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General packet radio service (GPRS) in GSM networks: Fixed-mobile network integration aspects

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Abstract

In the global system for mobile communications (GSM) Phase 2+ development, one of the most attractive aspects is the support of general packet radio service (GPRS). GPRS supports data services to GSM users, sharing on a dynamic and flexible basis between packet data services and other GSM services. The paper describes the different aspects to be considered when integrating the GPRS technology in a GSM network, particularly from the PLMN (public land mobile network) operator point of view. Key concepts of GPRS are explained in terms of network architecture interfaces and protocols Further, an overall description of different interconnection aspects that the PLMN operator has to consider, dealing with technologies and protocols typical of fixed data networks, from frame relay in the access network to IP in the backbone network is presented.

Key words: GPRS, GSM, IP, QoS, CoS, SMS, HSCSD.

1. Introduction

The demand for all-embracing mobile communication (at any time and at any place) is increasing. The main service now offered by most mobile radio systems, like the global system for mobile (GSM) communications network, has been voice communication; now the demand for data services is steadily increasing. Business users want to access their corporate networks wherever they go, so that they can access e-mail, the Internet and files on their corporate servers.

Data services on mobile are available today, but the limited throughput and efficiency makes them not suitable for several applications.[1] ETSI standards groups are working towards higher data rates but more significantly towards packet data services, initially with general packet radio service (GPRS) and multislot data but eventually universal mobile telecommunications system (UMTS) will provide much higher bandwidth. GPRS introduces packet switching in the GSM architecture, with an efficient utilisation of radio resources. Opposed to the use of switched data services on mobile, now the medium is used only for the duration that data is being sent or received. Furthermore, GPRS allows for simultaneous voice and data communication, so the user can still receive incoming voice calls or make outgoing voice calls while transferring data.

GPRS will support both the internet protocol (IP) and the X.25[2] protocol, even though the IP seems to be the leading protocol for the interconnection to data networks. It is likely that vendors and operators will emphasise IP services.

From the network operator's point of view, GPRS provides better opportunities in the road map to UMTS: fewer changes to existing radio network equipment, to be substituted with UMTS, and construction of a core network which will be used for a third-generation backbone.

2. The GSM cellular system

Global system for mobile (GSM) communications is the pan-European digital cellular standard defined by the ETSI[3] (European Telecommunications Standards Institute). It is safe to assume that by the end of 1999, GSM will have over 150 m customers and be a major influence across every continent on the planet. Telecom Italia Mobile (TIM), one of the mobile operators in Italy, has more than 15 mn lines, equivalent to 68% of the domestic market. Even more significant is the increase in volume of minutes of conversation, which amounts to more than 5 bn during the first three months of 1999, reflecting a 40% increase over the first three months of 1998.

Until 1995, Europe largely drove GSM specifications and policy, but the creation of regional interest groups has changed the framework. In the Asia–Pacific region, the total GSM subscriber base grew from 1.9 mn customers in 1995 to more than 6 mn by the end of 1996. In addition, the People's Republic of China has the potential to become the largest single GSM market in the world. China, which is home to one fifth of the world's population, is expected to support 30 mn mobile subscribers by 2000, with around 23 mn of these using digital GSM networks. Global roaming has always been the cornerstone of GSM's success. Users demand ubiquitous coverage and seamless mobility. The start up of GSM 1800 service could push the GSM ahead. This has led to optimal use of the networks as well as an increase in telephone traffic.

2.1. *GSM architecture*

The GSM architecture can be divided in three parts: base station subsystem (BSS), network switching subsystem (NSS) and operation and support subsystem (OSS). The BSS has been divided into two functional elements: the base transceiver station (BTS) and base station controller (BSC). A GSM network is usually made of thousands of BTSs (Fig. 1).

Only the BTS has radio functionality and its radio coverage area is called a cell. Typically, each BSC controls tens of BTSs. The BSC allocates radio channels during the installation of a call and deallocates the resources when the call is terminated.

The NSS has the role to manage the communications among mobile and other users. It also includes databases nedeed to store information about subscribers and to manage their

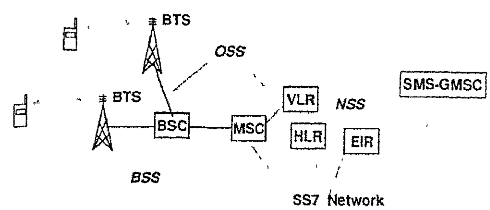

FIG. 1. GSM architecture and SMS support.

mobility. The OSS is the common reference for NSS and BSS blocks, in order to control, monitor and manage the GSM system and to control the traffic load of BSS.

3. Data services for GSM

A certain number of mobile data services like data and fax service at 9600 bit/s and short message service (SMS) are available today.

3.1. *Data and fax service at 9600 bit/s*

The traditional offering of data service on GSM is circuit-switched and is based on interworking between GSM and PSTN networks. The interworking with PSTN is taken care of by modems located in the mobile switching centre (MSC) interworking function. This function is widely implemented by most manufacturers of mobile equipment (Fig. 2).

Data transmission on GSM currently gives a maximum speed of 9.6 kbit/s, with or without automatic retransmission request (ARQ), and an average round-trip delay of 400–500 ms, while the connection set-up time is about 20–25 s. The user has a whole bidirectional voice channel for data transfer and the billing is the same as for voice services, e.g. time-based. Mobility management is the same as for voice GSM services.

Typical applications of data transmission at 9.6 kbit/s are connections to corporate networks with remote access server (RAS) by modem and PSTN, and to Internet service providers (ISP) by modem and PSTN

The facsimile Group 3 fax service, based on ITU-T recommendation T.30, gives compatibility with a large number of fax terminals in the world.

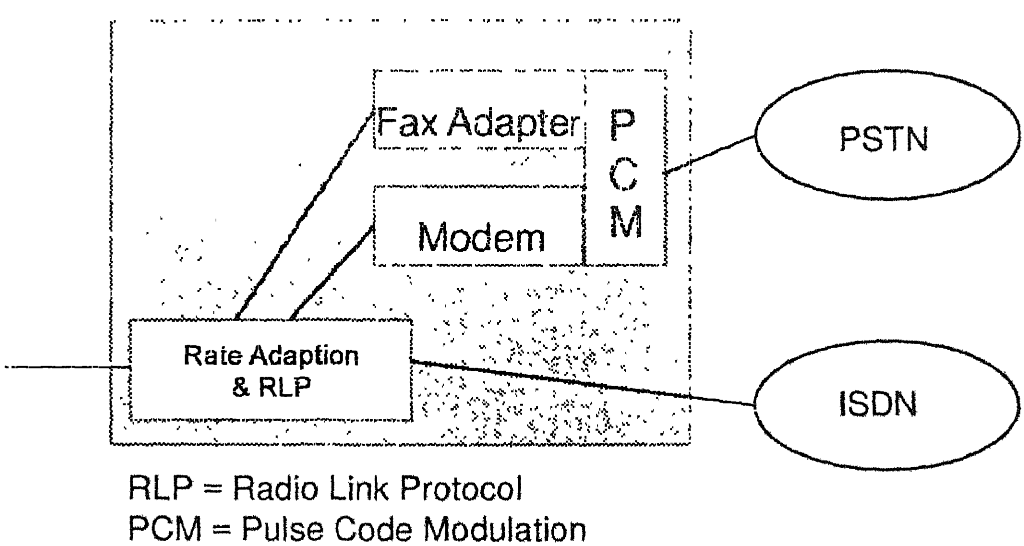

FIG. 2 Basic function for data and fax services over GSM.

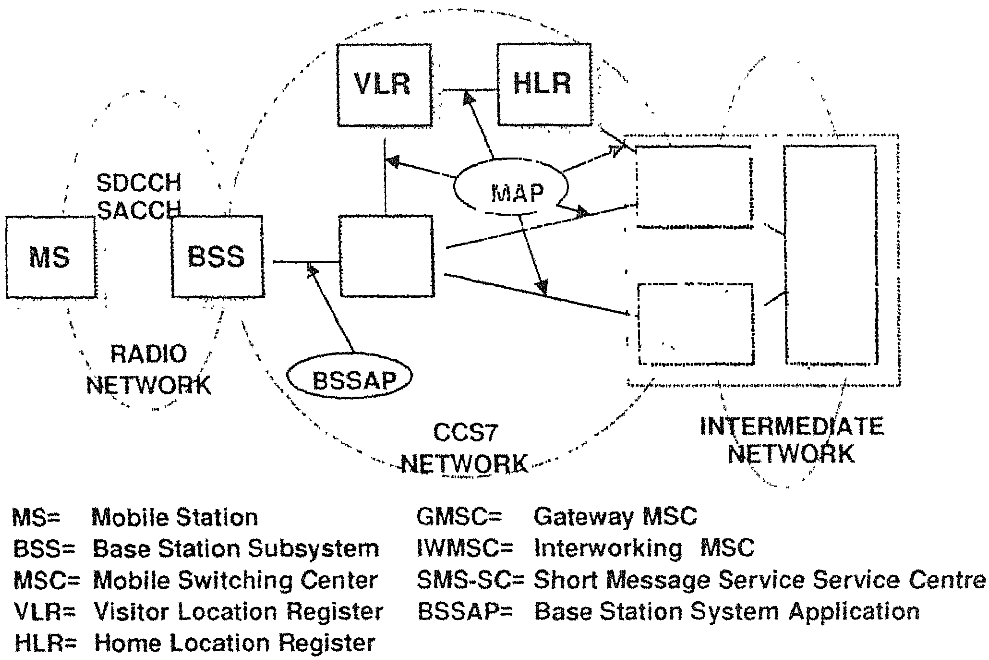

FIG 3. Basic function for data and fax services over GSM

3.2. *SMS*

SMS, a packet type of service providing transmission and reception of text messages up to 160 characters, is the fastest growing GSM data service. In many countries where mobile penetration has reached 20%, take-off of SMS has become exponential. In Italy, TIM forwarded about 2,000,000 short messages per day in 1999.

The SMS message is sent to a short message service centre (SMSC), which stores the message until it can be delivered to the recipient. Messages can be sent to the SMSC either direct from a mobile phone (SMS MO – mobile originate) or by a PC connected to Internet (Fig. 3).

The SMSC will store the message if the recipient's phone is out of coverage or is turned off and will automatically deliver when the phone is back in service. Messages can have an expiry time set, in which case the message will be deleted if it has not been delivered at the end of this period. For dial-up messaging, the expiry time is set by the network and varies from network to network.

While a mobile is having a call established, the message is transmitted in parallel on a slow associated control channel. SMS messages usually have extensive signalling requirements, which means an overhead of signalling links.

4. Evolution of data services: GPRS and HSCSD

Standardisation, production and installation of public GSM services require enormous investments. This is very important while considering new opportunities and development of mobile networks: enhanced services create good business opportunities, but the earlier investments have also to be taken into account.

The development of data transmission techniques and increase of transmission speed for GSM can follow two main directions:

- Development of circuit switched technique
- Introduction of packet switching technique

In the first case, the introduction of high-speed circuit switched data (HSCSD) service will allow speed rates up to 38.4 kbit/s. HSCSD increases the transmission speed by aggregating different channels while keeping circuit switching technique. The aim is to minimise network impact and consequently time and cost of deployment in the network.

In the second case, new 'packet elements' are introduced in the global network architecture and a new radio interface structure is defined, allowing the assignment of resources to the customer only when it is necessary to transmit a packet. The introduction of GPRS allows speed rates up to 144 kbit/s.

4.1. *HSCSD*

HSCSD is not a completely new service. It is an enhancement of the existing GSM data services. Its impact on the network elements is moderate.

HSCSD allows the aggregation of different full-rate traffic channels on the radio interface, where the channels of an HSCSD connection are allocated on a unique TRX, in consecutive time slots.

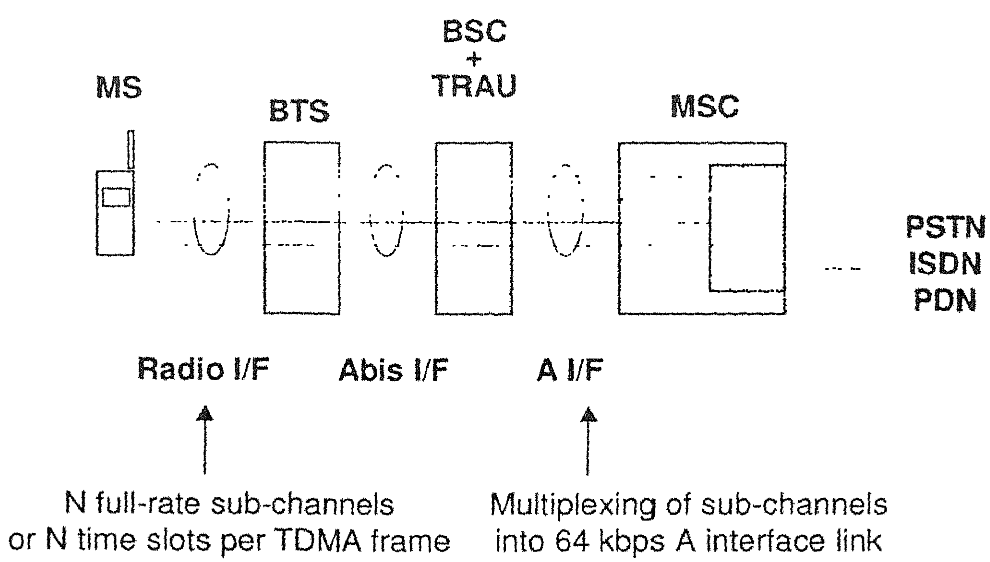

FIG. 4. HSCSD architecture.

The network architecture of the GSM HSCSD service is based on the usage of parallel subchannels for high-speed data connections. The main functionality in the multiple channel connection is the splitting and combining of the data stream over several independent subchannels (Fig. 4). The multiple channel functionality is based on numbering of data frames.

The maximum speed is 38.4 kbit/s (4×9.6 kbit/s). For GSM high-speed data service, the interesting modems are V.32bis and V.34, providing data rates higher than in the existing GSM system.

5. GPRS technology: an overview

GPRS[4] is a GSM Phase 2+ technology that will add packet switching to GSM with a packet air interface on top of the current circuit switched mode of operation: this brings packet switching to GSM, allowing an optimal utilisation of the radio resources (Fig. 5).

The main objective of GPRS is to offer access to standard data networks such as TCP/IP. These networks consider GPRS to be a normal subnetwork. The advantage of a packet-based approach is that GPRS uses only the medium, in this case the precious radio link, for the duration of time that data are being sent or received. New GPRS radio channels are defined and 1 to 8 radio interface time slots can be allocated per TDMA frame. The active users share time slots, and up/downlink are allocated separately.

- GPRS uses packet data channels (PDCH), which are dynamically allocated (capacity on demand) in such a way that radio resources are used only when there are data to be sent or received. PDCH are never permanently allocated (Fig. 6).

To use the GPRS service, a mobile station must:

- connect to the GSM network (GPRS attach), providing its identity for authentication and activating location area update procedures;
- connect to the data network, by activating one or more packet data protocol (PDP) context.

The signalling needed to set up a PDCH is carried over a dedicated GPRS control channel PCCCH, when available; otherwise a normal CCCH channel is used.

5.1. *GPRS network architecture*

New network elements have to be considered when implementing a GPRS network.

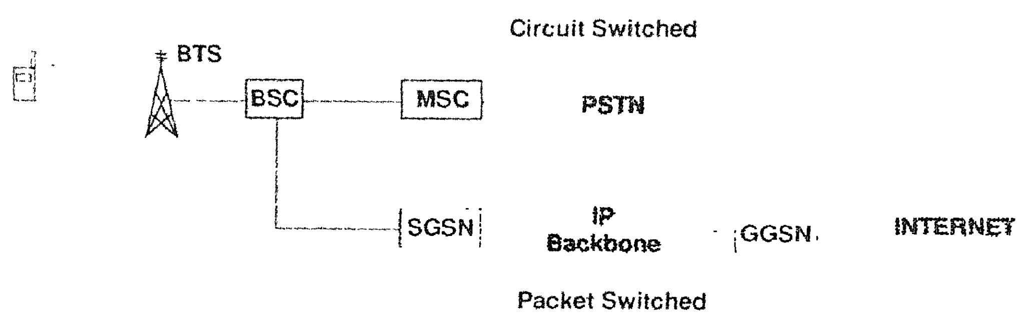

FIG. 5. GPRS architecture.

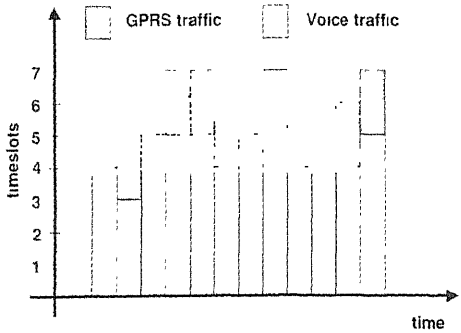

FIG. 6. Dynamic allocation of time slots in GPRS

- Serving GPRS support node (SGSN): It has the following functions: (i) protocol conversion between the IP backbone and BSS/MS, (ii) authentication and mobility management, (iii) routing within location area, (iv) charging and (v) traffic statistics. The SGSN is the node that is serving the MS. At GPRS attach, the SGSN establishes a mobility management context containing information pertaining to, for example, mobility and security for the MS. At

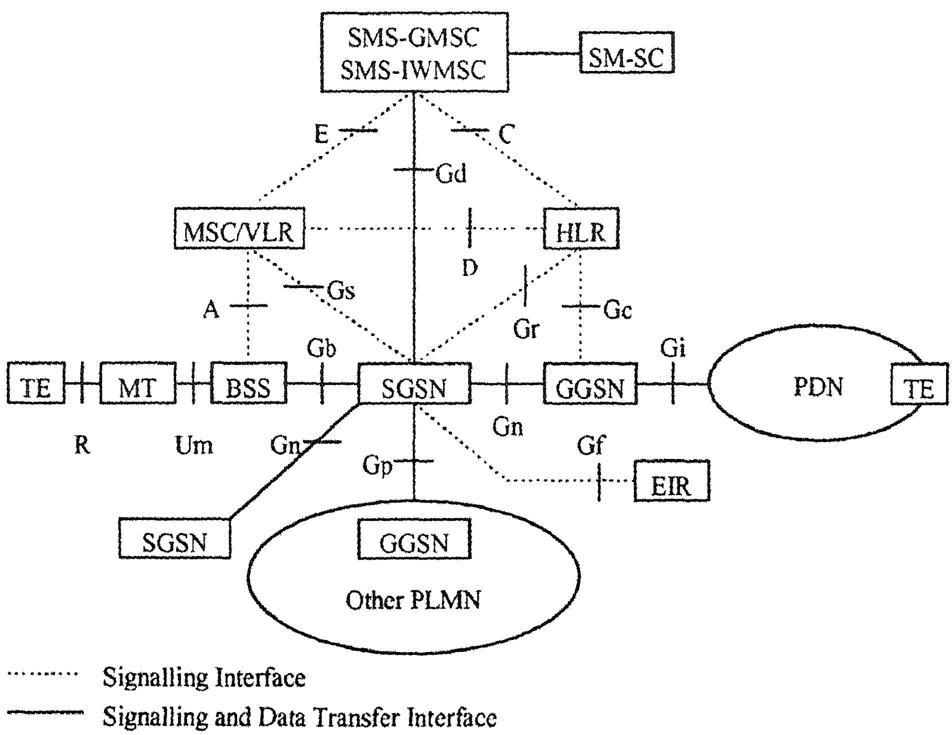

FIG. 7. GPRS Logical Architecture.

PDP context activation, the SGSN establishes a PDP context, to be used for routing purposes, with the GGSN that the GPRS subscriber will be using.

- Gateway GPRS support node (GGSN): It is the interface between the GPRS network and external data networks. From an external network, it is simply considered as a router to a subnetwork. It contains routing information for attached GPRS users which is used to tunnel PDUs to the mobile's current point of attachment, i.e. the SGSN. The SGSN and GGSN functionalities can be integrated in the same node. In Fig. 7 the GPRS logical architecture is reported.

In general, while considering the network operator point of view, different elements have to be considered when migrating to GPRS.

- the scarce system resources must be used efficiently, and an optimal utilisation of resources, especially radio resources, is essential;
- flexible sharing of available resources between packet radio and rest of the services is vital, since the capacity requirements vary dynamically;
- introduction of the service should not impact the offering of the existing services, in terms of hardware and software upgrade;
- a flexible network architecture is needed, as the growth of GPRS in the future is hard to define;
- no change to the low-level protocols in the air interface should occur.

5.2. *Role of GPRS network operator*

In the case of interworking with a TCP/IP network, GPRS network operator must decide whether to be an ISP or give simple mobile access connectivity to corporates or to other operators.

If the GPRS network operator acts as an ISP, it can give services such as DNS registration, e-mail and web hosting. Many network operators are considering the opportunity to use GPRS to help become wireless Internet service providers in their own right. In this case, the GPRS network must be configured as an autonomous system and must use BGP routing protocol. On the other side, the GPRS network operator, as mobile service access provider by GSM network, can give mobile access to traditional ISP. The GPRS operator can give a mobile network access to (a) users of other ISP and (b) mobile users of companies.

GPRS for ISPs can be just another access service, like ADSL, frame relay, ISDN, dial-up.

6. Aspects of fixed-mobile network integration

After SGSN and GGSN, other network elements, typical of data networks, have to be considered when implementing a GPRS network:

- the link between BSS and SGSN, which is a standard frame relay user-to-network (UNI) interface;
- the IP backbone, linking the different SGSNs and GGSNs, used to transport GPRS traffic and optionally to give other network services; the IP backbone can be directly implemented

over SDH, or based on an ATM multiprotocol core network, using one of the techniques for transport of IP over ATM, e.g. Classical IP over ATM, MPOA, etc.

- one or more domain name servers (DNS): this can be managed by the GPRS operator or by an external ISP.
- one or more firewalls: a firewall is a system (or group of systems) that enforces a security policy between a secure internal network (the GPRS network) and an untrusted network (Internet); it is designed to protect the information resources of the GPRS network by controlling the access from the external network.
- a border gateway (BG), giving interconnection to other GSM/GPRS operators; this gives to GPRS users belonging to a public land mobile network (PLMN) the opportunity to have GPRS connectivity by roaming to other GPRS operators.
- one or more GPRS networks interface to several different packet data (or other) networks: these networks may differ both in ownership as well as in communications protocol (for example, X.25, TCP/IP). The network operator should define and negotiate interconnection with each external (PDN or other) network.

After that, the BSS must be upgraded to support the GPRS. The BSS Gb interface must be a frame relay standard UNI interface.[5] Of course, not all the BSS need to be upgraded, but only those corresponding to the area where the network operator wishes to give GPRS access.

6.1. *Frame relay access*

Frame relay is a packet-based data transmission technology that provides statistical multiplexing, allowing several channels to share a transmission line. The connections can be permanent virtual circuit (PVC) or switched virtual circuit (SVC). All the connections are available simultaneously and each frame relay PVC/SVC can make full use of the bandwidth available, by allowing traffic on each PVC/SVC to send bursts within agreed limits.

Frame relay frames are variable in length, from a few to 1600 bytes or more. Frame relay has no acknowledgement, retransmission or flow control functions: it simply discards a frame when an error occurs. The upper layer protocols, e.g. TCP/IP, are in charge of detecting a frame loss and require retransmission.

Frame relay can transport efficiently all the protocols in use today. It operates at sublayer of OSI layer 2. It is, therefore, transparent to most of the commonly used protocols. This transparency is reinforced with standards and agreements on encapsulating protocols in frame relay frames. Frame relay is also highly compatible with ATM.

Frame relay is the protocol used in the Gb interface, between BSS and SGSN, as defined in ETSI specification 08.16.

Two different alternatives are to be considered while using a frame relay transport service:

- a physical direct point-to-point connection between BSS and SGSN;
- an intermediate frame relay network between BSS and SGSN.

In both the cases, when considering GPRS, only PVC is used, based on ITU-T Q.922 Annex A, ITU-T Q.933 Annex A and FRF.1.1 standards.

In the second case, while using an intermediate frame relay network, the GPRS provider may:

- get frame relay connectivity from a public service provider;
- build his own frame relay private network.

In some cases, it is possible to multiplex the Gb interface into the same physical connection used for the A-ter interface (from BSC to MSC).

6.2. *IP backbone: Addressing issues*

While considering GPRS, two different IP backbones must be considered (Fig. 8):

- an intra-PLMN, which is the IP backbone used to interconnect SGSN/GGSN of the same GPRS network;

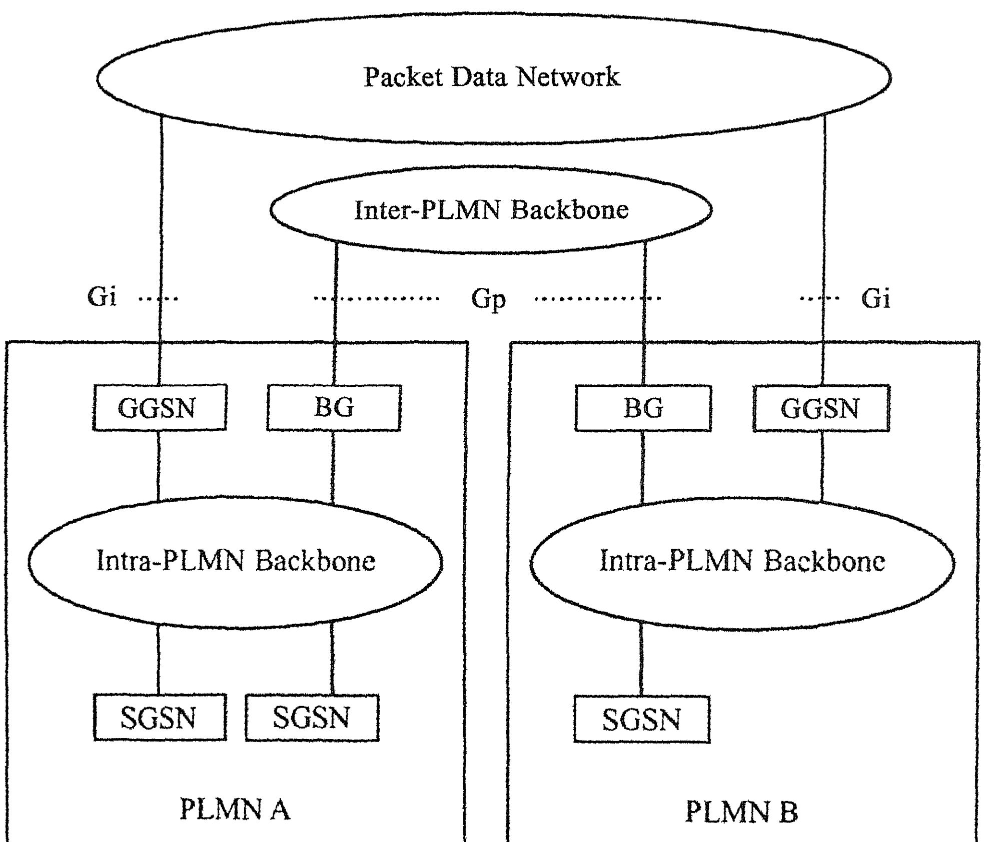

FIG 8. Inter- and intra-PLMN.

- an inter-PLMN, which is the IP backbone used to interconnect GGSN and intra-PLMN backbone in different PLMNs.

The primary purpose is to use IP version 6 for both IP networks, as soon as the protocol is widely implemented and tested well. However, since the introduction of GPRS is not likely to take place in the nearest future, early implementation of GPRS may be based on IP version 4.

As far as IP addressing issues are concerned, the introduction of GPRS means that IP addresses must be allocated for all the SGSNs and GGSNs. However, addressing problems arise when the network operator allocates the IP address space for use by mobile stations, either statically or dynamically. The main problem encountered is IP address exhaustion: the growth in Internet activity and the number of organisations requesting IP addresses in recent years have surpassed all the expectations of the Internet authorities.

The address is given either at subscription, in which case it is a static address, or at PDP context activation, when it is a dynamic address. A temporary address can be allocated to the mobile, taken from a pool of addresses in a foreign network. Procedures defined by, for example, dynamic host configuration protocol[6] (DHCP) can be used to acquire the address at the beginning of the session. As soon as the session is finished, the address is released, ready to be used by another mobile. DHCP protocol is defined in RFC 2131.[7]

Dynamic allocation is particularly useful for assigning an address to a mobile that will be connected to the network only temporarily or for sharing a limited pool of IP addresses among a group of mobiles that do not need permanent IP addresses.

One problem that arises while using dynamic address for mobile terminals is that the correspondent network nodes cannot initiate packet transmission between network and the mobile with temporary address, since they do not know the temporary address of the mobile. If the mobile changes its Internet point of attachment during the session, the transport and application protocols should be notified. Also DNS should be notified to update the mapping between name and address, providing reachability of the mobile node for other nodes. This method is appropriate for the existing GSM data services where an Internet connection is to be used. When a dial-up Internet service is used, there is no need to change the IP address during the session.

A solution to the problem of IP address exhaustion could be the use of private IP addresses: a network address translator (NAT) can do this. The idea of NAT is based on the fact that a host can have its own private IP address, not officially recognised by the Internet Assigned Numbers Authority (IANA). When this host wants to communicate outside, NAT translates the private address to a public IP address, chosen from a pool of IP-assigned addresses.

6.3. *Mapping GPRS–QoS to IP-QoS*

A general requirement for networks, in particular for data networks, is the introduction of features and capabilities like low delay for voice, high bandwidth for video, no error delivery for data to efficiently transport different information flows (data, voice, video, multimedia, etc.) according to their specific needs.

The GPRS technology on the one hand has been projected for allowing the coexistence between data and voice flows, with a mechanism based on flexible utilisation of time slots in the TDMA frames. On the other hand, data networks support flow of information as well: one of the main guidelines of a high-speed data technology, like ATM, is to define different classes of service (CBR, VBR, ABR, UBR) in order to transport any possible mixture of data and voice traffic. As far as frame relay is concerned, the introduction of class of service (CoS) is under consideration, as reported from Frame Relay Forum and ITU-T standardisation activities.

The purpose of introducing mechanisms for traffic management in IP-based networks, according to different CoSs, is one of the main goals for equipment providers, telecom operators, Internet service providers and even for IETF standardisation activities.

The major IP providers are introducing network architecture according to different approaches (i.e. MPOA, MPLS, IP/ATM switching, etc.) and following specific QoS mechanisms to differentiate data flows (i.e. CAR, RED, WFQ, etc.).

Telecom operators are introducing new offers, where the QoS provided is one of the main aspects to be considered in order to define service pricing. IETF is engaged in discussing general paradigms (integrated and differentiated services) in order to analyse the impact of very general choices on Internet. One of the consequences of this evolution perspective towards the management of different QoSs is that the different networks must interconnect to provide the end-to-end service. For instance, if IP flows use a transport network based on ATM and frame relay, the criteria introduced at IP level to differentiate data flows have to be mapped, integrated and maintained at the transport layer. A similar problem arises when using an IP network to transport traffic flows generated by GPRS network.

A QoS profile is associated with each PDP context. It defines the quality of service expected in terms of the following attributes:

- Service precedence class
- Reliability class
- Delay class
- Throughput class of user data (maximum bit or mean bit rate)

There are many possible QoS profiles defined by the combination of attributes. A GPRS operator may support only a limited subset of the possible QoS profiles. The different QoSs introduced for GPRS service have to be mapped on to the IP backbone, trying to respect requirements of different flows in the end-to-end path.

For most of the GPRS operators, a 'best-effort' GPRS service will be offered in the first phase, without the implementation of QoS profiles.

7. Conclusions

GPRS is a big opportunity for GSM operators to reach a real integration between mobile world and data services, in particular for IP services and networks. With GPRS, mobile users can have a real data transport support, where different services can be offered, from e-mail and web browsing to person-to-person services, such as video conferencing and videophone. But the introduction of GPRS in a GSM network is a big challenge for the telecom operator, since new aspects typical of fixed data networks like Frame Relay and IP protocols, IP addressing, support of QoS need to be considered.

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