The Internet: Challenging/Changing GSM Networks

In recent years, Internet applications have become extremely popular, and the demand for mobile access to Web-based applications is increasing accordingly. But the Internet is a packet switched network, and GSM is a circuit switched network. While packet switched services can be provided over the current circuit switched network, the network architecture was not designed for this purpose and does not perform this task particularly well.

Internet traffic is characterized as "bursty" traffic, as data is transmitted in spurts, or bursts, rather than in a continuous stream. This type of data traffic is poorly suited for circuit switched networks, since the connection exists even when no data is transferred. This is extremely costly for the end user and makes inefficient use of the operator's air interface capacities.

In addition to this basic architectural difference, current mobile networks also share other technical restrictions that must be addressed in order to enable mobile Internet applications:

- 9.6 kbps transmission rate too slow for Internet use
- 160 character limitation for SMS
- Long call establishment times make the network seem even slower – delays due to transfer networks between the Public Land Mobile Network (PLMN) and the external Packet Data Network (PDN) are common
- Connections are released when transmission quality over the air interface drops below a certain threshold value. Often the subscriber gets unusable fragments instead of complete files.

Considering these drawbacks, packet switching over a circuit switched mobile communication network proves unreliable and expensive. A new standard was developed to address these issues and make mobile communication networks "Internet ready".

GPRS: Preparing GSM Networks for the Internet

With its initial release in 1997, General Radio Packet Service (GPRS) Phase 1 was specified to create a sound foundation for packet switching in GSM networks. The standard defines central requirements such as point-to-point data transfer, identities, coding schemes, billing schemes based on data volume, security features, and TCP/IP and X.25 bearer capabilities. With

GPRS Phase 2 (specified in 1999), point-to-multipoint support and additional services are to be introduced. The following paragraphs describe the central ideas of GPRS and the key features defined in the standard:

Packet-switched methods are applied to efficiently transfer both data and signaling information. Using encapsulation and tunneling techniques, data is transparently transferred between the mobile station and the external packet data networks. (Among other advantages, this method helps overcome the 160-character limit currently placed on short messages.) GPRS supports the most common data protocols (IPv4 and X.25) and is open for additional interworking protocols in the future. Direct access to external packet data networks helps to increase data transmission rates and reduce call establishment time.

Billing is typically based on the amount of data transferred. This method provides a fairer pricing scheme for bursty traffic, as rates are directly related to actual usage volume.

Security features such as ciphering[4] and authentication are implemented as they are in existing GSM networks.

Quality of Service features allow for the definition of precedence between subscribers, determination of delay classes and data transmission reliability as well as the mean and peak throughput rates.

Strict separation of Base Station Subsystem (BSS) and Network Switching Subsystem (NSS) via an open interface to allow multi-vendor environments and the evolution to UMTS where a new radio access network is attached to the NSS.

Increased efficiency on the air interface is ensured using several methods:

- Capacity on Demand: A cell's physical channels can be dynamically allocated for circuit switched and packet switched use. For example, in a cell with two transceivers, there are 14 physical channels available to transmit traffic. If the operator wants to ensure a call completion probability of 98% for circuit switched calls, on average less than 9 physical channels are used. The remaining resources are used as a spare for peak traffic situations. Those spare resources can be used for packet switched traffic. If circuit switched traffic increases, more physical channels can be allocated for circuit switched use "on demand" and some packet switched users may have to wait to continue downloading their data.

Codec	Data rate (kbps)
CS-1	9.05
CS-2	13.4
CS-3	15.6
CS-4	21.4

- Increased data transmission rates are achieved using channel bundling and new coding schemes. With channel bundling, up to 8 timeslots per

[4] Referred to as encryption in packet switching contexts.

TDMA frame can be combined. Depending on the codec speed (see sidebar table), this allows for transmission speeds of up to 171.2 kbps (8 timeslots @ 21.4 kbps).

(Note: CS-3 and CS-4 require modifications to the Base Tranceiver Station and won't be implemented by most operators in the beginning.)

- Asymmetric resource allocation: Uplink and downlink resources are allocated separately and may differ in size/capacity/rate.

EDGE (Enhanced Data Rates for Global Evolution) increases the data throughput of GSM systems to over 473 kbps per carrier and is also called EGRPS (Enhanced General Radio Packet Service). As the term EDGE suggests, this technology supports higher data rates via enhanced modulation schemes on the radio interface, known as 8-PSK (Phase Shift Keying) and GMSK (Gaussian Minimum Shift Keying). EDGE, expected to be deployed in 2001, is a mayor step in providing 3G services over GSM systems. As an overlay solution to existing networks, EDGE does not require modifications to the existing air interface. EDGE is especially designed for operators that do not have additional spectrum allocated for UMTS, but still wish to offer competitive applications (e.g. multimedia) using the existing band allocation.

Network Architecture

The GSM Environment Today

Existing GSM networks (Phase 1or Phase 2) consist of a radio access network called a Base Station Subsystem (BSS), a core network solution referred to as a Network Switching Subsystem (NSS), and an Operation Subsystem (OSS). The BSS consists of Base Station Controllers (BSC) which are responsible for the radio resource control, Base Transceiver Stations (BTS) which handle ciphering, encoding, burst generation, radio frequency generation, etc. The Transcoder and Rate Adaptor Unit (TRAU) compresses 64 kpbs voice data to 13 kbps (Full Rate), 12.2 kbps (Enhanced Full Rate), and 5.6 kbps (Half Rate) and performs rate adaptation for data applications.

The NSS is made up of Mobile Services Switching Centers (MSC), which perform classical exchange tasks including traffic switching, flow control, and signaling data analysis. In cooperation with other network elements, the NSS handles mobile-specific tasks such as mobility management and authentication. Logically, MSCs may be either Visited MSCs (VMSC), which are responsible for all the mobile devices in its supply area, or Gateway MSCs (GMSC), which are the interworking nodes to the external public telephone networks. The Visitor Location Register (VLR) associated with the VMSC holds relevant subscriber data for all subscribers currently within the range of the VMSC - including international mobile subscriber identity (IMSI) and a record of subscribed services. The Home Location Register (HLR) supplies the VLRs with this data and supports the Mobile Terminating Calls (MTC). The Authentication Center (AC or AuC) generates the Triplets (RAND, SRES, kc) necessary for the authentication of the subscriber. Finally, the optional Equipment Identity Register (EIR) is used to check the validity of the subscribers' handheld. GSM networks are circuit switched and normally use SS7 for signaling and control information.

GPRS Enhancements to the GSM Network

With the introduction of GPRS, both the BSS and the NSS must be enhanced to support the key features outlined above (see GPRS: Preparing GSM Networks for the Internet). Several new logical network elements[5] enable the following high-level GPRS functions:

Network Access Control – A set of procedures are defined in GPRS to control access to the network's services and facilities. The subscriber may access the network via the air interface or an external packet data network. The operator can offer support for several protocols (X.25, IPv4, etc.) for access to external PDNs. The operator determines the extent to which services and access are restricted; six network access control functionalities are defined within the GPRS recommendations:

1. Registration: The user and the services to which he or she has subscribed must be known at the HLR. This includes the packet data protocols (PDP) subscribed for, the external PDNs (so-called access points) he or she is allowed to use, and the addresses (X.25, IPv4, etc.) of the mobile device.
2. Authentication and Authorization: These processes verify the subscriber's right to access the network and to use a specific service. The accompanying procedures correspond to those used in GSM.
3. Admission Control: When a subscriber requests a certain minimum amount of resources (quality of service) with a service, admission control checks whether they can be made available.
4. Message Screening: This functionality is used to filter unsolicited and unauthorized messages/data to and from the subscriber. In GPRS Phase 1, this is only network controlled.
5. Packet Terminal Adaptation: The maximum size of packets which can be transmitted via the GPRS network is limited to 1500 octets. Larger packets have to be segmented.
6. Billing Data Collection

[5] These new network elements are described below in the GPRS Network Element Overview section.