Cellular service providers, handset manufacturers, and system integrators are captivated by the promise of the wireless Internet, as this second of two articles on the subject makes clear

Cell phones answer Internet's call

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THE BIG NEWS IN THIRD-GENERATION CELLULAR telephony is that the future is arriving ahead of schedule. Until recently, wireless systems providing good Internet access and even some multimedia capabilities seemed a remote prospect, maybe even an illusion. Now suddenly they are about to be reality.

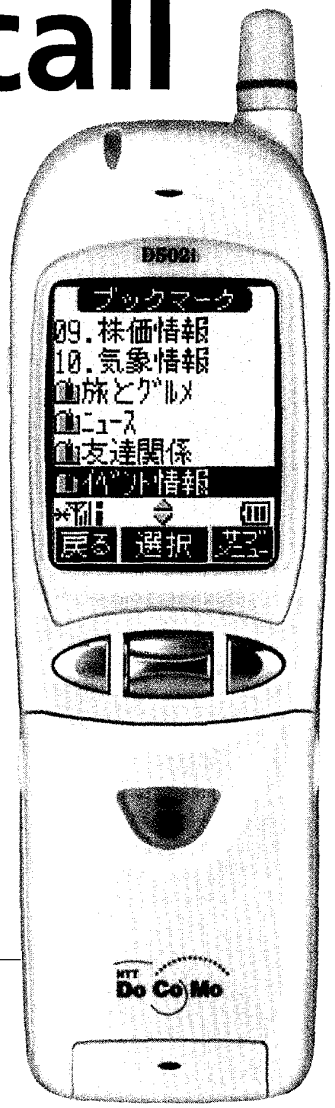
Their early arrival may especially surprise people in the United States, who are still struggling to sort out the pros and cons of the first- and second-generation wireless systems—the analog Advanced Mobile Phone Service (AMPS), the mainly digital time- and code-division multiple access (TDMA and CDMA) systems, and Global System for Mobile Communications (GSM) [see "Defining third-generation cellular terms," p. 45].

But the news may be less startling in Europe and in the 70 or so countries elsewhere now relying entirely or mainly on GSM, the digital TDMA-based system devised by European standards authorities in the 1980s and '90s.

ITU VISION GETS GREEN LIGHT

Basically, the leading contender to be the global standard for third-generation cellular telephony is the Universal Mobile Telecommunication System (UMTS). This is a wideband CDMA system designed to be smoothly backward-compatible with GSM, and also the leading member of the IMT-2000 family of third-generation systems sponsored by the International Telecommunication Union (ITU), in Geneva.

The IMT-2000 family of third-generation standards received a double endorsement in May, at meetings of the ITU's governing assembly and the World Radiocommunication Conference (WRC-2000), held in Istanbul. At the beginning of the month, the assembly formally ratified the technical specifica-



[1] Internet access is provided by the white cell phone, a D series i-Mode phone manufactured by Tokyo's Mitsubishi Electric Corp. as a preferred supplier to NTT DoCoMo. On the screen, the tabs at the bottom are [from left] for Back, Select, and Sub-menu. The list above the tabs provides links to stock prices, weather, travel and gourmet, news, "friendship," and events.

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tions for the "air interface" or radio component of the proposed systems. The specs cover Europe's UMTS system, cdma2000, and a TDMA system enhanced for delivery of packet data, UWC-136. This last is promoted by the Universal Wireless Communications Consortium (UWCC), Bellevue, Wash., a consortium of 130 companies in which AT&T Corp. is a leading player.

The radio interface for UMTS is called the universal terrestrial radio-access frequency-division duplex (UTRA-FDD), or more conveniently, wideband CDMA (WCDMA). As the name implies, it requires a wider frequency band than second-generation systems. The competing U.S. systems for the third generation aim to achieve somewhat comparable data rates within existing bandwidth.

Given that the radio interface specifications had largely been formulated and finalized well before the Istanbul conference, their endorsement by the ITU's Radiocommunications Assembly on the eve of this year's WRC-2000 was perhaps a formality. More significant, perhaps, was the identification by the conference of three new frequency bands for IMT-2000. In technical preparations for the main meeting, expert groups had concluded that about 160 MHz of new spectrum would be needed for the terrestrial components of IMT-2000 to accommodate expected growth in third-generation wireless telephony from now to 2010.

What the Istanbul conference did, in effect, was designate three alternative bands with a total of 519 MHz of spectrum—about three times what was called for—leaving it to further technical studies and national telecom authorities to decide what portions of which bands would be used first for IMT-2000 applications, and where. The frequency bands "identified" are 806–960 MHz, 1710–1885 MHz, and 2500–2690 MHz.

Since the systems favored by the United States do not require as much new bandwidth, the conference's allocation of ample new bandwidth for IMT-2000 would seem to clearly imply a preference for UMTS-UTRA, the wideband CDMA system. No doubt this is one reason why the huge U.S. delegation at Istanbul struggled persistently, but with little success, for language that would dedicate the new bands not to IMT-2000 in particular but to "advanced communications applications" in general.

That formulation could mean just about anything, so it met with skepticism, even bewilderment, among other delegations. The United States got half-hearted support from a handful of developing countries and some odd bedfellows like Russia and Israel. The only strong supporter was South Africa, which would like to use the additional spectrum to provide wireless telephony to fixed receivers, as an alternative to conventional wired telephony. The Chinese unequivocally supported IMT-2000, complaining only that the bands identified were inconvenient for them.

REAL-WORLD DEVELOPMENTS

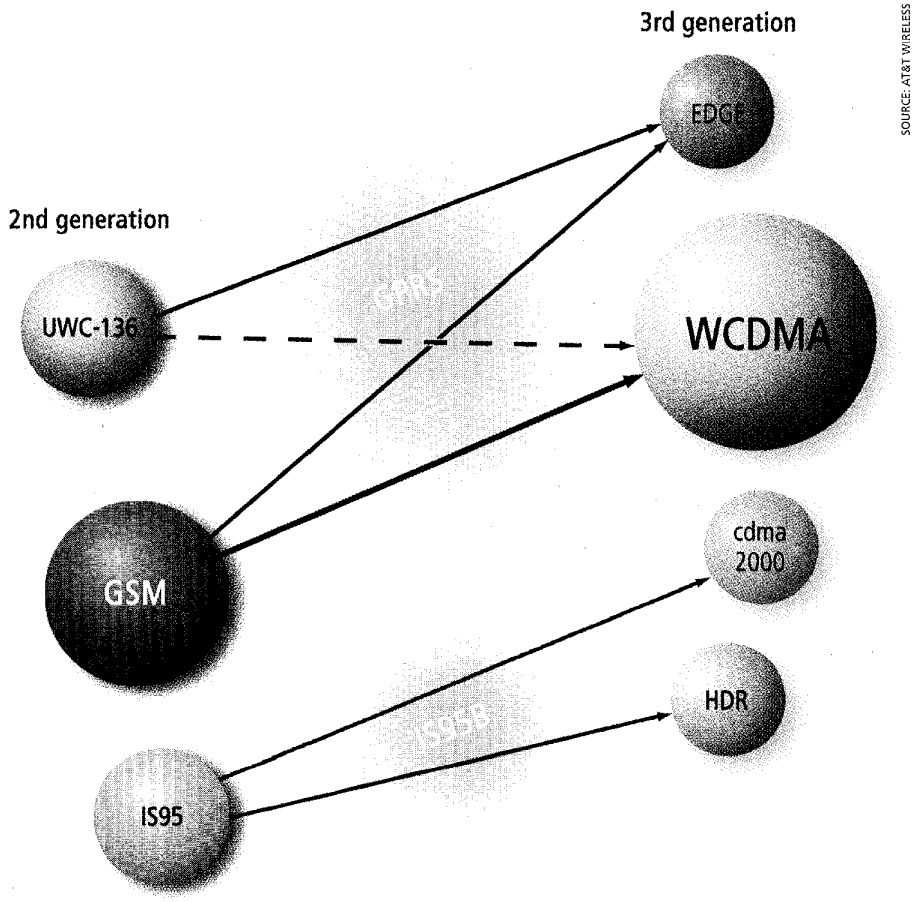
To someone watching delegations from some 150 countries hammer out detailed technical text at the Istanbul conference, speaking a multiplicity of languages with varying levels of skill, and meeting in sessions that often convened early in the morning and went past midnight, it was amazing that the conference ever reached agreement on anything. Yet if the adoption of the IMT-2000 radio specifications was a formality, so, too, in a sense was the identification of the new frequency bands. For what was swaying the assembled delegates, in the final analysis, were developments in the real telephone world.

As the attendees gathered in early May, anybody involved in the IMT-2000 talks had to have vividly in mind the astounding numbers wracked up by the i-MODE wireless Internet system in Japan [Fig. 1]. Its producer, NTT DoCoMo, in the two years since being spun off by the national telecommunications company NTT, had itself become the country's most highly capitalized company. And in the 15 months since it launched i-MODE, about seven million subscribers had signed up. Roughly $15 per month, about 25 percent more than their regular phone bill, gets them the privilege of being able to access a limited number of customized Web sites or exchange short text messages with colleagues or friends. Multiplying out and extrapolating those Japanese numbers suggest that wireless Internet subscribership is bound to exceed ITU projections on which spectrum needs were based.

Meanwhile, in countries like Italy and Britain, also world market leaders in wireless telephony, similar gains have been scored by providers of short message service (SMS). In Britain, in particular, transmission of short messages over cell phone networks has become wildly popular, "as chatty teenagers and traveling workers catch up with a fashion already well established in Germany and Italy," Reuters reported. One year after the short message service was introduced in Britain, 400 million messages were being sent per month, and across all of Europe, the number was two billion.

A couple of years ago it might have seemed implausible that people would happily surf the Net and exchange e-mail messages from their cell phones, despite the tiny screens and awk-

[2] A futuristic Nokia cell phone displays a sample Web page from CNN News. The flap [at left] folds down to reveal the keypad—better suited for accessing data than entering more than a short message.



SOURCE: AT&T WIRELESS

[3] The two main migration paths to third-generation cellular telephony are, by way of the General Packet Radio System (GPRS), from the dominant Global System for Mobile Communications (GSM) or time-division multiple access (TDMA). GPRS is being deployed now and gives specially equipped cell phone users some graphics capabilities.

An alternative migration path, from IS-95 to a version of wider-band CDMA called cdma2000, is also by way of a packet-switched system, IS-95B. For definitions of acronyms, see facing page ["Defining..."].

ward keypad [Fig. 2]. Now, people are unmistakably doing so, and in amazingly large numbers.

What's more, among service providers and equipment manufacturers, the buzz is about how wireless telephony is opening the door to a new kind of Internet, in which time and location will be all-important.

This is the kind of scenario they like to conjure up: you are arriving late Friday evening in a new city for a weekend's exploration. Knowing as soon as you use your phone where you are and what time it is, your cell service provider gives you, during your cab ride to your hotel, a list of your dinner options; as you unpack, it will show you a video tour of what you can see tomorrow. Then, when you are returning to work on Monday, you can review your appointments as you ride to your office, and the moment you sit down, you can be party on your phone to a live video conference.

That, roughly, is the main text used by backers of third-generation telephony to introduce the new world it will bring. The subtext is less obtrusive but still quite audible: when it comes to Internet and multimedia wireless telephony, the emergent leaders are Europe and Asia, while the United States clings to legacy technology and the habits of bygone days.

On Thursday, 27 April, a week before the four-week WRC-2000 conference opened for business in Istanbul, Britain concluded an auction of spectrum for wideband third-generation cellular systems. The sum reaped was $35.5 billion—10 times what had been expected when the bidding began eight weeks before. The biggest single bid, nearly $9.5 billion, came from VodaphoneAirTouch PLC, the British wireless giant that recently devoured Mannesmann AG's cellular business, forming Europe's most highly capitalized company. For this particular license, Vodaphone beat out British Telecommunications PLC, another big player, in Europe and globally, in wireless telephony.

LUCRATIVE SPECTRUM AUCTIONS

The British windfall, characterized by *The Economist* magazine as maybe the biggest since North Sea oil began gushing, naturally got the attention of finance officials around the world, above all in other European countries planning similar auctions. Italy and France immediately revised plans originally formulated mainly to protect domestic manufacturers. In Germany, the new expectation was that it would reap as much as $50 billion in an auction to be held at the end of July (as this issue went to press).

As investors began to grasp just how much the big telecom companies would have to pay for wireless licenses, the stocks of the companies tumbled, dusting some of the bloom off third-generation prospects. Some bidders dropped out in the Netherlands and Germany, deciding that prices were going too high. All the same, the basic impression remained that wireless Internet is coming fast, like it or not and regardless of cost.

The U.S. Federal Communications Commission (FCC) was to hold an auction at the end of July, on the 26th, but its prospects were clouded by what in hindsight may have been missteps. Unlike the many countries that have set aside spectrum for third-generation systems, the commission was re-auctioning frequency bands that it sold in the mid-'90s for advanced personal communications services (PCS). That sale reflected a vision of the evolution of next-generation cellular telephony that is somewhat different from what is embodied in the IMT-2000 family of standards. Anyway, by the time this issue of *IEEE Spectrum* appears, the FCC will have resold a 30-MHz band in 10-MHz slots, with results that are likely to be less dramatic than those witnessed in Britain and Germany.

The FCC has scheduled a second auction for September, in which it will sell 12

licenses—half consisting of 10-MHz, half of 20-MHz slots. It has suspended normal limits on the number of licenses that can be bought by a single purchaser, as well as local limits on the proportion of spectrum that can be held by a single owner.

THE UNITED STATES IN ISTANBUL

The spectrum the U.S. commission auctioned in the mid-'90s was the band of 1850–1990 MHz, which partly overlaps spectrum where WCDMA is likely to be first deployed in Europe and Japan. It also somewhat overlaps the lower part of one of the additional bands identified at WRC-2000 for IMT-2000. Thus it is only semi-available for third-generation systems, noted Nelson Sollenberger, who is division manager for Wireless Systems Research at AT&T Labs, Newman Springs, N.J.

Assessing the impact of the earlier auction, Sollenberger said that the spectrum allotted to PCS did indeed make wireless services much more available. But "the technologies put into use were already used for cellular services, so the new spectrum did not result in fundamentally new technologies. Primarily it provided enough spectrum for existing service operators to expand and for new operators to enter the market. The GSM, TDMA, and CDMA technologies deployed all existed prior to the PCS spectrum auction."

The United States is almost unique in having substantial cellular infrastructures based on both code- and time-division multiple-access, with GSM accounting for a small but fast-growing market share. There are about 22 million subscribers using TDMA systems in the United States and about 50 million worldwide, while about 250 million rely on GSM. [See. Fig. 3 for migration paths from TDMA and GSM.]

Obviously, U.S. communications companies have made big investments in existing systems, notably the TDMA and narrowband CDMA that lead in the Americas, but they are distant seconds globally. That, together with the fact that some of the spectrum identified at Istanbul for IMT-2000 already was committed in the United States to other applications, accounts to some extent for the reluctance of the U.S. delegation to earmark the additional bandwidth exclusively to the IMT-2000 family.

"Our proposal was a hard-fought compromise to satisfy various U.S. interests," a senior member of the U.S. delegation told *IEEE Spectrum*. "Those include PCS providers who are interested in evolution of second-generation systems, IMT-2000 proponents who were interested in obtaining as much additional spectrum as possible, multichannel multipoint distribution service (MMDS) interests, and U.S. government users.

"Our view remains," the senior delegate said, "that if IMT-2000 as we know it evolves to some other technology, or a new technology comes along, regulators and the ITU should not be a barrier to those technologies being deployed."

That said, one major set of U.S. interests would seem not deeply incompatible with the IMT-2000 decisions taken. The TDMA system used by AT&T in the United States and promoted by the 130 members of the UWCC consortium is evolving more or less in parallel with GSM, and by design.

WCDMA and TDMA are in a sense "kissing cousins," as Ritch Blasi, a spokesman for AT&T Wireless Systems, Bellevue, Wash., put it to *Spectrum*. Both currently are incorporating technology associated with the General Packet Radio System (GPRS), to provide bit-rates of 40–60 kb/s on not very complex terminals, and yield some graphics capabilities. And both are due in a few years to incorporate EDGE technology as well, which will double normal bit-rates and triple peak bit-rates. (In its European version, EDGE is spelled out in as "enhanced data rates for GSM evolution." The preferred U.S. version is "...for global evolution.")

Blasi argues that, under normal operating conditions, TDMA-EDGE bit-rates will be on a par with those attainable with UMTS without requiring extra-wide spectral bands to get the job done. That is, TDMA-EDGE will also be able to attain the rate of 384 kb/s set for UMTS where the user is moving (not too fast), and derived from ISDN (Integrated-Services Digital Network) standards. As for the 2-Mb/s rate that UMTS is supposed to provide to stationary users wanting multimedia capabilities, "well sure," said Blasi, "that's one person, standing under a cell tower." TDMA-EDGE can make the same claims, but only for ideal laboratory conditions.

Defining third-generation cellular terms

AMPS: the Advanced Mobile Phone Service, the United States' legacy analog cellular system.

CDMA: code-division multiple access, in which the signal intended for a given user is transformed into a wideband spread-spectrum signal, which the user's receiver restores to its original state using the same code.

GPRS: the General Packet Radio Service, a standard finalized in 1998 that provides connectionless packet access to data networks. It gives some Internet capabilities to so-called second-and-a-half generation versions of both the European GSM and the U.S. TDMA cellular systems [see below]. Specifically, it offers four alternative bit-rates per time slot: 9.06, 13.4, 15.6, and 21.4 kb/s.

GSM: the Global System for Mobile Communications standard, initiated in 1982 by a European postal and telecommunications organization and finalized in 1990 under the European Telecommunications Standards Institute (ETSI). A digital system based on TDMA technology and universal in Europe, it is by far the most successful cellular standard worldwide.

HDR: High Data Rate—an alternative wideband system compatible with IS-95 [below].

IMT-2000: a family of third-generation cellular systems developed in the framework of the International Telecommunication Union and designed to provide access to packet data at certain minimum speeds: 144 kb/s for a user in rapid motion or in a difficult environment, 384 kb/s for someone walking, and 2 Mb/s at rest in an office or home. Standards allow for migration both from the European GSM and U.S. TDMA systems [below].

IS-95: the United States' second-generation CDMA system, which is narrowband. Its third-generation version, still narrowband but a member of the IMT-2000 family, is cdma2000.

TDMA: time-division, multiple-access

UMTS/WCDMA: a third-generation system developed by the European Telecommunications Standards Institute, in a process modeled on the procedures that yielded GSM. The dominant approach to realizing IMT-2000, it relies on a version of wideband CDMA that employs direct-sequence spread-spectrum techniques in a 5-MHz channel.

US TDMA/TDMA-EDGE: both backward-compatible with the first-generation analog AMPS system, the second being an enhanced version of the first. The U.S. TDMA system, called UWC-136 in its dual-mode version employing a digital control channel, is supported by the Universal Wireless Communications Consortium (UWCC), in Bellevue, Wash. TDMA-Edge (IS-136+) incorporates GPRS packet switching [see above].

WAP: the Wireless Application Protocol, a common standard for the development of applications for wireless Internet devices. It allows graphical data to be received, displayed, and manipulated on the screen of a mobile phone, and enables user input to be returned to a server. It was developed by the WAP Forum: www.wapforum.org.

Sollenberger agrees. As he sees it, the wide bands identified for IMT-2000 are justified more by anticipated increases in data traffic than by a crucial need for extra-wide channel bands, as such.

But if that is so, and if TDMA-EDGE is a viable competitor to UMTS and recognized as a member of the IMT-2000 family, why then did the U.S. delegation at Istanbul fight so hard for generic language not linking the new frequency allocations specifically to IMT-2000? According to people associated with the delegation, the rationale for its position was ultimately ideological. For some 10 years, the United States had argued in such situations that policy decisions should as much as possible be technology-neutral and the market should decide.

LOOKING INTO THE CRYSTAL BALL

Besides GSM-EDGE and TDMA-EDGE looking to evolve into third-generation systems, there also is narrowband CDMA. In the form of cdma2000, it seeks to provide capabilities comparable to the IMT-2000 family members in their more modest versions. It may indeed be that a decade from now the United States will still be using three systems—the third-generation versions of TDMA, CDMA, and GSM—and that the rest of the world will have adopted the GSM descendant, UMTS.

This pretty much was the vision offered up by Gail Schoettler, the head of the U.S. delegation at Istanbul, who told more than one press conference that the cell phone she now carries switches between GSM and non-GSM bands. Why should she not, 10 years from now, be carrying a phone that switches between UMTS, TDMA-EDGE, and cdma2000?

Things may well work out that way, especially if cell phone usage remains different, and less demanding, in the U.S. environment from that in Europe and Asia. On those continents, where business people and tourists travel frequently among countries, it is a colossal and often crippling inconvenience to deal with the fixed telephone network in unfamiliar languages. Especially in an emergency, being able to communicate in writing on a handheld device can be a life-saver. In the giant U.S. market, where almost everyone speaks the same language and many people never leave, the advantages of bypassing the fixed network and conducting much business in writing are not quite the same.

But there also is a compelling counterargument. Members of U.S. businesses are operating in an ever more global environment, which place an ever-greater premium on seamless transitions from one language and culture to another. If every other person in that environment is using a different wireless technology from yours, it is going to cost you. And the more sophisticated the applications that get incorporated into those other wireless phones, the more it is going to cost you.

That point of view seemed at Istanbul to be generally held by the European and Asian leaders who hammered out the IMT-2000 compromise [Fig. 4]. If it holds true, the United States may ultimately have to adapt to the GSM-UMTS system being adopted everywhere else.

INTERNATIONAL TELECOMMUNICATION UNION

[4] Alan Jamieson, a New Zealand spectrum consultant based in Auckland, chaired the working group at WRC-2000 that forged a global consensus on third-generation cellular telephony.

SIGN OF THE TIMES?

Given that the rest of the world is bent on early introduction of IMT-2000 systems, mainly in the form of Europe's UMTS, leaders of the U.S. delegation argue they did well to have any impact on the debate at all. Rather than sulking on the sidelines, they managed to get language incorporated into the key documents guaranteeing regulatory neutrality as between the various frequency bands identified for IMT-2000. In addition, they obtained language that assured that newly identified spectrum could be used flexibly.

It bears noting, moreover, that the United States operates at something of a disadvantage in ITU meetings. The Asian and especially the European groups prepare and coordinate their positions carefully in advance, and when issues reach the conference floor, many countries in each group can speak to advance their causes. The United States, with just one voice and one vote, has less clout—yet, since the size of its delegation is similar to that of combined delegations representing whole country groups, it leaves the impression of being a gigantic monolith.

Nonetheless, the delegation also left an impression at Istanbul that it was being dragged along kicking and screaming into the new world of third-generation wireless, while just about everybody else enthusiastically endorsed the idea of a single world standard for the wireless Internet. After all, at a preparatory meeting less than a year before WRC-2000, the United States had unsuccessfully tried to talk the other American states into calling for no new spectrum for IMT-2000. And when it failed at that, it tried at WRC-2000—again without much success—to have language refer to advanced applications generally rather than IMT-2000 specifically.

From the U.S. point of view, does any of that matter much? Perhaps it does. For one thing, the U.S. position seemed to send a signal to U.S. manufacturers and service providers that they might profitably continue to work along many technical lines, while the rest of the world is signaling that all efforts should be concentrated on the IMT-2000 systems. What is more, purchasers of systems may now prefer the companies that are seen indeed to be concentrating their efforts.

Days after WRC-2000, China's second largest telephone operator, China Unicom, ditched a deal it had with Qualcomm Inc., San Diego, Calif., to deploy the company's narrowband CDMA technology. Instead, the Chinese will stick with their current GSM technology and then move more directly to wideband CDMA.

A month later South Korea's three leading wireless providers announced essentially the same decision. And, as this article goes to press, Deutsche Telekom is reported to have offered $30 billion for VoiceStream Wireless, a company recently formed in the United States to provide a GSM-based cellular service nationally. ◆

TO PROBE FURTHER

The competing third-generation technologies are described, in depth, by Malcolm W. Oliphant in "The Mobile Phone Meets the Internet," *IEEE Spectrum*, August 1999, pp. 20–28. In another *Spectrum* article, which appeared in October 1998, Billy Johnston described the IMT-2000/UMTS systems: "Europe's Future Mobile Telephony System," pp. 49–53.

The fundamentals of time- and code-division access (TDMA and CDMA) are laid out in the January 1998 issue of *Spectrum*, "Communications," pp. 29–36.

For more in-depth technical background, including the histories of standards, see three Artech House books: • *Wideband CDMA for Third Generation Mobile Communications*, edited by Tero Ojamperä and Ramjee Prasad (Boston and London, 1998). • *Universal Wireless Personal Communications*, by Ramjee Prasad (1998). • *Understanding WAP: Wireless Applications, Devices, and Services*, edited by Marcel van der Heijden and Marcus Taylor (2000).

A more detailed report on the WRC-2000 conference, describing both its political chemistry and technical substance, is available on the *IEEE Spectrum* Web site at: www.spectrum.ieee.org/special/wrc2000/index2.html.