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M-Business: Economy Driver or a Mess?

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ECONOMY DRIVER OR A MESS?

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ABSTRACT

Reports about mobile wireless technology in the media may be confusing. While we know that the telecommunication industry is in distress, we also observe a phenomenal, indeed unprecedented explosion of the use of mobile wireless devices and services all over the globe. This paper presents a balanced introduction to wireless technology including devices, mobile operating systems, and communication protocols. It discusses standardization efforts, technology evolution paths, and several new and potentially disruptive technologies, some still in the research stage.

The paper lists leading global wireless service providers in terms of the number of domestic subscribers and presents an analysis of the six U.S. national operators including their strengths and weaknesses. Only four of them are profitable now. Although the consumer market currently dictates technology evolution, several examples of successful business applications of wireless mobile technology are presented. Finally, the question presented in the title is addressed.

Keywords: mobile wireless, wireless devices, mobile operating systems, mobile communications protocols, mobile standardization, mobile technology, new mobile techniques, mobile telecommunications business, business applications of mobile technology.

I. BIG NUMBERS

Dangerously big numbers drive the interest in mobile wireless communications. The large and rapidly growing number of wireless users tempted telecommunications carriers into the largest bet ever on new technology introduction. They spent big numbers to acquire radio spectrum licenses and to upgrade existing wireless networks, first to add data to conventional voice communication, then to substitute packet-switching technologies for circuit switching, and finally to increase the data transmission speed or bandwidth continually.

Figure 1 shows the growth of the number of personal computers and that of cellular mobile subscribers worldwide from 1997 to 2002 with an estimate for 2003 [ITU, 2003]. While only 158 million of the 587 million computers were connected to the Internet in 2002, many newer wireless mobile handheld devices are Internet-Enabled (IE). The high-tech market research firm In-Stat/MDR forecasts that IE wireless mobile device shipments will increase from approximately 430 million in 2002 to about 760 million in 2006, a 15% compound annual growth rate [In-Stat/MDR, 2002].

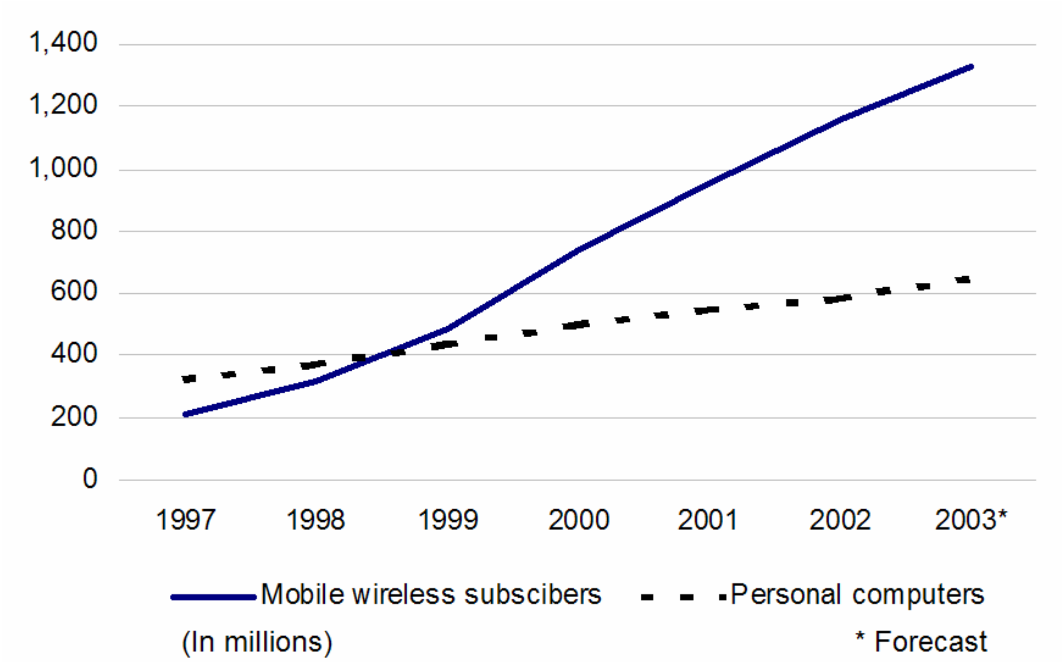

Figure 1. Number of Worldwide Mobile Phone and PC Users

Figure 2 suggests that in 2002, the European market for wireless phones was approaching saturation, while the situation in North America was quite different and unique: the number of PC users was higher than the number of mobile phone subscribers. The numbers also hint that both the supposedly low penetration of PCs and high penetration of mobile phones in Japan are myths. The penetration of PCs in Japan was comparable to that in France, Germany, and UK, while the penetration of mobile phones was actually lower.

The numbers regarding revenues, however, are rather modest. The Yankee Group also predicts that the size of the U.S. mobile commerce market will reach $15 billion by 2006 [Sun Microsystems, 2003]. This forecast is much lower than the January 2001 assessment by the Center for Research in Electronic Commerce that the [wired] Internet Economy will produce $830 billion in revenues in 2000 [Barua & Whinston, 2001]. Another study of Internet business solutions, based on data collected in September and October 2001, reports cumulative cost savings of $155.2 billion to U.S. organizations that adopted them, most of these savings having been gained since 1998 [Varian et al., 2001]. In addition, these organizations indicate that their Internet business solutions have also helped to increase revenues cumulatively by approximately $444 billion. In comparison, six forecasts of U.S. mobile commerce revenues for 2004 vary from $0.7 to $20 billion, with a median of $7 billion [Myers Medianomics, 2001]. This coarse comparison suggests that m-business is expected to be only a small fraction of total e-business at least through 2008. The entire U.S. cellular telephone service is predicted to be “only” a $94 billion industry in 2003 [Skvarla and Dooley, 2004]. In comparison with the size of investments to acquire radio spectrum licenses and to upgrade wireless networks, these numbers are not all that big, and should trigger a bit of concern. In other words, the numbers of wireless subscribers are impressive, but the revenue projections are less so. To paraphrase Robert Solow, we see wireless technology everywhere except in profitability statistics [Brynjolfsson, 1992].

To operate the “third-generation” (3G) networks, European mobile networks operators paid over $100 billion for radio frequency licenses in 2000 alone [Ure, 2003]. They will have to invest another $150 billion to build the network infrastructure [Rolnick, 2001]. These, too, are big numbers. The timing is also unfortunate. The technology sector is in a worldwide slump and the telecommunications industry is particularly hurting. Telecommunications companies’ debt worldwide is almost $2 trillion [Bernstein, 2003], which is causing doubt and delays. For example,

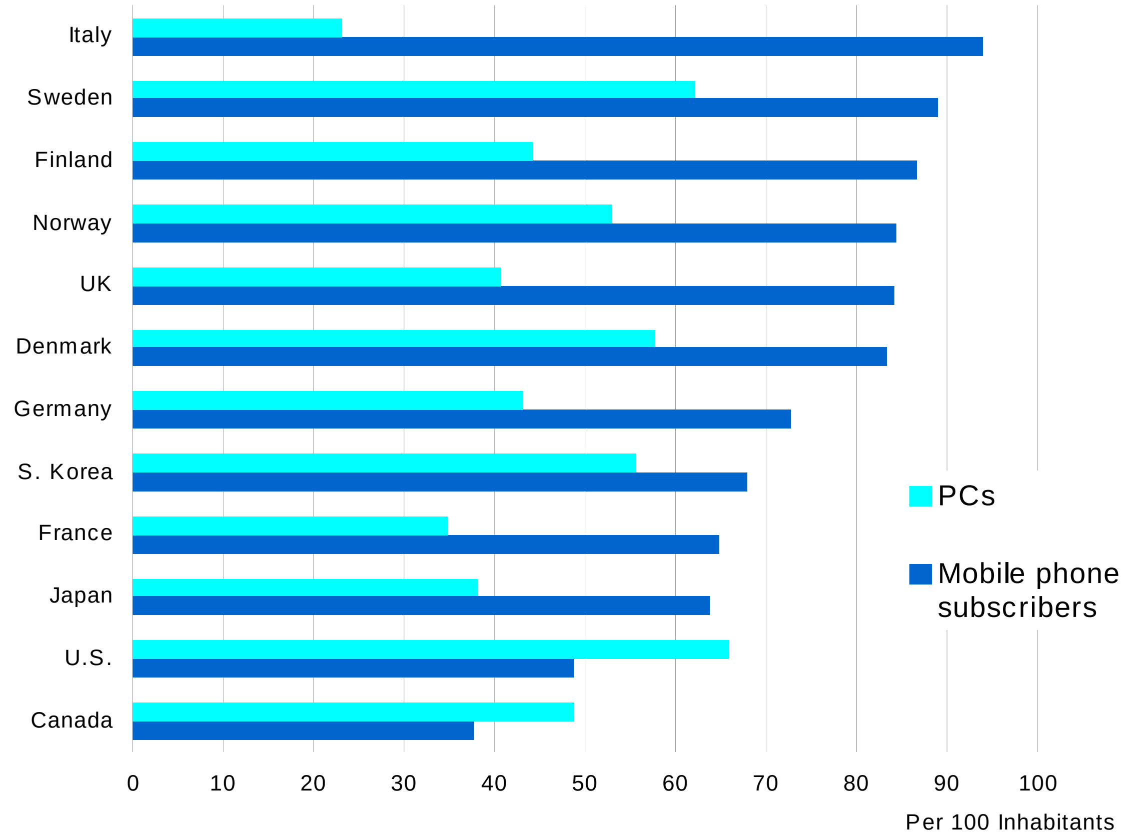

Figure 2. Penetration of Mobile Phones and Personal Computers in Selected Countries

the implementation of 3G services in Europe is in trouble and the expectations were scaled back to 2.5G.

Wireless operators and consulting companies have an interest in overestimating the impact of wireless technologies. As a result, statements such as:

> *"Mobility is clearly emerging as the next discontinuity in business and technology for enterprises, service providers, and vendors of IT and telecommunications products"* [Cosonato et al., 2002]

are being made. The wireless network operators may be trying to justify their spectacular gamble with an outburst of hype. Currently, mobile Internet is at a similar stage as wired Internet was in 1995. Hundreds of start-ups are trying to ride the hype wave, but nobody really knows what are the winning technologies and business models, and what consumers and corporate users really want. Many lessons will again be learned from mistakes. One of the known mistakes is a perception that mobile Internet is the same as its wired version, only mobile. It will, however, be something different, used in new and unexpected ways. We will now attempt to look beyond the hype.

II. WIRELESS TECHNOLOGIES

In this section, we discuss wireless devices, communication standards, wireless LAN, and other disruptive technologies.

WIRELESS DEVICES

The devices most commonly used for m-business are small handheld devices with wireless data communications capability. They are designed to be highly portable and people keep them handy most of their waking hours. Mobile devices are of three principal types:

- mobile phones,
- handheld computers (such as PDAs) and
- tablet, notebook, and laptop computers.

The handheld and laptop computers can connect to the wireless data networks if they are equipped with a radio-frequency communication interface. The range of mobile devices is broad and growing. It spreads from industrial robust portable computing devices to tiny wearable computers. Although wearable computers can also be found in industrial applications, they may soon become fashionable consumer items. Mobile computing and communication devices can also be built into larger mobile equipment, such as trucks, airplanes, trains, farming equipment, and automobiles.

The evolution of wireless technologies continues to be affected by a collision of vendors with diverse areas of expertise, such as telephone companies, computer vendors, the makers of various other electronic devices (including digital cameras and PDAs), vendors of popular electronic devices (for example MP3 players), content developers such as Time Warner, and software vendors such as Microsoft. Various forces, including the powerful leading technology vendors and their marketers—those who understand the importance of style and not just technology—will shape the success of wireless products. Highly mobile devices are designed more by factors closer to the fashion industry than the PC industry. The proliferation of devices, as symbolized in Figure 3, will continue through and beyond 2006. The next several years will bring increased complexity and divergence in physical device characteristics and their roles and types (e.g., business/consumer, phone/PDA, interactive TV/toy). For example, a new family of Sony digital video cameras is Web enabled and can be used to exchange email. A fragmented market will be driven by fun, fashion, function, and technology. The boundaries between different types of devices, such as phones and PDAs, will become inevitably blurred as some devices become, without doubt, multifunctional.

Can we expect a convergence of devices? At one extreme are highly portable, thin, and light cell phones, and at the other are tablet PCs and laptops. It is improbable to imagine a physical trend toward a common device, but we observe a logical convergence. Various functions, such as the support for a range of rich data types including MP3 and MPEG4, personal information management, 3D games, Bluetooth personal area networking (PAN), PC synchronization, location services, and security, are increasingly becoming available on both phones and PDAs. Manufacturers of single-purpose devices are incorporating additional functions; PDAs are increasingly supporting wireless voice and data, phones are offering PC-like functions, and camera technology is appearing in both PDAs and phones. Some users prefer multifunctional devices, the so-called smart phones, while others believe that they are necessarily compromises, handling neither voice nor data as well as specialized devices do. The final winners may also be separate devices linked together into a PAN, supported by Bluetooth or an alternative PAN technology. This logical convergence, however, will not be enough to enable portability of wireless applications among various types of devices [Jones, 2002a].

Figure 3. The Proliferation of Wireless Mobile Devices Will Continue

WIRELESS COMMUNICATION PROTOCOLS

The characteristics of wireless communication evolution are a migration from analog to digital formats, a substitution of circuit-switching for packet-switching technologies, and continually increasing transmission speed or bandwidth. First generation (1G) wireless technology, available through the 1970s and 1980s, featured mobile phones and analog voice signaling. Communication quality was rather poor, use of spectrum inefficient, and communication easily intercepted.

Second-generation (2G) wireless technology, introduced in the 1990s (and still the predominant technology in 2004), features digital format, circuit switching, support for voice and data, encryption, text messaging and Web browsing using wireless access protocol (WAP). 2G is usually identified as Global System for Mobile communication (GSM), but also includes Code Division Multiple Access (CDMA), and Time-Division Multiple Access (TDMA) protocols. The 2G technologies were improved steadily, offering increased bandwidth, packet switching, and the support of multimedia formats. This transitional state of mobile wireless communications is often called two-and-a-half G (2.5G), and is an evolutionary step toward Enhanced Data Rates for Global Evolution (EDGE) and Universal Mobile Telephone Service (UTMS). 2.5G, in use since 2000, offers improved and more advanced data services and always-on connections. It is usually associated with General Packet Radio Service (GPRS), a GSM upgrade. A competing network standard, Code Division Multiple Access (CDMA) and its upgrade, 1xRTT, allow data speeds comparable to those of GPRS, which vary from 28 up to 114 Kbps, enough for basic multimedia browsing.

3G promises to support:

- Enhanced multimedia, including voice, data, video and remote control
- Many popular modes, including cellular phone, email, paging, fax, videoconferencing and Web access
- Bandwidth of up to 2.4 Mbps
- Routing flexibility (repeater, satellite, LAN)

- Operation at approximately 2 GHz send and receive frequencies
- Roaming capability throughout Europe, Japan, and North America

While 3G is perceived relevant mainly to mobile wireless, it is also relevant to fixed wireless. In reality, the bandwidths in mobile wireless mode are only up to 384 Kbps and in fixed wireless up to 2.4 Mbps. Vendors actually disagree on the definition of 3G and on its first global implementation. South Koreans claim that their three mobile carriers started offering 3G services based on Qualcomm's wireless technology, otherwise known as cdma2000 1x, in September 2000 and that subscribers with compatible handsets are now able to download data at up to 144 Kbps. Korea's two largest carriers—SK Telecom and KT Freetel—started offering cdma2000 1x EV-DO (Enhanced Version Data Optimized) in January and May 2002, respectively. This technology delivers data at up to 2.4 Mbps. However, some claim that Japan's biggest mobile phone operator, NTT DoCoMo, introduced the world's first real 3G cellular phone service on October 1, 2001, based on the so-called wideband CDMA (WCDMA), a technology incompatible with cdma2000. NTT DoCoMo was indeed the first to implement the WCDMA technology, but the International Telecommunications Union (ITU) classified cdma2000 1x as a 3G technology. Therefore, the Koreans were officially the first to implement 3G wireless service.

The 3G world became even more complicated with the announcement by the Chinese government that it allocated radio spectrum for the third—and homegrown—flavor of 3G technology called TD-SCDMA (time division synchronous CDMA). This development could be a potential blow to the U.S. and European standards that foreign vendors are trying to sell in China, the world's biggest market. TD-SCDMA, a standard not considered outside China, could play a spoiler role [Bolande, 2002]. Table 1 compares communication speeds and spectrum requirements for most popular wireless communication standards.

Table 1. Communication Speed and Spectrum Width Comparison.

Communications Standard	Maximum Speed	Spectrum Width
2G	9.6 – 14.4 Kbps	30 KHz
TDMA	9.6 – 14.4 Kbps	30 KHz
GSM	9.6 – 14.4 Kbps	200 KHz
CDPD	19.2 Kbps, typically less than 10	25 KHz
GPRS	38.4 – 57.6 Kbps	200 KHz
3G	A minimum of 144 Kbps	1.25 – 5 MHz
WCDMA	3G speed	5 MHz
FOMA	Up to 384 Kbps (64 Kbps uplinks)	5 MHz
cdma2000 1x	144 – 288 Kbps	1.25 MHz
cdma2000 1xEV-DO	2.4 Mbps	1.25 MHz
cdma2000 1xEV-DV	1.2 Mbps mobile users 5.2 Mbps stationary users	1.25 MHz

The great promise of evolution to 3G—agreement on single global standard—is not yet achieved for various reasons, including international politics, patent licensing costs, and technical constraints in upgrading existing networks. Can global uniformity be accomplished with whatever comes after the third generation? The decision of NTT DoCoMo to speed up the implementation of the so-called fourth-generation (4G) network and launch it in 2006, instead of its initial target year of 2010, suggests that carriers are already developing future technologies without a blueprint of an international standard and that several incompatible technologies will likely be developed. However, the carriers must first find a justification for investments in the next-generation network at a time when telecommunication industry is in a deep slump and 3G implementers are still looking for any successful business model. Indeed, they must first secure a return on their initial 3G investments and further differentiate 4G services from the existing ones. Manufacturers also need to co-develop technologies with other industry players. Migration to 4G will thus depend on the success of 3G business, otherwise it will again be a technology in search of a market.

Why do we need the next-generation wireless technology anyway? The arguments in support include the suggestion that:

- 3G transmission speed is insufficient for future multimedia applications and does not support seamless global roaming,
- the 3G networks are complicated and expensive, and
- the spectrum will become congested.

It is believed that new technologies will require more advanced network infrastructures. The introduction of 4G technologies, which will likely require a wider radio spectrum width of up to 100 MHz, will also depend on the willingness of governments to license additional and substantial radio frequency bands to wireless carriers. This transformation is not going to be easy.

On the other hand, progress is only natural. Both government and industry organizations initiated research into next-generation wireless. Each country is likely to attempt to drive the standardization process in its favor, following different macro political and economic drivers and starting from different market positions and legacy networks. Although achieving unity of direction makes sense, it will be difficult to achieve a single global standard. The concept of the next-generation services is not yet defined. Table 2 compares 3G with 4G services.

Table 2. 3G and "After 3G"

Characteristics	Current 3G Generation	Beyond 3G
Service	Voice and lower speed multimedia	High speed multimedia
Frequency Band	2 GHz	20 – 60 GHz
Data Transfer Rate	144 Kbps – 2.4 Mbps	2 – 50 Mbps (or up to 150 Mbps)
Bit Error Rate	$10^{-3} – 10^{-4}$	$10^{-6} – 10^{-12}$
Switching	Circuit/IP	Full IP packet switching

THE REALITY – EVOLVING WIRELESS NETWORKS

Wireless and personal communication services operators around the world are upgrading their networks or launching new packet data networks. In 1999, the International Telecommunication Union (ITU) approved an industry standard for 3G wireless networks. This standard, called International Mobile Telecommunications-2000 (IMT-2000) consists of five operating modes including three based on Code Division Multiple Access (CDMA) technology patented by Qualcomm. These three CDMA modes are most commonly known as cdma2000, WCDMA, and TD-SCDMA. As noted above, the first two were the dominant choices for 3G until the Chinese government allocated s spectrum to the homegrown TD-SCDMA networks [3G Newsroom.com, 2002]. Operators are progressing toward the 3G along the paths shown on Figure 4.

The 3G evolution path an operator chooses does not depend solely on perceived or proven technological superiority of a particular standard, but also on politics, patents ownerships, and pride. San Diego-based Qualcomm owns a set of patents for CDMA technology, and even the Chinese government is hesitantly realizing that TD-SCDMA technology vendors will need to pay royalties to Qualcomm. However, intellectual property contributions vary among the three standards. European companies Nokia and Ericsson, for example, own about 1000 patents for their development of WCDMA. The EU parliament subsequently mandated WCDMA as the European 3G standard. Various vendors are progressing along alternative evolution paths in other regions of the world, including North America and East Asia, letting market forces decide the technology winners.

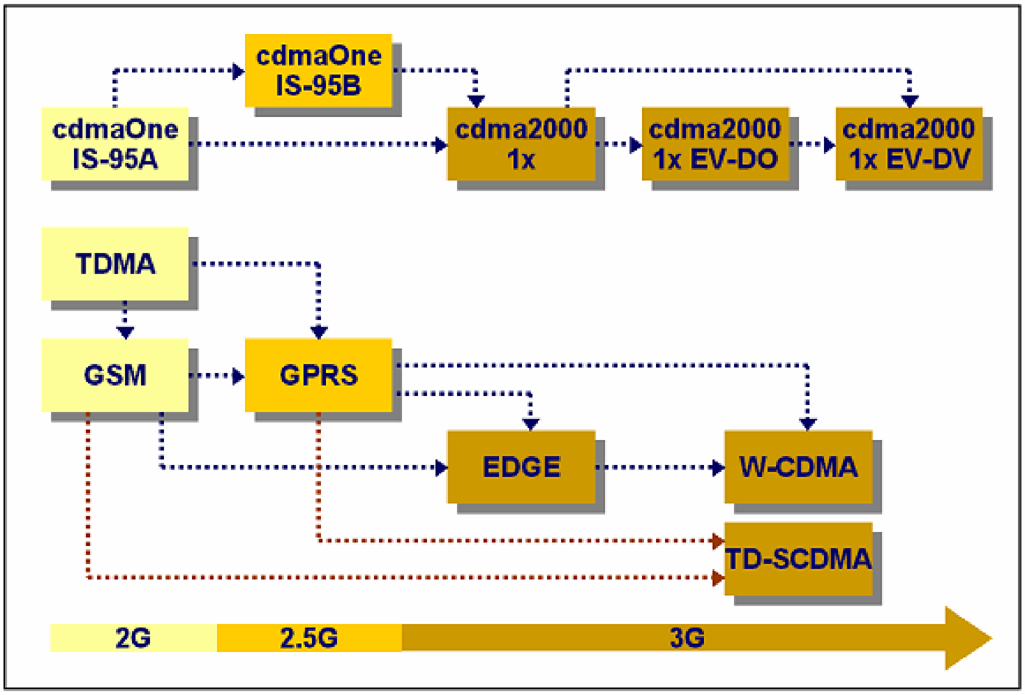

Figure 4. Wireless Standards Evolution Paths

As shown on Figure 5, cdma2000 is currently the winning technology, based on data through December 2003 [3G Today, 2003] and its lead still continues.

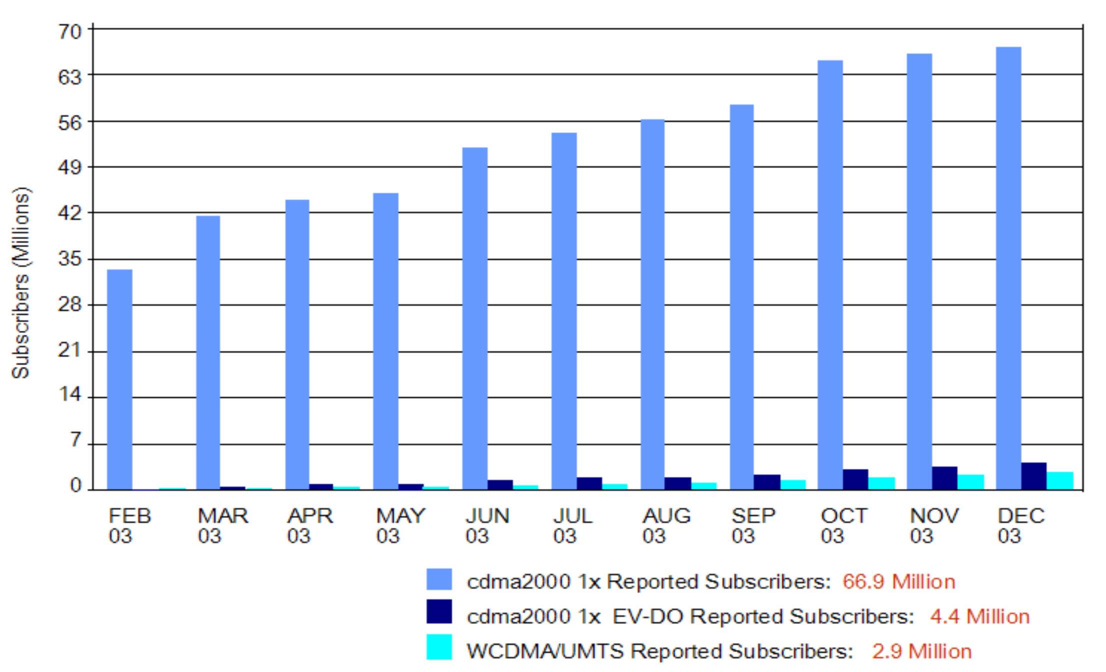

Figure 5. 3G CDMA Reported Subscribers

NTT DoCoMo offered the first commercial implementation of WCDMA, and it had a disastrous introduction. Through September 30, 2002 DoCoMo sold 140,000 3G subscriptions, a goal it had hoped to reach in March [Belson, 2002]. DoCoMo's competitor KDDI launched its cdma2000 1x system on April 1, 2002 (six months later) and attracted one million subscribers in three months. Why was KDDI at least initially more successful than DoCoMo, and how much of the success can be contributed to the technologies themselves rather than to other business decisions?

1. It turned out that the cdma2000 1x technology provided advantages that benefited the operators in several ways. One was availability. More than 145 different 1x affordable and attractive handsets were available and many operators launched 1x service. Handset prices were dropping and quality was improving. This advantage was amplified by the WCDMA implementation delays in Europe.

2. The capacity of cdma2000 1x is higher than that of WCDMA. It provides data rates of up to 307 Kbps with a typical speed of 144 Kbps. The increase of data capacity does not come at the expense of voice services; it doubles the voice capacity of previous cdmaOne networks, and provides six times the capacity of GSM or TDMA systems [LaForge, 2001]. WCDMA and cdma2000 1x continue to battle for the fastest commercially available wireless throughput. For now, 1x appears to have the upper hand, given its day-to-day speeds of 100 – 120 Kbps versus 80 – 90 Kbps for NTT DoCoMo's FOMA handsets [Carvalho and Shuper, 2002]. The cdma2000 1x EV-DO further increases these speeds: wireless carriers and infrastructure providers in the U.S. and Asian markets report average download speeds of 800 – 900Kbps [Shaw, 2002].

3. The capital expenditure for upgrading the networks to cdma2000 3G technologies is lower than that of WCDMA. Korean operators experienced lower expenditures for data upgrades than their Japanese counterparts. In the first four years of network deployment, Japanese operators typically spent over $14 billion on WCDMA networks versus approximately $4 billion for Korean operators on cdma2000 1x [Carvalho and Shuper, 2002]. The situation is similar in the U.S., where Verizon Wireless, Sprint PCS and other cdma2000 operators enjoy a much cheaper upgrade path than those operators on the path to WCDMA.

4. cdma2000 is backward compatible. Until dual-mode WCDMA handsets became available, a WCDMA user had to carry two phones to be able to make a call outside the 3G coverage. In contrast, the backward compatibility of cdma2000 1x and its more advanced 1x EV-DO and 1x EV-DV renderings means that users outside the range can immediately and seamlessly roam to an earlier generation system.

After a slow start, DoCoMo's 3G service took off in the second quarter of 2003 with the number of subscribers reaching one million in September [Dvorak, 2003] and 1.9 million at the end of December [Tsukimori and Wan, 2004]. The rate of growth in new subscriptions at DoCoMo is still much slower than that at KDDI, which is adding about one million subscribers per month to a total of about 12 million 3G subscribers in early 2004.

The real success story is NTT DoCoMo' 2G service called i-mode with over 40 million subscribers by the end of December 2003, but it provides top speed of only 9.6 Kbps [Tsukimori and Wan, 2004]. This outcome tells us that applications, fashionable color handsets, and marketing strength matter much more than speed alone. Both in Korea and Japan, revenue from data services is only a fraction of that from voice and most of the data-related revenue still comes from narrowband applications. For example, the top five services by South Korea's SK Telecom 3G network are:

- ring tone and picture downloads (40.1%)
- games and entertainment (30.3%)
- adult content (9.5%)
- location-based services, including travel and traffic information (6.4%)
- stock information and banking (5.0%)

Most of these services are available on slower 2G and 2.5G networks. They also are primarily consumer-related services. We do not see business use of mobile wireless technology or business applications driving the evolution of mobile wireless technologies.

IN THE MEANTIME – IEEE 802.11

As wireless carriers navigate in competitive markets and try to upgrade their networks, a different wireless technology seems to be taking the world by storm. A family of IEEE 802.11 standards—technology also known as Wi-Fi (wireless fidelity) or wireless LAN—was initially designed as an inexpensive alternative to wired Ethernet office networks. However, it took off in many unexpected ways. Over seven million wireless cards were sold in 2001 alone. The IDC prediction of 25 million users by 2005 may prove far too low, as Intel decided in 2002 to start integrating wireless Internet capability in all its mobile microprocessors to spur a fundamental shift in the way Americans will use the Internet [Markoff, 2002].

This unruly technology, initially a playground of hackers, hobbyists, and high-technology startups, is already sprouting like mushrooms in coffee shops, bookstores, airports, university campuses, hotels, homes, businesses and even a few parks. For example, the city administration in Athens, Georgia, built a wireless “cloud” covering the downtown as a service to attract new businesses to the city. Wi-Fi received a significant stamp of approval in 2002 as AT&T, IBM, Intel, and two investment firms formed a new company, Cometa Networks, to create a nationwide network. Wireless LAN services are easy to use. Customers of services from Cometa, T-Mobile, and others, such as Boingo, and Wayport, can keep their existing network access procedures, logons, passwords, E-mail addresses, and payment methods [Gareiss, 2002].

Figure 6 shows the current wireless technologies. Figure 6 can be redrawn to show the ranges on the vertical axis. As drawn, the range is only implied. Bluetooth’s range is only about 10 meters, and Wi-Fi’s is about 100 meters (if unobstructed), while cellular networks provide the ultimate mobility. It is hard to imagine that the coverage of Wi-Fi would not be limited to select hot spots, mostly in urban areas. Cometa’s ambitious project to install 20,000 access points by the end of 2004 will be limited initially to the 50 largest markets. Even so, hot spots in urban areas should not be more than a five-minute walk away from a user, and in suburban areas not more than a

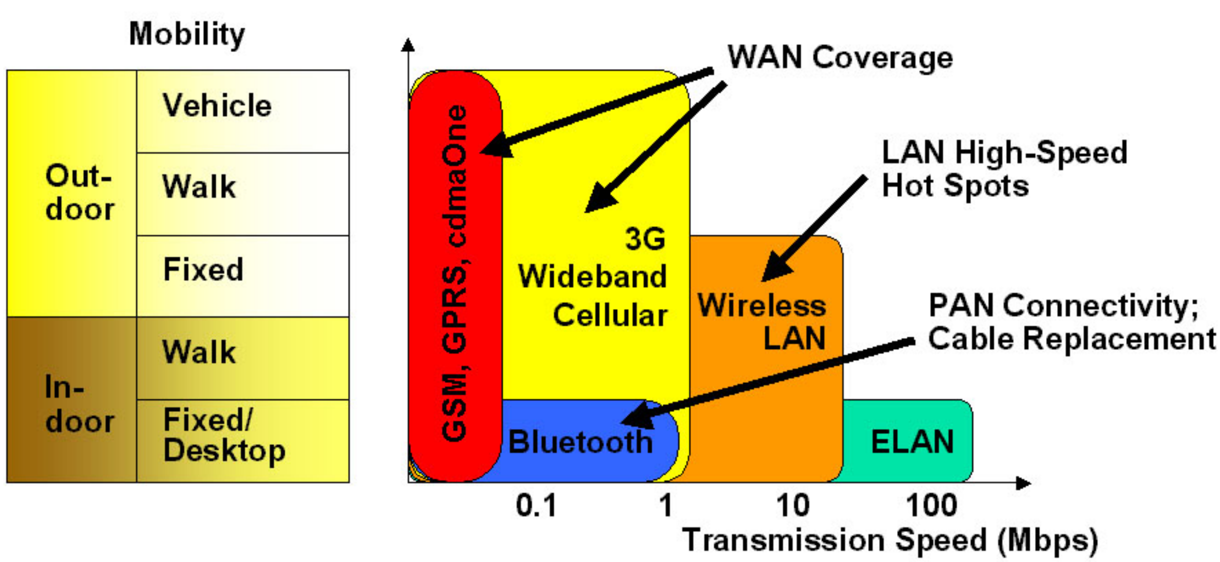

Figure 6 Complementary Wireless Technologies.

five-minute drive. The range and coverage differences suggest that the three technologies (Bluetooth, wireless LAN, and wideband cellular) will complement each other and coexist. Indeed, KDDI and Cisco successfully tested flawless data communications between different wireless technologies in moving cars in Japan. They drove through the areas with cdma2000 1x, cdma2000 1x EV-DO, and Wi-Fi coverage. Communications continued to work seamlessly while moving between different communication networks. The evolution of multimode devices is certainly exciting.

Wi-Fi is a family of standards developed by IEEE. The first standard, 802.11, published in 1997, provided speeds of up to 2 Mbps. IEEE soon refined it and developed two incompatible versions: 802.11b and 802.11a. The two versions use different coding and operate in different frequency ranges. The "11b" version operates in the 2.4 GHz band with speeds of up to 11 Mbps, while the "11a" version operates in the 5 GHz band with speeds of up to 54 Mbps. The 802.11b equipment appeared in the market first because it was simpler to develop and build. When the 802.11a equipment became available, it created confusion because users and manufacturers were forced to decide between two incompatible and non-interoperable standards [Carney and Solomon, 2002]. Moreover, 802.11g was approved in June 2003 as yet another IEEE standard. It provides wireless transmission at up to 54 Mbps, operates in the same frequency range as 802.11b, and is compatible with it.

The IEEE's 802.11 standards bodies are developing several additional specifications. The 802.11i committee is addressing the security issues, the 802.11e committee is defining the Quality of Service (QoS) capabilities, the 802.11h committee is advancing the dynamic frequency selection feature, and the 802.11n committee is trying to increase the bandwidth significantly.

Standardization authorities outside the U.S. are also working on standards for wireless local data networks. The European Telecommunications Standards Institute developed wireless LAN standard HyperLAN/2 working at 5 GHz, which meets the regulations for that frequency band used for radar in Europe. HyperLAN/2 has, so far, not achieved market penetration comparable to Wi-Fi in North America. The Japanese Multimedia Mobile Access Communication Systems Promotion Council is also developing specifications for short-range wireless networks, but IEEE is trying to define additional standards to meet Japanese regulatory requirements. Several vendors displayed mini-PCS card, ruggedized notebook and announced a single-chip radio combining two or more wireless technologies including Bluetooth, Wi-Fi and various WANs [Nobel, 2002]. First multimode radio cards, such as Nokia D211, are already on the market.

Two other working groups are also working on standards for wireless communication: the IEEE 802.16 Working Group defined and is now enhancing standards for broadband fixed wireless communication, known as wireless metropolitan area networks (WMAN) and Wi-Max, potentially an economic solution for the "last mile" problem, i.e., getting broadband into homes efficiently. The 802.15 Working Group is working on standards for short distance wireless networks or wireless personal area networks (WPAN).

The 802.16 standard is a WMAN technology that will provide broadband wireless connectivity to fixed, portable, and nomadic devices. It is officially known as the IEEE WirelessMAN standard and can be used to connect 802.11 hotspots to the Internet, provide campus connectivity, and provide a wireless alternative to cable and DSL connections for last mile broadband access. It provides up to 50-kilometers of service area range, allows users to get broadband connectivity without needing direct line of sight with the base station, and provides total data rates of up to 280 Mbps per base station. A single base station provides enough bandwidth to support hundreds of businesses simultaneously with speeds equivalent to a T1 line and thousands of homes with speeds like DSL lines [Anonymous, 2003]. Some wonder whether this alternative may turn out to be the 4G choice after all.

Notice, again, that the technology works, but the search for a profitable business model continues. Notice also that the global standardization situation is messy, but that it can, perhaps, be controlled with some additional device and processing costs.

OTHER DISRUPTIVE TECHNOLOGIES

Four other disruptive technologies threaten to render 3G wireless networks irrelevant. Of these, smart antennas are already in use, mesh networks are starting to appear, and ad hoc architectures and ultra-wideband transmission are still in the laboratories. Each of these challenges existing ways of providing wireless connectivity, and each on its own or in combination with others could shake up the wireless world.

Smart Antennas. Dumb wireless antennas broadcast in all directions within a cell. Directional antennas enable more efficient reuse of radio frequencies. An even better technology, called smart antennas, uses multiple antennas to provide more accurate directional targeting. One such technology, from ArrayComm, is deployed in 100,000 base stations in Japan, China and Taiwan. NTT DoCoMo is testing a system developed by the Institute for Communications Research from Singapore. Existing infrastructure suppliers do not show much interest in smart antennas technology, perhaps focusing too much on protecting their own R&D investments.

ArrayComm claims that its i-Burst technology performs better than 3G at a fraction of the cost and is about 40 times more efficient. It further suggests that i-Burst base stations with smart antennas, collocated with 2G base stations, provide speeds of 1 Mbps at about one-thirtieth of the cost of building a 3G network. The first receivers are big and heavy, but Kyocera and other licensees are expected to produce i-Burst receivers as PC cards. ArrayComm introduced i-Burst commercial service in Australia in December 2003. South Korean's Hanaro Telecomm launched i-Burst service in summer 2003.

Mesh Networks. Mesh networks require that a neighborhood is first "seeded" by installing of a "neighborhood access point" (NAP). It also requires homes and offices to install antennas of their own and that each of them acts as a relay for other homes beyond the range of the original NAP. If all works well, a large area can be covered quickly and inexpensively. Mesh networks are technically superior to traditional "point-to-multipoint" networks because they require a fraction (one-ten-thousandth) of power, offer redundant paths, are self-configuring and thus robust, and can be used in the unlicensed spectrum, such as that used by Wi-Fi. Nokia's RoofTop mash networks technology was tested successfully in Santa Rosa, California. Fifty operators, most of them small ISPs, are already installing AirHead units to seed the neighborhoods. One of them, Vista Broadband of Santa Rosa, charges $200 for installation and a monthly fee of $50. SkyPilot offers similar service in Menlo Park, California, in combination with smart antennas.

The challenge with mesh networks is to get them off the ground. SkyPilot plans to implement the access points itself and allow ISPs to resell the access. The other question is whether users would allow the batteries and other resources in their devices to be drained while relaying other users' messages.

Maitland, Florida-based MeshNetworks ran trials with city buses in Orlando, Florida, using off-the-shelf 802.11 radios and a proprietary radio to enable multi-hopping networks at vehicle speeds as fast as 70 mph. Combined with relay devices posted on light poles (two per square mile), the system claims to provide a quality of service sufficient to stream video and to support voice-over-IP (VoIP) calls [Margulius, 2002].

Ad Hoc Architectures. Ad hoc architectures consist of multiple devices, each of which also acts as a router for the others, resulting in a robust, self-healing infrastructure-less network. This technology, commonly associated with military and emergency applications, allows devices to be moving. The network topology is in a constant flux. While Bluetooth supports only single "hops" between devices, ad hoc networks do not impose such a constraint. For example, Wi-Fi-equipped laptops would act as relays for other machines, allowing packets to make multiple hops. Nokia and other wireless technology vendors are keeping a close eye on this promising technology.

Ultra-Wideband Transmission. Ultra-wideband (UWB) transmitters send out very short pulses simultaneously on a wide range of frequencies at low power (under 0.05 milliWatts). Conventional radio receivers cannot detect these less than a billionth of a second long pulses, but they are detected by UWB receivers. The information is encoded into streams of pulses and millions of them are emitted every second. Some of the companies working on UWB technologies are Time Domain, Radar, Inc., Zircon Corp., Pulse-Ling and Xtreme Spectrum, while many others including Intel are investigating UWB. Cellonix from Singapore already demonstrated 11.4 Mbps UWB transmission.

Since 1998, the Federal Communications Commission (FCC) has been attempting to a find a way to approve and promote UWB technology because of the potential commercial applications that include multiple streams of digital audio and video and wireless broadband connections between home appliances. In February 2002, it unanimously approved restricted rules to permit the marketing and operation of ultra-wide band technology, allowing wireless devices and services that deliver higher data bit rates (at least 100 Mbps) with lower power consumption than either Bluetooth or 802.11 [Mark, 2002]. This approval, however, limits the range to only 10 meters. Opponents of UWB technology fear interference from the devices could potentially disrupt public services such as aviation, fire, police and rescue efforts. The UWB standards approved by the FCC are based in large measure on standards that the National Telecommunications and Information Administration (NTIA) believes are necessary to protect against interference to vital federal government operations. The FCC plans to review the standards to explore the potential of more flexible standards, and to address the operation of additional types of UWB operations and technology. Similar moves are expected in Europe and Asia. Longer ranges may be allowed in the future.

In a speech at the University of Colorado at Boulder on October 2002, FCC Chairman Michael Powell reiterated his often-stated position that he intends to open spectrum use for a range of new devices and services [Powell, 2002]. Without mentioning it by name, he signaled that UWB might be one of those favored new directions [Venditto, 2002]. The UWB technology and ad hoc networks are a natural fit. If this combination evolves into the fifth-generation wireless technology, the entire structure of the industry could shift from a top-down approach to one organized from the bottom-up.

MACHINE-TO-MACHINE

One domain of mobile wireless applications that does not receive much media attention, but may become rather significant, is known as machine-to-machine (M2M) data exchange. It refers to the situation where a machine, whose primary function is not communication, is at one or both ends of the exchange. The name may be misleading, since many of the M2M applications will involve people. For example, a picture sent by a surveillance camera to a handset would classify as M2M according to this definition. Gartner [Jones, 2002b] categorized M2M applications depending on the range and bandwidth requirements as shown in Table 3.

Table 3. Categories of M2M Applications

Bandwidth Requirements	Short Range <100m	Long range >1Km
Very high, 10 to thousands of MBytes per day	E.g., public surveillance (streaming video) Wi-Fi	Unlikely to be technically or economically feasible on 2.5G or 3G networks
High, a few MBytes per day	E.g., real-time telemetry (process sensing) Wi-Fi, Bluetooth	E.g., domestic surveillance (motion-sensitive camera) 2.5G, 3G packet data, MMS
Low, hundreds of bytes per day	E.g., campus telemetry (freezer temperature) Wi-Fi, Bluetooth	E.g., telemetry, alerts (vending machine alerts) Messaging – SMS

Known domains of M2M applications include the following examples [Jones, 2002b]:

- Systems in vehicles supporting maintenance scheduling, tracking, routing, dispatching and navigation.
- Vending machines with applications such as stock monitoring, breakdown signaling, and cash removal requests.
- Telemetry applications by utilities, e.g., water level and road traffic sensing, utility meter reading, environmental monitoring and freezer temperature control.
- Medical applications, such as patient and equipment monitoring.
- Home security applications including fire and other alarms notification, motion-sensitive cameras, sending pictures, children monitoring etc.
- Security and surveillance, e.g., face recognition and sensors for chemical and biological agents.
- Logistical applications, such as tracking cargo containers and wagons and sensing condition of perishable or fragile goods.
- Controlling high-priced domestic appliances, such as heating and air conditioning, washing machines, freezers, and hot tubs.
- Entertainment-related applications, such as TV programs, enabling conventional broadcast stations to become interactive and compete better with cable companies.

Many factors will influence M2M market growth [Jones, 2002b]. Current prices for WAN wireless devices are in the $150 range and limit the application to more expensive equipment. By 2007, the price should come down by about half. WLAN and especially PAN equipment is less expensive. The implementation of Bluetooth finally started to take off. Pricing may also slow the spread of M2M. Currently, the 2.5G and above all 3G pricing is rather high and will limit the M2M implementation in the near future only to critical applications. Coverage is another limiting factor. In countries as large as the U.S., it will remain patchy and not available in rural areas. Although assuring security is progressing, radio transmission is still considered inherently vulnerable to interception.

Other factors that may influence the evolution of the wireless WAN M2M market include the proliferation of Wi-Fi use at home. If Wi-Fi or Bluetooth becomes widely used and people connect their homes to the Internet with broadband wireline connections such as DSL and cable, the home appliances will not depend on WAN wireless services. Some wireless M2M applications, such as surveillance, require high bandwidth connections, which may not be available in some regions of the world until the upgrades to 3G are made. Some political and economic factors may, on the other hand, speed up the implementation of M2M wireless applications. One example is increased needs for surveillance related to growing concerns about national security. Another example is contemplation by some governments to mandate the use of M2M devices in vehicles to trace stolen cars and monitor drivers, which might upset privacy groups.

RFID

Based on all these uncertainties, Gartner predicts the size of the M2M market to between $100 and $160 million by 2007 [Jones, 2002b]. This forecast, however, includes only wireless WAN and excludes LAN and PAN, which brings us to another very promising wireless technology just about ready to revolutionize applications such as supply chain management – radio frequency identification (RFID). Automatic Identification and Data Capture (AIDC) systems allow for non-contact reading and are effective in manufacturing and other hostile environments where bar code labels could not survive. RFID is established in a wide range of markets including livestock identification and automated vehicle identification systems because of its ability to track moving objects [Association for Automatic Identification and Data Capture Technologies, 2003].

Magrassi and Berg [2002] of the Gartner Group forecast that the following developments will occur by 2010:

- Many physical objects (such as products) will be hard-coded and become uniquely identifiable.

- Intelligent devices will be embedded in physical objects of all sorts, such as consumer goods, banknotes, clothing, and sheets of paper.
- Intelligent devices will increasingly be networked via the (by then mostly) wireless Internet.
- Consequently, all physical objects, animals and human beings carrying intelligent devices will also be networked, in addition to being identifiable.

RFID is a portable memory device on a chip that acts like a universal product code (UPC) currently used in bar codes [Smith and Konsynski, 2003]. However, RFID is more than UPC because this microchip can carry much more and dynamic information. It uniquely identifies not just a product line, but also each individual item. An inexpensive microchip can be embedded in any object and can store basic information about the item. Readers within a range from a few millimeters to 100 meters, depending on the design and power source, can read the information stored in these microchips. RFID devices, or e-tags, measuring 0.4 square millimeters and thin enough to be embedded in a sheet of paper, are available. By 2006, smaller e-tags costing less than 5 cents each will be common and produced by the billions. An RFID employs radio frequency communications to exchange data between the memory chip and a host computer. An RFID system typically consists of an e-tag containing data storage, an antenna to communicate with the tag, and a controller to manage the communication between the antenna and the server.

Passive e-tags do not use a power source of their own and are connected to antennas. The signal sent by the reader induces an electric charge in the antenna and powers the e-tag's circuitry used to read the memory in the chip and to send its content back to the reader. However, e-tags can also be manufactured as active devices with their own battery. These tags are typically read and write devices. The battery power of an active tag can give it a read range of up to 100 meters. Of course, active tags are more expensive and do not last as long operationally.

RFID-based systems are effective in various vertical industry applications, such as [Mobileinfo, 2001]:

- A military version of commercial supply chain management using RFID in combination with Global Positioning System (GPS) enables tracking of equipment and ammunition shipments
- Manufacturing and other hostile environments where barcode labels are not feasible
- Livestock and pets identification
- Tracking the movement of hazardous material
- Airline bag tracking and boarding passes
- Automated vehicle identification systems
- Library checkouts
- Consumer payment systems using RFID technology with smart cards
- Gas station and toll road payment systems

Perhaps the greatest potential for RFID applications, however, is in commercial and military supply chain management applications, where tracking can be completely automated. Even the product assembly instructions can be embedded into components to upload the process instructions to shop floor robots.

The main challenge regarding RFID technology is standardization. Vendors such as Hitachi are already marketing their products while national and international standardization efforts are still in progress. Instead of tagging the same item differently by suppliers, in the manufacturing process, or by distributors and retailers, a global standard similar to that used on the Internet should be established. The most active industry-supported standardization effort is directed by MIT’s Auto-ID Center, which is developing key technologies, such as the 96-bit electronic product code that will be placed on each tag to identify the item and a Product Markup Language that will give details about the product.

III. GLOBAL AND U.S. WIRELESS OPERATORS

Table 4 lists the 20 largest wireless operators worldwide by the number of subscribers in their domestic markets. It also shows the annual subscription growth rate for 2002 [Pittet, 2003].

Table 4: Top 20 Global Wireless Operators.

Rank	Country	Operator	Subscribers on Dec. 31, 2001('000s)	Subscribers on Dec. 31, 2002 ('000s)	Growth
1	China	China Mobile	103,815	142,000	36.8%
2	China	China Unicom	40,968	64,616	57.7%
3	Japan	NTT DoCoMo	39,635	42,874	8.2%
4	United States	Verizon	29,398	31,521	7.2%
5	Italy	Telecom Italia Mobile	23,950	25,300	5.6%
6	Germany	T-Mobile Germany	23,100	24,582	6.4%
7	Germany	Vodafone D2	21,890	22,732	3.8%
8	United States	Cingular	21,596	21,925	1.5%
9	United States	AT&T Wireless	18,047	20,849	15.5%
10	Mexico	Telcel	16,965	20,067	18.3%
11	France	Orange	17,220	19,215	11.6%
12	Italy	Vodafone Omnitel	17,431	19,000	9.0%
13	Spain	Telefónica Móviles España	16,780	18,500	10.2%
14	Japan	KDDI	15,849	17,317	9.3%
15	South Korea	SK Telecom	11,880	17,219	44,9%
16	Turkey	Turkcell	12,200	15,730	28.9%
17	United States	Sprint PCS	13,555	14,760	8.9%
18	France	SFR	12,235	13,547	10,7%
19	Japan	J-Phone	11,617	13,323	14.8%
20	United Kingdom	Orange	12,400	13,312	7.4%
	Total		**480,541**	**578,390**	**20.4%**

While the overall growth rate of over 20% is quite impressive, some of the older markets, such as Europe and Japan show lower growth than newer markets, such as China, Turkey, and Mexico. European and even U.S. market are approaching saturation. Consumers will continue purchasing handsets, but they will mainly be replacements. Average monthly revenue per subscriber has not been growing as the wireless operators hoped and data services still generate only a small part of total revenue.

The situation in the U.S. is a good example. Although the percentage of households using a cell phone grew from 34% in 1998 to 57% in 2002, and an average user extended the use from under 200 minutes to 530 minutes per month in the same period, the average monthly revenue actually decreased from $67 to $62 per subscriber.

As shown in Figure 7, one of the successful South Korean 3G operators, KTF, reported that while the use of data services depends on the capabilities of handsets, revenue generated is still minor compared with that generated by voice. However, the contribution of wireless data revenue at KTF to its total wireless revenue is growing rapidly. It increased from 10.7% in April 2002 to 15% in April 2003. In the U.S., the revenue from data services is still only about two percent of total wireless revenue, but IDC estimates that the U.S. market for wireless data will grow to $16.8 billion by 2006 [Parker, 2002]. In June 2002, Forrester Research estimated 47 % of global 3500 firms are piloting or considering deployment of enterprise mobile data solutions [Parker, 2002]. Nonetheless, few applications were compelling.

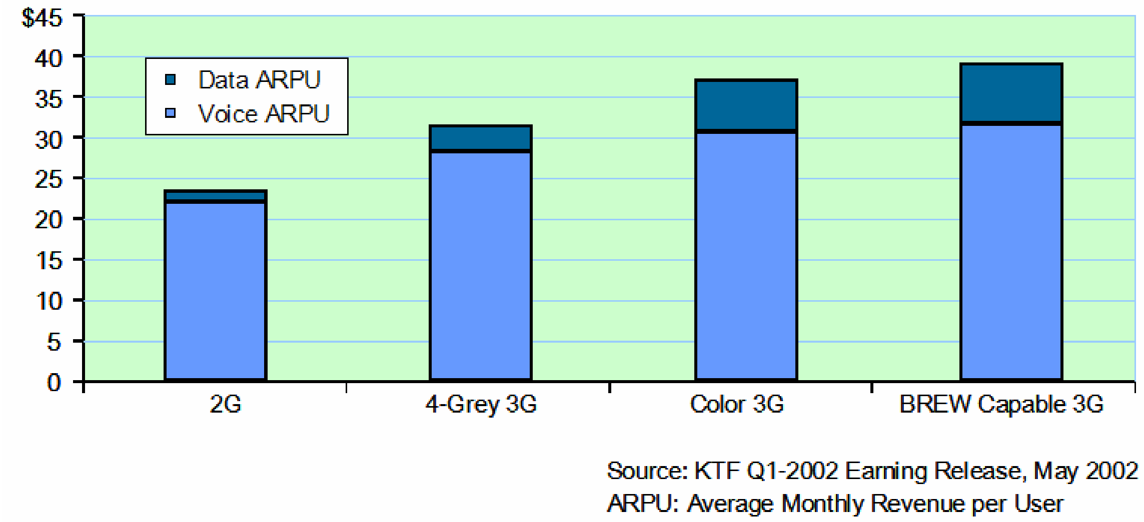

Figure 7. Voice and Data Revenue by Handset Type at KTF, South Korea

National U.S. wireless operators are Verizon Wireless, Cingular Wireless, AT&T Wireless, Sprint PCS, Nextel Communications, and T-Mobile USA. Other carriers provide limited or regional coverage. Table 5 presents market share, growth rate, and other information about these six largest U.S. carriers.

Table 5. Major U.S. Mobile Operators

Mobile Operator	Subscribers* (in millions)	Subscriber Market Share (%)	Annual Sub-scriber Growth Rate (%)	ARPU ($)	2G Network	3G Migration Path
Verizon Wireless	36.0	23.9	14.3	50	CDMA	cdma2000
Cingular Wireless	23.4	15.5	5.9	51	TDMA/GSM	EDGE/UMTS
AT&T Wireless	21.9	14.5	8.4	61	TDMA	EDGE/UMTS
Sprint PCS	15.5	10.2	6.6	63	CDMA	cdma2000
Nextel Commnctns.	12.3	8.2	22.1	71	iDEN/TDMA	WiDEN
T-Mobile USA	12.1	8.0	36.1	54	GSM	EDGE/UMTS

*Source: The Yankee Group, 3Q03 [Richtel & Sorkin 2004]

Verizon Wireless, Cingular Wireless, Nextel Communications and AT&T Wireless were profitable at the end of the third quarter of 2003, while the other two operators were not. Although T-Mobile USA experienced the highest subscriber growth rate, it was ranked fourth in the Technology Business Research's 3Q 03 mobile operators benchmark report [Market Wire, 2003]. Nextel received the highest rank and was followed by Verizon Wireless, Sprint PCS, T-Mobile USA, Cingular Wireless and AT&T Wireless. The analysts liked Nextel's leading position in ARPU, continuous growth due to its industry-leading subscriber retention and its Direct Connect walkie-talkie service for the business market segment. Verizon has strong brand, leading market share, profitability, continuous growth, broad network coverage, and network quality.

IV. THE BUSINESS OF MOBILE COMMERCE

> *"Who shot mobile commerce, and will it ever walk again? Repeatedly named the Next Big Thing by the now-humbled New Economy crowd, M-commerce suffered a flameout every bit as dramatic as any individual dot-com's during the bust."* [Ewalt 2002, writing in *Information Week*]

Was this statement a vastly exaggerated and premature death announcement?

Many M-business success stories appear in the computer press. For example, the same *Information Week* article reports that the use of wireless tablet PCs connected with computers in back offices in three Skyline Chili restaurants increased the efficiency and cut the costs as much as 14%. It also reports Giorgio Armani Corp. experienced improved control of its inventory and labor costs with the use of wireless LAN for store operations management. Armani considers it a mission-critical application [Ewalt, 2002]. However, these two examples describe the application of inexpensive wireless LAN technology.

The editor of *Computerworld*'s special report "Wireless at Work" [Fanning, 2003] writes that wireless technology spread beyond BlackBerries and hyped wireless access points at Starbucks and airport lounges. She lists a number of obvious applications including service technicians calling up repair information while at their customers' locations; bulldozer operators obtaining information on where to build the next road; and police officers catching crooks by monitoring mug shots, maps, and graphical data sent out from headquarters. Of *Computerworld*'s survey respondents, 64% considered wireless technology important to their business goals and 38% of them said the economic downturn did not impact their wireless rollouts [Johnson, 2003]. Moreover, IDC's survey results indicate that over half of corporate North America deployed a mobile or wireless solution at the beginning of 2002, but the market penetrated some vertical segments more effectively than others [Draper, 2003].

Researchers from Gartner discuss a concept called real-time enterprise (RTE) and suggest that wireless mobile services offer attractive opportunities to implement this model. However, they believe that mobility is currently driven by personal consumption rather than compelling enterprise applications. By 2007, however, over 80% of economically active people in North America, European Union nations, and countries such as South Korea, Japan, Australia and New Zeeland will carry with them at least one wireless mobile device. They will further expect access to various information sources from anywhere and to communicate with everybody at any time. These expectations will not be limited to personal use and will include business communications. Enterprises are thus advised to start experimenting with wireless technology, which will become ubiquitous in a few years. Strategic drivers for experimentation or full employment of mobile communication include the adoption of real-time enterprise principles, the need to serve customers using multiple communication channels, a potential for increase in employee efficiency, and the opportunities for cost reductions [Jones and Deighton, 2003].

Successful business wireless applications involve mobile employees or equipment, such as sales, field force and customer support, and logistics. The following paragraphs describe some successful applications from these categories.

- *Delivery Services*. United Parcel Service of America (UPS) drivers' next generation clipboard contains a touch-sensitive color screen, cellular modem, Wi-Fi and Bluetooth radios, infrared port, GPS receiver, acoustic modem and a keyboard. It not only collects customer signatures, but gives drivers directions to their next stop. UPS, which is spending $120 million to implement new wireless technology at its worldwide distribution centers, expects a 35 % productivity gain [Copeland et al., 2003].

  Similarly, UPS's competitor, FedEx Corp., expects that new Motorola PowerPad handheld will enable its drivers to save 10 seconds at each delivery of 3.5 million packages daily using AT&T Wireless services.

- *Real Estate*. On a smaller scale, Peggy Isakson, a Fargo, North Dakota, real estate agent, uses high-speed Internet access when showing houses. She can answer her email, upload photos of properties, and look up tax and county records when she is on tours with prospective buyers [Malik et al., 2003].

- *Finance*. Fidelity Investments realized in 1998 that its wireless subscribers were attractive customers. They owned more assets, were more financially active, and more advanced technology users [Collett, 2003]. Since 2003, 170,000 Fidelity Anywhere users get real-time stock quotes, make after-hour trades, short-sell, and call a Fidelity representative with a single press on a button on their BlackBerry handhelds with integrated phones. They can also manage their retirement accounts, charitable donations, and insurance needs from anywhere.

- *Chemicals.* Celanese Chemicals Ltd., a company headquartered in Dallas, expects to speed up maintenance at its chemical plants with wireless technology. Previously, maintenance workers needed to walk large distances across the plants first to diagnose the problem, then to arrange for repair from the control room, and then walk to a storage room to retrieve replacement parts. This process can take up to an hour. By the end of 2003, maintenance workers were able to arrange for repair parts and equipment to be brought to the site using wireless Pocket PCs [Collett, 2003].

- *Retail Chains.* The product repair division of Sears, Roebuck and Co. installed mobile base stations in all 10,000 repair trucks to provide its technicians 100% national coverage. The stations' controller software automatically selects between the cellular or satellite network depending on signal strength. The base stations also function as Wi-Fi access points, connecting technicians' laptops with built-in Wi-Fi radio cards. This combination of WLAN and WWAN technologies saves technicians invaluable time when they are locating parts because they can communicate and order them directly from their job locations, instead of first walking back to their trucks. The $60 million investment in hardware alone is reportedly recouped already by time savings in using the product and parts library databases directly from the work sites [Brewin, 2003].

- *Hospitals.* IDC reports that in mid-2003 eight out of ten hospitals were using wireless technology regularly. For example, an emergency room physician at St. Vincent's Hospital in Birmingham, Alabama, can retrieve patient's medical history from the hospital clinical databases to her PDA. Wireless applications are still being rolled out and caregivers will soon be able to access lab results, medication orders and surgery notes through wireless notebook computers or PDAs. Hospital management measures return on investment in time savings, less paper and storage, and increased patient satisfaction [ComNews, 2003].

  ePocrates provides healthcare professionals with drug, herbal, and infectious disease information via handheld devices. Already, 250,000 doctors nationwide use ePocrates handheld devices to determine the correct prescription and dosage for sick patients. An additional 600,000 doctors use this system via wired Internet connections [NIH, 2003].

- *Manufacturing*. General Motors expects to save $1 million at just one assembly plant. Wireless computers, mounted on forklifts, enable drivers to communicate from the factory or warehouse floor. They can receive work instructions wirelessly, which enables them to double the number of daily deliveries and lower the amount of traffic by 400 miles each day. Manufacturers are also experimenting with triangulation to determine exact location of moving and expensive equipment using RFID tags [Collett, 2003].

- *Transportation*. National trucking company TRL Inc. upgraded its mobile wireless equipment in all 600 trucks to enable wireless tracking and messaging. The technology automatically switches between cellular and satellite communications, enabling easier dispatching and loading. TRL expects improved productivity and customer service [Collett, 2003].

- *Unconventional Applications*. Four out of six Hong Kong wireless carriers support mobile betting on horse races [Ingelbrecht et al., 2003]. The carriers quickly recovered the costs of rolling out, marketing, and administering mobile betting services. The cost of placing a bet using a mobile phone is estimated at one-fifth the cost of manually placing a bet through one of the 3800 call center operators. On average, around 10,500 betting wireless transactions are processed per race. They are initiated by 53,000 regular users and represent 31% of all interactive betting users. The mobile betting channel attracted a disproportionate number of female users, a traditionally underserved part of the market. The Hong Kong Jockey Club is ahead of schedule on a five-year return on investment and the four carriers generated over $5 million in revenue and mobile betting subscription charges in 2002.

V. CONCLUSSIONS

The answer to the paper's inquiry whether m-commerce is an economy driver or a mess is unfortunately both a "no" and a "yes." These are pioneering times, when one can be connected all the time and from anywhere. Wireless mobile technology potentially can change the social and business environments significantly. We now know that the technology works.

Individual companies successfully introduced mobile wireless applications and, in at least some cases, quickly recovered the investment. Vertical applications in industries such as transportation, maintenance, logistics, and field service provide early success stories, but generally applicable business models are not yet identified.

Some, but not all, operators are profitable despite the slump in the telecommunications industry. Several successful operators flourish even though they provide low-bandwidth service. Others, particularly those who spent fortunes at radio spectrum auctions, struggle and are postponing their investments in network upgrades.

Ultimately, the consumer market is the wireless industry driver, and wireless devices represent as much a fashion statement as anything else. Data services still bring only a fraction of the revenue generated by voice services, but integration of digital cameras, multimedia message services (MMS), and network-based games will increase the data traffic and, consequently, revenues.

Wireless mobile technology is widely accepted, is an indispensable device in developed and developing parts of the world, and has been demonstrated to benefit businesses by reducing costs or improving productivity and customer service. Nevertheless, these achievements do not quite add up to being an economy driver.

At the same time, the wireless mobile world is also a mess. So many devices with different characteristics are in use that no organization can support them all. Companies need to control and be selective in their acquisition and support, which makes inter-organizational solutions quite difficult. Several operating systems are popular as are several incompatible transmission protocols. For example, ITU approved no less than five different operating modes as 3G industry standards, and, worse, the future of wireless technology evolution is challenged by several potentially disruptive technologies. The technology is influenced by politics, patent rights, existing network technologies and pride. Individual governments or their unions with diverging interests are making key decisions. Governments in various parts of the world also allocated different radio frequency bands to public wireless services.

Luckily, processing power follows Moore's law, and vendors are succeeding in their efforts to lower energy consumption, although rather slowly. These changes enabled the production of multi-modal and multi-frequency devices. Although we may not come to global agreement on unified wireless technology standards and frequency allocations, it is possible that devices will support several standards and enable universal connectivity. Of course, the competitive services will first need to agree to interoperate.

Some, but not all, business processes and practices can be improved using mobile wireless technologies. Many firms will discover such possibilities and engage in implementation projects. These projects should not be considered long-term and strategic, but medium-term and tactical because the technology evolution is still in transition and not mature. We can only say for certain that m-business will change during the next decade.

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EDITOR'S NOTE: The following reference list contains the address of World Wide Web pages. Readers who have the ability to access the Web directly from their computer or are reading the paper on the Web, can gain direct access to these references. Readers are warned, however, that

1. these links existed as of the date of publication but are not guaranteed to be working thereafter.

2. the contents of Web pages may change over time. Where version information is provided in the References, different versions may not contain the information or the conclusions referenced.

3. the authors of the Web pages, not CAIS, are responsible for the accuracy of their content.

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LIST OF ACRONYMS

1G	First generation wireless technology
2G	Second generation wireless technology
2.5G	Two-and-a-half Generation wireless technology
3G	Third generation wireless technology
4G	Forth generation wireless technology
AIDC	Automatic Identification and Data Capture
BREW	Binary Runtime Environment for Wireless
CDMA	Code Division Multiple Access
DSL	Digital Subscriber Line
EDGE	Enhanced Data Rates for Global Evolution
ELAN	Ethernet LAN
EV-DO	Enhanced Version Data Optimized
FCC	Federal Communications Commission
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSM	Global System for Mobile communication
iDEN	Integrated Digital Enhanced Network
IE	Internet-Enabled (wireless mobile handheld devices)
IEEE	Institute of Electrical and Electronics Engineers
IMT-2000	International Mobile Telecommunications-2000
ISP	Internet Service Provider
ITU	International Telecommunications Union
LAN	Local Area Network
M2M	Machine-to-machine
MMS	Multimedia Message Services
MP3	MPEG-1 Audio Layer-3
MPEG	Moving Picture Experts Group
NAP	Neighborhood access point
NTIA	National Telecommunications and Information Administration
PAN	Personal area networking
PC	Personal Computer

PCS	Personal communications services
PDA	Personal digital assistant
QoS	Quality of service
RFID	Radio frequency identification
SMS	Short Message Service
TDMA	Time-Division Multiple Access
TD-SCDMA	Time division synchronous CDMA
UPC	Universal Product Code
UMTS	Universal Mobile Telephone Service
UWB	Ultra-wideband
VoIP	Voice over IP
WAN	Wide Area Network
WAP	Wireless Access Protocol
WCDMA	Wideband CDMA
WIDEN	Wideband iDEN
Wi-Fi	Wireless fidelity
Wi-Max	Wireless protocol IEEE 802.16, a.k.a. WMAN
WMAN	Wireless metropolitan area networks
WPAN	Wireless personal area networks
WWAN	Wireless Wide Area Networks

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