Reviewing The Basics Of The General-Packet Radio Service

GPRS IS A POWERFUL DATA SERVICE THAT CAN BE OVERLAYED ON EXISTING GSM NETWORKS TO PROVIDE USERS WITH DATA TRANSMISSIONS AT RATES COMPARABLE TO TRADITIONAL WIRED MODEMS.

BY RICHARD MAGUIRE

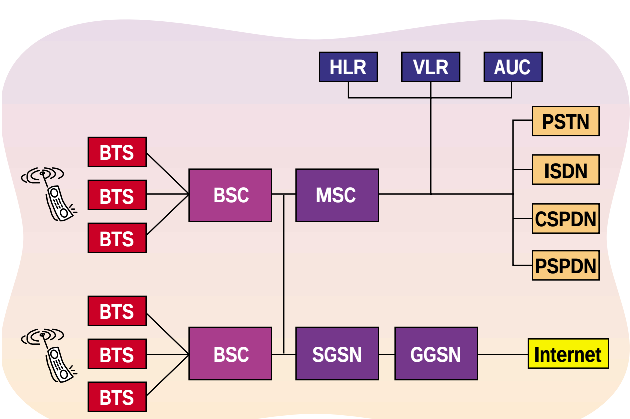
VOICE communications was the driving force behind the establishment of much of today's global wireless infrastructure. But with the maturation of voice services, demand increases for improved wireless data services. The general-packet radio service (GPRS) is a data service for Global System for Mobile Communications (GSM) networks that can arm a properly equipped mobile user with data-transfer rates comparable to those achieved with a traditional modem.

The GPRS standard is an overlay on the GSM system, adding protocol layers and two network components. GPRS achieves quick and efficient data transfer by using packet switching, multiple timeslots, and a new power-control procedure. To understand how much faster GPRS is than GSM, consider the following comparison: Two laptop users are downloading the latest virus program update, one using GSM, the other GPRS. The GSM user will wait approximately 13 minutes to transfer a 1-MB file, while the GPRS user could wait as little as 46 s.

Some may wonder why the high-speed circuit-switched-data (HSCSD) capability of GSM could not be used in place of GPRS. HSCSD is the first GSM data service allowing customers to use more than one timeslot during a call, resulting in data-transfer rates up to 58 kb/s. HSCSD is a connection-oriented technology, making it the best wireless data solution available for real-time applications such as wireless videoconferencing. GPRS is also a multislot service, but it bursts data using packet switching, making it a poor candidate for critical, real-time applications. Where GPRS shines compared to HSCSD is in throughput and efficiency. GPRS allows the user to burst on all eight timeslots, resulting in data rates that are three times higher than HSCSD, or up to 171 kb/s. The system does not assign dedicated channels. Rather, users and resources are connected only as long as either has data to send. This allows GPRS to fill every available timeslot with data and avoid unused timeslots that occur in GSM/HSCSD when the user stops talking, or while waiting for a download.

Figure 1 illustrates the various components in a GSM/GPRS network. To enable GPRS requires the addition of a pair of network components that provide the base-station controller (BSC) with a second path to route data. If the BSC receives voice signals, it sends them to the mobile-switching center (MSC). If it receives data signals, it sends them to the serving GPRS support node (SGSN). The SGSN provides the first glimpse into how GPRS was designed to fit in with modern data networks such as transition-control protocol/Internet protocol (TCP/IP). The services provided to the GPRS network by the SGSN are:

1. An IP router supporting fixed and dynamic addressing.
2. Security using new European Telecommunications Standards Institute (ETSI) ciphering standard.
3. Mobility management.
4. Authentication.



1. *This block diagram shows the various components that make up a GSM/GPRS network.*

5. Session management including Quality of Service (QoS).

The existence of an IP router means that GPRS mobiles will have an IP address, identical to every other addressable system on the Internet. Item 5 also draws attention as something new to the system. QoS is a set of parameters describing a cost-based level of service. Mobile users have a choice on session quality, knowing that a better QoS is going to cost them more money. The QoS values define session priority, data delay, connection reliability, peak throughput, and sustained throughput.

From the SGSN, data packets destined for a network external to GPRS go back and forth through the gateway GPRS support node (GGNS). This node provides the network with the following:

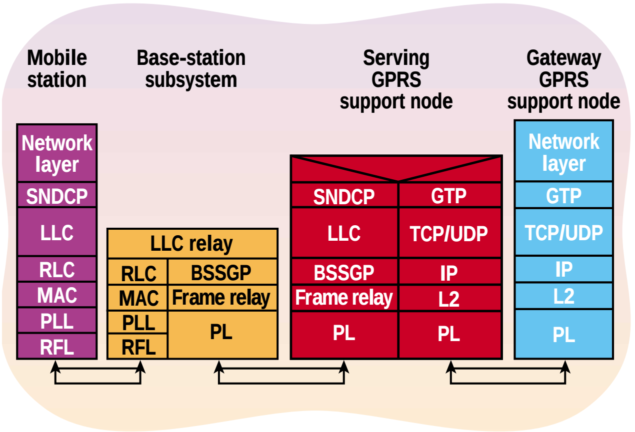
1. A gateway between the GPRS network and external packet-data networks.

2. A GPRS firewall.

3. Manages roaming between GGSN's.

4. Contains a point-to-multipoint (PTM) service center.

The SGSN and GGSN can be one unit, two units, co-located, or placed in separate entities.



2. *The various transmission layers of a GPRS network are shown for the GSM mobile station, the base-station subsystem, the GPRS support system, and the GPRS gateway.*

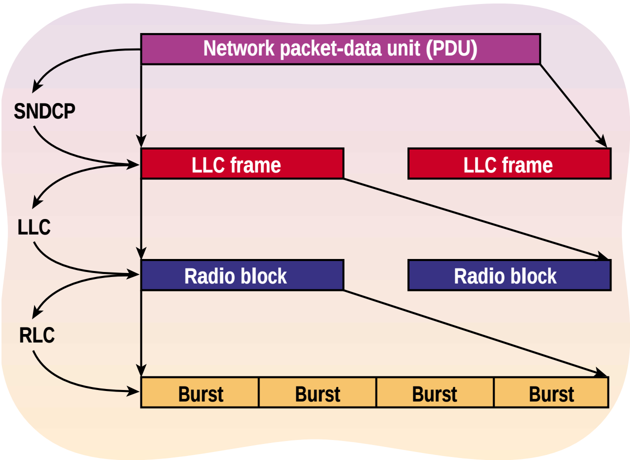
So much of GPRS is protocol that an understanding of the standard requires some familiarity with some of the layers. **Figure 2** shows the transmission layers for GPRS, a scheme based on a portion of the famous Open Systems Interconnect (OSI) model, spans a couple of layers. The first protocol layer of interest, and arguably the most important, is the radio-link-control (RLC) layer, which employs radio-link protocol (RLP). RLP is a complicated protocol charged with no less than perfection handling of logical-link-control (LLC) data frames. When data come or go from the LLC, it is segmented into radio blocks, which RLP tracks meticulously over the network. Data-unit framing is shown in **Fig. 3**. Each radio block is created with a unique number, the temporary-frame identity (TFI). The TFI is a combination of mobile-station identifier and frame-sequence number, which are known by the transmitting and receiving halves of RLP. Radio blocks traveling over multiple paths and multiple timeslots can arrive at the receiver (Rx) out of order. RLP uses the Automatic Repeat reQuest (ARQ) protocol to perfectly re-assemble LLC frames. If ARQ does not have all of the correct radio blocks for a frame, it will request a retransmission of the missing block, by TFI, from the transmitting RLP. This scheme only fails to transfer perfect data when the system-re-transmission timer times out. One drawback of this scheme is that a noisy channel in GPRS results in a significant amount of traffic generated in the re-transmission of radio blocks. Mobile users are almost guaranteed to get their data with GPRS, even if the channel is extremely noisy, as long as they are willing to wait for it.

Two other layers worthy of extra attention, the physical-link layer, and the RF layer (RFL), are doing what they have always done in the GSM network—forward-error correction, interleaving, modulation/demodulation, frequency selection, and other physical-layer tasks. A new task for these layers is implementation of a GPRS channel coding scheme. Four levels of coding are available, from the CS-1 level of 1/2 convolution coded, 9.6-kb/s "safe" data, to the CS-4 level of 21.4-kb/s non-error-coded, high-throughput data.

The most interesting change that GPRS brings to GSM is a different use of the channel. In GSM, mobile units and base stations share a dedicated uplink/downlink channel pair for the duration of a call, even if neither is transmitting data. With GPRS, mobile units are assigned timeslots only when they have data to send, thereby freeing "idle" slots for other users. The uplink and downlink channels are only loosely related in GPRS.

When a mobile wants to transmit, it contacts the BSC, provided it is multislot class and how much data it has to send. The BSC provides the mobile an uplink state flag (USF) for each channel/timeslot pair granted for transmission. The USF is a 3-b number unique to each mobile and timeslot, and is used to direct traffic on the Uplink. An important item to notice—a 3-b number allows up to eight mobile units to share each timeslot. Mobile units assigned to, for example, timeslot 4 on channel 6 will decode the USF on timeslot 4 of downlink channel 6. When the mobile unit decodes the correct USF by watching the downlink, it knows it owns the next radio block on the corresponding uplink channel. Once the mobile unit completes transmission, it releases the timeslot and resumes decoding USFs. The mobile unit performs this decode/transmit process individually for each slot assigned in a multislot transfer.

The network uses three Allocation Modes to define how many radio blocks it provides the mobile with unit based on the amount of transmission requested and current network traffic. In dynamic allocation mode, the mobile is assigned a number of timeslots and will listen to the USF on each. When it decodes its assigned USF, it will transmit a set number of blocks then release the channel and wait for another USF. The number of blocks will vary from one to some multiple determined by a granularity setting held by the network. Fixed-allocation mode makes the mobile and network agree on a fixed number of timeslots and radio



3. *GPRS employs a packet-switching scheme to send high-speed bursts of data.*

blocks. This mode is similar to a virtual circuit since the mobile can transmit all of the agreed upon data regardless of the USF. The final mode is known as extended dynamic allocation, which is an optional mode for the network. In extended mode, the mobile looks for its USF on each timeslot assigned. When the mobile decodes a USF meant for it, it can transmit the agreed upon blocks of data on the decoded timeslot, and all higher numbered timeslots assigned. Extended mode is similar to dynamic mode except that it is driven by only the first decoded USF.

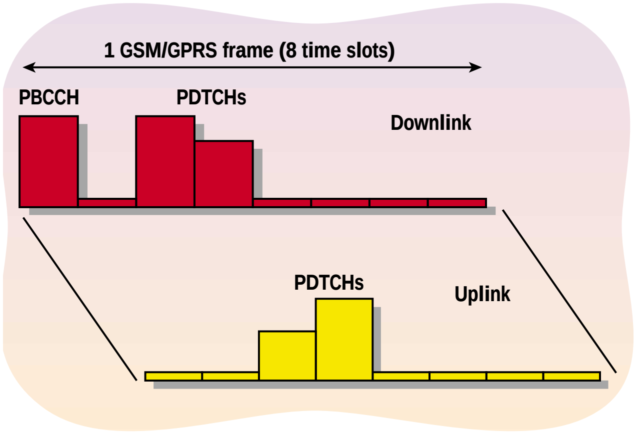
Another piece of information in the radio-block header besides the USF is the TFI—the parameter-matching radio blocks with individual mobile stations. In the process of waiting for a chance to transmit, the mobile unit is also looking for data blocks that contain its TFI. This process is similar to fast-food restaurants that take an order, give the customer a number, then call out the number when the food is ready. Similarly, the GPRS mobile units are similar to those customers waiting for their numbers to be called. Any number of mobile units can listen to a particular downlink timeslot for data since the TFI uses unique, mobile-station-specific codes.

With every burst possibly containing data, a fully implemented GPRS cell would be rather noisy. To make the situation tolerable requires a new and more-sophisticated power-control scheme. GPRS uses open- and closed-loop power control, such as code-division-multiple-access (CDMA) techniques, and mobile units and base stations can vary the power of individual timeslots. These changes are designed to reduce overall system power, thereby reducing overall interference. Refer to **Fig. 4** during the following discussion on power control, beginning with coverage of the uplink power control.

GPRS mobile stations can adjust power on a slot-by-slot basis, with the slot power being constant over the four bursts of a radio block. The mobile unit transmits at the lesser of two power levels—the closed-loop value, P^{MAX}, from the base-transceiver station (BTS), or the open-loop value calculated within the mobile unit. The open-loop equation variables are received power, frequency band, channel number, and a network constant.

For downlink power control, the situation is not as clear. It is important to remember that the base station is transmitting data to multiple mobile stations per timeslot. These mobile stations may be widely spread out geographically, with some very close to the station, and some at the geographic limits of the cell. The broadcast power must be sufficient for all mobile stations decoding the USF, so limits are put on just how much the base station can reduce power.

Two modes exist for the base station to vary power on the downlink. Power-control mode A can be used on a channel without regard to the Allocation Mode of each mobile station currently transferring data. In this mode, the base station can set power from a high of the broadcast-control-channel (BCCH) power minus a system constant, to 10 dB below that. This allows the network operator to reduce overall system power down to a level that is just adequate for the most remote mobile on that channel. The other mode, power-control mode B, is applicable for mobiles involved in a fixed-allocation data transfer and puts no limit on how low the base station can drop the



4. *A two-slot session is used here as an example to show the timeslots and power levels employed in GPRS.*

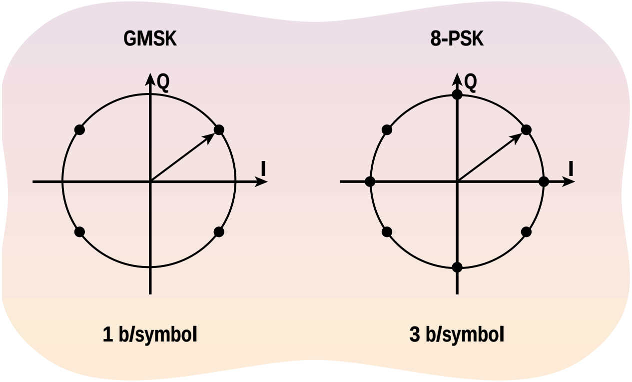
power. The power level is applicable to each timeslot and need only be high enough for the mobile to correctly decode the blocks. One note for power-control mode B transfers is that for every 360 ms the broadcast channel must increase the power so that other mobiles decoding the USF remain synchronized.

The logical channels of GPRS are almost identical to those used in GSM. The packet-BCCH (PBCCH) replaces the BCCH, providing identical functionality, only with GPRS-related information instead of GSM. The most exciting new feature with regard to logical channels is that the service provider can change the mix of GSM and GPRS channels in real-time. If, for example, traffic tends to be more data oriented at 5:30 p.m. each day, the service provider can change some voice channels over to data. When morning rush hour comes, the allocation can change the channels back to voice as needed.

Another interesting change is how the system treats the BCCH and the PBCCH. When a service provider decides to implement GPRS, they can opt out of transmitting a PBCCH and instead add GPRS information to the existing BCCH. If they decide to implement a PBCCH for GPRS mobile stations, they can include normal GSM information on the channel so that mobile stations, which are capable of GSM and GPRS, need only camp on one broadcast channel.

How are tests performed on GPRS? GPRS operates on the traditional GSM network, so the fundamentals of testing GPRS are the same as for GSM, with only a few additions. The 8960 series 10 wireless communications test set from Agilent Technologies (Liberty Lake, WA) is well-suited for evaluating GSM networks for voice communications as well as GSM/GPRS networks for data-communications performance. The test set's GSM power/time template must be modified to compensate for multislot operation when evaluating GPRS. Also, a new Rx test called block-error rate (BLER) has been added to the 8960 series 10 test set to check for completed radio blocks. ETSI has incorporated a test mode in the GPRS standard that allows a "camped" mobile station to be directed to transmit random or loopback data on a particular set of channels at defined power levels. This enables test equipment to perform all Rx and transmitter (Tx) tests without call processing.

Enhanced Data Rates for GSM Evolution (EDGE) are a modulation and link-management scheme used to turn GPRS into Extended GPRS (EGPRS). EGPRS is three times faster than GPRS and qualified to wear the third-generation (3G) title. **Figure 5** shows the eight-state phase-shift-keying (8PSK) modulation employed in EDGE, which transmits 3 b for every symbol as compared to 1 b for GMSK. The 8PSK modulation used in EDGE is fairly taxing on the system, so the network side must be updated for high data rates, and mobile stations for EDGE require a Tx to handle transitions through the origin.



5. *GMSK uses 1 b/symbol compared to 8PSK modulation with 3 b/symbol.*

The term "link management" describes how the network can change the channel structure real time to compensate for interference. In areas of high noise, the network can reduce modulation back to GMSK, add more channel coding, or both. Under better conditions, the bit rate can be increased and the error coding reduced. *WSD*

RICHARD MAGUIRE, *Product Manager, Agilent Technologies, E. 24001 Mission, Liberty Lake, WA 99019; (509) 921-4421, e-mail: richard_maguire@agilent.com, WWW: http://www.agilent.com.*