

If you build it, they will come

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Abstract. In 1991, Mark Weiser [11] first introduced the concept of pervasive computing and in his vision computers became “invisible”, integrated into the fabric of everyday life, allowing “people to live through their practices and tacit knowledge so that the most powerful things are those that are effectively invisible in use.” Today, this goal still eludes the research community and pervasive systems which offer seamless user experiences have not been fully realised. More specifically, pervasive systems are largely confined to indoor laboratories or urban city-centre “test-beds” in which only a subset of the lifestyle of an individual is considered. In this paper, we describe an initiative at Lancaster University which is in the process of establishing a multi-regional pervasive infrastructure and which leverages recent research on spontaneous and autonomic networking in order to move closer to Weiser’s original vision.

1 Introduction and Motivation

The promise of pervasive computing systems in which users are able to access information and services seamlessly whenever, wherever independent of location, device or communications mechanism is still, it seems a distant goal. This research area encompasses such a wide range of disciplines (ethnography, human centred design and HCI, networking, mobile and distributed computing) that it is often difficult or impossible to think outside our specific research domains in order to move towards the more general goal of “invisible” computing. What is common is that, as a research community, we become too heavily focussed on overcoming the technical challenges faced within each of these sub-domains. Furthermore, these technical challenges are often addressed within small prototype implementations or laboratory experiments, without involving real users or evaluating the scalability factors relating to a real-world system deployment.

Despite the recent improvements in developer tools, smaller, cheaper and more powerful hardware devices and richer platforms, designing, deploying and evaluating complex systems is still very hard. The progression away from the desktop toward seamless information and services which significantly impact our daily lives is not yet upon us and we believe long term user trials and studies are the key to this progression. Furthermore, spontaneous or ad-hoc communication between users who may be utilising heterogeneous devices and communications infrastructures is not easily sup-

ported since this requires aspects of discovery and self-organisation at the application, device and also the communications level. A significant challenge arises when one offers users the seamless delivery of digital content over heterogeneous communications infrastructures which comprise of multiple autonomous domains (such as 3G/Wireless/xDSL) using self-organising techniques.

Within the pervasive research community, it is often assumed that a ubiquitous network infrastructure exists which offers reliable and scalable communications. We contend that this assumption is misplaced and that not only is the current state-of-the-art in networking unable to offer *seamless ubiquity* but that the network research community is largely unaware of the real requirements of pervasive users and applications.

In the remainder of this paper we present Lancaster University's latest initiative which aims to establish the *real functional requirements* pertaining to software systems capable of supporting spontaneous communications based on *user studies* and *empirical evaluation*. More specifically, we believe that user studies and ethnographic research should play a more central role in future systems developments and, by making these implicit within in the overall design process we aim to directly inform and better dictate the research direction more strongly.

This research project leverages our past successes on projects such as GUIDE [3], CASCO [2], Equator [5], LandMARC (Lancaster and Microsoft Active Research Collaboration) [8] and the Mobile IPv6 Systems Research Lab [10]. One of the primary aims is to develop a pervasive platform which will bridge the gaps between the physical world in which we live and the digital environments in which we so heavily rely on. Moreover, along with our industrial partners, this initiative will target a wide range of both urban and highly rural locations covering indoor and outdoor environments (such as home, work, public spaces, community spaces and users on the move) and is based on the assumption that users spontaneously move between digital content, platforms and heterogeneous communications infrastructures through out the course of a normal day. The challenge will therefore be to enable seamless navigation between public and private sector content through the use of self-organising techniques within both the end-devices and the network infrastructure without placing unnecessary burden on an end user.

2 Previous Experience

Lancaster University has been at the forefront of developments within the mobile, distributed and ubiquitous computing fields since the early 1990's and the following projects briefly highlight our track record in these areas:

The GUIDE Project: Context-Sensitive Mobile Multimedia Support for City Visitors and City Residents was concerned with the challenges of developing, deploying and evaluating a context-aware tourist guide, capable of providing roaming city visitors with dynamic and context-sensitive multimedia information in an outdoor environment. The GUIDE project is regarded as the most significant application of its type to consider both the technical challenges of cell-based wireless networking and

positioning and the varied human factors and interaction issues relevant to its design and use [3].

The Equator project: Technological Innovation in Physical and Digital Life is an IRC (Interdisciplinary Research Collaboration) project involving eight U.K. sites including Lancaster [5]. The central aim of this project is to uncover and support a variety of possible relationships between physical and digital worlds through the utilisation of novel technologies. The Equator project is supporting the development of ubiquitous computing test-beds across member sites in order to support research into new application areas and to further understand appropriate evaluation methodologies.

CASCO: Context Aware Support for Cooperative Applications in Ubiquitous Computing Environments (CASCO) has explored the potential for utilizing ubiquitous computing technologies for sharing context. A major contribution of this project has been the 'Hermes' deployment of office door displays within the Computing Department [2]. In common with GUIDE, the design and deployment of this system has focussed on both technical and human factors challenges [7].

Mobile-IPv6 Systems Research Lab: This is a unique research network infrastructure for the design and development of next generation mobile network protocols, services and applications. Funded wholly by Cisco Systems, Microsoft Research and Orange, the primary aim of the project was the provision of an operational Mobile IPv6 network environment across the University campus, city centre (including local parks) and residential areas [10].

Autonomic Content Delivery Networks (CDNs): The main aim of this project is to investigate the benefits and suitability of the use of techniques for self-organization in CDNs. The use of self-organization is currently being studied within both the control plane and data transport plane of CDNs, as well as a technique for flexible content management. The central thesis of this project is that autonomic overlay structures and content management can not only improve the reliability and efficiency of CDNs while reducing their management overhead, but also extend their application spectrum by, for instance, transparently supporting streaming media to mobile users or providing interactive multimedia applications (e.g. video conferencing).

Local Loop Unbundling (LLU): Lancaster University is currently engaged in an initiative to offer last mile high speed broadband (24Mbps) to users in the North West of England. Lancaster University is the first and only University in the United Kingdom to hold a telecommunications license. As a result, Information Systems Services (ISS) now have the ability to install equipment within BT telephone exchanges within the region, and control the local loop circuits out to homes and businesses (known as Local Loop Unbundling (LLU)). Based on this, ISS are beginning the process of providing ADSL services out to a subset of University staff and students, as well as local businesses.

Lancaster University has gained significant understanding relating to the design, deployment and evaluation of research prototypes and also has extensive experience in deploying and managing a production level regional networking infrastructure and we aim to use this to our advantage throughout our current initiative.

3 Current Initiative

3.1 Overview

In order to fully explore and ultimately address the significant challenges faced when considering pervasive and spontaneous computing environments, a crucial part of our current initiative is a *large scale deployment* and *user trialling* of software systems and services. More specifically, we aim to create a truly pervasive infrastructure across the North West of England giving users access to multiple communications technologies across at least 1000 sites. This will differentiate our research from both our own past projects as well as others which have typically been laboratory based or centred around isolated urban test-beds [3], [6], [10].

Our pervasive infrastructure will provide a live (production level) platform on which to carry out both systems-level and human factors evaluation. Our qualitative ethnographic studies, user centred research methodology and ongoing analysis will be used to inform continued architectural design and systems development.

At present, our focus is centered on two key areas. Firstly, we are in the process of *enabling* users with broadband technology that will support their daily activities within a home environment, working environment and also while on the move. Secondly, we are in the process of attracting new users to our trial and beginning our ethnographic studies of these and existing users. A significant amount of effort has been exhausted to provide users with access to our infrastructure. This is being primarily achieved through the deployment of ADSL services and 802.11b technology which interconnect to our regional 10Gb backbone network [1], [4].

3.2 ADSL Services

Our LLU rollout is currently focusing on over 110 telephone exchanges within the Lancashire and Cumbria regions with 48 currently delivered. Our LLU activities are directed at offering ADSL2+ services which can offer subscribers up to 24Mbps (depending only upon the line length between subscriber and telephone exchange). A connection which affords this level of bandwidth capability will enable the use of multimedia applications and services such as high quality video content distribution (e.g. streaming educational content such as lectures and seminars), VoIP services, community based TV and multi-party video conferencing.

3.3 Wireless Services

Lancaster University maintains and is continually expanding its extensive wireless network which currently spans the University campus, the city centre of Lancaster (including Williamson Park and several residential areas). Wireless networking is

also available within a small rural village called Wray located approximately 10 miles from the city of Lancaster with a population of less than 500. Delivery of wireless to the village has been made possible through a 3 year University funded project that is looking at resilient networking. During summer 2004, we deployed a number of devices known as Meshboxes [9] and are currently investigating their ability to provide a reliable network infrastructure to the community at relatively low cost. This infrastructure is being used to study the impact of failure across parts of the mesh network, as well as developing ad-hoc routing protocols to try and improve the resilience of the network within the village.

At present, we are constantly monitoring the Wray MESH network in order to establish usage patterns from the residents and businesses connected. In addition, we regularly carry out stress tests in order to determine the performance and reliability of the MESH infrastructure, the results of which are freely available on our Wray project web site [12]. During the Wray fair¹ this year we installed a number of web cameras within the village in order to feed live images of the scarecrow festival directly to the Wray web site.

As a result of the Wray Broadband project, both the Management School at Lancaster University and the BBC are currently studying the life-changing impact that broadband has on individuals and small businesses within the village. The BBC carried out initial surveys and interviews in October 2004 and returned to the village in March 2005 in order to conduct the second phase of their ethnographic research.

To support users on the move, we are making use of both GPRS and 3G telecommunications technology in conjunction with our partner France Telecom Research and Development who already provide 3G coverage around the city of Lancaster [10]. France Telecom are the umbrella company for both Orange and Wanadoo Broadband and the aim is to develop high quality digital content that can be delivered across multiple networks and viewed on multiple devices. This is a key area for our research and will allow us to fully explore the notion of convergence, that is, how to autonomously manage the existence of multiple autonomous domains (such as 3G/GPRS/Wireless/xDSL) using self-organising techniques.

4 Conclusion and Future Work

In this short paper we have introduced a new initiative at Lancaster University which aims to address the salient challenges when considering pervasive environments. More specifically, we presented our research to date which is currently in the process of deploying pervasive networking infrastructure across the North West of England.

The paper described how we are currently using ethnographic studies to determine how users are making use of Broadband and wireless technologies within their daily lives and this will be critical as we move towards an inclusive design process.

The aim is to establish the largest European pervasive infrastructure and user community to date from a range of cultural, social and geographic communities

¹ <http://www.wrayvillage.co.uk/scarecrows.htm>

(across North West region of England) building on our previous experience with deploying and evaluating campus and citywide infrastructures.

From a systems perspective we are interested in how we can develop an 'autonomic' open-platform to support pervasive communication. More specifically, this will focus on self-organising techniques at many layers, ranging from the underlying networking support necessary to migrate between communication technologies, through to the 'virtual handshaking' service required as users move between private and public sector content. A significant challenge for our platform will be to bridge the gaps between: physical and digital environments; public and private sectors; urban and rural locations; delivery and retrieval of multimedia content; 'published' and community generated material.

Additionally, we aim to create open source 'platform agnostic' authoring tools that will exploit the services offered by our architecture. Furthermore, we will explore the delivery of personalised, context-aware content and access to interactive services across multiple platforms and devices irrespective of the communications infrastructure.

Finally, we are currently actively seeking new industrial partners and academic institutions to join our initiative. We invite others to use our infrastructure for testing purposes in order to continue to drive the research forward and move closer to Weiser's original vision of *invisible* computing [11].

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