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Abstract

The cellular revolution has been accompanied by a gradual evolution in functionality. The Motorola handie-talkie introduced in the early 1940's was a five pound behemoth that barely worked. Contemporary phones have become ubiquitous devices that are outfitted with camera, video, GPS, internet and e-mail. Fourth generation phones are expected to provide high speed internet access for data as well as multi-media through protocols that subsume existing standards. Beyond this, the capabilities of 4G phones have not been spelled out in detail. In this paper we outline our vision of a feature rich next generation phone that is backed up by an infrastructure of service offerings.

Keywords

4G client, 4G networks, mobile computing, supporting the mobile professional

1. Introduction

Since its introduction in the 1970's, the mobile phone has become an indispensable item of equipment to the mobile professional. When the device was introduced, it was barely functional. Current generation phones are able to provide internet, driving directions and email access among other features. The mobile phone has potential that extends well beyond internet and email access. An employee repairing a plane should be able to see the drawing of the relevant part, as a display through a wireless connection on his/her visor. Third generation phones such as the iPhone offer promise of such technologies. This functionality requires a more advanced design of the cellular client, integration of the cellular infrastructure and an added layer of service offerings. However, there have not been any cohesive efforts to study and elaborate on 4G features.

At the present time device functionality is limited by a number of factors including CPU capabilities, power requirements and type of transmission used. Carriers are based on many competing standards including the outmoded AMPS (Advanced Mobile Phone System), TDMA (Time Division Multiple Access) based GSM (Global Standard for Mobile Communication) and CDMA (Code Division Multiple Access). These competing standards present an obstacle for packet based data transmission because of differences between carriers. Not surprisingly there are few service offerings by vendors beyond texting and ringtones.

Industry observers expect that this situation will be remedied in the next generation. In the fourth generation it is expected there will be a convergence of standards between TDMA, WCDMA and the internet. Proposed 4th generation networks such as Long Term Evolution (LTE) are purely IP (Internet Protocol) based. It is also expected that the client will be free from power constraints. In this paper, we outline the vision for a feature rich next generation phone and discuss a service architecture to supplement it.

2. Evolution of cellular functionality

The cellular revolution started with Motorola developing the “Handie-Talkie,” in the early 1940’s. The H-T as it was called was a two way portable radio for the U.S. Army Signal Corps. The device weighed five pounds and had a range of 1-2 miles. Its sole function was communications but the device was barely audible. Cellular service was introduced soon after the war, but service was spotty due to oversubscription and limited range. The huge demand led AT&T to lobby the Federal Communications Commission (FCC) for allocation of frequency spectrum. Finally, in the 1970’s, the FCC allocated frequencies in the range of 800-900 Mhz for cellular communication. The frequencies were re-used by dividing the service area into cells. The concept was tested by researchers at Bell labs, two decades later when they implemented the cellular system on Amtrak’s metroliner. It allowed passengers travelling between New York and Washington D.C. to make phone calls. However, it was not until the 1980’s that the cellular concept became fully commercialized.

Table 1 summarizes the evolution of cellular functionality. As shown in the table, early technologies were analog based and could support only voice transmission. The focus was on supporting multiple users by assigning them channels within the 800-900 MHz part of the spectrum. By the Second Generation, they evolved into two competing standards, GSM and CDMA. GSM divides the available bandwidth into time slots using TDMA while CDMA assigns codes to cellular users, allowing them to share the same frequency. This increased channel capacity allowed data transmission in addition to voice. Short messages could be transmitted, leading to SMS service offerings by cellular vendors. Packet switching in the “2.5” generation further increased the capacity. Speeds of up to 100 Kbps were made possible. In the third generation, there is a trend towards integration. CDMA evolved into CDMA2000 and TDMA into WCDMA. These technologies are more compatible with one another; provide higher speeds and internet access. The recently introduced Apple iPhone characterizes this generation.

It is expected that in the 4th generation, integration of standards and integration with internet will continue to occur. Cell phones will take advantage of wireless infrastructure whenever possible, for faster data/voice transmission. Coupled with more powerful hardware, a major paradigm shift in functionality is possible. Many envision the cell phone as a ubiquitous device that can serve as a mobile desktop (Amaravadi 2003, Weiser 1993). To fulfill such a role the cell phone needs to be backed by a network infrastructure to deliver necessary capabilities.

Gene-ration	Time Period	Technology	Features
0G	1920s-1940s	Portable radio system.	Half duplex communication.
1G	1970's-1980's	Analog Cellular (AMPS).	Two way communication enabled by bulky devices.
2G	Early 1990's	Time/Code division multiplexing (TDMA/GSM, CDMAOne).	Digital voice, data (9.6 Kbps), SMS.
2.5G	Late 1990's	2G plus GPRS for sending packet switched data.	Enhanced voice/data (100 Kbps), SMS.
3G	2002-Present	Integrated CDMA (CDMA2000, UMTS/WCDMA) for voice and text, high speed.	Consumer electronics, PDA, phone, email, fax, MMS, web access (760 Kbps – 3 Mbps).
4G	2012?	WiMAX, Integrated, web-enabled, CDMA standard?	3G with high speed internet (100 Mbps), desktop access (?).

Table 1. Evolution of Cellular Technologies and Features (Koilpillai 2003)

3. A review of current generation phones

"The road to the fourth generation passes through the third generation" (Cavalcanti et al. 2005). Our quest for the 4th generation phone starts with capabilities of the current generation. 3G smart phones are increasingly becoming popular among business and individual consumers. According to a recent report, smart phones accounted for nearly 15% of the total mobile handset sales in 2007 (Bemisderrer & Lerro 2008). The hardware is not very powerful by desktop standards. The iPhone has an ARM processor capable of up to 700 Mhz with 128 MB of RAM. These phones use a number of different operating systems including Symbian, iPhone OS, Blackberry and Windows Mobile (see table 2). All of them support viewing of standard file types such as "Word" and "PDF." In addition to providing traditional phone service, 3G phones also provide access to personal information management resources, PDA tools, e-mail, and World Wide Web. QWERTY keyboards allow data entry for users. Most of the current generation smart phones are also GPS (Global Positioning System) enabled. Support for Wi-Fi and Bluetooth is another feature of the smart phone. They are even equipped with heuristics for selecting the best connection when multiple alternatives are available.

3G phones provide many innovative features to help employees on the move, but their support for corporate IS resources is limited. Limited access to data/files is enabled through special software applications. Edit capability for documents is still limited. Blackberry has dedicated features for accessing corporate business applications such as customer response, business intelligence etc. These applications are enabled through special software residing on the servers.

The expansion of functionality for the next generation will require special features in the client as well as in the infrastructure, which we describe subsequently.

Phone	**Blackberry Bold**	**iPhone**	**Nokia E90**	**Samsung Omnia**
Technical Specifications				
Keyboard	QWERTY	Onscreen QWERTY	QWERTY with notebook style	Onscreen QWERTY
Operating system	Blackberry	iPhone OS	Symbian	Windows Mobile
Cellular connectivity	GSM	GSM	GSM	CDMA/GSM
Wireless Connectivity	Wi-Fi, Bluetooth	Wi-Fi, Bluetooth	Wi-Fi, Bluetooth	Wi-Fi, Bluetooth
GPS	Yes	Yes	Yes	Yes
Memory	128 MB	128 MB	128 MB	128 MB
Business oriented features				
Productivity tools	PIM, Organizer	Widgets	Notes, calendar,	Contacts, Calendar and Tasks
E-mail- push	Yes, with Enterprise Server	Yes, with Yahoo mail	Yes, Nokia software	Yes
View File types	Text, Word, Excel, images and PDF	Text, Word, Excel, images and PDF	Quickoffice tools with editors	MS Office suite view and edit
Web browser	Yes	Yes	Yes	Yes
Corporate data access	Yes, with add-on services modules	Not mentioned	Not mentioned	Yes, with third party applications

Table 2. Feature comparison of Smart Phones

4. Relevant literature

Achieving 4G cellular requires addressing many issues, which are conveniently grouped into those that are related to: 1) client itself, 2) integration issues arising from existing carrier infrastructure and 3) additional infrastructure for providing services.

Mobile computing has assumed importance after the third generation, since prior to that emphasis has been only on communication. It fits in with the concept of ubiquitous computing which attempts to develop devices that can interact with other devices on an adhoc basis (Weiser ‘93). Along these lines, there has been some work in adapting the interface to meet the demands of mobile professionals. Dynamically changing the format of data (Lehtonen et al. 2006, Aleksy et al. 2008) and redesign of the interface for mobile data entry (Pascoe et al. 2000) are examples of this type of work. There has been some research on clients in the areas of data caching policy algorithms and protocols for multi-media access (Masonta et al. 2008). Device interfaces such as Wi-Fi have made seamless data transfer possible. However very little of the work addresses device functionality which we attempt to propose here.

4G involves seamless integration of internet with existing cellular networks, some of which could be 2/2.5 G. Integration issues arise at the device level, network level and application level. Devices must be enabled for a number of protocols such as mobile IP, WiMax, GSM etc. Some present devices already have this capability. At the network level, important issues are security, integration, mobility management and bandwidth. Maintaining security in wireless environments requires sophisticated approaches to security such as use of dynamic authentication keys, router authentication and parasitic authentication (Patel & McCubben 2005, Chalmers and Almeroth 2004). Much work is devoted to integrating cellular, wireless LANs and ad hoc networks (Brewer & Katz 1998, Cavalcanti et al. 2005). Mobility management, i.e., managing connections and handoffs, becomes an issue when internet gateways are not directly reachable. Algorithms have been devised for path selection, but these issues are too complex to be discussed here and are not of interest in this paper. At the application level there is some work on client architectures for mobile applications such as workflow, knowledge management (Pascoe et al. 2000, Davis et al. 2006) etc. There has been very little research into the service infrastructure requirements. Zhu et al. (2005) highlight a number of factors in creating a service infrastructure such as naming, registration, discovery etc. that are very pertinent to 4G carriers. Unfortunately very little of this work addresses 4G functionality.

5. Anticipated features of the next generation cellular client

The nature of cellular communication and its evolving architecture require many considerations. The devices are small and subject to vagaries of the medium. Extensions to functionality will require more power or more streamlined hardware. Device usage is so widespread that security, archival and provision of cellular services require special considerations. Finally, the integration of internet and cellular infrastructure and the uncertainty surrounding next generation technology are added desiderata. Here we will attempt to specify some basic parameters that we expect to be part of 4G phones.

5.1 Hardware will be adequate to the task

Hardware is key to achieving 4G functionality -- more powerful hardware requires a more robust power source; a tradeoff exists between operating time and hardware capability. By some estimates, desktop functionality requires processors that are three times more powerful than those in existing phones. Solutions range from better power management to using solar energy to using microwave power. We will assume that this challenge is surmounted.

5.2 Dynamic interaction mode

Mobile users could be in different situations and contexts that place restrictions on the mode of interaction. For example, in bright sunshine or on the beach, display screens are difficult to read. Similarly, in places where a user is in close proximity to other people such as in trains, visual displays are not expedient. The interaction mode is also dependent on the application. Some applications such as editing a formal report do not lend well to voice commands while dictation is a natural voice application. Thus interaction mode must be capable of being switched dynamically subject to certain constraints.

5.3 The device will be "context aware"

Context awareness is the ability of the device to sense its location and usage mode. This is a requirement for location-based applications such as driving directions or emergency services. Some 3G phones provide this facility. Security and interface settings will partly depend on the context. In our view, context awareness involves intelligent location sensing such as the ability of the device to detect if its owner is in a train, in his/her office or on the beach. Such features could be built around motion sensing and GPS technologies embedded in the devices.

5.4 Security Settings will be dynamic

In current devices, security measures include signal encryption and device level authentication which is performed at the Switching centers. Desktop access requires more elaborate measures which may interfere with the so called "lifestyle" enabled by mobile phones. There is a tradeoff between security and performance that users ought to be able to make. Built-in, dynamic security features together with user controllable options are required to achieve a middle ground.

5.5 The device will provide desktop and specialized services in addition to traditional services

As evidenced by the evolution of cellular services, the trend is to provide personalized services in addition to basic communication. The next generation phone will provide traditional services and other services that we have classified into three overlapping categories, based on function: "Utility," "Desktop/device," and "Domain." Utility services include maps, news, weather etc. Internet access is a necessary component here and access to microwave power is a possibility. Desktop/device services include access to files and devices. Typically, desktop devices will be a subset of domain services although this may not always be the case. Domain services will encompass those services ("get rate quote," "add new customer") provided by the enterprise managing the domain. A company such as State Farm could hypothetically allow its employees to access a customer database and request an addition. For both carriers and clients, location of the service is important. If the user is in proximity to the service, it is said to be a local service, while those that are geographically distant are considered remote. It would be advantageous for the user to know what services are locally available without special search. Local services (or coded proxies) can be broadcast on a special channel.

6. An architecture for the next generation mobile phone

An integrated architecture for the Next Generation Mobile Phone (NGMP) is shown in Figure 1. The NGMP is based on the client server architecture for two obvious reasons. First, client resources are conserved by making use of server resources whenever possible. Second, the client/server architecture allows a number of different services to be offered in different locations by different vendors. Here we discuss the client architecture first.

6.1 Client Architecture

As shown in the figure 1, each mobile device has a *client agent* that performs a number of functions in support of desktop operation. These include security enforcement, protocol management, session management, archival etc. These functions are briefly discussed:

Interface Management – This is the module which governs the presentation of information according to device and usage contexts. The presentation mode could change from visual display to voice and vice versa depending on the situation or user preference.

Context Identification -- The context identification module will use a number of tools including GPS and motion sensing to make intelligent decisions regarding security and archiving. It will utilize rules such as: "If user is in public place, security level = high" to govern system defaults.

Protocols – This module carries out necessary protocols to establish/terminate a session. They include those that are part of connecting to the communications infrastructure (example, connecting to a broadband network) as well as those related to service access (example, authentication to a Directory Server).

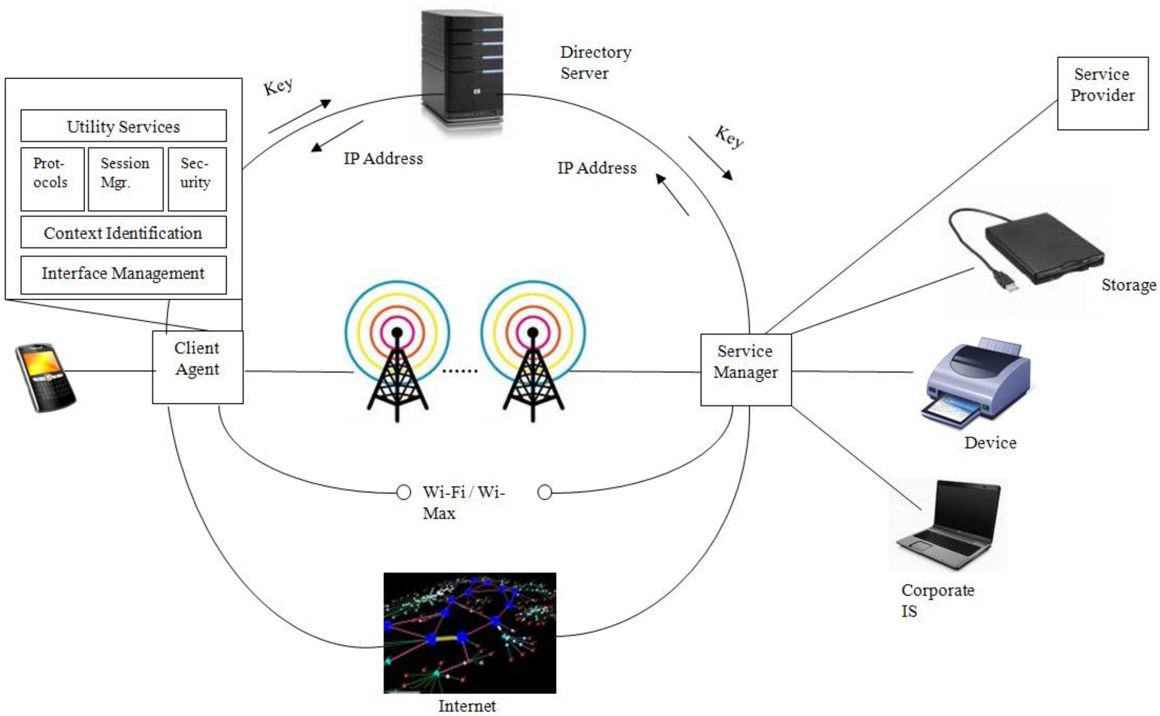

Figure 1. Integrated Architecture for the Next Generation Mobile Client

Session Management – This module performs dynamic management of interface, security and archival. It will adapt these to the usage context. For example, if archiving is requested by the user, the various states of the session are saved. In the event of an interruption the session is restarted from the archive

Security – This module manages device security, keys and IP addresses. These are stored in encrypted form and disabled if the device is lost.

Utility – This module provides direct access to services such as radio, traffic, alerts and help in emergencies.

Archival – The interruption of service is a nuisance in current phones. To ensure reliability, any business usage will require buffering of communications as well as archival of important documents. This module saves a session during usage. The settings are governed by the user.

Conventional functionality such as directory, camera, video has not been shown for brevity.

6.2 Service architecture

Figure 1 also illustrates the service architecture. The main features of the architecture are: 1) Client Agent, 2) Directory Server, 3) The heterogeneity of the network (will not be discussed), 4) Service Agent, and 5) Diversity and multiplicity of service offerings (will not be discussed).

The *Client Agent* which is part of the client architecture is located inside the device. It can be thought of as the manager of other modules. Service features are activated when the user presses the "Services" button on the cell phone. The main functions are to access the service infrastructure and to negotiate the necessary keys between the directory server and the human user.

Directory Servers are somewhat analogous to the concept of DNS/root servers on the internet. Their purpose is multi-fold: 1) to authenticate the client, 2) to hide services from clients (until authentication) for purpose of security and 3) to serve as an agent for service registrations.

Service Agents manage delivery of services. This involves: 1) carrying out a second authentication, 2) actually allowing access to the service, 3) managing billing and 4) especially in the case of information services, to provide additional support (such as audio format of text).

The mobile client is thus a gateway for desktop and other services. For this role, it requires a number of special features such as interface management, context identification and the ability to perform Wi-fi and other protocols. These have been duly incorporated into the architecture.

7. Conclusions

The cellular phone has evolved rapidly in the last decade but its potential for mobile support is largely untapped. Smart phone technologies have whetted consumer's appetites for devices with PC-like power and versatility. The notion of a mobile phone with ubiquitous computing capability will drive device manufacturers and carriers alike to innovate and develop advanced devices and networks. We researched state-of-the-art on next generation cellular technologies and proposed a possible architecture for visualizing them. A large number of issues remain unaddressed. These mainly deal with standards for: network integration, inter-device protocols and services. The proposed architecture is a starting point for addressing these issues.

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