Emerging Technology: Clear Signals for General Packet Radio Service

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Network Magazine, December 2000 issue
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(Note: Since this article was published, AT&T Wireless Services and Rogers AT&T Wireless in Canada have announced they will deploy GSM and GPRS.)

For years, wireless WANs have promised instant access to information from anywhere. But the reality has been otherwise, largely due to connection speeds that have crawled along at a maximum rate of 14.4Kbits/sec for most networks. While wireless WANs have proved their mettle among hard road warriors and in specialized vertical market applications, data still represents less than 5 percent of total wireless traffic, and voice remains the killer application.

The telecommunications industry's response has been to invent smart phones with microbrowsers that sip, rather than gulp, data. To make this approach work, the industry had to create the Wireless Application Protocol (WAP), which, although technically impressive, requires developers to produce content and applications specifically for wireless devices. Various companies have also invented middleware to enable wireless applications, but with limited success.

All this could change with the advent of higher-speed data services for most worldwide cellular networks. The first such service is called General Packet Radio Service (GPRS). GPRS will be the first globally available, high-speed, wireless IP network. Users will be able to connect to the Internet without ever having to dial, and will be able to keep sustained connections to the Internet. It will finally be possible to access the Internet and to operate office productivity applications without compromise.

GPRS works with Global System for Mobile Communications (GPRS) networks (for example, Voice-Stream, now owned by Deutsche Telekom), but will eventually also form the data core for wireless networks from Time DivisionMultiple Access (TDMA) operators, such as AT&T Wireless Services and SBC Communications.

Before we reach this wireless nirvana, it must be easy for consumers to purchase wireless modems and data-enabled cell phones, and carriers must offer widespread, reasonably priced service. In this article I'll explain how GPRS works, what you can realistically expect from this service, and how to take advantage of it. I'll also explain the starring role GPRS will play in third-generation (3G) cellular systems.

VIRTUAL POWER

GPRS uses IP, is fast, packet-based, has quality-of-service features, and will be available worldwide. The fact that it is packet-based is important because cellular data services so far (except for Cellular Digital Packet Data, or CDPD) have been circuit-switched, meaning users have to set up a dedicated connection before they can communicate any information. Circuit-switched service is fine for dialing AOL from home, but it wastes valuable radio resources when circuits stay up during idle periods. With a packet service, cellular operators can support more users with the same amount of radio spectrum. Packet service lets users maintain extended virtual connections, but only be billed when they actually communicate data. With the constant virtual connection, packet service can also push data to mobile users.

GPRS transports packets between mobile devices and packet networks. Packets can be IP or X.25, though with the Internet's popularity, operators and device vendors will probably emphasize IP. Mobile devices will have an IP address, either static or dynamic, and, once on the network, IP packets can originate from mobile devices and travel to external networks, such as the Internet or privately connected intranets. IP packets from external networks will reach mobile devices, even when moving. GPRS doesn't care what protocols operate above IP; this indifference enables all standard Internet protocols to operate, including TCP, UDP, HTTP, Secure Sockets Layer (SSL), and IPSec.

As for speed, you'll see figures quoted all over the map, because operators can flexibly deploy GPRS. Though GPRS' maximum theoretical rate is just over 160Kbits/sec, operators will initially offer speeds in the 26Kbit/sec to 52Kbit/sec range. Although not blazing fast, this speed compares to the speeds road warriors are used to, and works for many applications. QoS will enable applications to specify items such as throughput, latency, and reliability, but don't expect much emphasis on QoS in initial rollouts. Rather, think of QoS as a key feature for enabling future wireless multimedia applications, such as voice and video.

Another enticing aspect of GPRS is global coverage, though this will be more of a reality in Europe and Asia, where the underlying GSM cellular networks are much more dominant. Nevertheless, with VoiceStream emerging as a strong nationwide carrier in the United States, most U.S. users will be able to subscribe to GPRS services. Once operators have GPRS roaming agreements in place and multi-frequency devices become available, users may eventually access GPRS services in over a hundred countries.

TDMA carriers are also migrating towards GPRS by selecting a wireless data technology called Enhanced Data Rates for Global Evolution (EDGE). EDGE and GPRS are based on almost identical infrastructure and internal protocols, differing only in that EDGE uses a more sophisticated radio interface. In fact, you can upgrade GPRS networks to EDGE.

What about GPRS-capable devices? Let your imagination run wild, since anything you can imagine will probably become available, including mobile telephones with GPRS capability, PC Card modems for laptops, compact flash cards for handhelds, modules for Palm Pilots and Handspring Visors, and so on. GPRS is also compatible with WAP.

If you think GPRS will become obsolete once third-generation cellular rolls out, think again. Data services for Wideband Code Division Multiple Access (CDMA, the 3G version of GPRS) use an evolved set of GPRS protocols and infrastructure. In fact, cellular standards groups have already defined how voice itself could just become another IP application over GPRS in 3G networks. CDMA networks (utilized by SprintPCS and Verizon) employ a different wireless data architecture, which is outside the scope of this article. But, given GPRS's worldwide dominance, GPRS will be this decade's key wireless data technology.

GPRS PALEONTOLOGY

The best way of understanding GPRS is through its architecture and protocols, specified in the GPRS standard 03.60 and developed by the European Telecommunications Standards Institute (www.etsi.org). All cellular networks today use an architecture where base stations connect, either directly or through a base-station controller, to a mobile switching center that then connects to other telephone networks. Engineers designed this architecture in a circuit-switched-connection legacy, like most worldwide telephone networks today. GPRS provides packet-data capability by adding new infrastructure elements as an overlay, enabling packet data flow to and from mobile stations without having to touch the existing switching functions of the network, which are reserved for voice, circuit-switched data, and fax.

GPRS uses two essential new infrastructure elements, the Serving GPRS Support Node (SGSN) and Gateway GPRS Support Node (GGSN), as shown in Figure 1. The SGSN, which connects to base-station controllers, tracks the mobile station's location and sends data packets to and from the mobile station. It forwards packets using a tunneling protocol to the GGSN, which acts as a gateway to external networks, such as the Internet or private intranets. An operator will have multiple SGSNs for different service areas, but needs only one GGSN for each external network it interconnects with. The GGSN assigns IP addresses to mobile stations, and IP packets from external networks route to the GGSN, which tunnels them to the appropriate SGSN for delivery to the mobile station.

The GGSN also handles multicasting and tracks account activity for billing purposes. Another important element is the Home Location Register (HLR), an existing GSM element that holds user account information. For GPRS, the HLR holds additional information about the user's data service, such as what data rates they signed up for, whether they have a fixed or dynamic IP address, and so forth.

To convey data and signaling (control) information across the network, GPRS uses new protocols, as shown in Figure 2. These protocols transport IP datagrams between the mobile station and the GGSN. Operating between the mobile station and the SGSN, the Subnetwork Dependent Convergence Protocol (SNDCP) segments and compresses data. The LLC layer provides a logical link that hides radio-specific details from upper layers and encrypts data, and the MAC layer arbitrates access to the radio channel. The physical-link sublayer and physical-RF sublayer constitute the actual radio channel.

Between the SGSN and GGSN, the principal protocol is the GPRS Tunnel Protocol (GTP), which tunnels user IP data and control information, such as IP address assignment and routing information. GTP itself operates over a carrier's private IP infrastructure, based on either frame relay or ATM.

GPRS provides several security options. First, as with GPRS phones, a user must have a Subscriber Identify Module (SIM) card to insert into the GPRS device. In addition, the network can request a password from the user using the Challenge Handshake Authentication Protocol (CHAP) or Password Authentication Protocol (PAP). For privacy, GPRS encrypts the airlink. Between the GGSN and external networks, carriers can optionally employ IPSec. Moreover, since communication is based on IP, users can employ end-to-end security using VPN technology.

IN ACTION

Architecture and protocols are fine, but how do users actually connect to the network and send data, and how does the network keep track of users as they move around? When users turn on the GPRS device (GPRS PC Card modem) in a GPRS coverage area, the device first registers with the network and then requests a Packet Data Protocol (PDP) context. The PDP context activates an IP address for the device, generally a dynamic address assigned by the GGSN. At this stage the device can send and receive data.

To actually send a packet of data, the device makes requests using a packet random-access channel. Channels are logical data paths consisting of predefined time slots in select GPRS radio channels, and are the primary mechanism in the MAC layer. The network responds by assigning a data-traffic channel for a temporary period sufficient to send the data packet. GPRS networks use 200KHz radio channels, with each channel divided into eight time slots, as shown in Figure 3. Each time slot can support 13Kbits/sec of throughput in today's networks (though options exist to increase data rates to over 20Kbits/sec), and so actual user throughput will depend on the number of time slots a user's device can handle and the particular service options from the carrier.

Theoretically, a user could have all eight time slots in the radio channel, but carriers are likely to limit the number of download slots to four (or fewer), for a maximum of 52Kbits/sec, and the number of slots available for uploads to one, for a maximum of 13Kbits/sec. The principal reasons for limiting the number of time slots are to reduce the device's power consumption, temperature, and cost, and to increase the number of simultaneous users the network can support.

To support mobility, the GPRS device informs the SGSN when it's within a new base station's coverage range. If the user travels out of one SGSN's coverage to another, then the old SGSN and the new SGSN must collaborate and inform the GGSN of the user's new location. Users will also be able to roam into networks operated by other GPRS carriers.

If the user has a GPRS-capable mobile telephone, then he or she can receive a voice call while in a data session. GPRS defines three classes of user devices. Class A can handle voice and data simultaneously, class B can handle voice and data sequentially, and class C can handle data only. With a class B device, the most likely of initial devices, the network can notify a user of an incoming call, enabling the user to suspend the data session and accept the voice call.

WIRELESS TRIUMVIRATE: GPRS, WAP, AND BLUETOOTH

Two other prominent wireless technologies are Bluetooth and WAP. Both have an important relationship to GPRS. WAP consists of Transport-, Presentation-, and Application-layer protocols for building efficient wireless applications. These protocols all exist above the IP layer and so can readily operate over GPRS. A comparable situation exists today with AT&T Wireless Services using a CDPD network for its PocketNet phone service. The PocketNet phone uses the Handheld Device Markup Language (HDML), a precursor to WAP, and operates over the IP-based CDPD network.

So, will all GPRS applications use WAP? Absolutely not. Users can consider GPRS for any IP-based application, so long as the application isn't too bandwidth-hungry. Nevertheless, GPRS carriers are looking to GPRS as a key enabling technology for WAP because GPRS offers the perfect always-on, always-connected transport for WAP.

Carriers are interested in WAP for another reason. GPRS could quickly become a victim of its own success if too many people use it for large downloads. Since users contend for a limited number of GPRS radio channels, throughput will go down with an increasing number of active users. WAP addresses this issue by a text orientation and small screens, thus minimizing the network's load. Carriers are likely to push WAP over GPRS vs. general-purpose networking.

The article “Can Bluetooth Sink its Teeth into Networking?” (November 2000) explored the workings of Bluetooth, a wireless personal-area technology. Bluetooth will complement GPRS nicely, by making GPRS devices easier to use. Imagine a mobile telephone with GPRS, WAP, and Bluetooth built-in. Using the WAP browser, users could access information suitable for a phone's relatively small screen. But for looking at a normal Web page, or composing e-mail, users could pull out their palm-size computers or notebook computers, automatically establish a Bluetooth connection between their computers and mobile telephones, and then work on their computers with the mobile telephone serving as a wireless modem. Users wouldn't even have to take the phones off their belts or out of their purses.

EVOLUTIONARY DIRECTIONS

GPRS not only has a bright beginning but also has a bright future with a comprehensive evolution path. The first option carriers will have to enhance GPRS is adding new coding schemes that increase rates to 15Kbits/sec or 21Kbits/sec per time slot (up from the current data transfer rate of 13Kbits/sec). These new coding schemes reduce the amount of forward error correction, and so require a strong signal. No carriers have committed to these coding schemes, however, because the next upgrade step, EDGE, offers far better performance. EDGE is a new radio interface that employs a combination of new coding schemes, new modulation, and the ability to dynamically choose the best possible combination of coding scheme and modulation, based on instantaneous error rates. Using this advanced radio technology, EDGE can achieve almost 60Kbits/sec in each time slot, with a total maximum theoretical throughput of 470Kbits/sec using all eight time slots, some four times higher than GPRS.

The name for GPRS technology using the EDGE radio interface is Enhanced GPRS, or EGPRS. Today's ANSI-136 TDMA carriers (that is, AT&T Wireless Services and SBC) plan to provide next-generation data services, beginning in 2002, with a version of EGPRS technology called EGPRS-136. EGPRS is currently the highest-performing option for data services for both GPRS and ANSI-136 TDMA networks, where data services must integrate into existing second-generation cellular voice networks. But what if you wiped the slate clean, had new spectrum, and could design a cellular technology from the ground up? That's precisely what has happened with the next generation of GPRS, Wideband CDMA-also referred to as the Universal Mobile Telephone System (UMTS).

UMTS is one of the standards approved by the ITU as a 3G cellular technology. It meets the IITU's requirements for providing data rates of 144Kbits/sec when mobile, 384Kbits/sec at pedestrian speeds outdoors, and 2Mbits/sec indoors. Though it uses an entirely new radio technology based on 5MHz channels employing CDMA, UMTS retains the GPRS architecture for data service and uses the SGSN and GGSN nodes. With spectrum already available in major European countries and Japan, expect to see UMTS networks offering initial service in 2002, though widespread deployment may take the rest of the decade.

The next stage for GPRS is even more interesting. Though originally intended as a data service operating parallel to voice services, standards groups are defining how GPRS will be able to support voice services using Voice over IP (VoIP) protocols. Based on the Internet Session Initiation Protocol (SIP), the GPRS infrastructure could actually become the core network for 3G systems supporting a variety of multimedia services, including voice. Many details must still be resolved before such networks are feasible, the biggest of which is QoS. Just as with voice over the Internet, QoS standards and mechanisms are still evolving. Moreover, QoS mechanisms defined for wireless networks are somewhat different than for wireline networks, due to the nature of the radio interface, and the two types of mechanisms must be reconciled. Nevertheless, an end-to-end approach for multimedia over IP will enable many new kinds of applications, and promises to reduce the cost of core networks for carriers.

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GPRS Brass Tacks

Theory is fine, but how and when can you take advantage of the service, and what are the right applications? Here's a checklist of items for using the service:

Carrier and coverage. The principal Global System for Mobile Communications (GSM) carriers in North America are Pacific Bell Mobile Services (owned by SBC Communications), BellSouth Mobility (merging with SBC), Powertel (being acquired by VoiceStream), and Microcell in Canada. You'll need to make sure you have coverage in areas of interest. The carriers all have coverage maps, so check their Web pages. In Europe and Asia, except for Japan and Korea, GSM is widespread, and carriers are aggressively rolling out General Packet Radio Service (GPRS). If you want to roam from one GSM carrier to another, make sure the carriers support it. Realize that in different parts of the world, GSM operates at different radio frequencies-and only some devices will support multiple frequencies.

Throughputs. Expect initial devices to support only two slots downstream (26Kbits/sec) and one slot upstream (13Kbits/sec), followed by devices that use four slots downstream (52Kbits/sec) and one slot upstream (13Kbits/sec), and possibly other combinations as well.

Devices. Service is useless without user devices, and some networks will actually have GPRS before user devices are available to utilize it. Initially, expect to see both GPRS-capable mobile telephones and PC Card-format modems. GPRS telephones will typically include Wireless Application Protocol (WAP) microbrowsers, but may also have connection options for external computers, using either cables or infrared connections. If you're going to use the handset as an external modem, make sure the right connection option is available. Note that if you're connecting with a cable, the most likely connection to the handset will be through Point to Point Protocol (PPP), enabling you to use the TCP/IP stack on the attached computer. In the next 12 months, expect Bluetooth to become another local connection option.

Pricing. Carriers are just now finalizing pricing plans, but they're likely to be volume-based, with some flat-rate options available as well. CDPD service today costs about 5 cents per kilobyte, with flat-rate plans also available. Hopefully, GPRS prices will be lower, otherwise many applications will prove impractical. Carriers could offer WAP-based applications on a flat-rate basis and general-purpose networking on a volume basis, though most users prefer flat-rate pricing plans.

Applications. GPRS will make sense for both general-purpose IP networking and WAP-based applications. With WAP, carriers will be able to offer a variety of value-added services, and so are likely to aggressively market WAP-based data services. You need to decide what approach makes sense for your applications. Keep in mind throughput, pricing, and how well a given application handles disconnections. Cellular connections are inherently less reliable than wireline connections, and some applications handle dropped connections more resiliently.

Time frame. Finally, realize that GPRS won't roll out instantaneously around the world. Expect many GSM carriers to start making service available by the end of 2000, but only in a portion of their total coverage areas. By the end of 2001, coverage should be broadly available with a reasonable selection of user devices, but it may be 2002 before you can roam on a widespread basis.

Resources

Wireless industry organizations involved directly or indirectly with General Packet Radio Service (GPRS) include:

Bluetooth Special Interest Group

Cellular Telecommunications Industry Association (CITA)

GSM World

Mobile Advisory Council

Mobile Applications Initiative

Mobile Computing Promotion Consortium

Mobile GPRS

The Open Group

Portable Computer and Communications Association

Universal Wireless Communications Consortium

Wireless Data Forum

WAP Forum

Standards organizations involved (directly or indirectly) with GPRS include:

3G.IP

3G Partnership Project (3GPP)

European Telecommunications Standards Institute (ETSI)

TIA