MOBILE INTERNET TECHNOLOGIES AND INFRASTRUCTURE

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ABSTRACT

The development and propagation of cellular voice systems over past several years has exposed the capabilities and the usefulness of wireless communications and, thus, has paved the way for wide-area wireless data applications and mobile Internet. The demand for mobile Internet is experiencing a significant increase and is turning into a communications revolution that can change the lifestyle pattern in the near future. This paper examines the technologies and the infrastructure that provides the base for this revolution and reveals its potential.

INTRODUCTION

Two of the most influential technological developments in the past ten years have been the spread of the Internet and the mobile telephony. In last few years, the telecommunications industry in most countries has witnessed a new phenomenon – the fusion of mobile technology and the Internet, creating a new paradigm, "Mobile Internet". The "Mobile Internet" and "Wireless Data Communication" has become one of the hottest topics in recent years. It represents a communications revolution that has already started and is gaining momentum, and is enhancing and enriching the way people communicate and do business.

Although, the demand for mobile Internet is growing, the progress is slow, the process is complicated, and there is confusion, hype and unrealistic expectations. Most of the users and service providers have built up expectations that mobile Internet will provide a user experience similar to fixed Internet. Given high expectations for a mobile Internet offer that would replicate the fixed Internet experience, the mobile Internet as it exists today is an alien product for most of the users – the screen is small, access is slow, and the charges are high.

Even though the reality of mobile Internet is more prosaic, there are some good technologies available right now, and more are on the way. The spectacular success of Japanese operator NTT DoCoMo's i-mode mobile Internet service indicates that there is sizeable demand for such services. The next-generation cellular systems, public wireless LANs and new phones and PDAs offer significantly increased value.

KEY MARKET DRIVERS

To understand the future of mobile Internet and to find out how it will evolve, let's look at some of the key drivers of this market:

Growth in Internet Usage:

The number of Internet users, worldwide, is predicted to reach 500 million by 2003, growing at an average rate of

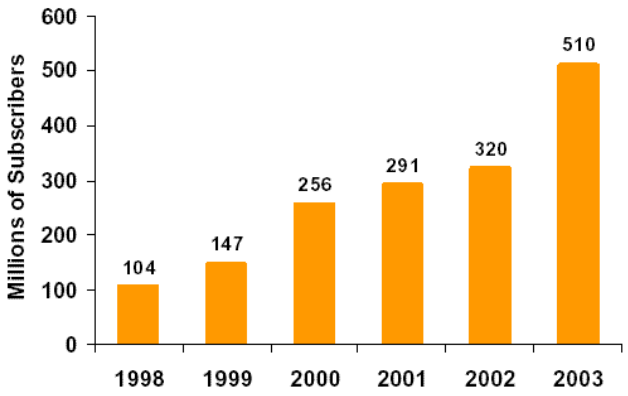

Figure 1: Worldwide Growth in Internet Users
(Source: CSFB)

29% since 1998. This desire to access information on the Internet will spill over to those users wanting it at all times and places via mobile devices.

Explosion of Mobile Communications:

According to Nokia, about 700 million users worldwide had mobile phone at the end of 2000. The company estimates that there will be 1 billion mobile phone users by the first half of 2002 – or one out of every six people on the planet. It also estimates that there were 60 million web-enabled handsets worldwide at the end of 2000 which will increase to more than 200 million by that time. Again, the growing number of mobile users and web-enabled handsets would result in increase in demand for Internet access.

According to Strategis Group, in United States alone, mobile data services will be used by 60 percent of the population in 2007 and subscribers will rise from five million in 2000 to 172 million during that seven-year span.

The Yankee Group Europe also predicts that by 2003, 25% of total wireless revenue will be accounted for by wireless data, up from just 5% at the end of 1998. This is an increase from $4.3 billion to almost $39 billion.

High Speed Standardized Platforms:

Over the next few years, mobile voice and data services will continue to be delivered over a number of network platforms. Gradually, the market will shift from current second generation technologies to second-plus, and then third-generation technologies. The introduction of WAP and other combined efforts to standardize key technologies will also result in huge demand for mobile Internet access. The Universal Mobile Telecommunications System (UMTS) Forum predicts that by 2010 data services will represent $300 billion or 66% of all worldwide 3G revenues.

Low Cost Devices:

The development and adoption of smaller mobile computing devices such as Palm Pilot, PocketPC, handheld PCs, smart phones and two-way pagers will make wireless data solutions more affordable and practical for a broader range of users.

MOBILE TECHNOLOGY LANDSCAPE

Today's wireless networks are a combination of incompatible technologies and standards. Subscribers cannot use their mobile devices outside their coverage area, and developers are potentially forced to create multiple versions of the same applications. In contrast, the wired Internet is a more homogeneous environment with globally implemented standards. Figure 2 provides a high-level view of just how different the wireless Internet landscape is from the wired Internet, and indeed how much more complex it is.

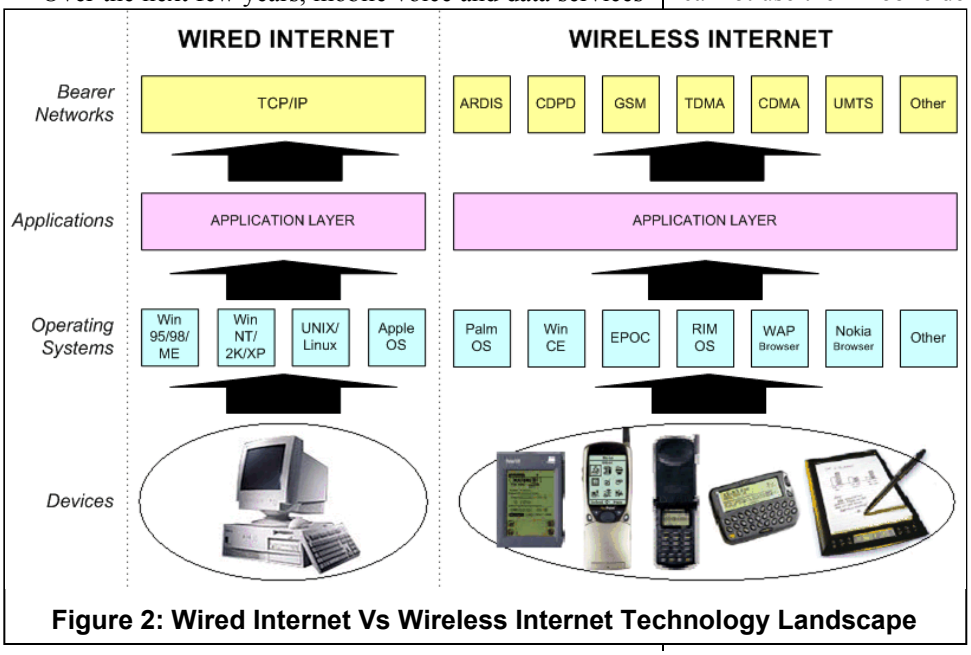

Figure 2: Wired Internet Vs Wireless Internet Technology Landscape

In the following sections we will review the three major components of a wireless landscape (bearer networks, devices and operating systems) and find out how the technology will evolve in next few years.

WIRELESS DATA NETWORKS

Just as wired telephone systems are advancing to deliver the promise of the information super-highway, so wireless systems are evolving to provide the similar capabilities, without the restriction of a fixed connection. Mobile Internet aims to move the Internet world onto a mobile environment. It is primarily affected by two components; portability and connectivity. The portability is the ability to carry computer during travel and use it at any place, and the connectivity is the ability to connect to external resources and have access to external data

Wireless data networks play a significant part because it can offer ubiquitous connectivity, that is, connectivity at any place, any time. For this reason, wireless data networks can be of real value to the business world since computer users become more productive when they exploit the benefits of connectivity.

Usually, portability and connectivity are at odds: the more portability increases, the more difficult it becomes to connect to external resources. However, wireless data technology provides the means to effectively combine both capabilities and, therefore, it is an essential technology for mobile Internet.

The wireless data networks are broadly divided into two categories according to their mobility characteristics – Wireless Wide Area Networks (WWAN) and Location-based wireless networks.

They are further divided into different categories based on different characteristics as shown in Figure 3. The most important of these characteristics is the data transport mode, also known as data connection type which is either circuit switched or packet switched.

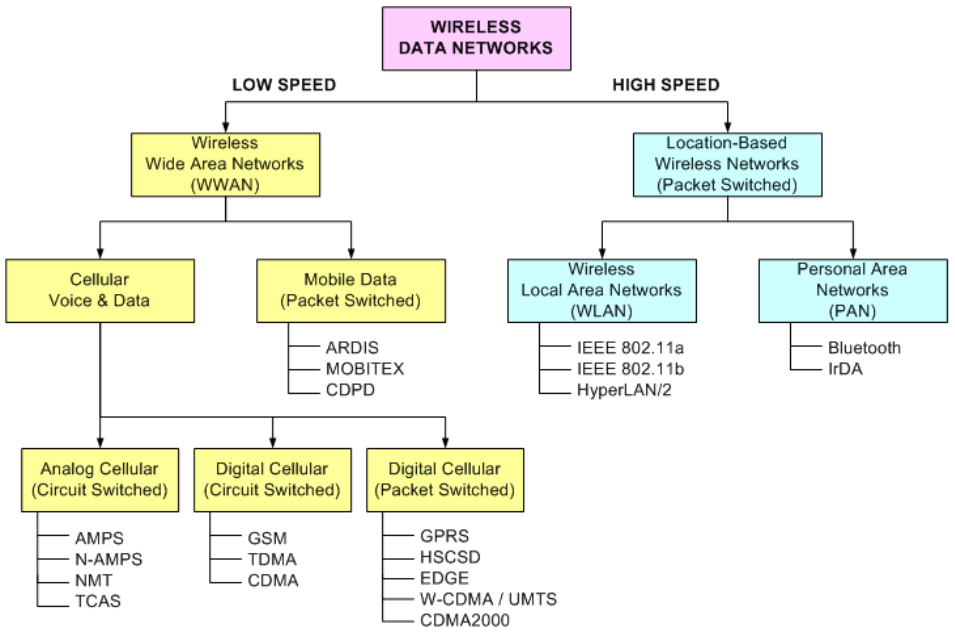

Figure 3: Categories of Wireless Data Networks

Circuit Switched Connection:

A device using a circuit switched network only connects to it when data is to be sent. They are similar to telephone calls, where a temporary circuit is dedicated exclusively to the sending and receiving nodes for the duration of the data transfer. The connection is only present when you need it and you only pay for the duration of the connection. While connected on a switched circuit network you have exclusive use of the established connection and data can be sent continuously. This type of data transaction is typically routed through the Public Switched Telephone Network (PSTN).

Packet Switched Connection:

A packet switched connection is one where you are connected all the time and only pay for the amount of data transferred. In this case, the data is divided into small packets and each packet contains a source and a destination address. Packets of data are sent from source to destination using the quickest route available. The network bandwidth is shared and multiple simultaneous users are allowed to access multiple locations across a network. Packet networks are more efficient for short data such as e-mail and database queries, and allow for instant communications without the need to establish a connection to the network. Packet switched data is typically routed over a high-speed Public Data Network (PDN). Nearly all data-only wireless networks are packet networks. In contrast, nearly all voice-only networks are switched circuit networks.

Circuit-switching and packet-switching can make a great difference in terms of transmission cost, throughput, and service quality. There are some applications that are best suited to the circuit-switched model, while others are best suited to the packet-switched model. In general, packet switched connection is more efficient and consequently less costly for applications that transmit small quantities of data at every transmission. On the other hand, circuit switched connection is more efficient for large file transmissions.

WIRELESS WIDE AREA NETWORKS (WWAN)

For wireless wide-area networks there are mainly two available technologies: data transmission over cellular networks, whether analog or digital, and data transmission over mobile data networks (Figure 2). The main difference between these technologies is the data transport mode. Cellular networks, being primarily voice oriented, generally utilize circuit switching technology; whereas mobile data networks employ packet switching technology. The new cellular network technologies support packet switching and many major wireless voice carriers have plans to move to this technology over next one to three years. Currently, due to physical layer constraints, wide-area networks typically feature low-speed wireless data transmission, on the order of 9.6 Kbps. However, with the emerging new protocols, much higher data transmission speed is supported.

CELLULAR VOICE AND DATA NETWORKS

Cellular standards fall into three categories; first generation analog cellular systems, and second and third

generation digital cellular systems. An interim technology, usually known as second generation-plus supports high speed data communication over today's digital cellular systems. Table 1 shows main feature of these technologies. A brief discussion and of these technologies and a comparison of data services follows:

Table 1: Main Features of Cellular Technologies

1st Generation	2nd Generation	2nd + Generation	3rd Generation
Analog trans.	Digital trans	Digital trans	Digital trans
Mainly speech	Mainly speech	Mainly speech	Speech and video
Voice band data	Digital data	Increasing digital data	Mainly digital data
Circuit switched	Circuit switched	Increasingly packet switched	Mainly packet switched
Local systems	Global roaming	Global roaming	Global roaming

First Generation Technologies

First-generation mobile communications systems, sometimes referred as 1G, were basic analog radio systems that established the first cellular radio infrastructure. The biggest problem with this system for cellular providers is the lack of capacity to handle the sheer number of users that demand voice service. The analog cellular networks use circuit switched connections for data transport; however, the radio link performance for data is considered marginal due to the limitations imposed by the analog nature of the technology. Radio channel dynamics such as dropouts, signal fades, and multi-paths, which can be tolerated during a voice connection, can be disastrous to a mobile data subscriber. Subscriber data rates of 2400 bits/s or less can be sustained using standard modems with some adaptation for connection to the cellular network.

In general, the analog cellular infrastructure systems are not an efficient means of sending data due to limited available capacities, limitations of data recovery, low security, and the high cost of use for many applications. Some of the widely used standards include the following:

Advanced Mobile Phone System (AMPS):

The AMPS was the first standardized cellular service in the world and was released for commercial use in 1983 in USA. The system uses 800 MHz to 900 MHz frequency band and the 30 KHz channel bandwidth. This is the most widely used analog cellular standard.

Narrow-band Advanced Mobile System (N-AMPS):

This system operates in 800 MHz range and provides three times greater capacity than AMPS by using 10 KHz channel bandwidths instead of the standard 30 KHz channel bandwidths used in the AMPS system.

Nordic Mobile Telephone (NMT):

This system was in use throughout the Nordic countries. The system has two variants based on the frequency of allocation. NMT450 operates on 450 MHz, while NMT900 operates on 900 MHz.

Total Access Communications Systems (TACS):

This system was based in the U.K and has several variants. The most popular are J-TACS (similar to AMPS) and E-TACS (Expanded TACS).

Second Generation Technologies

Second-generation mobile communications systems, sometimes referred as 2G, are currently predominant in the wireless communication industry. These use digital technology to provide many advantages for both the voice- and data-based mobile professional. These include increased system capacity, increased security against casual eavesdropping, superior cell hand-off, and better recovery of radio signal under different conditions. In addition to speech, these support services such as fax, short messaging, and roaming of mobile end-stations.

The second-generation technologies use circuit switched connections for data transport and provide data transmission rate of 9.6 to 14.4 Kbps. These implement a high level of flow control and error correction and provide reliable data transfer. With second-generation systems, multiple users can share a single cellular channel, thus reducing congestion and providing access for more users. These use the multiple access methods and provide extensive coverage with a proven and reliable communications infrastructure. The existing standards in use worldwide include the following:

GSM (Global System for Mobile Communications):

This was the first European digital open standard and is in commercial use in 1992. It was developed to establish cellular compatibility throughout Europe. Its success has spread to all parts of the world and by the year 2000, there were over 250 million subscribers worldwide. It is based on a combination of TDMA (Time Division Multiple Access) and FDMA (Frequency Division Multiple Access) techniques and operates at 900 MHz and 1800 MHz frequency bands in many parts of the Europe and Asia, and uses 1900 MHz in North America. Today, it provides an error-free Internet access at 9600 bps to the subscribers. Some analysts suggest that due to a single dominant network standard, GSM, Europe is 18 months ahead of the US wireless market.

TDMA (Time Division Multiple Access):

TDMA refers to products developed using the IS-136 specification for advanced digital wireless services. It was the first U.S. digital standard and was started in 1993. It is a natural evolution of analog AMPS networks and, therefore, was previously known as D-AMPS (Digital AMPS). It is the most widely used wireless technology in the USA, and as of year-end 2000, there were about 61 million TDMA

subscribers worldwide, with an estimated 31 million subscribers in the North America.

TDMA technology provides a 3 to 1 gain in capacity over analog technology by dividing a single radio frequency channel into a series of timeslots. Each user is assigned a set of timeslots during which they are allowed to broadcast. This technique is better at handling heavy traffic than others, since there is a hard upper limit on the amount of bandwidth that a particular user will utilize, but this is its weakness as well. Cells that do not have a large number of users will have underutilized bandwidth. Similarly, there is a much harder limit on the total number of users that can be supported within a cell.

Table 2: Technical Summary of Second Generation Technologies

	---- EUROPE -----	---------- UNITED STATES ----------	
	GSM	**TDMA**	**CDMA**
Frequency band	890-960 MHz	824-894 MHz	824-894 MHz
Allocated bandwidth	50	50	50
Access scheme	TDMA	TDMA	CDMA
Duplex method	FDD	FDD	TDD
Channel bandwidth	200 KHz	30 KHz	1250 KHz
No. of voice/freq. channels	8 / 16	3 / 6	
Total traffic channels	1000 / 2000	2496 / 4992	
Channel bit rate	270.833 Kbps	48.6 Kbps	Vendor dependent
Voice coding	22.8 Kbps	8 / 4.5 Kbps	8
Data rate	9.6 Kbps	9.6 Kbps	14.4 Kbps

CDMA (Code Division Multiple Access):

This system, known as IS-95, was adopted by the Telecommunications Industry Association (TIA) in 1993. It uses the same frequency bands as AMPS and supports AMPS operation, employing spread-spectrum technology and a special coding scheme. In this technique the call is spread over a series of frequencies based on a sequence of jumps that are semi random in nature. The spread spectrum approach minimizes signal loss within any particular frequency band, as well as providing security for the communications. The handset and the base station agree on the sequence ahead of time, which gives the base station the capability to minimize collisions within a cell. It is characterized by high capacity and small cell radius.

CDMA provides outstanding voice and call quality, fewer dropped calls, improved security and privacy, greater capacity, reduced background noise and interference, and possibility of simultaneous voice and data calls. Designed with about 4.4 trillion codes, CDMA virtually eliminates cloning and other types of fraud. Globally, commercial CDMA networks serve tens of millions of subscribers. Table 2 provides a comparison of the main features of the second generation cellular technologies:

Second-Plus Generation Technologies

The second-generation technologies provide data transfer rates only up to 14.4 Kbps. The high data speeds that are needed for video and graphic image transmission are not available on most of the today's mobile phone systems. Such capabilities require a highly complex and robust technology platform that will not be available in most of the countries until few years from now. An interim step to the next generation technologies is second-plus generation or 2.5G technologies as shown in Figure 4. These technologies support data transfer rates of 57.6 Kbps and higher and offer subscribers access to the Internet at speeds that are comparable to a wire-line ISDN connection or even faster. These include HSCSD, GPRS and EDGE. An overview of these technologies is given next:

HSCSD (High Speed Circuit Switched Data):

HSCSD is a circuit-switched mobile data standard that gives a single user simultaneous access to multiple channels, up to four, at the same time. In comparison, GSM supports only one user per channel per time slot. Assuming a standard data transmission rate of 14.4 Kbps, using four timeslots with HSCSD allows theoretical speeds of up to 57.6 Kbps. This is broadly equivalent to providing the same transmission rate as that available over one ISDN B-Channel.

HSCSD does not disrupt voice service availability. In fact, HSCSD can be preempted by voice calls- such that HSCSD calls can be reduced to one channel if voice calls are seeking to occupy these channels. In networks where HSCSD is deployed, GPRS (discussed in next section) may only be assigned third priority, after voice as number one priority and HSCSD as number two. HSCSD is therefore more likely to be deployed in start up networks or those with plenty of spare capacity – since it is relatively inexpensive to deploy and can turn some spare channels into revenue streams. It is however easier to implement in mobile networks than GPRS because some GSM vendor solutions require only a software upgrade of base stations and no new hardware.

HSCSD is expensive for end users as they have to pay for multiple simultaneous calls. However, being a circuit-switched standard, HSCSD could be the best way of communicating with other circuit switched communications media such as the PSTN and ISDN.

GPRS (General Packet Radio Service):

GPRS is a new packet-based bearer that is being introduced on many GSM and TDMA mobile networks from the year 2001 onwards. It is a non-voice value added service that allows a subscriber to send and receive data in an end-to-end packet transfer mode, without using any network resources in circuit-switched mode. It also permits

the user to receive voice calls simultaneously when sending or receiving data calls.

GPRS facilitates instant connections (no dial-up) whereby information can be sent or received immediately as the need arises. This is why GPRS users are sometimes referred to be as being "always connected". A GPRS mobile device displays a mobile portal service all the time, but it is only activated, and the user is only charged, when information is being transmitted. The main feature of GPRS is that it reserves radio resources only when there is data to send and that these radio resources are shared by all Mobile Stations (MSs) in a cell. It handles data transfer rates from 14.4 Kbps, using just one TDMA slot, up to 115.2 Kbps, using all eight TDMA slots. This will allow it to handle all types of transmission from slow-speed short messages, to the higher speeds needed for browsing complex web pages with high graphics content.

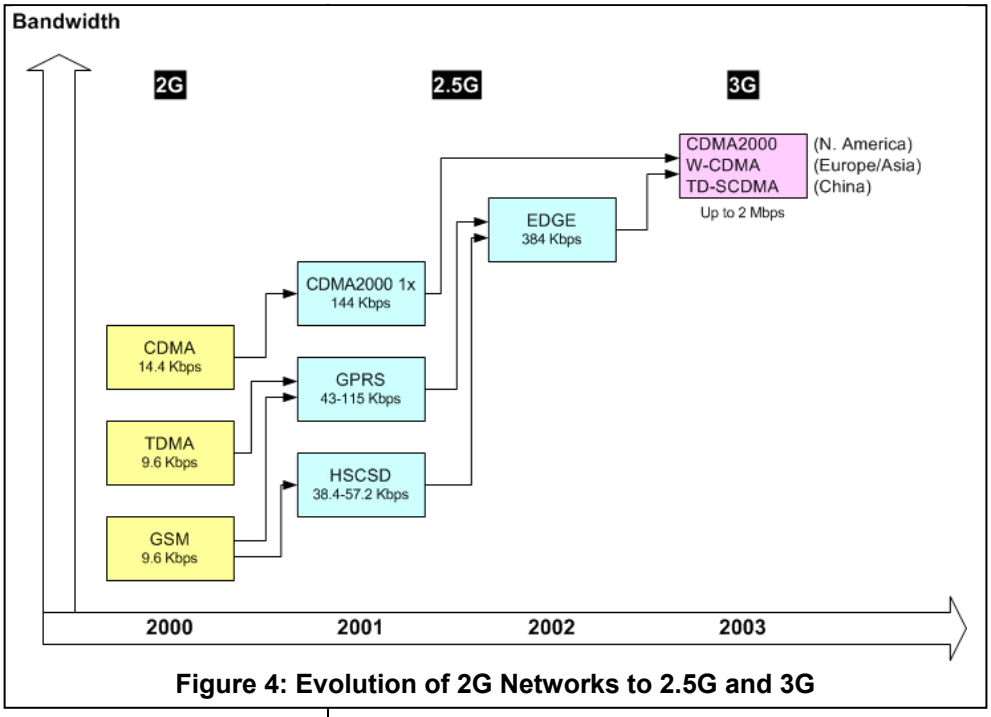

Figure 4: Evolution of 2G Networks to 2.5G and 3G

GPRS fully enables a true "Mobile Internet" scenario by allowing integration between the existing Internet and the GPRS network, via interfaces to TCP/IP. Its network can be viewed as a sub-network of the Internet with GPRS capable mobile phones being viewed as mobile hosts. This means that each GPRS terminal can potentially have its own IP address and will be addressable as such. Any service that is used over the fixed Internet today – web browsing, file transfer, chat, email, telnet – will also be available over mobile network via GPRS. In addition, higher data rates will allow users to take part in video conferencing and interact with multimedia websites and similar applications as well.

Enhanced Data rates for Global Evolution (EDGE):

EDGE is a radio based high-speed mobile data standard that was first proposed to the European Telecommunications Standards Institute (ETSI) in 1997 as an evolution of GSM. In fact, it was formerly called GSM384. It is the result of a joint effort between TDMA industry association and the GSM Alliance to develop a common set of third generation wireless standards which supports high-speed modulation. EDGE allows mobile operators to offer 3G services without having to purchase a 3G license. It allows data transmission speeds from 48 Kbps, using just one timeslot, up to 384 Kbps, using all eight timeslots. It supports 800/900/ 1800/1900 MHz frequency bands. Although it reuses the GSM carrier bandwidth and timeslot structure, it is by no means restricted to use within GSM cellular systems. In fact, by enhancing the capability of existing GSM or TDMA systems, it facilitates an evolution of existing cellular systems towards third-generation capabilities.

Implementation of EDGE by network operators has been designed to be simple. Only one EDGE transceiver unit will need to be added to each cell. The new EDGE capable transceiver can also handle standard GSM traffic and will automatically switch to EDGE mode when needed. EDGE capable terminals will also be needed since the existing mobile phone or terminals do not support the new modulation techniques and will need to be upgraded to use EDGE network functionality. EDGE provides the most cost-effective means to provide IP-based multimedia services and applications within existing spectrum. The advantages of EDGE include rapid availability, the reuse of existing GSM and TDMA infrastructure, and support for gradual introduction. In addition, it allows the full advantages of GPRS to be explored, with fast connection set-up, higher bandwidth, and data rates as high as 384 Kbps.

Third Generation Technologies

Two shortcomings of the second generation bearer networks are low bandwidth and limited network capacity which negatively impact the user experience and the reliability of the service. Third generation or 3G technology is a new technological evolution that will offer far more bandwidth and greater data and voice call capacity than today's digital mobile networks allow. It is a next giant step in mobile technology development with its goal being full interoperability and inter-working of mobile systems. The idea behind 3G is to unify the disparate standards that today's second generation wireless networks use.

With 3G technology, portable bandwidth will rise to the level of wired broadband connections and the data transfer

rates of up to 2 Mbps will be possible (128 Kbps in a car, 384 Kbps when a device is stationery or moving at pedestrian speed and 2 Mbps in fixed applications). When this speed is achieved, wireless technology will find a new audience that is interested in Internet browsing, wireless gaming, and listening to music. Current mobile networks are only designed for voice and text messaging, whereas 3G networks will allow faster and more complex data transmission such as streaming video and audio, video conferencing, satellite navigation and interactive application sharing. These networks will provide packet switched data access to the Internet with an end-to-end IP connection. This means that when the mobile phone is activated it is automatically connected to the Internet via a normal browser. Subscribers will then enjoy capabilities similar to today's fixed-line Internet services with significant add-ons such as location-based and highly personalized services.

Third generation technology allows handsets to be left permanently connected to the network and use capacity only when they receive or transmit packages. Subscribers can thus pay for the volume of data transmitted, not how long they talk.

Although the technology behind 3G may seem complicated, the ways in which 3G will affect all of our lives are easy to imagine. Just imagine having a combined camera, computer, stereo, and radio included in your mobile phone. Rich-media information and entertainment will be at your fingertips whenever and wherever you want. Being able to do so much, the end user device is no longer just a mobile phone, and will be referred to as a terminal

Standards:

Standardization of third generation mobile communications began in the mid-1990s under supervision of the International Telecommunications Union (ITU). The goal was full interoperability and inter-working of mobile systems capable of providing value-added services. In 1998, the ITU called for Radio Transmission Technology (RTT) proposals for IMT-2000 (International Mobile Telecommunications-2000), the formal name for the third generation standard. Under the brand IMT-2000, it approved three standards to achieve this: W-CDMA, CDMA2000 and TD-SCDMA. W-CDMA (Wideband Code Division Multiple Access) was backed by the European Telecommunications Standards Institute (ETSI) and the GSM operators in Europe and elsewhere; while the CDMA2000 was backed by the North American CDMA community, led by the CDMA Development Group (CDG). The third standard won the support in the other parts of the world. Earlier, in January 1998, the W-CDMA standard was also incorporated by ETSI in the specification of UMTS (Universal Mobile Telecommunications System) Terrestrial Radio Access; hence W-CDMA and UMTS are

Table 3: Market Snapshot and Status of Deployment of Mobile Internet Technologies

COUNTRY	MOBILE PENETRATION	HOME INTERNET PENETRATION	2G LICENSES	3G LICENSES	AMOUNT PAID FOR 3G LICENSES	2.5G LAUNCHED?	MMS AVAILABLE?	1ST 3G SERVICE LAUNCH
Australia	64.8% (Jun 2002)	50% (Dec 2001)	4	6	US$ 580 Million	Yes (Q2 2000)	Yes (Aug 2002)	Q1 2003
Canada	36.1% (Jun 2002)	49% (Dec 2001)	4	5	US$ 919 Million	Yes (Apr 2001)	Yes (Oct 2002)	Q1 2002
France	61.9% (Jun 2002)	23.9% (Oct 2002)	3	4	US$ 2.23 Billion	Yes (Q4 2000)	Yes (May 2002)	Q1 2004
Germany	67.9% (Jun 2002)	31% (Q3 2001)	4	6	US$ 46.11 Billion	Yes (Dec 2000)	Yes (Apr 2002)	Q4 2003
Hong Kong	86.8% (Jun 2002)	53% (Dec 2001)	6	4	US$ 524 Thousand	Yes (Q4 2000)	Yes (Jul 2002)	Q1 2003
Italy	91.5% (Jun 2002)	34% (Dec 2001)	4	5	US$ 10.04 B1illion	Yes (May 2001)	Yes (May 2002)	Q4 2002
Japan	55.6% (Jun 2002)	44% (Dec 2001)	5	3	N/A	Yes (Q1 1999)	Yes (Q4 2000)	Q4 2001
Malaysia	32.6% (Jun 2002)	5% (2001)	5	2	US$ 26.33 Million	Yes (Q2 2002)	No (Q2 2003)	2004
Singapore	67.5% (Jun 2002)	56% (Mar 2001)	3	3	US$ 173.4 Million	Yes (Q4 2000)	Yes (Sep 2002)	Q1 2004
South Korea	64.34% (Jun 2002)	58% (Dec 2001)	5	2	US$ 3.3 Billion	Yes	Yes	Oct 2000
Taiwan	100% (Jun 2002)	50% (Dec 2001)	6	5	US$ 14 Million	Yes (Q2 2001)	Yes (Oct 2002)	Q4 2003
U.K.	81.7% (Jun 2002)	38% (Dec 2001)	4	5	US$ 35.36 Billion	Yes (May 2001)	Yes (Jun 2002)	Q1 2003

Table 4: Comparison of Data Services for 2G, 2.5G and 3G Networks

SERVICES	2ND GENERATION	2ND + GENERATION	3RD GENERATION
Web browsing	Short text screens	100KB web page takes approx. 30 sec to download	100KB web page takes approx. 2 sec to download
File transfers	No	500 KB document takes approx. 2mn to download	500 KB document takes approx 10 sec to download
e-mail	Short Message Service (SMS)	Text-based with small attachments	Full attachments
Instant messaging	SMS	Text-based	With audio/video clips
VoIP (Voice over IP)	No	Limited	Yes
Streaming audio/video	No	Short clips	Yes
Access to corporate intranet	Very limited	Text-based	Yes
Access to corporate apps	Very limited	Text-based	Yes

often used synonymously.

IMT-2000 is to ensure that these technologies can work in different networks, primarily in IP networks, but for the sake of backwards compatibility, in the GSM and the American ANSI networks as well. Most major network operators in Europe and Asia are committed to the W-CDMA standard for 3G mobile communications. Nevertheless, other standards are being implemented in other parts of the world. In North America and Asia Pacific, the next generation wireless network is going to be mainly based on CDMA2000 and China, the world's largest market for mobile communication, will be using TD-SCDMA standard for 3G networks.

Availability:

Upgrading from 2G to 3G requires significant capital investment. In the UK, for example, five 3G mobile licenses were auctioned off at a total of $35 billion with the expectation that it will cost each license-holder between $4 billion and $9 billion to build out their 3G network. For this reason carriers have been reluctant to upgrade their networks before they see a real demand for high-speed wireless data and many view 2.5G as more than just an interim solution as it delivers significant bandwidth improvements at greatly reduced cost.

Today, however, as major wireless service providers assess the high costs of deploying 3G services and the accompanying technical difficulties such as 3G handset and network infrastructure readiness, a few are already working on deployment of W-CDMA in Europe and Japan. Table 3 shows market snapshot and status of deployment of mobile Internet technologies in some of these countries. NTT DoCoMo in Japan has already released a third generation phone service FOMA (Freedom Of Mobile multimedia Access) in major urban areas of the country. FOMA receives data at 384 Kbps and transmit at 64 Kbps, and delivers everything from movie trailers and sports highlights to music, video clips and news feeds.

The Strategies Group predicts that there will be 9.5 million 3G mobile high-speed data subscribers by 2005 and UMTS Forum predicts that by 2010 data services will represent $300 billion or 66% of all worldwide 3G revenues.

Fourth Generation Technologies

As the major network operators have just started providing 3G services, some groups and companies have already started working on fourth-generation mobile-phone system. The 4G technology will take mobile communication another step up to integrate radio and television transmissions, and to consolidate world's phone standards into one high-speed technology.

There are two key elements which are required to deliver a legitimate 4G network. First is the ability to roam across different wireless network standards with the one device; and the second, and most obvious, is a higher level of bandwidth. Figures of 100 Mbps have been tossed around, but a more reasonable figure to expect is about 20 Mbps.

At present, there are two competing 4G standards: a joint effort by Hewlett Packard and Japan's NTT DoCoMo to create Moto-Media, and the Wireless World Research Forum specifications with the backing of some of the Europe's largest phone makers.

The questions engaging most observers at the moment are just how big is the 4G market going to be, and when can the industry be reasonably expected to invest in a new network. Some of the analysts have estimated that the 4G mobile systems will have 50 million subscribers by the end of year 2007, and it would account for 14 percent of total mobile data revenues. But most of the analyst estimate the technology to be ready around 2008-2010. Nokia and Samsung have already teamed up to create 4G wireless equipment, a move which demonstrates the support for the 4G mobile systems.

Comparison of Data Services

The demand for mobile data services is growing. Increased mobility has fueled an expanding market for both consumers and the enterprises. A comparison of various data services for cellular networks is shown in Table 4. For consumers, second-plus and third generation networks will bring access to the Internet, with near wire-line speed and quality. 2.5G services will mostly be text-based with still images and short audio clips. Services will include web browsing, financial transactions, image downloads, e-mail

and instant messaging. As networks migrate to 3G, these same services will be enriched with multimedia content including full audio and video clips.

For enterprises, second-plus generation networks will allow access to corporate intranet and e-mail, business applications and databases, and increasing mobile sales and field employees' productivity. In the future, 3G capabilities will enable even greater benefits from wireless business applications through VoIP (Voice over IP), rapid file transfer and video-conferencing.

PACKET SWITCHED MOBILE DATA NETWORKS

A packet switched mobile data network is a type of specialized mobile radio system which functions as a wireless wide-area data-only network for the mobile professionals. Like first generation cellular telephone systems, these packet radio systems use analog radio technology. Unlike cellular systems, however, these networks offer connectionless support – subscribers do not maintain a dedicated, point-to-point connection to the destination station. Subscribers using the packet radio system are billed a monthly fee, plus a usage fee based on the amount of information (packets) transmitted through the system. The primary packet data services currently available in United States for mobile applications include ARDIS, MOBITEX, and a number of other services based on CDPD (Cellular Digital Packet Data) technology. A brief discussion of these services is given below:

ARDIS (Advanced Radio Data Information Services)

The ARDIS is a two-way radio service that is based on Motorola's RD-LAP technology. It was originally created and jointly owned by Motorola and IBM to serve IBM field technicians. However, later it was made available to the public. In 1998, it was acquired by the American Mobile Satellite Corporation. ARDIS support data transfer rate of 19.2 Kbps in urban areas, where it has 90% coverage of U.S business population (business population is considered the top 200-300 metro areas). Outside of those areas service can still be achieved, albeit at a lower 4.8 Kbps data rate. Due to overhead burdens associated with the radio channel protocol and error correction, subscriber data throughputs are actually much less than the raw data rate. Moreover, the network latency is fairly high. These limitations make the network unsuitable for most Internet and corporate intranet applications.

MOBITEX

MOBITEX protocol was originally developed by Swedish Telecom as a private mobile alarm system used by field personnel. However, later it evolved into a public mobile radio service. Commercial operation was introduced in Sweden in 1986 and, since then, a number of networks have been deployed in U.K, U.SA, Canada, Australia and Scandinavian countries. In United States, the MOBITEX was introduced by RAM Mobile Data which is now a wholly owned subsidiary of BellSouth Wireless Data.

MOBITEX covers about 93% of the U.S. business population, making it a serious contender for some applications. Originally, MOBITEX transmission rate was 4.8 Kbps but now it has been upgraded to 19.2 Kbps. However, similar to ARDIS, the subscriber data throughput is much less than the raw data rate due to data transmission overhead. Moreover, network latency is fairly high - often several seconds. For these reasons, it is suitable only for limited text messages, not graphics or file transfers.

CDPD (Cellular Digital Packet Data)

CDPD specification was developed by a consortium of eight U.S. cellular companies. It allows data transmission to be overlaid onto the existing analog cellular channels. It provides two significant enhancements to the AMPS cellular system – increased total system capacity and specifications for implementing data. CDPD networks are operated by various carriers in United States, including AT&T Wireless, Ameritech, Bell Atlantic Mobile and GTE.

CDPD offers standard RSA encryption over the air-link, making it the network of choice for public safety agencies and point of sale cash transactions. It offers users a raw data rate of 19.2 Kbps. However, overhead for coding and channel management to handle frequency hopping will reduce actual throughput. The reliability of CDPD data speeds is also questionable, particularly in mobile situations. Network-induced latency can be high, often more than one second. These limitations have made CDPD most useful for specific vertical-market applications.

LOCATION-BASED WIRELESS NETWORKS

The location-based wireless data networks provide wireless data service in a small geographical area – usually in offices, buildings and campus environments. They use packet switching rather than circuit switching to transport data. They do not experience the same rough physical layer constraints of their wide-area counterparts and, therefore, they are capable of supporting high-speed wireless data transmission, on the order of a few Mbps. The location-based wireless data networks are further divided into two alternatives: data transmission over Wireless Local Area Networks (WLANs) and data transmission over Personal Area Networks (PAN). These are discussed in the following sections:

WIRELESS LOCAL AREA NETWORKS (WLANs)

Wireless Local Area Networks use wireless transmissions (e.g. radio frequency) instead of phone lines or fiber optics to connect data devices. They cover limited areas and provide high-bandwidth wireless service. They will probably never replace the classical wired LAN; however, it can be a very effective means of extending the flexibility of a wired LAN. The dominant use for this technology is in hostile environments, such as factories, open-office settings and old buildings, where cabling is difficult or impractical; and on forklifts that rove through large warehouses. Several major airports are already providing this protocol as a service to computer-literate passengers, as are several major conventions.

WLAN uses 2.4 GHz, 5 GHz and 22-28 GHz ranges of radio frequency. This area was clouded earlier with the arrival of incompatible standards, but most of the new solutions are based on a standardized protocol known as 802.11 or Wireless Ethernet. This is briefly discussed in the following section:

802.11

802.11 is a family of specifications for wireless local area networks (WLANs) developed by a working group of the Institute of Electrical and Electronics Engineers (IEEE). It is perhaps the fastest-changing network protocol around. There are currently four specifications in the family: 802.11, 802.11a, 802.11b, and 802.11g. All four use the Ethernet protocol and CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance) for path sharing.

802.11:

The 802.11 standard is the first in the family. It provides 1 or 2 Mbps transmission in the 2.4 GHz band using either Frequency Hopping Spread Spectrum (FHSS) or Direct Sequence Spread Spectrum (DSSS).

802.11a:

The 802.11a is an extension to 802.11. It provides transmission speeds up to 54 Mbps in the 5GHz band. It uses Orthogonal Frequency-Division Multiplexing (OFDM) that makes high data speeds possible. But most commonly, communications takes place at 6 Mbps, 12 Mbps, or 24 Mbps. Due to higher absorption rate of signals at 5 GHz spectrum, 802.11a devices have shorter operating range of about 60 meter. 802.11a is relatively new technology and is expensive.

802.11b:

The 802.11b standard, often called Wi-Fi, is backward compatible with 802.11 and provides 11 Mbps transmission (with a fallback to 5.5, 2 and 1 Mbps) in the 2.4 GHz band. 802.11b uses only Direct Sequence Spread Spectrum (DSSS) modulation scheme and the devices have operating range of about 100 meter. It is inexpensive, readily available and is the widely adapted standard at present.

802.11g:

This is a most recently approved standard which offers both higher throughput and backward compatibility with 802.11b access points. It offers wireless transmission over relatively short distances at up to 54 Mbps. Like 802.11b, it operates in the same 2.4 GHz range and is thus compatible with it. 802.11g technology is relatively inexpensive and the devices have good operating range of above 100 meter.

PERSONAL AREA NETWORKS (PANs)

The Personal Area Networks are generally very small networks, covering a personal workspace, an office, or a meeting room. The major advantages of PAN are freedom from cables, automatic data synchronization between computers, and easy sharing of data between workers in a small area. Two types of technologies are available for PAN – infrared and radio frequency. A popular infrared networking standard, IrDA (Infrared Data Association), provides universal connectivity at a high-speed within a single room. On the other hand, Bluetooth is a new, low cost, short range radio frequency standard that can transmit, to some degree, through walls, floors, ceilings and non-metal objects. Both of these technologies are briefly discussed in the following sections:

IrDA

IrDA is a protocol suite designed to provide wireless connectivity between two devices that would normally use cables for connectivity. It is a point-to-point, half-duplex (data is sent in one direction at a time), narrow angle infrared (30° cone) data transmission standard designed to operate over a distance of 0 to 1 meter and at speeds of 9.6 Kbps to 16 Mbps. The short-range and narrow angle of IrDA provides a simple form of security as it requires the two devices to be facing each other for them to transfer data. IrDA is an inexpensive technology and is widely available on personal computers, peripherals, embedded systems and devices of all types.

Bluetooth

Bluetooth is a radio frequency (RF) standard for short-range, point-to-multipoint voice and data transfer. It uses low-power/low-cost transceiver chips embedded in mobile computers, mobile phones, printers and other portable devices. The embedded Bluetooth chip eliminates the need to use cables that is currently necessary to interconnect personal devices. Bluetooth supports up to 8 devices in a piconet (two or more Bluetooth units sharing a channel). The devices may also be connected to existing networks to create a network of any number of Bluetooth devices in the vicinity of each other. This way they can communicate and exchange data, even on the move. Bluetooth doesn't require an access point, and so is well suited for mobile devices.

Bluetooth operate within a license-free frequency band of 2.4 GHz, which is available all over the world. The

speed of data transmission is 1 Mbps at distances of 10 cm up to 10 meters, which is expendable to 100 meters by increasing the transmit power. It provides three voice and data channels via a one-to-one connection with built-in encryption and verification. Driven by Ericsson, the Bluetooth Special Interest Group was founded by Nokia, Ericsson, IBM, Intel and Toshiba. It now has several thousand members. Many mobile phones on the market have started to come with Bluetooth enabled accessories, such as headsets and chat-boards, but we are still some way before the technology is accepted as a lifestyle standard.

MOBILE DEVICES AND OPERATING SYSTEMS

In the new information age, the mobile phone will deliver much more than just voice calls. It will become a multi-media mobile terminal, capable of accessing Internet, connecting to corporate networks, video conferencing, and sending and receiving email messages, graphic images and movies. The transformation from using phones for basic communication to using them as all-purpose data devices is already evident in the use of SMS (discussed later), which lets cellular phones send and receive messages. The key ingredients for the transformation are the mobile devices and the operating systems.

MOBILE DEVICES

There is a broad range of mobile devices that can be used for wireless communication. The new devices are becoming available every day. They provide improved capabilities at lower prices in smaller form factors. They can be divided in the following categories:

Cellular phones:

The cellular phones provide the basic capabilities of voice communication. Most of digital phones include text messaging, and store phone numbers and appointments. Some advanced phones also include applications, like WAP (discussed in next section), for web access. According to some sources, at present, there are more than 1 billion cellular phones worldwide.

Personal Digital Assistants (PDAs):

PDAs are handheld devices with much larger screens than cellular phones and pagers, and are usually equipped with pen or stylus for inputting data. They allow users to use small applications, specially designed for the PDA, and provide PIM functions to store addresses and appointments. The PDAs usually connect to Internet through wireless modems and rely on operating system's standard software for web browsing, e-mail, and instant messaging. The major operating systems in use are Palm OS, EPOC /Symbian and Microsoft PocketPC. The example of such devices includes Palm Pilot, Handspring Visor, Psion Revo, and HP, Compaq and Casio PocketPCs.

Smart Phones:

There are a large number of new devices coming out that really are neither a cellular phone nor a PDA. They offer both wireless voice and data services, and include functions like text messaging, web access, and personal information manager (PIM). These devices are generally known as Smart Phones. These require compromises. However, These pit size and weight against input ease, display clarity, storage, battery life, and data integration. In the near future, experts expect cellular phones to be equipped with foldout keyboards, eyepieces, and color displays, and also may incorporate features such as speech recognition. The example of such devices includes Nokia's Communicator and Ericsson's MC218.

Pagers:

The latest generation of pagers support two-way messaging and personal organization tools, and allow interacting with mobile devices, desktop computers and the Internet. The Internet services allow users to establish preferences for information on various topics including stocks, weather, lottery and horoscopes. The information is then sent to the pagers on demand from WAP-enable websites. The example of such devices includes RIM's Blackberry, and Cross' NetPen and Crosspad.

Modems:

Wireless modems for the voice-and-data networks are usually wireless voice handsets. They allow computing devices, like PDAs, handheld PCs and Laptop PCs, to be connected to a wireless network. However, the technology behind the wireless modem doesn't reliably predict performance. All CDMA handsets and many of the new GSM handsets require only a serial cable to connect the handset to a computing device.

OPERATING SYSTEMS

The wired computing environment is largely homogenous, comprising a relatively limited set of mature and interoperable operating systems. In contrast, there are a plethora of operating systems and micro-browsers used to run web-based applications on mobile devices. Most of the PDAs and Smart Phones use Palm, PocketPC and EPOC. Some advanced cellular phones use Phone.com UP Browser and Nokia Browser, and pagers use proprietary operating systems like RIM OS and Motorola OS. The three main contenders to set the standard for wireless operating systems are as follows:

PALM Operating System:

PALM is the most popular operating system in PDA arena. By mid 2000, seven million Palm devices had been sold, giving Palm about three quarters of the global

handheld computing market. Palm is proactively taking steps to incorporate wireless support into Palm products for both GSM mobile phone standard and non-GSM world. Major Palm partners include IBM and Symbol. Other Palm operating system licenses include Handspring, OmniSky and Nokia.

EPOC Operating System:

Designed specifically for use in mobile devices, EPOC mobile operating system supports multiple communication standards. It is being used in PDAs such as Psion Series 5. It is offered by Symbian, a consortium formed in 1998 by Nokia, Ericsson, Motorola and Psion Software. Later, Psion's software division was folded into Symbian, along with some of the personnel from the other founding partners. Industry leaders such as Sony, Sun, Philips and NTT DoCoMo have joined the Symbian alliance and licensed EPOC.

Pocket PC:

Microsoft's PocketPC (formerly Windows CE) incorporates a subset of Win32 Application Programming Interface (API). This means that there is no need to learn a new programming language to develop an application for PocketPC. It comes in several form factors for the mobile market. These include PDAs, Handheld PCs and Industrial terminals for vertical markets. About a dozen companies such as Casio, Compaq, Everex, HP and Philips have launched consumer-oriented mobile devices based on PocketPC operating system.

MOBILE INTERNET ENABLING TECHNOLOGIES AND SERVICES

Mobile phones have a huge user base and it is growing very rapidly. This created a great demand for Internet access and messaging through mobile devices. Several wireless phone manufacturers recognized this and created specifications, either individually or in groups, for web access and for sending and receiving messages through mobile devices. Many of these technologies use existing Internet standards to provide Internet content to wireless clients. By elegantly combining the mobility of cellular networks with the power of Internet applications, these technologies are rapidly gaining market share worldwide. The most important of these technologies are as follows:

SMS (SHORT MESSAGE SERVICE)

SMS is a bearer network that, since 1992, has enabled mobile phone users to send and receive text messages of up to 160 alphanumeric characters (70 characters when non-Latin alphabets such as Arabic and Chinese are used). SMS is designed as a pager replacement technology for mobile phones. It is ideal for pushing brief information one-to-one or one-to-few. After a slow start, it has become so popular that billions of messages per month are now transmitted over GSM networks. SMS messages do not require the mobile phone to be active and within range – it will be held for a number of days until the phone is activated. SMS messages are transmitted within the same cell or to anyone with roaming capability. The messages can also be sent to mobile phones directly from mobile operator's website or by using gateway address in Internet email programs, like Microsoft Outlook.

Popular SMS applications include voicemail notifications, person-to-person messages, information services, chat, and downloading ringing tones. Network operators are also able to update their mobile services using SMS messages to communicate with the smart cards (usually known as "SIM cards") within GSM mobile phones. SMS offers some very useful features such as the ability to store and forward messages, confirmation of short message delivery to recipient, and simultaneous delivery with GSM data, voice and fax services. The main drawback is obviously that it only supports "short messages", but a "long message" service is currently being developed.

MMS (MULTIMEDIA MESSAGING SERVICE)

MMS is a service environment that allows different kinds of services to be offered, including messaging service that exploit multimedia. The messaging service enables the mobile phone users to send and receive messages comprising a combination of text, images, sounds and video. It is a natural evolution from SMS messaging which already has a large user base. The size of the message is only limited to the restriction imposed by the network operator.

MMS is standardized by 3GPP (Third Generation Partnership Project). Its functionality is being delivered in two stages – firstly over a GPRS bearer (2.5G rather than 3G) – where it will contain a subset of the media such as still images (but not video) followed by 3G where it will contain 'full' multimedia such as video clips. MMS require not only new network infrastructure but new MMS compliant terminals – It will not be compatible with old terminals. However, the messages can be sent to/from email which may overcome the problem of initial limited device availability.

MMS, like SMS, is a non-real time service. The message first goes to MMSC (Multi Media Service Centre) which sends the receiver a notification that a new message

is waiting. The receiver can then download the message immediately or download it later. More content rich applications can be developed using MMS than are currently possible with just 160 text characters available with SMS. Possible examples of an MMS based applications are stock quotes that can be viewed as diagrams, weather report with images, and animated text messages.

WAP (WIRELESS APPLICATION PROTOCOL)

WAP is an application environment and a set of communication protocols that enables mobile devices to access the Internet and advanced telephony services. It is emerging as an open global standard that empowers users of cellular phones, smart phones, PDAs, and two-way pagers to easily access Internet/Intranet information – independent of their bearer network, operating system, and terminal. They can access the same wealth of information from a pocket-sized device as they can from the desktop. It was invented and is driven by the WAP Forum – a group originally formed by Nokia, Ericsson, Motorola and Phone.com in 1997. It now has 500 member companies.

WAP can be built on any operating system including PalmOS, EPOC, PocketPC, and JavaOS. Its specification supports most wireless network services and protocols, including GSM, TDMA, CDMA, CDPD, GPRS, and next-generation network standards, and is specifically devised for small-screen devices intended for one-hand navigation without a keyboard. WAP is based on WML (Wireless Markup Language) which is a derivative of XML (Extensible Markup Language) and is similar to HTML (HyperText Markup Language) but more restricted. WML's user interface is a micro-browser that works well with small displays such as those on cellular phones. With WAP and WML, content can be pulled from the Internet and formatted for use on small hand-held devices.

Currently, web sites have to be specifically designed for WAP – only about 1% of the web is available in WML. Moreover, browsing is limited to online shopping, trading stocks, location guides, weather reports, sending email, and similar activities, in text-only mode. Due to lack of content and a clumsy interface, public reaction to WAP is, therefore, hostile and the take-up is low. Although relatively unpopular at the moment, many companies and analysts predict a massive surge in WAP use once GPRS becomes a worldwide standard. Seen by many as the perfect partner for WAP, GPRS has distinct time slots serving to manage data packets in a way that prevents users from being penalized for holding standard circuit-switched connections. Moreover, the current WAP version 1.1 is going to be replaced with version 2, which uses something close to standard Internet Protocols.

I-MODE (INFORMATION MODE)

On February 22nd 1999, Japanese mobile service operator NTT DoCoMo launched i-mode, its own specially developed mobile Internet service. Ever since its introduction, the i-mode has been a huge success. It was taken up so quickly that in just three years (as of March 31, 2002), the number of i-mode users in Japan reached to 32 million – about 25 % of Japans total population. The i-mode explosion can actually be attributed to two factors – the cultural readiness of the Japanese people to accept the technology, and the foresight of DoCoMo to properly engineer the technology to benefit both the user and the developer.

The i-Mode standard is much more an adaptation of existing Internet standards than is WAP. It works on a packet-switched network, so the user is constantly connected to the service, and only pays for the information downloaded to the mobile phone. The data transmission rates are just about the same as for WAP (9.6 Kbps) but since the service is always-on, it saves all the dial-up time. For developers, the i-mode sites are written in cHTML (Compact HTML), which is actually a subset of HTML 4.0 and therefore extremely intuitive. The cHTML user interface is superior to that of WAP, boasting four directions in which the user can navigate instead of two, and uses HTTP as its transport protocol. It also supports color and allows display of GIF images among other things. It means that i-mode micro-browsers can read the majority of standard Internet pages. Again, the problem with WAP was that its language, WML, was a brand new specification. Today, i-mode offers a wide array of websites from internationally known companies such as CNN to very local information.

CONCLUSION

Cellular technology today is primarily intended for speech and not particularly good at delivering data. It currently provides low-speed wireless data transmission, typically in the order of 9.6 Kbps. Significant evolution and innovation is to be expected in the future with the introduction of 3G systems, such as W-CDMA (UMTS) and CDMA2000. These systems will handle data transmission rates up to 2 Mbps. They are being tested in parts of Europe and the Far East, but they are not expected to be deployed in most of the countries until few years from now. In the meantime there are few intermediate steps that are being considered.

As a first step, the GPRS, which is being deployed at present in many countries, will provide cost-effective wide-area packet data service with transmission rates up to 115 Kbps. Further evolution is expected with the implementation of EDGE which will allow network

operators to offer wireless multimedia services and applications at speeds up to 384 Kbps.
The introduction of GPRS and EDGE, and the evolution to 3G technologies, will provide the potential for a whole range of mobile multimedia services, such as videoconferencing, web surfing, online shopping, stock trading, sending email, access to corporate networks and intranets, and financial transactions from a mobile terminal. Regardless of the technologies that drive the market, based on the conjunction of circumstances that are required, most analysts agree that the mobile Internet market will be sizeable in next few years. The Internet provides a data source that makes it useful to be connected. The digital cellular infrastructure provides the basis for digital data communication. Finally, wireless technology advancements that have made such communication possible at reasonable speed and reliability provide the last requirement.
The world of Mobile Internet is not simply an advanced stage of Internet evolution, but rather an entirely new world shaped by mobility. The less developed Internet infrastructure in Asia and Europe will contributed to mobile Internet popularity, whereas high-speed landlines in the United States have set expectations unreasonably high for the handheld devices. Already, Asia and Europe are leading the world when it comes to mobile Internet. The remarkable success of Japan's DoCoMo service, i-mode, has provided a glimpse of what mobile Internet access is going to mean for a user in the future. The first wave of the Internet has connected millions of users, but the mobile Internet wave will connect billions in every country around the world.

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