 6.10. Here, the data supplied by two users (U1, U2) – both heavy taggers in the area, is now discussed.

At the start of the trial, when the density of tags was sparse, more obvious, generic, tags were favoured. These described the area as a whole, or some of the most prominent features present. For example, U1 tagged "University of Lincoln" and "MHAC" (faculty building for media and computing) and U2 tagged "Lincoln uni science" (faculty building for sciences) and "Lincoln Uni lib" (campus library). As the trial progressed, the area became more densely populated by tags and the most obvious tags had already been used, leading to a tagging style which needed to be more personalised to ensure originality. Later tags started to reveal a more creative and detailed description of aspects of the environment (this shows parallels to the tagging seen in the Guessing Game where users deliberated on original ways to label their environment, reflected in figure 4.11). Increasingly precise semantic language was used in descriptions, such as "Atrium" (the well known phrase used by staff and students to label the canteen area within the main campus building) and "E shed car park" (car park for the student union buildings), showing an inclination by users to have a precise representation of their context as opposed to using a tag from a nearby location which is almost correct. Additionally, personalised and creative tag responses were seen later in the tag progress, including "By the mud" (area of campus where some building work was taking place) and "The big Lincoln sign" (at university entrance).

4 See source code at A02

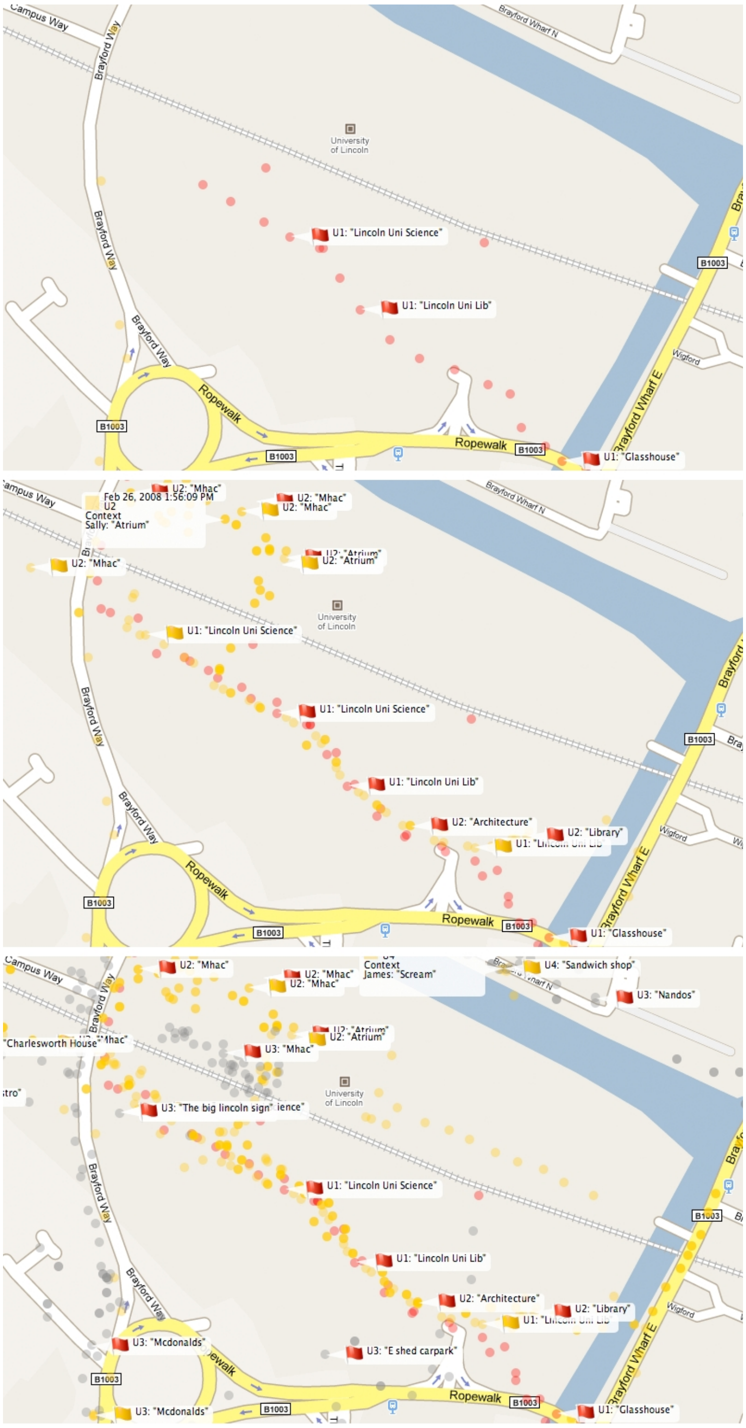

Figure 6.10. Tagging around a wider area. This shows how content evolves around the central university area. As application use progresses and most obvious tags are taken, these change from general descriptions to more semantically and spatially precise identifiers.

To generalise: under sparser tag placement tags are generic, wide and often geographic. Under a denser tag placement tags are more refined and frequently personal.

Another way these tags evolved was through the refinement of their GPS position over time. The position of existing tags would be adjusted by users, through re-placing them many times, as a way to update their context when they neared the area. An example of this is the tag 'MHAC', which became used multiple times around the building it represented. This has the effect of mapping the edges of the building, which could have useful applications in the area of human computation and collaborative mapping [185][98][156][92]. Also revealed are the paths taken by users while traversing the area, a potentially useful source for generating tourist routes, walking routes, or satellite navigation routing data; similar techniques have been used to accurately record the paths of tourists and locals as they cross cities using the geospatial metadata of Flickr photos [76]. Determining optimal routes around buildings and revealing the typical 'desire lines' favoured by users may also have applications in areas as diverse as architecture and urban design.

6.4.3. Tag Boundaries: Social, Temporal and Spatial

Boundaries were one of the main influences upon the way users placed and interpreted tags in the trial. Locative computing research has previously revealed these boundaries to be an important aspect of group interaction [15][154]. Three distinct boundary types were seen in ItchyFeet: *social*, *temporal* and *spatial*. Due to the length of the ItchyFeet trials and the number of participants that took part, information on how social and temporal boundaries were used was somewhat limited. As a result, the following discussion focuses predominately on spatial boundaries.

The general concept of boundaries is first introduced by the example of a train journey taken by members of group G4 during the trial, illustrated by figure 6.11. The creation of tags while travelling was, in fact, a common occurrence. In this particular example, participants were seen to label the train station, where they meet as a group. The labelling of this is significant, as it defines a clear start point for the journey and stipulates the beginning of a shared social event. On their journey, users tagged the areas they passed through as a group, reflecting the passing changes in the environment as well as the group's attitudes towards it ("a field", "sleaford/sleazeford", "the sticks"). Along the journey, users left the group at different intervals and their tag updates marked the point of their departure from the shared social narrative into a more personal one (with U2 labelling "Home =)", U4 "Home" and U1 "Home sweet home").

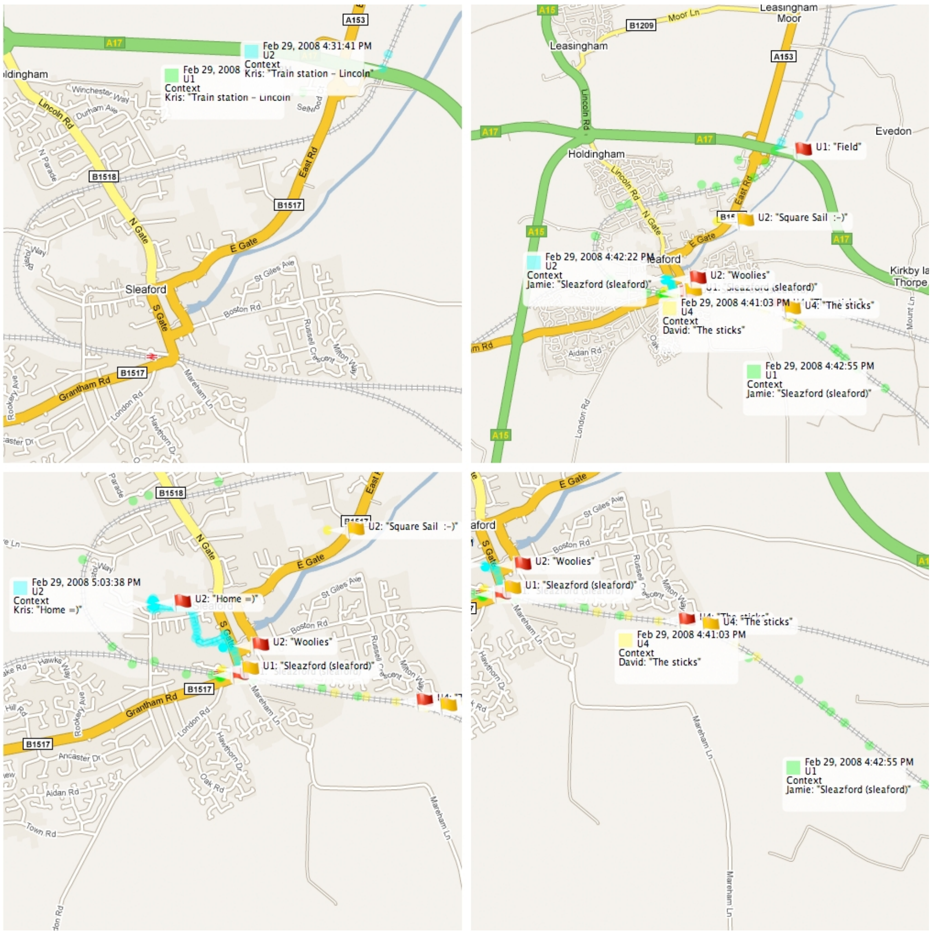

Figure 6.11. Tagging on the train. Users frequently created tags on forms of transport as a way of occupying time; this example depicts a shared train journey partaken by users of G4. During these experiences, users preferred tagging elements of the passing environment and geographic place names.

6.4.4. Social Boundaries

One way tags were separated was in terms of their social boundary. The size of these boundaries varied depending on the reach of the social group a tag was intended for. There were no ItchyFeet tools to directly manage these social boundaries (making them difficult to study), but users were able to adjust the social reach indirectly by obfuscating or personalising tags to the extent that they would only be understandable by certain groups of people. Some tags were highly personal, for example "St Faith squalor" and these were specifically intended to be understood by particular users socially close to the author, while other tags were slightly more generic and could be applicable to the wider University of Lincoln network as a whole, for example “Lincoln uni science”. Finally, other tags others contained information that could be of relevance to any residents of the city, for instance “The cathedral”. The heat maps summarising user behaviour in figures 6.3-6.5 show how certain tag locations were frequented across groups, while others were not. Directing tags towards specific users is something also seen in related studies e.g. [14].

A second type of social boundary also existed; that between one social situation and another. Boundaries between social narratives were often fuzzy; users would frequently access the application as individual users, with their narratives later intertwining as they entered a social event. The users would continue to use the application as a group, before later splitting off from the group and continuing along their own paths. Crossing the boundaries of these interactions (for example when entering or leaving a social event) was often a trigger to tag generation. An example of this can be seen in figure 6.11 as users joined and departed the train journey. The encapsulation of tags within a defined window of interaction shows a preference for episodic mobile interaction, as evidenced in studies of pervasive gaming [80].

6.4.5. Temporal Boundaries

Certain tags were highly time specific and became less relevant after a particular time had passed. For example, a tag describing where users met for a social event would no longer be relevant for recording user context once that day was over. However, these 'expired' tags were not considered redundant; users reported in questionnaires that these should be retained in the tag space as a way of providing a memory of the event and to encourage discourse on services such as Facebook:

> “- this is the crack in the pavement where so and so fell down...these recorded events could encourage communication on Facebook.” [G1]

Other tags were reported to vary in relevance depending on time of day and this is discussed further in section 6.5.4.

6.4.6. Spatial Boundaries

The spatial relevance of tags also changed over time, as the tags became applicable to new areas, or as users encountered new locations to which they applied. ItchyFeet supported this by offering the re-placement of former tags into new areas.

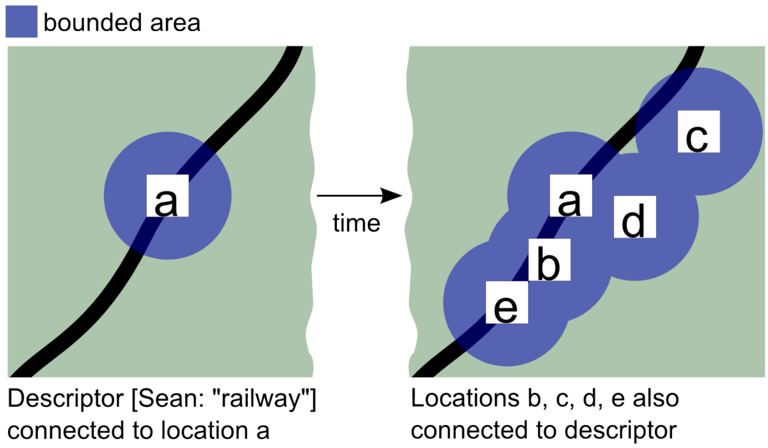

Figure 6.12. The Flexible Spatial Boundary approach currently implemented by ItchyFeet. The area bounded by a tag grows to encompass new spatial areas as the tag is re-placed by subsequent users.

Each tag in ItchyFeet was surrounded by a spatial boundary, which defined the area within which the tag would take effect; any users crossing into this territory would see their context updated to reflect the tag. A spatial boundary is centred around the originating GPS location of a tag. As tagging became more dense and users re-placed a tag around an area, the tag's boundary automatically expanded to the bounded area (shown in Figure 6.12). These flexible boundaries were inspired by the 'personal auras' suggested as a solution for the interaction difficulties present at GPS content boundaries in the Savannah field trials [26].

This approach intended to increase the impact of high frequency tags, but trials revealed this was not always desirable. As the tag density increased further and the boundaries of tags began to overlap, selecting the most appropriate tag for a user's context became more problematic, rendering the current tag selection algorithms inadequate. Even in the week long user trials of ItchyFeet, some evidence of 'tag flipping' was reported as tag density built up (see section 6.4.2). Because multiple tags can be applicable to a single area in a densely populated environment, a method of differentiating between them is necessary. One way this could be achieved is to separate tag data into different levels of localisation – utilising the themes in figure 6.7 for example, a large boundary could define the geographic area such as

'Lincoln', smaller boundaries would encompass the localised area (historic part of town) and the smallest would mark individual events, landmarks and buildings, for example 'Cathedral'. There are two challenges to handling this multi-level overlapped tag data; firstly, more generic wider-area tags may be preferable over (nearby) specific ones, depending on target audience and secondly, a newer tag should not necessarily make an old one redundant.

To address these challenges, two improved models of handling tag boundaries in mobile social applications are proposed. Firstly, tags could be spatially managed in a hierarchical way, ordering tags from generic/impersonal to precise/personal – boundaries within boundaries. This hierarchy would also be temporally browsable. Secondly, the spatial boundaries that encompass a tag could have the ability to expand and contract as a way to encompass groups of semantically similar tags together ('Lincoln', 'City', 'City Centre' for example), reducing repetition. Two techniques have been devised which incorporate these features: *extended group boundaries* and *multi-layered tag boundaries* and these are discussed further in section 8.7.3.

6.4.7. Thematic and Narrative-Based Tagging

Social interaction did not only concern single, easy defined events in time. In many cases, series of tags were bound by overarching themes and narratives, which spanned across longer time periods and these were frequently appropriated by multiple users. The unique properties relating to this style of interaction and the narratives that ensued are discussed in this section.

Narrative-based tagging: In narrative-based tagging, tags were allocated by users in chains of interrelated tags, which formed part of a larger event. A central theme governed the tag content and each individual tag related to this overarching entity, forming a small part of the story. Although not explicitly supported by the system, narrative tagging is another example of interaction that emerged as a result of the trial.

Similar user behaviour has been observed by other researchers; the Highway Experience [34] explored how narratives could be dynamically mapped onto real-world encounters to enhance car journeys, whereas Benford et al investigated the 'trajectories' that map between story narratives and real world time [80]. Most of this existing research has focused on scripted narratives that were scripted as an integral part of the experience. Conversely, in ItchyFeet the narratives are user-generated stories, which build from the natural interaction that occurs between users and the application and the desire of users to tell stories. Although more subtle than the dramatic and theatrical changes offered in hybrid experiences, ItchyFeet offers a convincing argument for the influence of narratives in everyday mobile interaction. In one instance during the trial, a group of users went on a geospatial 'bar crawl', each tagging pubs that they visited, whilst in another event, two users went on a shopping trip (seen in figure 6.13), clearly demonstrating how narrative can determine tagging decisions. Comments on events, such as “comfy office chairs staples” could be utilised as a real-world bookmark to an interesting product, acting as a 'wish list' for either themselves, or a Facebook friend.

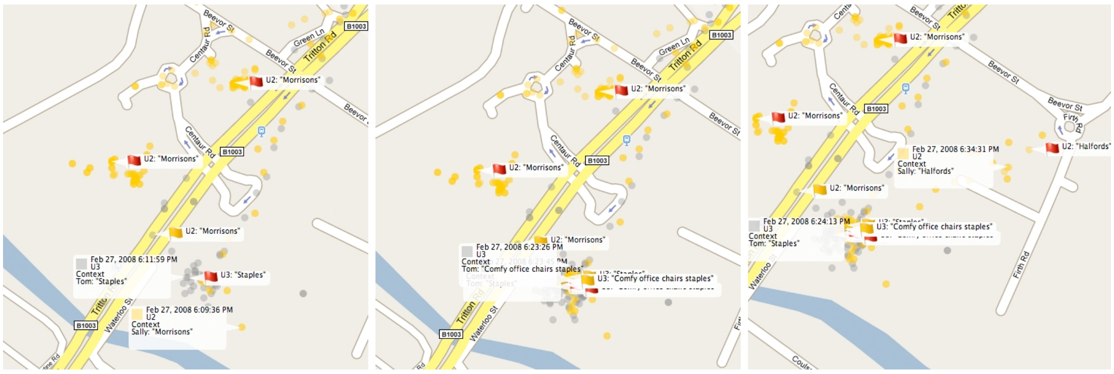

Figure 6.13. Tag behaviour frequently followed an overarching story. This shows a shared shopping narrative recorded by two users, in which shop names and related observations are highlighted. The overarching theme of the episode is 'shopping' and the tags created reflect this. Both users adopt this theme and collaborate to develop it, laying appropriate tags. During the short period, the users create tags relating to shops they visit “Morrisons”, “Staples”, “Halfords” and comment on key events within their trip for example, “comfy office chairs staples”.

Narrative coordination: The example in figure 6.13 also demonstrates the coordination of themed tags between friends. Similar behaviour has been revealed in related studies investigating the tagging of mobile photo content for online photo sharing [4]. In these studies, tagging was often found to focus around social events, where users intentionally created a common tag that would be used to explicitly identify content collectively generated by users, that related to a specific event. Research into status tagging in the Connectio study [14] showed users had a significant bias for telling stories through tag content, although the stories were told by single individuals. Contrary to these studies, ItchyFeet used a GPS based approach that allowed for a higher density of tags and also restricted tagged content to status-only data. This encouraged a faster-paced interactive experience, which could keep up with the rapid social interactions that occurred between the friends, thus naturally supporting the stories that were collaboratively generated over time. As has been identified, ItchyFeet users also displayed a preference for telling these stories in a social manner, breaking up the entries of each microblogged narrative between one other.

Benford et al suggest that “any journey through physical space takes noticeable time and is experienced continuously” [80] and that these journeys which cross space, time and roles, are at odds with the trajectories undertaken in typical desktop applications, such as browsing the web, where transitions between pages are instantaneous. In these orchestrated experiences, both the orchestrators and the participants themselves were able to steer the trajectory that was taken. Parallels can be drawn between these journeys and the naturally emerging real-life journeys experienced by ItchyFeet users. In ItchyFeet, only the participants were able to steer the experience, since content was purely user generated, but findings have already established that a strong influence from social peers on the ground (and perhaps even observers on the web interface) were seen. An interactive link between online observers and users on the ground might provide a powerful way to direct these real-world journeys and through doing so could provide a more engaging, connected experience for web users and users that are distant from their peer group. This communications channel might be used to suggest the next stage of a user's journey, allowing the user to visit somewhere they would not normally frequent, encouraging a situationist-inspired exploration of their environment, or perhaps to request that the observer and participant should meet up, allowing their trajectories, in terms of their planned schedules, to converge.

Hierarchies of themes: It is possible to further split these narratives into more precise sub-episodes, which can be arranged in a hierarchical manner. Hierarchy is a natural form of categorisation for users; people use it frequently in the everyday world while using maps and locations, internet pages and computer UIs. Reusing the example in figure 6.13, the highest level of the hierarchy is the 'shopping' theme. Further down the hierarchy, sub-themes consist of various commercial outlets, such as “staples”, “comet”. Within these sub-themes are increasingly finely grained tags that relate to user context within them; e.g. “Comfy office chairs...”. In order to interpret many of these tags, additional knowledge of the higher level themes within which they reside is required, so understanding preceding tags can be a vital part of interpreting tag data in social tagging systems. To aid this task, it would be useful to group themed tags by presenting them in a hierarchical microblog format on the application web page, in a similar manner to the hierarchical blog organisation that was adopted by the LocoBlog mobile blogging application as a way to visualise online the ongoing mobile journeys that users had made [10].

Now that the tagging behaviour of users has been clarified, the next section looks at the specific factors that influenced this behaviour.

6.5. Influential Factors

The tagging behaviour of trial users has been described above. ItchyFeet utilised locative context as a way of positioning tags but numerous other factors, often of a human nature, also influenced user behaviour when creating and interpreting tags. Previous experimental studies have suggested how background knowledge and other external factors influence users when creating and interpreting content in mobile trials more generally [195][160][166] and furthermore, have emphasised the difficulty of interpreting this content whilst in a different contextual state, or outside the social group [4]. A number of such factors were discovered in the trials of ItchyFeet and these are identified and discussed in this section.

1. Personal status: Some of the most prevalent factors to influence application use were individualistic ones. One important aspect was emotive feeling; investigated by concept devices such as the LoveBomb [101], which facilitated emotive communication between strangers. ItchyFeet trials demonstrated numerous cases where a user would leave a tag to convey a particular emotive response or feeling that had been initiated by their surroundings. These were subtly represented in tags using emoticons such as “Cubes lol”, “Home =)”, or emotive language, e.g. “St Faith squalor” - referring to an untidy environment. Another way that users gave personal responses was by reporting their personal activity or behaviour as meta-content that supplemented the main tag, for instance “Scream – lunching”, “Home sleeping”, these hybrid tags have also been seen in related mobile cell tagging applications [14]. In ItchyFeet, a user’s response to cues in their environment was seen to be a dynamically changing relationship, with their current situation (activity or social network status), affecting the validity and importance of content. Further examples of this are seen in section 6.5.4.

2. Availability: The availability of both the user and technology affected a user's ability to interact with the device. Users suggested that the physical ability to interact with the device and appropriateness of using a mobile device at a particular time and location were common influences, revealing that they left tags “...based on whether I have the time to set one up”, or “If I have time to tag”. This implies a casual mode of interaction where users access the application when they are available to give attention to the experience. This is synonymous with many other mobile usage studies, which have identified a link between cognitive load and mobile usage [161]. The effect of personal availability to interact is further emphasised by the large proportion of tags generated in travelling scenarios, such as the social journeys seen in figure 6.11. Travel has been identified as a scenario where users are more likely to use mobile devices, due to boredom or as a way of maintaining social contact while alone; this use is further discussed in section 6.4.7. Another example where user availability visibly drove tag generation was the frequency that users updated tags on application startup or on arrival at location. The user would start up the application and on observing the currently displayed tag was no longer applicable to their current situation, immediately update it, for example creating the tag “Starbucks”; one reason for this is their attention was already on the device, meaning they could confirm the displayed status. Similarly, at the point that they reached their destination or completed their journey, the time was available for them to stop and interact with their device.

Location-aware smartphone handsets are still maturing and seams [41] in these technologies will inevitably affect user experience. Of the participants, 9 reported that GPS signal ‘significantly affected’ their use of the application and five cited battery life – a current side affect of frequent GPS scans and data transfer, which meant the device would often be attached to a wall socket rather than being on person. These technological seams were found to drive tagging style in the application, with users reporting to leave tags “when GPS available”. One group [G3] who were all unfamiliar with GPS technologies, were significantly disengaged from the experience by difficulties with GPS signal availability not meeting their expectations. In a similar way, the availability of data connectivity is as a key factor in determining whether a user sends an update in a social status update service.

3. Experiential knowledge: Statistically, most users perceived the tags to be personal to their group. All users felt the tags were easy to comprehend themselves, but fewer believed that an observer from outside the group would understand them. The main reason cited for this was that an observer would need to first know the nuances and experiences of the social group to understand the tags. Users would routinely draw from knowledge and experience when creating tags. This can be separated into local, personal and group based knowledge.

There was a clear preference for users to insert personal meaning into tag content and section 6.4.2 demonstrated that the level of personalisation was synonymous with tag density. Personal knowledge was utilised in tags as a way of disseminating new information into the group. At times this allowed the user to create a richer, more informative description of their current context, for example “the quiet end of the ok diner on the a1” and “Hand carwash on carholme which is always bust”. Other times, it would be used as a method to exemplify a user’s context, such as “the pikey end of Lincoln”, or “the sticks”. Knowledge and past experiences of the group as a whole were also used to label social areas, such as “By the mud”, which explained a particularly muddy part of the university campus frequented by the group and “Bs house”, used to quickly reference a friend of the group. Experience was also used as an influence for ‘in group’ jokes and banter, seen in the tag “Oh look swans!”.

Microblogging trials have previously shown that social experience and shared knowledge between users is used as an effective way to interpret tags and co-ordinate group social interactions [14]. Commonly held local knowledge about the local area was also exploited in the ItchyFeet trial, for example “Earth quake scene” was tagged in the city centre, referring to a recent earth tremor. Much of the local knowledge could be described as cultural experience; i.e. the recording of tags which relate to common historical or cultural aspects of a user's surroundings. This was emphasised in the historic quarter of the city, where tags included “Top of the hill”, “The cathedral” and “Bishopgate”, effectively acting as a socially-generated geographic 'tour guide' around the city's points of interest [9], something that emerging commercial applications such as Locogo and Socialight [197] aim to capitalise on.

Another influence of group knowledge was in deciding where to lay a tag and this varied between areas. For example, the high street area of Lincoln consists of a mix of shops, bars and cafes and users appeared to selectively tag only the bars and shops with relevance to their group and often make use of 'hybrid' tags for increased personalisation. In contrast to this, areas such as the train station and historic cathedral areas contained very little personalisation with regard to tags. It is possible to define a hierarchy of the types of knowledge included, an example is shown in table 6.1, which defines the relationship between type of knowledge recorded and levels of personalisation. At the top, more generic, non-personalised descriptions are contained, which would be relevant to members of the local public. The lower down the hierarchy, the more personal the information becomes and as a result, fewer people will understand it.

Many can understand - generic	Local area knowledge	“Lincoln”
	Local demographic knowledge	“Drill hall”
	Social group knowledge	“Tim's house”
Few can understand - specific	Personal knowledge	“The sticks”

Table 6.1. Levels of personalisation for tag content. The knowledge a user borrows from ranges from widely known information about the local area, down to personal observations. The level of personalisation used will affect the ability of the target audience to understand.

In referencing shared knowledge, a powerful and personalised connection with the rest of the peer group is established. Methods to extend the application in order to direct tag data to specific users depending on the level of personalisation are further discussed in section 8.7.3. In addition, ways to query these networks of hierarchical knowledge as a human computing resource are identified.

4. Spatio-temporal effects: In the trials, spatio-temporal context was a common measure by which users would decide when to leave a tag. The events that occurred in the moments before a user assigned a tag have been analysed in detail, in order to help determine the type of situations that led to a user to dropping a social tag. One such situation was marking arrival at their destination. In one example, a user's status is set to the "Gill Nadin Studio". Despite the tag being an incorrect indication of their current context, the user retains it until arriving at his or her destination, where the tag "My flat" is left. Further examples can be seen when users arrive home in figure 6.8 and reach their travel destinations in figure 6.14, tagging each destination on arrival. It was also common for users to determine areas for tagging depending on the amount of time spent at a location and the frequency with which they visited it (see section 6.3.3). One spatial effect recognised by users was the element of surprise that could occur when a user's context changed and a tag was serendipitously discovered. This is a powerful feedback mechanism [176][179] and ItchyFeet's participants revealed that serendipitous content discovery in these lesser frequented areas was seen as another motive to placing tags. Indeed, it acted as a delayed form of social discourse – as one user reported:

> "I got half way between Spalding and on the train...there were just fields everywhere and I put 'the sticks' and it locked it! Just a random tag on the train track. Perfect! People will pass through that and see it suddenly changes." [G4]

Temporal aspects led to juxtaposing sets of tags for different times of the day, clearly evidenced by comparing the entertainment and social-focused night time tags to those recorded during the day. Users expressed desire to separate these time-separated groups of tags, to allow group status updates to be more relevant to their current activity:

> "What would be nice would be if you could select which lists are shown...otherwise you would end up with really random things. You'll actually be on the way to uni and they'll be random tags like traffic lights, lampposts! It's like 'how do you identify ones that are used for social times?'; where you might have more silly tags...you could just say 'bring up my social tags now', but if I'm on my way to work, I might not want to be troubled with like 'ah xxx fell over here!'

```
Oh great well I'm on my way to a meeting so let's keep
these ones minimal(!)" [G1]
```

```
"Yeah I guess so 'cos if we go out for a drink or
something, it changes...from an everyday basis to an
evening one...you tag more places during the day -
well I did." [G4]
```

Additionally, many tags were bound by a limited timespan of relevance. Some tags appear to be extraneous to the time they were created; a static building marked “Uni” is very unlikely to change in the near future, whereas others are extremely time-specific; such as status updates reporting “I'm here” which would become worthless after a few minutes. The software did not have any way to differentiate between these tags, but one solution would involve the very time specific tags being less 'sticky' than the more static examples, which would allow persistent tags to take precedence over the temporary ones.

5. Target tag audience and privacy: The analysis has already established that there were numerous tag styles adopted by ItchyFeet users, but one question which has not been asked is whether these tags were intended for any particular recipient and how this was affected by tag content and privacy implications.

The ItchyFeet client did not support definition of user groups for the receipt of tags, although a user could globally adjust which friends were able to view their ItchyFeet status on the web page via the inbuilt Facebook privacy settings; at the time of the trials these groups were defined as: *friends*, *friends of friends* (FoF) and *everyone*. Each trial was constricted to the participant group of four friends, so there was no opportunity to explore group control directly. However, user opinions on the privacy implications of content disclosure to various external social groups were revealed by questionnaires. Results showed that all users felt they were ‘in control’ of their location information when using the application and participants reported to be ‘likely’ to disclose their location to their one hop friends – as was the case in this closed trial amongst friends. Privacy was never cited as an influential factor for leaving tags during the trial in the way it was executed, but users hinted this would be a much stronger influence in a more open trial; declaring it ‘very unlikely’ they would share location information with strangers on Facebook or unknown users who are in their local networks. This reinforces the view that location data is particularly privacy sensitive asset that must be protected [13] and that augmenting social networking profiles with contextually aware data was considered a controversial subject, as exemplified by the media and public backlash over the Cityware initiative [32]. These findings also imply that special considerations would need to be taken to protect the privacy of users if the social data set was to be utilised for third party applications to build upon, such as those suggested in chapter 8.

Communicating coordination and positioning data is a key aspect of voice telecommunication etiquette and users exchange this in a format that is meaningful to their conversation [217]; importantly, customised reporting of position is also supported by ItchyFeet's semantically descriptive tags. From a privacy viewpoint, an advantage of the free text tags adopted by ItchyFeet (as opposed to Cartesian representations of location), is that users can fashion them to be as vague or precise as they require depending on their inclination to disclose context. Nevertheless, there is a sense that mobile locative applications inherently suffer from privacy implications [196] and that particular care needs to be taken to ensure privacy is protected when status updates are autonomously, rather than manually disclosed [195]. However, these privacy concerns were not reflected in the trial of ItchyFeet and users revealed their location by laying a precise network of tags which that relayed a real-time indication of the status of their social peers at key locations, including peoples homes, e.g. “Amy, Emma and Chris' house”. A reason for this openness could be due to the knowledge that this information would be disclosed only to their direct social network; the type of information they would often be willing to communicate with them anyway either via mobile phone conversation or other mobile social utility [217] and questionnaire responses suggested users would be less willing to share this information with the wider social group in a more open trial.

6. Learning process: Users were encouraged to make their own decisions about where, when and how the application should be used and this resulted in a learning curve. This was supported by user comments, with 6 of the users not understanding how to ‘get the most’ out of the application after a day of use (mainly due to not seeing the function of the application, experiencing problems with location detection and the feeling they were still learning); this decreased to 3 users by the end of the trial, showing user comprehension to improve over the course of the trial. Furthermore, when asked about how their experience of the application changed over the course of the trial, 10 users claimed that the main difference was their improved understanding. An understanding of how mobile social applications should be used is frequently a collaborative consensus determined as a group [216] and team negotiation on how new technologies should be used and how peers should act tactically in a social gaming situation has been the focus of mobile computing studies [15]. Similar findings were seen in ItchyFeet, where the user learning process was by no means solely an individualistic experience. Part of this learning process was gaining a comprehension of the positioning and device technologies themselves and half of users reported an improved understanding of GPS and mobile technologies by the end of the trial. An additional aspect to learning was reaching an agreement on how to use the application and 14 of the users agreed that their group had reached a shared consensus on how the application should be used as a group by the end of the trial, further supporting evidence for group learning. It is important to note that individuals in the groups were co-located for large amounts of the trail period and reaching a consensus of use in a distributed group of friends could result in a disparate learning experience, for example the more isolated learning seen in Gophers.

The target group was reasonably technically informed of recent mobile technologies and supplying the users with a commonplace, off the shelf mobile handset had the benefit of familiarity to users. Despite this, there was still a learning process to operating the devices themselves, as explained by one user:

> "wish I had it on my own phone...cos when you're using a different phone, it's...all built differently, you're pressing the wrong button – I tend to [accidentally] press shutdown and I come out of it." [G4]

Ideally, the preferred mode of trialling the application would be to install the user's personal device, but as described in section 5.2.1, this would have created additional challenges in hosting the trials.

7. Social distance and travel tags: Research shows that status sharing in mobile systems is influenced by who is requesting to see their status and for what purpose [49][160], but findings in ItchyFeet have demonstrated that the wider social group as a whole can also retain a powerful social influence over a user's tagging decisions. One way to assess the impact of a participant's immediate social group is to look at what happens when they are away from the group. During the trials, numerous group members travelled away from the the group, creating tags as individuals. Of the 14 users who did this, 12 reported this had affected their tagging style; with four of these citing social differences. Although tagging frequency remained high, the trend for users in these situations was to create a much more individualistic, literal set of tags, as depicted in figure 6.14, many of which were created while travelling by road or rail. Tag themes were mainly focused around geographical descriptions, such as town names ("Thorpe on the Hill", "Alton"), transportation related tags ("Nottingham Train Station", "Alton Station", "Leicester Train Station", "Peterborough

Services", "London Waterloo") and road names ("A46", "A1"). The tags present a literal reflection of user context, while conveying little else about the social and environmental influences that may have been present. These tags also overwhelmingly lacked the emotive content seen in other tags (such as those described in section 6.5.1). Essentially, tagging moved from being a form of social engagement to a simple location reporting tool, which users reiterated in questionnaire responses:

```
"experience was personal rather than group influenced"
[U4]
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"[they] could see my route of travel and recognised I
was travelling home" [U11]
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This can be seen as a method to allow an observer to more reliably interpret the user's context, when there are fewer cues available to interpret the situation, such as experiential knowledge – particularly true if the viewer is unfamiliar with the geographic area or current user activity. Additionally, it is possible that application users are simply less creative outside the influence of their application group, under circumstances when they cannot build on their friend's tags and actions for creative inspiration. Finally, by tagging in an area rarely frequented by others rendered it unlikely these tags would evolve over time.

Figure 6.14. Examples of tagging activity while distant from the trial group. Tags presented a literal depiction of a user's context, tending towards geographic and transport-related tags.

> Typical tags included: U1: London Waterloo, U3: Northampton, U3: Ikea, U3: Birchwood, U1: Guildford, U1: Alton, U1: Alton Station, U3: Pub – Blackbirds, U3: Bedford train station, U3: Toddington, U3: Peterborough services, U3: Leicester train station, U3: Nottingham train station, A46, A1, Thorpe on the Hill.

These were in stark contrast to the tags created in the atmosphere of social activity, around Lincoln city centre, where users were frequently in close proximity to peers. Many of these tags were rich in creative, personal and emotive content. It was observed that tag creation frequently occurred on the fringes of social boundaries, where group meetings occur (see section 6.4.3); these tags would often borrow from prevailing social events; and the creation of tags was also seen as a social activity in itself, depicted by the way tag evolution occurred as a form of social collaboration, discussed in section 6.4.2. Furthermore, the familiarity of a location to the social group influenced whether a tag would be left; questionnaires show 10 of the participants considered the areas to tag as a group, supporting this view. These findings are in keeping with related mobile tagging research; the PePe [123] and Connecto [14] field studies for example, demonstrated how users created more specific tags in familiar social areas and favoured geographic tags in less familiar areas. The context aware note-making system e-graffiti also showed the presence of audience to act as a catalyst to encourage content generation [35] and similarly, mobile photo geotagging has also been described as a 'socially contagious' activity [4].

However, whilst in extremely proximal situations (for example sharing the same house), users found ItchyFeet's function as a status reporting tool to be less relevant and chose mainly to discuss the application:

> "You just know where people are and don't necessarily read ItchyFeet" [U7]

> "...we discussed it more than anything else" [U4]

8. Influence of design: Designing trials around a particular purpose can constrain and direct a user's decisions and behaviours during interaction. User Interface design, for example the placement of UI elements on a form, has been shown to influence content exchanged between users in mobile identity applications [158]. Additionally, trial design and execution plays an important role, as seen in mobile gaming trials which are carefully orchestrated to direct user behaviour along a predefined narrative path [79]. ItchyFeet adhered to a less directed approach to support collection of social media, through use of free text labels and this gave the users creative freedom to use the application as they see fit. ItchyFeet has offered an exploratory experience shaped by the users' visions of how a mobile social application should be utilised as part of users' daily lives. The effect of this liberal design approach is reflected in the diversity of content tagged by users, exemplified by figure 6.6. The results presented in this chapter have therefore provided an insight into how users believe mobile social applications should be used in the present day.

6.6. Summary of ItchyFeet Findings

Locative computing studies have revealed that there is more to a user's mobile context than locative data [190] and as a result, researchers are beginning to combine locative information with other measurable data such as social position [181] and physiological data [33][135]. It is clear from the tagging styles adopted by ItchyFeet participants that this also holds true for the genre of mobile geotagging, where both measurable factors and subtle human factors, influence user actions whilst recording and interpreting tags. Of these, social factors played the biggest part in influencing users. Furthermore, an analysis of users' interactions with ItchyFeet has provided a detailed picture of the decision making processes and typical interaction styles that users will adopt when interacting with a mobile social tagging service in the wild.

A number of clearly identifiable behaviours were exhibited by users of ItchyFeet and these were uncovered during the analysis. Firstly, three main interaction styles were adopted when using the service: *individualistic*, *cooperative* and *non-cooperative*. Secondly, the social media tagged by users was seen to evolve over time, as a result of individual and social interactions around both fine-grained locations and distinguished geographic areas. Finally, *social*, *temporal* and *spatial* boundaries were identified, which also affect interaction style and it has been suggested that these should be adapted to be more accommodating of tags.

Tagged content was naturally arranged into themes and narratives, as application use began to integrate into a user's everyday activities. Narrative and event-based tagging was a common use for the application and this was frequently performed in a collaborative way. The findings advocate a change in application interaction to better explore this narrative based content. The use of the application whilst travelling was also particularly popular, as a way to connect and share with their social peers, break up the boredom of travel and to initiate the potential for surprise encounters from friends who travelled the same route, serendipitously encountering the tags.

Further to the above, numerous factors have been uncovered that influenced the creation and evolution of tags over time. Firstly, shared comprehension, collaboration and evolutionary properties, such as the tags that exist prior to a user arriving, influenced tag creation. Also important was the target audience a tag was intended for and the privacy affordances that must be considered when targeting the content to a particular user. A range of spatio-temporal properties were uncovered that influenced tags, for instance the time of day the application was used. Content was also affected by social properties, such as the peers that were present at the time of tagging. ItchyFeet demonstrated that users not only receive inspiration from current properties, but also the historical and experiential properties form events that occurred in the past; this led to the tagging of data in chains of interlinked events and references to the past in tag content. In addition to their surroundings, personal status was a powerful influence, such as a user's ability to interact with the device, their current mood, or availability of free time. Tags were not necessarily stand alone entities and they frequently acted as small parts of a narrative, existing as intrinsically linked elements of an over-arching theme. Finally, the technological implications of the devices and software were essential to the operation of the software, with problems such as GPS blackspots and battery life dictating where and when the application could be used and how accurate tag placement would be.

In response to the original research aims (I01), ItchyFeet has been proven as a platform to investigate social tags in a real social network environment by analysing the results of formal research trials, including the tags created by users and typical interactions made. Crucially (I02) the results have uncovered that location is not the only influence of tag creation and a number of other factors have been identified, with social influence found to be particularly relevant. (I03) Finally the research has shown that peer tag sharing successfully distributed tags amongst peers and labelled a range of social locations around the City of Lincoln. Furthermore, these tags were modified over time and regularly formed part of an overarching narrative that spanned across time, people and locations.

Despite the important findings of ItchyFeet, there were also shortcomings to the study. These included technical limitations of the location technology itself, which have been identified above. Another limitation was the exclusion of non-application users. It was possible to assess the sociality and interactions of application users in detail, but little – or indeed nothing - is known about the circumstances of non-application users. As a result of this, the discussion relating to social interaction behaviour, such as shared narratives and social events is based on observations of the presence of application users only; additional data relating to the presence of friends and strangers who are not using the application is not considered. Related research [163][120] has focused on exploring our everyday social interactions with strangers and studying how these individuals play a part in social tagging systems would allow for a more complete picture of the influence of social surroundings.

The ItchyFeet study has successfully demonstrated the operation of a locative social tagging service and as a result highlighted the limitations of this type of service. In particular, it is clear that mobile social applications should take more than just location into account and that other contextual factors are equally important. In order to build upon these findings and address some of the former limitations, a final study was designed to pilot an alternative method of positioning social content in real world environments, by introducing a novel social-based positioning system which targets proximal social peers, rather than the location at which interaction occurs. It was intended that this study would address some of the limitations seen in GPS-based social content and offer a more in depth focus on the social factors that influence user interaction in mobile social systems. The application designed for this study was termed MobiClouds.

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The next chapter analyses findings from the trial of the MobiClouds application, which investigated a novel people tagging system as an alternative method of positioning tags. The findings from this are contrasted with ItchyFeet. Following this, the concluding chapter discusses the main findings of the PhD as a whole.

7. MobiClouds: A Socially Positioned Mobile Service

The previous Gophers and ItchyFeet studies focused on the tagging of content in mobile social systems using locative positioning methods. These trials identified a number of limitations in using locative methods to represent and distribute social media amongst peers. MobiClouds, introduced in chapter 5, is the last of two social tagging studies, building upon the results of ItchyFeet and reusing much of the architecture. The study aimed to assess the new concept of 'people tagging' in terms of positioning social media within a user's social surroundings, incorporating non-application users and to contrast this with the type of tagging observed in the previous locative tagging studies. The MobiClouds technology further refines the collaborative tag process of ItchyFeet, but substitutes locative tags with this new tagging technique, which is based on relative Bluetooth positioning. It also introduces a social visualisation of user context based on the common web2.0 paradigm of 'tag clouds'. The analysis considers the implications of using people tagging as a way to socially tag user-generated social media.

The application was assessed in user trials over four weeks and this chapter provides an analysis of how users interacted with the MobiClouds application within their everyday environment, assessing the tagging patterns adhered to and the main factors that influenced their interaction style. It begins by introducing the concept of social positioning, a key facet of the MobiClouds application, before going on to describe the research aims and the experimental setup. Following this, a general overview of user behaviour trends is provided, exploring overall tag themes and the growth of the social network. Next, the questionnaire results are summarised. The chapter then discusses the trial outcomes, including what was tagged, how users behaved and what boundaries exist that influenced tags. In keeping with ItchyFeet, the factors which influenced this tagging behaviour are then summarised. Finally, the key application findings are summarised in relation to the original research aims. These findings further contribute towards a model for mobile social application designers, by proposing alternative methods of creating and exploring mobile social content.

7.1. The MobiClouds Concept

Previous research has investigated the inclusion of non-application users in mobile computing scenarios for a number of settings. An early example was the mixed reality experience 'Uncle Roy', which made powerful use of social surroundings [79] and similarly, Insectopia used the existence of people directly to generate in-game content [164]. The benefits of doing so is that it can offer a new depth of application experience, where a strong, engaging link to real-world events is made and also it also offers a way for non-application users to participate in an experience, without installing an application or possessing a specific mobile device, as in [201]. By employing a novel positioning technique based around social surroundings, MobiClouds has assessed how this could be applied to the genre of social tagging.

MobiClouds is a social tagging application designed to be used in conjunction with the popular online social network; Facebook. The client application runs on Nokia series 60 mobile handsets. It is based upon the underlying design of ItchyFeet, but features a number of important differences. Rather than monitoring a user's locative position, the system periodically scans a user's surroundings for nearby Bluetooth devices (these are expected to most frequently represent mobile devices held by people, who may be social networking friends, everyday friends or even strangers). These devices can be either individually or collectively tagged by users through tags of their choice; in effect, building a rich description of their social surroundings. Each device can be tagged multiple times by trial users and these tags existed indefinitely. As with ItchyFeet, tags are collaboratively generated and added to a shared tag pool - any newly created tags will be inherited by other users that are immediate 'friends' on the social network.

Co-present mobile devices and their associated tags are shown on a user's mobile handset via a tag cloud visualisation, seen in figure 7.2. This tag cloud is representative of a user's current social situation or context and an up to date copy of it is also replicated on their Facebook profile. It is possible for users to view the social contexts of their friends either by viewing their Facebook wall, or directly using the mobile client interface; a feature that was requested by ItchyFeet users.

7.1.1. Research Aims

The intention of MobiClouds was to further explore the social aspects that influenced users when sharing content in mobile social systems. As with ItchyFeet, the MobiClouds service is based upon the existing Facebook network and associated APIs. The service focuses specifically on the tagging of social content through Bluetooth proximity. The investigation considers two main aims:

M01: *Demonstrate the concept of 'people tagging' as a vehicle for positioning mobile social media and assess it's effectiveness in integrating with social surroundings and incorporating non-application users.*

M02: *Compare the use of Bluetooth people tagging with locative geo tagging of social media.*

The main aim, M01 was to create a mobile social service based around people tagging and closely monitor the interactions and tags created by users whilst using the service in their everyday social surroundings. The second aim, M02 compares the type of tags logged in the trials and typical user interactions observed with those of locative tagging systems, i.e. ItchyFeet.

7.1.2. Limitations of Previous Studies

The MobiClouds design was conceived after identifying limitations associated with the location-based tagging techniques utilised in the ItchyFeet and Gophers studies, namely:

(i) Exclusion of non-application users: Individuals who were not part of the study trial or those not running the application on their mobile were excluded from the application experience. This resulted in a distorted and narrow view of the user's surroundings, which was only influenced by a small subset of people.

(ii) Location-aware status updates: Because of the familiar, 'one-tag at a time' method employed by users and context only being dependent on where the individual user was located, tags tended to reflect the status of the individual, rather than representing the shared social experience of the group.

(iii) Service availability and accuracy: The underlying technologies significantly influenced application usage. For example, the GSM Cell-ID positioning in Gophers suffered from coarse positioning and fluctuation, while the GPS tagging in ItchyFeet was affected by blackspots, affecting application availability.

More specifically, the GPS blackspots revealed during the ItchyFeet trials, caused by phenomena such as urban canyons, meant that the application was not always available for use when the user wished to tag and similarly, line of site requirements removed the potential for accurate indoor social tagging. Because of frequent service disruptions, it was difficult for users to achieve a shared social state unless users all concurrently received a GPS lock (most of the time when users achieved this, they had to actively work towards it). This limited potential for collaborative use.

7.1.3. Social Positioning

MobiClouds aimed to address the above limitations using a novel method of tagging social content, termed 'social positioning'. This technique offers a number of technical differences, designed to change the way users tag in mobile applications:

(i) Inclusion of non-application users: Non-application users, non-Facebook users or static electronic beacons are all included in the experience. Making use of non-application users helps solve the problem of critical mass that is associated with many UGC systems; something that has been demonstrated in pervasive gaming studies that made use of them to supplement in-game content to great effect [148][153][25][164][129]. From a societal context, this is also beneficial as it offers a more inclusive experience, where individuals can play a part regardless of their mobile handset age, ability to install an application, or make potentially costly data transfers. These benefits were demonstrated during a study of a social network based around barcodes temporarily set up at a recent music festival [201]; without representing all these users, the service would exclude the vast majority of individuals who are encountered on a day to day basis.

(ii) Content is published relative to social surroundings: The relevance of recording location data to represent a social context needs to be questioned; ItchyFeet demonstrated that in social networking services, the events, opinions and social commentary recorded by users are frequently tied up in the social relationships that occur around them, rather than the locations they happen to frequent. Furthermore, recording isolated contexts of each user is an individualistic way of solving a problem which is actually highly social – a solution which takes into account the individual’s social surroundings and their dynamic relationship with their peers over time could be a more relevant route to take. By considering the passing serendipitous encounters with these people and devices, the MobiClouds application aims to provide a much richer, more accurate representation of the user’s social surroundings, something that is demonstrated in figure 7.1, which depicts a user's co-present social surroundings at a point in time.

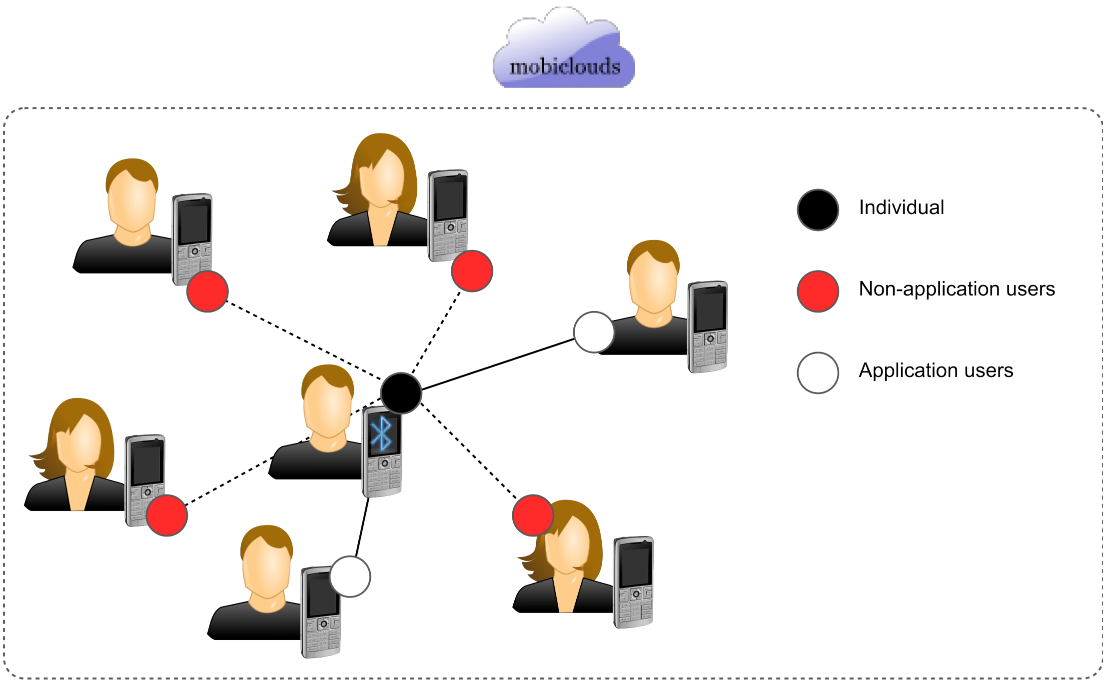

Figure 7.1. A user surrounded by their close proximity social group. Typically this will include a combination of application users and non-application users. By including all these social encounters, MobiClouds builds a richer interpretation of a user's surroundings.

(iii) Continuous Availability: Continuous application interaction was an essential part to the rapid interactions seen in the ItchyFeet study and also applies to pervasive mobile applications more generally [159], where there is an expectation for short bursts of use, wherever and whenever a user interacts. Using Bluetooth for positioning in MobiClouds aims to solve the issues associated with GPS availability. A side effect of this is that remote areas where devices are not present will be out of bounds, but since the trials focus on social tagging and a trend exists between places that are considered 'social' and the number of tags present (see section 6.2.1), the technology characteristics are expected to map well onto the application domain.

7.1.4. Social Tag Visualisation

A social visualisation has been created, influenced by the web2.0 tag cloud paradigm. The cloud is used by the application to represent a user's current status on the device screen in a live, animated form (shown in figure 7.2) and on their Facebook page as a periodically refreshed badge, which displays their last recorded status. This is based on the multilateral tag clouds that were conceptualised from the ItchyFeet findings in section 6.4.6 and it will represent an amalgamation of all nearby social activity for a specific time period. The visualisation is further discussed in chapter 5.

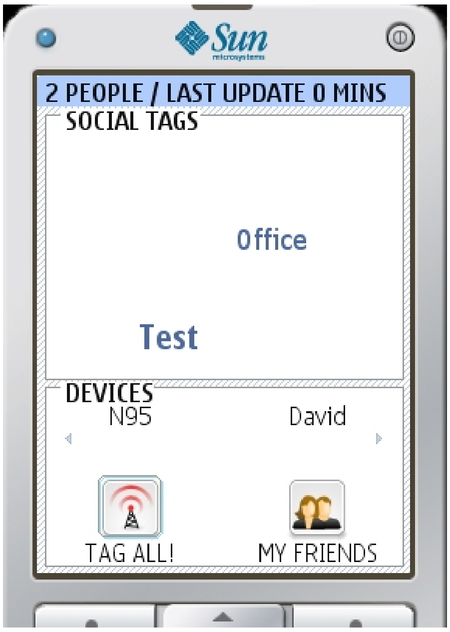

Figure 7.2. A user is shown social tags in their vicinity. These are represented by a live animated tag cloud visualisation on their mobile device.

7.1.5. Related Studies

Many examples of pervasive social networking research have advocated the use of Bluetooth logging as a way to build social networks for both personal or enterprise settings. Studies have investigated the development of algorithms designed to automatically produce friend recommendations based on Bluetooth traces [170] and created peer to peer social networks from scratch by utilising the ad-hoc discovery properties of Bluetooth to build networks and exchange content between real-world users [167]. Finally, these properties of Bluetooth have been used as the basis to create new gaming experiences by exploiting surrounding mobile devices [224][164][129][148]. These differ from MobiClouds, which advocates the use of Bluetooth as a way to tag social situations and as a consequence of this, also collects useful tags for the people themselves.

The concept of tagging people from online social networks is a relatively new one and most current research is based confined to non-mobile social networking. Examples of this include Collabio, an online social network game which successfully demonstrates that accurate tags can be generated about social network friends [27] and FringeContacts which assesses the usefulness of people tagging as a method of grouping contacts in an enterprise setting [73]. Currently there are no significant research studies that incorporate people tagging into pervasive social networks, although the Bluetooth-based Cityware initiative has suggested that the tagging of people may be a future focus [120]. MobiClouds aims to meet this need.

7.2. Experimental Setup

In keeping with the ItchyFeet trials, MobiClouds was trialled over a period of four weeks by 16 individuals, formed of four groups of volunteer university students who were current users of Facebook, depicted in figure 7.3. During the period, 139 unique tags were created. While using the application, the surroundings were scanned for Bluetooth devices 7337 times and 17,906 devices were encountered, 461 of them unique. As with previous trials, names have been made anonymous throughout the analysis.

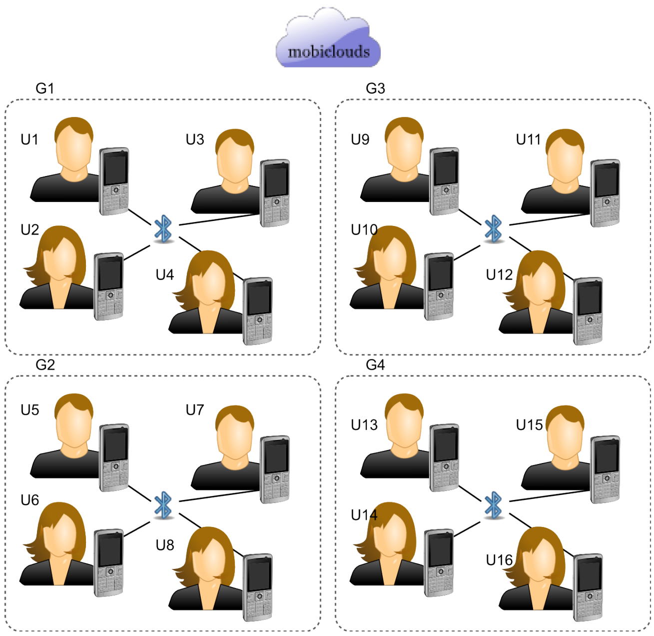

Figure 7.3. The experimental setup. 16 users were selected and each assigned a UID. Each trial group consisted of an individual network of users, connected by their social network.

The mobile devices distributed to participants were the same Nokia N95 mobile handsets used for ItchyFeet, which were loaded with sufficient mobile data credit for the duration of the trials. The openness of these devices and easily programmable Bluetooth Stack made for a useful research platform. In addition to this, users could access the MobiClouds Facebook webpage from any web browser. A full description of the experimental methods used is provided in section 5.4.

7.2.1. User Demographic

In comparison to ItchyFeet, 8 participant were members of regional and academic networks, indicating slightly less zealous set of social networking users. In addition, only five participants were seen to use social networks outside Facebook. As was the case with ItchyFeet, all respondents' mobiles were under two years old. Only a few (4) were current users of Facebook mobile prior to the trial, showing mobile social networking was still an emerging technology at the time of the trials. Since then, these technologies are rapidly becoming more pervasively used. The introduction of numerous custom social networking clients for mobile phones (eg, Android, Nokia, Apple), combined with an increased preference of the use of mobiles for internet purposes, has led to Facebook being the most frequently accessed site of mobile internet users [96]. All of the users' personal handsets were Bluetooth capable and just over half the users exploited this functionality; the most popular use for it was the transfer of files and user generated content (such as photos and ringtones) to their friends or computer, but some also used it for mobile gaming. This demonstrates some prior knowledge of Bluetooth technology by the majority of participants.

7.2.2. Methodologies

A key challenge in the trial design was visualising the results. The main analysis tool was the MobiClouds Bluetooth Visualiser. This was an extension of ItchyFeet's GPS visualiser tool, which was extended as the existing techniques did not translate well from locative to social-based content system. While established methods exist to visualise and analyse GPS interaction data against a map [153], to visually graph changing Bluetooth traces and social tags in the same way presented a technical challenge. The resulting tool allowed for fine-grained exploration and plotting of encountered tags and device interactions for each user at different points in time, through use of a dynamic tag cloud graphic, similar to those adopted for the web site (see for example, figure 7.11).

In addition to the main visualiser, a number of other visualisation methods were used to explore the data set; graphs showing the main tag themes, social tag exchanges between group members/devices and the most frequently assigned tags for each user were produced. Results from these are shown in section 7.3.

7.2.3. Scope

The literature review identified a range of studies that already focused on mapping Bluetooth devices across urban areas and the relationship of these to social networks; hence the scope of the trial does not include an analysis of Bluetooth traces themselves. Instead, the proceeding analysis focuses on the social situations that occur and how these encounters affect the style of tagging.

MobiClouds focused on the tagging of users with social status data. Concentrating on a specific subset of mobile tagging applications reduced the learning curve of the application and improved the speed at which of content built up during the defined trial period.

The findings from the study are discussed within the wider context of mobile social services, where a more diverse range of social content might be shared, such as information on the local area, services and current events.

7.3. Overview of User Behaviour

This section provides a general overview of the trial activity. To begin, figures 7.4-7.5 assess how social interaction affected tagging activity. Following this, general tagging trends seen in the trials are shown in figure 7.6, as a way to summarise typical application usage. Next, in figures 7.7-7.9, visualisations have been produced that show the changing ad-hoc social network built from Bluetooth encounters during the course of the trial. Finally, figure 7.10 provides an in-depth overview of each individual's tag cloud, providing an sense of the type of social encounters experienced by them.

7.3.1. Social Encounters and Tag Activity

The first question explored by the analysis is whether reciprocity of user generated content in the trial was influenced by social behaviour of a user. It was possible to analyse real-world social context though the logged Bluetooth encounters, unavailable in the ItchyFeet experiment. The data was analysed using the following process, following the execution of SQL calls to extract data on device encounters and tag creation from the data set. The data was put into a spreadsheet, then for each device (bluetooth address), the total number of 'unique encounters' *e* between the device and users were counted and a count of the total number of tags created for each device was performed. A graph in figure 7.4 was then generated to compare encounters *e* against mean number of tags. Following this, for each Bluetooth device, the number of separate users that had encountered it and the total number of tags that are associated with it were summated. Next, the mean number of tags for devices that have been encountered by 1, 2...*n* users were taken. The result of this process is shown in figure 7.5. Using the graphed results, any relationships between number of device and user encounters and tags created could then be visually identified.

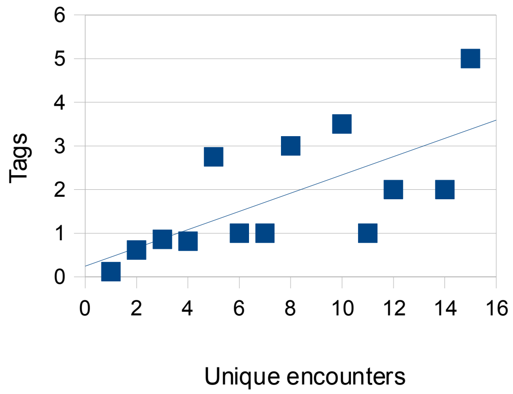

Figure 7.4. Relationship between frequency of device encounters and tags created. This shows a trend for increased tagging of encountered devices.

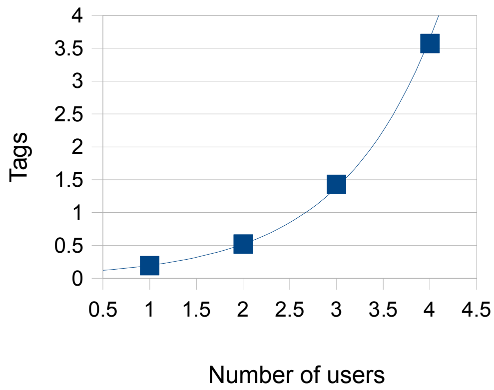

Figure 7.5. Relationship between group members encountered and tags created. This regularly indicates the more social a user is, the more tags they are likely to receive.

Figure 7.4 compares the number of unique encounters between users and devices and the average number of tags that were created. A *unique encounter* is defined as a mobile client detecting a Bluetooth device in its presence, which has not been spotted for at least ten minutes. The graph clearly shows how social activity of users influenced tagging trends; the more frequently a device was encountered, the more tags it was likely to receive. This suggests a significantly higher level of social interest for social encounters that occurred on a regular basis.

The data logs highlighted a number of Bluetooth devices that were encountered by more than one group member, indicating friends who were common across the social group. Figure 7.5 compares the number of group members who encountered a device with the number of tags created for it. It indicates that social integration to the group also affected tagging style. The trend reveals that the more a person socialised across the group, the more tags were received.

Overall the results show that in Bluetooth people-tagging applications (i) serendipitous and chance individual encounters will receive few tags whereas (ii) those that regularly socialise with all members of their social network will be assigned most tags.

7.3.2. Tag Categorisations

Thematic analysis of the social tag descriptors was performed to highlight the most popular tag themes; the result of this is displayed in figure 7.6. The process followed for creating and analysing these tag categorisations was identical to that followed for ItchyFeet, described in section 6.2.2.

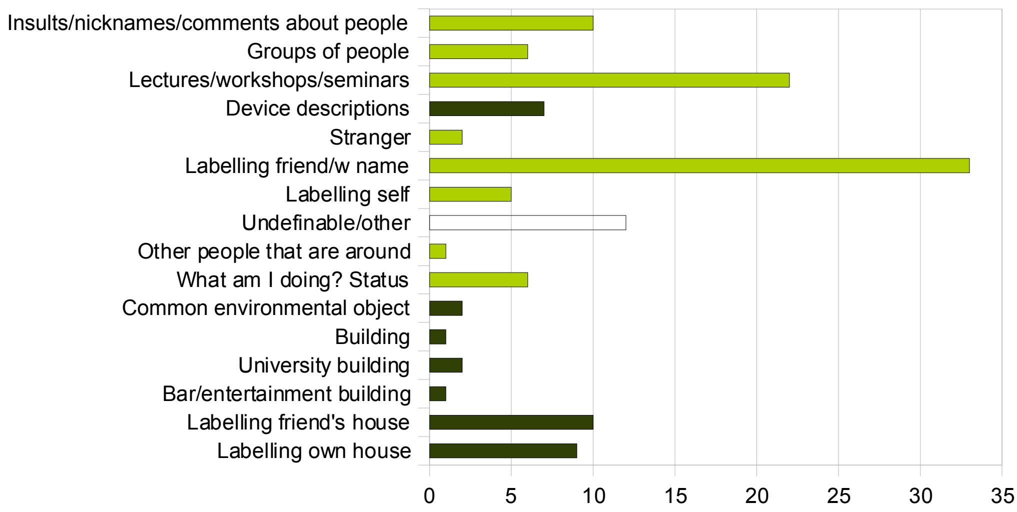

Figure 7.6. Typical tag themes resulting from unique MobiClouds tags, where light columns indicate tags related to people and darker ones, about places and devices. Tags were thematically analysed and the number of instances of each theme recorded. In contrast to ItchyFeet, popular tags focused on friends names and activities such as lectures and seminars.

Tag themes relating to people have been highlighted in light green, while those about locations and devices in dark green. It is clear from the graph that the users' tagging style varied significantly from ItchyFeet; instead of location tagging, they were now people tagging. The most common theme in MobiClouds for example was labelling a friend's name, compared with the most common in ItchyFeet, labelling a friend's house. When considering tags created around the university campus, activity was tagged by MobiClouds users in terms of the lectures, workshops and seminars that were active, rather than ItchyFeet which focused on the buildings within which they were partaking. In general, MobiClouds tags contained more content about real-world social activity (names of friends, name of self) as opposed to ItchyFeet in which tags referenced geographic places where activity occurred (friend's house, own house, street name, geographic area). These findings indicate that tag style varies significantly as a result of the underlying technology choice.

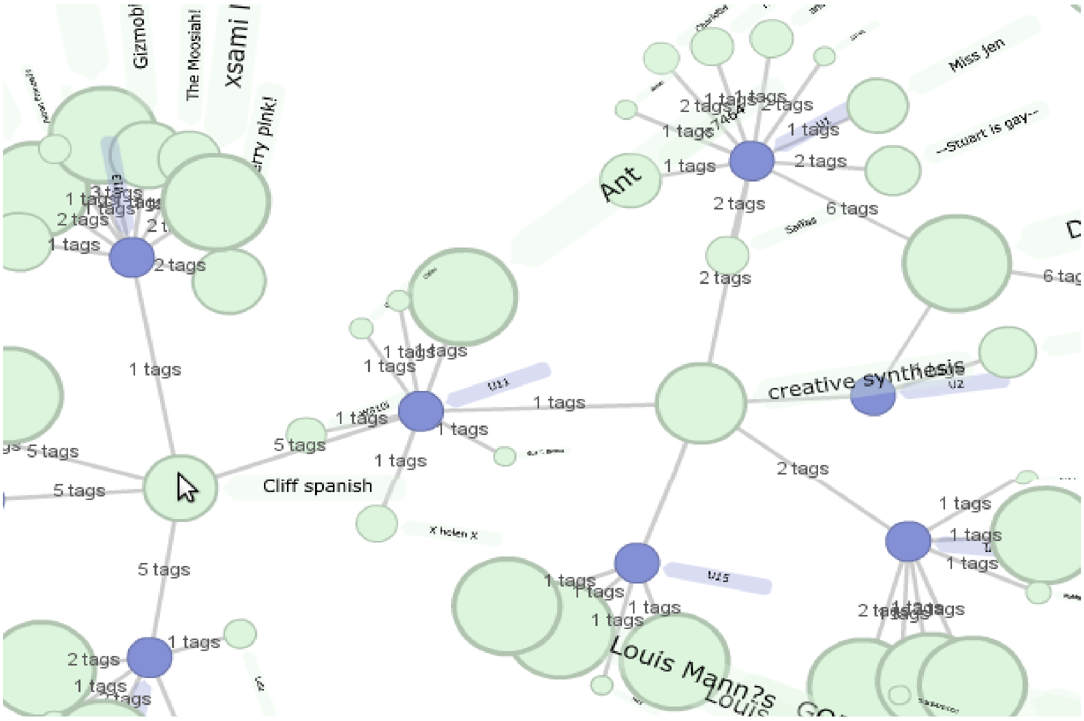

Figure 7.7. Visualises the devices encountered and tags created by two of the trial groups and demonstrates that cross-group relationships existed in the tags. The blue nodes represent the mobile devices of MobiClouds users, while green ones denote encountered devices. Links between devices indicate a social encounter occurred and the size of the node represents the length of encounter time. Links are labelled with the number of tags created and nodes are labelled by their Bluetooth 'friendly name'.

The tag results also differed from existing desktop-based people-tagging research, such as Collabio [27], where tags focused on hobbies and personalities and Fringe Contacts [73], where tags identified collaborative work groups. This indicates that context of use and intended application are further influences on tagging style.

7.3.3. Social Exchanges

The concept of the Gophers graph visualiser (discussed in section 4.7.3) was used to inform the design of a tool to visualise the changing ad-hoc networks resulting from MobiClouds Bluetooth interactions. The interactive, web-based visualisation tool, based in PhP and utilising the Flash 'Graph Gear' library [95] is shown in figures 7.7-7.9. The visualiser is fed with an XML summary of encounters from the trial data set and using this, a connected graph of social relationships can be generated for any period in time. The blue nodes in the diagrams denote participant's mobiles and the green nodes show encountered Bluetooth devices. The interconnecting links between nodes indicates a social encounter has occurred between the two devices and is labelled with the number of tags (if any) that exist between the two entities. The size of each graph node varies relative to the number of times a device has been spotted and nodes are labelled with their Bluetooth 'friendly name'.

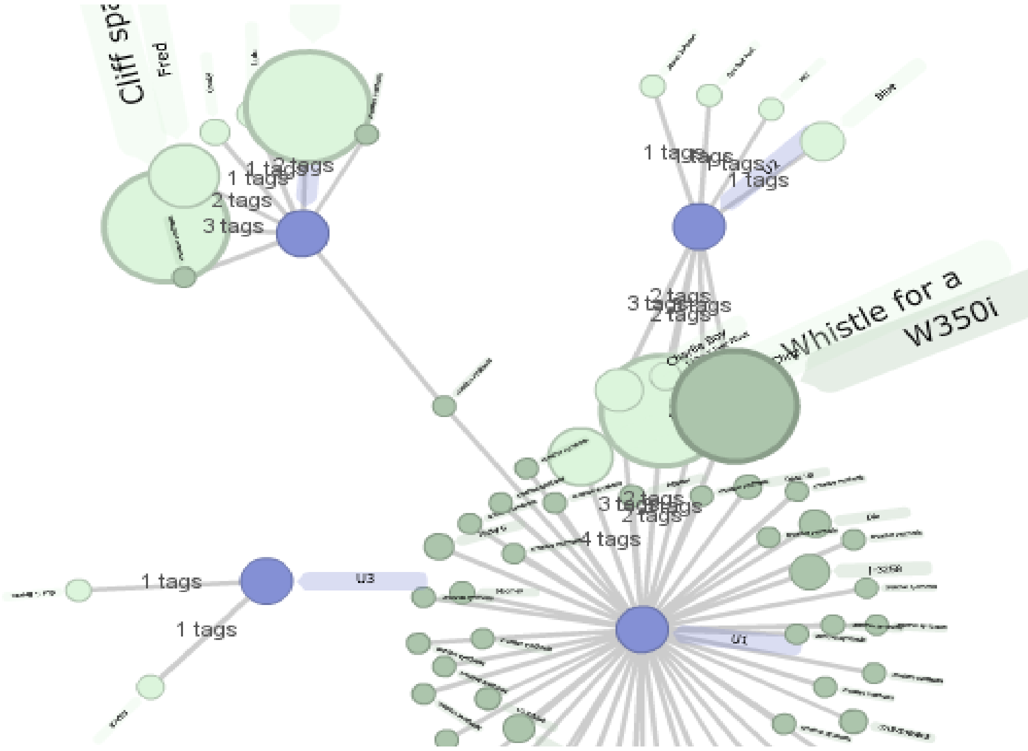

Figure 7.8. Visualisation showing tag activity and social encounters of G3 early in the trial. The additional dark green nodes indicate devices which have not been tagged. This shows a small network of Bluetooth devices.

The highly connected graph displayed in figure 7.7 shows the devices that were encountered by two MobiClouds trial groups. It demonstrates that links exist between tagged devices, not only within the trial groups themselves, but that these links also span across trial groups and trial time. This shows a crossover between groups and social encounters and indicates that automatic dissemination of socially relevant content will occur as users from different groups encounter similar social experiences in the future. It is expected that these inter-group links would evolve further in longer trials as the network graph expanded.

The nodes in figures 7.8 and 7.9 follow a similar visual pattern, but with the addition of dark green nodes. These represent devices that were encountered, but never tagged. Due to the greater computational difficulty involved in visualising this configuration, these graphs only display a subset of tagging activity from G3.

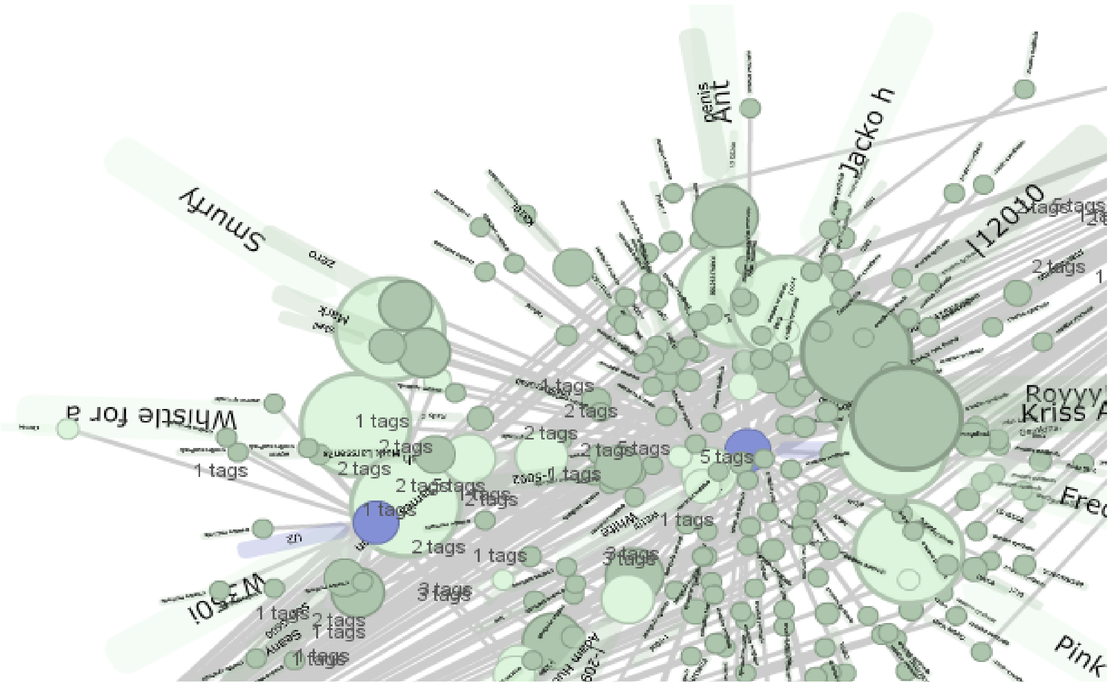

Figure 7.9. Graph depicting a selected subset of the tagged and untagged encounters experienced at end of G3's trial, after 7 days of use. Social encounters and interactions caused a complex graph to evolve. The resulting social network has evolved into something large and complex.

Figure 7.8 shows the sparse social network near the beginning of the group's trial period, which consists of a small set of connected graphs with a number of links. The speed at which social encounters and tagging activity cause the network to evolve is highlighted by figure 7.9 which presents the network at the end of the 7 day trial period. The result is a large graph of interconnected complex relationships and indicates the potential of human computation in collecting useful information about real-world social interactions. Potential applications for this data are discussed in section 8.6.

The graphs show that many of the devices portrayed were encountered by multiple participants (indicated by the multiple links protruding from a device node) and these relationships also spanned trial groups, showing the benefit of sharing social tags between participants. They also emphasise the number of regularly encountered nodes that form a significant part of the application experience, but are never tagged – in effect, the Bluetooth version of the familiar strangers we pass on a daily basis, who we are aware of but do not interact with. It is clear from these findings that a large amount of activity occurs in mobile social applications beyond those devices that are directly involved in the user generated content. This extraneous background activity would normally be considered as noise to be discarded, but an important area of future research will be to exploit this background social activity in creating mobile applications that are truly socially aware.

In MobiClouds the main way users accessed social tags was by encountering peers directly as their social surroundings changed. But the rapid evolution of connected social graphs suggests that it would be possible to send queries beyond the user's immediately proximal peers using packet forwarding-like mechanisms. Offering a two way communication channel between individual and their social network would allow queries to be posted to the group and responded to, using Crowdsourcing like practices [222][106]. This would offer an enhanced range of content to the users about their surroundings and could be particularly beneficial in the quieter locations where users commented on the lack of tags (see questionnaire results in section 7.4.4). Existing applications such as WikiHood [218] already offer the ability to access nearby human computing knowledge using GPS location as a filter; in a similar way, online social networks allow information to be accessed about social groups that are closely related to your current social network. The benefits of using a Bluetooth node network to access similar content is that the data set would be both *dynamic* and *current*, offering information on what is occurring in a user's local vicinity at an exact moment in time. It also exposes the user to a range of individuals that are part of their real-world everyday interactions who they may not otherwise communicate with. Privacy would be an essential element to the acceptability of this more distributed model of content distribution. One way of controlling the disclosure of content might be to limit the visibility by number of hops it is broadcast, in a similar style to the way gophers were summoned from nearby GSM cells, described in section 4.4.1.

7.3.4. Individual Tag Clouds

To illustrate the type of tags that were typically encountered by each user during the trial, another web visualisation was created, seen in figure 7.10. This reused the server log data in order to create tag clouds of the five most common social tags encountered by each user. In this, tag size and opacity were set relative to their commonality. The tool is based in PhP and uses the 'WordCloud' web API [132] to render the clouds. The code for this is available from the online appendix in 'Mobi Social Graph', A02.

A number of observations emerged from the tag themes. Firstly, the tags were mainly associated with friends that were encountered and concentrated heavily on day to day social relationships and social aspects of users surroundings. The establishment of common friendship groups between users was also clear, for example “Flat mates” (see section 7.5.2). Tags were also encountered when participating in certain social activities, for example “@pub” and “Software workshop”, or simply in meeting an individual (see section 7.5.2). Furthermore, it revealed that static non-human devices were regularly encountered, for example “Goffy PC”. Finally, self-tagging was also apparent, in which users created tags exclusively to apply to themselves, for example “Me!” and “My phone”. Reasons behind this unexpected tagging behaviour are further discussed in section 7.5.2. The broader tag themes are further discussed in sections 7.5.2-4.

7.4. Questionnaire Results

The 'daily diary' questionnaires employed in MobiClouds followed a similar format to ItchyFeet, reusing the Likert scales and themed text responses, but replacing location-related questions with socially-related ones. Questionnaire responses were analysed using the same techniques described in section 4.7.2, giving an insight into the application from a user's points of view. An example of the questions answered by users is provided at A05.

As with ItchyFeet, all the participants completed questionnaires in full and users were expected to complete sections on a daily basis, tracking their experiences of the application. Below, the main opinions are summarised and contrasted with the results seen in ItchyFeet; these are referenced to support the findings in latter sections of the analysis.

Figure 7.10. Tag clouds showing the 5 most popular social tags encountered by users. The size of a tag is relative to commonality. Most common tags are social groups and friends they have been socialising with and static devices users have spent time interacting with.

7.4.1. Tag Sharing

The personal viewpoints on disclosing tags to third parties were much the same as the ItchyFeet trial, with users being most likely to share this information with Facebook friends and least with non-friends and strangers. This shows that the privacy implications concerning accountability/disclosure of geotags discussed in section 6.3.2, are just as relevant as when handling Bluetooth connected tags. Again, mirroring ItchyFeet, the vast majority of participants (15) felt in control of their information, showing that automatic disclosure of social tag data to their immediate peer group was not a cause for concern. Unlike ItchyFeet, three users actually went on to invite others to use the application.

7.4.2. Tag Reasoning

The decisions made by users to determine what location to leave tags were based mainly on changing social situation (6 respondents); in contrast to changing location in ItchyFeet. Participants identified these situations using measures such as the regularity of the event “When I'm in a group that I'm likely to be in again” and the familiarity of the people “tagging people I know when they're in close proximity to me”. In tagging these events, the tags would be detected the next time the situation arose or the same friends were present. Another driving factor to leaving tags was the type of device or number of devices present (3). This was important for one user due to the lack of Bluetooth devices encountered in their proximity, reporting “I rarely picked up other devices. I made one at every given opportunity”. Finally, others used any opportunity to lay tags (3), tagging devices irrespective of whether they knew the person or not: “I tag people whenever I see them”. Unlike ItchyFeet, technological availability was not cited as an influential factor, reiterating the fact that Bluetooth does not typically suffer from the same periods of unavailability seen by the GPS units in ItchyFeet. Finally, only two users claimed to feel 'a responsibility' to create tags, showing tag creation to be a personal decision, rather than a result of trial or group pressure.

When reflecting upon what time they decided to leave tags, six users cited social surroundings as an influence and four personal feeling “When I was in the mood for playing on my phone”, or personal availability to interact with their device “Whenever I was sat around I would check for devices”. These themes were in keeping with the responses of ItchyFeet users. However, unlike ItchyFeet, the type and familiarity of devices present (6 responses) also affected a user's decision to tag, with one user reporting to tag “When I found new devices with an owner that I knew”. Users additionally expressed some distrust of tagging devices owned by people they did not know, as explained by one user "I do not understand whether or not I should be tagging randomers at a shopping mall" – an issue that has also been raised in the Gophers study in relation to the tracking of third parties (see section 4.7.6).

7.4.3. Group Proximity/Social Influence

Users were asked whether they were away from the group during the trial and if so, how this affected their experience. As was the case in ItchyFeet, many participants (11) were away from the group at some point during the trial. Of these respondents, 9 changed the way they used the application. Like ItchyFeet, changing social circumstances were the main way that interaction changed, at these times finding fewer devices to tag (5 users), or being confronted with a landscape of unfamiliar tags, making tagging difficult; one user reported they "didn't know what to tag the devices as didn't know who they were". Four users commented that less tags were encounters and one of these observed that the relationship between user and content creation changed, with more emphasis on actively tagging and creating content and less of a reciprocal relationship. This creates a ecosystem where users are rewarded less for the good tagging effort they invest. All these observations show how, in keeping with ItchyFeet, presence of social peers had a significant bearing on how the application was used.

Most users were in very close proximity with other participants at some point in the trial (13) and 10 of these reported that this affected application use. Fewer participants than ItchyFeet (2) reported using these periods to exchange application discussion. 7 users commented that this improved their application experience due to a greater presence of familiar devices and tags and the increased social tag exchange between friends that ensued. However, others received a less satisfying experience, with one user commenting that the resultant increase in tags could be overwhelming and attributed to confused status reports. Technical problems that resulted from scanning many close devices were also identified by two users; polling large numbers of Bluetooth devices and downloading their associated tags led to poor performance.

Overall, MobiClouds users indicated the application would be very likely to be used in socially active environments, such as gathering with friends or when in a group, but very unlikely to be used in socially isolated situations such as when alone, or in the library.

7.4.4. Tagging

Generally, users regarded that tags represented their personal situation well. Like ItchyFeet, tag accuracy was seen as generally good and only two users reported encountering tags that seemed 'wrong'. Additionally, for most users MobiClouds did not select the wrong tag for a user's social situation and no users saw their tag status change unexpectedly. Again, all 16 users perceived the meaning of the new MobiClouds tag clouds as easy to understand. Overall ItchyFeet was shown to produce accurate sets of tags that were meaningfully related to social locations and in keeping with this, MobiClouds results displayed an accurate environment of social tags connected to Bluetooth addresses, with little noise present. As with ItchyFeet, there was a general feeling amongst MobiClouds users there were 'too few' tags and 'too few' devices in their environment; by limiting the trial period to 7 days, perhaps insufficient time was allowed for tags to disseminate into their everyday social lives.

A unique function introduced to MobiClouds was the 'Tag All' feature, which allowed users to create a group level tag, which would annotate all Bluetooth devices in their vicinity. This proved to be a popular feature, with 11 respondents using it regularly. The main application of this was to record shared social experiences, such as lectures and social gatherings in the pub, or to identify groups of people that shared a common thread (for example, sport teams, members of a family, or categorising groups of friends - as one user did using “uni”, “home” and “church” tags). This shows a desire by users to use social relationships as a filter when distributing user generated content in a social network.

7.4.5. Real-World Usability

MobiClouds users were prompted to give feedback on the usability of the application and interface in the real-world. Generally the UI and application were seen to function as designed. Nearly all users (14) considered the meaning of the social tag indicators as easy to understand, 12 reported that the tactile buzz caused them to check the application and this only interrupted users activity in five cases. Users 'rarely' found the application distracting, with only two users changing their personal routine as a result of interacting with the application, which showed that MobiClouds pervasively fitted in to people's everyday lives; as was the case with ItchyFeet.

Most users (10) found the ability to view their friends status when mobile, using the 'my friends' tool to be a useful feature; something that was added to the MobiClouds client as a result of previous feedback. User understanding increased during the course of the trial, with 13 commenting that increased application understanding was the main difference between the start and end of the trial. This highlights a noticeable learning curve, something that was also present in ItchyFeet.

7.5. Trial Outcomes

This is the main section of the analysis, which looks at the in-depth tagging activity of users. As with ItchyFeet, this is based mainly on the server logs, collated while users interacted with the system. Using an updated version of the visualiser, described in section 5.4.4, an in-depth study focusing on the development of the social tag network, the changing group dynamics and social states of users over time has been performed.

After loading the trial log data into the MobiClouds visualiser, the data was analysed in broadly the same way as ItchyFeet, which is described in section 6.4. The main differences in the analysis process were that only atomic presence data on the surrounding users was available and that non-application users could also be measured. Using the screenshots taken from the analysis, a number of observations were made, which are included in this section.

MobiClouds has been designed as an example of a mobile social service based on Bluetooth proximity tagging, so the findings discussed henceforth are applicable to the wider area of people tagging systems in general. In keeping with the ItchyFeet trials, users were able to tag in an open and unrestricted way. The results derived form these freeform explorations are discussed and where relevant, contrasted with those of ItchyFeet users. Observations show an overall application use that was markedly different to ItchyFeet. MobiClouds was designed as an extension to ItchyFeet, which through use of Bluetooth scanning, could provide improved logging of social situations. In practice however, users saw the application primarily as a 'people tagging' system – something which went beyond a new sensor layer and resulted in very different usage patterns compared to ItchyFeet. It emerged as an experience that transcended the thinking of the user as an individual entity; where and when the application was used was no longer an individual's decision and instead it was determined by the social fabric that occurred around them.

In this section, emergent user interaction styles are summarised, notable tagging styles are identified, application seams and boundaries are identified and the issues of user uncertainty discussed. Following this, the analysis focuses on the main factors that influenced these tag styles and the content that was created. Finally, the main findings are summarised and key factors of interest to the wider area of mobile social systems are discussed.

7.5.1. User Interaction Styles

Reflecting the discussion of ItchyFeet, the interaction styles were separated into the same broad categories: individual, social/cooperative and non-cooperative.

(i) Individual: Because most application interaction revolved around the Bluetooth devices carried by real people, any tagging that occurred was inherently social. In these particular situations, individualistic forms of interaction were not technically possible, but a small amount of individualistic tagging was also recorded, such as the tagging of non-human devices and tagging of a user's own device(s), further discussed in section 7.5.2.

(ii) Social/cooperative: In contrast to ItchyFeet, MobiClouds contained little collaborative creation of tags, discussion of application use, or participation in the shared tagging journeys and activities. This implies that limited collaboration existed between users when creating tags. One aspect that made collaboration difficult was the increased serendipity of application encounters and the difficulty of pre-empting social situations when using a positioning technology which is *socially directed*, rather than the *personally directed* type seen in locative systems. In other words, an individual's situation is dictated by who happens to be proximal to them and is not necessarily something which can be controlled by their actions. Users reflected this when reporting on where they left tags:

> “When lots of people were around me or my friends were near by.” [U1]

> “When there were a lot of devices (in public places)” [U7]

The second aspect that made mobile collaboration difficult was the inability to achieve a consistent shared state on multiple phones – a result of the constantly changing Bluetooth environment as users moved in and out of a device's scan range and the sometimes unpredictable performance of the Bluetooth stack when scanning for specific devices [164]. Users identified these issues when attempting to tag each others devices (see section 7.5.3). In addition, the choice of an animated tag cloud in the device UI as an ambient representation of social surroundings led to confusion of some users, who expected relative position of tags in the cloud to be location-accurate; this suggests the use of preconceived knowledge in conceptualising the technology:

> "GPS shows incorrect tag locations." [U15]

Reduced tagging collaboration was therefore one of the key differences of using a socially-sensitive positioning method over a locative one. However it is also be possible to interpret Bluetooth tagging as a collaborative process in itself, since it includes other individuals. This was evidenced in the use of the 'Tag all' function, which was seen by participants as a way of drawing maximum number of individuals into the tagging experience, as revealed in the questionnaire results (see section 7.4.4).

(iii) Non-Cooperative: Similar to the conflicts that occurred between users when describing locations in ItchyFeet, users disagreed about the labels describing individuals in MobiClouds. This occurred when the author was unclear on who a device belonged to and it led to multiple unique names being assigned to a single device. Often this uncertainty would be denoted by an "?" preceding the name, for example one user was tagged both "Jack?" and "Freddy" by different users. This clearly reveals that conflicts of interest exist between users when tagging people, just as they did when tagging locations. No instances of the 'tag race' gaming elements apparent in ItchyFeet were seen in MobiClouds, this could be due to the usual association of racing with reaching a location [87] but not a person.

7.5.2. What Gets Tagged?

This section discusses how people tagging compared with the location tagging behaviour established in ItchyFeet, in terms of the themes that were tagged and the places this tagging occurred. To assess this, the tag themes graph in figure 7.6 and the individuals' tag clouds in figure 7.10 were consulted. A number of tagging patterns have been identified that were common across users:

Tag accuracy. Overall the tag themes in figure 7.6 show that, in keeping with ItchyFeet, very little tag noise was present. This reinforces the concept of high quality metadata being generated within the setting of 'accountable' social networks, exemplified by the way users work to control their self-presentation in a social awareness system [14].

Socially-centric nature of tags: Generally, the tags in MobiClouds were more socially oriented. Figure 7.6 shows that social tag themes varied dramatically from geographical

ItchyFeet tags, with MobiClouds users choosing to refer to their changing social surroundings. This was done predominantly through personal/name-based social tags ("Aj", "Flat mates"), in contrast to the location-based tags of ItchyFeet ("Uni", "Brayford Pool"). Again, the availability of a user to lay tags was socially driven by the individuals that were around them.

The labelling of friends: In addition to tags being socially centric in general, many of these specifically focused on the labelling of friends. Results from figure 7.10 show that people were regularly identified using personal descriptions, nicknames and insults, but further to this there were a high instance of friends that were tagged using real names, without using any additional metadata. This simple name tagging can be seen as a way of establishing a friendship link between users without commenting on the ongoing social situation – the equivalent of adding a contact in an online social network.

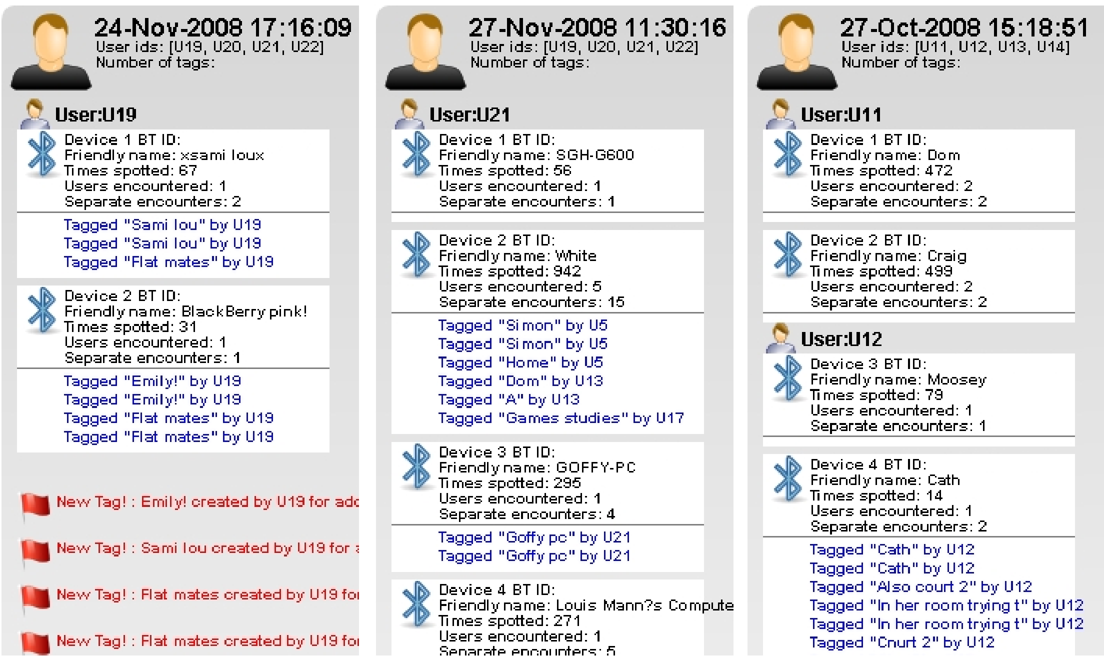

Figure 7.11. Examples of tag uses showing users depicting their flat mates with a joint tag, tagging group activities, non-human devices and personal status.

Collating friends into groups: Groups of similar users or friends were identified in MobiClouds using a common tag identifier, applied using the the 'tag all' function. This feature applied the same tag to all proximal devices. It was exploited by users in two ways. Firstly, as a method to denote a shared context amongst users: "Home", "Atrium", "Games studies", for example. By using tag all, the same contextual tag would be applied to all devices within Bluetooth range, creating a shared social state online, but also resulting in an unusually large tag on the user's Facebook page. This is potentially a way for users to 'shout' a message by putting additional emphasis on their current context or social situation, which draws parallels to the all-caps shouting seen to alter interpretation of messages in online forums [139]. The second use was to group individuals that shared a common bond, such as “friends”, “flat mates” or “random” (when surrounded by new devices/strangers). This provided a way to sub-group friends into fine grained social groups, an example is seen in figure 7.11.

Through separation of social groups using tags, the application provided an indication of the type of social activity the user was participating in, depicted by the friendship groups they were socialising with at the time. Additionally it was able to inform group members when they were proximal through the re-appearance of these shared tags during an encounter. However, as was the case with ItchyFeet locations, the relevance of shared group tags can rapidly become outdated as other contextual factors change, as divulged by one user:

> “...their tags became mine...Drew, Dave and Si lived together it meant that when I was at uni with them my phone thought we were all at their house. Which I wouldn't necessarily want all my friends thinking!” [U14]

Self tagging: The increasing acquisition of mobile devices in today's connected world has resulted in people possessing a range of Bluetooth-enabled devices and this was also reflected in the MobiClouds results, where certain users carried multiple devices. In many instances, users were observed tagging their own personal devices, using labels such as “me”, “my phone” and “my actual phone” (see figure 7.10), as a way of identifying them as 'known' personal devices. There were two drivers for using this self-tagging technique. Firstly, it allowed users to remove the ambiguity that ensued from owning multiple Bluetooth devices and distinguish between these:

> “Myself and others connected to their own phones and labeled them 'me'” [U13]

One question that arises from this finding is whether the application logic should consider single devices to represent a user presence or if instead a 'cluster' or subset of different devices should be used. The second use of this tagging style was as a method of reporting personal context when no devices are around, for example in figure 7.12. One unforeseen limitation of a Bluetooth based awareness system is that context cannot be reported when no devices are present and this technique was seen as a way to overcome the problem.

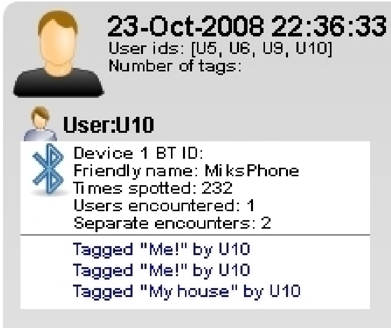

Figure 7.12. A user tags their own mobile device.

Reporting on group activities: The identification of current events such as “@pub” and “@workshop” was another way of using tags. The inclusion of the @ symbol in these instances was an emerging technique employed by one trial user to denote an activity (inspired by Twitter responses [211]). Other common group-based activities included work scenarios, such as “games workshop” or “atrium”. It was notable that the vast majority of activities identified by users were large social meetings where an abundance of Bluetooth devices would naturally be present. This was reflected by participants in questionnaires, where they claimed tagging mainly occurred in socially active situations with friends; see section 7.4.3. The reliance on availability of social peers for tagging in MobiClouds reflected the results of ItchyFeet, where availability of GPS systems routinely influenced tagging. This is a prime example of underlying technological seams affecting usage scenario. Social density was also shown to be a driving factor in some cases and one user reported in the questionnaires to leave tags:

> “When there were a lot of devices (in public places)” [U7]

Tagging non-human and static devices. Social surroundings were not the sole target of users' tags and the tagging of Bluetooth devices using hardware names, such as “W129i” was another notable phenomena. This indicates an alternative, technology-focused interpretation of the social landscape by certain users, where low-level device presence is noted, instead of the human presence that it represents.

In addition to tagging mobile devices, the presence of less mobile, impersonal hardware devices, such as printers and computers, also played a part in the experience. Users tagged these static devices with names such as “Goffy PC” (representing a home computer) and “TomTom” (an in-car GPS unit). This was an unexpected feature of the evolving Bluetooth network and hence, the application was not designed to make any special treatment of such devices. However, these type of devices could be of interest, as they tend to remain relatively static, unlike social devices such as mobiles, which are in constant flux. It may be possible to exploit this to enhance the MobiClouds experience, for example by tagging these static beacons to physical real-world coordinates or geo-semantic meanings, they could be used to provide absolute locations of users, allowing for a real-world bearing of where social interaction takes place. Another use would be to exploit the fact that different static beacons are picked up in different contexts and use this as an additional contextual cue, for instance the presence of a TomTom might represent a 'travel' context for a user. The appearance of this additional layer of non-mobile devices did lead to some misunderstanding of what devices should and should not be visible to the user; for instance one user believed that a wireless router operating over 802.11 should be visible to the application:

> “Couldn't pick up my router (though I'm not sure if its meant to)” [U13]

A hierarchy of tag personalisation. It is possible to categorise tags into a hierarchy of different levels of social positioning, similar to the geographic hierarchy that was defined in ItchyFeet (see table 7.1).

Individual	Personal nick names/comment	“Me”, “Stranger”
	Individual group members	“Sean”
	Activity, subset of group	“Games studies”
Wider social group	General friendship groups	“Flatmates”

Table 7.1. Levels of personalisation for tag content. The references vary from how they are represented as an individual, down to the wider social groups they are part of. The level of personalisation used will affect the ability of the target audience to understand.

At the top of the hierarchy are the very individualistic tags that were used specifically to identify the user as an individual entity. Going down the hierarchy, tags become wider and more indicative of how the user related to the wider social group, for example indicating the higher level social groups they were part of. The level of personalisation used will affect the ability of the target audience to comprehend the tags.

Relationship Between Social Activity and tag reciprocity. The number of users encountered was related to the quantity of tags associated with a device – figure 7.5 shows that those who were 'part' of the social group were overwhelmingly more likely to be tagged.

7.5.3. Exposing Application Seams

The concept of 'seams' in HCI research refers to the point at which a user experience breaks down, to reveal aspects of the technological infrastructure that is running beneath the service. Analysis of the trials revealed that application seams from both a software design and underlying hardware standpoint were frequently encountered and exploited as part of the tagging process. Seams were apparent in a number of areas:

Exposing application bugs. One instance where seams were exposed was when the Bluetooth stack performed in an unexpected manner, for example when it reported devices that were not present. Tagging of erroneous devices was utilised as a way to self-report these problematic situations. This was seen in the descriptor "Glitch", tagged by a user when a spurious device re-appeared many times, to notify other users or the developer of problems. This shows the potential for users to go beyond solely producing application content and begin to act in a participatory way, by helping in the design and maintenance of the underlying software services themselves.

Exposing tag visualisation UI. As described in section 7.5.2, more frequent tags left larger tags in the Facebook status window. Users learnt that through using the 'tag all' feature, they could exploit this seam as a way to emphasise their context.

Exposing underlying hardware. The seams of the underlying Bluetooth device network were exposed by users through tagging devices using real world hardware names and Bluetooth 'friendly names' as descriptions (as tag themes show in figure 7.6). In addition, users exposed underlying hardware and sometimes its purpose, by imposing real device names when tagging non-mobile and non-personal devices, such as PCs, satellite navigation devices and printers (see section 7.5.2).

7.5.4. Handling Uncertainty

There was an increased uncertainty when working with a landscape of Bluetooth devices, which was not present in the GPS positioning of ItchyFeet. This was the result of the unique properties of social positioning and it occurred in a number of ways:

Unpredictable social surroundings. Firstly, it was more difficult for users to predict what changes would occur in a social situation than changes in physical location; users could not pre-empt situations by deciding what would be tagged, or tagging in advance of a situation arising, since this was typically dictated by their dynamically changing social surroundings. The start and end points of a social event were also unpredictable; often there was a short window within which to log a tag, when the social surroundings were stable.

Technical problems. A technical limitation of Bluetooth scanning on mobile devices was revealed in questionnaires, showing that if very large numbers of devices are present, not all of them will appear. This means that a specific social device of interest may not be detected by a user.

Unknown devices and social surroundings. People and device names surrounding a user are likely to be regularly unknown, whereas the locations around them are not. This was seen to mostly be the case when users were away from their application group, as revealed by questionnaires in section 7.4.3. In scanning for surrounding mobile devices, the software informed the user of all changes to their social surroundings. The graphs in figures 7.7-7.9 reveal that a subset of these devices may be of interest, but generally the majority will be unknown to the user. As a result, unless the user has exchanged data with a device before, the device's friendly name is particularly descriptive, or it is the only device around (rare in a highly social situation), then it is difficult for the user to differentiate a friend's device from the others. Because the emergent use of the application was as a people-tagging system, the ability to accurately identify friends was seen as a necessity to some, as reflected by user comments:

> "In my apartment where I know which Bluetooth name is which person." [U8]

> "didn't know what to tag the devices as didn't know who they were." [U5]

Establishing shared rules. Tags were frequently labelled in a way that indicated possible elements of inaccuracy, such as "Jack?", "Someone?" or "Sofa?". One reason for this is that users were not always certain how the device visualisation mapped onto their real-world social surroundings. Misunderstanding and uncertainty of any defined 'rules' about how the application should be used and should behave, also created uncertainty; some users were tagged with multiple names for instance those shown in figure 7.11. User questionnaire comments reflected this misunderstanding:

> "It took me several days to fully understand whether I was tagging situations, people, or the phones themselves." [U8]

Numerous users divulged an initial misunderstanding of how the application should be used. As in the previous Gophers and ItchyFeet studies, a distinct learning curve was encountered. One example of this was a difficulty in abstracting away from the convention of GPS representing mobile context; the concept of connecting tags to anything but geographic location was a foreign one. Users reflected this in questionnaire responses, where they reported that the tags on the cloud were 'not in correct position' relative to the spatial locations of those persons (see section 7.5.1).

7.5.5. Tag Boundaries

Boundaries played a significant influence over interaction in ItchyFeet, with the spatial and temporal extremities of interaction acting as a common trigger for the creation of new tags. In MobiClouds, boundaries were formed around social and temporal extremes; it was not possible to know the relative spatial context of users, since the Bluetooth discovery stack only provided an atomic indication indication of presence, lacking proximity measures. Below, the influence of MobiClouds temporal and social boundaries are summarised.

7.5.6. Social Boundaries

Social boundaries affected MobiClouds tagging in a number of ways:

Across social groups. Participants were instructed to interact with one another in their trial groups and trials were separated by time. Accordingly, the edge of each social trial group was expected to be a clear boundary separating interaction. However, this was not shown to be the case, with tagging of devices in numerous cases spanning across trial groups, demonstrated in the 'social exchanges' network graphs (see figure 7.7). These inter-group links show that a setup such as MobiClouds could be utilised as a novel method of distributing social media amongst similar peers, which is further discussed in section 8.7.4.

Tagging of Strangers. Strangers and familiar individuals are those on the edge of the user's social scope and the relevance of these on our daily activities are explored in numerous studies [163][64]. These social groups also featured in the MobiClouds data set. Strangers in MobiClouds are defined as those who were only seen in passing, i.e. detected for less than two Bluetooth scans before disappearing; analysis of the tagging trends of users in section 7.3.2 shows that the serendipitous tagging of these individuals was uncommon, but did occasionally elicit a response. Log data shows that in general, strangers were assigned impersonal tags which disguised their identity, such as “Random”, “Cheesy boy”, “Someone?” or “The guy upstairs”. Some participants exhibited uncertainty on whether there was a purpose or even ethical right to tag these people at all, instead preferring to tag where known social devices were present:

> "Tagging randomers while outside would seem redundant" [U8]

7.5.7. Temporal Boundaries

Temporal boundaries were a further influence on tagging:

Limited window of interaction. Users typically have a limited window within which they are able to interact with mobile devices, depending on their personal ability to devote time to the activity [159]. In MobiClouds, this window needed to coincide with the presence of socially interesting Bluetooth devices in order for a tag to be created. This is something which is often beyond a user's control, is not always predictable and may be a brief and infrequent occurrence. These properties can make tagging a situation less likely than GPS, where even if a tagging opportunity is missed, a user may have the opportunity to tag again next time they pass a location, or intentionally return to a location to lay a tag. Conversely, in social positioning, if personal circumstances made it difficult to create a comment in situ, the opportunity is usually missed. This is suggested as one reason for the reduced number of tags seen in MobiClouds (see figure 7.6 compared with ItchyFeet figure 6.6).

One feature that could make social tagging easier would be to allow rapid tagging of current situations without text, for comment later. Users often prefer a 'take now, comment after' analogy in mobile UGC systems, demonstrated in related mobile computing studies, in which users showed a preference for rapid photo snapshots over text comments in tagging situations where interaction time is limited [11] and further emphasised by the commonality of photo responses in responding to Gophers tasks [38]. Another option for capturing situations after they happened would be to add ability to 'post tag' a user's context online. After logging on, a list of recently encountered social situations, which are algorithmically selected to be 'significant' [147] would be presented to the user as a series of blog placeholders – similar to the photos which often spring up after social events. Using the same technique, these social traces could then be tagged after the event, where the user is able to commit more attention to writing a good description. Support for this behaviour in MobiClouds could promote improved quantity and depth of tag content.

Change over time. Mirroring the results of ItchyFeet, MobiClouds social tags were not static entities and users expressed the desire to modify them when circumstances changed, such as changing personal context, the situation a tag referred to longer holding true, or members of a tagged group alternating. One user for example, referred to the tagging of their own [personal] phone with the label “at home”, which resulted in their [trial] phone picking up this tag and later misrepresenting their status, since both phones were carried while away from home:

> “I tagged my own phone (my actual phone) as 'at home'. I soon realised that I was 'at home' 90% of the time” [U8]

Another highlighted the fact they don't necessarily want the tags inherited from flatmates representing their status at work:

> “...x, x and x lived together it meant that when I was at uni with them my phone thought we were all at their house. Which I wouldn't necessarily want all my friends thinking!” [U14]

This demonstrates a need for a simple way to change tag data, but also highlights the fact that tag content should be adaptive to new situations and a single sensor technology such as Bluetooth or GPS is not always sufficient for accurate representation of context.

7.6. Influential Factors

Social proximity was the principal measure by which tags were recorded in MobiClouds. However, numerous other experimental and personal factors were seen to influence the content tagged. This section summarises them and where applicable, they are contrasted with the findings of the locative tagging application, ItchyFeet.

1. Personal Status/feeling: Users were observed giving emotive responses in MobiClouds. Unlike ItchyFeet, where these were used to indicate personal feeling in response to their surroundings via emoticons and status updates, the comments in MobiClouds were generally aimed at other individuals. These were reported in the form of opinion on character and insults, for example “Some fool”, “Ginger”. In addition, the personal behavioural tags commonly used to indicate the user's own context in ItchyFeet, were also reversed. Instead users commented on other users behaviour, “Making a sandwich” for example. These findings infer that the service was used by most participants primarily as a means to comment on other social peers and *not* the self.

2. Availability: In keeping with ItchyFeet, users reported that a common influence for leaving a tag was their personal availability to interact with the application, for example “When I had spare time”, or “When I remembered about the application”. However, the introduction of social positioning technology meant that availability of friends (and availability of *their devices*) was also relevant; as one user explained, they would tag when they “...met up with friends who have Bluetooth (many of my friends don't)”. Travel was not an influence for tagging (whilst it was with ItchyFeet) and there was no evidence that tags had been left while on transport. One reason for this is that social surroundings do not change much when using transport such as travelling by train or car, whereas spatial surroundings are constantly changing. In ItchyFeet the application was seen as a way of combatting boredom and continuing to socialise while away from the social group, whereas the lack of social presence meant MobiClouds technology did not adapt well to such situations.

Technology availability remained a consideration with the Bluetooth sensors favoured by MobiClouds. Although the application did not suffer from complete loss of availability (as was the case with GPS blackspots), Bluetooth performance still varied in unusual situations. One example was the technology giving spurious results or being slow at polling devices in highly populated areas (see 'Glitch' example, section 7.5.3). Another case was the reliance on friends devices being powered on with Bluetooth enabled and in range, as one user commented, “...often there are no Bluetooth devices tuned on to tag”. When compared with GPS technologies, six users reported that Bluetooth performance significantly affected their experience of the application – an improvement over GPS and similarly, five indicated battery life was a significant encumbrance.

3. Learning Experience: Again, an open approach to participant training was adopted, where users were left to decide where and when the application should be used. Only 8 users understood how to 'get the most' out of the application after a day of use although 13 of the users claimed that experience resulted in their understanding of the application improving through the course of the trial, suggesting a significant learning curve was associated with the novel tagging methods employed. It is proposed the increased initial confusion over application use was due to the unfamiliar nature of using Bluetooth as a representation of social context – unlike GPS technologies which are frequently used in this manner. Questionnaires revealed all but one participant solely used Bluetooth for it's primary purpose of file sharing, supporting these preconceptions about the technology. Uncertainty in using the application also emerged from a number of other sources, identified in section 6.5.4:

> "Was unsure about what tags were for at the start but have a clearer idea now." [U5]

Users learnt to use the application over time but unlike ItchyFeet, MobiClouds users did not adopt an understanding of the application in a social way. Only six respondents discussed how the application should be used as a group and six reached a shared consensus on where and when the application should be used by the end of the trials – significantly less than ItchyFeet, in spite of the inherently social nature of the application. This was consistent with the reduced collaboration when laying tags generally, discussed in section 7.5.1. This more individualistic learning process could have contributed to a disagreement on how application was used in practice; this is reflected in figure 7.10, which shows one user tagging device names and others tagging friends and activities.

4. Knowledge and experiential: Users felt the tags created were less personal to the group than those seen in ItchyFeet and most believed they would make sense to an outside observer. This is because less event-based, thematic and experiential knowledge was used in the formation of tags, such as references to past events and activities. As such, tags in MobiClouds remained as self-contained entities with few references to social events or activities that had occurred in the past.

What did require group knowledge and experience was the exploration and learning of the tag landscape surrounding the users – something that was not true in a locative experience. The mapping between device names and their human counterparts often required prerequisite knowledge. The knowledge of what device IDs or Bluetooth friendly names mapped to particular friends and groups was vital to the creation of tags (see section 7.5.4). As a result, tagging became more difficult in unfamiliar social environments, evidenced by the discussion in section 7.5.4. In many cases the user could not be altogether confident of the accuracy of their knowledge and in these cases a '?' symbol was added to the tag as a suffix. Another area where personal knowledge was imperative was when labelling social peers using real names or nicknames. This would further assist with the grouping of friends using in-group knowledge to categorise friend types, often using the 'tag all' feature to do this, as described in section 7.5.2.

A hierarchy of knowledge has become apparent from the MobiClouds tags. Like the knowledge users revealed in ItchyFeet, which could be categorised by the geographic area the tag bordered, MobiClouds tag content can be categorised by the number of peers the information refers to. This ranges from general peer group knowledge down to personal nick names, or comments aimed at individuals and an example is depicted in table 7.1.

Because the specificity and confidentiality of tag content varied, in some instances it was undesirable to distribute these tags to all users and in others, a world readable message was required. This demonstrates that sufficient controls need to be in place to adjust the impact of published social media, in terms of how far through the social group these messages can filter. The implementation of such a feature is discussed in section 8.7.4.

5. Socio-Temporal effects: Social and temporal contexts were a common influence for users leaving tags. Because the real-time user tracking data offered by GPS tagging in ItchyFeet was not available, it was not possible to measure the precise user actions in the moments leading up to a tag being created. However the more general effects of these properties are discussed in sections 7.5.5-7, which summarises the unique effects social groups, strangers and temporal properties inflicted on social tag content; for example, the existence of a limited window of interaction, resulting from the prerequisite for an active social situation before a tag could be created.

6. Target audience and privacy: Overall, privacy concerns were not a critical issue for users in the closed trials of ItchyFeet and users openly disclosed their location. Almost all MobiClouds users felt 'in control' of their own information and as with ItchyFeet, it was possible to intentionally obfuscate the tag content to adjust the level of information disclosure. Results suggest that users respected the privacy of others, with no potentially sensitive information (such as phone numbers, addresses, email) being tagged; far less revealing than much of the information revealed by popular social networking applications as a matter of course[5]. However, the reach of user content in ItchyFeet was constrained to members of the trial group, but in MobiClouds, tagged content had the potential to be distributed beyond the bounds of the social group and as such, third party non-application users could become the target of tags without their knowledge. The ethics surrounding involvement of non-application users in pervasive games has been the focus of past research [144] and similar ethical issues were raised by MobiClouds users; for example in section 7.4.2 users questioned whether they should target strangers in the people-tagging process, suggesting that they were less confident controlling information about others in their surroundings.

These privacy fears for non-application users were raised by media coverage and some trial participants of the Cityware people tagging study who expressed concerns over users being tracked [120]. In this, the connection of two separate technologies which users are normally willing to give access to – Facebook profiles and Bluetooth addresses – caused concern. Similarly, fears were reported by people and vehicles 'spotted' at a fixed period of time in Google street view, leading to the blurring out of potentially incriminating personal content such as faces and vehicle licence plates [91]. MobiClouds could potentially further these privacy fears by connecting tags to non-application users, if the disclosure of information is not easily controllable by non-application users. This is an important issue, as the non-application users in MobiClouds have not 'opted in' to the trial process.

One way to solve the issue of security and access control is to store tags in a distributed fashion, with tags only ever stored locally on the target user's mobile device. This would allow the user to fully control the distribution of their tags [223] in a similar style to the content storage on the open source social network project Diaspora [58]. The disadvantage of this method is that it limits those that can be tagged to application users. There are two important arguments in favour of allowing tagging of strangers. Firstly, is capturing a user's mobile device any different to capturing them with another medium, for example in the background of a personal photo? Secondly, non-application users *do* actually have control over whether their information was released or not – they can easily 'opt out' of the experience by turning Bluetooth visibility off. This could be achieved in a more formalised manner through the use of an 'unlisted' or 'ex-directory' list of Bluetooth addresses that the

5 Facebook privacy policy changed numerous times between the course of the two trials, giving use control over what is shared and to whom [66]. Significant effort is going into creating more transparent privacy-aware social networking infrastructures, in particular the Diaspora project [58].

application will never pick up. The detailed study of such privacy measures is beyond the scope of the investigation, but the issues are further discussed in section 8.5.2.4. Research suggests that this will be a key aspect to future mobile social services.

7. Social distance: ItchyFeet demonstrated that the wider trial group retained a strong influence on the tagging an individual elicited. This bond was significantly stronger in MobiClouds, where the utilisation of proximity-generated social tag clouds meant the presence of the wider trial group formed an inherent part of the tagging process. To assess the real impact that other group members had on a user's tags, it was necessary to look at whether users interacted differently while away from them. Of the 11 that were distant from group members at some point, 9 participants believed this affected their tagging style; with 8 of them directly citing social differences. A number of differences occurred when users were engaged in this mode.

Firstly, the balance of social tags changed to a more producer/less consumer oriented basis; normally users received people-tags created by other users and five users specifically identified that these were reduced and responses indicate application use was less satisfying as a result. Reciprocity is seen as an essential element to the ecosystem of online content creation services; studies of consumption in the Digg network for example, have suggested that the existence of a small amount of popular, high quality content production and large amount of consumption is desirable for social networks [133]. The lack of reciprocity in MobiClouds led to users consciously adapting their use of the application in these situations to something that was primarily focused on creation of content, as reflected by one user: "The only use for the application was to tag other people". This mirrored results from ItchyFeet.

Secondly, fewer tags were created compared with ItchyFeet. This was partly caused by the unknown device landscape and the lack of known devices available to tag in these places, as reported by five users and additionally the reluctance of some to tag strangers (see section 7.5.6). There was also the prerequisite of active Bluetooth devices being present before any tags could be created – making tagging more challenging in the sparser Bluetooth environments typically seen in rural areas outside the city. Similar properties were seen in the cell ID positioning utilised by Gophers (see chapter 4) and Hitchers [61].

Finally, the mode of tag content did not significantly vary between states. The friendship groups that were being tagged changed, but the style of tag content did not – typically 'people tags' were still being created. In contrast to the results of ItchyFeet, no transportation-related tags were noted when users were away, as discussed in section 7.6.2.

When this usage is compared with very proximal tagging situations, the balance of social tag consumption/production differs again, with the main difference being a big increase in tag reciprocity. This is true in two senses – firstly in the sense that more tags created by other users were inherited, as one user reported: “We were able to see all the tags that the others had made” and secondly, the reciprocity that ensues from a user themselves being tagged; something that can only happen amongst other application users. Another difference in closely proximal situations was an increase in unexpected technical issues and application behaviour – further discussed in section 7.4.3.

Overall, ItchyFeet showed a tendency for more generic, geographic tags when away from the group and more personal/emotive ones when very close to their social peers. In contrast, MobiClouds showed similar tag content in both situations, but tag reciprocity changed from a producer/consumer relationship when near the group, to mainly producer when away from group members.

8. Influence of design: As with ItchyFeet, MobiClouds was designed to be as open as possible, with users left to use the application as they wished. The design largely remained the same, but elements that did change were the choice of Bluetooth sensor technology and user interface – and these have effectively directed users towards 'people tagging' over 'situation tagging'.

7.7. Summary of Findings

A four week user trial of the system showed tagging in MobiClouds to be mainly socially and device-driven; for example it was limited to those areas where Bluetooth devices and social peers exist. Tagging trends show that a higher level of interest was generated for regularly encountered, socially active devices. The system was mainly used as a people tagging system, with tag content focusing on the labelling of friends, friendship groups and social activities, in contrast to the previous location-aware study, ItchyFeet where tags focused on locative situations. Over time, compelling graphs of social connections were built from the Bluetooth encounters that occurred in the real world; a focus for future research is whether this knowledge could be harnessed for its human computing potential, to provide dynamic and current information on social surroundings. The main way users consumed social media in the application application was by encountering people tags that others had created, as opposed to checking Facebook or mobile status of a friend's cloud.

A number of common user behaviours were revealed in the analysis. Compared with ItchyFeet, tagging was rarely performed as an individual, but was inherently cooperative, as the ability to tag relied on nearby social peers (the exception to this being when users 'self tagged' or tagged static devices). This inevitably influenced application availability, which was governed by existence of Bluetooth devices at the time of tagging. Unlike ItchyFeet, the unique seams of the technology, such as the underlying Bluetooth devices, were more exposed and as a result, users worked around these. Users required prerequisite knowledge about their Bluetooth network in order to tag devices and because the Bluetooth network was not something users experienced on a regular basis, this led to uncertainty in terms of identifying which devices related to which users; exploring and learning these surroundings became a key part of the learning process. Using the application while travelling and the narratives that existed between sets of tags, while popular in ItchyFeet, were not seen in MobiClouds; instead tags were short, self-contained descriptors, that were simple to understand independently. In keeping with ItchyFeet, social and temporal boundaries existed which constrained tagging; for instance, the potential window of interaction around a social encounter was restricted and concerns were raised about social etiquette, such as the tagging of strangers. Potential changes have been identified that would make more optimal use of these.

The inclusion of non-application users in the tagging process allowed for an engaging application experience, even when no users are present. This was especially important in an experimental system which will only have a limited distribution, or when using the system in sparsely populated environments. In addition it allowed application users to break from the enclosed and often segregated world of social networking and consider the real-world social environment that is happening around them every day.

In response to the original research aims, (M01) the study demonstrated how people tagging can be used as part of a social awareness service, which successfully integrated into a user's wider social surroundings, encompassing non-application users as part of the tag process. (M02) In addition, the tagging style used was notably different from locative tags in previous studies, with a tendency for users to tag people and social groups, rather than geographic locations. Significantly, these tags tended to be issued as self-contained updates and did not form part of an overarching narrative.

The research addressed some of the limitations identified in ItchyFeet, by offering improved sensor availability and a way to include non-application users in the experience. Various other shortcomings were identified with the technology; in particular it must be used in social surroundings, application use is limited to a short window of interaction and finally it relies on prerequisite knowledge about the mapping between a user's social peers and the Bluetooth devices they own. These are further discussed in the concluding chapter 8. It is hoped that these limitations will be a focus for future research.

MobiClouds demonstrated the use of a new method of positioning social content, based around using Bluetooth proximity and people tagging as a way to address some of the limitations of location based social tagging services. It further identified the social aspects that affect users when interacting in mobile, social tagging applications. In addition, it demonstrated how non-application users can be included as part of a real-world social tagging experience. It also clearly highlighted the unique properties afforded by social positioning techniques over locative ones and how the choice of sensor technology and reliance on others can significantly affect the target use of a social tagging application.

8. Conclusions

The research described within this dissertation contributes to the understanding of the way users exchange social media in MoSoSos and the external influences that govern this discourse. This chapter begins by summarising the main findings of the three studies, which were based around three general themes; using these findings, the original research question and individual aims are revisited. Following this, the chapter provides some reusable guidelines for designers of these applications and identifies limitations of the research trials and technologies that were developed. Finally, potential applications for the technologies are discussed and recommendations for future research in this area are outlined.

8.1. Discussion of Research Outcomes

The research described in this dissertation set out to investigate the user exchange of social media in mobile social services and the factors that influence this. In this section, the research outcomes from each of the three studies are discussed in relation to this.

8.1.1. Gophers

Gophers was a wide, exploratory investigation into mobile social services. It comprised of a mobile social game installed on mobile smartphones and incorporated a number of elements such as digital agents, collection, task-based play, geospatial social media, thematic narratives and real-world interactions, to form an enticing play experience. A number of experimental concepts were established in the study and as such, there were numerous ways users could interact with the software. The game was trialled over an 18 day period, using a group of 13 students, aged 17 to 18 who were left to play the game in a competitive scenario. Results were collected from logged user interactions, questionnaire responses and interviews. There were a number of research findings from the trial:

- **Task participation successfully elicited exchange of social media:** Social media was exchanged by users in order to complete tasks and this was achieved for the duration of the trial period.
- **Player-assigned tasks fell into four main categories:** These were (i) *collection*, (ii) *social interaction*, requiring players to interact socially, (iii) *travel*, requiring users to change location and (iv) *information finding*, where users collected some form of

useful information as a result of play. Each of these required different forms of user interaction and strategies for successful task completion.

- **Potential for human computing:** Task participation yielded information that could be useful beyond the realm of entertainment. The semantic Guessing Game tags showed geographic relevance when visualised in a graph and in addition, many of the tasks collected information of a potentially useful nature.
- **Different social media formats served different purposes:** In general, feelings and emotive content while mobile were commonly recorded in Guessing Game, whereas photos and gossip focused on task-related entries.
- **Effectiveness of peer review moderation system was proven:** The system ensured the generation of verified, peer reviewed, geotagged social media. The overall lack of noise present in tasks showed that this was successful in encouraging good content. However the presence of 'fake' content indicated that this could not also verify the authenticity of content.
- **Certain game elements were utilised in a pervasive way, while others were not:** Many players preferred the socially isolated, indoor locations typically associated with console gaming for play. One reason for this is that users were still learning how to best use the technologies, but the time of year and user demographic of the trial also played a role. Contrary to this, the majority of Guessing Game results showed evidence of a more pervasive play style, with mobile and outdoor responses favoured.
- **Ethical questions were raised regarding informed consent:** Non-players became targets of tasks and an intrinsic part of social media narrative. This led to players registering their concerns in these instances.
- **Concept of gopher 'agents' received positively by users:** Gophers were seen as a personalised and accessible broker for indirect social media exchange and it is suggested that the use of agents encouraged different types of social media to be exchanged. Another unique aspect was that social groups were built dynamically around task interaction.
- **Group comprehension and learning posed a challenge:** A lack of shared learning existed between users. Users were physically distributed for much of the trial, raising the question of how to ensure shared comprehension between groups of isolated

users. A steep learning curve existed, due to the number of novel concepts in the experience.

Multiplayer mobile games in the main provide a rich environment in which to study the social networks that evolve through normal play. The trials of Gophers, which focused on social media exchange and task based-play, demonstrated a more ecologically valid platform for this investigation. Overall, the tag-based Guessing Game proved a particularly popular element of the trial, so this concept was further explored in the subsequent studies of ItchyFeet and MobiClouds.

8.1.2. ItchyFeet

One of the most successful aspects of Gophers was the Guessing Game, which allowed users to compete against other players asynchronously, in a geospatial word guessing challenge. This resulted in a large number of accurate semantic descriptions being generated for popular social locations. The next study chose to focus on this area in greater depth. With this aim, ItchyFeet was a MoSoSo that allowed users to tag popular social locations with personalised descriptions that were then used as a way to automatically report the context of friends when they were in vicinity of these places. The application was tested by a group of friends who were already avid users of a commercial social network. Trials took part over four weeks and comprised of four groups of four users each. Results were collected in the form of logged user interactions, GPS trails and tags, along with daily questionnaire responses and mini-interviews. There were a number of core trial findings:

- **There is more to social tagging than location:** Numerous other factors were found to influence tagging in the presence sharing system. These included shared comprehension, collaboration, evolutionary properties, intended audience of tags, privacy affordances, spatio-temporal properties such as time of day, social properties such as peers present, historical and experiential properties, personal factors including availability and mood and finally, the technological shortcomings of devices and sensors.
- **Social factors were a key consideration:** These were demonstrated by the differences in tag style and quantity of tags when users were proximal or far away from the group. In addition, tag content frequently focused on friends' actions.

- **There were three distinct user interaction styles:** These were: (i) *individualistic*, where the application was used as a simple presence update tool, (ii) *cooperative*, where the application was used for micro-coordination between users, or to engage in shared narrative and (iii) *non-cooperative*, where users contradicted one another's tag descriptions, or competed to be the first to tag a location.
- **Tags evolved over time:** Rather than being static entities, tags were dynamic in nature and evolved over time as users worked together to modify tags with updated and improved entries.
- **Social, temporal and spatial boundaries were important:** The study findings demonstrated how these could be modified to better accommodate tags.
- **Overarching narratives and event-based tagging were common:** There was frequently a common overarching theme that connected a set of tags. Themes and narratives naturally flourished around user interaction in the trails and users collaborated to contribute towards these.
- **Social group proximity affected tag style:** Differences in user tagging styles were a clear trial outcome. When away from the group, a more individual, literal set of tags was built and this changed to more creative, personal and emotive content when close to a user's social group. The existence of 'travel tags' was also apparent, as users harnessed the application to connect to peers and pass time while travelling, using the tags to report their geographic whereabouts and status. The use of tags that would elicit serendipitous discovery by peers was also noted.
- **Group comprehension and learning was accomplished via several channels:** This included online discourse, group debate when users were physically proximal, questions to moderators and pre-trial discussion.

The ItchyFeet study successfully investigated the real-world usage of a presence sharing system based around social geotags that was strongly integrated with an existing online social network. The trials demonstrated that there were many potential influences for users exchanging social media in this social tagging service and that overall, social properties were considered to be the most major influence on user interaction.

8.1.3. MobiClouds

The emphasis that social factors played in influencing ItchyFeet users led to the focus of the last study. The MobiClouds service was another MoSoSo, based on the same architecture as ItchyFeet, but instead of geotagging, it made use of experimental 'people tagging' technology to place mobile tags. The technology was designed to position social media in a way that was more relevant to a user's evolving social surroundings and aware of non-application user presence. The application allowed users to create tags describing social situations as they occurred, which would then be applied to the people that surrounded them. These tagged individuals were used to provide updated indications of friends' contexts, when the same tagged people were proximal to them. The trial period and user groupings were synonymous with ItchyFeet. User interactions and the scanned Bluetooth encounters with people were logged, along with questionnaire responses and the analysis of these led to a number of important findings:

- **People tagging acted as a social indicator:** The trial results showed that people tagging was less effective as a stand alone social media service in itself, but would be more suited as metadata to tag other social media such as mobile photos, acting as a real time 'social indicator'. This could be useful for a number of areas, specifically the introduction of new social network contacts, the creation of dynamic social groups for mobile social networking purposes, mobile photos, or blogging.
- **Many influences existed beyond social surroundings:** As with the geotagging in ItchyFeet, there were numerous other external factors that influenced the social tags that were created in MobiClouds and these are discussed in section 8.1.4.
- **Users tagged when away from their group:** Tagging was still possible when users were away from their peers, which makes the technology useful for applications set in sparsely populated environments. In these situations, the way application was used changed; fewer devices to tag and an unfamiliar device environment meant tagging was more challenging for users. This also meant a user's relationship with their social networking peers changed from a reciprocal one to being solely a producer of social media.
- **People tagging was an inherently social, device-driven concept:** The nature of the technology meant that tagging was limited to situations where devices and peers were proximal. Results showed that regularly encountered social peers were most likely to

be tagged. Overall, this makes the technology map well to the intended application of the technology – the positioning and tagging of social media.

- **Social tags focused on naming people, friendship groups and shared activities:** Furthermore the tags were short and self-contained. This wholly contrasted to ItchyFeet results, where tags focused on geographic situations. They were affected by the UI tag length restrictions and the limited window of user interaction that existed around social encounters.
- **Large graphs of connected social encounters grew over time:** These were demonstrated by visualising both Bluetooth and friend encounters at different trial periods. In revealing the large networks of continuously encountered users, it shows potential for accessing group knowledge in a viral, peer to peer manner.
- **Users mainly consumed tags in-situ:** Despite the ability to lookup the status of peers both online and whilst mobile, most of the time users encountered these tag clouds in the real world as their social context changed. This shows users were more interested in using these applications as a real-world experience, where they were more likely to interpret the social media in the same context it was recorded.
- **Group comprehension was a major factor:** A reasonable understanding of their social Bluetooth surroundings, device names and the way proximal people tagging worked were all prerequisites to users creating tags.
- **Tags were discrete entities:** No evidence of narratives were seen in comparison to ItchyFeet results. Instead, tags were short, self-contained descriptors that were simple to understand as independent entities. This tag style is potentially more suited to the short interaction styles associated with mobile applications.
- **Social and temporal boundaries were important:** The results discussed how these were utilised when tagging people. Tag content was highly dynamic and changed over time, with some tags possessing a very limited timespan of social relevance.
- **Ethical considerations regarding people tagging are considerable:** Users were aware of these potential problems and reflected upon them in tag comments. These limitations are further discussed in section 8.5.2.

The results from MobiClouds successfully demonstrated the concept of people tagging in a mobile, social presence sharing system. It showed how non-application users can be considered as an integral part of the tagging process. In doing so, the trial revealed that people tagging produces a different type of social media to that of geospatial tagging. Overall, the findings of MobiClouds suggest that people tagging alone has the potential to record information about the type of people that were present at the time of significant social events, through generation of social tag clouds. Although this information may not act as effective social media in itself, the results indicate that it would act as a method to tag other social media with real world metadata.

8.1.4. Reflection on Outcomes

This section reflects on the research outcomes, discusses differences exhibited in each study and suggests reasons for these.

One of the main outcomes of the studies was the identification of factors that influenced user interaction when creating and exchanging social media and these relate directly to the main research question of the dissertation. A number of such factors were identified while analysing each of the studies. Firstly, the personal status of users, for instance their emotive response, was an influence in all three studies. The learning process and ethics affected users in both Gophers and MobiClouds studies, mainly due to the novel concept of the technologies and inclusion of unaware users in the content creation process. The availability of users to interact, their knowledge and experience, the target audience of tags, their social distance from others and the influence of application design were all seen as influences to ItchyFeet and MobiClouds users. Finally, spatial-temporal effects and socio-temporal effects affected the users of ItchyFeet and MobiClouds respectively, a result of the positioning technologies employed. Further discussion of these factors is provided in the study chapters 4, 6 and 7.

Another outcome across the studies was their potential for sharing real-world social knowledge. Results suggest that task-based gaming experiences such as Gophers are a useful way to entice users to supply specific content that is verified, geotagged and timestamped. In these task-based experiences, most of the social media naturally relates to the overarching task and themes would need to be artificially set if required to collect a specific type of information (for instance, “tag the potholes”), breaking the open ended nature of the experience. One option to achieve this would be to run data collection tasks in parallel to the main game threads, offering additional rewards for those that participate. In contrast to this, ItchyFeet managed to collect a large amount of potentially useful data, despite the lack of a formal 'peer review' system; these results suggest the integration of the system into an established social network community acted as an effective peer review service in itself. As such, when integrating these applications in this manner, artificial peer review systems are not strictly necessary.

The type of data recorded in ItchyFeet focused on the labelling of buildings, houses and geographic areas and the individual tags frequently formed part of a much larger, overarching narrative. These narratives emerged as an unexpected result of interaction in ItchyFeet, showing that this form of interaction would naturally flourish, despite the lack of formal narrative definition that oversaw the social media creation in Gophers. It was clear that this data could be useful in many applications, which are further discussed in section 8.6. A specific subset of tagging associated with ItchyFeet was that of transport related tags. The existence of these suggests that the rapid spatial changes associated with travel are a major influence to GPS based systems, but were not necessarily important to the people tagging system. A different type of data was collected in the people tagging technology employed by MobiClouds, with the social tags relating primarily to social surroundings, focusing on friends names, friendship groups and activities they were involved in. The data was less useful as standalone entities 'out of the box', but could potentially be used as metadata to tag other social media for example, mobile photos. The chief benefits of the technology are that it is able to reflect upon non-application users and it also has the potential to monitor the changing social surroundings of users as circumstances change and the dynamic social groups around them shift. This was exemplified by the tagging of friendship groups, made possible by the popular 'tag all' function. Although overall the results for MobiClouds were less dense and varied than was anticipated, it acts as a proof of concept for this new technology.

All three studies collected socially relevant data that could be harnessed in different ways, by both social and non-social applications; some of these are discussed in section 8.6. The drawback of the latter two studies was that, although their potential for collecting useful data was clear, the data stream of tags produced was unpredictable and there was no obvious way to control the type of data collected. Further to this, the people tagging method has been shown to have great potential in defining ad-hoc and long term community groups in a mobile social network. By tagging user groups in-situ, distribution lists can be set up or modified at the touch of a button, offering a unique method of controlling the flow of social media to social network peers. Overall, in order to collect data on focused topics, a hybrid approach might offer the best solution, combining the high accuracy systems seen in the latter studies and the social awareness of people tagging with the task-based collection seen in Gophers. It is expected this would provide a highly effective way of collecting human computing data.

Narratives existed that were explicitly defined in Gophers and emerged naturally in ItchyFeet. No narratives were seen in MobiClouds, where tags were entirely self-contained. Results suggest this difference was due to the short window of interaction that was available for users to create tags in this study. This suggests that the people tags are best suited to labelling social content from a fixed time or place, whereas the narrative based tags seen in the locative systems could provide effective labelling for social media that spans across time and space. Another common thread was the effect that proximity to their peer group had on a user's tags. Locative tags in ItchyFeet tended towards geographic descriptors when users were in a location unfamiliar to others that they were the first in their group to experience. This was especially true in the case of 'travel tags', recorded by users whilst moving as a way to disclose geographic whereabouts. In comparison to this, MobiClouds users created fewer tags when away from the group. Tagging was more difficult for MobiClouds users, since they were unfamiliar with the device environment and this is considered one of the main drawbacks of the technology. However, since the application was designed to tag social situations, its use was less relevant in these circumstances in any case. Gophers users did not experience interaction at a distance, since all interaction was concentrated within the city boundaries, which users did not leave; this could be attributed to the age, demographic of users, or the time of year.

Learning and group etiquette was another important characteristic of the three systems. In MobiClouds and Gophers, the underlying sensor infrastructure was exposed to users and discovering the nuances of this became a part of the learning process, as Gophers users could not interact with agents outside of their mobile cell (without play cost) and likewise, MobiClouds users missed the opportunity to tag people once they strayed outside a social cloud.

Tag boundaries were defined in different ways by the systems; in Gophers, these were determined by the coverage of mobile GSM cell masts, in ItchyFeet, boundaries were defined in an ad-hoc manner from the centre of new tags and in MobiClouds, the boundaries of (moving) Bluetooth devices were peripheral edges. Determining tag boundaries was a problem in ItchyFeet, where tags became increasingly cluttered, but less so in MobiClouds. Trials suggest that exposing boundary seams more explicitly could have been advantageous in the design of the ItchyFeet system. Doing so would give a sense of a bounded 'interaction space' within which social tags could be recorded and exchanged, rather than the unpredictable feelings that users expressed discovering tags in a more serendipitous manner. This would give a defined contextual region within which discussion resides and applies to, rather than an arbitrary 'location', with little to no scope implied.

Two approaches to handling sensor data were trialled in the studies; exposing the sensor layer, or hiding it from users. Hiding the sensor data, as was the case with Gophers and ItchyFeet, blurred any inaccuracies on the sensor edges and as such, made any minor problems less obvious to users. However, when this method did go wrong, it created some unexpected results for users; as demonstrated by the mast flipping problem exhibited in Gophers, which was invisible to users until it manifested in gameplay problems. In contrast, the seams of underlying sensor data were transparently exposed to users of MobiClouds, by visualising surrounding Bluetooth devices in real time and this was an essential aspect of using people-tagging technology. Although the experience was arguably less accessible in terms of technical knowledge required, the 'seamful' benefits of revealing this data was that users were notified of errors and the data acted as an indication of sensor data quality; when inaccurate data caused large numbers of identical devices to be relayed, users publicised this anomaly in the form of tags.

A final consideration of these applications was the ethical considerations over their use. The use of third parties, for example was questioned in Gophers and MobiClouds studies, but this concern did not emerge in ItchyFeet. This was due to the nature of tasks in Gophers and directly tagging these users in MobiClouds. In response to these concerns, some of the issues surrounding use of non-application users have been explored in section 8.5.2.4.

8.2. Research Aims Revisited

This section reflects upon the original research aims that were identified in chapter 3, using the findings from the three dissertation studies. Firstly, the main research question of the dissertation is addressed:

R01: *How do users exchange social media in mobile social software services and what are the factors that influence them?*

External factors affect users when creating and interpreting social tags and these include personal availability, experiential properties and spatial, social and temporal boundaries. Social surroundings are a particularly strong influence and user interaction differs significantly in mobile social services when users are co-present or distant from their peers. These factors influence whether a user will interact with a service and what social media they will create. Overarching subject themes have a strong influence over play style in task-based social games and it has also been shown that these can naturally emerge through interaction in a more open, geospatial social service, where tags form small parts of a higher level narrative. Subject themes are less prevalent in people tagging services however, where tags are typically stand-alone entries.

The discussion now considers aims of the pervasive gaming study, Gophers:

G01: *Assess the suitability of using mobile social games as a social platform for collecting useful, situated content about the world which bears a social and locative relevance.*

The results from Gophers show that the potential for human computing in social games is great. The mobile game trial has highlighted the possibilities afforded by these experiences in collecting potentially useful information about the real world, with the themes of tasks generated by users directing others towards collecting a particular resource of use. These could eventually be useful across a variety of applications and the collection themes fell into a number of categories, with examples including: *finding the price of a new games console* and *locating a specific shop in town*. Although the themes showed great potential, the blogged content lacked the contextual relevance that was expected to develop. In contrast to this, more semantic meaning was revealed by tag data from the Guessing Game and its potential for human computing was clear, with connected networks of semantic meanings being built over time. If the game was managed differently and hosted in the present technological climate, where improved location sensing and a better understanding of LBSs (Location Based Services) exists, it is expected this would forge more pervasive play styles and increased contextually-relevant social media.

G02: *Evaluate the suitability of task based non-linear play and social agents as a way to direct the exchange of mobile social media.*

The task based play in Gophers offers a novel perspective on pervasive gaming, allowing for a limitless range of gaming scenarios to be conceptualised by the self-sustaining community. Gophers agents themselves were seen as social mediators, with dynamic social groups forming around their tasks; published content was shared between these peers, allowing users to contribute towards task narratives in a collaborative manner. The concept of social agents as a broker for interaction is appealing, as it is analogous to the way users interact with their mobile devices already; in effect, exchanging socially with peers. An alternative mode of communication could see this more intrinsically implemented as part of the phone's functionality, for example via SMS. The vast majority of tasks engendered social exchange and a number of tasks explicitly encouraged social exchange in the real world, using digital tasks to illicit social interactions in the physical world. On occasion these would even encourage the user to converse and pass on information to a person, for example “find *name* tell them *this*” and this was a prime example of the 'spilling' of information from the digital world into the physical one.

G03: *Measure the success of using gaming mechanics, credit-based economies and peer review as incentives to delivering good quality social media.*

The gaming mechanics in Gophers created an ecosystem which encouraged good, valid content. Also, it was clear that users were prepared to engage in the jury process when offered a reward. This was seen to hold the interest of users over the course of the trial and they accepted the system as an intrinsic element of the gameplay. A combination of the entertaining scenario and review system contributed towards the good quality, verified social media that was being exchanged in the trial. One element the system did not protect against was faked content.

The geospatial tagging service, ItchyFeet addressed a number of research aims which are now summarised:

I01: *Devise a test framework based around mobile social geotagging that allows for logging and monitoring of user interaction.*

ItchyFeet has successfully demonstrated a platform that can be utilised to investigate real-world interactions between users in a simple social geotagging and presence sharing application. In order to provide an investigation that is representative of users' real-world social network habits, the service connects to a user's existing online social network. The trial setup was proven to function effectively and attain the user data required over the four week period. Through use of trial data, the analysis methods and visualisers that were implemented allowed for precise monitoring of user interaction in a simple presence sharing service 'in the wild'. This has provided a detailed picture of user interactions that is applicable to location-based MoSoSos more generally.

I02: *Discover typical usage patterns exhibited and document the effects of real-world influences on user interaction.*

The trials have identified a number of common user behaviours while tagging. The main influences on these behaviours were established through analysis of the trial results. Crucially, these have revealed that the location of users was not the sole subject of user generated tags and instead, measurable and less measurable human factors were identified as influencing these, including experiential properties, personal status and availability to interact. A user's social surroundings were of particular relevance, for example, whether they were distant or proximal to their social peers, as well as the spatial boundaries of tags, which dictated the 'activation area' that they encompassed. It is suggested that these factors should act as a guide to MoSoSo designers.

I03: *Assess the relevance of peer tag sharing as a way to record semantic meaning for real-world locations.*

The peer tag sharing in ItchyFeet was seen as a successful method to distribute social media amongst friends and it also provided an engaging way explore this tag landscape as users moved around the real world. As a result of the trial, a large number of social locations were accurately labelled around the City of Lincoln. These locations went beyond simple, discrete semantic meanings for locations and in many cases developed as a dynamically evolving meaning, increasing in accuracy and depth over time as different users contributed to them. Many of these tags formed part of a larger, ongoing narrative, often resulting in a trail of spatially distributed tags providing meaning to a connected series of locations. Results demonstrate that tag sharing applications should therefore consider these meanings as compound entries that are liable to change over time.

Finally, the aims of the MobiClouds people tagging study are scrutinised:

M01: *Demonstrate the concept of 'people tagging' as a vehicle for positioning mobile social media and assess it's effectiveness in integrating with social surroundings and incorporating non-application users.*

People tagging demonstrates a novel approach to positioning social media in a MoSoSo and this has been proven in the MobiClouds study. Participants used this as a way to report on their wider social surroundings, demonstrated by the frequent tagging of non-application users. By logging the Bluetooth encounters, it became clear that a large amount of the surrounding social landscape was successfully encompassed into the tagging process.

M02: *Compare the use of Bluetooth people tagging with locative geotagging of social media.*

The social people tagging style varies notably from the locative tags seen in previous studies. There was a tendency for users to tag individuals and groups using the technology, contrary to the geographic locations and situations preferred in geotagging systems. Furthermore, the people tags acted as rapid, self-enclosed updates of who was around at a point in time and did not flow as narratives or themes. Clear ethical and technical issues exist with the technology, for example the tagging of non-consenting individuals. Finally, the people tags were less meaningful as a presence indicators in themselves, as they lacked the depth of the locative tags, but in their present form, would best serve as metadata to associate with other, more stand alone social media, for example mobile photos and messages.

8.3. Technological Developments

The twin areas of mobile and social technology are extremely rapid areas of change, in terms of both hardware and software evolution. Unsurprisingly, a number of technical developments occurred during the research described in this dissertation, which began in 2006.

The most prominent change has been with the uptake of mobile devices. Smartphones in particular were relatively specialised at the start of the study and only offered by select manufacturers, but devices are now offered by most major manufacturers, making use of iOS, Android, Windows Mobile and Series 60 platforms and worldwide smartphone sales grew by 72% in 2010 [86]. These devices offer many features besides increased memory and CPU performance (a major source of problems in Gophers), such as integrated assisted GPS receivers, gyroscopic tilt sensors, QR readers and capacitive, high resolution touch screens. The convergence of multiple technologies into a single convenient device has allowed for both application functionality and user interaction to be improved tremendously, for example many applications now take advantage of LBSs and augmented reality is even possible, showcased by applications such as Google Sky Map and Goggles [93][88]. Regardless, certain aspects of mobile technology have not developed as was envisaged, namely battery technology which remains an ongoing impediment.

The ability to access the web on the move is now an established function on these devices, with highly capable webkit-based browsers offering a much improved browsing experience; in addition most major web sites now offer mobile counterparts, often wrapped as 'web apps', which are optimised for smaller screens and this provides an extremely rapid way to develop simple services on a device. Mobile video streaming to these devices has allowed a richer variety of media to be delivered to users' handsets. The introduction of HTML5 will further the possibilities of web-based mobile applications.

Furthering the trend for mobile devices is the emergence of new mobile paradigms in the form of tablets; namely iPad and Android based devices. These offer the ability for improved user interaction on the move, at some cost to portability and are expected to form an important part of mobile social networking in the future. To complement these developments, mobile interaction guidelines are now available from mobile manufacturers (which were somewhat experimental at start of the dissertation), meaning a more consistent experience across mobile applications.

The emergence of specialised mobile application or 'app' stores has led to an explosion in the number of users who download and are prepared to pay for 3rd party software to their devices and the popularity of mobile games releases is attracting non-gamers to start playing. Many of these applications connect to social services and the inclusion of real-world social elements is becoming more commonplace. A prime example of this is Twitter, which has emerged as the de facto mobile publishing and microblogging platform. Mobile social networking is becoming more customary to users and this functionality is becoming an expectation of new devices, with most of the main websites releasing mobile client software to interact with their services. Some manufacturers have seamlessly integrated this into mobile communication device interface, further blurring the distinction between phone and social communications device. In 2011, social networking is proving increasingly popular and mobile social networking use in particular has become a particularly large growth area, with approximately 50% of total mobile web use now spent on social networking sites [99].

In unison with a willing consumer base, developer support has also improved dramatically. APIs have emerged that allow on device sensor data to be accessed via high level calls and most online social network operators offer APIs to access their social media; the Facebook API allowed access to the profile and contact data of users in ItchyFeet and MobiClouds trials for instance. Fully featured development SDKs now make real-time debugging on-device a simple task. Major improvements with client side data storage have occurred since Java ME RMI storage used in the research studies, with SDKs now supporting object-driven data models and SQLite query support. Furthermore, better libraries exist to support asynchronous and secure communication, avoiding lockups and providing secure sessions [3]. In addition to this, an improved network infrastructure has emerged and 3G is near universal in UK cities, along with readily available high capacity data tariffs. These are making mobile data services much more appealing to users. Next generation 4G trials[6] have taken place, which promises to offer higher 'application speed' and importantly low latency; this will offer more real-time interactions and updates in mobile web connected applications.

The near future presents a number of exciting developments on the horizon. The further integration of mobiles and social networking technology will likely see greater acceptance of using these services in real-world. The push towards decentralised social networks may reduce the reliance on closed, online social network providers for exchanging user data, instead focusing on the peer to peer exchange between trusted parties [53]. In addition, services such as DBPedia [29] allow application developers to access user contributed semantic knowledge networks with ease, allowing for powerful semantic inferences to be made about user-generated social media. Finally, cloud based storage offers potential for massive, ubiquitously accessible personal data stores, wherever and whenever a user requires and offer better opportunities for multi-platform operation.

The research trials contained set out to be as ubiquitous as possible to people's lifestyles and to this end, they showed some success, but learning of the technologies was still a hurdle for many users and as a result the application content needed to be toned down in places. Now users are becoming more used to these technologies, researchers will be able to explore more complex nuances of how these applications can fit into a modern lifestyle. The ongoing technology developments since 2006 have lowered the point of entry for developers to access the domain of mobile applications development and in particular, that of mobile social applications. With the continual shift towards the utilisation of mobile devices as fully featured social tools, it is vital that researchers continue to explore and understand the issues of using such services in real world settings.

8.4. Guide to Designing MoSoSos

In conducting the three studies, a valuable insight was attained regarding the design of mobile social services in general. This section identifies a number of caveats which emerged from the research process, that are intended to act as guidelines on what others should be doing when running research trials in this domain.

- **Entertainment aspects can offer an engaging social experience for users.** Playful elements of the social experiences proved to be an engaging way of involving users in

6 This is primarily focused on the UK market, but similar developments in infrastructure are being witnessed worldwide, with some countries opting for WiMax-based transmitters

mobile social applications – even to non-gamers. Designing game mechanics based around user generated social media can allow for a variety of play styles and good retention by users.

- **Designers should allow content to evolve over time and to different uses.** Over time, social media can change, or become redundant and this continual adaptation should be supported in mobile social services. Furthermore, different social media is useful in different circumstances and use cases, for example home use or work use. Applications should be adaptable to this change and designed to filter content depending on a user's employment of the application.
- **The choice of sensing technology affects outcomes.** The sensing technology utilised can determine how the application will be used, where it can be used and which users are able to access it. For example, people tagging technology varies notably from location tagging. Designers should therefore carefully select the sensors used to integrate a mobile experience into their everyday world, depending on the target application domain.
- **Peer sharing.** The sharing and reuse of social media amongst related peers can create a shared ecosystem of real world social media that users contribute towards in a collaborative way. This can reduce the burden of creating social media as individuals and additionally, can help inspire users to create new content and extend this to suit their own needs. As such, peer sharing of media is a powerful addition to these systems.
- **Use everyday technologies where possible.** To ensure integration into users' current social practices as much as possible and maximise the retention of applications, new MoSoSos should make use of existing technologies, including typical web2.0 paradigms, bootstrapping onto already established social networks and making an application that is capable of running on a large range of existing mobiles.
- **Allow users to experiment.** Many different user interaction styles emerged though the trials that were not foreseen. Different users will use these applications for different purposes. MoSoSos should therefore be as flexible and open as possible to allow the users to decide how best to make use of them as a group, rather than directing the users down a prescribed path; this can be achieved for example through use of free text fields and generic interfaces. The learning process between users

often occurs as shared process and this takes time to develop – users should therefore be encouraged to discuss this as a group using application features (such as in-application chat) for more rapid learning and a shared establishment of an application etiquette.

- **Create incentives which foster 'good' content.** User contribution to these applications is not entirely altruistic and they be designed to create benefit for the user creating 'good' content. One way to do this is thorough use of incentives such as peer scoring and peer review mechanisms, or by closely integrating into a user's social network, where a tight-knit community exists.
- **Basic mobile usability guidelines still apply.** MoSoSos should be designed in accordance with existing mobile usability guidelines, by incorporating short interaction times, resilience to interruptions and the ability to handle sensor data and communications failure. To do this, the number of tasks/clicks a user needs to perform should be kept to a minimum and network communication should be infrequent and robust.
- **Allow social media to be viewable in-situ.** An effective method of users consuming social media is to allow them to do this using 'information encounters' as they explore their environment. By allowing users to consume this information in-situ, MoSoSos can offer a more passive way of viewing content as they take part in their normal everyday routines and in addition, users can experience it in the same context that it was recorded in; much of these environmental cues are lost when a user views this content online, which could cause them to interpret it differently.
- **Keep application mechanics simple.** The mechanics of MoSoSos can become complex, as the user is frequently learning new concepts in using them. This can lead to a steep learning curve for new users, potentially reducing user take up and retention. There is a temptation to add many novel features, but the dissertation findings suggest that introducing too many unfamiliar concepts can lead to confusion in users. This can be avoided by introducing users gradually to new features over time, or keeping application design simple.
- **Inclusivity of users.** For maximum heterogeneity of content and a good reflection of real-world society, it is vital for social applications to be as inclusive of different user demographics as possible. To maximise this, applications should minimise the

technical boundaries of entry, in terms of device type required, expense and learning curves. A further way to involve users in the application process is through considering non-application users by using technologies such as people tagging.

- **Event history should be easily accessible.** The content of past events are an important aspect to creating content, so MoSoSos should include mechanisms for users to easily browse old entries, reminding them of these and providing cues when creating and interpreting new social media.
- **Applications should scale well.** Another property that MoSoSos should posses to ensure inclusivity of users is good scalability. A well designed application should allow spatially or socially distant users to interact as well as those in close proximity. Applications should allow users to benefit from geo content when away from main action and their design should handle variable tag density, especially when establishing a service with few users, allowing the service to be usable with a very sparse environment of tags as well as extremely dense tag landscapes.
- **Look for higher level meanings.** Higher level meanings in the social media should be exploited. Narratives are an extremely important aspect to this; there is usually a higher level meaning or bigger story around most social media. By taking advantage of these narratives, application designers can group associated content by theme and present it in a way which is more meaningful, in the context of the wider narrative.
- **Monitor emerging use.** The social acceptability and etiquette around use of these applications is still being determined and any new application will be exploring these issues. Application designers should expect this to change as the genre (and law) becomes more mature and to reflect this, should be prepared to refine their application design with time.

The next section looks at the research limitations that were exposed while trialling the three tagging services.

8.5. Research Limitations

There are various limitations that existed in the three studies, in terms of trial methods, technological and usability limitations. The limitations are documented as a way of identifying the scope of the results when interpreting the findings and additionally they act as a guide for what would be changed in future social tagging research studies.

8.5.1. Trial Methods

This section discusses the overall limitations of the methodologies employed by the three studies. In all trials, the number of possible concurrent users that could be involved in the trial was limited by the number of devices available. Gophers trials were restricted to the 13 users in question who trialled the application in one sitting over 18 days, but ItchyFeet and MobiClouds were also open to the wider Facebook community. 36 users from 15 countries voluntarily downloaded and used the ItchyFeet application on their own devices, but it was more difficult to recruit volunteers from the university who could take part in the trial itself using their own phones. The need for a specific model of phone (GPS-enabled Nokia series 60 devices), along with the potential expense of data transfer and the reluctance of users to install 'untrusted' applications on their own devices, were all barriers to entry. As a result, all participants were loaned devices from the university; four handsets were available and these were used by 4 groups, each comprising of 4 users and trialling the application over 7 day period in sequential trials. The limited number of users and the closed trials meant that the development of tag environments could only be observed on a small scale and the effect of social tagging between social groups was not explored. If the trials were repeated today, the wide availability of 'app stores' (which were not established at the time of the trials) would lower the barriers to entry and make it far easier to generate interest amongst the mobile community; in using an increased sample size statistical analysis of the results would also be possible. Performing longer term trials would allow investigation of longer term behaviour, increased reuse of tags and more accurate semantic mapping of the trial area. This would give an insight into the long term sustainability of mobile tagging systems, evolution of tags over long term periods, the potential of human computing to generate useful data from them (as introduced in the Guessing Game) and raise the questions of handling scalability and tag filtering in very large tag environments. Increased trial time would have allowed the investigation of how inter-group links between social networks develop and an exploration of this cross-network social activity. It would also show how users' opinions on how app should be used would evolve to be used as a medium-long term social 'people' bookmarking system.

Trial interaction in Gophers mainly took place in and around a local secondary school in the City of Lincoln, where the participants were studying. In ItchyFeet and MobiClouds trials, the participants were all students recruited from the University of Lincoln and this naturally meant that most application use would be focused around the university area and centre of town. Keeping trials within a single, spatially focused area was necessary to allow comparison between behaviours of different groups. However, urban environments are just one potential setting for mobile social tagging applications and it would be beneficial to also study the different tagging styles and motivations that might occur in disparate locations. For example, studying user interaction in common outdoor leisure spots, such as the Peak District national park in the UK, would be particularly beneficial in the design of mobile social services for leisure applications [200][87][189], or investigating communication between friends who were spatially distant from one another could suggest ways that these systems might operate over a distance. Finally, there is also a need to investigate use of social applications in other areas which are fertile grounds for future MoSoSos, but would not normally be considered due to technical difficulties, for example the London Underground rail network [16].

In all three trials, a rich collection of data was gathered from the questionnaires, including commentary on user experiences of the trial and recording any errors that occurred. This was limited to hand written daily diaries, but it was often desirable to link these entries to the time and location they related to. In all trials, users demonstrated the willingness to divulge trial problems such as software bugs or opinions by electronic means, for example by posting gossip messages in Gophers, or geotagging comments about where the problem arose in ItchyFeet. One enhancement to the primary diary method would be to add the ability for users to report this type of data in-situ, using mobile experience sampling methods that respond to a user's context [109]. These could be implemented as an integral part of the application, allowing for answering of diary questions, or posting of error reports and would allow for key application events to be linked to spatiotemporal metadata, for more detailed analysis.

There were also limitations associated with the process of gathering and abstracting from the trial data. One area concerns the analysis of heat maps in ItchyFeet, in which patches were manually summated (see section 6.2). It would be beneficial to automate this analysis, since doing it visually had some potential for inaccuracies (eg. In determining patch colour). Furthermore, the squaring of the area into fixed size quadrants caused difficulties, since they did not map naturally to real-world areas. Another limitation concerned the abstraction from questionnaire responses, performed in all three studies, which relied on manual reading and interpretation; a more automated method, such as those previously discussed would improve this. Finally, the manual browsing and interpretation of visualiser data in all studies was slightly arduous, since typically mobile interaction occurs in sparse bursts. The automated identification and clustering of points of interest could assist in this process.

Alternative methodologies could have been employed by the studies; specifically, more formal ethnographic user studies, such as those discussed in section 2.4.1, or large scale mobile app-store trials, as discussed in section 2.5.3. Orchestrated experiences that use formal ethnographic methods, such as filming user interactions would have been unsuitable, since an open and unrestricted way of running the trials was required to allow the natural and emerging use of the application in the real world to be studied. The large scale 'app store' deployment was not available at time of trials. Additionally, one of the cited benefits of using this method is the increase in the spatial distribution of the user base [140]; as such, the technique is arguably less appropriate for studying the interaction of users within a defined spatial area (such as a single city).

8.5.2. Technology Limitations

The software that was implemented also included a number of limitations that were discovered while overseeing the trial process and these were revealed by the user responses provided post-trial.

8.5.2.1. General Limitations of the Technologies

This section discusses general technological limitations which apply to the three technologies that were developed for the dissertation studies. The mobile applications for all three studies were developed using the Java ME SDK. This was found to be severely limited in terms of its cross platform capabilities and the use of customised toolkits, such as Placelab in Gophers and on-device GPS and Bluetooth sensors furthered this. For this reason, specific device types were targeted in software development: series 60 2nd Edition Nokia 6680 in Gophers and Nokia N95 in latter trials. Loaning these handsets, rather than users utilising their mobiles, meant they were required to learn to interact with a new, unfamiliar device and this resulted in an additional learning curve; as reported by one ItchyFeet user:

> "[I] wish I had it on my own phone…cos when you're using a different phone, it's…all built differently, you're pressing the wrong button – I tend to [accidentally] press shutdown and I come out of it" [G4]

A way to improve access to users, allowing them to connect to the game from legacy devices in a more basic form would be to offer an interface for SMS/MMS interaction with the applications, an approach adopted by Day of The Figurines [80] to great success. This has the further benefit in a social agent system such as Gophers of potentially offering a more natural interaction style with these agents, which is analogous to the way they communicate with their friends.

In designing the technologies, it was clear that the limitations of the devices themselves can be seamfully designed around to a point, but will inevitably have some impact on user experience. Notable device problems related to power requirements, positioning availability (it was not possible to get a GPS lock when in urban canyons), mobile network coverage, running out of data credit and usability factors, such as screen size and the difficulty of data input. The availability of on-device positioning sensors was found to be an intrinsic influence on where the application was used; for example users reported that GPS coverage negatively impacted use of ItchyFeet and MobiClouds users were prevented from tagging when no Bluetooth devices were present (see sections 6.5.2, 7.6.7). In addition, inaccuracies in the data these sensors provided caused uncertainty in the application, seen by users who reported 'losing' Gophers caused by mast flipping (see section 4.3.1). The situation will improve as GPS mobile devices become more mature, but in the near future it is suggested that a multi-sensory approach that offers secondary sensing techniques, as pioneered in Placelab system [105] would offer a more robust solution. Finally, slow Bluetooth scanning in MobiClouds could be replaced by WiFi to offer a higher performance ad-hoc positioning solution [164].

A general limitation of recording social media in all the studies was that tags and social media could only be recorded in-situ. Sometimes it was not possible for users to create this content at the time of the event due to cognitive strain or availability; a solution to this might be to allow users to tag in-situ then comment later, or even allow others in their social network to comment on their own status, offering greater interaction; the Pepe field study suggests that collaboratively created place definitions are a future topic of research [123]. Another option could be to suggest socially relevant locations algorithmically to users, for example in [7], reducing the burden on application users providing all of these tags.

Finally, because of their experimental nature, all these systems were developed as closed trials, but in wider real world distribution, the portability and openness of the social media generated is critical for continued innovation. As a result, future systems should allow access to recorded social media via APIs to allow additional applications to build upon of the social media, whilst guaranteeing the anonymity and privacy of users.

8.5.2.2. Gophers Technologies

A number of limitations are concerned specifically with the development of Gophers technologies. Although the game was intended as a way to investigate mobile social applications, it did not contain many of the features typical to social networking applications, such as creating lists of friends, sharing gophers with them, maintaining a user profile and suchlike. At the time of development, no adequate APIs were available for integrating applications into existing social networking sites and hosting a bespoke social network was beyond the scope of the study. Gophers like technologies were reimplemented in the Familiars application [116], which was based on a social network community. In addition, there was no mobile access to the blogs themselves and this limited the distribution and speed at which players could receive content; a more real-time approach would involve pushing gopher blogs as RSS feeds to players' mobiles.

Overall, player feedback indicated that the learning curve was too steep for a casual mobile game and the length of typical interactions too long. An improved approach would be to incrementally ‘unlock’ new features as play commenced, preventing the novice player being swamped by the initial feature set. In addition, this improvement may reduce overall interaction times and hence assist with mobile participation. In terms of gopher movement, the boredom threshold (where a gopher would leave the phone after a specified period of inactivity) was originally an attempt to reduce ‘hoarding’ of gophers on a player’s phone. This did not take into account that the phone could be turned off, effectively ‘trapping’ the gophers. Analysis of server logs showed that many of the gophers who did not complete their tasks had been trapped on the phones of inactive players. As an improvement, the server could be made to release the gophers a player was holding after detecting a disconnection.

Although the peer review system was successful in ensuring meaningful content, it did not verify the origin of the information. This limitation would be important if the system was attempting to collect useful real-world information. The system could be extended to look at geospatial data, time of capture and image analysis as methods to identify likely fakes. There was also a lack of shared comprehension between separate/distributed users and this has been assessed in later studies by taking users from an existing social network and creating more opportunities to discuss the application as a group. Finally, checking for gophers was very much a manual process, requiring user attention. This potentially limited the chance of players finding new gophers and meant serendipitous discovery of new agents and tasks was not possible. Creating an automated way of receiving real-time game updates would allow gophers to be a secondary augmentation to their environment and would act as a reminder for users to interact with the application at key game moments.

8.5.2.3. ItchyFeet and MobiClouds Semantic Tagging Technologies

The semantic tagging technologies implemented by ItchyFeet and MobiClouds were broadly similar and hence, suffered from similar limitations.

The process of creating tags was limited in a number of ways. Firstly users had burden of identifying locations manually themselves; a more passive solution might be to suggest locations to them using mathematical behaviour prediction. The technique adopted for distribution of tag updates amongst users required periodic client-server requests in order to synch the two data models (described in section 5.3.4) and this resulted in a delay between the creation of tags and this data becoming visible to users. Although tag distribution performance was not a problem under normal circumstances, the technique was less suited to situations where user location changed rapidly, where the delays limited the possibility of co-present synchronous application use; examples of this can be seen in the high-speed rail and road journeys shared by participants, where a tag would be created by a group member and the others would cross its outer boundary before their devices were aware of it (see section 6.4.3) – thus resulting in their status not being updated. Furthermore, the technology did not lend itself well to the rich experiences afforded by serendipitous social encounters, since this was something it could not adapt to. Increasing the frequency of updates, stretching the boundaries of these tags, or distributing them between co-present users via an alternative technology such as Bluetooth, could improve the sharing of tags and group context in these circumstances. More real time use of these systems is challenging, but intelligent scaling of update speed could assist this.

Many tags were found to be clearly linked by over arching narratives, recorded in threads of linked entries and frequently these threads crossed from user to user. However, these were presented as isolated entities in the UIs, which could result in the meaning and context of some tags being lost if the tag histories were necessary to the interpretation of tag content. In linking tags together, it would be possible to provide easier to read narratives; for example a number of related users' threads could be associated automatically if they had taken the same spatial paths. Developing methods to cluster tags that are part of the same narrative and display these together would improve meaning by showing their natural continuity.

In order to sense the presence of application users, ItchyFeet presumes these individuals are both running the application and capable of sending regular GPS updates to the server. Due to the aforementioned device limitations, this is not always the case and in some circumstances a user could be depicted as being alone, when in fact other non-visible users are present. It is desirable to minimise these cases, either through improved device technologies (which are beyond the control of the mobile application designer), or alternative techniques for sensing location and exchanging data, such as mobile cell positioning or allowing data exchange through open WiFi access points [19].

Tags were shared amongst 'friends' in Facebook and the separation of the trials into separate groups meant there was a disconnect between user peers. The effect of this was that social media exchange was bounded by the groups pre-determined by the trial recruitment process. This limited the scope of tags and more wide ranging semantic data, such as 'Lincoln' and 'University', which could be relevant to the wider Facebook network, was restricted to the trial group. In addition to social scope, users also lacked control over the temporal lifespan and evolution of tags and so tag entries remained for the course of the trials. This meant that social media that was relevant only for a limited timespan was indistinguishable from tags that possessed more long term relevance. A desire to change the meaning of tags over time by re-placing tags was demonstrated by users in section 6.4.2 and so, better support for controlling the evolution of content is an essential element to allowing social media to be maintained by users. A collaborative approach to modification could take inspiration from a Wiki approach to the problem.

A less successful element of the ItchyFeet application was the re-placing of previously created social tags, which did not occur as frequently as expected and this was limited by a number of factors. Firstly, users considered the chronological organisation of tags as difficult to browse, suggesting that simple UI improvements would improve tag reuse. Alternative approaches might order existing tags by proximity from user (since nearby tags are more likely to be relevant), or use of auto-completion when entering tag names, proven to be popular in related geotagging research [4]. Secondly, it is clear that the representation of the self in ItchyFeet required a more personalised edge than the tagging of more static digital media such as photos; users demonstrated this by replacing their own tags to reflect their changing context (shown in section 6.4.2) and also replacing other's tags, as a way to 'leave their mark' on an area [85]. The reuse of tags without modification was insufficient to convey this personalisation.

Two further limitations existed in ItchyFeet, which MobiClouds went on to address. Firstly, the only option for checking on the status of friends was via the online Facebook web application, leading to the number of online observers being lower than expected; it would often be preferable to be able to check the status of friends via the mobile application, in-situ as they were updated. This shows that multi-platform deployment of application functionality is not desirable in settings where timeliness of social media and mobile accessibility is important. Secondly there was no ability to monitor presence of *non-application users*. This meant that the social activity of co-located trial participants could be closely monitored, but it was not possible to measure the social vibe that was occurring outside this group. Past studies of urban computing systems have shown the additional importance of *Familiar Strangers* as part of our everyday social landscape [163]. The study of non-application users was made possible in the MobiClouds trial, which was able to detect social presence via Bluetooth scanning. This approach was still limited, since it was only able detect users carrying mobile handsets, with Bluetooth visibility enabled - but at the time of writing, this is still the optimal technique for detecting these individuals.

8.5.2.4. A Semantic People Tagging Technology

A novel technology that manifested from the MobiClouds study was *social positioning*, driven by the concept of *people tagging*. This was an experimental system and there are various social, ethical and technical challenges that still exist with the technology.

Firstly, there were UI limitations associated with the interface used to report current tags and devices. The application listed all the devices surrounding the user using an animated device list. This was overwhelming for users and made it difficult for them to identify the devices of interest. A more intelligent algorithm would learn and identify devices of interest over time, such as those used in [147] and only notify the user when these were present. Tags were also limited in their ability to provide an accurate representation of user context. The interpretation of the tag clouds was supposed to provide a cumulative representation of what was socially occurring around users, combining to provide an indication of user context. But in reality the tags generally remained isolated entities which described the users surrounding them, rather than being an indication personal context, as seen in figure 7.11. In terms of analysing the trial data, gaining access to the relative spatial proximity of users would have allowed for more in depth research into mobile social interaction, providing an insight into deeper aspects, such as the proximal distance at which users interact. This could be provided by experimental Bluetooth drivers that facilitate reporting of RF signal strength [12].

Overall, a lack of tags existed in the trial and results suggest that this was due to the lack of participant understanding about their Bluetooth environment. This could also have been limited by the small window of social interaction surrounding each event, within which tagging needed to take place. This could be revised to improve tagging opportunities, for example post-event tagging could be offered by providing a blog style feed of recent social encounters, which the user could revisit at a later time and label with tags. Another limitation was the inability to transfer a user's identity across devices. It was common for users in the trial to carry at least one other Bluetooth device in addition to the trial phone, but these were considered as mutually exclusive entities, rather than being combined to form an aggregate indication of a user's identity. Another option would be to exploit this multiple device ownership, to build a profile of user states over time and allow rule-based reasoning to create a more in depth contextual indication of a user's state (for example, when a user is carrying a laptop or satellite navigation unit they are travelling). In addition, in a world where users frequently upgrade their devices, the transfer of their presence details between devices would need to be supported in order to associate a user's presence tags with their new device address and this is an important consideration when users will be investing significant time building a social profile.

The technology lacked ethical affordances and this limitation was revealed during the course of the trial. Some users had questions about the ethical use of tagging, for example whether strangers should be tagged, which sets the technology apart from location-based systems. It is recommended the development of a set of ethical guidelines for users could clarify these issues. The system also incorporates non-application users in the trials and a further limitation of the system was that once their Bluetooth presence is logged by the system, they retained no control over their data. This privacy infringement is one of the challenges with Bluetooth presence and mobile social systems more generally and it is suggested that the implementation of ethical guidelines has not caught up with the sensing technologies themselves. In order to support better privacy methods in such systems in the interim period, non-application users must be given the ability to lookup their logged presence and easily manage their identity in these applications via privacy controls, in the same way a registered user is able to do so in an online social network. These features should be accessible by the user in a simple way, for example entering their device's serial ID or Bluetooth address on a global website or modifying the tag properties through a universal URL; these tools should also offer the ability for users to effectively opt out of such sensor networks, by setting their device to 'unlisted' or 'ex-directory'.

The key usage trends of the application indicated that the technology rewards for socially active users and the study has shown that regular socialisers are much more likely to receive tags themselves (see figure 7.5). However, there is limited support for socially inactive or individual use, since a user's MobiClouds context cannot be reported when no other devices are present. A further limitation therefore relates to the potential isolation of these socially inactive users. Reducing isolation by distributing social media to less socially active users is likely to be a key challenge in using social activity as a measure for content distribution.

Finally, a number of technical limitations exist with the Bluetooth sensing technology. Firstly, the general speed of scanning is slow and secondly, the system does not handle situations well where large number of devices are present; reflected by the bug in section 7.5.3 which caused the same device to be reported numerous times and some devices to be disregarded completely. It is suggested that use of alternative technologies such as WiFi might alleviate these problems [164].

8.6. Wider Applications of the Research Findings

The three research studies have provided an investigation into how user generated social media can be recorded and exchanged in mobile social systems, but on their own, there are few compelling reasons to use these technologies beyond entertainment and status disclosure.

A principal consideration of the research was the potential of these technologies to collect useful human computing data as a product of “normal interaction”. In the trials this social media was explored as flat semantic tags and images, but mobile social applications could build upon these rich social data sets by establishing higher level meanings and trends; this section outlines a number of them, grounded in a wide range of genres. In relation to these suggestions, it is important to note that various important challenges, such as the protection of a user's identity from undesirables, or the potential for pervasive targeted advertising, would need to be addressed before they could be realised.

8.6.1. Real-World Tours

Many social media applications could be radically enhanced for a viewer if the experience were augmented with some of the factors originally encountered by the author at the time of capture. The most common way to make use of these factors is to tag the blog data or photos with contextual data at the time of creation, for example using geospatial tag data to position photos to a map, or making use of proximally close social peers to suggest user-created semantic tags [4]. But a more novel use for the rich, contextually tagged data collected by Gophers and ItchyFeet would be to recreate the real-world experience and relay this to the viewer as an interactive pervasive journey.

Local area guides, such as Google Maps mobile, WikiMapia and FourSquare [219][92][81] offer users the ability to explore their surroundings via geotagged, user generated content throughout the world. There are numerous ways these applications could be enhanced using the journeys and narratives that were found to build up around interactions in both Gophers and ItchyFeet as a way to offer real-world geographic 'tours'. One example would be to invisibly disseminate Gophers content into the environment and present this to users at the appropriate moments. In the application a number of gophers could be personalised for different visitor tours [43] and ‘trained’ with content for each. A user would pick up the appropriate gopher at the start of the tour that would then stay with the user, allowing them to roam freely along their chosen route and offer up information when at the appropriate location or context. This method of delivering the tour narrative via an agent is a much more natural, explorative approach than the rigid presentation experienced by an audio guide, for example.

Typically these guide applications relay discrete pieces of information based upon spatial whereabouts (for example reviews, local attractions, etc) and another way they could be enhanced is by using the type of social narratives that are recorded by peers in ItchyFeet to allow for real-world guidance. In such a scenario, new blog entries would be discovered as 'information encounters' via a user's GPS enabled smart phone, as they move around in the real world. As their spatial – and other contexts, change to match the author's, this would allow the user to sense a similar experience and in addition, effectively recreate the time differences associated with experiencing this continuous social media as part of a real journey. This would allow for representation of the content in the form that was intended. One scenario might involve a user who has been found to be visiting the city of Lincoln for the first time. It is apparent they are exploring the historical quarter of the town and are alone and looking for inspiration. The application detects this information and matches the user with a previous user experience; a local resident who explored some of the local sites the previous weekend. It then responds to the user by suggesting a tour of historical landmarks that was recorded by this anonymous individual. A second scenario might occur when a small group of friends are socialising around the high street area one evening. When prompted for suggestions on what to do, the application detects a short chain of restaurant and bar visits which were tagged by another group of friends, some of whom are one hop friends from a user in the current group. The application responds by suggesting this as a possible route of interest.

8.6.2. Trail-based Sport Applications

Sport applications are one area where users have already become accustomed to using mobile, social applications and so are a fertile area for potential near-future applications. Sport tracking services, such as the mobile Sportstracker application and Geoladders [200][87], are able to record and replay routes for a variety of sporting applications and share them amongst members of a social network. One way to use the route logs that were generated in ItchyFeet is to assist in these social applications. Currently, most sport tracking applications provide access to routes via a web browser map, a translation of the experience encountered by the original authors. One way to enhance these applications would be to offer mobile users a way to passively follow these routes as they run, walk or cycle through their environment in real-time. A dynamic route lookup in-situ could automatically suggest routes that are particularly suitable to a user's current spatial, social and personal context. This route recommendation could also be based upon a set of weighted factors describing the user's surroundings, inspired by those identified in section 8.1.4; by fuzzy matching these factors with the surroundings of other users who had created or experienced (and enjoyed) routes, it could recommend routes based on these past users' experiences. As a result, the system could improve the likelihood of a user interpreting and enjoying a route in similar circumstances.

To offer a more dynamic experience, a further enhancement is to make these experiences dynamically adapt to changes in a user's status, or based on their enjoyment of the current journey. The shared, intertwining narratives that occurred as a result of Gophers and ItchyFeet interaction created spatial junctions where different users' narratives met, then later forked as users deviated from their peer group to continue on a different path. These junctions could be utilised by applications as possible points to change the narrative tact, depending on weighted user factors previously discussed, or the user actively deciding to select a particular path in the fork. In addition, there may be spatially close user narratives that the user could be directed towards for a more significant change of route. It is expected that the fuzzy route generation techniques discussed would map much better to the impulsive, varied decisions that frequently occur in real life.

8.6.3. Crowdsourcing Applications

The human computational potential of Gophers was also highlighted by the results. Building upon the concept of crowd sourcing, Gopher style agents could be assigned specific context dependent data collection tasks as a way of harnessing the type of local community knowledge which could not normally be attained from the internet. It was also clear that the human computation potential of people tagging in MobiClouds was notable and that this technology produces unique social data as a product of normal use. Using this attribute, a 'social query' application could be developed as a way to tap into the dynamically changing social knowledge that surrounds the user; something exemplified by the concept of Crowdsourcing [106]. One technique would involve users creating special 'question tags', which an application would virally distribute between users in a peer to peer manner; these would later receive replies from localised experts via 3G. Using this might even have the potential to reach some non-application users via unsolicited Bluetooth requests.

But use of the high quality social knowledge already collected as a result of normal interaction with the dissertation applications could also radically enhance social networking applications; by extrapolating from the tags users encounter and places they go, a profile of semantic knowledge could be built for each individual. These user profiles could be queried in real-time, using a query language that incorporates text, timestamps and geospatial queries. One practical use of these user profiles would be a 'social knowledge' application, allowing the user to ask their group high level queries about the of preferences of their peers, for instance: “Where do my friends live?” or “What is our favourite cafe?”. A more advanced use case might make use of this data for dynamic scheduling purposes, combining information on typical user patterns and behaviour prediction and providing an interface to this logic. Using this, a user could make social scheduling queries and decisions based on event prediction, for example on passing an appealing cafe in the high street they might ask: “Who can I likely meet for lunch here tomorrow?”. The application would then look at the past behaviour of those in the user's social network and asses which peers are likely to be in the area, or more specifically which had frequented similar venues around lunch time. This may be followed up by creating an event invite for a potential shortlist of automatically suggested peers. This could have similar application scenarios in fields such as CSCW.

8.6.4. Social Media Distribution

Social groups were dynamically created in Gophers as the result of shared social interest in a task. These have potential implications for future social networking technologies since group members are likely to share interests and as such could be used for distribution of relevant social media, or for new friend recommendations. In a similar fashion, the social spaces that existed around MobiClouds users in the real world were sensed by the application and these ad-hoc groups were regularly labelled by users via the 'tag all' method. These tagged groups could be exploited for social media distribution, rather that the rigid online methods that are typically used to define these; in doing so, users would receive messages as a result of a real-world encounter.

In addition to defining peer groups for the distribution of content, the findings also suggest new methods to allow the recipients of social media (for instance subscribers to a microblog feed) to more easily filter content. One option is *trail-based filtering* which builds upon the location-based filtering seen in related research studies [188]. A problem routinely associated with social applications such as microblogging is that of information overload. Through analysis of the venues a user has visited, the social events they have partaken in and the semantic tags they have generated, a user's microblog subscriptions and friend news feeds they receive could be autonomously managed and weighted using key word filtering, removing much of this administrative burden from the user. Basing these filters on ongoing social events would allow them to dynamically respond to changing social circumstances and trends in real time. This would result in a more current and useful depiction of a user's preferences and interests, in comparison to the manual indicators currently employed by social networks that are often based on 'Like this', 'Don't like this' choices.

An important factor that was seen to influence interpretation of social media is past knowledge and experience and as such, another method proposed for filtering social media is based on these factors. Consider the microblog example again: *Knowledge-based* filtering would filter and present messages differently depending on a user's shared experience with the author, local knowledge, social closeness and shared interests, which could be acquired from analysis of historically encountered tags. These multi-faceted blog feeds would take advantage of the relationship between author and reader by offering blog viewing on multiple layers, with content automatically revealed or hidden according to the reader's *ability to interpret* or *interest* in different pieces of information. This will be exemplified with a real-world scenario of a user who publishes regular updates on their day spent relaxing and exploring their home town. Viewers of their blog feed could have many different perspectives and requirements; a resident planning to find some new parts of the city to explore might want to gain knowledge on current events, activities and lesser known sites from a local person's perspective, whereas a close friend might prefer a feed which follows more fine grained social updates focusing on their personal status, encounters with friends and current activities.

8.6.5. Social Gaming

In order to benefit the wider area of social mobile games, information collected regarding player context in Gophers could eventually be used to allow in-game characters to act in a more intelligent, situation-aware manner. Also the real-world tagging technologies exhibited in the latter studies could be used in the creation of new social gaming scenarios, for instance the social encounters that are invisibly documented by MobiClouds have great potential as a platform for pervasive gaming. The covert nature of this tagging process has been realised by MobiClouds like technologies in the Blowtooth game [129], which made use of these encounters as basis for a virtual drug smuggling experience. Other scenarios might include games based on 'Tag' or 'Hide & seek', using MobiClouds people tags as a way to 'catch' a runner once in range; the short range nature of Bluetooth sensors would allow a player to effectively hide. Furthermore, a treasure hunt game could be envisaged using ItchyFeet application, in which one tag acts as a clue to the next.

8.6.6. Social Media Interaction

An emerging finding of ItchyFeet was the importance of narratives in tagging and the way these frequently intersected and diverged around social events. Further to their aforementioned use in trail-based sports applications and tours, these higher level semantics could be used as the basis of a new paradigm based on *multi-path blogs*, to assist with the exploration of microblogs or social network updates. Rather than exploring narratives of one individual at a time, entries would be presented as a social mash up of all the blog entries that converged at a particular location (and time); from this, the multiple narratives from their associated users that fork from the event could be further explored by following links to each of their associated blogs. Presentation of narratives in this way is a new concept which would require new visual representations to be developed. The concept suggests a powerful new way to browse related mobile blog feeds, which would be much more analogous to the clashing social threads that are encountered in exploring the real world, for example the brief snippets of conversation we often overhear in passing a group of strangers.

8.6.7. Social Surroundings

Because people-tagging technology revealed a more socially oriented basis for tagging, many potential applications for the technology will be found in this realm. Often the tags recorded in the application also conveyed an emotive response and these could be exploited in potential applications. One such concept is a 'social vibe' application, inspired by applications such as Mappiness [136], which could present real-world emotive feeling of a place on a more localised level by exploiting the people tags already created by surrounding users. A scenario where this might be used is a music festival, where many of the social tags created will reveal the response of individuals to the music via emotive language or emoticons; on leaving the arena or stage, users would pass a Bluetooth scanner which would log recent people tags. From real-time analysis of the data, mood themes could be established and this would allow outsiders to get an overall vibe of the audience before travelling to a stage. Similar systems could be used in public art galleries or exhibitions, as a way to receive public and personal opinion of an exhibits or entire events, building on past tagging systems, e.g. [207], a further example would be a social weather report built upon the tag set from the Guessing Game.

Other opportunities for people tagging could be found in 'people-bookmarking' applications for peer recommendation purposes. In its most simple form, this tool would offer a way to 'friend' people as a result of a real-world encounter, adding them to their social network, but a more advanced tool could offer more automated 'social recommendation' functionality. Deploying such a tool in the music concert example above might allow a user to tag their real-world social surroundings at the performance; the resultant people tags could later allow the user to identify potential social peers that attended similar events to themselves or determine those with similar interests, i.e. “people at this venue are also fans of this music”.

8.7. Recommendations for Further Research

The trial outcomes identified in section 8.1 could firstly be enhanced by addressing the limitations discussed in section 8.5. But given the area of mobile social tagging is a relatively immature research topic, there are a number of other wide suggestions for major areas of future study. This section identifies them, before overviewing the more specific suggestions for continuing the research in each of the three studies.

8.7.1. Over-Arching Challenges

As a result of the trials, the applications collected a notable amount of useful human computing data. An important future direction for the research generally is to archive and expose this knowledge to other application developers, to prevent it becoming discarded or locked away in proprietary systems. One gap that currently exists is the existence of an open, global human computing knowledge resource that MoSoSo developers can contribute to and make use of. Social media would be supplied to the database from social applications alongside context; for example indicating the event, location and social surroundings of the user that published the media. The stored data would be anonymous, verified, multi-format and importantly would support access control so only verified parties could make use of it. The resource would be accessible via a web API and a semantic predicate language would enable queries based on this knowledge. Future applications could then build upon this knowledge database, for example a recommendation engine based on other's actions, or other applications discussed in section 8.6. Creating an open repository of this knowledge should be a priority for social network researchers.

The only source of social media considered across the three applications were the tags created by users. But many other sources of social data exist and exploring these is an important future extension to the research which would give the tags additional context. Examples include the data stored on a user's online social network profile (such as profile information, recent activity) and the personal data held on the user's handset (such as call logs and interactions); mining this information is challenging at present and requires the installation of third party tools [45].

High level themes that connected social media were common to the first two studies and an aim for future research is to make more explicit use of these in applications. An initial direction for this work is the use of high level knowledge to connect and identify related tags.

Locative inferences or semantic databases such as DBpedia [29] could supply the data to allow higher level meanings be inferred from tag based social media, giving the ability to thematically associate tags that share a common thread and furthermore allowing for automatic identification of narratives and events, for example “these tags all relate to 20th century artworks”, “these tags all relate to high street/retail”. Exposing this meta knowledge is an essential prerequisite of many of the applications outlined in section 8.6.

An important consideration in all the studies was tag distribution, namely the *scope* of social media tags (for example in ItchyFeet tags might be intended for a specific group of users) and the *stickiness* of them (for example in MobiClouds a person's name tag should stay with them indefinitely whereas a question of “who wants to go out today?” would require a much more limited scope). Both were shown to be important to users of the studies, but there was no way to formally control this distribution. This fine grained control would be essential to maintain relevance and privacy in a more long term tagging trial; investigations into how users could control and manage these parameters over time should be an additional focus for future research.

Finally the research studies demonstrate social media based around three different sensing systems and found that the characteristics of each technology meant they were suited for particular tagging scenarios and one of the prime influences was the sensor system used, clearly depicted by the differences between Bluetooth and GPS. Future research should consider the benefits of amalgamating these into hybrid sensing systems (previously investigated more generally in Placelab [105]), which might allow a social application to be used in more diverse scenarios, being just as useful in an airport as when roaming around the countryside. Furthermore, they should consider the affordances of integrating new computer vision developments being made on mobile devices, such as augmented reality to improve visualisation of social data and the use of real-time computer vision processing, for automatic generation of metadata.

8.7.2. Future Research of Relevance to Gophers

The concept of agents was a positively received aspect of Gophers, but future research should look towards further reaching areas where these could be used beyond entertainment, for example the Crowdsourcing applications in section 8.6.3. One limitation of the Gophers experience was its isolation from a user's online social activity, despite the fact most users were members of social networks. A clear area for future research would be investigating the benefits of integrating the game features into an existing social network; something that was not possible at the time of the trial. This could offer a number of enhancements. Firstly, giving the agents social networking profiles would allow online as well as real-world communication, meaning tasks do not necessarily need to be solved in the real-world (online interaction with Gophers-like agents was also investigated in Familiars [115]). Secondly, by using in built social network functions, friends could recommend gophers to specific users, or assign tasks to a particular user or group. This could even be achieved in an automated way, using social network profiles to match peers and suggest Gophers and narratives they may find interesting.

Participants enjoyed the task based experiences in Gophers, but much of their interaction was in static locations and as such, research should investigate ways to encourage more pervasive play styles in these games, for example by trialling the application on user's own devices, or allowing contextual objectives to be programmed into missions (where tasks can only be completed when a certain real-world location is reached). Another area is the study of new game mechanics that could increase competition, or unlock game features over time. Increased competition could result in better social media and a more satisfying game experience. In the current form, players are rewarded with points for good performance and indirectly, with the ability to create new gophers. An alternative might be to reward players with access to new game features (effectively acting as a level system) or allowing them to increase the spatial ‘scope’ of gophers (i.e. better players could be given the ability to create gophers that could travel further). This could be a vital mechanism for controlling agent populations in a larger scale game and also provide a gentler learning curve for inexperienced users.

The Guessing Game collected responses that acted as a powerful descriptive connection to real-world locations. Future enhancements to the software could reinterpret this data in order to create more context sensitive aspects of gameplay. Through further analysis of locative content, it may also be possible to categorise spatial areas (for example, if numerous players are guessing the same words in one particular area). Similarly, it may be possible to identify areas depending on player type (players who share a particular interest may label areas in a certain way). This could provide enhancements to social aspects of the gameplay. It would be more difficult to include photographic and descriptive content in such analysis. One method of mitigating this problem could be to present the content to a second player who would examine the information and provide a response. The meta-responses, rather than the source content, could then be used in the analysis.

Finally, the advances in mobile and social technology since the trials are significant, as is the exposure of users to locative social applications in general. For this reason, a revisit of the Gophers experience using current technologies might also be a beneficial research exercise.

8.7.3. Future Research of Relevance to ItchyFeet

An area of future research in ItchyFeet is in allowing control over the scope of tags. To encourage exchange of this transferable social media across group boundaries, users need the ability to explicitly define the social scope of a tag. One method of doing so might employ a sliding scale of distribution distance, using either a social mnemonic such as specifying a maximum number of degrees of separation, or a physical measure such as spatial travel distance. In doing so, higher level user communities could be built around the more generic, geographic tags for example. The existence of spatial boundaries between users also hindered social tag exchange and as such, the ability to adjust spatial scope is another important factor. This was reflected by the isolated, individualistic tag style exhibited by users who interacted with the application at a distance from other trial participants.

Another aim is to find ways of measuring the external factors that influence users in greater depth, so these can be better designed for; since many of them were human factors and difficult to measure, future investigation might involve real-time experience reporting at the time of tagging [82] to more accurately track these. Also apparent throughout the trial was the way application use changed depending on the changing circumstances of users, which is particularly prevalent in mobile applications where a user's context can change rapidly. In many cases, new and unexpected methods of using the application emerged. One future area of research for social tagging applications is in implementing 'adaptive tag' support. These tags would better adapt to changing circumstances, presenting the user with information that is more relevant to their current state; and not just relying on location to determine this. The desire for such measures is exemplified by the fun/work tag categories discussed in section 6.5.4. Adaptive tags should also be aware of when to 'scale back' when no longer considered relevant or interesting; even the results of a medium term trial such as ItchyFeet yielded circumstances where users attempted to 'overwrite' redundant tags by dropping new ones on top of them. An important consideration of this future research is that tags should not simply be deleted and forgotten; there may be a point in the future where the social tag will become important to the social group again. Tags should be considered dynamic entities in a continual state of flux, a truly adaptive application should be able to recognise states of importance or redundancy and also identify which tags are more relevant to particular users than others. One way this might be achieved through monitoring group dynamics, user behaviour patterns [187] and external user influences, allowing the tag importance to take more or less presence as is appropriate, but future research should identify the optimal way to achieve this aim. This area comprises of numerous multi-disciplinary aspects, so the implementation of an adaptive tag presence system is nontrivial.

Throughout the trial, tags were treated with the same weighting, irrespective of whether they were repeated many times during the trial, or were obscure one off references (for example detailing a user's encounters with swans earlier that day, see section 6.5.3). One way to increase the weighting of the more commonly used, socially significant tags would be to ensure these have bigger boundaries so be more likely to take precedence. Another way to organise tags such as these would be to arrange them in a hierarchy, where depth is relative to the frequency of each (similar to the semantic word matching in the Gopher Guessing Game described in section 4.3), such as: “Lincoln → lincoln uni → architecture → oh look swans”. A way to represent this hierarchy in the browsing of tags and representation of user state could offer more meaningful indication of tag patterns and at the same time be more analogous to the often hierarchical geographic landscapes they are applied to. Two methods of organising these tags using grouping are now suggested.

Two improved methods of grouping tags have been considered for investigation in future research. The first is the concept of *extended group boundaries*. Many tags that were created in the ItchyFeet trials were repeated across different locations, in identical or similar forms.

Wider geographic tags were a common example of this, with tags containing the words 'Lincoln' or 'City', being recorded up to 20 times. The new technique aims to associate tags of similar semantic meaning into a single grouping, for improved representation of user status. These tags were non-specific and were relevant not only to the immediate area they were created in, but to the wider area as a whole. Extended group boundaries would extend the trigger area for these tags to include the entire geographic region they bound, as depicted in figure 8.1. As a result, mobile users could trigger these tag 'Lincoln' (from the above example) wherever they were located in the city boundaries. This trigger area would be labelled using a common thread to link the tags, or a tag cloud encompassing all the area tags. A challenge of tag grouping will be detecting which tags should be grouped and which should remain independent. Many tags exist which on face value may appear equivalent, but in actuality are interpreted by the group in different ways. Take, for example the tag 'home' and its variants, which was used multiple times by users. These tags were mainly used to identify an the author's home, so were interpreted differently depending on which user created it. They represent a single isolated location, so should be treat as separate geographic entities. Personal tags such as these would need to be carefully identified and excluded from any automatic tag boundary scheme.

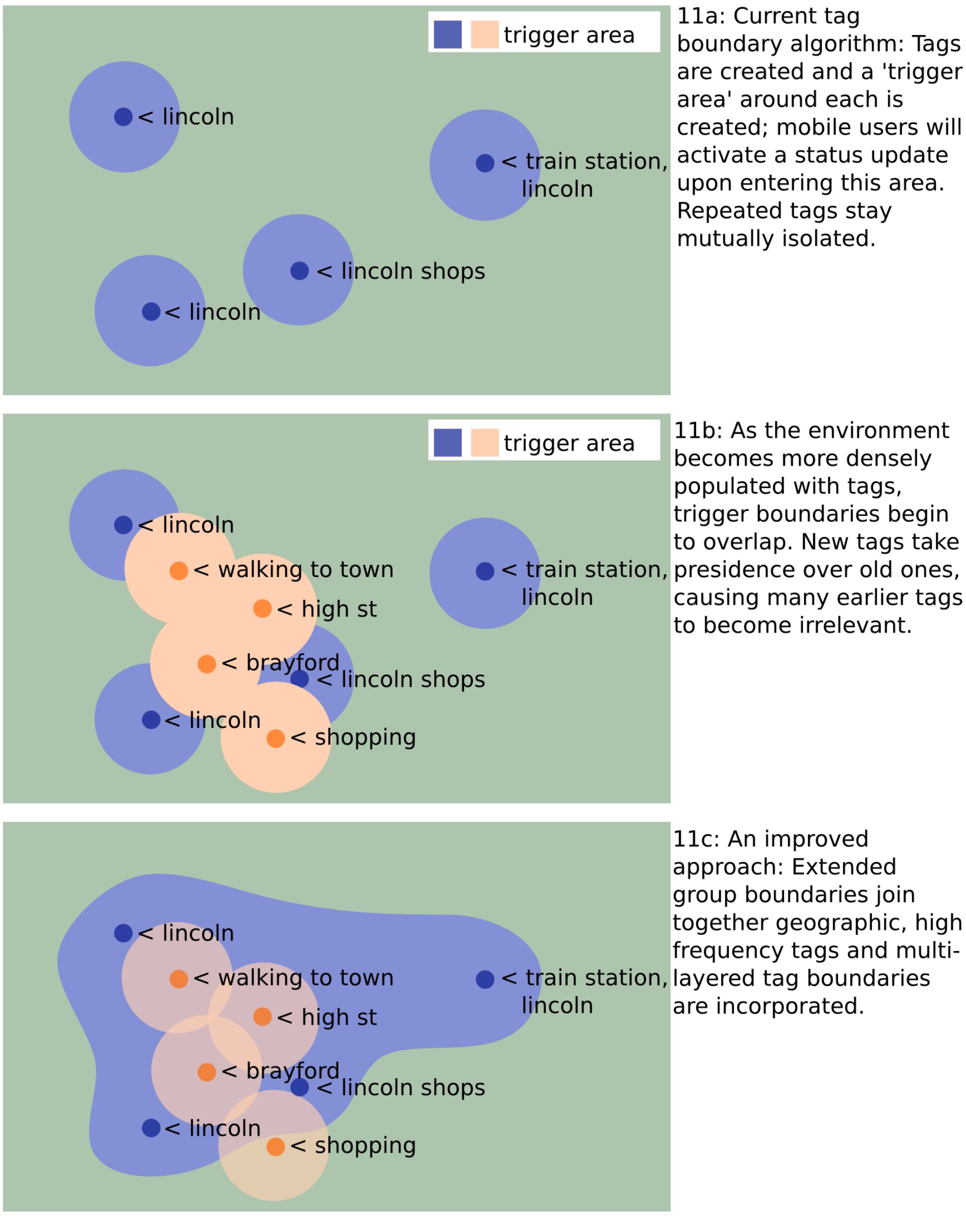

Figure 8.1. Proposed Extended Group Boundaries approach which would offer more intelligent grouping of tags. In this, high frequency repeating tags are joined to define a larger area.

The second approach is the use of *multi-layered tag boundaries*. ItchyFeet tag boundaries become overlapped as tag density builds up and the trigger areas of new tags overlap those of existing tags. When this occurs, the most recent tag is layered on top, in effect masquerading any tags below it, as depicted in figure 8.1. Users took advantage of this seam as a method to overwrite tags placed by others, as described in section 6.4.2. However, giving preferential weighting to newer tags could result in useful information being lost from the older tags they obscure – there is no clear computational way to identify which of the tag layers would be the most relevant. A proposed alternative approach would expose all applicable layers of tags as a hierarchy of descriptions. Either the whole hierarchy itself could be used to as an indication of the user status, or the user could select the preferred tag from the available layers. This could be graphically represented in the form of a tag cloud, with the larger tags representing the most location and temporally-relevant descriptions and smaller tags representing more generic, less location relevant identifiers, exemplified in figure 8.2.

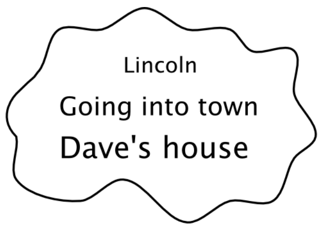

Figure 8.2. Proposed Multi-lateral tag representation, to solve problem of multiple tags at one location.

Other ways of visually ordering these tags could be found by considering additional factors, for example giving more emphasis to tags commonly selected by users, or by utilising further contextual measures, such as social surroundings, or time of day to emphasise the tags that are most representative of the user's current situation. Identifying these measures will be an aim of the research and establishing the optimal methods of weighting tags is an important basis to many of the applications discussed in section 8.6. User experience research should also investigate the preferred methods of conveying multilayered social tag data to users.

Another clear outcome of the trial that warrants additional investigation are the overarching themes and ongoing narratives that frequently connected the socially generated tags across users, time and space. Future research should place emphasis on identifying these themes and exploiting them as a way to categorise social tags and social media, for example ways of associating them together in the UI and how to make use of these relationships online. In hyperlinking social media that shares an overarching narrative, for example automatically connecting photos, messages and peers that shared an event, powerful new methods could be found of browsing associated media on online social networking sites and this would provide the basis a number of future applications discussed in section 8.6. Improvements in technology since the trial has made augmented reality a possibility on mobile devices [88] and this could also be investigated as a novel method to layer these ongoing narratives across the real world.

Finally, the status of non-application users is another fertile area of research. It is possible to assess the sociality and interactions of application users in detail, but little is known (or more often nothing) about the circumstances of non-application users and furthermore, determining co-presence of application users relies on them having the application running and a GPS lock. As a result of this, the discussion raised relating to social interaction behaviour, such as shared narratives and social events is based on observations of the presence of application users only. Additional data relating to the presence of friends and strangers who are not using the application (such as those in [111]), would make for a more complete analysis of the influence of the wider social population. This is something that the MobiClouds study began to assess and this work needs to be continued. Additional methods of including other users in the application might be gained from an investigation of the relationship between online observers and participant, which is currently a unidirectional one and was not fully utilised in the trials. One way to better engage online observers might involve offering two way communication between these actors; this might offer further benefit in allowing users to interact when physically distant from their social group.

8.7.4. Future Research of Relevance to MobiClouds

Many of the recommended areas of future research for ItchyFeet are also applicable to the MobiClouds study, but the results from MobiClouds people tagging were inherently more social. Over time, large graphs of social connections were built from the Bluetooth encounters that occurred in the real world while using MobiClouds, emphasised by the diagrams that evolved in section 7.3.3 and research needs to investigate how to make more meaningful use of this real-time social landscape. Many of the applications identified in section 8.6 focus on harnessing this knowledge for its human computing potential, taking inspiration from the concept of Crowdsourcing [106] and peer to peer content distribution [208][168]. Using real-world social networks for these purposes promises advantages over more static online social networks, since the data is dynamic, current and socially relevant. Future research should analyse how the ad-hoc social knowledge surrounding a user should be accessed; one notion is to send queries to these individuals in a viral manner in real time, where query range would be constrained by a maximum hop distance. Another research area that could enable these applications is in accessing proximal users as local services that can be discovered (by being proximal) and communicated with using a standard specification; where different resources are exposed depending on device abilities and privacy settings. A final focus is how automated responses to social queries could be mined from social networking profiles of users, to automate many trivial social networking queries and reduce the burden on users. A potential challenge in social knowledge research will in allowing real-world queries that scale well over very large graphs, as the popularity of people tagging grows.

Before these areas can be investigated, the underlying people tagging technology needs to be improved, to solve the problems of speed and tag repetition that occurred around large groups, identified in section 8.5.2.4. An investigation into improving performance using alternative sensor technologies such as ad-hoc WiFi connections is one focus of this, as well as looking at sensing relative distances of users to offer more situation aware indications of user activity. The studies also revealed a need to improve the frequency of people tags and research should investigate ways of offering more opportunities to create tags by: making it easier to identify which devices link to which people resulting in a reduced learning curve, implementing functions to create of social tags after an event has occurred and, offering automated tag and social event recommendations, using multi-hop tags to increase the range of tags in an environment, as well as making it easier to for users to engage with MobiClouds when physically distant from their peers. Another aspect of research should look at how to make use of the underlying device landscape more effectively and help users understand their digital surroundings by giving these devices some context, for example the rich infrastructure of static devices that exists and the enhancements that could be offered by associating Bluetooth devices with the social network profiles of users, as in [120]. Because the ethical issues in the trials were revealed to be significant, with users questioning who and where they could tag, investigations into the wider ethical and privacy issues of using these applications are vital for more longer term investigation, especially for non-consenting individuals; clear guidelines for how to use and who can be tagged by the system would assist users, as well as ways for users to easily access the tags that have been associated with them. One way this could be achieved in future iterations of the technology is by allowing unregistered users to manage tags by entering their Bluetooth address into the application web page. In addition, accurate methods of adapting people tags to differing personal situations need to be identified, similar to the adaptive tags suggested for ItchyFeet, to ensure the current tag pool better relates to a user's current surroundings.

Another expected direction of future research is the opportunities of using people tags in the area of social media filtering. One question is whether content could be filtered depending on the tags an individual encounters and the peers they socialise with. In the trials, people tags were used solely to indicate user status, but they could be used to indicate a number of things such as: the type of shared interests present, recent events the user has attended and activities they have participated in. An important area of future research is whether the tag histories built by users of MobiClouds like services can be thematically meta-analysed, to automatically build a social profile of their tastes and maintain this over time. Using this information, filtering algorithms could be generated for incoming social media, which would filter social network feeds to better relate to a user's current activity, delivering for example, new contact recommendations based on profile interests and recent events that peers have attended that might be of interest to the user. As well as offering new application opportunities such as those previously suggested, this could help with the very real problem of 'information overload' commonly associated with social media. In addition, research should investigate how these profiles could be used by authors of social media to aim their tag content at specific peer groups.

Since the people tags themselves are simple standalone entities that lack meaning in themselves, future research could investigate ways of using these to meta-tag other social media that is captured in the real world. The social tags generated in MobiClouds could also benefit existing web2.0 services. A research focus is how the logged social tag encounters could be plugged into existing applications. From the tags encountered, content filters could be generated for online social tools, such as last.fm, flickr, or amazon, allowing for profile filters, automated media tagging, updates and recommendations all based on social tag encounters in the real world. The creation of an open source web API allowing access to MobiClouds like social data sets would encourage developers to create plugins for these popular social media tools in a more mature people tagging system.

Finally, the MobiClouds trial has proven the concept of the technology and this identified general tag themes preferred by users, but overall, this data set was too small to form any meaningful tag trends over time. As such, richer data sets are needed before research can begin in these areas, which could be acquired from longer term trial periods, where a user's social patterns, activities and tag themes could be assessed over time. By doing so, it will be possible to assess whether the social tools built onto this technology are successful in taking advantage of a user's surroundings and tune their logic to perform optimally. Another aim for these more complete trials is to interpolate patterns from the themes, such as the sports a user likes, or exhibitions they have frequented; this data set would provide a basis for the aforementioned research on social content filtering. Collecting data from long term studies of people tagging should therefore be a core aim for future research.

8.8. Contributions

Mobile social networking software, or MoSoSos, have recently emerged, which offer an additional social layer over the everyday world, in the form of presence updates, friend finders, local services and other applications. Presently a lack of understanding exists regarding real world use of this technology and the aspirations of end users. This thesis contributes to this knowledge by offering the first study, in subjective detail, on how users typically exchange social media in MoSoSos and more specifically, in mobile check-in services, through analysis of three experimental mobile social trials. The recent proliferation in the use of mobile check-in services adds further worth to these investigations.

There are a number of caveats to the contributions that are made in the thesis. Firstly, the findings are based upon trial observations that were restricted in scope, in terms of the number of participants, trial time and geographic locations. As such, they cannot be statistically proven in their current form. Secondly, there are significant ethical issues regarding the monitoring of non-application users and these would need to be considered in any large scale deployment of the technologies. Finally, without careful implementation, these technologies could risk an increased digital isolation for those parts of society that are already technologically disconnected.

More specifically, the thesis has presented a number of caveats for designers of MoSoSos, as well as suggesting directions that future researchers should take to enhance these tools. It demonstrates how users naturally want to relay their social network status, using semantic tags. It identifies the naturally emerging high-level narratives and themes that govern these social tags, in many cases developing in a social way themselves. Finally, it shows that user interaction changes depending on personal circumstances and also upon the underlying choice of sensor technology (ie. locative or person tags).

Furthermore, by studying the actions of trail participants, the research has identified the external factors that affect users when creating and interpreting social media. It is intended this knowledge will be applicable to the wider world of MoSoSos, allowing them to be better designed to meet the needs of end users. The thesis also contributes three mobile social technologies to the area, each containing novel elements; (i) Gophers: a game based on mobile social media and virtual 'social agents', (ii) ItchyFeet: a collaborative geotagging and presence sharing service and (iii) MobiClouds: a collaborative tagging and presence service, based around the concept of 'people tagging'. In addition, it contributes numerous important research findings regarding the exchange of social media within these scenarios, which are summarised in section 8.2.

Finally, the contributions of the thesis reach beyond the three featured applications – having wide implications for the areas of mobile social software services and HCI more generally. The findings could inform the way users interact with such services, for instance the exploitation of higher level social themes could lead to the creation of novel user interfaces for social networking. Various further areas where the research findings could make a contribution have been suggested, along with areas where the application concepts might be reused, including: tourism, sport, crowdsourcing, social media distribution and social gaming.

8.9. Overall Summary

This chapter has identified the main findings of the three dissertation studies; Gophers, ItchyFeet and MobiClouds and in doing so, has assessed the original research aims specified in chapter 3 and provided a guide for designers of similar MoSoSos. It has discussed some of the main limitations of the studies, in terms of the trial methods employed, the enabling technologies utilised at the time of the trials and drawbacks of the software developed. The social media recorded in these systems was fundamentally affected by positioning data used and the studies have focused on two types of locative tagging and a novel people tagging method. Use of these social technologies is notably different depending on whether users were co-present to their peers, or interacting at a distance. The narratives and discourse that developed over time between users of the studies became an ingrained part of the social media they created and acted as a higher level meaning to the content.

The three mobile trials were designed to be as pervasive and unobtrusive as possible, by being mobile phone-based, integrating into existing social networking tools and retaining an open-minded approach over how the applications should be used. Through doing so it has been possible to remove ourselves from the investigation of a narrow, application-specific mobile content sharing system, such as those based on geotagged photos or mobile blogging, and thus minimise the influences of application theme, design and mobile development over the results. The results can therefore be considered a more general purpose guideline for tagging behaviour in MoSoSos generally.

In addition to the implications for MoSoSo design, there are numerous related application areas that could benefit from the unique technologies that have been developed; a number of important future applications have been suggested that could make use of the technologies in the areas of tourism, leisure, web2.0 and others. The chapter concludes by recommending some near future directions that mobile tagging research should take.

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During the course of the dissertation, mobile social media has made the transition from a niche to everyday technology. As a result, the research findings acquired are even more relevant today. This research has provided the initial steps of this investigation, with a focus on the area of social tagging. It is expected that continued exploration in this, and related areas will become simpler, yet increasingly vital, as users become more frequent adopters of these technologies in coming years.

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