PCS Data Knowledge Site

The Evolution of Cellular Data: On the Road to 3G

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Peter Rysavy, Rysavy Research

Introduction

Wireless phone use is taking off around the world. Many of us would no longer know how to cope without our cellphones. Always being connected offers us flexibility in our lifestyles, makes us more productive in our jobs, and makes us feel more secure. So far, voice has been the primary wireless application. But with the Internet continuing to influence an increasing proportion of our daily lives, and more of our work being away from the office, it is inevitable that the demand for wireless data is going to ignite. Already, in those countries that have cellular-data services readily available, the number of cellular subscribers taking advantage of data has reached significant proportions. We want wireless Internet, we want our organizational data from anywhere, and we want it now.

But to move forward, the question is whether current cellular-data services are sufficient, or whether the networks need to deliver greater capabilities. The fact is that with proper application configuration, use of middleware, and new wireless-optimized protocols, today's cellular-data can offer tremendous productivity enhancements. But for those potential users who have stood on the sidelines, subsequent generations of cellular data should overcome all of their objections. These new services will roll out both as enhancements to existing second-generation cellular networks, and an entirely new third generation of cellular technology. Our job here is to describe this road to the third generation (3G), as well as to show you how these services will allow new applications never before possible.

The World Today

Before we peek into the future, let's quickly look at where we are today. In 1999, the primary cellular-based data services are Cellular Digital Packet Data (CDPD), circuit-switched data services for GSM networks, and circuit-switched data service for CDMA networks. Some brave souls connect their PC Card modems to their analog cellphones, but this approach is not very popular because it is tricky to configure. All of these services offer speeds in the 9.6 Kbps to 14.4 Kbps range. Why such low speeds? The basic reason is that in today's cellular systems, data is allocated to the same radio bandwidth as a voice call. Since voice encoders (vocoders) in current cellular networks digitize voice in the range of 8 to 13 Kbps, that's about the amount available for data. Remember, too, that today's digital and PCS technology designs started over five years ago. Back then, 9.6 Kbps was considered more than adequate. Today, it can seem slow with graphical or multimedia content, though it is more than adequate for text-based applications and carefully configured applications.

There are two basic ways that the cellular industry is currently delivering data services. One approach is with smart phones, which are cellular phones that include a microbrowser. With these, you can view specially formatted Internet information. The other approach is through wireless modems, supplied either in PC Card format or by using a cellphone with a cable connection to a computer. See Figure 1.

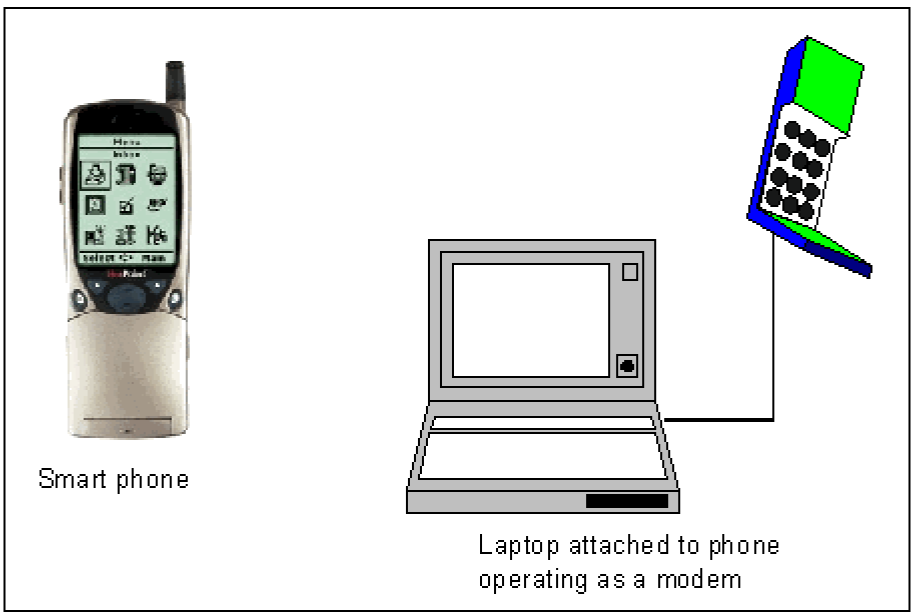

Figure 1: Smart phone versus phone connected to laptop

Both approaches can give you access to Internet sites and corporate systems, including e-mail, databases, or host-based systems. But both approaches also require that the user take throughput and latency of the network into account. In contrast, next generation networks promise throughput, global coverage, and ease-of-use that will greatly expand your mobile computing options.

The World Tomorrow

Before diving into details of different network technologies, we need to realize that from a user perspective, the offerings from all of these networks will be largely comparable. Introduction dates of services may vary by up to a year, and exact data rates may differ by 20 or 30%. But just as voice users today may be hard-pressed to distinguish between the quality of an IS-136 call using AT&T's wireless network, a GSM call using Omnipoint's network, or a CDMA call using Sprint PCS network, data users will notice great similarity between the new cellular-data services.

In thinking about the rollout of next generation services, consider what features can be added to existing networks, and what features will require vastly new network infrastructure. Since we refer to the current generation of cellular as second generation, then new feature advancements to the current network are sometimes called 2.5G. Generally, 2.5G technologies have been developed for third generation (3G) networks, but they are applied incrementally to existing networks. This approach allows carriers to offer new high-speed data and increased voice capacity at much lower cost than deploying all new 3G networks. Plus, they can do so using their existing spectrum.

Let's consider data rates in more detail. The global standards body for communications is the International Telecommunications Union (ITU). The 3G standards effort is called International Mobile Telephone 2000 (IMT-2000). IMT-2000 mandates data speeds of 144 Kbps at driving speeds, 384 Kbps for outside stationary use or walking speeds, and 2 Mbps indoors. Does this mean that we'll all be using our cellphones at 2 Mbps? No. The indoor rate will depend on careful frequency planning within buildings, and possibly an organization's commitment to work closely with a carrier. However, since high-speed services such as wireless LANs already offer speeds of up to 11Mbps, it's difficult to predict the expected market demand for 2Mbps indoor service when 3G networks roll out.

What is of much greater interest is the 384 Kbps data rate for outdoor use, as this IP protocol-based packet service will be available over wide areas. This service is the one that will let us extend our office to any location. And the good news? The technology that will provide 384 Kbps in 3G networks is the same technology that will be deployed in 2.5G networks, albeit at slightly lower data rates in the 50 to 150 Kbps range. But this is still some ten times faster than most options today. More good news? 2.5G services will be released in the year 2000, well in advance of 3G networks that won't start rolling out until 2002 at the earliest. See Table One.

Core Technology	Service	Data Capability	Expected Deployment

GSM	Circuit-switched data based on the standard GSM 07.07	9.6 Kbps or 14.4 Kbps	Available worldwide now
	High-speed circuit-switched data (HSCSD)	28.8 to 56 Kbps service likely	Limited deployment 1999 and 2000 as many carriers will wait for GPRS
	General Packet Radio Service (GPRS)	IP and X.25 communications over Kbps	Trial deployments in 2000, rollout of service 2001
	Enhanced Data Rates for GSM Evolution (EDGE)	IP communications to 384 Kbps. Roaming with IS-136 networks possible.	Trial deployment in 2001, rollout of service 2002
	Wideband CDMA (WCDMA)	Similar to EDGE but adds 2Mbps indoor capability. Increased capacity for voice.	Initial deployment in 2002 or 2003
IS-136	Circuit-switched data based on the standard IS-135	9.6 Kbps	Some carriers may offer service, but not expected on widespread basis because key carriers already offer Cellular Digital Packet Data (CDPD)
	EDGE	IP communications to 384 Kbps. Roaming with GSM networks possible.	Initial deployment 2002 or 2003
	WCDMA or Wideband TDMA (WTDMA)	Similar to EDGE but adds 2Mbps indoor capability	No stated deployment plans
CDMA	Circuit-switched data based on the standard IS-707	9.6 Kbps or 14.4 Kbps	Available by some carriers now
	IS-95B	IP communications to 64 Kbps	Expected in Japanese markets by early 2000
	CDMA2000 - 1XRTT	IP communications to 144 Kbps	Trial deployment in 2001, rollout of service 2002
	CDMA2000 - 3XRTT	IP communications to	Initial deployment in

	384 Kbps outdoors and 2 Mbps indoors	2002 or 2003.

Table One: Summary of forthcoming cellular-data services.
Time estimates by Rysavy Research.

How the three major cellular technologies will provide these services varies, but all have a similar roadmap. In fact, as we detail in subsequent sections, these technologies are slowly converging, beginning with a convergence of IS-136 and GSM data services, and followed by a harmonization of the 3G versions of GSM and CDMA. By harmonization, we mean that while differences will continue to exist, the systems will interoperate more readily.

There are some other important trends to note. The first is that standards bodies are working not just on radio technologies, but also on the networking infrastructure. One objective is to allow users to seamlessly roam from private networks (e.g. Ethernet, WLAN) to public networks. Such roaming will require the implementation of standards such as Mobile IP. Another goal is to simplify the connection between mobile computers and wireless devices through personal-area network (PAN) technologies such as Bluetooth. Yet another trend is voice over IP. As terrestrial networks start using IP for voice and multimedia, it will be important for such IP communications to extend all the way to the wireless device.

Perhaps the most important trend of all is for ubiquitous coverage. This will be achieved not just by converging wireless standards, but also by sophisticated new devices that operate in multiple modes and at multiple frequencies. This is the world of tomorrow. To understand how we'll get there, we will look first at GSM and IS-136 networks, and then CDMA networks.

Networks in Detail

GSM and IS-136

GSM dominates the world today, with over 200 million users in over a hundred countries. As the most mature digital-cellular standard, GSM networks offered circuit-switched data services well in advance of other networks. Now in trials is a service called high-speed circuit-switched data service (HSCSD), which combines two to four of the time slots (out of a total of 8 in each frame) to provide service from 28.8 Kbps to 56 Kbps. HSCSD is attractive to carriers because it requires minimal new infrastructure. Nevertheless, most GSM carriers are putting their bets on a service called General Packet Radio Service (GPRS), a 2.5G technology. GPRS can combine up to 8 (out of 8 available) time slots in each time interval for IP-based packet data speeds up to a maximum theoretical rate of 160 Kbps. However, a typical GPRS device may not use all 8 time slots. One proposed configuration is four time slots (80 Kbps maximum, 56 Kbps typical) for the downlink and one timeslot (20 Kbps maximum, 14.4 Kbps typical) for the uplink. GPRS supports both IP and X.25 networking. Entering field trials in 2000, GPRS service should start rolling out in 2001.

GPRS can be added to GSM infrastructures quite readily. It takes advantage of existing 200 kHz radio channels and does not require new radio spectrum. The principal new infrastructure elements are called the Gateway GPRS Support Node (GGSN) and the Serving GPRS Support Node (SGSN). The GGSN provides the interconnection to other networks such as the Internet or private networks, while the SGSN tracks the location of mobile devices and routes packet traffic to them. GPRS capability will be added to cellphones, and will also be made available in data-only devices such as PC Card modems. Pricing will either be flat rate or based on the volume of information communicated. Services such as GPRS are exciting not only because of their higher data rates, but also because packet service allows constant "virtual" connections without the need to constantly "dial" into the network. Click here for a white paper that discusses GPRS in detail.

The phase after GPRS is called Enhanced Data Rates for GSM Evolution (EDGE). EDGE, generally considered a 3G technology, introduces new methods at the physical layer, including a new form of modulation (8 PSK) and different ways of encoding data to protect against errors. Meanwhile, higher layer protocols, such as those used by the GGSN and SGSN, stay the same. The result is that EDGE will deliver data rates up to 500 Kbps using the same GPRS infrastructure. Keep in mind though that 500 Kbps represents a best case scenario, with a strong signal, no interference, and a user device accessing the entire 200 kHz radio channel. In addition, this radio channel must also be shared by multiple users in that sector of the cell site. Consequently, practical throughputs may be only half the maximum rate. EDGE data services could start rolling out in 2002, depending on market demand and actual carrier deployments.

Though developed initially for GSM, the Universal Wireless Communications Consortium (UWCC), an organization that represents IS-136 carriers and vendors worldwide, has decided to embrace EDGE for IS-136 networks. The tricky part of adopting EDGE is that IS-136 networks use 30 kHz radio channels. Deploying EDGE will require new radios in base stations to support the 200 kHz data channels. The GGSN and SGSN will be virtually the same for both GSM and IS-136 networks. EDGE data users will eventually be able to roam between IS-136 and GSM networks around the world. EDGE data services for IS-136 networks will probably roll out shortly after EDGE for GSM networks, possibly in 2002 or 2003. Figure 2 shows the common network technology used by both GSM and IS-136 networks.

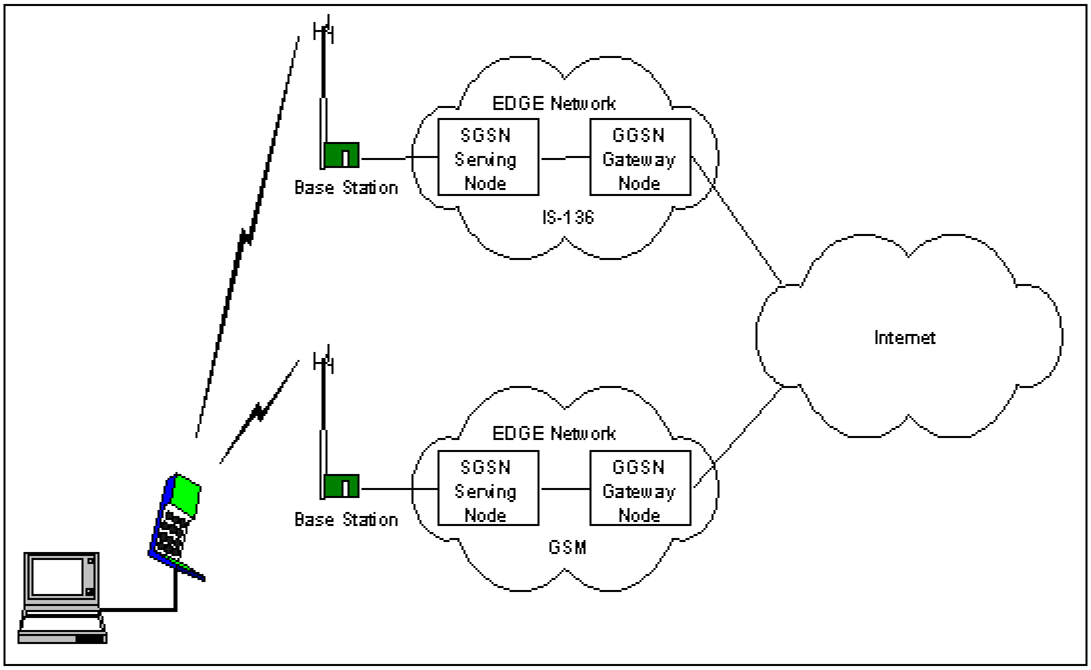

Figure 2: The same EDGE wireless device will be able to communicate across both IS-136 and GSM networks.

IS-136 networks will also converge with GSM for voice related functions. For instance, the same vocoder technology will eventually be used by both networks. Meanwhile, in advance of common vocoders, multi-mode cellphones are planned that will allow voice operation across IS-136, GSM, and AMPS networks worldwide.

The 3G version of GSM, Wideband CDMA or WCDMA, is based on CDMA technology. This version of CDMA deviates from American standards, although it uses the same spread spectrum principles. For data, WCDMA adds the capability for 2Mbps data rates indoors. The airlink, using either 5MHz, 10MHz, or 20MHz radio channels, will be completely different from GSM's current 200 kHz channels. However, the data networking for WCDMA will likely be based on EDGE/GPRS infrastructure protocols, such as the GPRS Tunneling Protocol. The earliest WCDMA deployment is expected in Japan in 2002. IS-136 carriers might eventually use WCDMA technology, though a wideband TDMA (WTDMA) approach has also been proposed.

CDMA

CDMA network deployment and subscriber growth have developed considerable momentum, and data services are now available from a number of carriers. Currently, these carriers use circuit-switched technology operating at 14.4 Kbps. As with GSM, CDMA requires a handset that specifically supports data. Connect the phone to a laptop, and the phone operates just like a modem, enabling you to establish dial-up connections to the Internet, your corporate remote access server

(RAS), and so on. WAP-based microbrowser applications are also being made available. Another service for CDMA networks is called QuickNet Connect. By eliminating conventional modem connections, this service allows fast connections (of approximately five seconds) to the Internet. See Figure 3. To the user, the carrier appears like an ISP offering dial-up Internet service.

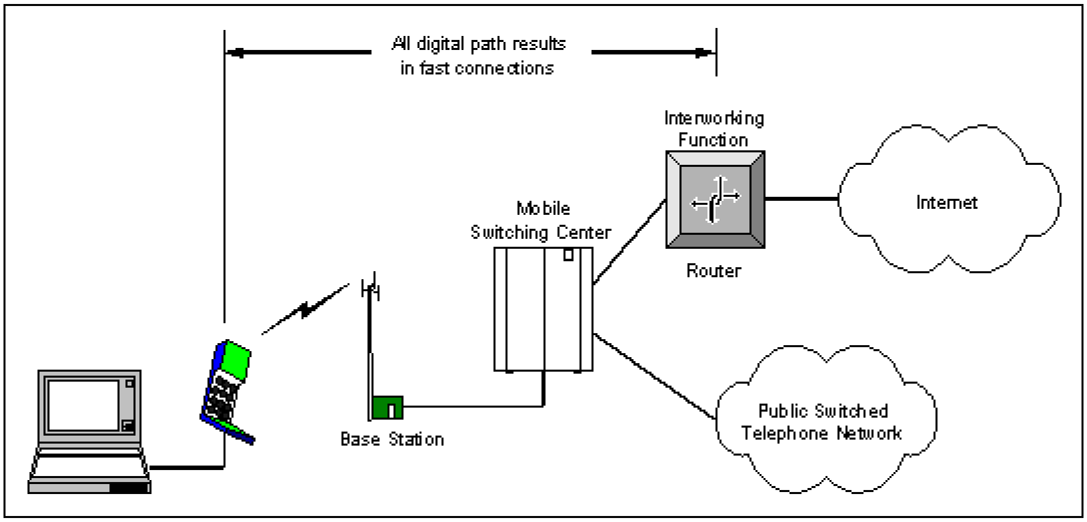

Figure 3: QuickNet Connect for CDMA

Today's CDMA service is based on the IS-95A standard. A refinement of this standard, IS-95B, allows up to eight channels to be combined for packet-data rates as high as 64 Kbps. Japanese CDMA carriers, IDO and DDI, are planning on deploying this higher-speed service by early 2000.

Beyond IS-95B, CDMA evolves into 3G technology in a standard called CDMA2000. CDMA2000 comes in two phases. The first, with a specification already completed, is 1XRTT, while the next phase is 3XRTT. The 1X and 3X refer to the number of 1.25 MHz wide radio carrier channels used, and RTT refers to radio-transmission technology. CDMA2000 includes numerous improvements over IS-95A, including more sophisticated power control, new modulation on the reverse channels, and improved data encoding methods. The result is significantly higher capacity for the same amount of spectrum, and indoor data rates up to 2Mbps that meet the IMT-2000 requirements. The full-blown 3XRTT implementation of CDMA requires a 5MHz spectrum commitment for both forward and reverse links. However, 1XRTT can be used in existing CDMA channels since it uses the same 1.25 MHz bandwidth.

1XRTT technology is thus a convenient stepping stone for CDMA carriers moving to 3G, and it can also be thought of as a 2.5G technology. 1XRTT can be deployed in existing spectrum to double voice capacity, and requires only a modest investment in infrastructure. It will provide IP-based packet-data rates of up to 144 Kbps. Initial deployment of 1XRTT is expected by US CDMA carriers in 2001, with

3XRTT following a year or two behind, depending on whether new spectrum becomes available.

But what about the differences between CDMA2000 and WCDMA? If the goal of IMT-2000 is a single worldwide standard, can these two versions of CDMA be harmonized into a single standard? That is the very question being addressed by the CDMA Operators Harmonization Group that is developing the Global 3G CDMA standard (G3G). Since there are some irreconcilable differences between CDMA2000 and WCDMA in the radio portion, the approach is a modular architecture as shown in Figure 4. This approach allows any of three airlink technologies to be used in a network, including WCDMA, 3XRTT, and a time-division duplex form of spread spectrum. In addition to the three types of airlinks, the architecture recognizes that network infrastructures may be based on either GSM-MAP protocols or ANSI-41 protocols. G3G will give operators flexibility in choosing the airlink and network infrastructure that best addresses their particular needs.

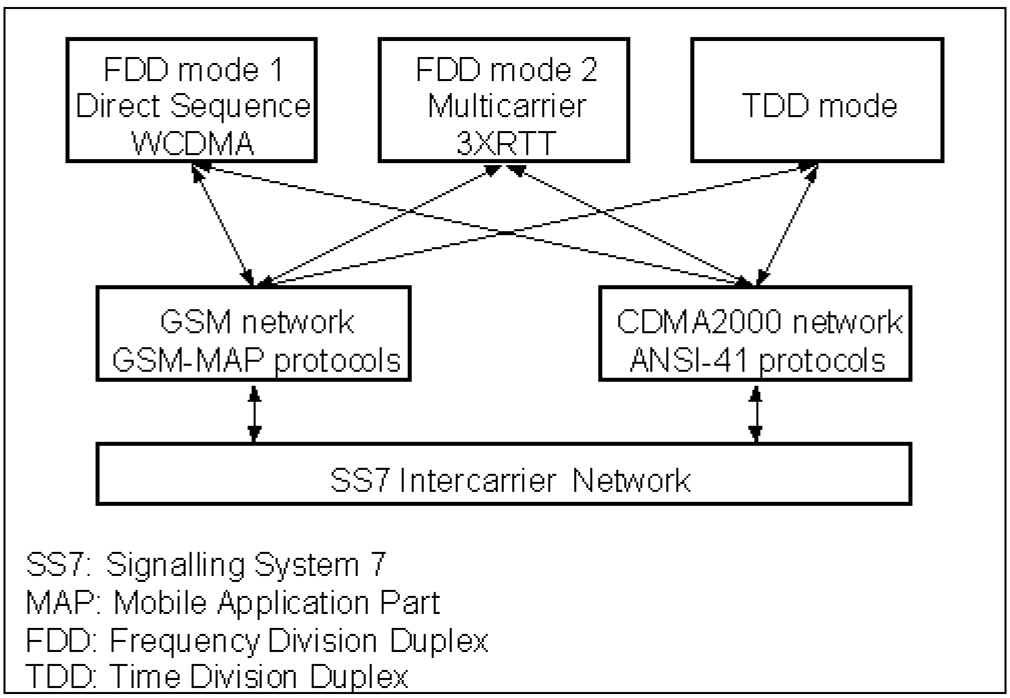

Figure 4: Modular approach used in the Global 3G CDMA architecture

One issue in harmonizing CDMA data is that WCDMA is based on GPRS protocols, which use the GPRS tunneling protocol (GTP) to forward IP packets to the mobile station. Mobility management is also handled by specific GPRS protocols. CDMA2000, however, is based on the Mobile IP standard. Any harmonized CDMA standard should ideally be based on the same set of tunneling and mobility standards. For this reason, the European Telecommunications Standards Institute (ETSI), responsible for GSM and GPRS, has started an investigation of how GPRS/EDGE could integrate Mobile IP.

3G In Context

3G cellular technology is a huge technological and market phenomenon, but it needs to be understood in the context of other developments. One development is that there will be other high-speed wireless-data solutions available. For instance, don't overlook Metricom's Ricochet network. Though service is restricted to just several cities today, significant new investment from Paul Allen and MCI WorldCom, combined with a new high-speed service at 128 Kbps, will propel this service to much wider availability in 2000.

Consider also the Personal Handyphone System (PHS) deployed widely in Asia, a form of cellular technology limited to pedestrian use. PHS will soon offer 64 Kbps data service. Nextel has also recently unveiled a new data service for its Integrated Dispatch Enhanced Network (iDEN) – based technology. This service uses Mobile IP to provide both WAP service and IP-based packet data at about 20 Kbps. Also, some companies are planning on deploying wireless LAN technology in public places such as airports. Will all of these developments stifle the demand for cellular-based data? Probably not, but they will offer options, increase competition, and help drive down prices.

Finally, some market developments will both shape the nature of wireless-data networks, and increase the demand for such services. These include the following:

- The control network used in telephone networks today is called Signaling System 7 (SS7). This system will evolve into an IP-based system, increasing the importance for IP-based control mechanisms in wireless networks.
- IP will increasingly be used for voice communications, so delivery of IP-based voice to cellphones will be critical. This will require the resolution of difficult, quality-of-service issues in wireless networks.
- As E-commerce becomes common, users will want to safely conduct transactions from their mobile terminals. Such use will make robust security protocols a must for wireless networks.
- Mobile users will want to access private information from anywhere, driving the demand for secure communications and related technologies such as virtual private networks (VPNs).
- As a huge population of mobile-data users emerges, content developers will start producing material specifically for these users, including items related to travel, entertainment, news, weather, and recreation. Though such developments are already underway, they are still in their infancy.

There is no question that a myriad of new applications will be possible with next-generation, wireless-data networks. But keep in mind that these are massively complex networks, and it will take both time and large investments to develop and deploy the technology. Many of the advantages that these networks will offer are already available using existing data services. Organizations that gain experience with wireless technologies today will be the ones best positioned to take advantage of new networks tomorrow.

Peter Rysavy is president of Rysavy Research, a consulting firm that helps companies research, develop, and deploy communications technologies.