Data Over Cellular: A Look at GPRS

While we wait for 3G to emerge, another 2.5G data-over-cellular system has emerged from the labs and is currently in field trials in several locations. GPRS is an extension of the GSM system, and uses the same channels, the same modulation, and the same network backbone as the existing GSM network.

By Doug Grant, Esben Randers, and Zoran Zvonar

There is often a long lag time between the settlement of a new communication protocol or standard and the availability of chips with which to implement that standard. General Packet Radio Service (GPRS) is a welcome exception to that rule. Enabling wireless users to gain network access at speeds over 100 kbps, GPRS takes advantage of advances in cellular chipsets and the existing GSM network infrastructure.

The GSM digital cellular standard is well-entrenched in most of the world. Industry analysts predict that over half the cellular phones sold in the world in 2000 will be GSM, with the remainder divided among IS-95 code division multiple access (CDMA), IS-136 time division multiple access (TDMA), personal digital cellular (PDC) (in Japan only), and analog systems such as the AMPS system used in the US. Network operators in most of the world use the original GSM spectrum allocation at 900 MHz. Additional spectrum at 1,800 MHz is used for the GSM derivative called DCS-1800, and this band is used in many countries. Some countries with cellular allocations at 450 MHz may begin deploying GSM in that band as well to replace old analog networks. In many areas of the United States, there are GSM systems operating in the 1,900-MHz PCS frequency band. Considering the many options available, dual-band GSM phones are quite commonplace now. A few tri-band (900/1,800/1,900 MHz) phones are also available, allowing a GSM subscriber to use the same phone almost anywhere in the world.

Circuit-switched voice calls are still the most commonly used services in cellular systems. However, mobile users are beginning to turn to the cellular networks for wireless data and Internet access. There are two basic modes of data access over a wireless network: circuit switched and packet switched. A typical example of circuit-switched access is the user who plugs a modem into a connector on a cellular phone instead of a wired phone jack, and dials the phone number of the ISP or network access point. The connection is a dedicated connection, and the user is billed, using the same method as that used for a voice call, by the minutes of usage. A network operator cannot use that channel for any other user while this user is connected.

Packet switching makes use of data's bursty nature. Data streams are broken up into packets, each packet is then quickly routed to its destination over a shared medium. An early example of this technology on a cellular network is the cellular digital packet data (CDPD) protocol. This system, operated over the AMPS network in the US, provides up to 19.2 kbps of raw data speed over the AMPS network. Each user time-shares channels with other users, allowing the operator to sell the same channel to other users. Billing is done on a cents-per-packet basis, independent of the time spent online.

2G to 3G

Second-generation (digital) cellular networks such as GSM, IS-95 CDMA, IS-136 TDMA, and PDC would seem to have a natural advantage in transmitting data due to their digital nature. However, since these networks were originally developed to provide increased capacity and features for voice traffic, data services were not a high priority. Now, however, as the Internet becomes more and more ubiquitous as a medium, access (preferably at reasonable speeds) to that medium has become necessary. See Table 1 for a comparison of these air interface specifications.

The existing GSM network provides data access at speeds up to 14.4 kbps. This was considered a reasonable speed when the system was developed, but users are now accustomed to at least V.90 dial-up speeds (56 kbps maximum), and many are now using ADSL or cable modem connections to get even higher rates. The evolution of the wireless network to provide data rates in the same range is being accomplished in two stages, which are often referred to as "2.5G" and "3G."

3G services will offer data rates that rival the best wired data rates now available to the consumer. Speeds up to 2 Mbps will be available to mobile users, depending on their distance from a base, and whether they are physi-

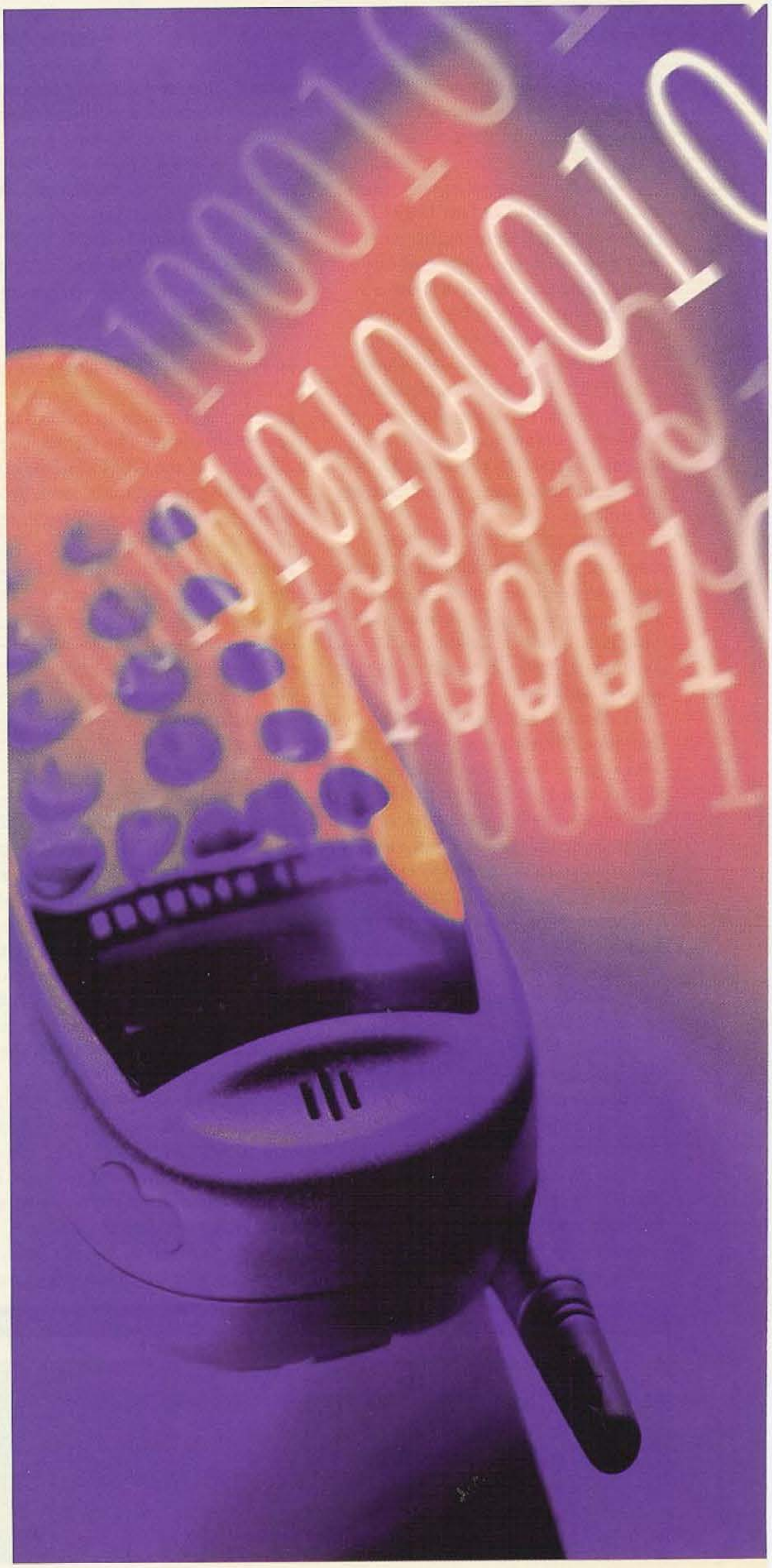

ILLUSTRATION: JANE HAMBLETON

cally in motion while connected. These data rates are sufficient to allow fast Web surfing and streaming video feeds with modest resolution.

The regulatory bodies have been struggling to gain consensus on the 3G system for several years, with an agreement on the air interface only reached in late 1999. Disputes and disagreement over the optimum technology and intellectual property ownership have considerably slowed the process. Even now, the compromise agreement on the radio standards shows several different and incompatible air interfaces. It remains for the network operators and infrastructure manufacturers to make choices and begin developing plans for true 3G rollout.

The so-called "2.5G" systems represent an intermediate upgrade in data rates available to mobile users. There are several of them, and while there is no clear consensus of what constitutes 2.5G, a few systems certainly qualify.

Enhanced Data for GSM Evolution (EDGE) is a representative 2.5G system. It uses the GSM or IS-136 network backbone, and allows data rates up to 384 kbps. This is accomplished by switching to a different modulation scheme than either IS-136 or GSM currently uses, to get a higher number of bits per transmitted symbol. In the case of use on IS-136 networks, EDGE requires a wider channel than the 30 kHz presently used.

EDGE will be deployed by network operators in some GSM countries and also in the US by IS-136 and GSM operators. As of yet, there is no specific date set for the deployment.

The IS-95 (also known as cdmaOne) system includes an evolutionary path to 3G. The first step, known as "1xRTT," is a straightforward upgrade to cdmaOne using the same channels and modulation system, but using modified digital processing. It allows data rates up to 144 kbps, and is being tested in several locations as of this article's preparation. The 3G extension, known as 3xRTT, will allow higher data rates by using three combined CDMA radio channels. When it is fully implemented, the 3xRTT version (also known as cdma2000) will offer the 2-Mbps data speeds touted by 3G designers.

While we all wait for 3G to emerge, another 2.5G data-over-cellular system has emerged from the labs and is currently in field trials in several locations. The GPRS is an extension of the GSM system, and uses the same channels, same modulation, and same network backbone as the existing GSM network. This makes deployment a relatively simple matter, at least compared with the installation of a completely new infrastructure at every level. With GSM operators in 140 countries, GPRS offers the promise of a high-speed data connection for users in most of the world.

The mobile terminal

There are several classes of GPRS mobile terminal. They are classified by how many of the GSM slots are used in each direction — more slots mean higher data speed. Currently, GPRS infrastructure is operational in some networks, with commercial service planned for late 2000. Subscriber equipment will take several forms, and will be ready when the networks are ready.

Today's GSM phone is, well, a phone. It handles circuit-switched voice traffic, and through the connector on the bottom of the unit, it can also be used for circuit-switched data. However, new devices are emerging which can benefit from non-voice wireless connectivity, such as PDA-type computing devices. Even a laptop computer can make use of a wireless modem card in a PC-card form factor, with no need for voice capability at all. Using circuit-switched connections, data rates of 14.4 kbps are now available. Multislot operation in circuit-switched mode is possible, and allows higher data rates. This high-speed circuit-switched data (HSCSD) mode will be offered by some operators, and allows data rates up to 57.6 kbps. It is likely to be more expensive than GPRS service.

GPRS terminals, or mobile stations, fall into various phases, classes, and multislot classes, documented in GSM 05.02, Annex B. Annex B is shown in Table 2 in its entirety. There are two phases of GPRS. A Phase 1 GPRS terminal operates in a point-to-point mode. Phase 2 allows point-to-multipoint operation. Since Phase 2 requires additional changes at the network level, it will probably lag behind Phase 1 in deployment. See Figure 1 for a diagram of the mobile station.[1]

TABLE 1: Comparison of GSM, IS-136, and EDGE Air Interface Specifications

	GSM	IS-136	EDGE
Channel bandwidth	200 kHz	30 kHz	200 kHz
Raw channel bit rate	270.833 kbps	48.6 kbps	812.5 kbps
User bit rate	14.4 kbps	19.2 kbps (analog CDPD)	Up to 384 kbps
Modulation	GMSK	$\pi/4$ DQPSK	8-PSK

Table definitions

For HSCSD, only multislot classes 1 through 18 are recognized. A mobile station with a higher multislot class number will indicate a suitable multislot class less than 19 for HSCSD applications (see GSM 04.08). The following is a list of definitions for Table 2.

- *Rx:* Rx describes the maximum number of receive time slots (TS) that the mobile station can use per TDMA frame. The mobile station must be able to support all integer values of receive TS from 0 to Rx (depending on the services supported by the mobile station). The receive TS need not be contiguous. For type 1 mobile stations, the receive TS shall be allocated within window of size Rx, and no transmit TS shall occur between receive TS within a TDMA frame.
- *Tx:* Tx describes the maximum number of transmit TS that the mobile station can use per TDMA frame. The mobile station must be able to support all integer values of transmit TS from 0 to Tx (depending on the services supported by

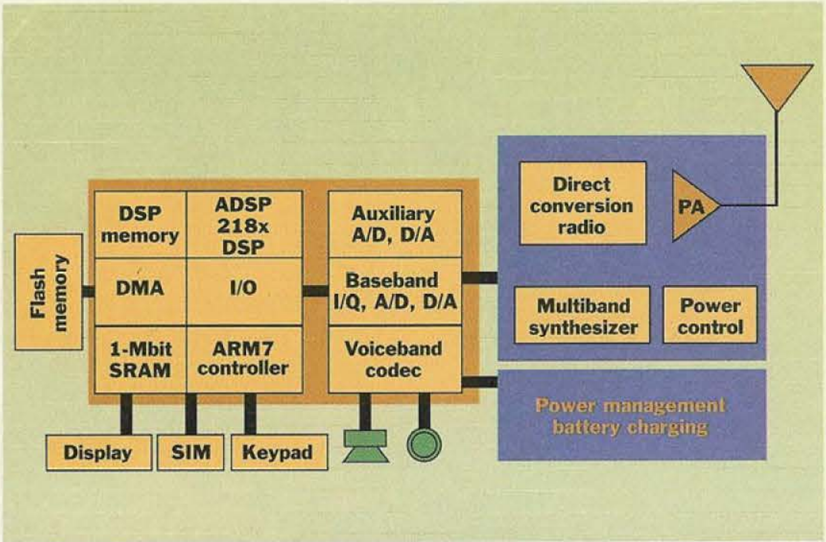

FIGURE 1: *Block diagram of a typical GSM mobile station.*

TABLE 2: GPRS Multislot Classes.[1]

Multislot class	Maximum number of slots			Minimum number of slots				Type
	Rx	Tx	Sum	T_{ta}	T_{tb}	T_{ra}	T_{rb}	
1	1	1	2	3	2	4	2	1
2	2	1	3	3	2	3	1	1
3	2	2	3	3	2	3	1	1
4	3	1	4	3	1	3	1	1
5	2	2	4	3	1	3	1	1
6	3	2	4	3	1	3	1	1
7	3	3	4	3	1	3	1	1
8	4	1	5	3	1	2	1	1
9	3	2	5	3	1	2	1	1
10	4	2	5	3	1	2	1	1
11	4	3	5	3	1	2	1	1
12	4	4	5	2	1	2	1	1
13	3	3	NA	NA	a)	3	a)	2
14	4	4	NA	NA	a)	3	a)	2
15	5	5	NA	NA	a)	3	a)	2
16	6	6	NA	NA	a)	2	a)	2
17	7	7	NA	NA	a)	1	0	2
18	8	8	NA	NA	0	0	0	2
19	6	2	NA	3	b)	2	c)	1
20	6	3	NA	3	b)	2	c)	1
21	6	4	NA	3	b)	2	c)	1
22	6	4	NA	2	b)	2	c)	1
23	6	6	NA	2	b)	2	c)	1
24	8	2	NA	3	b)	2	c)	1
25	8	3	NA	3	b)	2	c)	1
26	8	4	NA	3	b)	2	c)	1
27	8	4	NA	2	b)	2	c)	1
28	8	6	NA	2	b)	2	c)	1
29	8	8	NA	2	b)	2	c)	1

NOTES:
a) = 1 with frequency hopping.
= 0 without frequency hopping.
b) = 1 with frequency hopping or change from Rx to Tx.
= 0 without frequency hopping and no change from Rx to Tx.
c) = 1 with frequency hopping or change from Tx to Rx.
= 0 without frequency hopping and no change from Tx to Rx.

the mobile station). The transmit TS need not be contiguous. For type 1 mobile stations, the transmit TS shall be allocated within window of size Tx, and no receive TS shall occur between transmit TS within a TDMA frame.

- *Sum:* Sum is the total number of uplink and downlink TS that can actually be used by the mobile station per TDMA frame. The mobile station must be able to support all combinations of integer values of Rx and Tx TS where 1 <= Rx + Tx <= Sum (depending on the services supported by the mobile station). Sum is not applicable to all classes.
- T_{ta}: T_{ta} relates to the time needed for the mobile station to perform adjacent cell signal level measurement and to get ready to transmit. For type 1 mobile stations, it is the minimum number of TS that will be allowed between the end of the previous transmit or receive TS and the next transmit TS when a measurement is to be performed between. In practice, the minimum time allowed may be reduced by amount of timing advance. For type 2 mobile stations, it is not applicable. For circuit switched multislot configurations as defined in subclause 6.4.2.1, T_{ta} is not applicable.
- T_{tb}: T_{tb} relates to the time needed for the mobile station to get ready to transmit. This minimum requirement will only be used when adjacent cell power measurements are not required by the service selected. For type 1 mobile stations, it is the minimum number of TS that will be allowed between the end of the last previous receive TS and the immediately following transmit TS, or between the previous transmit TS and the next transmit TS when the frequency is changed in between. In practice, the minimum time allowed may be reduced by the amount of the timing advance. For Type 2 mobile station, it is the minimum number of time slots that will be allowed between the end of the last transmit burst in a TDMA frame and the first transmit burst in the next TDMA frame.
- T_{ra}: T_{ra} relates to the time needed for the mobile station to perform

adjacent-cell signal-level measurement and to get ready to receive. For type 1 mobile stations, it is the minimum number of TS that will be allowed between the previous transmit/receive TS and the next receive TS when measurement is to be performed between. For type 2 mobile stations, it is the minimum number of timeslots that will be allowed between the end of the last receive burst in a TDMA frame and the first receive burst in the next TDMA frame.

- T_{rb}: T_{rb} relates to the time needed for the mobile station to get ready to receive. This minimum requirement will only be used when adjacent cell power measurements are not required by the service selected. For type 1 mobile stations, it is the minimum number of timeslots that will be allowed between the previous transmit TS and the next receive TS, or between the previous receive TS and the next receive TS when the frequency is changed in between. For type 2 mobile stations, it is the minimum number of timeslots that will be allowed between the end of the last receive burst in a TDMA frame and the first receive burst in the next TDMA frame.

GPRS terminal classes

There are three classes of GPRS terminals. A Class C terminal can operate in either circuit-switched or packet-switched mode, but the mode is manually selected. A Class B terminal can operate in circuit-switched mode and be in GPRS idle mode at the same time. When a GPRS terminal is in idle mode, it can make its presence known to the network. If the network wishes to send data to the terminal (or the terminal wishes to send data to the network), it must then switch to the standby state and then to the ready state, during which it can transfer data. A Class B terminal must be able to return to circuit-switched mode quickly. Class A terminals are capable of full, simultaneous operation in circuit-switched and packet modes. Most manufacturers are tending towards development of Class B and C equipment at this time.

The multislot classes are more complicated to explain — there are 29 of them. First, recall that GSM operation divides time into eight TS. This slot structure enables TDMA operation. Normal voice calls use three slots: one for the mobile-to-base transmission (forward link), one for the base-to-mobile transmission (reverse link), and one for the monitor slot (when the mobile device can monitor neighboring cells). Thus, several users can use the same radio channel, each transmitting during a different time slot than the others. The mobile station never transmits and receives at the same time. In contrast to analog systems, the IS-95 CDMA system and several proposed 3G systems are full-duplex systems that use frequency division duplex (FDD) technology.

The 29 GPRS multislot classes are differentiated on the number of transmit slots and receive slots used. Classes 13 through 18 are denoted as type 2, and are special, since they are based on the assumption that the

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