The Wireless Internet: Promises and Challenges

David J. Goodman
Polytechnic University

As computing becomes increasingly mobile, the limitations of third-generation cellular telephony and the wireless applications protocol become increasingly apparent. The author asserts that only a new approach can make the Internet truly wireless.

In the 1980s, the personal computer migrated from the hobbyist's den to the corporate desktop, thus becoming the biggest development of the decade in information technology. Ten years later, that honor fell to the Internet and wireless telephones, which until now have followed separate paths.

This decade will see the convergence of wireless communications and the Internet. Although the commercial impact of wireless communications has thus far been limited to cellular telephones, the business and technical communities anticipate rapid growth in wireless data services. Almost daily, some prominent company announces plans for a "wireless e-commerce" enhancement to its business.

In this article, I examine the outlook for wireless data. Specifically, I consider the utility of wireless data services, why they have not been widely adopted until now, the technology trends that promote wireless Internet convergence, and the obstacles preventing their implementation.

MOTIVATORS AND INHIBITORS

With the emergence of spreadsheets in the mid-1980s, personal computers began to catch on rapidly, displacing monolithic mainframes. By 1990, the PC had fostered two further trends, as shown in Figure 1: portable computers and networking. Prior to these developments, the PC was a stationary, stand-alone device that communicated only with a printer. The immediate success of portable computers signaled that people want their information to be as portable as they are. Networking's rapid advance, on the other hand, shows that we want our information connected, not isolated.

Wireless communications may be able to resolve the paradox between the contradictory goals of being unattached and yet connected. This potential has been widely recognized since the early 1990s, when many observers anticipated a large market for cellular digital packet data in the US, and for related technologies grafted onto cellular networks in other parts of the world.

Despite widespread optimism, mobile wireless computing has not taken off. Four major obstacles have inhibited its widespread use:

- wireless data services suffer from low transmission rates,
- the services cost too much,
- radio modems consume too much power, and
- the user interfaces poorly match the needs of people on the move.

Figure 2 shows that, over the past several years, industry has taken two complementary approaches to implementing wireless data technology. One approach has created a new, "third generation" of cellular radio transmission technology, referred to as 3G. The other approach has created a technology that delivers an array of information services to cellular telephones. Much of this technology is incorporated in the wireless application protocol. WAP and 3G separately overcome some barriers to widespread adoption of wireless data. Yet each offers only a partial solution to the overall problem and, even taken together, they leave important gaps.

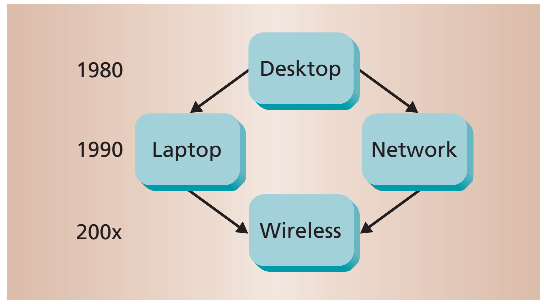

Figure 1. The widespread adoption of the personal computer fostered two important information technology trends: increased mobility via the laptop computer, and increased connectivity via local- and wide-area networks. The wireless Internet will result from the convergence of these trends.

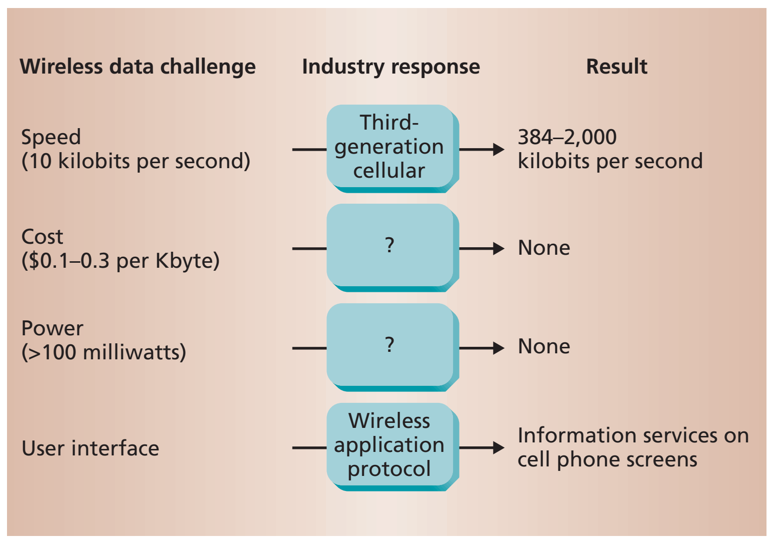

Figure 2. To implement wireless data technology, two complementary approaches have been developed: 3G, a third-generation cellular radio transmission technology, and WAP, the wireless application protocol.

THIRD-GENERATION CELLULAR RADIO TRANSMISSION

The original "first-generation" cellular systems used analog frequency modulation to transmit voice signals. Most of today's cellular phones employ "second-generation" technology that conveys speech in digital format at bit rates of around 10 Kbps. As Figure 2 shows, 3G focuses on high data rate communication with portable computers. Data rates cited in technical standards are 384 Kbps for devices moving outdoors at high speed—in cars or trains, for example—and 2 Mbps for slowly moving devices in or near suitably equipped buildings. At these rates, the proponents of 3G expect people to use portable computers for many of the exotic information services they enjoy at home and work. One company's videotape shows a man transmitting live audio and video of his exploits on a speedboat to his family thousands of kilometers away. Another videotape shows information workers on a beach participating in a wireless videoconference, using high-speed wireless links to exchange complex documents with their less fortunate colleagues in the office.

Unfortunately, a closer look at 3G technology reveals flaws in these glamorous pictures. These flaws arise because 3G addresses only one of the barriers to the adoption of wireless data: transmission speed. The problems of cost and power consumption remain. There is less than meets the eye to the data rate solution as well: 3G and other advanced cellular technologies employ "rate adaptation techniques" that tailor the data rate to the environmental conditions of the data terminal.[1] Doing so means that the high speeds quoted in the 3G promotional literature can be attained only in certain places at certain times. Under less favorable conditions, people must settle for lower quality of service.

3G's basic problem is that it adds only incrementally to the radio transmission technology that has supported the remarkable commercial success of cellular telephones. Conscious of the need for an evolutionary path from today's second-generation cellular systems, the industry has developed third-generation systems that can be described as "cell phones on steroids." In effect, they have sent cellular technology to a gymnasium to pump up the bit rate. Yet they have not addressed the basic differences between telephone conversations and other information services.

Further, the rate adaptation built into 3G compromises the "anytime, anywhere" theme that has motivated advances in cellular telephony. Worse, in those places and times when high data rates can be attained, third-generation communications will be power hungry and costly. Recent radio spectrum auctions in the United Kingdom saw operating companies commit more than £20 billion in licensing fees for access to 3G frequency bands. Clearly, this sum, added to the costs of building new networks, places a significant floor under future service charges.

Table 1. Wireless communications paradigms: Old and new.

Cellular paradigm	AAA approach
Licensed spectrum	Unlicensed
Standard radio signals	Adaptive signals
Network infrastructure	Ad hoc network
Symmetric, two-way channels	Asymmetric information transfer
Ubiquitous coverage	Local coverage

WIRELESS APPLICATION PROTOCOL

WAP's underlying assumptions differ fundamentally from 3G's. Rather than transmit Web content and other Internet applications through the air, WAP recognizes that cellular phones are not PCs, and that many information services developed for PCs are of little use to people moving about with small devices. WAP therefore focuses on applications tailored to the capabilities of cell phones and the needs of their users. Taking into account the constraints of mobile radio channels, WAP employs various compression techniques to reduce the number of bits transmitted through the air.

With respect to information delivered to the phones, WAP uses WML, the Wireless Markup Language, to display text and icons on the telephone's screen. Instead of point-and-click navigation through hypertext, people use the phone's small keypad to send information upstream. WAP thus creates an information web for cellular phones, distinct from the PC-centric Web. WAP functions well in the low-data-rate, low-power environment of present cellular systems.

On the other hand, the wireless Web created for cellular phones suffers from several deficiencies relative to the Internet. In contrast to the Web's organic evolution, cellular operating companies manage the wireless Web's development and will control the material customers can access through it. The kind of spontaneous creativity seen during the Web's expansion will likely be excluded from the WAP world.

On the technical side, WML is primitive relative to other languages that incorporate modern software engineering features designed to promote reliability. Moreover, its capabilities are too closely matched to today's cellular telephone technology. Consequently, we have reason to be concerned that WAP in general—and WML especially—will be insufficiently powerful to deliver a wide range of services to future-generation terminals. WAP critics assert that the technology will serve as a stopgap for the few years until 3G radios, proxies, and advanced terminals bring the entire Web to small portable devices. WAP proponents claim that the technology is sufficiently scalable and extensible to do the job indefinitely.[2]

A NEW APPROACH

The WAP and 3G products reaching the market in the next few years will provide only partial solutions to the present shortcomings of wireless data. Their deficiencies will become increasingly acute relative to the requirements of advanced information services.

In addition to wireless communications that link computers, telephones, and PDAs, the computer industry anticipates a future with billions of small microprocessors that contain wireless modems for exchanging information with each other and with backbone networks. The radio communications techniques used by these tiny, inexpensive devices must diverge radically from the 3G cell phones on steroids.

Reversing an old paradigm

To move forward, we must break radically from the 25-year-old foundations of cellular telephone technology, which will involve reexamining five interrelated properties of cellular telephone networks. These networks operate within an *infrastructure* of base stations that transmit *standard* radio signals in *licensed radio spectrum* bands. Doing so produces *ubiquitous* coverage areas for *symmetric*, two-way information transfer.

By reversing these conditions, we arrive at a new paradigm for wireless communications that can break the logjam currently inhibiting the flow of wireless data. In the future, there will be scope for wireless systems that create *ad hoc* networks operating in *unlicensed* frequency bands. These networks will use signals *that adapt themselves* to the changing operating environment, thereby achieving *location-dependent* quality of service and *asymmetric* information flow between network nodes.

Table 1 compares the key characteristics of the old and new wireless communications paradigms.

Srikanta Kumar of the Defense Advanced Research Project Agency refers to the new paradigm as the AAA (adaptive, ad hoc, asymmetric) approach to wireless communications. AAA, at present only a conceptual framework for advancing wireless technology, requires research on several fronts to become feasible.

For example, communication in unlicensed bands raises the issue of "peaceful coexistence" when unrelated systems compete for radio resources. Ad hoc networks require technology for mobility management, service discovery, and energy-efficient information routing. In addition to these and other information-management issues that must be addressed, AAA communications require a new generation of low-power radios and energy-efficient signal-processing techniques based on intelligent partitions of functions between hardware and software.

AAA's challenges have already attracted widespread attention from the research community. For example, the Mobihoc workshop on ad hoc networks to be

Wireless Internet Resources

The following sources provide information on the work under way and report on progress made by some of the industry consortia and research groups devoted to the enabling technologies that contribute to a wireless Internet.

WAP Forum
http://www.wapforum.com
Focuses on the technology and standardization of the Wireless Application Protocol.

Third Generation Partnership Project
http://www.3gpp.org
Covers the efforts of standards organizations in Europe, North America, and Asia to support emerging third-generation technology based on wideband CDMA.

CDMA Development Group
http://www.cdg.org
Provides information about the evolution of second-generation North American CDMA cellular systems.

Universal Wireless Communications Consortium
http://www.uwcc.org
Chronicles the evolution of second-generation North American TDMA cellular systems.

Winlab
http://www.winlab.rutgers.edu/pub/Index.html
Offers news, workshops, symposiums, online seminars, and other information about the Wireless Information Network Laboratory, which participates "in the precompetitive stage of technology creation" for a wireless Internet.

Berkeley Wireless Research Center
http://infopad.eecs.berkeley.edu:80/BWRC/
Reports on advances in low-power power-adaptive radio circuits and computer-aided design tools.

Advanced Communications Technologies and Services, (ACTS)
http://www.de.infowin.org/ACTS/
Contains information on a wide range of Pan-European research projects related to advanced wireless communications technology.

held in August 2000 (http://www.cs.tamu.edu/faculty/vaidya/mobihoc/) received 82 responses to its call for papers and will host 25 presentations from 13 countries.

At Polytechnic University, my colleagues and I are focusing on adaptive location-dependent allocation of battery power to signal-processing and communications functions. The Berkeley Wireless Research Center at the University of California at Berkeley concentrates on small, low-power radios, and Winlab (Wireless Information Network Laboratory) at Rutgers University addresses a range of systems issues at the boundary of mobile computing and wireless communications. The Infostations project,[3] initiated at Winlab, provides a good example of the promise and challenges of delivering information services in a system with location-dependent radio coverage. The "Wireless Internet Resources" sidebar provides several links to these projects and related research.

INFOSTATIONS

Infostations conform to the unlicensed, location-dependent, and asymmetric elements of the AAA paradigm. Like a gas station, an Infostation provides a source of "fuel"—in this case, information. Each Infostation contains a radio transceiver that provides low-power, high-data-rate Internet access to portable devices in a limited area surrounding the Infostation. As such, it promises to overcome the data rate, power, and cost obstacles to widespread use of wireless data.

In contrast to a gas station, an Infostation won't force you to stop while you transfer information to or from the Internet. That will happen automatically when you move near the Infostation. People acquainted with the Infostation idea have generated a host of potential sites.

Airport example

My favorite site is the airport Infostation. It works like this: At my departure airport, as my laptop computer goes through the X-ray machine, the Infostation downloads lots of information that might be useful to me during the flight, such as e-mail, voice mail, faxes, and reading material about attractions and events at my destination. When my plane lands and I walk through the jetway corridor, an Infostation will upload data I generated during the flight and download new material from my home server, as well as local weather and traffic reports.

The airport setting is but one example of a place where Infostations can play a useful role. Other anticipated applications include electronic commerce, education, healthcare, and military settings.

Plusses and minuses

With respect to the obstacles blocking the proliferation of wireless data, Infostations offer an appealing alternative because of their restricted coverage area. In my airport example, the radio signals need travel no more than three meters. This range offers the advantages of a low power budget and high available data rate. Simple radio modems are appropriate, and, with operation in unlicensed spectrum bands, the cost of the radio component of the Infostation and the

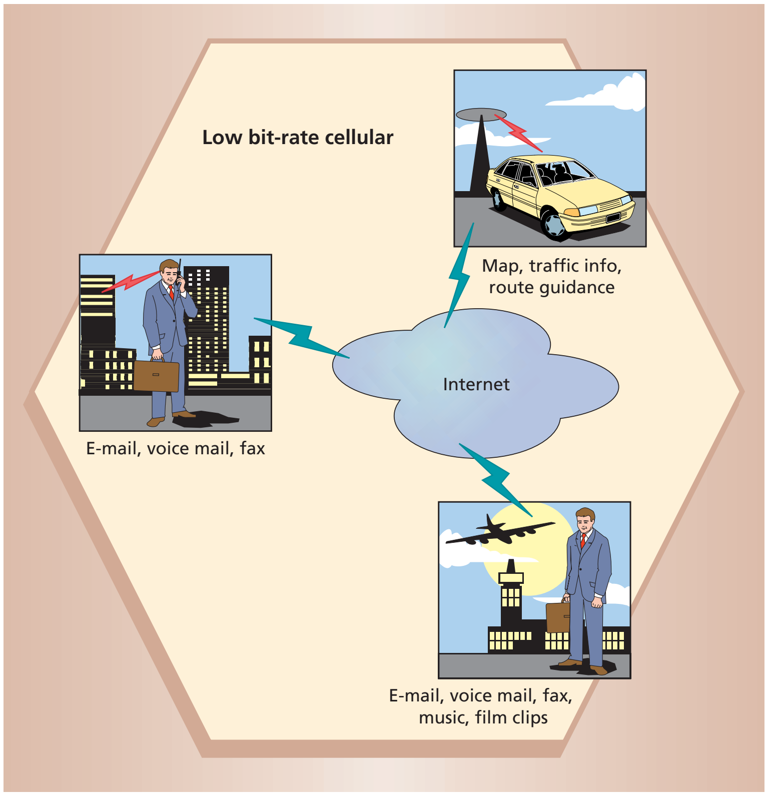

Figure 3. Infostations will function much like the information equivalent of gas stations, allowing users to send and receive data automatically from a variety of convenient locations.

radio modem in the portable terminal will be marginal. Such economies are encouraging because they suggest that many Infostations can be deployed at a reasonable cost in areas people are likely to pass through. Technologies incorporated in the Bluetooth (http://www.bluetooth.com) and IEEE 802.II (http://grouper.ieee.org/groups/802/index.html) standards are candidates for initial Infostation inplementations.

On the other hand, the restricted range of an Infostation introduces problems of its own. One issue yet to be addressed is that a portable terminal is likely to be within range of an Infostation only briefly—just a few seconds in the airport Infostation example. While this would be enough time to transfer several megabytes of data at the high rates available at short range, the functions necessary to organize the information transfer would probably take much longer.

The cellular connection

So how can we send to the Infostation the information to be downloaded in time for my laptop to receive it during the few seconds it is within range? Doing so requires a means of alerting the backbone network that supports the Infostations to my changing location. Figure 3 shows that Infostations will be located in a cellular service area. This relationship suggests that the cellular system could support the Infostation network. Thus, cooperation between overlapping heterogeneous networks represents another area for investigation.

Even under the most optimistic assumptions, however, many situations will arise in which completing all necessary data transfers while the terminal is within range of a single Infostation will be impossible. The transfer will have to be accomplished over time as the terminal transits the coverage areas of several Infostations. Data distribution to Infostations thus becomes another issue for investigation. To hold Infostation costs down, the budget for connecting each Infostation to the Internet must be low. This constraint potentially reverses another cellular assumption. It suggests that there will be high-speed data transfer to and from portable devices, but restricted throughput in the feeder links to the radio access points.

This brief description of the issues raised by the Infostation model shows that, to achieve the greatest possible benefits from the convergence of wireless communications and the Internet, we must reexamine our existing assumptions. Beyond the technology details, the move toward a wireless Internet prompts a new examination of the nature of information transmitted to and from wireless terminals.

INFORMATION IN TIME AND SPACE

For 20 years, the expression "anytime, anywhere" has been a cellular telephony mantra. At first only a lofty goal, the combination of satellite telephones and terrestrial cellular systems has made "anytime, anywhere" a reality for telephone calls and short text messages. Even after years of development effort devoted to 3G technology, however, the anytime-anywhere promise remains problematic with respect to wireless data's cost, power consumption, and bit rate.

Anytime, anywhere is a rigorous taskmaster for wireless technology. Thus, we would do well to examine wireless data applications to determine the conditions in which ubiquitous, instantaneous coverage is essential, rather than merely a convenience to be weighed against its costs.

An analysis of this sort reveals many types of information that need not be everywhere all at once. The Infostation example refers to e-mail, voice mail, fax, news services, and travel information. For people to conveniently get the data they need when they need it, we must make this information available as quickly and easily as obtaining fuel for our cars is now.

Services inappropriate to the "many-where, many-time" Infostations model include emergency communications and real-time interactive services. In these categories, cellular systems do a good job with text messaging and telephony. The step up to interactive video and browsing for high-resolution graphics will require all the sophistication of 3G technology, but will incur the added costs of money and energy consumption. Such costs may well inhibit the widespread use of these services by a population accustomed to low-cost, high-speed Internet access.

Beyond raising the question of which information must be available everywhere all the time, rather than intermittently at specific locations, the notion of a wireless Internet prompts us to examine in general terms the temporal and spatial nature of information itself.

As its name implies, the World Wide Web is pervasive. Its content is everywhere, regardless of relevance. On the other hand, wireless networks lead naturally to the exchange of information relevant to the location of each terminal. An article in the *Wall Street Journal*[4] refers to location-based services as "one of the hottest areas of Web development." To put the worldwide and location-specific models of information in context, consider the resolution in time and space of various information types. As a starting point, Table 2 provides binary classifications of time and space resolution, and suggests one type of information that fits into each of four categories.

By thus analyzing a wide range of information types, we can match information services and information technology to the nature of information and the needs and budgets of people who use information services.

Table 2. Binary classification of time and space resolution for information.

	Geographically localized	Geographically independent
Localized in time	Traffic reports	Share prices
Time independent	Restaurant locations	Music recordings

In the early 1990s, when a new periodical sought to popularize the interface between cutting-edge computer technology and society, *Wired* seemed an appropriate title. How times have changed. Were a new magazine to be launched in the next year or two with the same mission, a savvy publisher would christen it *Unwired*.

Undoubtedly, the emergence of WAP and 3G technologies will promote the long-awaited convergence of wireless communications and the Internet. Yet both new technologies are too closely bound to the foundations of cellular telephones. To realize the full potential of a wireless Internet, we must gain a deeper understanding of the information moving to and from wireless terminals, and create technology that directly addresses the challenges of the wireless Internet. ✷

References

1. S. Nanda et al., "Adaptation Techniques in Wireless Packet Data Services," *IEEE Comm. Magazine*, Jan. 2000, pp. 54-64.
2. N. Leavitt, "Will WAP Deliver the Wireless Internet?" *Computer*, May 2000, pp. 16-20.
3. R.H. Frenkiel et al., "The Infostations Challenge: Balancing Cost and Ubiquity in Delivering Wireless Data," *IEEE Personal Comm.*, Apr. 2000, pp. 66-71.
4. T.E. Weber, "With Wireless Gadgets, Web Companies Plan to Map Your Moves," *Wall Street Journal*, 8 May 2000, p. B1.

***David J. Goodman** heads the Department of Electrical Engineering at Polytechnic University in Brooklyn, New York. His interests include telecommunications networks, wireless communications systems, and mobile computing. He received a PhD in electrical engineering from Imperial College, University of London. Contact Goodman at dgoodman@poly.edu.*