DESIGN CHALLENGES AND COMPLEXITIES OF FUTURE MOBILE PHONES FROM EMBEDDED SYSTEMS PERSPECTIVE

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The Award of the Degree of

MASTER OF TECHNOLOGY

IN

COMPUTER SCIENCE & TECHNOLOGY

By

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Dedicated to :

My Beloved Parents

For their unfailing love and selfless sacrifice.

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CERTIFICATE

This is to certify that the dissertation entitled **"Design Challenges and Complexities of Future Mobile Phones from Embedded Systems Perspectives"** which is being submitted by **Mr. Paominlen Haokip,** to the School of Computer and Systems Sciences, Jawaharlal Nehru University, New Delhi for the award of **Master of Technology** in **Computer Science and Technology,** is a record of bonafide work done by him under my supervision.

This work has not been submitted in part or full to any university or institution for the award of any degree.

12/8/05

Dean
School of Computer
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System Sciences

(Prof. C.P. Katti)
Supervisor

Declaration

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Date:

Prof. C.P. Katti
(Supervisor)

Acknowledgement

At the outset, I thank God for the opportunity to learn new things, especially in the field of pervasive and ubiquitous computing and smart phones in particular. New challenges and technological advancements that I began to encounter with my research work are really amazing and worth studying, pondering and learning.
I thank ***Professor CP Katti****, my supervisor and* ***Professor PC Saxena*** *for their sincere guidance and timely advice.*

The cordial and intellectual atmosphere of the university offers much more than mere knowledge. Great values like love and respect for one another and peaceful co-existence despite cultural and geographical origins, I believe, have transformed many of us into better human beings. With this regard, I express my gratitude to all my Professors, batch mates and friends for their help, wisdom and co-operation.
Special thanks to members of JNU –KWS prayer cell for their prayer support.

(Paominlen Haokip)

ABSTRACT

The ubiquity of mobile phones with all the functionalities of PDA[©] belongs to the third and fourth generation in the history of mobile phones, namely the future mobile phones or the smart phones. These smart phones[*] have been referred to as the first platform for Pervasive or ubiquitous computing since they are capable of achieving wireless mobile access to various computer systems and information-based services from almost everywhere in the world. Various standards like WAP[®], UMTS [G12], GPRS[□], Bluetooth or IrDA have been created by large cross-industry initiatives, defining the necessary communication protocols as well as the underlying physical connections. GPRS is the beginning of the packet switched data rollout for mobile devices and smart phones in particular, designed for compatibility with X.25 [G11] and IP packet based networks. In all these, the Internet has evolved to be the backbone of worldwide private and public networks. The technological mechanisms of Bluetooth that enables seamless wireless connectivity between notebook computers, cellular phones and other portable handheld devices within 10m of each other shares up to 720kbps of capacity. The multimedia technology with Internet connectability in smart phones today comprise the largest group of pervasive device. For instance, a smart phone prototype, the MultiMobile can play MPEG-4 video files as well as MP3 [G7] audio files. The small physical size of mobile phones increases the design challenge as multi-features and technologies have to be incorporated or embedded into the smart phones. The physical, functional, technological challenges are the design issues. The complexities may be physical limitations and those of the technical difficulties involved with the technologies and the platforms in the design of smart phones. Analysis of these design challenges or issues and complexities will offer the desirable outlook or reaction to the challenges and also the solution with regards its complexities and limitations beneficial for the smart phone users. The dissertation looks into the selective design issues and complexities and not all of them as the vast scope of the study still remains unlimited. The social interaction in communication features significantly despite given- the multiple references to the paramount importance of the embedded technologies in pervasive computation with special reference to smart phones. This dissertation explores the viable options resulting from the complexities evolving as a result of the incorporation of all the in-built technicalities, keeping in a close check the main purpose of smart phones-communication.

[©] *Short for **personal digital assistant**, a handheld device that combines computing, telephone/fax, Internet and networking features. A typical PDA can function as a cellular phone, fax sender*

[*] Guest editors' introduction, Pervasive Computing, April-June 2005, IEEE Publication.

[®] Short for the ***Wireless Application Protocol***, a secure specification that allows users to access information instantly via handheld wireless devices such as mobile phones, pagers, two-way radios, **smartphones** and communicators.

[•] *GPRS Short for **General Packet Radio Service**, a standard for wireless communications which runs at speeds up to 115 kilobits per second, compared with current GSM (Global System for Mobile Communications) systems' 9.6 kilobits.*

CONTENTS

INTRODUCTION

i) Embedded Systems:

An embedded system is a special-purpose computer system usually built into a smaller device. It can also be defined as an electronic device that incorporates a computer system (usually a microprocessor) within its implementation.The computer system used in such a device is primarily for simplification of the system design and for providing flexibility.Often the user of the device is not even aware of the presence of a computer-system.An embedded system consists of a piece of microprocessor based hardware and a suitable software to undertake a specific task.

An embedded system carries out a specific work/purpose for which it is designed unlike a desktop computer which serves many purposes and applications.

a) Properties /Attributes of Embedded Systems:

Embedded systems often share the following attributes:

- They are tightly connected to the outside world via sensors and actuators(i.e. motors, relais, switches etc)
- They often monitor and control processes
- Data logging and transformations is less important
- They have a mimnimal user interface
- They start on powerup and have to remain operational until power is removed.
- Programming cannot be changed except in ways that its original programmer intended.
- Often no "real" keyboard

The environment in which the system is going to operate and the production method/run pose requirements on embedded systems, regarding:

- Price of parts
- In-circuit programmability

- Environmental requirements: temperature ranges, vibrations, humidity etc

b) Some Application Areas:

Aerospace, e.g. navigation systems, automatic landing systems, flight altitude control

Automotive, e.g. fuel injection control, anti-lock braking systems, passenger environmental controls, airbag control etc

Communications e.g. Satellites, network routers, switches, hubs etc

Office Automation e.g. Fax machines, copiers, telephones, cash registers etc

Personal e.g. Personal Digital Assistants (PDA), pagers, wristwatches, cell phones, portable MP3 Players, video games etc

As a matter of fact Embedded Systems account for 100% of worldwide microprocessor production and Embedded System: desktop = 100: 1

ii) MOBILE PHONES:

a) Background

The modern cellular mobile telephone dates back to the late 1970s and early 1980s when the first cellular networks were launched in Japan and Scandinavia (Kiljander 1997). During the following 25 years the mobile phone has undergone a transition from a technology-focused professional tool of the early adopters and wealthy businesspeople, first to a yuppie show-off status gadget, and finally to a mass-market, consumer product and a highly integral part of the daily life of hundreds of millions of people globally. It must be noticed, though, that the mobile phone is still mostly a phenomenon of the developed countries in the world, as the least-developed countries have no or poor telecommunications infrastructure, and the current phones and subscriptions are too expensive for the majority of people in those markets.

The wireless communications business is now of substantial size and continues to grow. The estimated mobile phone subscriber and sales volume growth is shown in **Figure 1** below.

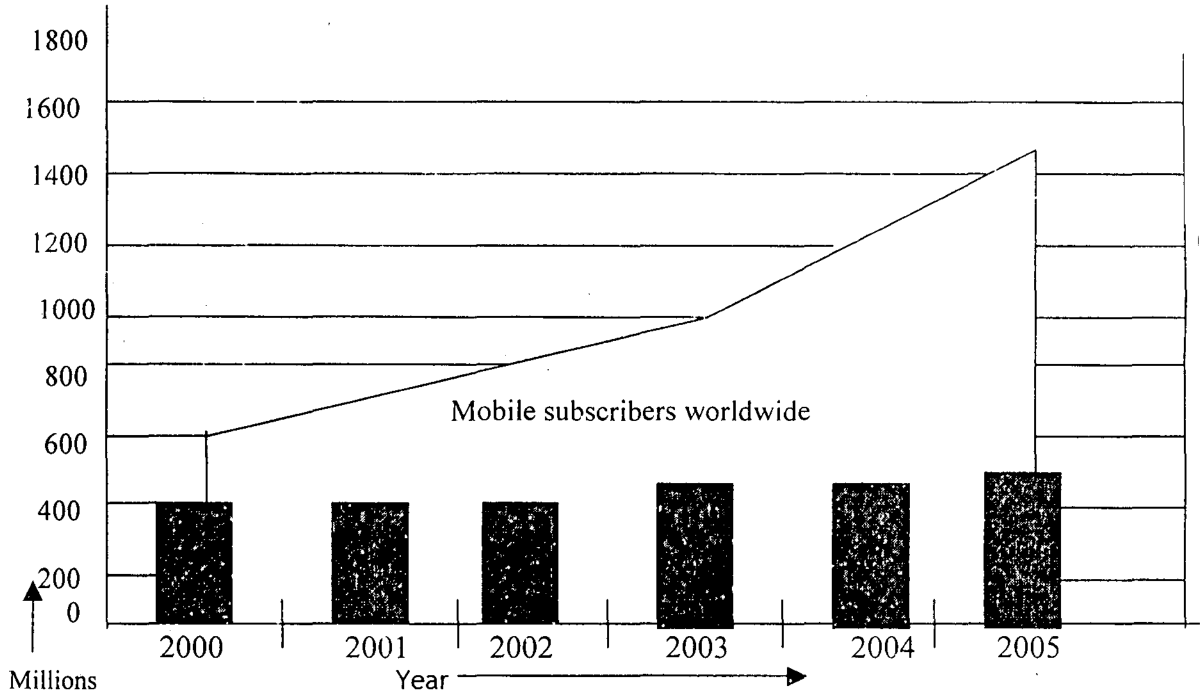
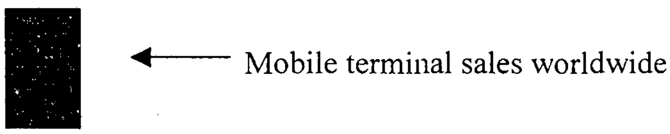


Fig.1 Mobile telephone subscribers and terminal sales estimates



At present, the popularity of mobile phones can be understood by the fact that over a billion mobile phones exist today, a third of which are in China. In many Asian countries, more mobile phones are used than domestic landlines; in Singapore, mobile phones outnumber citizens.*

b) Generations and development trends

Land mobile communication systems can be classified into first generation mobile communication systems, second generation and **third generation** mobile communication systems.

* G. Bell, " The Age of the Thumb: A Cultural Reading of Mobile Technologies from Asia," published in *Thumb Culture: Social Trends & Mobile Phone Use*, Bielefeld, 2005.

The older type analog systems are referred to as the first generation mobile communication system, while more recent digital type systems are called second-generation systems. Third generation systems are referred to as advanced or 'Future systems'

There have been different surveys conducted regarding trends in mobile communications. The general trends indicated by a survey [Idoucon, 1990] conducted in 1990 were the following:

- Development of digital systems
- New frequency allocations
- High speed transmission
- Multimedia capability, etc.

As land mobile communication systems are developed and continue to proliferate, a higher level of offered services can be expected which presumes the realization of more fully digital systems and system integrated for multiple services, in addition to **multimedia capability and greater portability of terminals.**

Development stages

Analog systems

↓

Digital systems (2^{nd} generation new systems), PHS, etc

↓

Integrated service Systems (3^{rd} generation future systems), IMT-2000, mobile ISDN, UMTS, **Smart Phones**

Development trends

Digitalization

↓

Personal communications, integrated wired and wireless systems, multimedia services like video clips, mpegs, etc

↓

Service integration, globalization

iii) RESEARCH AIM AND OBJECTIVES

Since mobile phones will evolve to include an extra applications processor with the capability of running a complex OS and middleware, in view of all the complexities and design challenges involved, I would like to study the trends of technological developments to identify the general complexity issues and then incorporate embedded system technologies into the mobile phones for reduction of complexities, better user application capabilities , more cost effective re-designs or upgrades for higher performance and reliability for the end user..

The main research problem- how the various aspects of design challenges and complexities of future mobiles affect the usability of mobile phone for the enduser , the affect upon researches and design in mobile companies and also analysis of those challenges and complexities with respect to its application ie social interactions of mobile phones in communication.

iv) RESEARCH SCOPE

The diversity of cellular phones is incredible; their functionality too: the endless list of features gets longer every day. There are manyfold games, fancy form factors, built-in FM radio, and even PIM(personal Information Management) functionality. The operating systems used in cellular phones are quit manifold too.Mostly proprietary systems like RTOS (real time Operating System) from Siemens or GEOS*(Genetic Engineering Operating System) from Geoworks are used. Others like EPOC ®are applied by several companies.

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* **GEOS** An operating system that provides a graphical interface for PDAs and consumer-oriented devices from the Breadbox Computer Company, Port Richey, FL (www.breadbox.com). Originally developed by Geoworks Corporation of Emeryville, CA, the GEOS patents were licensed and then sold to Breadbox in 2003

® **EPOC** - A 32-bit operating system designed by Symbian and written in C++. It is used in mobile phones and PDAs, including PDAs manufactured by Psion. And yes, that is really what it stands for.

The areas of pervasive computing have to be explored where users of future mobile phones get enabled to exchange and retrieve information they need quickly, efficiently and effortlessy, regardless of their physical location.

v) MAJOR DIGITAL CELLULAR SYSTEMS

There are four major digital cellular system types deployed worldwide.

- **PDC:** Personal Digital Cellular, previously known as Japanese Digital Cellular(JDC). This system is widely deployed in Japan.

- **TDMA:** Time Division Multiple Access, also known as IS-136. This system is deployed in the United States and South America.

- **CDMA:** Code Division Multiple Access, also known as IS-95. This system is widely deployed in the United States.

- **GSM:** Global System for Mobile Communications. This standard was developed in Europe by the Conference of Posts and Telecommunications(CEPT).

With an estimated 705 million subscribers worldwide as of June 2002, GSM is by far the most widely deployed and fastest growing system. CDMA follows with about 126 million subscribers, while TDMA and PDA have about 102 mullion and 59 million subscribers, respectively. The worldwide total number of digital cell phones is currently about 1 billion.This number is expected to double in the next 10 years.

The work/ thesis mainly focusses on the **GSM digital cellular system** with the analysis design challenges and complexities involved in the same.

vi) GSM

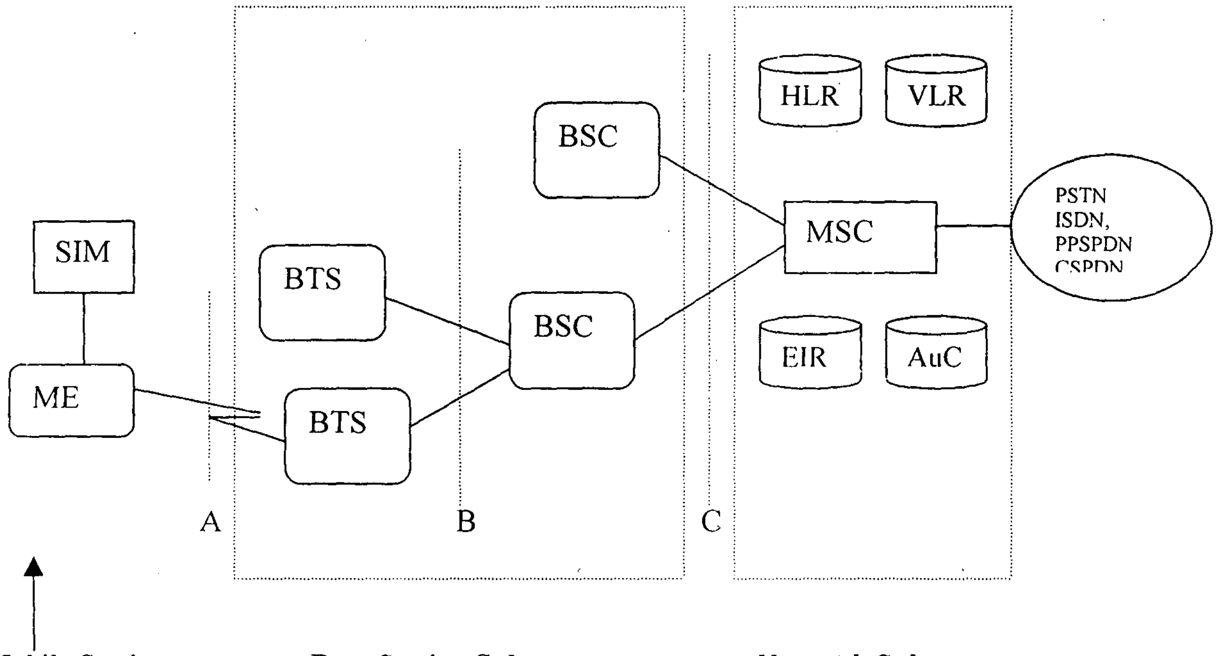
In 1982 the Conference of European Posts and Telegraphs (CEPT) formed a study group called the Groupe Spécial Mobile (GSM) to study and develop a pan-European public land mobile system. The proposed system had to meet certain criteria:

- Good subjective speech quality
- Low terminal and service cost
- Support for international roaming
- Ability to support handheld terminals
- Support for range of new services and facilities
- Spectral efficiency
- ISDN compatibility

vii) ARCHITECTURE OF THE GSM NETWORK

A GSM network is composed of several functional entities, whose functions and interfaces are specified. Figure 2 shows the layout of a generic GSM network. The GSM network can be divided into three broad parts. The Mobile Station is carried by the subscriber. The Base Station Subsystem controls the radio link with the Mobile Station. The Network Subsystem, the main part of which is the Mobile services Switching Center (MSC), performs the switching of calls between the mobile users, and between mobile and fixed network users. The MSC also handles the mobility management operations. Not shown is the Operations and Maintenance Center, which oversees the proper operation and setup of the network. The Mobile Station and the Base Station Subsystem communicate across the Um interface, also known as the air interface or radio link. The Base Station Subsystem communicates with the Mobile services Switching Center across the A interface.

The general architecture of GSM network is given on the next page.



Mobile Station **Base Station Subsystem** **Network Subsystem**

SIM Subscriber Identity Module **BSC** Base Station Controller

EIR Equipment Identity Register **MSC** Mobile services Switching Center

ME Mobile Equipment **HLR** Home Location Register

BTS Base Transceiver Station **VLR** Visitor Location Register

AuC Authentication Center

Figure 2. General architecture of a GSM network

Figure 2. General architecture of a GSM network

GSM uses a combination of FDMA and TDMA to allow multiple access.The available frequency spectrum is first divided into carrier frequencies spaced 200 kHz apart.Each carrier frequency is then divided into slots that can be assigned to individual mobile stations or used to transmit control information.

In this thesis, the complexities and design challenges of future mobile phones with special reference to **smart phones** will be analysed from embedded systems perspectives. GSM community has developeded a new set of network layer protocols to support packet data services to the Internet or **X.25** * network packet data networks.[2] The service is called **General packet radio service(GPRS)**.This is different from **cdma 2000's** approach of using IP-based protocol as network layer protocol . This service has been introduced in the GSM phase 2 standard and is of immense help in the study of smart phones, as will be seen in chapter 3. But in the immediate next chapter,ie chapter 2, an introduction to pervasive computing (also called ubiquitous computing) and third generation or future mobile phones, ie smart phones, is given with characteristic features and few interaction styles in communication.

* *X.25 is an International Telecommunication Union-Telecommunication Standardization Sector (ITU-T) protocol standard for WAN communications that defines how connections between user devices and network devices are established and maintained. X.25 is designed to operate effectively regardless of the type of systems connected to the network. It is typically used in the packet-switched networks (PSNs) of common carriers, such as the telephone companies. Subscribers are charged based on their use of the network. The development of the X.25 standard was initiated by the common carriers in the 1970s. At that time, there was a need for WAN protocols capable of providing connectivity across public data networks (PDNs). X.25 is now administered as an international standard by the ITU-T.*

Chapter 1

PERVASIVE COMPUTING AND FUTURE MOBILE PHONES (*Smart Phones*)

Introduction

At the turn of the last century, telecommunications' focus changed considerably, from traditional wired telephony-oriented services and infrastructures to databased services; from homogeneous to heterogeneous networks; from non-intelligent devices to smart handhelds, personal digital assistants, and mobile computers. To enable the growth in these expanding spheres of interests and developments, we need to think about their future, their technologies, and their markets' convergence. Here I would like to discuss on how communications has begun to develop pervasively.

Beyond the era of personal computing, the era of *Pervasive Computing* (or *Ubiquitous computing**) begins: A new class of devices make information access and processing easily available for everyone from everywhere at anytime. Among all the manifold Pervasive Computing devices that extend e-Business from the offices to ubiquity, cellular phones achieve wireless mobile access to various computer systems and information-based services from almost everywhere in the world. There is a high demand for new pervasive technologies in the study of mobile phones.[1]

Future mobile phones or smart phones are the third generation mobile phones with latest features and technology. For instance, a consortium called Mobile VCE (Virtual center of Excellence) which includes such names as Nokia, Sony, Vodafone, and the BBC is funding the development of software for future smart phones that will actually enable one's mobile phone to make purchases on one's behalf, independent of one's interaction.

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* ***Ubiquitous computing*** *describes the evolution of computing toward the so-called third era of computing. The primary goal of ubiquitous computing is to embed many small and highly specialized devices within the everyday environment so that they operate seamlessly and become transparent to the person using them, either offline or online. Ubiquitous computing products aim to be everywhere (for example, by being portable); small; and aware of they're environments, users, and contexts.*

Interesting thing is that the phone buys stuff without the user having to be there. These smartphones will perform tasks such as booking hotel rooms and plane tickets when they notice travel plans in one's (the user's) electronic date book. They will also learn to recognize repetitive behaviors, such as going to the movies every Friday. The phone will then purchase movie tickets ahead of time .In the following are given the features in more details.

1.1 SMART PHONES:

Smart phones combine a mobile phone with a handheld organizer into an all-in -one communication system. In other words, smart phones are handhelds that combine the communication capabilities of a cell phone with the computing functions of a PDA The smart phone represents the current pinnacle of mobile phone development, coupling phone capabilities with the additional functionalities of a PDA.[2] There are two kinds of smart phones: those that are phones first and PDAs second, and those that are PDAs first and phones second. The i700 [figure 1 below] is one in which the PDA genes dominate. With the standard battery attached and including the sizable 160x240, 64,000-color screen and on-board camera), it weighs about 7 ounces.

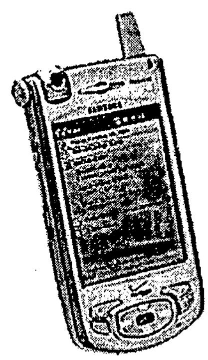


Figure 1.Samsung SPH i700

Nokia Communicator 9110, for instance, is another smart phone that can be unfolded to access a small keyboard inside. The Communicator is based on the GEOS operating system and features an Intel embedded 386 class processor with 24 MHz. 4MB of RAM are occupied by the operating system and the included applications. 2 MB is free for user data and another 2MB is used for program execution. The monochrome display has a good resolution of 640X200 pixels. The communicator is based on dual band GSM wireless communication and provides fax, email, short messages, Internet access, and Personal information Management (PIM) applications. While PC connectivity is via Infrared and serial port is a common feature, telnet and a VT100 emulation are an additional way of accessing data on servers of interest.[3]

1.2 MSE-ENABLED SMART PHONES

The MSE (Mobile service explorer) performs three primary functions:

- ***Connection establishment.*** We use machine-readable visual tags to establish connections to site-specific services. The MSE contains image-processing software that decodes tags. Users establish connections by pointing the smart phone's embedded camera at a visual tag and pressing the Select button.

- ***Personal information management.*** The smart phone contains a repository of personal information. MST servers can request personal information from the MSE to provide personalized services. The MSE chooses whether or not to supply the requested information in accordance with the user's privacy policy.

- ***General-purpose data entry and display.*** The MST server can push user interfaces to smart phones and supports both thin-client functionality (similar to Virtual Network Computing) and WAP (Wireless Application Protocol)-like user interface controls.[4]

1.3 INTERACTION STYLES IN SMART PHONES

In the following is given shorthand notation for interactions between people, loosely based on the number involved:

- 1 represents an individual, with 1–1representing person-to-person communication

- N represents a group, with $1–N$ representing person-to-group communication and $N–N$ representing within group communication
- ∞ represents the world, with $1-\infty$ representing person-to-world communications and $N-\infty$ representing group to-world communication.

If we can support all of these communication styles using the smart phone as the main user device, we can determine that it's indeed a useful device for pervasive computing, able to support a multitude of communication approaches.[5]

1.4 SIX DIMENSIONS OF MEETING EXTRA USER NEEDS

(Building upon core phone features)

i) Gaming capabilities...Multi-player games; mobile access to online worlds

ii) Entertainment: Filling "slack time" enjoyably...Audio, Graphics, Video, Quizzes, Horoscopes

iii) Personal productivity: Scheduling, jotter, to-do's

iv) Business productivity: Access to corporate data

iv) Easy access to tailored information...Location, navigation, presence, neighborhood, education

vi) Electronic commerce (electronic wallet)...Buying, selling, banking,

References

1. Uwe Hansmann, Lothar Merk, Martin S.Nicklous and Thomas Stober, *Principles of Mobile Communication,* Springer Publication, *2nd edition, 2003.*

2. Eleanor Toye, Richard Sharp, Anil Madhavapeddy and David Scott," Using Smart Phones to Access Site-Specific Services " *IEEE CS and IEEE ComSoc Publication, April-June, 2005.*

3. Uwe Hansmann, Lothar Merk, Martin S.Nicklous and Thomas Stober, *Principles of Mobile Communication,* Springer Publication, *2nd edition, 2003.*

4. Eleanor Toye, Richard Sharp, Anil Madhavapeddy and David Scott," Using Smart Phones to Access Site-Specific Services " *IEEE CS and IEEE ComSoc Publication, April-June, 2005.*

5. Russell Beale, "Supporting Social Interaction with Smart Phones" Published by the IEEE CS and IEEE ComSoc, *Pervasive Computing*, April-June 2005.

Chapter 2
SMART PHONES TECHNOLOGIES

Introduction

It is believed that *Smart Phones* are the devices that have the greatest chance of successfully becoming universal remote controls for people to interact with various devices from their surrounding environment; they will also replace all the different items we currently carry in our pockets. Smart Phone is an emerging mobile phone technology that supports Java program execution and provides both short range wireless connectivity (Bluetooth) and cellular network connectivity through which the Internet can be accessed.

The future mobile phones (smart phones) of all manufacturers also take advantage of high-speed wireless communication networks like GPRS (General Packet Radio service) and UMTS. Besides the phone and organizer functionality, these devices are able to exchange video and audio streams as self-evident as SMS. For instance, connecting a phone to a site-specific service requires wireless networking technology. Various choices exist, ranging from operator-provided data services such as GPRS (General Packet Radio Service) to short-range, point-to-point solutions such as IrDA (Infrared Data Association) and Bluetooth.

2.1 SMART PHONES TECHNOLOGY

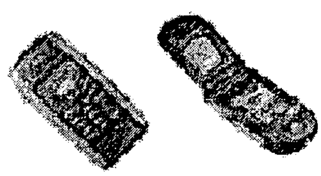


Figure 1. Example of Smart Phones: Sony Ericsson P800 (Left) and Motorola A760 (Right)

With more than a billion mobile phones being carried around by consumers of all ages, the mobile phone has become the most pervasive pocket-carried device. We are beginning to see the introduction of *Smart Phones*, such as Sony Ericsson P800/P900[1] and Motorola A760[2] (Figure1), as a result of the convergence of mobile phones and PDA devices. Unlike traditional mobile phones, which have limited processing power and act merely as "dumb" conduits for passing voice or data between the cellular network and end users, Smart Phones combine significant computing power with memory, short-range wireless interfaces (e.g., Bluetooth), Internet connectivity (over GPRS), and various input-output components (e.g., high-resolution color touch screens, digital cameras, and MP3 players).

Sony Ericsson P800/P900 runs Symbian OS[3], an operating system specifically designed for resource-constrained devices such as mobile phones. It also comes equipped with two versions of Java technology: Personal Java[4] and J2ME CLDC/MIDP.[5] Additionally, it supports C++ which provides low-level access to the operating system and the Bluetooth driver. The phone has16MB of internal memory and up to 128MB external flash memory. Motorola A760 has a Motorola i250 chip for communication, Intel's 200 MHz PXA262 chip for computation, and 256MB of RAM memory. It runs a version of MontaVista Linux and comes with Java J2ME support.[6]

Bluetooth[7] is a low-cost, low-power standard for wireless connectivity. Today, we can find Bluetooth chips embedded in PCs, laptops, digital cameras, GPS devices, Smart Phones, and a whole range of other electronic devices. Bluetooth supports point-to-point and point-to-multipoint connections. We can actively connect a Bluetooth device to up to seven devices simultaneously. Together, they form an ad hoc network, called *Piconet*. Several piconets can be linked to form a *Scatternet*.

Another important development for the mobile phone technology is the introduction of General Packet Radio Service (GPRS)[8], a packet switching technology over the current GSM cellular networks. GPRS is offered as a nonvoice value-added service that allows data to be sent and received across GSM cellular networks at a rate of up to 171.2kbps, and its goal is to supplement today's Circuit Switched Data and Short Message Service. GPRS offers an *always-on* service and supports Internet protocols. There are several technologies supporting the smart phones as mentioned above like GPRS, Bluetooth, and CMOS etc. But here the **Bluetooth Technology** of smart phones will be more specifically dealt with in detail.

2.2 BLUETOOTH TECHNOLOGY FOR SMART PHONES

Introduction

- Named after a Danish Viking and King, Harald Blåtand
- It is a **cable-replacement technology**: new technology using short-range radio links, intended to replace the cable(s) connecting portable and/or fixed electronic devices
- Conceived initially by Ericsson in 1994, set to commercially come out in bulk around 2002
- A standard for a **small, cheap radio chip to be plugged into computers, printers, mobile phones, etc**
- The Bluetooth Special Interest Group (SIG) was founded by Ericsson, IBM, Intel, Nokia and Toshiba in February 1998, to develop an open specification for short-range wireless connectivity

Bluetooth wireless technology is a short-range radio technology. Bluetooth is a specification for a radio solution that is small form-factor, low-cost, and low power, that provides seamless wireless connectivity between notebook computers, cellular phones and other portable handheld devices. Bluetooth operates in the license-free 2.4GHz ISM band at a link range of 10 meters. With improved transmission power and receiving sensitivity the range can be increased up to 100 meters. Bluetooth is a standard feature on the Smart Phones, PDAs and computers. The most compelling application for Bluetooth is believed to be always-on Internet access at homes, offices, and public locations through a Bluetooth Internet Access Point.

Ericsson was the first company to introduce a Bluetooth module product based on its own RF and a VLSI/Philips base band chip in early 2000. These first generation Bluetooth silicon solutions are based on three architectures: the ASIC plus RF chip (Ericsson), the DSP plus RF chip (Motorola and National), or a single chip CMOS implementing both RF and baseband (CSR). Moreover, three different silicon technologies are used: BiCMOS (Ericsson), CMOS (OKIand CSR), and Silicon-on-Insulator (Silicon Wave).

- Bluetooth radio modules operate in the unlicensed ISM band centered at at 2.45GHz. RF channels: 2420+k MHZ, k=0..78.
- Bluetooth devices within 10m of each other can share up to 720kbps of capacity
- Projected cost for a Bluetooth chip is ~$5. Plus its low power consumption means you could literally **place one anywhere.**
- Can operate on both circuit and packet switching modes, providing both synchronous and asynchronous data services
- It is intended to support an open-ended list of applications, including data, audio, graphics and even video.

Smart Phones are one of the first devices to incorporate Bluetooth. Ericsson and Motorola have announced their respective cell phone products, the Ericsson R520 and the Timeport 270. Motorola has also introduced its Bluetooth PC cards and USB devices through its Digianswer group. In August, Intel announced its Ambler module technology for notebook support. Palm has demonstrated Bluetooth-enabled handheld computers at Cebit 2000.

2.2.1 FEATURES OF BLUETOOTH TECHNOLOGY

Bluetooth must be able to:

- Recognize any other Bluetooth device in radio range
- Permit easy connection of these devices
- Be aware of the device *types*
- Support service discovery

➢ Support connectivity aware applications

Examples of Bluetooth uses:

➢ *Briefcase email*: access email while the PC is still in the briefcase; when PC receives an email, you are notified thru the mobile phone. Use the mobile phone to browse the email.
➢ *Cordless desktop*: connect your desktop/laptop cordlessly to printers, scanner, keyboard, mouse, etc.

2.2.2 BLUETOOTH ARCHITECTURE

➢ Up to 8 devices can communicate in a small network, called **piconet.**
➢ 10 piconets can coexist in the same coverage range of the Bluetooth radio.
➢ Each piconet has 1 MASTER and the rest serve as SLAVES. SLAVES within a piconet only have links to the MASTER.
➢ Multi-hop communication is obtained thru the scatternet.

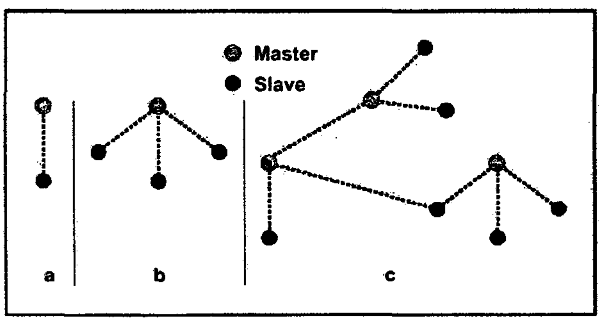


Fig.1 Bluetooth Architecture

2.3 IMPLEMENTATION OF BLUETOOTH

A typical implementation of Bluetooth includes the RF, baseband, HCI interface, and host stack software.

2.3.1 RF

Bluetooth operates in the license-free 2.4-2.4835GHz ISM band by frequency hopping at a rate of 1600 hops/s within 79 1MHz channels. For instance, Japan, France and Spain have a smaller band but these issues are being resolved. Bluetooth supports 10-meter range and 1Mbps rate and a 100-meter range with improved transmission power and receiving sensitivity. There are three classes of transmit power for Bluetooth: Class 3 at 0 dBm (1 mW), Class 2 at 4 dBm (2.5 mW) and Class 1 at 20 dBm (100 mW). The minimum receiver sensitivity level is -70 dBm (but most products are between –75dBm and –90dBm) for 10-3 BER.

2.3.2 BASEBAND

A wireless PAN (Personal Area Networking), more often referred to as a Piconet, provides the cable replacement for connectivity among various devices such as a notebook PC to a cell phone, a cell phone to a headset, a PDA to a notebook, a cell phone to PSTN, a notebook/PDA to Internet and LAN, and other ad-hoc networking applications. Multiple devices (256 parked, 8 active) can participate in a Piconet.

Bluetooth communications in a Piconet is based on a master/slave relationship, where one unit serves as a master and the rest serve as slaves. The access is synchronized via master identity whose Bluetooth address determines the frequency hopping sequence and system clock determines the phase. Each slave will follow the hop sequence and add an offset to its clock to follow the master. Each Bluetooth packet has a fixed format that starts with a 72-bit access code that is based on the master identity and is unique to the Piconet. Then a 54-bitheader containing error correction, retransmission and control information follows. Finally, a payload of 0 to 2745 bits ends a packet.

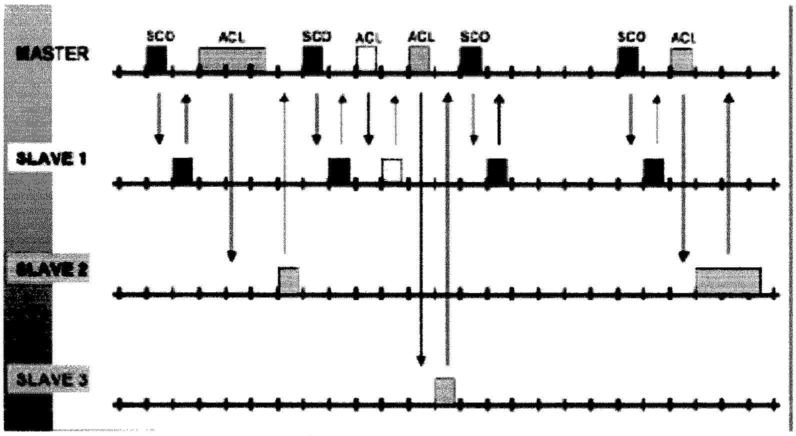


Figure-1. **Master-to-slaves connection in a Piconet**

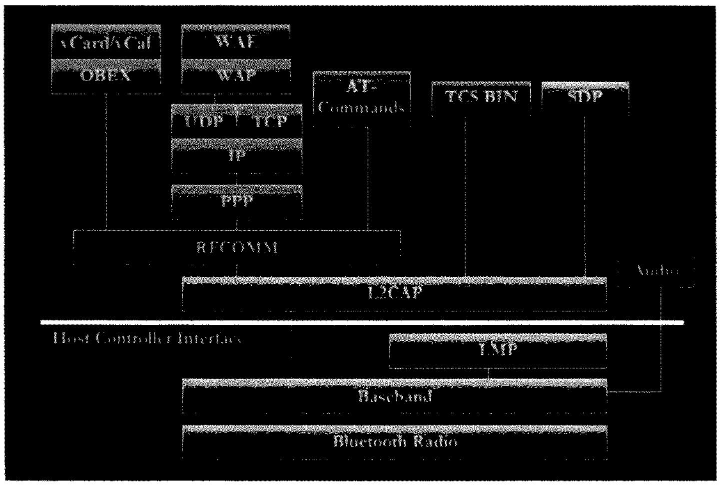
Bluetooth uses frequency hopping, at 1600 hops/s, among 79 one MHz channels at 1 bit/symbol GFSK (Gaussian Frequency Shift Keying). To provide full duplex operation, it uses Time-Division Duplex (TDD) scheme to divide the channel into a number of 625 us time slots with a 220 us TDD guard time. Master and slave alternatively transmit. The master shall transmit in even-numbered time slot only while the slave shall start its transmission in odd numbered time slots. The time slots are numbered based on the Bluetooth clock of the piconet master. The numbering ranges from 0 to (227 –1) and is cyclic with a cycle length of 227.

Bluetooth protocol is a combination of circuit and packet switching. Reservation of slots can be made for Synchronous Connection-Oriented (SCO) links for circuit switching audio application. Bluetooth can support three 64Kbps voice channels. It also supports an Asynchronous Connection-Less (ACL) link for packet data switching, based on a polling access scheme. Typical packet size is one slot but can span multiple slots as defined in the specification. Bluetooh provides maximum data rate of asymmetrical 721 Kb/s upstream (57.6 Kb/s downstream), or symmetrical 432.6 kb/s data transfer rate. The master controls all traffic in a Piconet. It allocates capacity for SCO links and handles the polling scheme for ACL links among slaves. Slave may only send in the slave-to-master slot after being addressed in the preceding master-to-slave slot. Figure-1 illustrates master-to-slaves connection in a Piconet.

The Host Controller Interface, HCI, provides a uniform interface method for accessing the Bluetooth hardware capabilities. It contains a command interface to the Based band controller and link manager and access to hardware status. Typical connection w/standard interfaces include USB, UART, and PCMCIA.

2.4 HOST PROTOCOL STACK

The Link Manager Protocol, LMP, is responsible for link setup between Bluetooth devices. It manages master slaves witch, lower power mode (hold, sniff, park), clock offset, and packet size negotiation. It handles generation, exchange and control of link and encryption key for authentication and encryption.



Adopted protocol

Core protocols **Cable replacement protocols** **Telephony control protocol**

Figure 2. **Bluetooth protocol stack.**

2.4.1 Radio Layer: specifies details of the air interface:

- Uses unlicensed ISM band, around 2.45GHz
- Spread spectrum with **frequency hopping***
- Frequency hops are fixed at 2402+k MHz, where k= 0,1,...,78
- Hop rate is 1600 hops per second (hop slot of 625 microseconds)
- FH sequence is determined by the MASTER and is a function of its BA
- Radio communication uses TDD (time division duplex
- Medium access technique is TDMA

2.4.2 Baseband: concerned with connection establishment within a piconet, addressing, packet format, timing and power control.

2.4.3 Link manager protocol (LMP): responsible for link setup and link management. Includes security aspects (encryption & authentication).

2.4.4 Logical link control and adaptation protocol (L2CAP): adapts upper layer protocols to the baseband layer. Provides both connectionless and connection oriented services.

2.4.5 Service discovery protocol (SDP): queries a device for device information, services and service characteristics.

2.4.6 HCI (host Controller Interface): allows the implementation of lower Bluetooth functions on the Bluetooth device and higher protocol functions on a host machine.

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* **Frequency hopping** is one of two basic modulation techniques used in spread spectrum signal transmission. It is the repeated switching of frequencies during radio transmission, often to minimize the effectiveness of "electronic warfare" - that is, the unauthorized interception or jamming of telecommunications. It also is known as frequency- hopping code division multiple access (FH-CDMA).

2.4.7 RFCOMM: a reliable transport protocol, which provides emulation of RS232 serial ports over the L2CAP protocol.

2.4.8 TCS BIN (telephony control specification): bit oriented protocol that defines the call control signaling for the establishment of speech & data calls between BD.

2.4.9 OBEX: object exchange protocol. Provides functionality similar with HTTP. It provides a model for representing objects and operations. Examples of formats transferred are vCard and vCalendar.

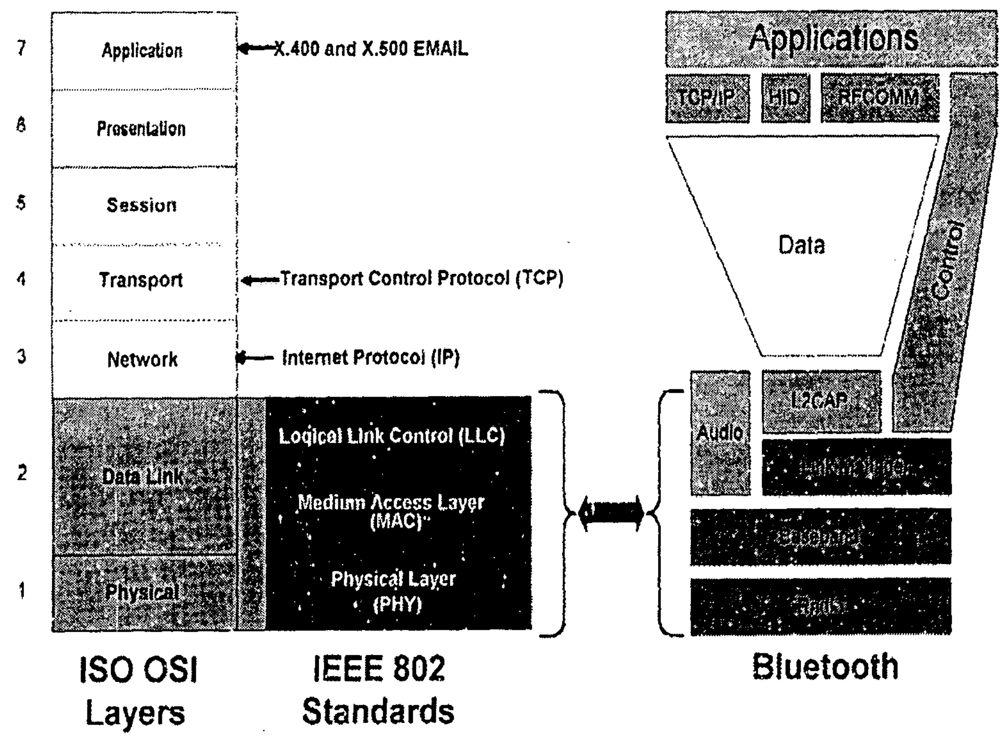

Figure 4: **Different layers and applications**

2.5 PHYSICAL LINKS

2.5.1 Synchronous Connection Oriented (SCO): allocates a fixed bandwidth between a point-to-point connection involving the master and one slave.

- The master reserves slots periodically.
- It primarily supports time-bounded information like voice.
- SCO packets do not include a CRC (Cyclic Redundancy Check) and are never retransmitted.
- The master can support up to 3 simultaneous SCO links

2.5.2 Asynchronous connectionless (ACL): a point-to-multipoint link between the master and all slaves in the piconet.

- Packet-switch style of connection
- Delivery may be guaranteed thru error detection and retransmission
- Only single ACL link can exist

2.6 BLUETOOTH PROFILES

Figure 5 shows the Bluetooth profile structure and the dependencies of the profiles. There are four general Bluetooth profiles as follows. Generic Access Profile defines the generic procedures related to discovery of Bluetooth devices and link management aspects of connecting to Bluetooth devices. It defines procedures related to use of different security levels. In addition this profile includes common format requirements for parameters accessible on the user interface level.

Service Discovery Application Profile defines the features and procedures for an application in a Bluetooth device to discover services registered in other Bluetooth devices and retrieve any desired available information pertinent to these services.

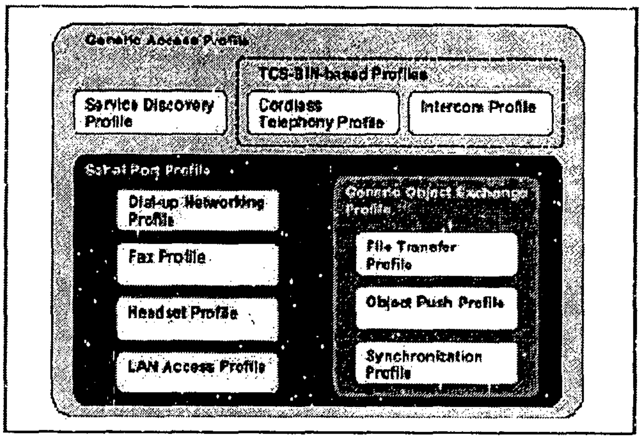

Figure 5. **Bluetooth Profiles**

Serial Port Profile defines the requirements for Bluetooth devices necessary for setting up emulated serial cable connections using RFCOMM (radio frequency oriented emulation of the serial COM ports on a PC) between two peer devices. The requirements are expressed in terms of services provided to applications, and by defining the features and procedures that are required for interoperability between Bluetooth devices.

The LAN Access Profile defines how Bluetooth-enabled devices can access the services of a LAN using PPP (Point-to-Point Protocol). Secondly, this profile shows how the same PPP mechanisms are used to form a network consisting of two Bluetooth-enabled devices. Generic Object Exchange Profile defines the requirements for Bluetooth devices necessary for the support of the object exchange usage models. The requirements are expressed by defining the features and procedures that are required for interoperability between Bluetooth devices in the object exchange usage models.

2.7 BLUETOOTH COMPLIANCE AND QUALIFICATION

The Bluetooth Qualification program establishes the rules and procedures by which the manufacturer demonstrates compliance to the Bluetooth specification. The Bluetooth Qualification Administrator (BQA) is responsible for administering the Bluetooth qualification program on behalf of Bluetooth Qualification Review Board (BQRB). BQRB authorizes Bluetooth Qualification Test Facility (BQTF) to test products and Bluetooth Qualification Body (BQB) to check declarations and documents against requirements, reviewing test reports. The tests include conformance tests for lower layer protocols and interoperability tests focusing on profiles, followed by compliance declarations and documentation review. Products are certified and enlisted by a Bluetooth Qualification Body (BQB).

2.8 Connection Establishment in Bluetooth

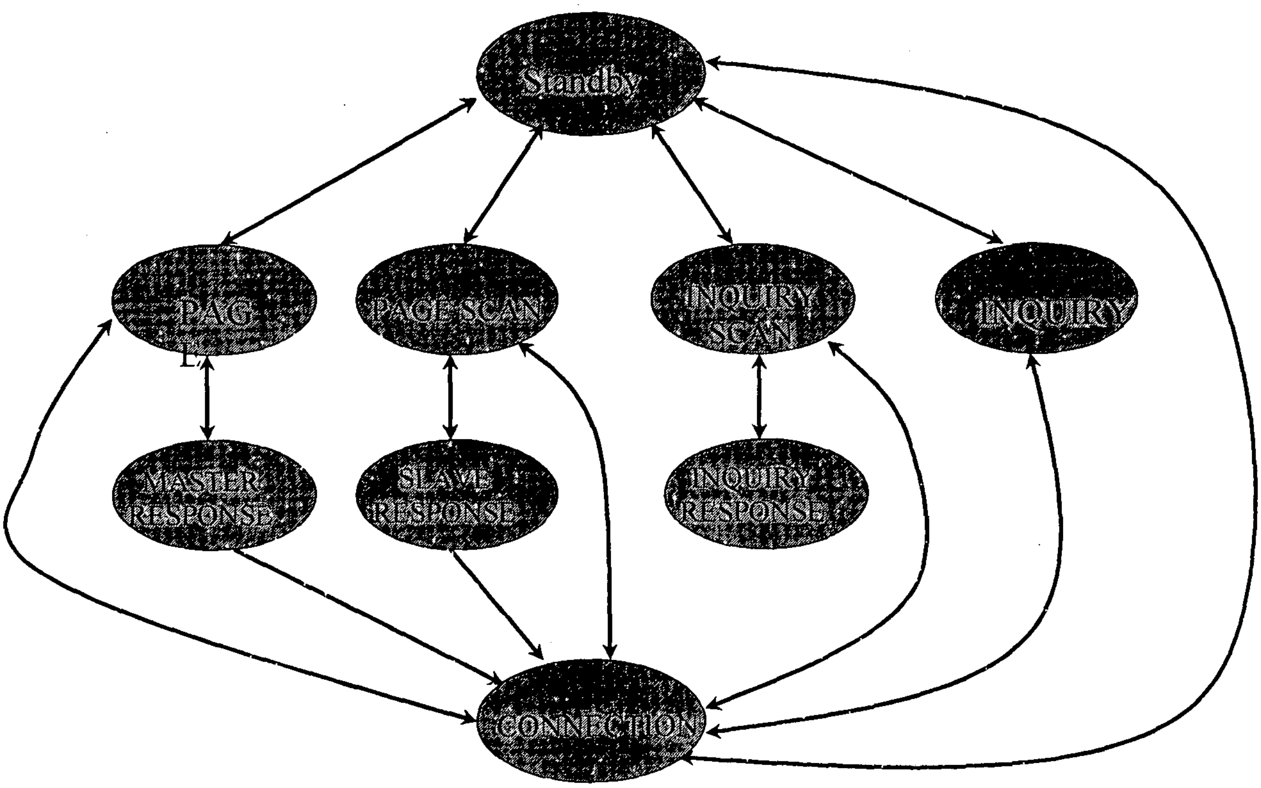

Figure 6. **BLUETOOTH State Transition Diagram**

2.8 CONNECTION ESTABLISHMENT STATES

- **Standby**: the default state; a low power state in which only the native clock is running.
- **Connection**: the device is connected to the piconet as a master or slave.
- **Page**: device has issued a page. Used by the master to activate and connect to a slave. Master sends page msg by transmitting slave's DAC (device access code) in different hop channels.
- **Page Scan**: device is listening for a page with its own DAC
- **Master response**: master receives a page response from a slave. The master can enter the connection state or return to the page state to page for other slaves.
- **Slave response**: a slave responds to a page from the master. If connection setup succeeds, device enters connection state, otherwise page scan state
- **Inquiry**: device has issued an inquiry to find the identity of the devices within range
- **Inquiry scan**: device is listing for an inquiry
- **Inquiry response**: a device that has issued an inquiry receives an inquiry response

2.10 Inquiry procedure

- Invoked when a potential master identifies devices in range that wish to participate in a piconet
- In *Inquiry* state, master sends an IAC (inquiry access code) over each of 32 wake-up carriers (out of 79) in turn
- Devices in the *Standby* state periodically enter *Inquiry Scan* state to search for IAC msg
- When a device receives the inquiry, enters *Inquiry Response* state and returns an FHS packet with its device addr and timing info. Then it moves to the *Page scan* state to await for a page from the Master to establish the connection

- If a collision occurs in *Inquiry Response* phase (more devices respond to an inquiry), no page will be received and the device may need to return in *Inquiry Scan* state
- The master does not respond to FHS pkt and may remain in *Inquiry* state until is satisfied with all radios found.

2.11 Page procedure

- For each device, the master uses the device's addr to calculate a page FHS (The Filesystem Hierarchy Standard).
- The master pages by using an ID pkt, with a DAC (Device access code) of the specific slave
- The slave responds by returning the same DAC ID pkt to the master in the same FHS used by the master
- Master responds in the next master-to-slave slot with its own FHS pkt containing its device addr and Bluetooth clock value
- Slave sends a response DAC (Device access code) ID packet to confirm the receipt of the master's FHS The master may continue to page until it has connected all desired slaves then enters the *Connection* state.

2.12 Connection State

- A POLL* packet is sent by the master to verify that the slave has switch to master's timing and FHS (Filesystem Hierarchy Standard). The slave can respond with any type of pkt

* **POLL** - When one computer, device, or program asks for an answer to a query from another computer or device over a period of time until a condition is met. For example, a program may poll an IP address to see when it is available.

The slave can be in following modes of operation:

- **Active**: the slave actively participate in the piconet by listening, transmitting and receiving pkts. The master periodically transmits to the slaves for to maintain synchronization
- **Sniff**: The slave listens on specified slots for its msgs. It can operate in a reduced-power status the rest of the time. The master designates a reduced number of time slots for transmitting to a specific slave.

- **Hold**: the device can participate only in SCO pkt exchanges and runs in reduced-power status. While it is no active, the device can participate in another piconet.

- **Park**: a low power mode with very little activity. Used when a slave does not need to participate in a piconet, but still is retain as part of it. The device is changing AM_ADDR ® PM_ADDR. With this mode, a piconet may have more than 7 slaves.

2.13 BLUETOOTH INTERNET ACCESS POINT BASED ON LAN ACCESS PROFILE

The LAN Access Point (LAP) is a Bluetooth connectivity device that provides PPP server function for access to a LAN (Ethernet, Token Ring, Cable Modem, DSL, Firewire, USB or Home Networking).

Figure 7 shows a typical protocol stack communication between a Data Terminal (DT) and LAP. Both the LAP and the DT must enforce encryption that is operating on the baseband and physical link while any PPP traffic is being sent or received. Bluetooth pairing occurs as a means of authenticating the users. A PIN or link key must be supplied.

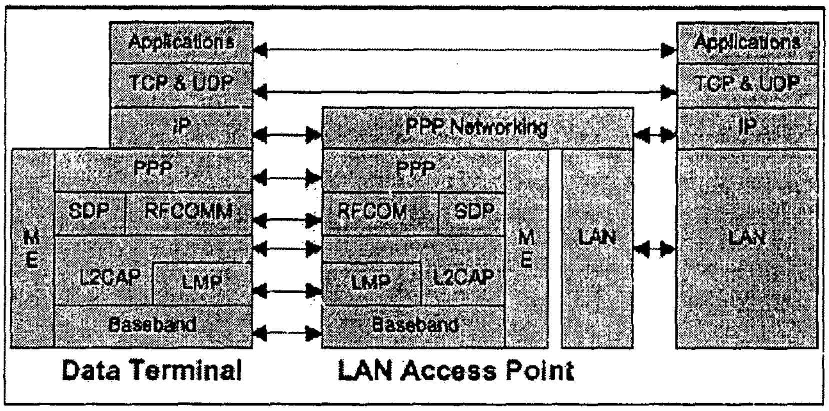

Figure 7. **Protocol for LAN Access Point and Data Terminal**

The PPP connection is carried over RFCOMM to transport the PPP packet and it can be used for flow control of the PPP data stream. The assumption for the DT is that it is a PPP client that forms a PPP connection with a LAP in order to access a LAN. A single DT uses a LAP as a wireless means of connecting to a LAN. Once connected, the DT will operate as if it were connected to the LAN via dial-up networking and access all of the services provided by the LAN. Multiple DTs can also use the LAP via dial-up networking and communicate with each other via the LAP.

Figure 8 (next page) shows a Bluetooth Internet Access Point. Within the coverage area of the device, the access point serves as a wireless to wire-line gateway to the Internet. Any standard Bluetooth-enabled device that is a PPP client can connect to any access point that meets the LAP profile. After connection, these clients could use a standard HTML or WML browser for viewing Web or WAP content.

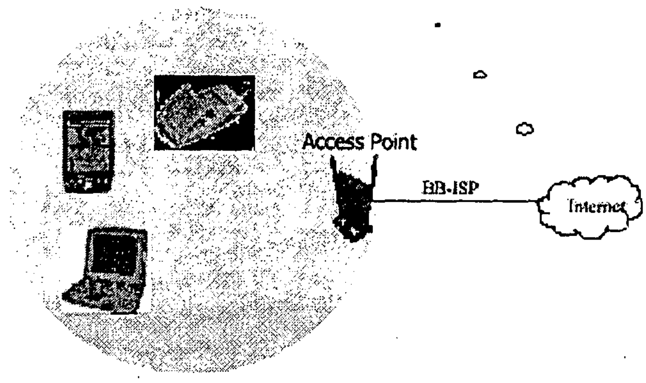

Figure 8. **Bluetooth Internet Access Point**

We believe that the following features are important for a Bluetooth Internet Access Point based on LAP:

- Standards Compatibility: Supports standard Bluetooth-enabled devices including Smart Phones without software modifications
- Extended Range and Sensitivity: Increased from 10 meters to 40-100 meters of range while conforming to the Bluetooth specification
- Seamless Internet Connectivity: Provides seamless multiple access for standard Internet content
- Low Cost Implementation: Targets mass market adoption

2.14 Security – Authentication

4 parameters used for security:

- Unit address – 48 bits device addr, publicly known
- Secret authentication key – a secret 128 bit key
- Secret privacy key – a secret key with length 4-128
- Random number – a 128 bit random number derived from a pseudorandom generator algorithm, executed in the Bluetooth unit.

Authentication:

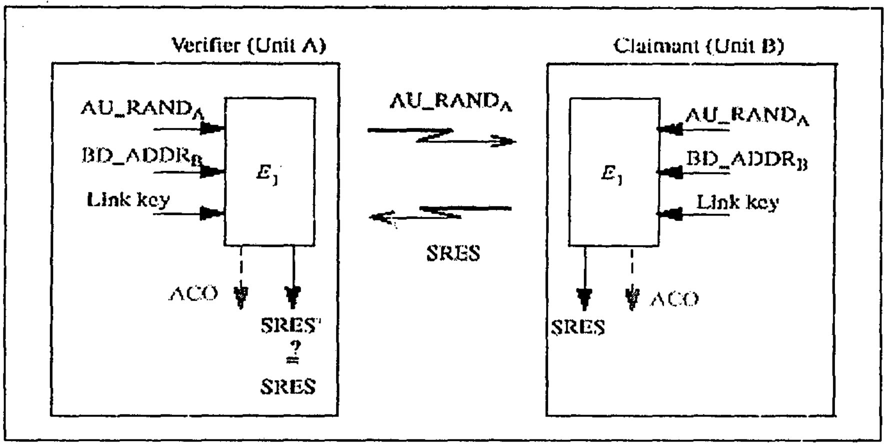

Figure 9: **authentication using the E_1 algorithm.**

Security – Encryption

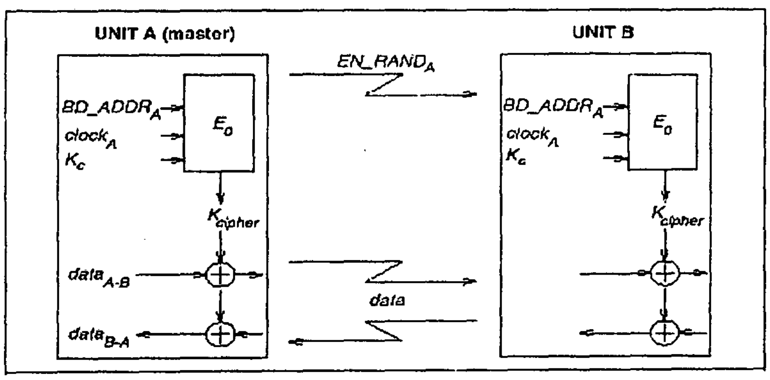

Figure 10: **Encryption of data over a Bluetooth link.**

2.15 Security – Encryption

- Only the pkt payload is encrypted
- For each pkt, a new encryption key is generated
- E0 is a LFSR (Linear Feedback Shift Register)

2.16 Error correction

At the baseband level, Bluetooth uses 3 error correction schemes:

a) **1/3 rate FEC** (forward error correction):

- Used in high quality voice pkts.
- This scheme sends 3 copies of each bit. Each received triple of bits is mapped into whichever bit is the majority.

b) **2/3 rate FEC:**

- Used in data or voice pkts.
- Uses Hamming code: can correct all single errors and detect all double errors in each codeword.

2.17 ARQ (Automatic Repeat Request)

- Used with data or voice pkts

❖ **Error detection**: dest discards pkts in error. Uses a CRC (Cyclic Redundancy Check) error detecting code

❖ **Positive ack**: dest returns a positive ack to error-free pkts

❖ Retransmission after time-out.

❖ Nack and retransmission: dest returns a nack to pkts in error. The source retransmits such pkts.

2.18 UMTS

The Universal Mobile Telecommunication System (UMTS) is—from a radio perspective—a third-generation cellular technology, which is defined by the International Telecommunication Union (ITU) in its IMT-2000 framework. From a conceptual point of view, it represents a technology step to mobile NGNs' facilitating ubiquitous computing.

After the first approach based on combined circuit – and packet-switched principles, researchers conceived UMTS to combine Internet protocol (IP) and mobile technologies to offer personal communication and personalized content everywhere. Its goal is to apply Internet protocols for mobile services control and end-to-end applications. The importance of UTMS could be understood by the fact that by the end of 2004, there were more than 16 million3G/UMTS customers subscribing to 60 networks based on WCDMA technology in 25 countries –and many more networks were either in advanced testing or in pre-commercial launch phase, with a total of more than 125 licenses awarded to a mixture of incumbent operators and new players (as shown in the graph below).

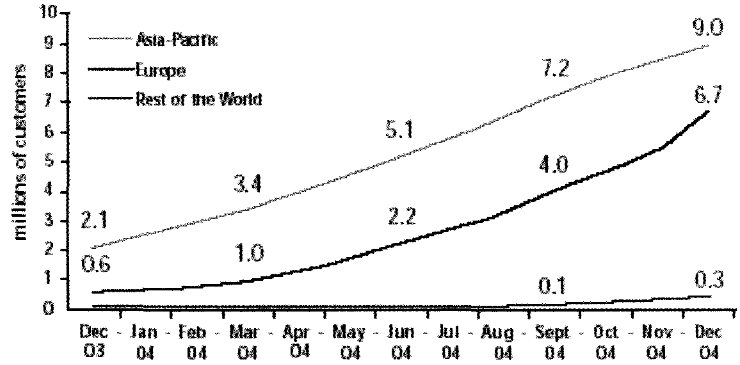

Diagram (above) showing customers (in millions) on 3G/UTMS launches, terminals and services between December 2003 and December 2004.

2.19 SMART PHONES AND MULTIMEDIA

With the evolution from second- to third-generation (2G to 3G) mobile networks, wideband radio access and Internet-based protocols characterize the way from a mobile handset to a mobile multimedia device.

As mobile operators worldwide migrate to third-generation (3G) networks, conversational video-telephony services are becoming a key differentiator between new 3G offerings and existing 2G/2.5G services. Although it's possible to have limited video-based services—such as a multimedia messaging service—that deliver pictures and video clips over 2.5G services, these are delay-insensitive applications that could run over a packet-based wireless network like General Packet Radio Service (GPRS) or Code Division Multiple Access (CDMA)'s 1XRTT. The 3G-324M system is a derivative of the International Telecommunication Union (ITU) H.324 protocol standard for low-bit rate multimedia communication, which ITU-T developed for the public switched telephone network (PSTN).

As PDAs and mobile phones have grown in popularity and capability, people have become enthusiastic about watching multimedia content through their mobile devices. The capabilities of these devices vary widely and are limited in terms of network connectivity, processor speed, display constraints, and decoding capabilities. As a result, when people use these mobile devices to view multimedia content, they generally restrict their viewing time because of the smaller displays. Because of the existence of such heterogeneous user clients in addition to the wide variety of data sources, it's a real challenge to implement a universally compliant system to fit multiple usage environments.

One common requirement for almost all high-bandwidth video—regardless of the platform or the application—is the need to personalize the content for the user and summarize the video for easy retrieval. One of the latest design frameworks for the summarization system is a three-tier architecture of *server, middleware, and client.* The server maintains the content video shot or scene. To summarize the video, one has to display the images all at once in a storyboard fashion. Some summarization systems display summarized videos using several key frames for each detected scene to generate a storyboard.

Researches have been carried out to demonstrate the use of storyboards for personalized TV news programs based on user preference. For video summarization, we expect to view a moving video and listen to the audio accompaniment. The extracted video segments can be based on video shots or on semantic video structures.

Video shots could be played back with their corresponding audio tracks. Some researchers have generated video summaries to compress and represent the original video into short, highlighted segments. A summary of a home video collection could include video excerpts along with an independent commentator speech and some background music. One research team demonstrated such an audio-annotated summarization system for home videos. One can effectively represent a video shot in a composite representation called a mosaic. The mosaic is essentially created from images of a common scene. Mosaics can be displayed as a static composite or animated with foreground objects traversing the background.

One popular use of the mosaic is in surveillance videos where the scene is essentially static and uneventful except for the occasional activity of intruders and unauthorized personnel. The user can also use this technique for video indexing or video browsing. Using the audio channel to derive the semantic meaning can improve video summaries that simply rely on visual data. For example, the user could process the speech signal with a speech-to-text engine to generate relevant keywords. Otherwise, the audio signal could convey interest through a volume energy-based classifier or an applause detector. One team used the speech signal to select shot segments of interest for summarizing a digital video library. Another team generated video summaries by using user attention models based on multiple sensory perceptions.

On examination of the semantic structure of videos, we can divide and categorize content by its inherent semantic properties. For news videos, for example, this can mean partitioning a one-hour news program into 10 categories such as local news, international news, and so forth. Furthermore, one could detect individual stories from each category. The semantic structure evidently creates semantic relationships between the structured segments of a video. One team's research incorporated film structure rules to detect coherent summarization segments, while another team summarized video scenes from TV programs with a coherent scene mosaic composition. It is possible to explore the hierarchical semantic structure of videos and use context clustering to generate coherent video summaries dynamically.

2.20 Adaptation engine

The adaptation engine performs the optimal set of transformations on the selected content in accordance with the adaptability declarations and the inherent usage environment. The adaptation engine must be equipped to perform transcoding, filtering, and scaling so that the user can play the final adapted personalized content. For instance, the Video Ed and Universal Tuner are adaptation engines. The adaptation engine must extract audiovisual segments from shot boundaries and combine them depending on the personalization selection.

Traditionally, MPEG files are split into shot segments and stored separately, which thus requires extra management and storage payload. In Video Ed , MPEG system-layer compressed domain editing technique, the tool directly extracts video-audio information from the original MPEG sources and combines them dynamically to generate a single MPEG file.Manipulated wholly in the system bit- stream domain, this method does not require decoding, reencoding, or resynchronization of audio and video data. Thus, Video Ed operates in real time and can provide great flexibility. Finally, the composite MPEG file can be transmitted and displayed through any Web interface.

The Universal Tuner system includes a transcoder for mobile devices. The Universal Tuner converts MPEG-1/2 video or live broadcasting video into a client-dependent format for PDAs. The input of the transcoder is a stream of video frames of MPEG-1/2/4 files. The video frames are first decoded and resampled to either80 × 80 or 160 × 160. Then, depending on whether the PDA device is black and white or color, the color RGB frames are either dithered using half toning or mapped to 256 colors using a shot-based optimal color map. In the color mode, shot boundary detection functionality can be added to update the color codebook for each new shot. After this step, the transcoder can selectively enable an entropy-coding process and a frame-differencing process to reduce the bit rates.

2.21 Few protocol standards for multimedia communication

2.21.1 ITU-T H.324 system:

The ITU-T H.324 standard is an umbrella recommendation developed by the ITU-T between1994 and 1998. It includes several components: a multiplexer defined by the ITU-T recommendationH.223; a V.34 modem; a session command, control, and indication system defined by the ITU-T recommendation H.245; audio and video codecs; optional data protocol for applications, such as data sharing (for example, the ITU-T T.120suite); and. optional encryption support.

An H.324 application isn't required to have each of these functional elements, except for theV.34 modem, H.223 multiplex, and H.245 system control protocol, which are mandatory to allH.324 terminals. However, H.324 mandates that terminals offering audio communication support the G.723.1 audio codec. Various H.324 terminals offering video communication are required to support the H.263 and H.261 video codecs. Additionally, H.324 terminals offering real-time audio-graphic conferencing are required to support the T.120 protocol suite. (3G-324M mandates specific audio and video codecs irrespective of H.324.)

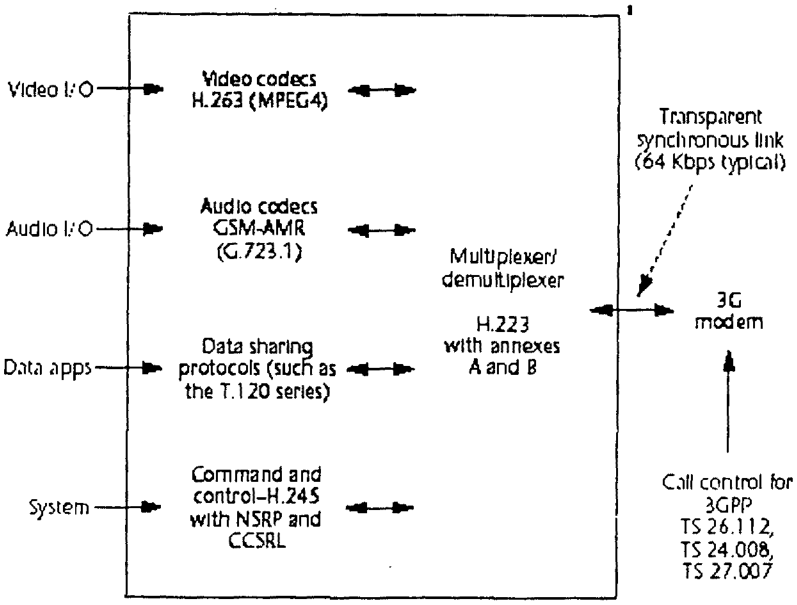

Figure 11. **Block diagram of the 3G-324M system. GSM-AMR is the Global System for Mobile Communication; Adaptive Multirate. NSRP is the numbered simple retransmission protocol. CCSRL is the control channel segmentation and reassembly layer. 3GPP is the Third Generation Partnership Project.**

2.21.2 H.324M system

The H.324 protocol (and in particular the baseline H.223 multiplexer) were designed for PSTNs. Through a series of annexes to H.324 and its components, the protocol has been extended to deal with error-prone mobile networks. Annex C of H.324 and annexes A, B, C, and D of H.223deal with increasing levels of error resilience.H.324 together with these annexes is usually referred to as H.324M. The most prominent extension features of H.324M are H.223's annexes A through D. For example, annex A of H.223defines a mobile level 1 (mobile level 0 is the baseline of H.223) and provides 16-bit flags for framing the multiplexer payloads instead of the8-bit high level data link control (HDLC) flags used in baseline H.223.

Annex B defines mobile level 2 and provides 16-bit flags and an extended header for the multiplexer payloads. Annexes C and D define mobile level 3 and provide additional adaptation layers and redundancy coding for highly error-prone channels. Other prominent differences between H.234 and H.324M reside in the modem requirements. The ITU modem related standard requirements (such as V.34/V.8/V.250) don't apply, although V.250is commonly available in mobile modems.

2.21.3 3G-324M system

Figure 5 shows a block diagram of the 3G-324M system. The 3GPP3G-324M technical specification defines a video-telephony service based on H.324M as follows: Using the ITU-T H.324 umbrella recommendation and its annex C. This defines the overall video telephony service, includingH.223 and H.245. Using annexes A and B of H.223 ITU-T to enhance the framing facilities of the multiplexer in error-prone conditions. Using the mobile command and control facilities of H.245. Using specific audio and video codecs. For example, it mandates the Global System for mobile Communication; Adaptive Multi rate GSM-AMR) audio codec and the H.263 video codec.

Other audio and video codecs are proposed as options (such as MPEG-4 video andG.723.1 audio codecs). Using a transparent circuit-switched channel (bearer) for carrying the overall multiplexed bit stream. Interfacing the video-telephony system to a modem and defining modem commands to configure for multimedia operations. The 3GPP defines a set of AT modem commands to configure and manage modems used in the context of 3G-324M.

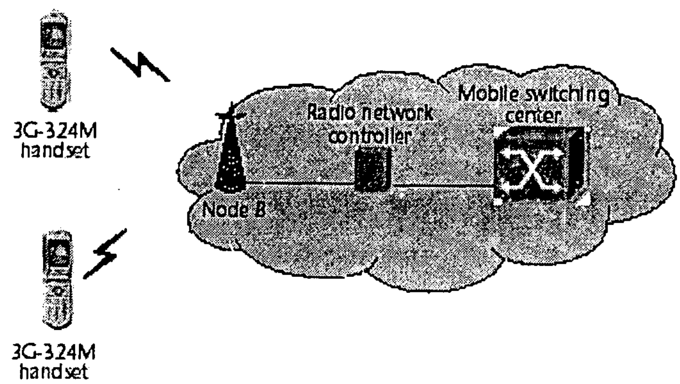

Figure 12. **Typical connectivity in a 3G-324M mobile-to-mobile service.**

2.21.4 Operations in a 3G-324M session

A typical session between 3G-324M terminals involves the following procedures: call signaling (dialing a number and establishing a bearer following a call's acceptance); mobile-level negotiation (terminals agree on an H.223 mobile level); and. using H.245 messages to exchange terminal capabilities, determine mastership of session, open audio and video logical channels, define multiplexing definitions, and process other messages that could be application dependent—for example, transmitting keypad presses for video mail navigation.

Figure 12 shows an overall network diagram. **Call signaling and bearer establishment** Low-level connectivity is about establishing a digital bearer (link) between two handsets. Handsets use 3G-call signaling, which involves using code points in the call-signaling records to indicate3G-324M capabilities. These are the H223and H245 code points. The code point is communicated when handsets initiate their call signaling through the mobile switching center (MSC), which uses the code point to detect the capabilities of both end points and decides how to handle the call. Following successful call signaling, a transparent data bearer (at 64 Kbytes per second) is established over which the 3G-324M-bit stream (with multiplexer payloads separated by framing flags) will flow.

2.21.5 Mobile-level detection

This is the first step in the protocol-establishment process. Each terminal starts transmitting bytes (flags) corresponding to the highest mobile level it supports (typically mobile level 2, corresponding to annex B of H.223). As soon as both end points detect that they're transmitting and receiving flags corresponding to the same mobile level, they both settle on that as their starting level. Otherwise, after repeating the same sequence several times without success, each handset drops its mobile level and starts transmitting the flags corresponding to the lower mobile level. At the end of the procedure, the handsets can connect at mobile level 2, 1, or 0.

2.21.6 Transporting MUX-PDUs

After the terminals have established a common mobile level, the H.223 multiplexer (MUX) immediately becomes operational on the datalink. From this point, we can only transmitH.223 protocol data unit (MUX-PDU) frames separated by framing flags on the link. A MUX-PDU is a frame that consists of a header and an information field. The header includes a multiplexing table entry index and a cyclic redundancy check (CRC) code associated with that index. At this early stage of the communication, this corresponds to multiplexer table entry zero, which corresponds to the built-in multiplexing mode that lets the MUX-PDU carryH.245 command and control messages encapsulated into special frames.

2.21.7 H.245 Numbered Simple Retransmission Protocol

Assuming MUX-PDUs are well-formed, the payload of the MUX frames at this stage of the link will carry H.245 messages (using the prede-fined logical channel zero and the multiplex table entry index zero). The H.245 messages are encapsulated using the Numbered Simple Retransmission Protocol (NSRP). An NSRP request frame consists of a header and a payload. The H.245messages are contained in the payload as an array of bytes in the abstract syntax notation 1 (ASN.1, ITU recommendation) format. That is, H.245messages are first serialized using an ASN.1encoder that converts messages into a string ofbits, and the resulting octet array—which can hold one or more H.245 messages—makes up the payload field of the NSRP request frame. According to NSRP specifications in H.324, anH.245 entity can't transmit a new NSRP request frame until it receives an NSRP response (acknowledgment)

References:

1. Motorola A760. *http://motoinfo.motorola.com/motoinfo*.
2. Motorola A760. *http://motoinfo.motorola.com/motoinfo*
3. Symbian OS. *http://www.symbian.com/*.
4. Personal Java. *http://java.sun.com/j2me/*.
5. MIDP Profile. *http://wireless.java.sun.com/midp/*.
6. Bluetooth. *https://www.bluetooth.org/*.
7. General Packet Radio Service (GPRS).
8. Ibid.,

Chapter 3
DESIGN CHALLENGES OF SMART PHONES

Introduction

The small physical size of mobile phones increases the design challenge.Hardware/software partitioning is an important design challenge.Hardware and software are co-designed and the requirements include keeping the risks low still targeting efficient design.Risk must be minimized.Real-time requirements must be secured by design.One true design challenge is to provide ample processing perfomance that meets the requirements, at a minimum power dissipation, with few and small chip .

3.1 Challenges

Below, are mentioned a few of the **functional challenges** poised in the design of smart phones:

1. **Communications focused** - smart phones, and this is where, for instance the Palm model, another smart phone, is struggling most. Often smart phone users will not recognise they have an operating system, let alone one that allows them to buy third party applications, and this doesn't work in the favour of a smart phone. Some who tightly focused communications solutions have had incredible success with narrow emphasis on simple email solution, despite having the capability for broader application support.
2. **Information focussed** - networked digital assistants, where the smart phone has had its traditional market appeal, despite the erosion from PocketPC-based devices. As more professional and white-collar workers need to have information to hand, this is moving from being solely a field service and logistics application set. Vertical applications and partnerships are key.

3. **Entertainment focussed** - connected media consoles, which historically have been based on closed operating systems, but the opportunity for connection both for download and game play has revenue potential for operators and content providers. A new potential opportunity, but even fixed games consoles have not been an easy market for others to break into.

To map applications onto embedded parallel task-processors in a cost and performance optimal manner, profiling and iteratively refining the architecture of the embedded system under consideration is required. Hence, retarget able compilers for parallel arrays of task-processors are needed to accomplish the design efficiently and cost optimally.

The mobile phone market continues to evolve at a rapid-fire pace. Device life cycles are shrinking as new features and functions become available and consumers adopt their mobile phone as part of their lifestyle. Consumers are increasingly selecting mobile devices for their style and form, subjecting one's design to shorter and shorter development cycles as fashions change.

These market forces are significantly impacting all participants in the value chain. Mobile operators are rapidly rolling out new network technology to help improve the consumer experience while boosting revenue opportunities. There is an extreme regional differentiation in market needs from low-cost, low-tier solutions for emerging markets to advancing 2.5G markets in highly industrialized economies. Outsourcing device design and development is routine, exerting dramatic downward pressure on component prices. Demands on processing performance, power consumption and component parts differ widely for each generation of mobile services.

To win in this highly competitive marketplace, Original Device Manufacturers (ODMs), Original Equipment Manufacturers (OEMs), Integrated Design Houses (IDHs), and others are all faced with the same challenge: How to bring new devices to market in record time, at the lowest possible costs, with the greatest possible features and in a stylish eye-catching design.

Smartphone applications present a variety of design issues, some common to all portable devices and some specific to these designs. Smartphone designers are tasked with combining cellular functionality with the applications processor functionality. The i.MX series of microprocessors provides the applications processor portion in the Innovative Convergence™ cellular platform. This companion chip approach enables functionality to be changed and enhanced in the applications processor without the need to re-certify the cellular functionality of the Smartphone with carriers. In addition, Freescale has best-in-class process technology that provides extremely low power consumption for extended battery life.

The i.MX1 are a family applications processor used by Zodiac mobile entertainment console —based on the ARM920T™ core—and the ATI Image on graphics accelerator to provide high quality support for all games. High quality video is a significant market differentiator for the Zodiac, especially when compared to the typical mobile gaming experience on a cellular handset or Game Boy. Palm OS® operating system currently supports some 19,000 applications from a wide range of developers.[1]

The use of the i. MX1 processor allows support for high. The benefits of the i.MX1 are:

i) Balance of processor power and low power consumption

ii) Close integration with peripherals, especially Bluetooth and

iii) System cost

The i.MX family of applications processors contain the perfect blend of performance, features, and low-power consumption to suit the entire range of Smartphone products.[2] In recent years, Wireless Internet Service Providers (WISPs) have established **Wi-Fi** hotspots[3] in increasing numbers at public venues, providing local coverage to traveling users and empowering them with the ability to access email, Web, and other Internet applications on the move. While the mobile computing landscape has changed both in terms of number and type of hotspot venues, there are several technological and deployment challenges remaining before hotspots can become an ubiquitous infrastructure. These challenges include **authentication, security, coverage, management, location services, billing, and interoperability**. Wireless local area networks (WLANs) have emerged as a promising networking platform to extend network connectivity to these public places, or *hotspots*, as they are commonly known.

3.2. Technological Challenges

At first, it seems that the scenario just described is easily realizable using the existing component technologies -- wireless LANs, wide-area data services, secure authentication, data encryption, dual mode WLAN **[G0]** operation, and WLAN-based location determination. However, a closer look at the requirements for the whole system to work in a seamless, convenient, and reliable manner reveal challenges that arise from the fact that the system as a whole is greater than the sum of its parts. In this section, we focus on the technological challenges of authentication, security, radio frequency range, network performance, network management, and support for context-aware services.

Smart phones make use of the Bluetooth industry or Technology that needs to meet the challenges on cost, compatibility, interoperability, reliability, and security. The positive note on security is that Bluetooth supports authentication and encryption, combining with frequency hopping, to give the technology the robust security. Three entities are used, a 48-bit Bluetooth address, 64-bit private user key, and a 128-bitRAND. The link level security of each pair of Bluetooth devices in a connection is based on a secret 128-bitrandom number link key that is used for authentication and encryption. For error correction, Bluetooth uses Forward-Error Correction (FEC) including 1/3 rate, 2/3 rate and ARQ scheme for data.

3.2.1 *Security Challenges*

Despite the aforementioned research and standards efforts in wireless hop security, commercial hotspot operators have not yet included any form of security support in their networks due to various practical limitations. Thus it is imperative to raise the following open research questions below:

- **Mutual Trust**: How can wireless-hop security be provided in a way to ensure mutual trust between the user and the hotspot provider? For instance, approaches like WEP [*Wired Equivalent Privacy*] assume an implicit trust in the key distributor. However, this opens up the potential for malicious users to spoof the keys and launch masquerading attacks.
- **Simplicity**-Robustness Tradeoffs: Can hotspot networks employ WEP-based security by choosing from a set of *guest access* WEP keys **[G1]** as opposed to a single access key, thereby providing stronger security? Can these networks trade-off implementation, reduce the slight overhead in key management?

  How can WEP keys be distributed transparently and scalably under circumstances?
- **Dynamic Key Management**: How can key exchange be renewable, simplified and transparent? Approaches like 802.1X **[G2]** require firmware support on the access points, system support on the mobile clients, and explicit reauthentication with roaming. Software architectures like the CHOICE, on the other hand, involve third-party software installation and configuration.
- **Hardware Approaches**: Are there ways to provide the robustness of 802.1X through alternative hardware-based approaches?

Do smart cards provide the appropriate tradeoff between security and convenience?

- **Denial-of-Service**: Current 802.11 Wi-Fi networks are highly susceptible to denial-of-service (DoS) attacks targeting the management and media access aspects of the 802.11 MAC protocol **[G3].** What countermeasures can hotspot provider stake to protect their networks against such attacks? Even standards bodies like the 802.11 TGi have deferred discussion about protection against such attacks, yet the public nature of wireless hotspots make them highly vulnerable.
- **Malicious Attacks**: Hotspots are a comparatively open environment for malicious users to eavesdrop on communication traffic and threaten network security. What measures must these vendors take to prevent masquerading attacks?

3.2.2 *Radio Frequency Range*

A third challenge posed by wireless LANs is radio frequency range. Inherent limitations of range and multipath interference from indoor RF propagation restricts user mobility to within the hotspot. If RF coverage is not adequate, roaming users can easily lose connectivity. Therefore, to provide uninterrupted connectivity to roaming mobile users, hotspot operators need to find ways to increase the density of hotspot coverage to span larger geographic regions. Today's wireless LANs are severely range-limited and the RF signals are subjected to limitations posed by the structural properties of hotspot location. There are numerous research solutions that have addressed the problem of range extension through dynamic power management, bridging, specialized antenna technology, and interoperation with cellular networks. The use of these solutions in hotspot networks raises several research questions:

- **Power Management**: How can wireless LAN range be effectively increased through varying the power levels of the access points? Since the power of the transmitted signal directly affects the cell size, can increasing the access point transmit power help mitigate the effects of indoor RF propagation?

- **Wireless LAN Bridging**: What are the tradeoffs in using wireless bridges between access points to increase wireless network range? Recently, some hotspot vendors have used wireless LAN-to-LAN bridging to cover a larger geographic area, thereby making the network accessible from a parked car or inside a cafe. For example, hotspot vendor WiFi Metro has created *hot zones* that provide tens of miles of blanket Wi-Fi coverage in downtown San Jose and San Francisco.

- **Hardware Approaches**: How effective are directional antennas using phased arrays in increasing the range of contemporary wireless LANs? Can such sophisticated hardware be deployed in hotspots and be economically viable? If so, will it be backward compatible with existing wireless LAN hardware?

- **Wireless MANs**: Metropolitan-area networks (MANs) like Seattle wireless and NYC Wireless claim to offer uninterrupted connectivity over a few miles of outdoor city areas. While this solution seems to address the problem of range, it poses several management and performance bottlenecks including lack of a single management entity, heterogeneous vendor hardware, and lack of infrastructure support.

What are the ramifications of connecting through such metropolitan networks? What infrastructure support do these networks provide?

- **Multihop Hotspots**: Can mobile nodes that are out of range of an access point access the network through other nodes that have better connectivity? With the use of higher-bandwidth, but range-limited access technologies, future hotspot architectures could be *multihop*, i.e., a network where mobile nodes reach the access point over one or more hops of an ad hoc network. Multihop hotspots pose several challenges to the network designer.

- **Interoperability with Cellular Data Networks**: It might be more efficient for roaming users to use wide-area wireless data services when they go out of range of hotspot networks. Interoperation between cellular and hotspot networks is beneficial to both wireless carriers (indoor wireless LAN users can help take the load off the cellular data network) and hotspots (users that are out of range of hotspot networks get better connectivity outdoors through cellular data services). However, cellular-to-Wi-Fi roaming service handoff is an open problem and raises many interesting questions. When a user on a cellular network enters into a Wi-Fi[4] coverage area, how can connectivity be seamlessly handed off from the cellular network to the Wi-Fi network, and vice-versa? Do all mobile devices have the hardware capability to use both networks on the same host?

3.2.3 Network Performance and QoS

A fourth challenge facing hotspot administrators is the ability to adequately provide capacity and coverage to handle dynamically varying, location-dependent user load. Further, as users pay for connectivity, it is reasonable that they expect a certain minimum level of quality of service (QoS) from the network in the form of sustained wireless bandwidth, end-to-end delay bound, etc. For instance, a user might be performing a large file transfer that requires a certain minimum bandwidth for her to complete his task before his flight departs. It is crucial for the network to manage the wireless bandwidth scalably and efficiently. Dynamic load management and bandwidth provisioning in the wireless network require that the network:

(i) has an understanding of the users' arrival behavior, data-rate demands, and duration in the network;

(ii) adapt to the changing resource availability or the changing traffic characteristic either statically (through over provisioning) or dynamically by readjusting load; and

(iii) suggest some form of corrective action to the user if adaptation is not possible in the time-scale that the resource change happens.

We discuss each of these requirements below. Traffic characterization studies of campus, conference-room, and enterprise have given initial insights into the usage patterns of these networks. Although these environments likely share characteristics with other similar wireless settings, it is not clear whether these usage models and network throughput characteristics directly translate to hotspots in public areas. To handle network load dynamically, hotspot providers need to better understand mobile user behavior and network resource demand in hotspot settings such as airports, hotels, parks, and so on.

As mentioned before, one of the ways to manage resource usage is to install enough access points to handle the estimated load as given by a traffic measurement. Unfortunately, there are limitations to this approach. First, installation and operation of more access points translates to a larger infrastructure and maintenance cost. Dynamic resource adaptation, on the other hand, requires:

(i) a robust and accurate way of measuring load at each access point; and
(ii) a way to allocate available resources assuring at least a minimum guarantee.

Suggesting corrective actions to users broadens the range of possibilities for adaptation, and may be very useful when users cannot accept the resources allocated through dynamic adaptation. To effectively manage scarce wireless resources and plan network capacity, the following research questions still need to be addressed:

- **Measurement and Modeling**: To what extent do measurements and models of user behavior and network performance in previously measured wireless networks apply to current and future hotspot network deployments?

- **Monitoring**: To what extent should hotspots be introspective, using measurements of throughput, channel contention, packet errors, etc., to improve service and network utilization?

- How can the hotspot network effectively measure and monitor load on its access points? Is the average throughput at the access points a good measure of load? Does media access delay to acquire the channel need to be taken into account?

Under fluctuating channel conditions, Wi-Fi clients to hop between data rates depending upon the bit-error-rate (BER) in the channel. Therefore, a client that operates at a lower data rate (e.g. 1 Mb/sec) occupies the channel for a longer duration, even though its contribution to the instantaneous throughput at the access point might be small. How does this affect the accuracy of the estimated load at the access point?

- **QoS Enforcement**: How can MAC protocols be designed to guarantee users a fair share of the wireless bandwidth and better channel utilization? If users are allocated certain share of the bandwidth (through admission control and reservation), how is this bandwidth provisioned and monitored for accounting purposes and trend studies? For example, is it possible to determine the percentage of users that account for over 80% of the consumed bandwidth? And how should the network curtail users who consume a disproportionately large share of the bandwidth?

- **End-to-End QoS**: How important is last-hop quality of service provisioning as opposed to end-to-end QoS? What is the effect of wired network congestion on the effectiveness of resource reservation in hotspots?

3.2.4 *Network Management*

A related challenge to load balancing is network capacity planning. As hotspot coverage grows, access points need to be installed at various parts of the network, which in turn brings the additional challenge of network management. Furthermore, access points can only be effectively installed after a *site survey* to estimate the ability of RF signals to propagate under the geographic constraints of the space (walls, metallic objects, etc.). And, besides additional network management, it incurs extra capital cost (cabling, VLAN **[G4]** routing, site survey, etc.). The need for network management raises a number of research questions:

- **Heterogeneity**: Organizations providing hotspots (e.g., airport authorities, mall owners, etc.) might handle network installation through third-party contracts. Therefore, the network may have access points from multiple vendors. How can such a network be best managed? Is there a common management interface (e.g., SNMP) that all access point support?

- **AP State Management**: Dynamic capacity planning requires sharing state information between various access points. How is this best done in large networks? There is no standardized Inter-Access-Point-Protocol that all vendors support.

How do large networks share state information between access points under these circumstances? In the CHOICE network architecture, state management is performed by a centralized hotspot controller. What are the trade-offs of centralized vs. decentralized management?

- **Switched Wireless LANs**: Can wireless LAN switching serve as an alternative to managing large numbers of access points?

Recently, companies such as Vivato and Aruba Networks have introduced wireless LAN switches to target coverage over an entire building or a large campus environment, eliminating the need for multiple access points. How can such switched networks interoperate with contemporary wireless LANs in hotspots?

3.2.5 *Multihop Hotspots*

As mentioned earlier, range limitations of next-generation technologies such as 802.11a may push hotspots beyond single-hop access to multihop, i.e., a network where mobile nodes reach the access point over one or more hops (through intermediate network nodes, or users). Multihop access increases the network diameter and allows clients out of range of access points to receive connectivity. However, multihop hotspots introduce many challenges to the network and protocol designer because of their inherent dynamic nature:

- **Node Mobility**: In hotspots, users may constantly enter or leave the network or may be mobile while communicating.

Consequently, the number of active nodes in the ad hoc network, the network topology, and the volume of network traffic is constantly changing . How does node mobility affect the end-to-end throughput and delay characteristics of TCP(Transport control Protocol) connections? How are routing algorithms that send userdata using available topology information tolerant to shorttermand long-term route loss?

- **Channel Interference**: Since all nodes in the ad-hoc network are not within RF range of the access points, they may not hear the access point transmission. However, their transmissions can cause interference (due to the particular topology, hidden terminals, etc.) at the access points, degrading effective throughput and the channel capacity. How can co-channel interference be mitigated when nodes are in an ad hoc network are operating within transmission range of the access point?
- **Power Management**: Since each node in a multihop network may be transmitting information on behalf of other nodes, nodes may be more severely power constrained. Therefore, more *power-aware* channel access protocols and more effective power saving algorithms need to be implemented.

- **Multiple Network Access**: Finally, nodes in the multihop hotspot that are just one hop away from the access point act as the access routers, or gateways, between the two networks. (i.e., the ad hoc network of user nodes and the infrastructure mode network w.r.t. the access point). How can such devices communicate with multiple physical networks simultaneously? To do so, such nodes need:

(i) wireless network adapter with more than one radio;

(ii) or a wireless network adapter with the capability to multiplex connections from more than one network; or

(iii) than one wireless adapter

3.2.6 *Granular power management*

Among the most power-hungry components are the loudspeakers. The small membranes and lightweight magnets of speakers used in smart phones generally result in lower efficiency, which is difficult to improve without making the speaker unacceptably large, heavy or expensive. The audio CODECs [compressor/decompressors] and amplifiers driving these speakers, however, offer considerable latitude for power savings.

The three output transducers (earpiece, loudspeaker and headset) are usually driven by three separate output stages, only one of which needs to be powered up at any given time. To avoid unnecessary supply current drain, smart-phone audio ICs feature increasingly granular power management — ideally with a separate control bit for each output driver, input preamplifier, digital-to-analogue converter, analogue-to-digital converter and analogue mixer. Software designed with power efficiency in mind takes advantage of this controllability to disable any functions not currently needed.

3.2.7 *Sample rate conversion*

Another perennial problem is the requirement to record and play back audio files recorded at different sample rates. Although digital sample rate conversion can be used to make this possible, the method is computationally very expensive, slowing down the CPU and increasing its power consumption. Two alternative methods avoid that drawback. The first is to let the audio digital signal processor (DSP) cores associated with D/A and A/D converters run at different speeds depending on the sample rate. Phase- locked loops (PLLs) provide a power-efficient way to generate the necessary clocks — usually by multiplying the word clock, whose frequency equals the sample rate, by a fixed number, such as 256.

Another method is the variable-rate audio feature built into AC97-compliant CODECs **[G5]**. This makes it possible to support all standard sample rates while keeping the master clock constant, at 24.576 MHz, and while transferring data across the digital interface at 48 kHz irrespectively of the sample rate. When playing or recording audio at sample rates below 48 kHz, such as the commonly used 44.1-kHz rate, the CODEC **[G5]** skips sampling approximately one out of every 12 data frames and times the 11 remaining samples more evenly. Even simultaneous recording and playback at two sample rates can thus be achieved. The power consumption of the extra digital logic that implements variable-rate audio is comparable to that of one or two high-quality PLLs **[G6]** and is far lower than for the digital sample rate conversion performed by a CPU.

3.2.8 Serving two clock domains

Opportunities for power savings also exist in the CODECs' digital core. Reflecting the origin of smart phones as hybrids between traditional mobile phones and PDAs, today's typical audio subsystem consists of a mono voice CODEC and a stereo, hi-fi CODEC, which may or may not reside on the same piece of silicon. Although they are interconnected in the analogue domain, each CODEC has its own digital core and audio interface, and is slave to its own clock domain. The voice clock is synchronized to the communications processor; the hi-fi clock is derived from the applications processor.
Besides increasing chip size, this architecture also results in two cores' running simultaneously when music, MP3 **[G7]** ring tones or other signal tones are played during a call, as well as in phone call recording. While sample rate conversion combined with digital mixing could unify the two audio streams for processing in a single CODEC, the power consumed in the process would far outweigh any power savings achieved through the elimination of one CODEC.

There is, however, another approach, which only requires a single audio DSP core, while preserving separate D/As and analogue signal paths. AC97 CODECs are particularly suited to this because, as discussed above, the variable-rate audio mechanism keeps their master clock constant, at 24.576 MHz. With the hi-fi clock thus fixed at one frequency, the voice clock can be locked to it as a fixed ratio: Dividing the 24.576-MHz hi-fi clock by six yields a 4.096-MHz voice clock (512 times the standard telephony sample rate of 8 kHz). By generating the clocks on-chip and operating as clock master on both audio interfaces, the audio subsystem eliminates any frequency mismatch that might otherwise result in unintentionally dropped samples and thus in audible distortion

3.3 New Challenges in Ultra Wideband Radio

Communications under the **ultra wideband (UWB)** regime is of emerging interest at both the theoretical as well as the practical implementation levels. Given the long history of UWB in radar systems, its potential applications in geolocation, inventory control, and as a supplement to GPS **[G8]**, are obvious. But in establishing the realistic potential of UWB communications (short range, indoor LANS, sensornets, LPI modes, etc.), there is a need to develop realistic and tractable models that capture not only the spectral characteristics of the wideband propagation channel, but also the antenna response, the impact of unstructured interference, and the potential ability to resolve closely spaced multipaths, particularly with pulsed signaling.

Receiver implementations for UWB systems are particularly challenging due to interference, synchronization, and channel estimation issues. Recent information theory analyses indicate that the requirement of high quality channel estimates greatly inhibits system operation over large bandwidths.

Fundamental issues relating to multi access protocols, modulation schemes, and signal processing algorithms need to be addressed while taking into account the characteristics of the wideband channel, the presence of very large number of multipaths, the difficulty in timing and channel acquisition (particularly in the episodic or duty-cycled mode), the existence of interference from narrowband and other UWB devices, the apparent necessity of sub-Nyquist sampling, and the limitation of DSP (such as ADC). Innovative approaches to UWB networking that combine physical and higher layers will be required. These issues will impact the prototype single user UWB radio in terms of complexity, size, weight and power.

The co-existence issue: i.e., the impact on (and of) conventional narrow-band radio *NSF/ONR/ARL* systems, and wideband radars must be quantified. There is an apparent need to revisit robust signal processing techniques in order to mitigate the UWB transients or impulses that may be seen by a narrowband receiver. Innovative all-digital radio receiver design that can be facilitated only by the development of low-power small footprint high precision high rate analog-to-digital converters (ADC) that can be embedded in a mobile device. Trade o.s with alternative higher rate but lower precision sampling schemes must be studied. The UWB signal design problem cannot be decoupled from antenna design, i.e., the design of miniaturized, perhaps directional, wideband antennas that ideally do not distort the signal. Thus, there are opportunities for multidisciplinary approaches involving modulation, coding, signal processing algorithm development, protocol design, VLSI [G9] and RF front end (antenna, ADC, variable delay correlator) design.

3.4 Power Consumption of Smart phones – Design Challenge

The convergence of a growing number of features and functions on smart phones is placing new demands on batteries and battery-charging technologies. Applications such as video playback and games, cameras with flash, MP3, and Web surfing draw more current than the more limited voice and productivity applications of single-function phones or PDAs. Multifunction converged devices will need bigger batteries with greater and more complex charging requirements. These changes mean *new design challenges* for portable wireless OEMs (Original Equipment Manufacturers), which affect the designer's choice of charging methods and battery-charger ICs.

In particular, the upcoming 3G and High Speed Downlink Packet Access (HSDPA) air-interface standards will make possible streaming video on smart phones and other compact portable systems. *Video/gaming mode is highly power consuming*, because it puts to work simultaneously the system's RF, base band, video processor, audio, and display. Running these applications would quickly deplete the typical 500-700-mAh batteries in today's 2.5G phones. Most of the battery cells used in existing smart phones have capacities over 1,000 mAh.

Along with bigger batteries come tougher charging requirements and design challenges, some of which result from end-user demands. First, even though the newest phones have batteries with up to double the capacity of older phones, users don't want to spend more time charging them. To maintain an equivalent charge time, when battery capacity is doubled, the charge current must also be doubled, which increases the size and cost of the charger IC. However, even though total power consumption is increasing, smart phones continue to require smaller components as system size shrinks. OEMs must therefore consider the tradeoff between current provided, size, and cost when choosing charger ICs.

Another challenge is the advent of USB ports as a convenient power source for charging handsets and portable devices. However, USB is limited to 100 or 500 mA, and some power will be lost in the conversion from 5 V. This limitation demands that new generations of mobile systems be designed with charging paths from both USB and dedicated adapters. A second set of design challenges results from the basic properties of rechargeable lithium cells. First, there are certain safety issues when designing with the most common lithium batteries: LiIon and LiPolymer. A LiIon pack contains multiple levels of protection, including mechanical and electrical protection-circuit modules, which prevent charging above 4.3 V, discharging below 2.3 V, and short circuits. Some types of LiPoly cells don't suffer from this volatility during an overcharge but must still be protected from short circuits and over-discharge to prevent catastrophic failure or damage. Because the charger IC is an integral part of this protection, it must work inside these parameters.

Next, specific precautions must be taken to protect battery life. LiIon cell makers typically recommend a maximum charge current of 1.0C (where C is battery capacity). For example, for an 800-mAh-capacity cell, a 1.0C charge current is 800 mA. Some LiPoly suppliers recommend current ranging from 1.0C to 0.5C, depending on the cell type. Other precautions include 0.1C charging at voltages below 3 V; minimizing the discharge below 3 V; not charging/discharging with excessive current; avoiding continuous charging by terminating charging when current attenuates to 0.1C in constant voltage mode; and staying within the recommended temperature range, typically 0°-45°C, during charging.

Finally, although different charging methods might be used, cell makers recommend the constant-current/constant-voltage (CC/CV) charging method to avoid damage caused by over-current and over-voltage conditions. For instance, a charger IC would begin charging a 2.7-V deeply discharged battery at 0.1C trickle charge mode to prevent damage. When the voltage reaches 3 V, the charger would transition to constant-current mode in which fast charging takes place at 1.0C. When the battery approaches full charge, its voltage will reach 4.2 V and the charger enters constant-voltage mode, so the cell's maximum voltage isn't exceeded. At this point, the current exponentially tapers off until 0.1C trickle current is again reached, indicating the end of the charge. An alternate method is using a timer to terminate charging, typically after 3 hrs. That is used to detect damaged cells.

References:

1. "Freescale i.MX Case Studies: Tapwave Case Study, September 2003". ©Freescale Semiconductor Inc, 2004
2. *http://www.freescale.com/*webapp/sps/site/application.jsp?
3. **Wi-Fi** Short for *wireless fidelity* and is meant to be used generically when referring of any type of 802.11 network, whether 802.11b, 802.11a, dual-band, etc. The term is promulgated by the Wi-Fi Alliance.
4. **Ibid.**

Chapter 4

COMPLEXITIES OF SMART PHONES

Introduction

As already mentioned,smart phones are handhelds that combine the communication capabilities of a cell phone with the computing functions of a PDA.As such functional complexities are inevitable. In general, the functional complexity of the emerging communication standards is very high, partly since development takes place in parallel with the standardization process, and partly because many functionalities that are optional from the system network side are mandatory for the terminals.There are applications with hard real-time requirements (e.g.the physical layer of the wireless communication), as well as with soft real-time, quality-of-service requirements (e.g. higher communication layers, most multimedia related user applications).

4.1 Physical complexities

Like most other PDA/phone combos, the smart phones, (for instance, i700) have proved difficult for the user to manipulate with one hand. Even with the assortment of hardware buttons adorning the i700, the user put himself or herself, and others, at risk when he or she tried to use it while driving. In fact, every smart phone comes with too many buttons. They were finicky, too: The user has to keep inadvertently activating the voice recorder, or the on/off switch, or the brightness toggle.[1] Because of its overall size and relatively large display, the users, it has been found, is often gnawed by the fear of accidentally dropping it.As such,Patrick Houston once said, If one gets a smart phone, one should strongly consider signing up for the optional damage insurance[®] .

[®] Patrick Houston, Editorial Director,Anchor Desk on "The skinny on Samsung's new smart phone"

Several waves of rapid change are in store for cell phone handsets. Multi-mode smartphones, wireless PDAs and multimedia devices are encroaching on territory once dominated by the simple, voice-only, single-mode cell phone. A new wave of technologies including Bluetooth, 802.11 wireless LAN (WLAN) and global positioning services (GPS) are converging in mobile devices, pressuring handset designers to devise innovative solutions that meet the stringent design constraints of the wireless market including cost, form factor, performance and power consumption

As if these aforementioned design constraints of converging technologies weren't enough, another wave of technologies involving additional radio frequency (RF) capabilities is soon to follow. Some handsets on the market today already feature FM radio and analog television reception. In addition to these capabilities, an increasing number of handset designs will implement additional radio interfaces such as ultra wideband (UWB), digital TV and satellite radio. As more radios are incorporated into single devices, design intricacies become increasingly complex.

4.2 Technological Complexities

Today's emerging Pervasive Computing technology in smart phones faces serious technical issues: Most of these devices have strong limitations on memory usage and processor performance as well as tight constraints on power consumption.[2] The ubiquity of world wide web embedded in smart phones needs considerable attention in that while technology will always place limits on user experience, the dominant technology for user interaction at present, ie the web, has a model for interaction based on pages and 'client-server' communication. This kind of interaction can be disconcerting for users. It most affects consumers on slow Internet connections. Smart phones ' complexities also surface with the limitations of the various technologies employed therein. In the following are mentioned some of the limitations of GPRS, Bluetooth etc – technologies used in smart phones.

4.2.1 GPRS - limitations

Smart phones make use of the GPRS service which is not free from problems. Although GPRS has many benefits there have been a few problems. Connection speeds until the end of 2004 performed badly on some networks running at around 12Kbps, a far cry from the expected. This year 2005, however there do not seem to be as many problems, probably due to the fact that operators are improving due to trial and error. GPRS is after all a recent technology.

Another problem sometimes encountered is customer expectation. Many companies have applications running on a 10 megabyte LAN and expect the same performance from their GPRS devices. Although the connection speeds these days are good it still is not as fast as ISDN or Local Area Networks. To a certain extent operators have themselves to blame for this, since in the past their marketing has tended to promote the speed aspects of 2.5 and 3G. Today, they are working hard to reduce expectation in this respect. Earlier problems with things like mail servers not sending mail because of latency problems to GPRS devices have all been much eradicated through optimisation programs. Peoplerunning Citrix Thin Client have also encountered problems with latency although a few Thin Client forums suggest that Citrix are addressing the issue. Deployment on some networks has been slow.

GPRS roaming has not been implemented in many countries on a lot of networks as yet. This is where a user can use the GPRS service from any network operator. At the moment although your GSM mobile will work, GPRS may not work at all. Accesses by third party application providers are having a lot of difficulty obtaining an APN from providers to offer their own GPRS services. This somewhat limits services to that provided by the GPRS operator.

4.2.2 Bluetooth Limitations

- Does not address routing, most network functions are pushed into the link layer
- Does not support multi-hop multicasting
- Does not address how to cope with mobility!
- The MASTER node is the bottleneck
- Number of nodes in piconet is limited
- Does not address power-saving methods done at upper layers, above the link-layer

4.2.3 Multiple platforms

For many online services it is desirable for them to be accessible from a variety of platforms. However, creating interfaces that work effectively across a number of platforms while feeling the same to the user and behaving consistently is time and resource-consuming for businesses, and increases support and maintenance costs.

4.3 Abstracting interaction principles

Interaction design is moving to many varied platforms from mobile phones to public kiosks and television screens, while data (enabled by structured markup languages such as XML) is increasingly being separated from presentation. The way in which information is best presented varies between these platforms: from the small, black and white mobile phone screen often viewed in poor light to the large, color personal computer screen. Modes of interaction also vary: from a small device with a limited number of small buttons, rockers and jog wheels often operated on the move, to a full-size keyboard and mouse. Interaction designers will need to create design solutions based on a high level of abstraction that embodies sets of rules for presentation and interaction that can be adapted to all these platforms and thus minimizes required maintenance. This will also be valuable for the internationalization and localization of websites and other products.

4.4 Designing for novices and experts

As more people use interactive products it becomes a greater challenge for the interface to support all these users. Also, as products become more complex, interaction design needs to support users who are expert in some aspects of an application but novices with respect to others.

4.5 Mapping the physical world and the network

The network is an enhancement of, not an alternative to, the real world. Interaction designers will need to develop design solutions that support people performing a task that moves from one environment to the other. Bringing new technologies into an existing design is difficult in its own right, but designers of handsets must also contend with the most demanding constraints of all— those imposed by end consumers. Failing to meet or beat consumers' expectations for extended battery life, increased multimedia performance, sleek form factors and low cost would be disastrous. As well, time-to-market often trumps many of the designer's technical considerations.

4.6 Facing Reality

Assuming that the requisite technical advancements and higher levels of integration are achieved so that future waves of technologies do indeed converge on handsets, new designs still will face the inevitable market-driven tests of cost, performance, board space, power consumption and time-to-market. In addition, a converged handset with multiple functions sharing certain resources only accentuates the importance of other prickly issues such as certification and security.

It is not difficult to imagine a usage scenario for a converged handset where three technologies—cellular, Bluetooth, and 802.11— are active at the same time, and where Bluetooth and 802.11 are sharing the resources of a single RF transceiver. For example, a cellular phone call could be directed to a handset while the user is listening to music that is streaming through the handset's WLAN interface before it is transferred via Bluetooth to a headset.

Of course, system certification is always a critical development hurdle to overcome. Type approval of a handset's cellular interface is complex and involves extensive testing. The process becomes even more complicated when multiple air interfaces are included in a single handset. This necessitates the simultaneous fulfillment of multiple certification standards promulgated by multiple worldwide standards agencies. Over and above the cellular certification process, WLAN and Bluetooth have their own requirements for interoperability testing and for meeting certain regulatory requirements.

Even though a high level of silicon integration will not decrease the amount of testing required for certification, reducing the system's complexity gives manufacturers greater confidence that serious problems will not occur during the certification process. For example, semiconductor vendors can provide example layouts for the small number of external devices that would accompany an integrated solution. Since an integrated solution would reduce the form factor layout of the system, these external devices could be easily adopted with only minor changes to the design. Consequently, high levels of silicon integration ease system integration and make the path through system certification simpler and more predictable.

Security is always a concern in today's world, and the wireless handset is no exception. As more technologies converge on handsets, the number of access points into the system increases, raising the vulnerability of handsets to attack. It is incumbent upon handset developers to design security measures into their architectures and to take advantage of the security features of wireless chipsets.

Modular architectures lend themselves to strict security measures because each module can establish its own security perimeter. Breaking into one module would not necessarily compromise the security of the entire system. At the same time, integrated security features like hardware-based secure boot loaders and sophisticated cryptographic engines are very effective at keeping hackers, viruses, worms and other types of malevolent code at bay. As the handset market continues its rapid pace of growth and innovation, handset designers will be challenged to control the convergence process instead of being controlled by it. That will mean careful architectural planning, close collaboration with component suppliers and creative innovation.

References:

1. Patrick Houston, "The skinny on Samsung's new smart phone" *http://reviews-zdnet.com.com/*AnchorDesk/4630-7296_16-5084581.html

2. Uwe Hansmann, Lothar Merk, Martin S.Nicklous and Thomas Stober, *Principles of Mobile Communication,* Springer Publication, 2^{nd} *edition, 2003.*

CONCLUSION

Now is the age of pervasive computing where social interactions play a major role,it has been studied and found that in a pervasive environment, phones exist in a social setting where the focus is communication, not computation.[1] This is to say that the PDA role of the smart phones render multiple complexities. Yet the technological advancements as step to innovation and challenges cannot be overlooked.

It was mentioned in the fifth chapter about the complexities encountered with regards to the physical features of Smart Phones-the risks involved in its handling.Nevertheless, few other users have found themselves using it to work productively during their daily subway commute--reviewing their calendar, going over e-mail, and updating their task list.[2] So the physical utility outweighs the physical complexities by the efficiencies provided in its usage, as per this argument.

Nevertheless one thing is sure, ie smart phones should find a niche among style-conscious business users, including executives and big-ticket sales types who want e-mail, calendaring, and wireless data synchronization more than they want voice communications. But for everyday cellphone users, it's too data-oriented, too delicate, and too expensive.

In the earlier chapter, the utility and limitations of one of the embedded technologies in smart phones, i.e. Bluetooth have been discussed with still challenges ahead in future.

Bluetooth as a global, RF-based (ISM band: 2.4GHz), short-range, connectivity solution for portable, personal devices will offer end-to-end solution through its implantation in a single chip will allow many devices to be Bluetooth-enabled for better performance. Yet in future, limitations of Bluetooth like- problems in address routing, pushing of most network functions into the link layer, not supporting multi-hop multicasting, etc need to be addressed and the impact of Bluetooth is still to be seen in the study of mobile communications in general and smart phones, in particular.

Still today, there are challenges ahead, and smart phones will need to deliver more licensees to restore momentum and remain credible. But if it can continue to improve the platform fast enough and make progress in specialized markets, then the PDA category that Smart Phones have popularized will at last evolve into a family of networked and corporation-friendly devices.

But today, as smart phones become more and more ubiquitous in our life with all the embedded technologies inbuilt, they tend to get *more and more invisible.*[3] In near future, a computer system built into a mobile MP3 player **[G7]**, which downloads music titles from the Internet, will be the most natural thing in the world No one will care if there is Java inside and how the TCP/IP or the Bluetooth Protocol stack is implemented. Not the enabling technology, but the applications and the delivered services will have a strongly visible influence on our high-tech culture.

With the introduction of all the challenging and innovative multidimensional features into the smart phones, *the complexities both physical and technological increase manifold* as mentioned in the earlier chapters. For instance, let's consider power consumption of smart phones that was discussed in chapter 4. The growing number of features and functions on smart phones places new demands on batteries and battery-charging technologies and it has been found that features such as video playback and games, cameras with flash, MP3, and Web surfing draw more current than the more limited voice. At present, though these features significantly contribute to the growing the market value of smart phones, it is possible that energy consumption by them, if not properly managed can interfere with the need for voice communication and henceforth the market in the long run.

These complexities pose paradoxical derivations. On analysis, two cases arise of which the first suggests the positive implication whereas the second suggests the contrary. The positive implication is that smart phones with all the inbuilt features are desirable since communication; computation, entertainment, business transactions, etc are at your fingertips with the usage of one. Thus in this same line of thinking, we can say that this is a sign of technological advancement, the progressive move of civilization.

On the contrary, with numerous features and incorporation of various technologies embedded into the smart phones, the minuteness of the sizes that come out as products from manufacturers increase the complexities making them "not-user-friendly". This is a serious lapse as far as social interaction via communication is concerned. It is to be noted that the primary function of smart phones is communication and not computation or multimedia features.

Lastly I would like to conclude with the argument that the application development for a convergent device exhibiting both telephony and PDA capabilities as seen in smart phones is more likely to succeed if the applications augment what many see as the device's primary purpose—communication.

References:

1. Eleanor Toye, Richard Sharp, Anil Madhavapeddy and David Scott," Using Smart Phones to Access Site-Specific Services " *IEEE CS and IEEE ComSoc Publication, April-June, 2005*

2. Patrick Houston, "The skinny on Samsung's new smart phone" *http://reviews-zdnet.com.com/*AnchorDesk/4630-7296_16-5084581.html

3. Uwe Hansmann, Lothar Merk, Martin S.Nicklous and Thomas Stober, *Principles of Mobile Communication,* Springer Publication, *2nd edition, 2003.*

Bibliography

1."Freescale i.MX Case Studies: Tapwave Case Study, September 2003". ©Freescale semiconductor Inc, 2004.

2. "The European Path Toward UMTS," *IEEE Pers.Commun.*, special issue, Feb. 1995

3. Bluetooth Resource Center, *http://www.palowireless.com/infotooth/*0-7695-2118-5/04 $ 20.00 © 2004.

4. Andrew S.Tanenbaum, *Computer Networks 4/e*, Prentice Hall,2003.

5. Bluetooth Tutorial, http://www.ee.iitb.ernet.in/uma/~aman/bluetooth/Bluetooth. *https://www.bluetooth.org/.*

6. C.Christopoulos, A.Skodras, and T.Ebrahimi, "The JPEG 2000 Still Image Coding System", *IEEE Transactions on Consumer Electronics*, Nov.2000.

7. C-K Toh, *Ad Hoc Mobile Wireless Networks, Protocols and Systems*, Prentice Hall 2002

8. Eleanor Toye, Richard Sharp, Anil Madhavapeddy and David Scott," Using Smart Phones to Access Site-Specific Services " *IEEE CS and IEEE ComSoc Publication, April-June, 2005*

9. Ericsson P800. *http://www.sonyericsson.com/*P800/.

10. G. Bell, " The Age of the Thumb: A Cultural Reading of Mobile Technologies from Asia," published in *Thumb Culture: Social Trends & Mobile Phone Use*, Bielefeld, 2005.

11. General Packet Radio Service (GPRS).

12. http://www.cisco.com/univercd/cc/td/doc/cisintwk/ito_doc/x25.htm

*13.http://www.freescale.com/*webapp/sps/site/application.jsp?nodeId=02XPgQ3ZPc59md# designChallenges.

14. Joao Schwarz Dasilva,Demosthenes Ikonomou, and Heiko Erben,European Commission, "European R&D Programs on Third-Generation Mobile Communication Systems", *IEEE Personal Communications*, February 1997.

15. Josef F. Huber, "Mobile Next-Generation Networks (NGNs)", *Published by the IEEE Computer Society, January-March 2004.*

16. Li Fun Chang,Wireless Internet- Networking Aspect,AT & Labs- Research MIDP Profile. *http://wireless.java.sun.com/midp/.*

17. Motorola A760. *http://motoinfo.motorola.com/motoinfo/*products.asp?product=A760&y=2003.

18. Patrick Houston, "The skinny on Samsung's new smart phone" *http://reviews-zdnet.com.com/*AnchorDesk/4630-7296_16-5084581.html.

19. Personal Java. *http://java.sun.com/j2me/.*

20. R.Pon,M.Batalin, M.Rahimi,Y.Yu, D.Estrin, G.J.Pottie, M.Srivastava, G.Sukhatme,and

21. W.J.Kaiser, "Self-Aware Distributed Embedded Systems", *Proceedings of the 10th IEEE International Workshop on Future Trends of Distributed Computing Systems* (FTDCS'04)

22. Rene Meier, "Communication Paradigms for Mobile Computing", *Mobile Computing and Communications Review*,Volume6, Number4, October 2002, pp.56-58

23. Russell Beale, "Supporting Social Interaction with Smart Phones" Published by the IEEE CS and IEEE ComSoc, *Pervasive Computing*, April-June 2005.

24. Shengjie Zhao, Xiaodong Wang, "Optimal Resource Allocation for Wireless Video over CDMA Networks" *IEEE Transactions On Mobile Computing*, Vol. 4, No.1, January/February 2005, *http://www.gsmworld.com/technology/gprs/intro.shtml*.

25. Symbian OS. *http://www.symbian.com/.*

26. Uwe Hansmann, Lothar Merk, Martin S.Nicklous and Thomas Stober, *Principles of Mobile Communication,* Springer Publication, *2nd edition, 2003.*

27. W. Stallings, *Wireless Communications and Networks*, Prentice Hall 2002

28. Wen-Chih Peng, "Design and Performance Studies of an Adaptive Cache Retrieval Scheme in a Mobile Computing Environment" *IEEE Transactions On Mobile Computing*, Vol. 4, No. 1, January/February 2005.

29. **Wi-Fi** Short for *wireless fidelity* and is meant to be used generically when referring of any type of 802.11 network, whether 802.11b, 802.11a, dual-band, etc. The term is promulgated by the Wi-Fi Alliance.

GLOSSARY OF TERMS (Gs)

[G0]. WLAN- Acronym for *wireless local-area network.* Also referred to as *LAWN.* A type of local-area network that uses high-frequency radio waves rather than wires to communicate between nodes.

[G1]. WEP- Short for *Wired Equivalent Privacy*, a security protocol for wireless local area networks (WLANs) defined in the 802.11b standard. WEP is designed to provide the same level of security as that of a wired LAN.

[G2]. 802.1 *or* **802.11** - *802.11* refers to a family of specifications developed by the IEEE for wireless LAN technology. 802.11 specifies an over-the-air interface between a wireless client and a base station or between two wireless clients. The IEEE accepted the specification in 1997.

[G3]. MAC Protocol Short for *Media Access Control.* **MAC address** uniquely identifies each node of a network and The Media Access Control Layer is one of two sub layers that make up the Data Link Layer of the OSI model. The MAC layer is responsible for moving data packets to and from one Network Interface Card (NIC) to another across a shared channel.

[G4-G4] VLAN Short for *virtual LAN*, a network of computers that behave as if they are connected to the same wire even though they may actually be physically located on different segments of a LAN. VLANs are configured through software rather than hardware, which makes them extremely flexible. One of the biggest advantages of VLANs is that when a computer is physically moved to another location, it can stay on the same VLAN without any hardware reconfiguration.

[G5]. Codec Short for *compressor/decompressor*, a codec is any technology for compressing and decompressing data. Codecs can be implemented in software, hardware, or a combination of both. Some popular codecs for computer video include MPEG, Indeo and Cinepak.

[G6] PLLs Short for *phase-locked loop*, an electronic circuit that controls an oscillator so that it maintains a constant phase angle (i.e., lock) on the frequency of an input, or reference, signal. A PLL ensures that a communication signal is locked on a specific frequency and can also be used to generate, modulate and demodulate a signal and divide a frequency. PLL is used often in wireless communications where the oscillator is usually at the receiver and the input signal is extracted from the signal received from the remote transmitter.

[G7] MP3 The name of the file extension and also the name of the type of file for MPEG, audio layer 3. Layer 3 is one of three coding schemes (layer 1, layer 2 and layer 3) for the compression of audio signals. Layer 3 uses perceptual audio coding and psychoacoustic compression to remove all superfluous information (more specifically, the redundant and irrelevant parts of a sound signal. The stuff the human ear doesn't hear anyway). It also adds a MDCT (Modified Discrete Cosine Transform) that implements a filter bank, increasing the frequency resolution 18 times higher than that of layer 2. The result in real terms is layer 3 shrinks the original sound data from a CD (with a bit rate of 1411.2 kilobits per one second of stereo music) by a factor of 12 (down to 112-128kbps) without sacrificing sound quality. Because MP3 files are small, they can easily be transferred across the Internet

[G8] GPS Short for *Global Positioning System*, a worldwide MEO(Medium or middle earth Orbit) satellite navigational system formed by 24 satellites orbiting the earth and their corresponding receivers on the earth. The satellites orbit the earth at approximately 12,000 miles above the surface and make two complete orbits every 24 hours. The GPS satellites continuously transmit digital radio signals that contain data on the satellites location and the exact time to the earth-bound receivers. The satellites are equipped with atomic clocks that are precise to within a billionth of a second. By using four satellites, GPS can also determine altitude.

[G9] VLSI Abbreviation of *very large-scale integration*, the process of placing thousands (or hundreds of thousands) of electronic components on a single chip. Nearly all-modern chips employ VLSI architectures, or ULSI (ultra large scale integration). The line between VLSI and ULSI is vague.

[G10] **CMOS** Short for *complementary metal oxide semiconductor*. Pronounced *see-moss*, CMOS is a widely used type of semiconductor. CMOS semiconductors use both NMOS (negative polarity) and PMOS (positive polarity) circuits. Since only one of the circuit types is on at any given time, CMOS chips require less power than chips using just one type of transistor. This makes them particularly attractive for use in battery-powered devices, such as portable computers. Personal computers also contain a small amount of battery-powered CMOS memory to hold the date, time, and system setup parameters.

[G11] *X.25* is an International Telecommunication Union-Telecommunication Standardization Sector (ITU-T) protocol standard for WAN communications that defines how connections between user devices and network devices are established and maintained. X.25 is designed to operate effectively regardless of the type of systems connected to the network. It is typically used in the packet-switched networks (PSNs) of common carriers, such as the telephone companies. Subscribers are charged based on their use of the network. The development of the X.25 standard was initiated by the common carriers in the 1970s. At that time, there was a need for WAN protocols capable of providing connectivity across public data networks (PDNs). X.25 is now administered as an international standard by the ITU-T [2].

[G12] **UMTS** Universal Mobile Telecommunications Service, part of the IMT-2000 initiative, is a 3G standard supporting a theoretical data throughput of up to 2 Mbps. First trials started in 2001. It should be rolled out in most of the world by 2005.