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QoS in GPRS

Abstract

Mobile telephony has been for many years the most popular application supported by mobile systems such as the Global System for Mobile communications (GSM). Recently, the use of mobile data applications such as the GSM Short Message Service (SMS) has gained popularity. However, the GSM system can only support data services up to 9.6 kbit/s, circuit switched. The General Packet Radio Service (GPRS), developed by the European Telecommunications Standards Institute (ETSI), is a new packet switched data service for GSM that can allow bitrates, theoretically up to 170 kbit/s per user. However, commercial GPRS systems will be able to support rates up to 115 kbit/s. This document presents current developments and research activities in the area of Quality of Service (QoS) provisioning in GPRS Release 1998 and Release 1999. Moreover, new procedures that are used to enable the interworking between the GPRS QoS framework and the IntServ framework and as well the interworking between the GPRS QoS framework and the Diffserv framework are introduced.

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Contents

List of Abbreviations

2G	2nd Generation
3G	3rd Generation
3GPP	3rd Generation Partnership Project
AA	Anonymous Access
APN	Access Point Name
BB	Bandwidth Broker
BSS	Base Station System
BSSAP+	Base Station System Application Part +
BSSGP	Base Station System GPRS Protocol
BVC	BSSGP Virtual Connection
BTS	Base Transceiver Station
CAMEL	Customised Applications for Mobile Network Enhanced Logic
CH	Correspondent Host
DHCP	Dynamic Host Configuration Protocol
DNS	Domain Name Server
ETSI	European Telecommunication Standardisation Institute
FA	Foreign Agent
GGSN	Gateway GPRS Support Node
GMM/SM	GPRS Mobility Management and Session Management
GPRS	General Packet Radio Service
GSN	GPRS Support Node
GTP	GPRS Tunnelling Protocol
GW	GateWay
HA	Home Agent
HLR	Home Location Register
HO	HandOver
IETF	Internet Engineering Task Force
IMT2000	International Mobile Telecommunications 2000
IP	Internet Protocol
IP-M	Internet Protocol Multicast
IPR	Intellectual Property Rights
IPv4	IP version 4
IPv6	IP version 6

ISP	Internet Service Provider
ITU	International Telecommunication Union
LLC	Logical Link Control
MAC	Medium Access Control
MIP	Mobile IP
MN	Mobile Node
MM	Mobility Management
MTP2	Message Transfer Part layer 2
MTP3	Message Transfer Part layer 3
MS	Mobile Station
MT	Mobile Terminal
MIPv4	Mobile IP version 4
MIPv6	Mobile IP version 6
NS	Network Service
NSAPI	Network layer Service Access Point Identifier
NSS	Network SubSystem
PDCH	Packet Data CHannels
PDN	Packet Data Network
PDP	Packet Data Protocol, e.g., IP or X.25
PDP (2)	Policy Decission Point, this term is used in the Diffserv concept
PDU	Protocol Data Unit
PEP	Policy Enhancement Point
PHB	Per Hop Behavior
PPP	Point to Point Protocol
PTM	Point To Multipoint
PTM-M	PTM-Multicast
PTM-G	PTM-Group
PTP	Point To Point
QoS	Quality of Service
RFC	Request For Comments
RLC	Radio Link Control
RR	Radio Resource
RSVP	Resource Reservation Protocol
SAP	Service Accee Point

SAPI	Service Access Point Identifier
SGSN	Serving GPRS Support Node
SLA	Service Level Agreement
SLS	Service Level Specification
SNDC	SubNetwork Dependent Convergence
SNDCP	SubNetwork Dependent Convergence Protocol
TBF	Temporary Block Flow
TCAP	Transaction Capabilities Application Part
TCP	Transmission Control Protocol
TFI	Temporary Flow Identity
TE	Terminal Equipment
TI	Transaction Identifier
TID	Tunnel Identifier
TLLI	Temporary Logical Link Identifier
UDP	User Datagram Protocol
UMTS	Universal Mobile Telecommunication System
VLR	Visitor Location Register
W-LAN	Wireless – Local Area Network

1 Introduction

Until recently, the main application of the most mobile systems, e.g., Global System for Mobile communications (GSM), has been mobile telephony. Recently, the use of mobile data applications such as the GSM Short Message Service (SMS) has gained popularity. However, the GSM system can only support data services up to 9.6 kbit/s, circuit switched. The General Packet Radio Service (GPRS) (see e.g., [GSM02.60], [3GPP22.060], [CaGo97]) developed by the European Telecommunications Standards Institute (ETSI), provides packet switched services in a GSM network that can allow bitrates, theoretically up to 170 kbit/s per user. However, commercial GPRS systems will support a maximum bit rate of 115 kbit/s. Furthermore, GPRS is able to provide additional features such as:

- more efficient use of scarce radio resources;
- faster set-up / access times;
- connectivity to other external packet data networks by using IPv4 [RFC791] or [RFC2460] or X.25 [X25].
- user differentiation based on Quality of service (QoS) agreements;

In [HoMe98] and [KaMe99], by using simulation and in [ArBi98] by using analytical modelling, is shown that GPRS is suitable to support TCP/IP bursty traffic. GPRS compared to circuit switched networks, allows a better utilisation and end-to-end delay for bursty traffic.

This document, in general, presents recent developments and research activities in the area of QoS provisioning in GPRS Release 1998 and Release 1999. The main difference between GPRS Release 1998 and GPRS Release 1999 is that the first one is capable of supporting GPRS access networks while the later one additionally is capable of supporting Universal Mobile Telecommunications System (UMTS) access networks. Furthermore, the QoS management principles used for GPRS Release 1999 are similar to the ones used for UMTS Release 1999.

In particular, this document emphasises the developments and QoS research topics [ZeAi99] on the integration of the Integrated Services [Intserv] and Differentiated Services [Diffserv] with GPRS. Furthermore, we introduce new procedures that will enable the GPRS technology to support the Intserv and/or Diffserv QoS frameworks.

In this document it is assumed that the reader is familiar with the GPRS, TCP/IP protocol stack, and Integrated and Differentiated Services frameworks.

All the ETSI GPRS specifications used in this document are referring to the GPRS Release 1998. The 3GPP GPRS specifications are referring to the GPRS Release 1999.

The organisation of this document is as follows. Section 3 presents the current status of the GPRS system (Release 1998 and Release 1999). Section 4 describes the QoS management and mobility support provisioning in GPRS. Sections 5 and 6 describe how the Integrated Services requirements and the Differentiated Services requirements, respectively, are fulfilled by GPRS. These requirements are specified in [ZeAi99]. Finally, the conclusions are presented in Section 7. Note that the existing IPRs (Intellectual Property Rights) on QoS over GPRS are listed in [ZeAi99]. Moreover, note that the ideas proposed in this document by the authors do not imply any kind of Ericsson strategy.

2 Terminology

2.1 Glossary used in GPRS

Note that, parts of this section are copied from [GSM 2.60].

[..

access delay: The value of elapsed time between an access request and a successful access.

accuracy: A performance criterion that describes the degree of correctness with which a function is performed..

bearer service: A type of telecommunication service that provides the capability for the transmission of signals between user-network interfaces.

best effort service: A service model which provides minimal performance guarantees, allowing an unspecified variance in the measured performance criteria.

broadcast: A value of the service attribute "communication configuration", which denotes unidirectional distribution to all users.

calling user: Entity which originates a call to the General Packet Radio Service (GPRS).

connectionless service: A service which allows the transfer of information among service users without the need for end-to-end call establishment procedures.

dependability: A performance criterion that describes the degree of certainty (or surety) with which a function is performed regardless of speed or accuracy, but within a given observational interval.

destination user: Entity to which calls to the General Packet Radio Service (GPRS) are directed.

distribution service: Service characterised by the unidirectional flow of information from a given point in the network to other (multiple) locations.

functional group: A set of functions that may be performed by a single equipment.

geographical routing: The conversion of the PDU's geographical area definition, which specifies the area in which the PDU will be broadcast, into an equivalent radio coverage map.

group: A set of members allowed to participate in the group call service. The group is defined by a set of rules that identifies a collection of members implicitly or explicitly. These rules may associate members for the purpose of participating in a group call, or may associate members who do not participate in data transfer but do participate in management, security, control, or accounting for the group.

guaranteed service: A service model which provides highly reliable performance, with little or no variance in the measured performance criteria.

interactive service: A service which provides the means for bi-directional exchange of information between users. Interactive services are divided into three classes of services: conversational services, messaging services and retrieval services.

mean bit rate: A measure of throughput. The average (mean) bit rate available to the user for the given period of time.

mean transit delay: The average transit delay experienced by a (typically) large sample of PDUs within the same service category.

mobile station: Equipment intended to access a set of GSM PLMN telecommunication services. Services may be accessed while the equipment capable of surface movement within the GSM system area is in motion or during halts at unspecified points .

mobile termination: The part of the mobile station which terminates the radio transmission to and from the network and adapts terminal equipment capabilities to those of the radio transmission.

multicast service: A unidirectional PTM service in which a message is transmitted from a single source entity to all subscribers currently located within a geographical area. The message contains a group identifier indicating whether the message is of interest to all subscribers or to only the subset of subscribers belonging to a specific multicast group.

multipoint: A value of the service attribute "communication configuration", which denotes that the communication involves more than two network terminations;

network connection: An association established by a network layer between two users for the transfer of data, which provides explicit identification of a set of network data transmissions and agreement concerning the services to be provided by the set.

network operator: Entity which provides the network operating elements and resources for the execution of the General Packet Radio Service (GPRS).

network service data unit (NSDU): A unit of data passed between the user and the GPRS network across a Network Service Access Point (NSAP).

network termination: A functional group on the network side of a user-network.

packet data protocol (PDP): Any protocol which transmits data as discrete units known as packets, e.g., IP, or X.25.

] [GSM 2.60]

PDP (2) (Policy Decission Point): is an enity specified in the Diffserv concept which is responsible for determining the actions that are applicable to packets. The PDP is used to control the actions that are performed by the Policy Enforcement Points (PEP). PEP is usual located in a Diffserv node and is responsible for the enforcement and execution of the policy actions.

PDP context (applied for GPRS Release 1998): information sets held in MS, SGSN and GGSN that are used to specify the tight connection between one PDP address that identifies an application, a PDP type and one QoS profile.

[..

Ericsson's proposed PDF context: is affiliated to an established PDP context and identifies a data flow of one or several application flow(s). The PDF context consists mainly of a PDF context identifier a QoS profile and optionally of a flow template. PDF contexts provide transmission capabilities for either symmetric or asymmetric flows. An asymmetric PDF context can either be up-link or down-link biased, as indicated by the QoS attributes affiliated to it.

Ericsson's proposed PDP context: is a logical connection from an MS to a packet data network (i.e. ISP, Intranet or LAN) consisting of a PDP (IP) address, host configuration parameters, tunnel identifiers, etc. A PDP context contains at least one PDF context, the *initial* PDF context.
Note that a PDP context with it's initial PDF context corresponds exactly to a PDP context as specified within the PDP context in GPRS Release 1998.**] [SMG12 C-99-460].**

PDP context (applied for GPRS Release 1999 and UMTS Release 1999): information sets held in MS, SGSN and GGSN that are used to specify the tight connection between one subscriber that identifies an application, a PDP type and one QoS profile. More PDP contexts with different QoS parameters can share the same PDP address. In order to activate PDP contexts two types of procedures can be used. The first procedure, called Activate PDP Context includes subscription checking, APN selection, and host configuration. The second procedure, called Secondary Activate PDP Context procedure may be used to activate a PDP context while reusing the PDP address and other PDP Context information from an already existing PDP Context, but with a different QoS Profile. The later procedure can be repeated. Note that at least one PDP context shall be activated for a PDP address before a Secondary PDP Context Activation procedure may be initiated. The “first” PDP context, defined for GPRS Release 1999 is similar to the PDP Context defined in Ericsson’s proposal. The Secondary PDP Context (s) are similar to the PDF Context (s) defined in Ericsson’s proposal. Furthermore, note that the Release 1999 of the Universal Mobile Telecommunications System (UMTS) uses the same PDP context principles as the Release 1999 of the GPRS system.

[..

packet transfer mode: Also known as packet mode. A transfer mode in which the transmission and switching functions are achieved by packet oriented techniques, so as to dynamically share network transmission and switching resources between a multiplicity of connections;

peak bit rate: A measure of throughput. The maximum bit rate offered to the user for a given time period (to be defined) for the transfer of a bursty signal.

point-to-multipoint (PTM) service: A service type in which data is sent to ”all service subscribers or a pre-defined subset of all subscribers” within an area defined by the Service Requester.

point-to-point (PTP): A value of the service attribute "communication configuration", which denotes that the communication involves only two network terminations.

point-to-point (PTP) service: A service type in which data is sent from a single network termination to another network termination.

protocol: A formal set of procedures that are adopted to ensure communication between two or more functions within the same layer of a hierarchy of functions;

quality of service: The collective effect of service performances which determine the degree of satisfaction of a user of the service. The set of performance parameters that can be directly observed and measured at the point at which the service is accessed by the user. There are three criteria by which performance is measured: speed, accuracy and dependability.

reference configuration: A combination of functional groups and reference points that shows possible network arrangements.

reference point: A conceptual point at the conjunction of two non-overlapping functional groups.

service access point (SAP): In the reference model for OSI, the points through which services are offered to an adjacent higher layer.

service attribute: A specified characteristic of a telecommunication service.

service bit rate: The bit rate that is available to a user for the transfer of user.

service category or service class: A service offered to the users described by a set of performance parameters and their specified values, limits or ranges. The set of parameters provides a comprehensive description of the service capability.

service data unit (SDU): In the reference model for OSI, an amount of information whose identity is preserved when transferred between peer (N+1)-layer entities and which is not interpreted by the supporting (N)-layer entities (source: ITU-T X.200 / ISO-IEC 7498-1).

service delay: The time elapsed from the invocation of the service request, to the corresponding service request indication at the Service Receiver, indicating the arrival of application data.

service provider: Entity which offers the General Packet Radio Service (GPRS) for subscription. The network operator may be the service provider.

service receiver: The entity which receives the service request indication primitive, containing the SDU.

service request: This is defined as being one invocation of the service through a service request primitive.

service subscriber: Entity which subscribes to the General Packet Radio Service (GPRS) service.

signalling: The exchange of information specifically concerned with the establishment and control of connections, and with management, in a telecommunications network (source: ITU-T I.112).

terminal equipment: Equipment that provides the functions necessary for the operation of the access protocols by the user. A functional group on the user side of a user-network interface.

throughput: A parameter describing service speed. The number of data bits successfully transferred in one direction between specified reference points per unit time.**] [GSM 2.60]**

[.. Ericsson's proposed Traffic Flow Template (TFT): specifies how to identify the traffic as well as the rules for policing. It may be affiliated to a PDF context and is applicable for PDP-types IP and PPP. The initial PDF context in a PDP context does not have a TFT, while further PDF contexts must have a TFT affiliated to them.**] [SMG12 C-99-460]**

[..

GPRS Release 1999 (and UMTS Release 1999) - Traffic Flow Template: TFTs are used by GGSN to distinguish between different user payload packets and transmit packets with different QoS requirements via different PDP context but to the same PDP address.] **[3GPP29.060].**

[..

transit delay: A parameter describing service speed. The time difference between the instant at which the first bit of a protocol data unit (PDU) crosses one designated boundary (reference point), and the instant at which the last bit of the PDU crosses a second designated boundary (source: ITU-T I.113).

user access or user network access: The means by which a user is connected to a telecommunication network in order to use the services and/or facilities of that network.

user-network interface: The interface between the terminal equipment and a network termination at which interface the access protocols apply.

user-user protocol: A protocol that is adopted between two or more users in order to ensure communication between them.

variable bit rate service: A type of telecommunication service characterised by a service bit rate specified by statistically expressed parameters which allow the bit rate to vary within defined limits.

] [GSM 2.60]
RLC/MAC control block: A RLC/MAC control block is the part of a RLC/MAC block carrying a control message between RLC/MAC entities (see subclause 10.3).

RR connection: An RR (Radio Resource) connection is a physical connection established between a mobile station and the network to support the upper layers' exchange of information flows. An RR connection is maintained and released by the two peer entities.
RLC data block: A RLC data block is the part of a RLC/MAC block carrying user data or upper layers' signalling data (see subclause 10.2).
Temporary Block Flow (TBF): A Temporary Block Flow (TBF) is used in the RLC/MAC layer and it represents a physical connection used by the two RR (Radio Resource) peer entities to support the unidirectional transfer of LLC PDUs on packet data physical channels. A TBF is temporary and is maintained only for the duration of the data transfer.
TBF abort: The term "abort" as applied to TBF is used when the TBF is abruptly stopped without using the Release of TBF procedures defined in clause 9.
TBF release: The term "release" as applied to TBF is used when the TBF is stopped using one of the Release of TBF procedures defined in clause 9.
Uplink State Flag (USF): The Uplink State Flag (USF) is used on PDCH channel(s) to allow multiplexing of uplink Radio blocks from different mobile stations.

[..

Mapper/translator: is a function that has to play two roles in the edge devices. The first role is the translation between the QoS parameters of the external networks and the QoS attributes of GPRS. The GPRS QoS attributes determine the characteristics of the PDF contexts between the MS and the GGSN. The second role is the classification of packets at the ingress interface and the selection of the correct PDF context to carry each packet. This role is identical to what is described as packet classifier in IP networks.

Monitor: Monitor function measures the amount and characteristics of the traffic. The output of this function is used by the policer function to determine its actions. This functionality is identical to what is described as packet or traffic metering in IP networks.

Policer: Policer function ensures that the traffic at the ingress interface does not exceed the negotiated QoS profile including limits such as data rate, or burst size. The output of this function is the traffic stream to be forwarded from the egress interface. Policer function needs to be configurable such that it can take different actions, e.g., dropping, delaying (also called as shaping), or lowering QoS profile (re-marking) for packets identified as non-conformant. The same functionality is used in different IP network QoS frameworks.] (**[SMG12 C99-462]**)

3 GPRS architecture and protocols

3.1 Introduction

Packet data services, e.g., World Wide Web (WWW) and e-mail, mainly generate traffic that is characterized by periods of alternating high and low traffic loads, i.e., bursty traffic. Up to date the GSM service can not provide efficient ways of supporting such traffic. A solution to this issue is given by GPRS, a new mobile technology developed by ETSI, that can provide an optimal sharing of the available radio resources. These resources are allocated dynamically to the different GPRS users depending on their demands, e.g., delay, and on the provided network and end-terminal capabilities.

An extra advantage of GPRS compared to a circuit switched mobile technology, e.g., GSM, is that it provides the possibility to a user to be online connected to the network without being charged for the time it remains in that situation provided that no bandwidth is used. Furthermore, GPRS can provide besides Point to Point (PTP) also Point to Multipoint (PTM) services. The main feature of a PTM service is that it forwards a single packet to multiple receivers. This forwarding process can be accomplished in two different ways. It can be either multicasted, i.e., sent to all receivers located in a geographical area, referred to as PTM-M (PTM-Multicast), IP-M (Internet Protocol Multicast) or forwarded to a predefined group (mainly independent of their geographical location), referred to as PTM-G (PTM-Group).

This section describes the GPRS network architectures for Release 1998 and Release 1999. Moreover, it presents the signaling and transmission protocols used in GPRS.

3.2 Network Architecture

The packet switched GPRS (Releases 1998 and 1999) service can co-exist with the circuit switched GSM service and therefore, it can utilise the existing GSM physical nodes (see Figure 3-1). However, additional physical nodes are required to support the GPRS functionality. These are the Gateway GPRS Support Node (GGSN) and the Supporting GPRS Support Node (SGSN). Note that the names of the interfaces between the physical nodes are identical to the ones used in the GPRS standards.

GSM based physical nodes

BSS Base Station Subsystem (BTS + BSC)
BSC Base Station Controller
BTS Base Transceiver Station
EIR Equipment Identity Register
HLR Home Location Register
MSC Mobile Switching Centre
MS Mobile Station
MT Mobile Terminal
TE Terminal Equipment
VLR Visitor Location Register

Specific (new) GPRS nodes

GSN GPRS Support Node
GGSN Gateway GSN
SGSN Serving GSN

Others

PDN Packet Data Network
PLMN Public Land Mobile Network

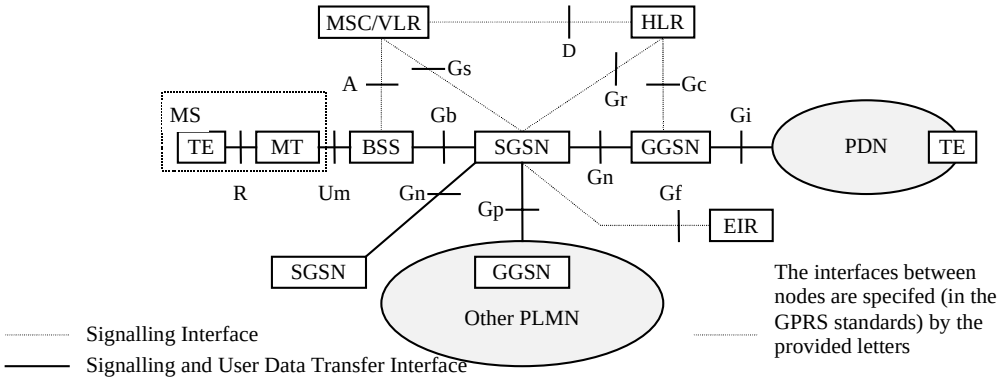

Figure 3-1: GPRS system architecture

The SGSN physical entity is in general responsible for the communication between the GPRS network and all the GPRS users located within its service area. It supports the mobility management (among others storing the Visitors Location Register (VLR), the visitors user profile (International Mobile Subscriber Identity) and the Packet Data Protocol (PDP) context), security management (i.e., authentication and ciphering), charging information and logical link management for each Mobile Station (MS) that is roaming in its service area. A PDP is representing the network protocol used by an external Packet Data Network (PDN) that is interfacing to GPRS. The PDP context represents the relation between a PDP (e.g., IP) address, PDP type (i.e., static or dynamic address), the address of a GGSN that serves as an access point to an external PDN, and a Quality of Service (QoS) profile. The PDP context is stored in the MS, SGSN and GGSN.

The GGSN is the gateway towards external networks, such as GPRS networks operated by different network operators, IP and X.25 networks. It can translate data formats, signalling protocols and address information to allow communication among different networks. Furthermore, the GGSN can provide dynamic allocation of network (e.g., IP) addresses.
The Home Location Register (HLR) contains GPRS subscription, e.g., user profile, and routing information that is mainly used to locate a GPRS subscriber.
The Visitor Location Register (VLR) is a location register that is used in a GSM circuit switched topology, to store location information for a roaming mobile station currently located in its area. Note that in GPRS the fucntionality of the VLR is accomplished by the SGSN.
The Mobile-services Switching Centre (MSC) is used in a GSM circuit switched topology and provides an interface between the GSM radio system and the fixed networks, performing all necessary functions in order to handle the calls to and from the mobile stations.
Similar to VLR and MSC the Equipment Identity Register (EIR) is used in a GSM circuit switched topology and it stores the International Mobile Equipment Identities (IMEIs) information.
The entities MSC and EIR are used in GPRS only for the situations that both circuit switched and packet data services are supported.

The Mobile Station consists of two entities, the Terminal Equipment (TE) and the Mobile Terminal (MT). TE is supporting the exchange of application layer messages with other end user terminals residing in different networks. The main functionality of MT is to manage the terminal capabilities and the radio transmission, e.g., speech encoding/decoding, flow control of signaling and user data and rate adaptation of user data.

3.3 GPRS transmission plane protocol stack

The transmission plane is used to transfer the user data information among the different GPRS physical nodes. The protocol stack used by the GPRS (Releases 1998 and 1999) transmission plane is shown in Figure 3-2. The following protocols can be identified:

- the Application layer transfers application based information among end points (e.g., MS).
- IP (or X25) layers are used as network layers.
- the GPRS Tunnelling Protocol (GTP), specified in [GSM 09.60] and [3GPP29.060], is able to tunnel signalling and user data between the GPRS Support Nodes (i.e., GGSN, SGSN);

- the network-level characteristics, including the QoS profiles, are mapped onto the characteristics of the underlying network (see Figure 3-3) by the Subnetwork Dependent Convergence Protocol (SNDCP) layer, specified in [GSM 04.65]. The Logical Link Control (LLC) layer it may support the SNDCP layer or a signalling and session layer. SNDCP, can support a set of different protocol entities, i.e., PDPs, that consists of commonly used network protocols. Furthermore, the SNDCP entity performs multiplexing of data coming from different PDP entities to be sent using the service provided by the LLC layer. The Service Access Point used by the PDP to interact with the SNDCP is called Network Service Access Point Identifier (NSAPI). This is an index to the PDP context of the PDP. Each active NSAPI has to use the services provided by the Service Access Point Identifier (SAPI) in the LLC layer. Furthermore each active SAPI will use the services provided by theTemporary Logical Link Identifier (TLLI) in the Radio Link Control (RLC) / Medium Access Control (MAC) or Base Station System GPRS Protocol (BSSGP).
- the reliability of the underlying logical link is managed by the Logical Link Control (LLC) layer, specified in [GSM 04.64];
- the Base Station System GPRS Protocol (BSSGP) layer specified in [GSM 08.18] performs the transfer of QoS related information and routing between BSS and the SGSN physical nodes. Error correction is not performed by this layer;
- the Radio Link Control (RLC) / Medium Access Control (MAC) layer consists of the RLC and MAC sub-layers. RLC is specified in [GSM 04.60] and it provides a reliable radio link. The MAC, specified in [GSM 04.60], controls radio access signalling procedures, e.g., request and grant. Furthermore, it maps the LLC frames onto the GSM channels. The RLC/MAC layer is a bitmap-based selective ARQ (Automatic Repeat reQuest) type protocol with a slotted ALOHA random-access based packet reservation for uplink transmission. More than one time slots can be used by one MS for packet data transfer.
- in the BSS and SGSN physical nodes interworking functions (Relays) between the RLC and BSSGP and between SNDCP and GTP respectively are required;
- the BSSGP packet data units (PDU) are transferred between the BSS and SGSN by the Network Service (NS) layer, specified in [GSM 08.16] and is based on Frame Relay technology;
- the GPRS radio physical layer (see [GSM 04.60]) consists of two layers. One of them is the Physical Link Layer (PLL), that is providing radio physical channels between the MS and BSS. The other layer is the Physical RF layer (RFL) and is mainly providing modulation and demodulation.

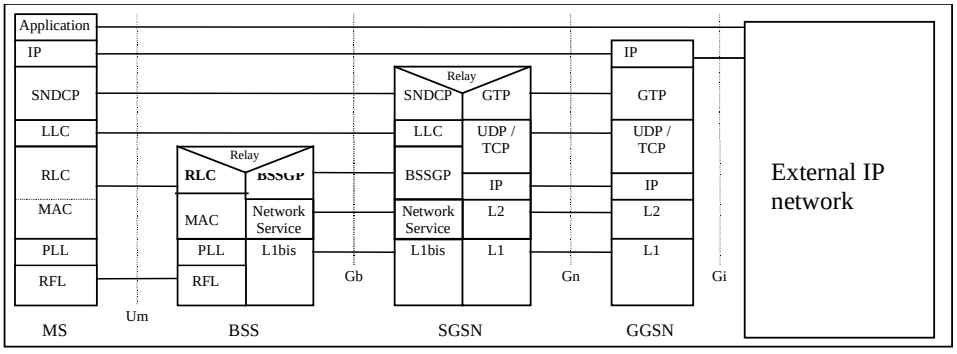

Figure 3-2: GPRS transmission plane protocol stack

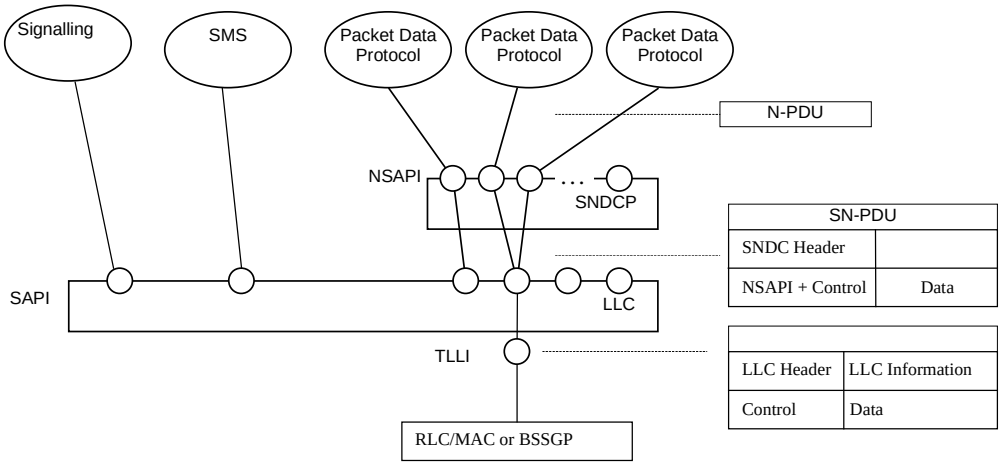

Figure 3-3: Mapping of network level characteristics to underlying network level characteristics

3.4 GPRS signalling plane protocol stack

The signalling plane, is used to transfer signalling information between the different GPRS physical nodes. The main GPRS functions that are supported by the signalling plane are related to network access control, e.g., QoS (Quality of Service) management, packet routing and transfer, mobility management, and radio resource management. The complete list of the functions that are supported by GPRS (Releases 1998 and 1999) and their mapping to the GPRS logical architecture is given in Table 3-1. The GPRS signalling plane protocol stack can be separated in the following signalling plane parts:

- between MS and SGSN, described in Section 3.4.1;
- between SGSN and HLR, described in Section 3.4.2;
- between SGSN and MSC/VLR, described in Section 3.4.3;
- between GPRS Supporting Nodes (GSNs), described in Section 3.4.4. Note that the GSN nodes can be either SGSN or GGSN;
- between GGSN and HLR, described in Section 3.4.5.

Function	MS	BSS	SGSN	GGSN	HLR
Network Access Control:					
Registration					X
Authentication and Authorisation	X		X		X
Admission Control	X	X	X		
Message Screening				X	
Packet Terminal Adaptation	X				
Charging Data Collection			X	X	
Packet Routeing & Transfer:					
Relay	X	X	X	X	
Routeing	X	X	X	X	
Address Translation and Mapping	X		X	X	
Encapsulation	X		X	X	
Tunnelling			X	X	
Compression	X		X		
Ciphering	X		X		X
Mobility Management:	X		X	X	X
Logical Link Management:					
Logical Link Establishment	X		X		
Logical Link Maintenance	X		X		
Logical Link Release	X		X		
Radio Resource Management:					
U_m Management	X	X			
Cell Selection	X	X			
U_m-Tranx	X	X			
Path Management		X	X		

Table 3-1: Mapping of functions to Logical Architecture (based on [GSM03.60] and [3GPP23.060])

3.4.1 Signalling plane MS – SGSN

The signalling plane protocol stack used between the MS and SGSN consists of the protocol layers depicted in Figure 3-4. Except the GPRS Mobility Management and Session Management (GMM/SM) layer, all other layers depicted in Figure 3-4 are described in Section 3.3.

The GMM/SM layer is described in [GSM 03.60], [3GPP23.060] and it supports mobility management procedures, such as GPRS attach and detach, security, routing area update, location update and PDP context activation, modification and deactivation. Note that the PDP specifies a protocol that is used by an external packet data network interfacing to GPRS. Furthermore, the PDP context represents the information sets that are stored and held in the MS, SGSN and GGSN. These information sets mainly contain the required information that has to be used during the mobility management and QoS management, e.g., QoS profiles (see Section 4).

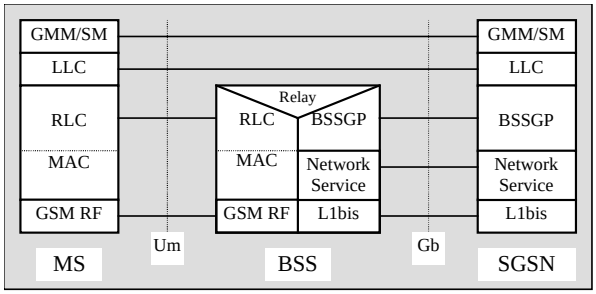

Figure 3-4: Signalling plane between MS - SGSN

3.4.2 Signalling plane SGSN – HLR and SGSN - EIR

The signalling planes between the SGSN and HLR or SGSN and EIR consists of the protocol layers depicted in Figure 3-5. The protocol layer used at the top of the protocol stack, i.e., Mobile Application Part (MAP) is a specific GSM / GPRS layer. The layers used below the MAP layer are Signalling System 7 (SS7) protocol layers specified by the International Telecommunication Union (ITU).

- the Mobile Application Part (MAP) layer is specified in [GSM 09.02], with enhancements that are described in [GSM 03.60] and is providing the support of mainly mobility management signalling exchange between the SGSN and HLR;
- the Message Transfer Part (MTP) layer is specified in [ITU: Q701] and it consists of three levels, MTP1, MTP2 and MTP3. MTP1 corresponds to the physical layer and it provides bidirectional transmission path for signalling. MTP2 is a data link layer and it provides error detection, correction and monitoring as well as flow control. MTP3 realises the signalling message handling and the signalling network management functions. The signalling message handling function manages the interaction between signalling points and messages. The signalling network management function is responsible for network management in e.g., situations of signalling link failures.
- the Transaction Capabilities Application Part (TCAP) layer is specified in [ITU: Q771], [ITU: Q772], [ITU: Q773] and [ITU: Q774] and it realises the dialog between applications running on different nodes through a query/ response interaction.
- the Signalling Connection Control Part (SCCP) layer is specified in [ITU: Q711], [ITU: Q712], [ITU: Q713] and [ITU: Q714] and it extends the MTP3 addressing capabilities by identifying and delivering messages to SCCP users and translating the logical addresses to MTP3 parameters.
- the L1 layer represents the MTP1 physical layer.

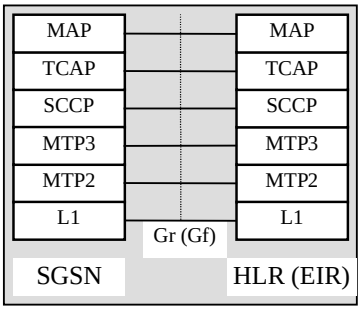

Figure 3-5: Signalling plane between SGSN – HLR or SGSN – EIR

3.4.3 Signalling plane SGSN – MSC/VLR

Figure 3-6 shows the protocol stack used to support the signalling exchange between SGSN and MSC/VLR. This signalling exchange is applied for the situation that the GPRS system is able to co-operate with a GSM circuit switched network. Compared to the protocol stack described in Section 3.4.2, this protocol uses in place of the MAP protocol layer, the Base Station System Application Part + (BSSAP+). This protocol layer specified in [GSM 03.60] and [3GPP23.060] is an enhanced version of the BSSAP layer specified in [GSM 09.18] and it mainly supports mobility management signalling between the SGSN and MSC/VLR when the co-ordination between GPRS and conventional GSM functions is necessary.

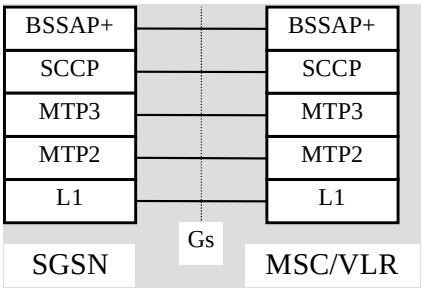

Figure 3-6: Signalling plane between SGSN and MSC/VLR

3.4.4 Signalling plane GSN – GSN

The protocol layers used for signalling exchange between either two GGSN's or between two SGSN's or between one SGSN and one GGSN are depicted in Figure 3-7. The GPRS Tunnelling Protocol (GTP) supports multiprotocol signalling (and user data) to be tunnelled through the GPRS network between GSN's. A GTP tunnel is required to transfer packets from an external network to the MS. This tunnel is characterised by two PDP contexts located in different GSN's and is identified by a Tunnel ID. The User Datagram Protocol (UDP) described in [RFC 768] and the Internet protocol (IP) are specified by the Internet Engineering Task Force (IETF).

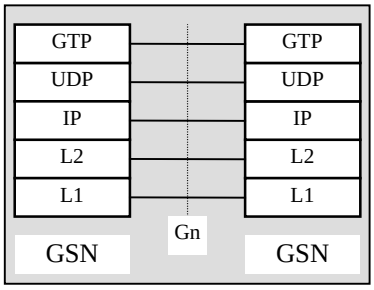

Figure 3-7: Signalling plane between GSN's

3.4.5 Signalling plane GGSN – HLR

The signalling plane between the GGSN and HLR can be realised in two different manners. The first manner is shown in Figure 3-8, where it is assumed that the SS7 layers described in 3.4.2, are supported by the GGSN. The second manner of realising the signalling plane between the GGSN and HLR is depicted in Figure 3-9, where the originating GGSN does not support the SS7 protocols. The signalling exchange between the originating GGSN and the HLR is accomplished via an intermediate GSN physical node, i.e., SGSN or GGSN. This intermediate node is able to support two protocol stacks, i.e., the one that is supported by the originating GGSN and another one that is SS7 specific.

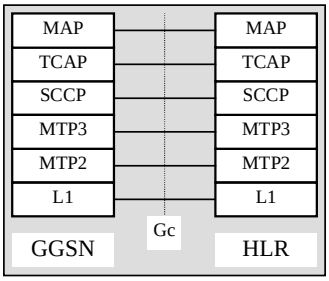

Figure 3-8: Signaling Plane between GGSN and HLR (SS7 available at the GGSN)

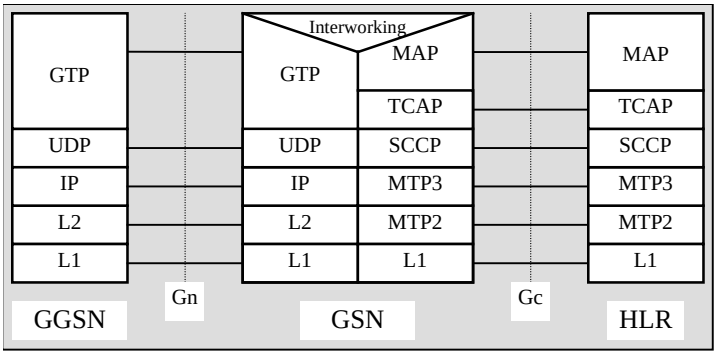

Figure 3-9: Signaling Plane between GGSN and HLR (SS7 is not available at the originating GGSN)

3.5 GPRS air logical channels

The logical channels (see [GSM 04.60], [GSM 03.60] and [3GPP23.060]) used in the GPRS (Releases 1998 and 1999) air interface are briefly described in Table 3-3. These are the following:

- The Packet Common Control Channel (PCCCH) type comprises channels for common control signalling. These are:
  - Packet Random Access Channel (PRACH): used by a MS to initiate an uplink transfer for user data or signalling;
  - Packet Paging Channel (PPCH): the network pages a MS to downlink packet transfer. This can be used for both circuit switched and packet data services;
  - Packet Access Grant Channel (PAGCH): is used only on downlink direction during the packet transfer establishment phase by the network to send resource assignment to an MS before packet transfer;
  - Packet Notification Channel (PNCH): is used only in the downlink direction and is used by the network prior a PTM-M transfer, to send to a group of MS users a PTM-M notification.
- Another type of packet data channel is the Packet Broadcast Control Channel (PBCCH) that is used only in the downlink direction by the network to send data specific System Information.
- The Packet Data Traffic Channel (PDTCH) is allocated for uplink or downlink data transfer.
- The Packet Dedicated Control Channels type consists of the following channels:
  - Packet Associated Control Channel (PACCH) that conveys information, e.g., acknowledgements and Power Control information, related to a given MS.
  - Packet Timing advance Control Channel, uplink (PTCCH/U) is used uplink to transmit random access bursts to allow estimation of the timing advantage for one MS in packet transfer mode.
  - Packet Timing advance Control Channel, downlink (PTCCH/D) is used by the network to send timing advantage information updates to several MS's.

The Packet Data Traffic Channels (PDTCHs) use four different channel coding schemes, described in [GSM 04.60] to transfer the packet data traffic. Table 3-2 lists the used channel coding schemes and the data rates that can be obtained by using these coding schemes per time slot. The maximum data rate that can be obtained on PDTCH channels is 171.2 kb/s, i.e., *(8 time slots) * (Maximum data rate for CS-4 for a time slot)*.
The logical channels can be mapped in physical channels. This mapping is accomplished either in frequency [GSM 05.05], i.e., partitioned in radio frequency channels (RFCHs), or in Time Division Multiple Access (TDMA) time frames [GSM 05.01], i.e., 8 time slots. On top of the TDMA frames an additional partitioning in complex multiframes is accomplished. For example, for Packet Data Channels (PDCHs), one such multiframe consists of 52 TDMA frames.
The GPRS air interface on uplink and downlink channels can operate in an asymmetric and independent way. For example, in a certain TDMA slot, a PDCH on an uplink channel may transfer the packet data from one certain MS to BSS and furthermore, transfer the downlink packet data from the BSS to another MS.
As mentioned in Section 3.3, the RLC/MAC protocol layer is using a bitmap-selective ARQ type protocol with a slotted ALOHA random-access based packet reservation mechanism for uplink data transfer. By implementing a multislot MAC layer operation, a high flexibility is obtained. One MS can use more than one PDCH (corresponding to one time slot in a TDMA frame) for the packet data transfer. The uplink bandwidth per MS can be varied allocating one to eight time slots in each TDMA frame. This allocation is depending on the multislot capabilities of the MS, the number of available PDCHs and the current system load.

Table 3-2: Channel coding schemes applied per time slot

Channel coding scheme	Data rate kb/s
CS-1	9.05
CS-2	13.4
CS-3	15.6
CS-4	21.4

Table 3-3: GPRS air interface logical channels

Group	Logical channel	Function description	Direction
Packet Data Traffic Channel	PDTCH (Packet Data Traffic Channel)	Data Traffic	MS <-> BSS
Packet Broadcast Control Channel	PBCCH (Packet Broadcast Control Channel)	Broadcast Control	MS <- BSS
Packet Common Control Channel (PCCCH)	PRACH (Packet Random Access Channel)	Random Access	MS -> BSS
	PAGCH (Packet Access Grant Channel)	Access Grant	MS <- BSS

	PPCH (Packet Paging Channel)	Paging	MS <- BSS
	PNCH (Packet Notification Channel)	Notification (for PTM-M on PCCCH)	MS <- BSS
Packet Dedicated Control Channels	PACCH (Packet Associate Control Channel)	Associated Control	MS <-> BSS
	PTCCH (Packet Timing Advance Control Channel)	Timing Advance Control	MS <-> BSS

4 QoS management and Mobility support

4.1 Introduction

The transfer of GPRS (Releases 1998 and 1999) user data is initiated after that several GPRS management functions (see Table 3-1) are successfully carried out.
First of all, a MS can use GPRS services only after it has registered to a SGSN. During this phase, that is called GPRS attach (see [GSM 03.60], [3GPP23.060]), the GPRS user is authorised and a P-TMSI (Packet Temporary Mobile Subscriber Identity) is assigned to this user. Furthermore, the user profile that is stored in the HLR, is copied to the SGSN. The MS registration to the GPRS network, is terminated by using the GPRS Detach procedure.
After performing a GPRS attach procedure an MS can communicate with an external PDN (e.g., IP network) by applying for one PDP address (e.g., IP address). For each session between the external PDN, GPRS network and MS, a PDP context is created.
For GPRS (Release 1998) the PDP context is stored in the MS, SGSN and GGSN and represents the relation between one PDP (e.g., IP) address, PDP type (i.e., static or dynamic address), the address of a GGSN that serves as an access point to an external PDN, and one Quality of Service (QoS) profile. More PDP contexts with different QoS parameters can not share the same PDP address.
For GPRS Release 1999 the PDP context is defined as the information sets held in MS, SGSN and GGSN that are used to specify the tight connection between one subscriber that identifies an application, a PDP type and one QoS profile. In contrary to the GPRS Release 1998, this GPRS release (1999) provides the possibility to a subscriber to use more than one PDP contexts with different QoS parameters and share the same PDP address.
In this section only the GPRS (Release 1998 and Release 1999) QoS management and mobility support procedures will be discussed. For all other GPRS management procedures listed in Table 3-1, see [GSM 03.60] and [3GPP23.060].
The success for the deployment of GPRS will be significantly influenced by the introduction of efficient and variable QoS management and supporting mechanisms. In GPRS, the QoS management can be performed by using the PDP context management procedures, such as PDP context activation, modification and deactivation.

4.2 Mobility support

As already mentioned we consider that the mobility support in GPRS is provided by using the mobility management, cell selection and re-selection that includes the handover procedure and the path (packet) routing.

4.2.1 Mobility management

Mobility management (see [GSM 03.60], [3GPP23.060], [BrWa97]) is used to keep track of the current location of an MS within the home PLMN or within a foreign PLMN.
In GPRS Release 1999 for the situation that an external Packet Data Network (PDN) interconnects one or more GPRS PLMN's an additional mobility method is mentioned [3GPP230.60]. This mobility method is making use of IETF protocols such as Dynamic Host Configuration Protocol (DHCP) [RFC2131] and Mobile IP (MIP) [RFC2002]. In case of DHCP the GGSN provides the function of DHCP Relay Agent [RFC2131] and in the case of MIP the GGSN provides the function of Foreign Agent (FA) [RFC2002]. In this document we will not describe the operation of MIP. Its operation is described in e.g., [Kar99].
The mobility management procedure uses a state machine model that is distributed on each MS and on each SGSN physical node. The model is depicted in Figure 4-1 and it consists of two types of state machines. One of them is used in the MS and the other one is used in the SGSN. Both state machines consist of three states, IDLE, READY and STANDBY. The state machines describe a certain

functionality and store the required information. The information sets that are stored in the MS and SGSN are denoted as Mobility Management (MM) contexts.

In the IDLE state the MS is not attached to the GPRS network. By accomplishing a GPRS Attach procedure the MS or SGSN MM model change to the READY state. The MS and the SGSN establish then, the Mobility Management contexts for their subscribers. In this state the MS informs the SGSN of any movement to a new RA. For the MS MM, the change from the READY to IDLE state is achieved when a GPRS Detach procedure is performed. For the SGSN, the change from the READY to IDLE occurs either if a GPRS Detach procedure occurs or if Cancel Location event occurs.

The MS management model changes from the READY to STANDBY state either if the MS did not sent packets to the SGSN for at least a period of time that is longer than the READY timer or an enforced change of state occurs. For SGSN, the management model changes from READY to STANDBY either if the SGSN did not receive any packets from the MS for a period of time longer than the READY timer or if an enforced change of state occurs or if an abnormal RLC condition occurs

The MS management model changes from the STANDBY to READY state if the MS sends a packet to the SGSN while for the SGSN, this state change occurs when it receives a packet from the MS.

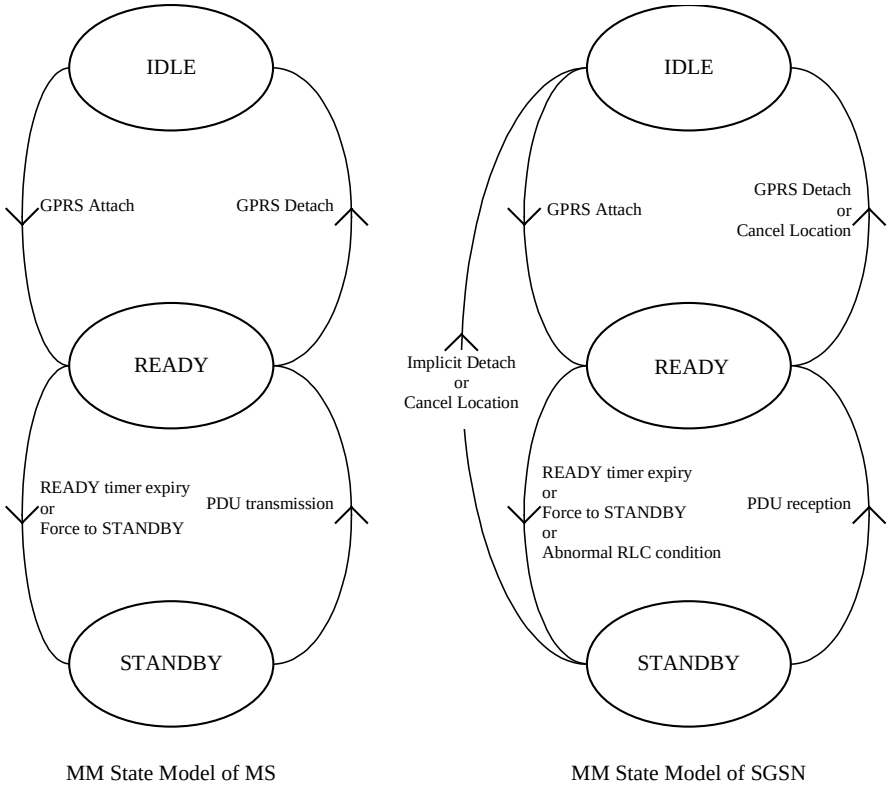

Figure 4-1: Mobility management state model (from [GSM 03.60])

4.2.1.1 Location Management

The GPRS (Releases 1998 and 1999) location management procedure, consists of the location update and paging procedures. The location (or Routing Area) update procedure is used by a roaming MS to inform the GPRS network about its location in an certain area, called Routing Area (RA). Paging is a procedure that is used by the GPRS network to find the exact location of the roaming MS in a RA.

The GPRS covering area consists of several Location Areas (LAs). Each Location Area is managed by one HLR and it consists of one or more RAs. Each RA is managed by one SGSN and it consists of several cells. However, one SGSN may manage more RA's.

Two types of Routing Area updates scenarios can be distinguished, i.e., intra-SGSN and Inter-SGSN RA updates. For Intra-SGSN RA updates the MS is roaming from old to new RA attached to the same SGSN. For Inter-SGSN RA, the MS is roaming from an old RA to a new RA attached to different SGSNs.

Another procedure used in combination with the location management, is the paging procedure (see [GSM03.60] and [3GPP23.060]). This procedure is used by the GPRS network to locate a MS that is located in a certain RA, when another end terminal wishes to communicate with this MS. If the MM context is in Standby state, the paging procedure is initiated by the SGSN in the RA that the MS accomplished the last routing area update procedure.

4.2.2 Cell selection and reselection

The cell selection and reselection procedures (see [GSM 03.60], [3GPP23.060]) are considered to be RR (Radio Resource) management procedures and are used to select or modify the channels allocated to the MS when this MS is either in idle mode or in dedicated mode and is roaming between different cells.

In idle mode, the MS is not allocated any dedicated channel. This mode is for example, applicable for the situations that the MS is not yet attached to the GPRS network.

When the MS can use at least two dedicated channels then the MS is working in a dedicated mode.
In idle mode the MS has to find a suitable cell, and possibly register within the PLMN. This suitable cell should satisfy various requirements (see [GSM 03.22]) before it is selected. These requirements are:

- it should be an accessible cell of the selected PLMN;
- the radio path loss between the MS and the BTS should be less than a certain criterion, set by the PLMN operator.

The selection of such a cell is accomplished by using the cell selection and reselection procedures. Cell reselection is used when a cell fails to satisfy the above given requirements and when another cell is in the vicinity of the MS and it can satisfy these requirements.
In dedicated mode the MS roams from one cell to another by using network-controlled handover procedures [GSM 04.08], i.e., hard handover.
The handover procedure consists of the following actions:

- suspension of normal operation (except for RR management).
- the main signalling link and possibly other links are disconnected, via local end release (layer 2);.
- the previously assigned channels are disconnected (layer 1).
- the new channels are activated and connected;
- triggering of the data link connection establishment on the new channels;

4.2.3 Packet Routing

The procedure that routes the packets in the GPRS system is called packet routing. In order to explain the packet routing, we use the GPRS network scenario depicted in Figure 4-2.

Consider that MS1 roamed from its home domain, i.e., GPRS PLMN1, to GPRS PLMN2. Suppose now that a Terminal Equipment (TE) node attached to an external IP Packet Data Network (PDN) wants to communicate with the MS1. TE sends an IP packet to the IP PDN network, i.e., routing step 1. The addresses of the IP packets will have the same subnet prefix as the address of the GGSN1 that is located in the Home Domain of MS1. Therefore, the IP PDN network will send these IP packets to GGSN1, i.e., routing step 2. GGSN1 queries HLR to find out the RA wherein MS1 is located, i.e., routing step 3. The HLR informs the GGSN about the new location of MS1, i.e., routing step 4. The IP packets are then (GTP) encapsulated by GGSN1 and tunnelled through the Inter-PLMN GPRS network to SGSN2, i.e., routing steps 5 and 6. The SGSN decapsulates the GTP encapsulated IP packets and delivers them to BSS, i.e., routing step 7. The BSS delivers these packets to the MS1, i.e., routing step 8.

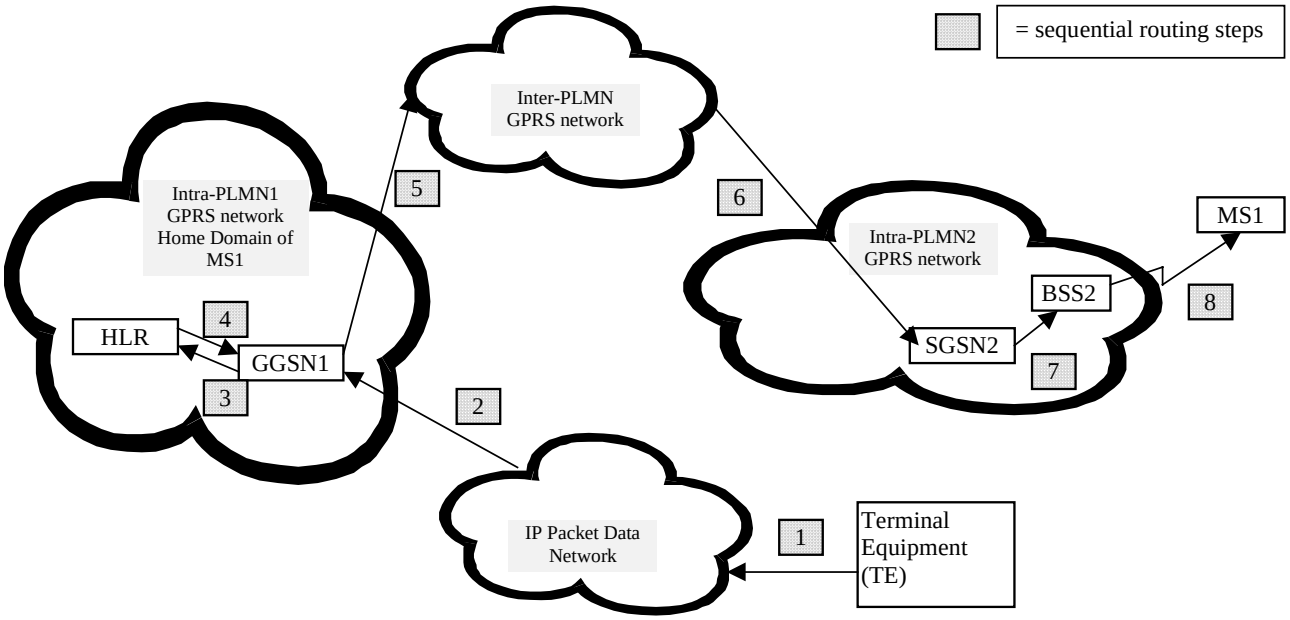

Figure 4-2: Inter-domain routing

4.3 Quality of Service

Quality of Service (QoS) in GPRS (Releases 1998 and 1999) is defined as the collective effect of service performances which determine the degree of satisfaction of a user of the service. QoS enables the differentiation between provided services.
The QoS attributes used in the GPRS Release 1998 and GPRS Release 1999 are similar. The differences between these two QoS attributes are related only to the throughput QoS attributes.

4.3.1 Quality of Service attribuites in GPRS Release 1998

In GPRS Release 1998 five QoS attributes [GPRS 03.60] are therefore defined. These attributes are the precedence class, delay class, reliability class, mean throughput and peak throughput class. By the combination of these attributes many possible QoS profiles can be defined.
Each attribute is negotiated by the MS and the GPRS network. If the negotiated QoS profiles are accepted by both parties then the GPRS network will have to provide adequate resources to support these QoS profiles.
The mapping from the negotiated QoS profiles to available resources is done by the SNDCP layer (see Section 3.3).

The following mechanisms are used by the lower layers to provide the negotiated QoS profiles.
[..
The RLC/MAC layer supports four radio priority levels and an additional level for signalling messages as defined in [GSM 03.64] and [GSM 04.60]. Upon uplink access the MS can indicate one of four priority levels, and whether the cause for the uplink access is user data or signalling message transmission. This information is used by the BSS to determine the radio access precedence (i.e., access priority) and the service precedence (i.e., transfer priority under congested situation), see [GSM 04.60]. The radio priority leves to be used for transmission of MO SMS shall be determined by the SGSN and delivered to the MS in the Attach Accept message. The radio priority level to be used for user data transmission shall be determined by the SGSN based on the negotiated QoS profile and shall be delivered to the MS during the PDP Context Activation and PDP Context Modification procedures.] ([GSM 03.60]).
Each of the above listed QoS attribute can be subdivided in classes.
The Precedence (priority) classes give the opportunity to the GPRS network to assign different priorities to services, such that in case of congestion, services with a higher priority will receive a better treatment. Three levels (calsses) of priorities are applied (see Table 4-1).

Table 4-1: QoS Precedence classes (from [GSM 03.60])

Precedence	Precedence Name	Interpretation
1	High priority	Service commitments shall be maintained ahead of precedence classes 2 and 3.
2	Normal priority	Service commitments shall be maintained ahead of precedence class 3.
3	Low priority	Service commitments shall be maintained after precedence classes 1 and 2.

The reliability classes represent the probabilities of loss, duplication, out of sequence and corrupted packets. The three reliability classes are listed in Table 4-2.

Table 4-2: Reliability classes (from [GSM 02.60])

Reliability class	Lost SDU probability (a)	Duplicate SDU probability	Out of Sequence SDU probability	Corrupt SDU probability (b)	Example of application characteristics.
1	10^{-9}	10^{-9}	10^{-9}	10^{-9}	Error sensitive, no error correction capability, limited error tolerance capability.
2	10^{-4}	10^{-5}	10^{-5}	10^{-6}	Error sensitive, limited error correction capability, good error tolerance capability.
3	10^{-2}	10^{-5}	10^{-5}	10^{-2}	Not error sensitive, error correction capability and/or very good error tolerance capability.

The delay parameter is defined as the end to end transfer time between two MSs or between a MS and the Gi interface (see Figure 3-1) to an external PDN. Two types of delays are specified as QoS parameters. One of them is the mean delay and the other one is the maximum delay in 95% of all transfers. In **Error! Not a valid bookmark self-reference.** four delay classes are listed for two types of SDU (Service Data Unit) sizes, i.e., 128 and 1024 octets.

The throughput parameter defines the mean octet rate per minute and the peak octet rate per second measured at the Gi and R interfaces (see Figure 3-1). The peak throughput and mean throughput classes are listed in Table 4-4 and Table 4-5, respectively.

Table 4-3: Delay classes (from [GSM 02.60])

Delay Class	Delay (maximum values)			
	SDU size: 128 octets		SDU size: 1024 octets	
	Mean Transfer Delay (sec)	95 percentile Delay (sec)	Mean Transfer Delay (sec)	95 percentile Delay (sec)
1. (Predictive)	< 0.5	< 1.5	< 2	< 7
2. (Predictive)	< 5	< 25	< 15	< 75
3. (Predictive)	< 50	< 250	< 75	< 375
4. (Best Effort)	Unspecified			

Table 4-4: Peak throughput classes (from [GSM 03.60])

Peak Throughput Class	Peak Throughput in octets per second
1	Up to 1000 (8 kbit/s).
2	Up to 2000 (16 kbit/s).
3	Up to 4 000 (32 kbit/s).
4	Up to 8 000 (64 kbit/s).
5	Up to 16 000 (128 kbit/s).
6	Up to 32 000 (256 kbit/s).
7	Up to 64 000 (512 kbit/s).
8	Up to 128 000 (1 024 kbit/s).
9	Up to 256 000 (2 048 kbit/s).

Table 4-5: Mean throughput classes (from [GSM 03.60])

Mean Throughput Class	Mean Throughput in octets per hour
1	Best effort.
2	100 (~0.22 bit/s).
3	200 (~0.44 bit/s).
4	500 (~1.11 bit/s).
5	1 000 (~2.2 bit/s).
6	2 000 (~4.4 bit/s).
7	5 000 (~11.1 bit/s).
8	10 000 (~22 bit/s).
9	20 000 (~44 bit/s).
10	50 000 (~111 bit/s).
11	100 000 (~0.22 kbit/s).
12	200 000 (~0.44 kbit/s).
13	500 000 (~1.11 kbit/s).
14	1 000 000 (~2.2 kbit/s).
15	2 000 000 (~4.4 kbit/s).
16	5 000 000 (~11.1 kbit/s).
17	10 000 000 (~22 kbit/s).
18	20 000 000 (~44 kbit/s).
19	50 000 000 (~111 kbit/s).

4.3.2 Quality of Service attribuites in GPRS Release 1999

In GPRS Release 1999 four QoS attributes [3GPP22.060] are therefore defined. These attributes are the service precedence (priority) class, delay class, reliability class, throughput class. The first three classes are identical to the QoS classes defined in GPRS Release 1998. The throughput class is defined by two negotiable parameters: the maximum bit rate and the mean bit rate. The maximum bit

rate will depend on the type of the channel and the number of slots that are used. By the combination of these attributes many possible QoS profiles can be defined.

4.3.3 QoS Management

The QoS profiles and classes can be negotiated and managed by using the mechanisms of PDP context management. In both GPRS Releases (1998 and 1999) the PDP context management procedures are accomplished by the SM (Session Management) applied between MS and SGSN, and by the GTP layer applied between SGSN and GGSN. The European Telecommunications Standardisation Institute (ETSI) has standardised the PDP context management procedures, i.e., activation, modification and deactivation. The procedures specified for the GPRS Release 1998 are specified in [GSM 03.60] and are explained in Section 4.3.3.1. However, Ericsson has proposed within ETSI, new enhanced PDP context management procedures. These are described in [SMG12 C-99-460], [SMG12 C-99-461] and [SMG12 C-99-462]. The main difference between these two PDP context management procedures is related to the way the QoS profiles are assigned and managed. The GPRS Release 1998 PDP context management specifies a tight connection between mainly one PDP address, used to identify an application (not a flow), and one QoS profile. In other words, the PDP context contains the agreed QoS requirements for a particular application. Only one PDP context is assigned to one PDP address. However, more applications that require identical QoS can use the same PDP context and the same PDP address. In the Ericsson's proposal the one PDP context that is identified by one PDP address consists of more PDF (Packet Data Flow) contexts. Each PDF context specifies a tight connection between one flow and one QoS profile. In other words, the PDF context contains the agreed QoS requiremens for a particular flow or application. More PDF contexts may be assigned to one PDP address. This means that more than on applications with different QoS can use different PDF contexts that are identified by the same PDP address. These PDP Context procedures are explained in Section 4.3.3.2.

The new PDP context management procedures proposed by Ericsson, after minor modifications, are introduced in the GPRS Release 1999 and UMTS Release 1999 [3GPP23.060]. These PDP context procedures are explained in Section 4.3.3.3.

4.3.3.1 GPRS Release 1998 PDP context management procedures

A MS needs to be identified with one or more addresses in order to exchange packets with another MS within the GPRS network or with an external PDN. This address is called PDP address, which can be either an IP or an X25 address. The allocation of the addresses can be static or dynamic. In the first situation the HPLMN (Home PLMN) operator assigns a PDP address permanently to the MS. In the second situation, the HPLMN or VPLMN (Visiting PLMN) operator assigns a PDP address to the MS only when a PDP context is activated.

For each session, information sets called PDP contexts, are created and stored in the MS, the SGSN and GGSN. These information sets contain the requested QoS, the PDP type (e.g., IPv4, X25), the PDP address assigned to the MS, e.g., IP address, and the access point name (APN), i.e., the access point address of the GGSN that is used as a gateway (GW) to an external PDN.

In this subsection the GPRS (Release 1998) PDP context management procedures specified in [GSM 03.60] are described. The PDP context can exist independently in one of the two states depicted in Figure 4-3. In the INACTIVE state the data services, e.g., routing information or mapping information, that should be provided by the GPRS network to a certain PDP address are not activated. In the ACTIVE state these data services are activated and can be provided to a subscriber identified by a PDP address. The state model changes from INACTIVE to ACTIVE after performing a PDP Context Activation procedure. The change from ACTIVE to INACTIVE state takes place when either a Deactivate PDP Context procedure is performed or a MM state changes to IDLE.

The PDP Context Activation procedure can be classified depending on which entity is initiating the activation procedure, i.e., MS initiated or network initiated. Moreover, the PDP context activation procedure can be normal or anonymous. In the case of anonymous PDP context activation the user using the PDP context remains unknown to the network. This type of PDP context is used for the situation that e.g., pre-paid services are provided to a user that does not want to be identified.

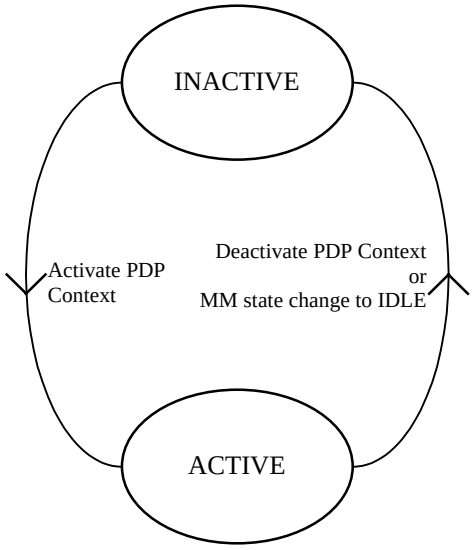

Figure 4-3: Functional PDP State Model (from [GSM 03.60])

Figure 4-4 depicts the normal MS initiated PDP context activation procedure. The MS sends an "Activate PDP Context Request" message to the SGSN. This message contains several information elements, i.e., the QoS Requested that comprises the list with the requested QoS attributes, the Transaction Identifier (TI), the Network Service Access point Identifier (NSAPI), the PDP type (e.g., IPv4, IPv6, X25), the PDP address assigned to the MS, e.g., IP address, the GGSN Access Point name (APN) that is used as a gateway (GW) to an external PDN and the PDP Configuration Options, e.g., optional PDP parameters requested from the GGSN. Note that the PDP address can be static or dynamically allocated. If this address should be dynamically allocated then the PDP address in the "Activate PDP Context Request" message should be left empty, such that the network should be able to assign a dynamic address.

After the SGSN receives this message, security functions (see [GSM 03.20]) are started to authenticate the user that initiated the PDP activation procedure.

The SGSN can accept or reject the request message. If the SGSN accepts the request then a "Create PDP Context Request" message is sent to the GGSN. The information elements contained in this message are similar to the ones contained in the "Activate PDP Context Request" message. The differences are the following. In place of the QoS Requested, the QoS Negotiated information element is sent. Note that the QoS Negotiated information element comprises the list with the agreed QoS attributes. This is done due to the fact that the SGSN may restrict the requested QoS attributes, because of its current capabilities, current load and the subscribed QoS profile. Furthermore, the Tunnel ID (TID) and the Selection Mode information elements are introduced. The TID is created by combining an ID used in the MM context, called IMSI and the NSAPI sent by the MS. The Selection Mode specifies if a subscribed or unsubscribed APN was selected.

The GGSN receiving the “Create PDP Context Request” message can accept it or reject it. The GGSN uses the Selection Mode information element when to decide whether to accept or reject the PDP Activation procedure. Furthermore, GGSN is rejecting the request message if the QoS Negotiated parameters sent by the SGSN are incompatible (i.e., different) with the PDP context being activated (e.g., the reliability class is insufficient to support the PDP type).

If it is accepted, then the GGSN creates a new entry in the PDP context information set and introduces a new information element called Charging ID. This element is used for charging that is based on the transmitted data volume, the type of the service and the chosen QoS profile. Furthermore, The GGSN may further restrict the QoS Negotiated due to current capabilities and current load. The GGSN sends a “Create PDP Context Response” message to the SGSN. Some of the information elements contained in this message differ than those included in the “Create PDP Context Request” message. These are the BB (BackBone) protocol, Reordering Required, Charging ID and Cause. The BB protocol information element specifies either if TCP (Transmission Control Protocol) [RFC793] or UDP (User Datagram Protocol) [RFC768] should be used to transport user data between the SGSN and GGSN. The Reordering Required instructs the SGSN whether it will have or not to reorder the N-PDU packets that will have to be send to the MS used e.g., in case of compression.

The SGSN receiving the “Create PDP Context Response” message, inserts the NSAPI along with the GGSN address in its PDP context information set. The SGSN sends a “Activate PDP Context Accept” message to the MS. This message contains the information elements, PDP type, PDP Address, TI, QoS Negotiated, Radio Priority and PDP Configuration Options. The Radio Priority element is a new information element that is created by using the QoS Negotiated information element. This element is used during the uplink (MS to BTS) radio link communication.

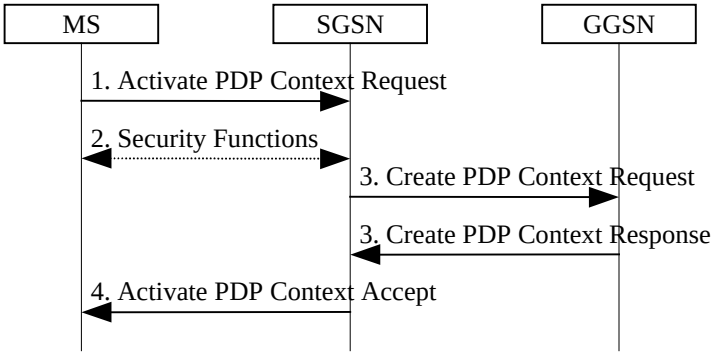

Figure 4-4: PDP Context Activation Procedure (from [GSM 03.60])

There are situations that a PDP PDU sent by an external PDN, is received by a GGSN and it has to be delivered to a PDP address that is not included in any active PDP context. In this situation the GGSN will start a Network-Requested PDP Context Activation procedure (see Figure 4-5). The GGSN, if needed, requests the required routing information for the PDP address from the HLR. If the HLR has the required information then the GGSN can continue the procedure by sending a “PDU Notification Request” message to the SGSN. The SGSN returns a “PDU Notification Response (Cause)” message to the GGSN, informing it that a message will be send to the MS to start the PDP Context activation procedure. Afterwards, the SGSN sends the “Request for PDP Context Activation” message to the MS. The MS is then activating the PDP context, by using the procedure depicted in Figure 4-4.

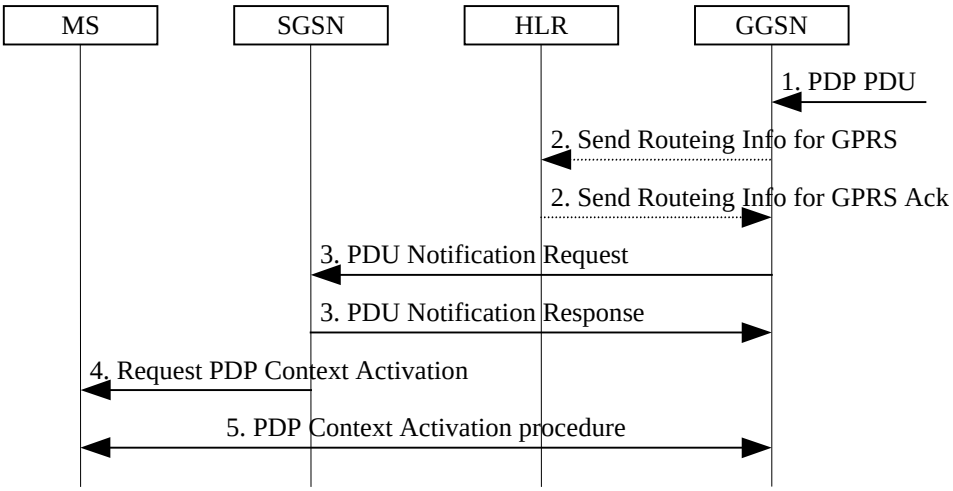

Figure 4-5: Network-Requested PDP Context Activation Procedure (from [GSM 03.60])

The anonymous PDP context activation procedure is depicted in Figure 4-6. The difference between this procedure and the normal PDP context activation procedure, shown in Figure 4-4, is that the security functions are not any more required. Furthermore, the PDP address is dynamically allocated.

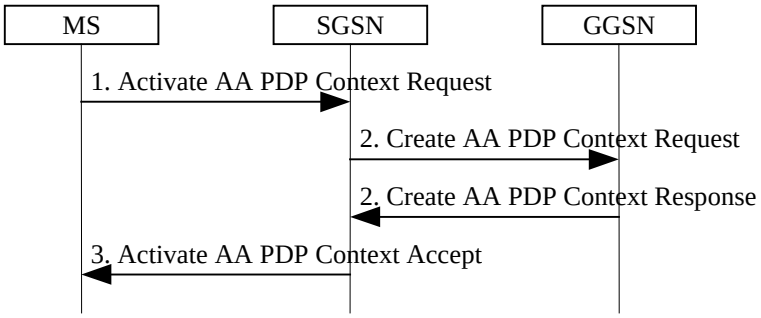

Figure 4-6: Anonymous Access PDP Context Activation Procedure (from [GSM 03.60])

An SGSN, triggered by an MS or HLR, can modify QoS parameters, i.e., QoS Negotiated and Radio Priority, that were negotiated during the PDP Context Activation procedures. The MS can inform the SGSN about changes in subscription data for a subscriber by using the Subscriber Management Function. The PDP Context modification procedure is depicted in Figure 4-7. SGSN requests from the GGSN to update the PDP context. If the GGSN accepts the update then the QoS Negotiated may be changed according to the current capabilities and load of the GGSN and an update response is sent to the SGSN. The SGSN sends a “Modify PDP Context Request” message to the MS, containing the TI, QoS Negotiated and Radio Priority information elements. If the MS accepts this modification then an “Modify PDP Context Accept” message is sent to the SGSN. If the modification is rejected then the MS has to start an PDP Context Deactivation procedure, to deactivate the PDP context.

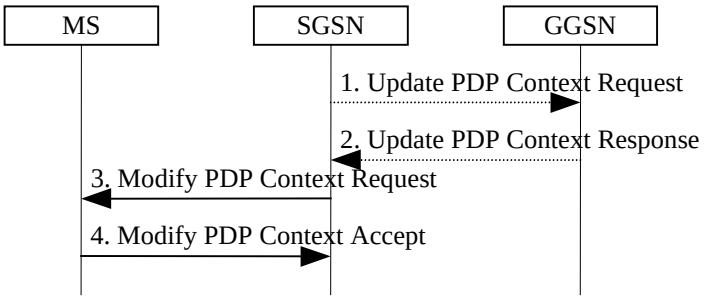

Figure 4-7: PDP Context Modification Procedure (from [GSM 03.60])

The scope of the PDP Context deactivation procedures is to deactivate the PDP context (see Figure 4-8). These procedures can be initiated by the MS, SGSN or GGSN. In the PDP Context Deactivation procedure initiated by MS, depicted in Figure 4-8, the MS sends a “Deactivate PDP Context Request” message to SGSN. The information element contained in this message is the TI information element. Afterwards, security functions may be used. The SGSN sends a “Delete PDP Context Request” message to GGSN. The information element contained in this message is the TID information element. GGSN deletes the PDP context stored locally and sends a “Delete PDP Context Response” message to SGSN. Note that if for the PDP Context a dynamically allocated PDP address has been used, then the GGSN releases this PDP address and makes it available for a new activation by another MS. SGSN, afterwards sends a “Deactivate PDP Context Accept” message to MS. The PDP Context Deactivation procedures depicted in Figure 4-9 and Figure 4-10 are similar to the one depicted in Figure 4-8. The difference is that these procedures are initiated by the SGSN and GGSN, respectively.

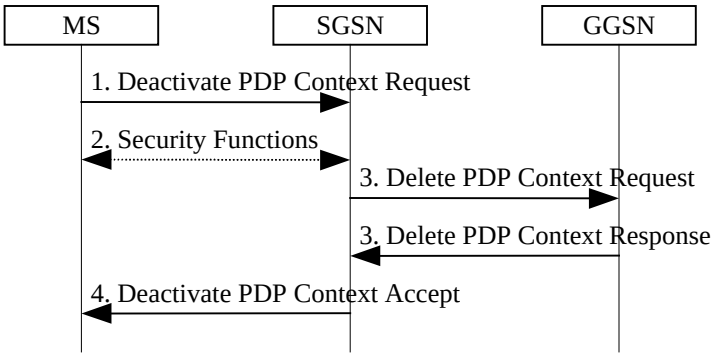

Figure 4-8: PDP Context Deactivation Initiated by MS Procedure (from [GSM 03.60])

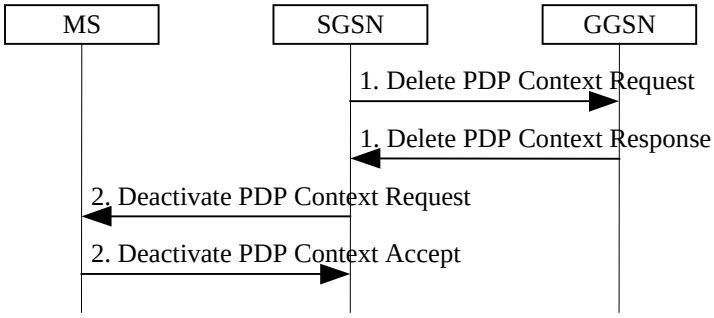

Figure 4-9: PDP Context Deactivation Initiated by SGSN Procedure (from [GSM 03.60])

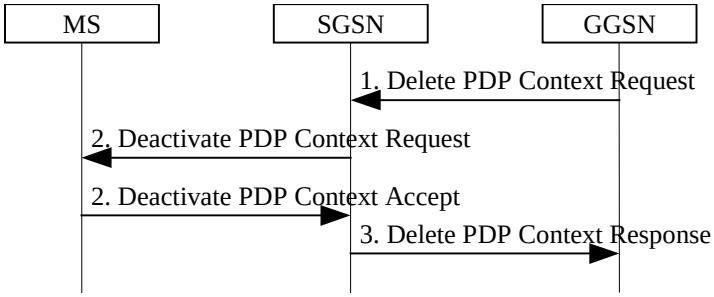

Figure 4-10: PDP Context Deactivation Initiated by GGSN Procedure (from [GSM 03.60])

Figure 4-11 depicts the anonymous PDP Context Deactivation procedure initiated by the MS. The MS informs the SGSN that the (MM) READY timer has been expired. The SGSN sends a “Delete PDP Context Request” message to the GGSN. GGSN deletes the PDP context and releases the PDP address. This PDP address can be activated by another subscriber. Afterwards, the GGSN sends a “Delete PDP Context Response” message to SGSN. The anonymous PDP Context Deactivation procedure initiated by the GGSN is similar to the one initiated by the MS and is depicted in Figure 4-12.

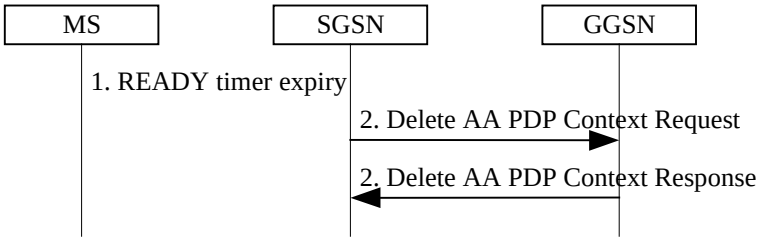

Figure 4-11: Anonymous Access PDP Context Deactivation Initiated by MS Procedure (from [GSM 03.60])

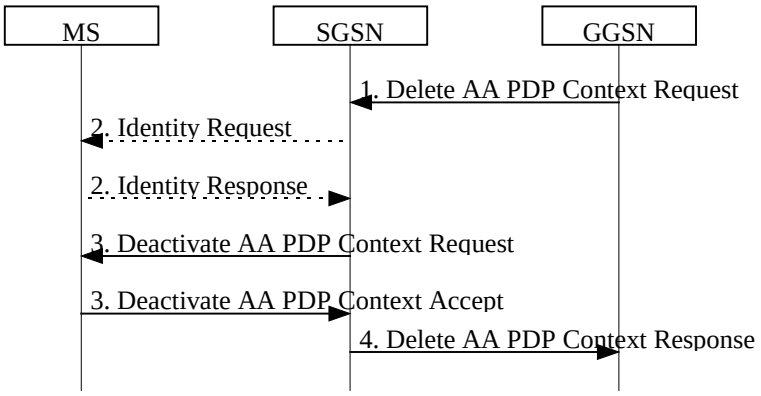

Figure 4-12: Anonymous Access PDP Context Deactivation Initiated by GGSN Procedure (from [GSM 03.60])

4.3.3.2 Ericsson's proposed PDP context management procedures

As mentioned earlier Ericsson has proposed to ETSI a set of new GPRS PDP context management procedures. The main characteristic of these procedures is that they enable to provide QoS support per one or more GPRS flows. In this proposal one PDP context that is identified by one PDP address consists of more PDF (Packet Data Flow) contexts. Each PDF context specifies a tight connection between one or more flows and one QoS profile. Additionally, each PDF context includes a TFT (Traffic Flow Template) that specifies how to identify the traffic as well as rules for policing. Note that the definition of flow in the Ericsson's proposal is similar to the one used in the IETF Integrated Services concept.

Note that these new PDP context management procedures proposed by Ericsson, after minor modifications, are introduced in the GPRS Release 1999 and the UMTS Release 1999 [3GPP23.060]. The message sequence charts used in GPRS Release 99 for PDP Context Activation, Modification and Deactivation procedures are shown in Section 4.3.3.3.

Figure 4-13 depicts the relation between the PDP and PDF contexts. The PDP context is assigned to one PDP address and includes the following information elements: ID (i.e., NSAPI), PDP address, PDP type and the host configurations. A PDP context consists of one or more PDF contexts. Each PDF context is related to one application flow and includes the following information elements: the ID (i.e., NSAPI and FlowID: Note that in the proposal up to 16 PDF contexts per NSAPI can be specified), QoS and Flow Template.

The PDP and PDF context can be established and released by either the MS or the GGSN. Each PDF can be modified by either the MS, the SGSN or the GGSN. Note that compared to the GPRS (Release 1998) PDP context modification procedure, in this proposal the PDP context modification is not available, due to the fact that the PDP context does not contain any QoS information. The QoS information is included in each PDF context. For each PDF context, the negotiation and modification of the QoS profile and flow template is supported and can among others be directly initiated by the MS (this is not possible in the the GPRS (Release 1998) PDP context modification procedure).

The establishment procedure for one or more PDF contexts, that are included in a certain PDP context, can only be initiated after the "parent" PDP context has been established. During the "parent" PDP context establishment also at least one PDF context is established with an assigned QoS profile. This PDF context does not contain a traffic flow template.

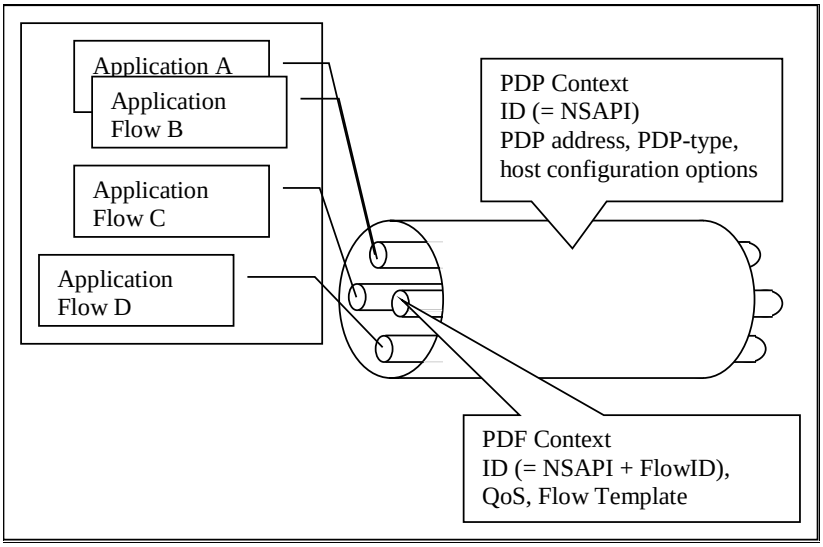

Figure 4-13: PDP and PDF contexts (from [SMG12 C-99-460])

The PDP or PDF establishment procedure initiated by the MS is shown in Figure 4-14. The information flow sequences is similar to the one defined in Figure 4-4. The difference is now that the BSS is also included in the PDP or PDF context establishment procedure. The request for PDP context establishment contains also at least a request for the initial PDF context establishment. Each PDF context may include a requested QoS profile and a fallback QoS profile included in the MS.

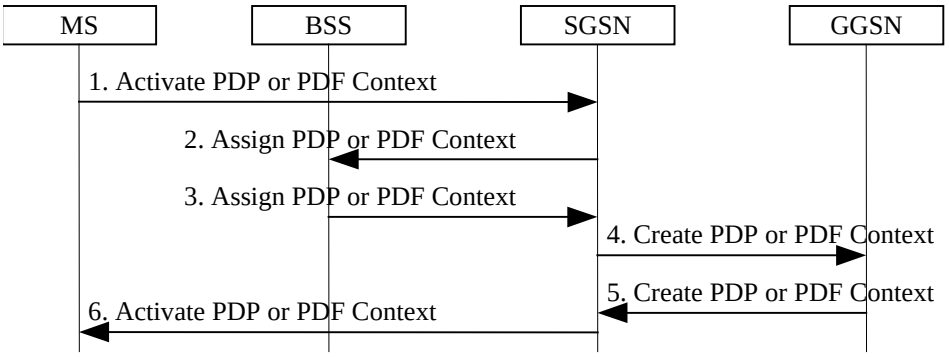

Figure 4-14: MS initiated PDF (or PDP) context establishment (from [SMG12 C-99-460])

The PDP or PDF context establishment can also be initiated by the GGSN. The PDP context establishment is similar to the one depicted in Figure 4-5. For network initiated PDP context establishment, no PDF context establishment is requested by the network. However, the GGSN can also initiate PDF context establishment procedures (see Figure 4-15). The procedures that are activated by the messages shown in Figure 4-15, are similar to the ones applied for Figure 4-5.
Note that the PDP context establishment initiating entity, i.e., MS or GGSN, may introduce two QoS profiles and a flow template to each PDF context. After the negotiation of the QoS profiles, the network entities, i.e., BSS, SGSN and GGSN, (or the MS if it is not the requesting entity) may indicate to the requesting entity the negotiated QoS profile and the negotiated flow template for that PDF context. Furthermore, the negotiated QoS profile shall be in the range specified by the two requested QoS profiles.

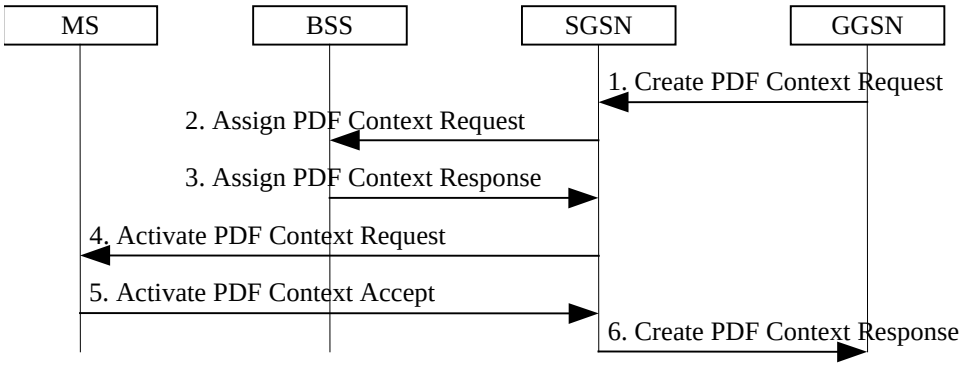

Figure 4-15: Network initiated PDF context establishment (from [SMG12 C-99-460])

The PDF context modification procedure that is initiated by an MS, GGSN and SGSN are depicted in Figure 4-16, Figure 4-17 and Figure 4-18. The PDF context modification procedure can only be applied if the ‘parent” PDP context is activated.
It should be noted that each subsequently established PDF context should have a different QoS profile then other already established PDF context belonging to the same ‘parent” PDP context. If the

additional PDF context has the same QoS profile as an already existing PDF context, then this additional PDF context should be rejected. However, the flow of an already existing PDF context can be modified such that it can also carry the flow that initiated the additional (and rejected) PDF context.

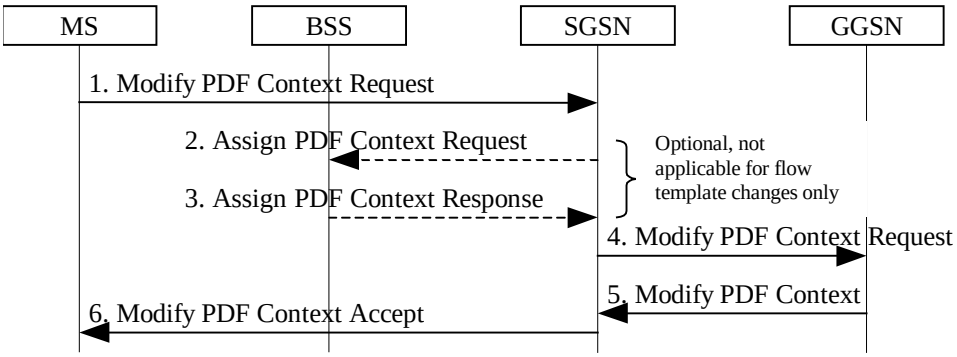

Figure 4-16: MS initiated PDF context modification (from [SMG12 C-99-460])

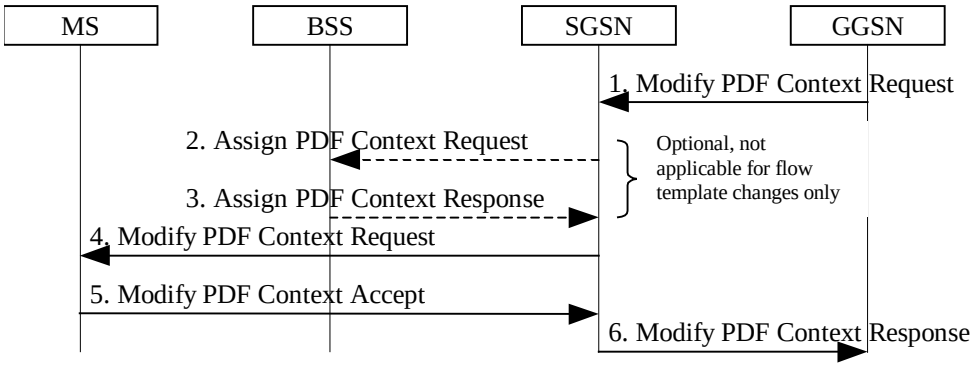

Figure 4-17: Network (GGSN) initiated PDF context modification (from [SMG12 C-99-460])

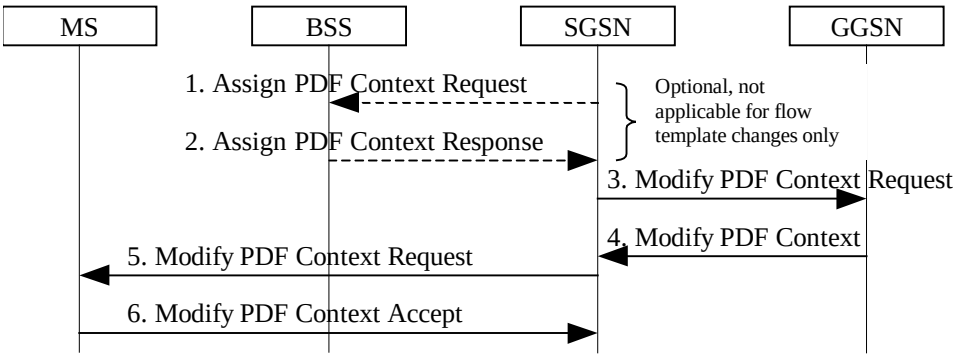

Figure 4-18: Network (SGSN) initiated PDF context modification (from [SMG12 C-99-460])

The PDP and PDF context release procedure can be initiated by the MS or the GGSN. When a PDP context is released then all associated PDF contexts are also released. Note that the initial PDF context in an active PDP context must not be released, because then also the PDP context will be released.

4.3.3.3 GPRS Release 1999 PDP context management procedures

This section presents the information flow sequences used in GPRS Release 1999 for PDP Context Activation, Modification and Deactivation procedures. The PDP context specified for GPRS Release 1999 is defined as the information sets held in MS, SGSN and GGSN that are used to specify the tight connection between one subscriber that identifies an application, a PDP type and one QoS profile. More PDP contexts with different QoS parameters can share the same PDP address. In order to activate PDP contexts two types of procedures can be used (see also Figure 4-19). The first procedure, called Activate PDP Context includes subscription checking, APN selection, and host configuration. The second procedure that can be repeated is called Secondary Activate PDP Context procedure. It may be used to activate a PDP context while reusing the PDP address and other PDP Context information from an already existing PDP Context, but with a different QoS Profile. At least one PDP context (in this document we call this first PDP Context as “first”) shall be activated for a PDP address before a Secondary PDP Context Activation procedure may be initiated. A new parameter called Linked TI is shown in Figure 4-19. This parameter indicates a TI value assigned to any one of the already activated PDP contexts for the same PDP address and APN. The TFT is defined as the Traffic Flow Template that is used by a GGSN to distinguish between different user payload packets and to transmit packets with different QoS requirements via different PDP context but to the same PDP address.

The principle of static and dynamic addressing is also used in GPRS Release 1999. It is similar to the same principle used for GPRS Release 1998. The difference is regarding the external PDN address allocation procedure where the responsibility of allocating and releasing PDP addresses becomes to be the responsibility of the MS and the PDN. This is usually accomplished by using IETF protocols such as Dynamic Host Configuration Protocol (DHCP) [RFC2131] or Mobile IP (MIP) [RFC2002]. In case of DHCP the GGSN provides the function of DHCP Relay Agent [RFC2131] and in the case of MIP the GGSN provides the function of Foreign Agent (FA) [RFC2002].

Note that the “first” PDP context, defined for GPRS Release 1999 is similar to the PDP Context defined in the Ericsson’s proposal. The Secondary PDP Context(s) is similar to the PDF Context defined in the Ericsson’s proposal. Furthermore, note that the Release 1999 of the Universal Mobile Telecommunication System (UMTS) uses the same PDP context principles as the Release 1999 of the GPRS system.

The PDP context can be activated and released by either the MS or the GGSN. Each PDP context can be modified by the MS, the SGSN or the GGSN. The QoS information is included in each PDP context. For each PDP context, the negotiation and modification of the QoS profile and TFT is supported and can among others be directly initiated by the MS (this is not possible in the GPRS (Release 1998) PDP context modification procedure).

The activation procedure for one or more Secondary PDP context, can only be initiated after the “first” PDP context has been established. The “first” PDP context does not contain a TFT.

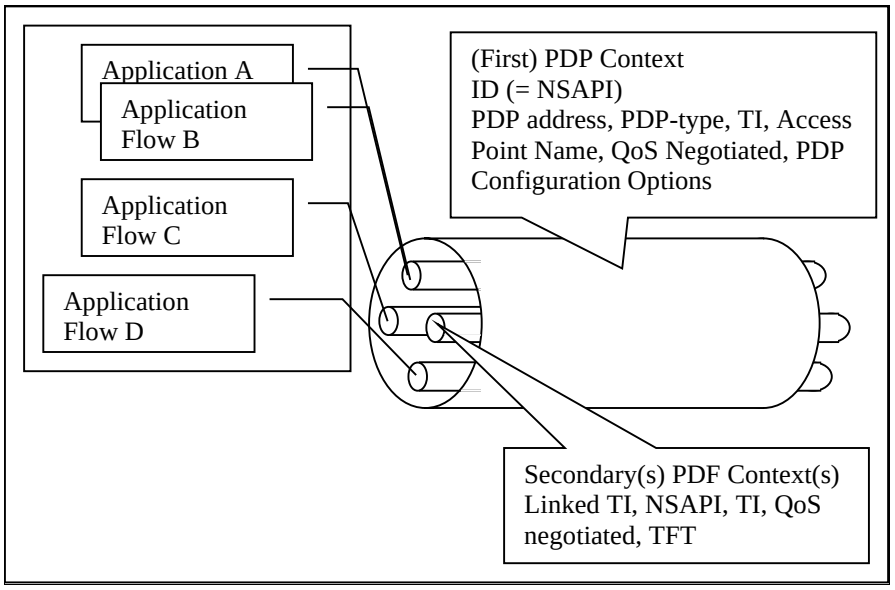

Figure 4-19: "first" and Secondaries PDP contexts

The "first" PDP context activation procedure initiated by the MS is shown in Figure 4-20. The term 2G (Second Generation) is used to specify that the entities SGSN and GGSN are supporting the GPRS system. Similarly the term 3G (Third Generation) is used to specify that the used entities are supporting the UMTS system. The information flow sequences is similar to the one defined in Figure 4-4. The difference is now that the BSS is also included in the PDP context activation procedure. The Invoke Trace message is sent by the SGSN to BSS in case that the BSS trace is activated (see [3GPP23.060]). This message contains among others the Trace Reference and the Trace Type. The Trace Reference identifies a record or a collection of records for a particular trace, while the Trace Type identifies the type of trace, e.g., MSC/BSS trace, HLR trace, and/or SGSN/GGSN/BSS trace. Each PDP context may contain a requested QoS profile for the MS. Compared to the Ericsson's proposal, the PDP Context activation procedure used in the GPRS Release 1999 does not include a fallback QoS profile. However, in GPRS Release 1999 is also mentioned that if a QoS requirement is beyond the capabilities of a PLMN, the PLMN negotiates the QoS profile as close as possible to the requested QoS profile. The MS can either accept the negotiated QoS profile, or deactivate the PDP context. Probably, the selection of the fallback QoS profile could be considered as an implementation issue.

The blocks C1 and C2 define the GPRS to/from Customised Applications for Mobile Network Enhanced Logic (CAMEL) interaction (see [3GPP23.078]). In particular, C1 block represets the CAMEL-GPRS-Activate-PDP-Context procedure and the C2 block represents the CAMEL-GPRS-SGSN-Create-PDP-Context interaction procedure.

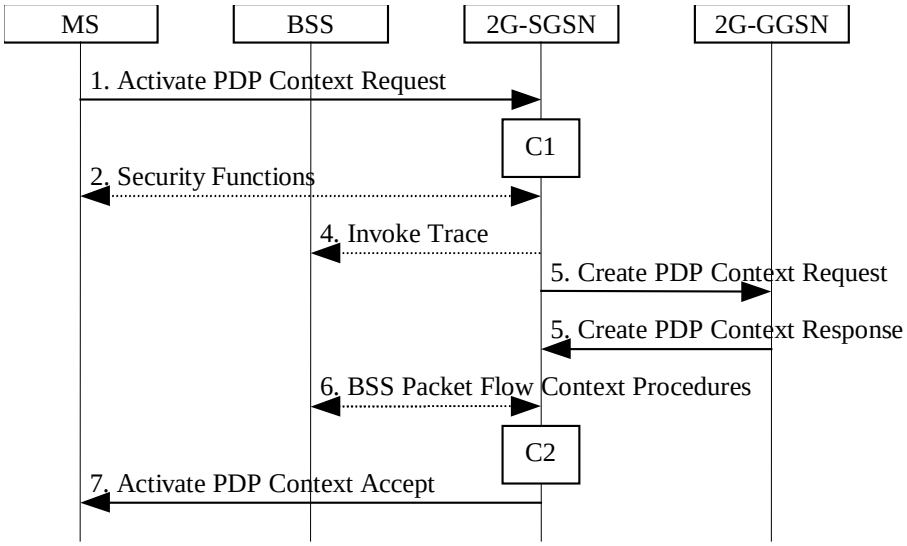

Figure 4-20: MS initiated ("first") PDP context activation (from [3GPP23.060])

The Secondary PDP context activation procedure is depicted in Figure 4-21 and is similar to the one depicted in Figure 4-20. The main difference is that the Invoke Trace procedure is not any more used. This activation procedure is used to activate a PDP context while reusing the PDP address and other PDP Context information from an already existing PDP Context, but with a different QoS Profile. At least one PDP context shall be activated for a PDP address before a Secondary PDP Context Activation procedure may be initiated. This procedure can be executed without providing a new TFT, if all the existing PDP contexts that use the same APN and PDP address have a TFT. If that is not the case then the Secondary PDP context activation procedure should create a TFT. The attributes contained in a TFT specify an IP header filter, used to direct the IP data packets received from the external packet data network to an activated PDP context.

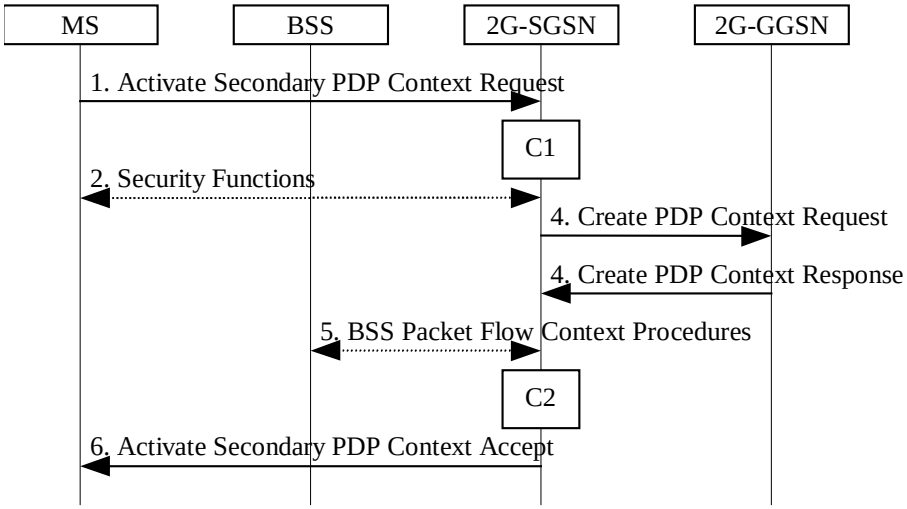

Figure 4-21: MS initiated Secondary PDP context activation (from [3GPP23.060])

Additionally to the PDP activation procedure, the MS can initiate an Anonymous Access PDP Context Activation Procedure (see Figure 4-22). The used messages that are specific for this scenario are similar to the ones depicted in Figure 4-6.

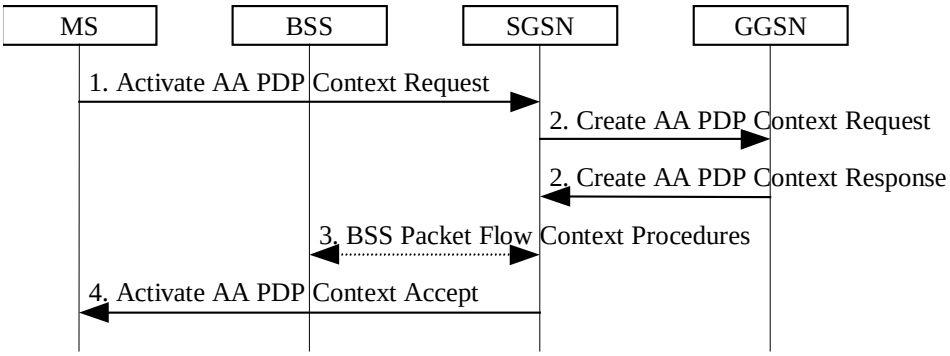

Figure 4-22: Anonymous Access PDP context activation (from [3GPP23.060])

The PDP context activation can also be initiated by the GGSN. The PDP activation is similar to the one depicted in Figure 4-5. When the GGSN receives a packet that has to be sent to a particular PDP address it checks if a PDP context is established for that PDP address. If that is not the case then a network-requested PDP Context Activation procedure is started to create a new PDP context (see Figure 4-23). The procedures that are activated by the messages shown in Figure 4-24 are similar to the ones applied for Figure 4-5.

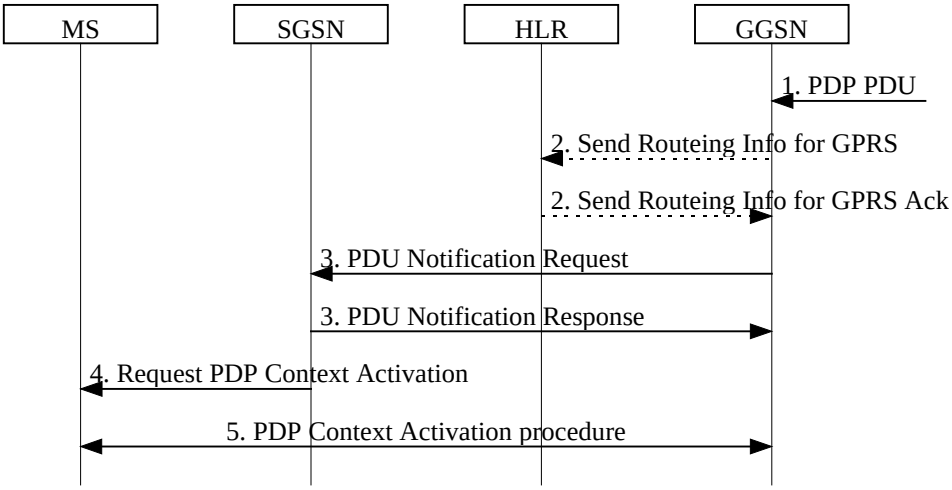

Figure 4-23: Network-requested PDP context activation (from [3GPP23.060])

The PDP Context modification procedures can be initiated by the MS, GGSN or the SGSN. These procedures can be directly requested by the MS or GGSN. The SGSN, possibly triggered by the HLR decides to modify the parameters that were negotiated during an activation procedure for one or several PDP contexts. The parameters that can be modified during these procedures are:

- QoS Negotiated;
- Radio Priority;
- Packet flow Id;
- PDP Address (in case of the GGSN modification procedure);
- TFT (in case of MS initiated modification procedure);

The PDP context modification procedure that is initiated by an MS, GGSN and SGSN are depicted in Figure 4-24, Figure 4-25 and Figure 4-26, respectively. The PDF context modification procedure can

only be applied if the “first” PDP context is activated. The operation of the modification procedures are similar to the ones explained in Section 4.3.3.2.

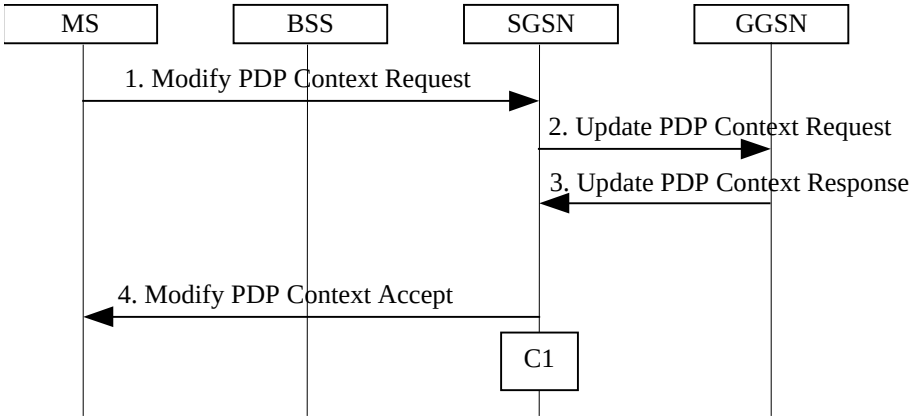

Figure 4-24: MS initiated PDP context modification (based on [3GPP23.060])

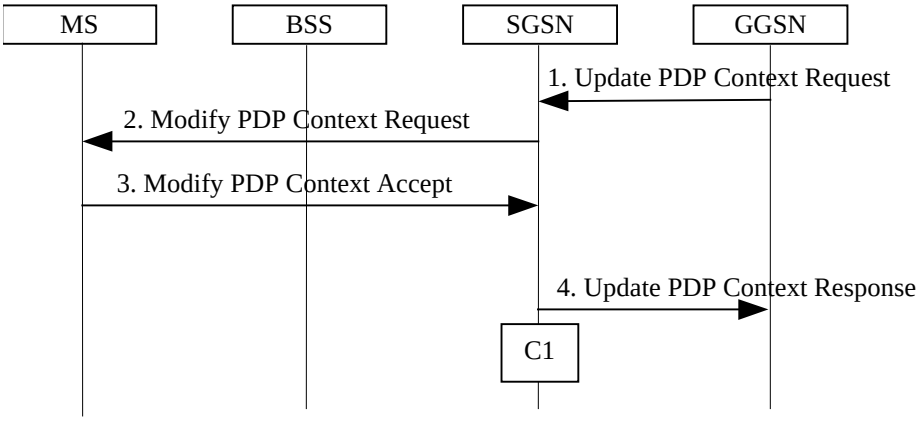

Figure 4-25: Network (GGSN) initiated PDP context modification (based on [3GPP23.060])

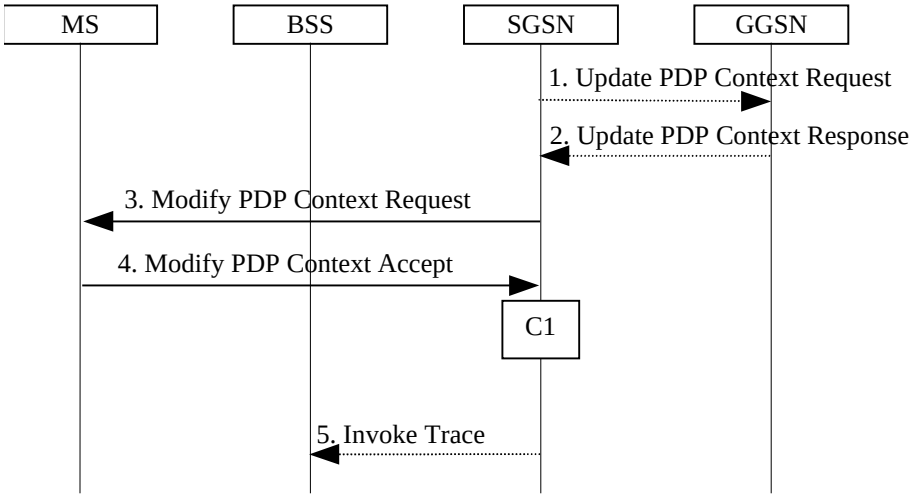

Figure 4-26: Network (SGSN) initiated PDP context modification (based on [3GPP23.060])

The PDP context deactivation procedure can be initiated by the MS, SGSN or GGSN. In the situation that the deactivation request message contains only the parameter TI then only the PDP context related to this TI will be deleted. However, when the deactivation request message contains a parameter called Teardown Ind, then all the active PDP contexts will be removed.

5 Integrated Services in GPRS

5.1 Introduction

As mentioned in [QWING], two major trends can be identified in the Information and Communication Technology (ICT) industry. The first one is the Internet technology, and the second one is the freedom of users to communicate, compute and access information, regardless of their location by means of wireless technology. It is expected that the convergence of these two trends will probably be the number one future communication infrastructure. However, this convergence will put requirements on the wireless access technologies. Especially, the support of QoS will impose significant requirements on the wireless technology, e.g., GPRS. IETF has specified two frameworks that can be used to support QoS in IP networks. These are the Integrated Services (IntServ) and Differentiated Services (DiffServ) frameworks.

The IntServ framework requires some protocol, e.g., Resource reSerVation Protocol (RSVP), to communicate with the IP routers, along the path of the intended flow and reserve the resources necessary for the QoS provisioning.

This Section describes how the IntServ QoS requirements, specified in [ZeAi99], are supported by the GPRS technology. Note that this description is provided for the GPRS QoS management contexts discussed in Section 4.3.3.1, i.e., the GPRS (Release 1998) QoS management mechanisms, Section 4.3.3.2, i.e., Ericsson's proposed QoS management mechanisms and Section 4.3.3.3, i.e., the GPRS Release 1999 QoS management mechanisms. It has not been mentioned in a 3GPP specification standard, but we believe that the QoS mechansims that were proposed by Ericsson and described in [SMG12 C-99-462], can also be used in GPRS Release 1999. The main reason for this is that the QoS concept specified in the Ericsson's proposal and the concept used in the GPRS Release 1999 are almost identical. The QoS requirements are the following:

- Resource Reservation;
- Admission Control;
- Flow Separation and Scheduling;
- Policing and shaping;
- Soft State;
- Scalability;
- Fault Tolerance and Recover;
- Independence from Higher Layer Protocol;
- Support for different Filter Styles;

5.2 Resource Reservation

In the IntServ framework, resource reservation is used in intermediate routers located along the path from sender to receiver. Three questions created in [ZeAi99] are used to test if the GPRS wireless technology is capable of supporting resource reservation.

Q1: Is the wireless technology able to reserve resources?

Solution provided by the GPRS (Release 1998) QoS management mechanisms:

This mechanism (see Section 4.3.3.1) is able to reserve resources for one PDP address and not per individual flow. This means e.g., that the same QoS profile has to be applied to at most two uni-directional connections, i.e., upwards and downwards, or to two or more applications that are using the same PDP address. The resource reservation is accomplished by using the PDP context activation procedures.
In Section 4.3 is mentioned that if the negotiated QoS profiles are accepted by both parties then the GPRS network will have to provide adequate resources to support these QoS profiles. The negotiated QoS at the network level will be mapped (see Section 3.3) to the characteristics of the underlying network by the SNDCP layer. For example, based on the mapped negotiated QoS profiles the MAC layer [GSM 03.64] will allocate (i.e, reserve) the transmission resources that are taken from a common pool of physical channels available in a cell. However, regarding the process of reserving resources on the IP subnetwork that is interconnecting one SGSN and one GGSN, we observed the following. This IP subnetwork will only be capable of supporting the negotiated QoS specified in the PDP context by either being over-provisioned or using a mechanism that is capable of reserving a certain network capacity, e.g., Diffserv, RSVP. The network capacity reservation mechanism will use the negotiated QoS parameters to define the resources that will be reserved on the unidirectional downstream and upstream links between SGSN and GGSN.
We define that an IP subnetwork is over-provisioned when at any time its available capacity exceeds the traffic demands.

The resource allocation (i.e., reservation) at the MAC layer can support three medium access modes: [..

- Dynamic Allocation characterised by that the mobile station detecting an assigned Uplink State Flag (USF) value for each assigned PDCH and block or group of four blocks that it is allowed to transmit on that PDCH
- Extended Dynamic Allocation characterised by the mobile station detecting an assigned USF value for any assigned PDCH allowing the mobile station to transmit on that PDCH and all higher numbered assigned PDCHs in the same block or group of four blocks
- Fixed Allocation characterised by fixed allocation of radio blocks and PDCHs in the assignment message without an assigned USF] [GSM 04.60].

USF is used on packet data channels, i.e., PDCH to allow multiplexing of uplink Radio blocks from different mobile stations. A radio block can be defined as the sequence of four normal bursts carrying one RLC/MAC protocol data unit.

At the MAC layer the resource reservation can be accomplished either separately for the uplink and downlink transmission or simultaneously for both transmission directions. Particularly, for the uplink transmission the MAC layer employs a Slotted-Aloha based reservation protocol. This protocol works in the following way. Each user that is using a time slot remains in a so called origination mode with a certain probability. When a packet is created the user becomes immediately backlogged and will not generate new packets while remaining in this mode. The backlogged users transmit their packets with a probability that is depending on a chosen transmission scheme, e.g., exponential backoff.
In [FrBr98] three different approaches for slotted Aloha access control with four priority levels are compared. These are:

- Bayesian Broadcast Control scheme was introduced in [Rive87]. For this scheme the transmission probability for backlogged users is equal to the ratio of the offered traffic to a certain slot and the number of backlogged users in the slot. The value of this probability is broadcasted by the base station to all the mobile terminals before the beginning of the next slot.

- Exponential backoff scheme was introduced in [RaJo90]. In this scheme for unsuccessful attempts, the retransmission probabilities decreases with a predefined backoff rate up to a predefined retransmission attempt.
- Stack based scheme was introduced in [BuWa96]. In this scheme each user manages a counter (C). When a packet arrives then the counter C is increased by 1. If there is a collision and C > 1 then the counter is incremented by *i*, where *i* is the priority of a packet class. If there is no collision then the counter C is decremented by 1. If the counter C = 1 then a retransmission is made.

The main conclusion of this work is that the bayesian scheme regarding throughput and access delay performs better than the other two schemes. Furthermore, is mentioned that the exponential backoff and the stack based schemes are not suitable to be used in GPRS.

Moreover, if the GPRS supports the traffic mix of the typical GSM voice services and the new GPRS data services, then the resource reservation is accomplished dynamically using the Capacity on Demand principle described in [GSM 03.64]. By using this principle the number of allocated packet data channels, i.e., PDCHs in a cell can be increased or decreased according to the demand. A number of functions are used to accomplish this:

- Load supervision: such a procedure may monitor the load of the PDCHs. Using this monitoring results the number of allocated PDCHs in a cell can be increased or decreased according to the demand. This procedure may be implemented as a part of the MAC functionality. The common channel allocation function located in BSC is used for the GSM services.
- Dynamical allocation of PDCHs: the unused channels can be allocated as PDCHs to increase the overall quality of service for GPRS.
- De-allocation of PDCHs can take place when a resource reservation request is received from other services with higher priority.

Furthermore, in [Ostro96] an analytical performance model for packet data networks, such as GPRS is described. By using analytical performance models, a performance study of networks that support integrated data and voice services has been accomplished. In this study it is considered that a channel is shared with voice and data traffic. Three different channel allocation strategies are compared and analysed. These are:

- Full sharing channel allocation to a mix of data and voice traffic;
- Partial sharing of voice channels and a fixed number Nd channels that are reserved for data only.
- No sharing with voice channels, a fixed number Nd channels that are reserved for data only.

The performance measures used in this analysis are the latency, throughput and network utilisation. The partial sharing strategy mainly performs better than the other two strategies.

Solution provided by Ericsson's proposed QoS management mechanisms:

This mechanism (see Section 4.3.3.2) is able to reserve resources per flow. However, the observation we made (see above) regarding the process of reserving resources on the IP subnetwork that is interconnecting one SGSN and one GGSN, it also applies for this solution.

The resource reservation process is accomplished by using the PDP and PDF context establishment procedures. The mapping of the negotiated QoS into the capabilities of the underlying network has not yet been specified. However, the procedures specified for the GPRS (Release 1998) GPRS QoS mechanisms could be used.

Solution provided by the GPRS Release 1999 QoS management mechanisms:

This mechanism (see Section 4.3.3.3) is able to reserve resources per flow. The observation we made regarding the process of reserving resources on the IP subnetwork that is interconnecting one SGSN and one GGSN, it also applies for this solution.

The resource reservation process is accomplished by using the GPRS (Release 1999) PDP context activation procedures. The mapping of the negotiated QoS into the capabilities of the underlying network (see [3GPP23.060]) is similar to the ones used in the GPRS Release 1998.

Q2: Is the mechanism able to do both multicast and unicast reservations?

Solution provided by the GPRS (Release 1998) QoS management mechanisms:

Regarding the PDP context management procedures, it should be possible (see GSM 02.60]), but these procedures have not yet been specified. Note that these procedures should be specified in [GSM 03.61] for PTM-M communication and in [GSM 03.62] for PTM-G communication, but this is not yet accomplished.

Regarding the reservation of radio resources, it should be possible to do both multicast and unicast reservations (see [GSM 03.64], [GSM 04.60]):

- allocated uplink and downlink radio resources for point-to-point, point-to-multipoint multicast or group call service types used independently of each other, or in a symmetric manner.

In particular the MAC layer (see [GSM 03.64]) uses the concept of Temporary Block Flow (TBF), that is a physical connection used by two RR entities for the support of the unidirectional transmission of Logical Link Control (LLC) PDUs on packet data physical channels. The TBF comprises a number of RLC/MAC blocks carrying one or more LLC PDUs and is temporarily maintained for the duration of the data transmission. The GPRS network assigns to each TBF a Temporary Flow Identity (TFI). This flow identity is unique among concurrent TBFs in each direction and is used instead of the MS identity in the RLC/MAC layer.

Solution provided by Ericsson's proposed QoS management mechanisms:

It should be possible, but it has not yet been specified.

Solution provided by the GPRS (Release 1999) QoS management mechanisms:

Regarding the PDP context management procedures, it should be possible (see [3GPP22.060]), but similar to the GPRS Release 1998, these procedures have not yet been specified. Regarding the reservation of radio resources the same mechanisms as the ones used for GPRS Release 1998 are applied.

Q3: Is the mechanism able to change its reservation (style and requested resources) during a session?

Solution provided by the GPRS (Release 1998) QoS management mechanisms:

The mechanism described in Section 4.3.3.1, can support the modification of a reservation during a session using the PDP context modification procedure. Note that this procedure is initiated by the network. However, the MS can inform the SGSN about changes in subscription data for a subscriber by using the Subscriber Management Function. Afterwards, the SGSN can start the PDP context modification procedure.

Solution provided by Ericsson's proposed QoS management mechanisms:

The mechanism described in Section 4.3.3.2, can support the modification of a reservation during a session using the PDF context modification procedure. This procedure can be initiated by MS, SGSN or GGSN.

Solution provided by the GPRS (Release 1999) QoS management mechanisms:

Similar to the QoS mechanisms described in the Ericsson's proposal, the GPRS Release 1999 mechanisms can support the modification of a reservation during a session using the PDP context modification procedure. This procedure can be initiated by MS, SGSN or GGSN.

5.3 Admission Control in MS, BSS and SGSN

Admission control is a mechanism that is used by a network to accept or reject new service requests. Four questions created in [ZeAi99] are used to test if the GPRS wireless technology is capable of providing admission control.
In GPRS (see [GSM 03.60], [3GPP23.060]) the scope of the admission control procedure is to calculate which network resources are required to provide the quality of service (QoS) requested, determine if those resources are available, and then reserve those resources. This procedure is performed in association with the Radio Resource Management functions in order to estimate the radio resource requirements within each cell (see also to the answer to Question Q1 regarding the MAC resource allocation). The admission control function is performed at the MS, SGSN and GGSN (see Table 3-1).

In literature, [ShBu97] provides an analytical model that is developed to evaluate the single slot and multislot data packets integrated (i.e., data and voice) systems under the use of different Call Admission Control (CAC) policies. The impact of the handover procedure on the GPRS performance is included in the evaluation. The basic CAC policy used, is specified in [Call95], where the voice and data operate in different regions such that the different QoS requirements can be guaranteed. It is considered that a predefined number of (*N*) data Mobile Terminals (MT), i.e., different PDP contexts, may be permitted to get access to unoccupied channels if these are not occupied by voice MT or are in idle mode. In the situation that channels are available, voice or data calls can be served on a First In First Out (FIFO) basis. Additionally, the handover data packets can be queued ahead of the originated data packets by using the Head of Line (HOL) discipline.

From the single slot experiments and based on certain assumptions, it can be concluded that when the traffic load is small or medium, the data traffic delay depends heavily on both the offered traffic load and the number of reserved channels. When the traffic load is high the impact of the selection of the reserved channels on the packet data delay may not be significant.

Q4. Is the mechanism able to estimate the level of resources needed to meet the QoS requirements, knowing that there is a non-perfect link layer?

Solution provided by the GPRS (Release 1998) QoS management mechanisms:

In [GSM 3.60] it is mentioned that the following requirements should be fulfilled:

- calculate which network resources are needed to fulfill the required QoS;
- determine if those resources are available and reserve them in combination with Radio Resource Management functions ;

However, it is not certain upon which level the non-perfect link will be taken into account.

Solution provided by Ericsson's proposed QoS management mechanisms:

In [SMG12 C-99-462] a new functional decomposition of the MS and GGSN is introduced, see Figure 5-3 and Figure 5-4, respectively. A “Monitor” function is defined in MS and GGSN that is used to monitor the traffic at the R and Gi (see Figure 3-1) interfaces. This type of admission control is often called measured based admission control.

However, it is not certain upon which level the non-perfect link will be taken into account.

Solution provided by the GPRS (Release 1999) QoS management mechanisms:

In [3GPP22.060] is mentioned that the MS may monitor the current QoS level. However, it is not certain upon which level the non-perfect link will be taken into account.

Q5. Does the mechanism support mobility? For instance, is the mechanism able to predict the bandwidth needed by immigrating users, with a QoS contract, moving from an adjacent cell to the cell in consideration?

Solution provided by the GPRS (Release 1998) QoS management mechanisms:

The mechanism can in general support mobility, due to the fact that it supports the modification of the contracted QoS. In addition, the immigrating users are treated head of line (HOL). However, the mechanism is not able to predict the bandwidth needed by immigrating users.

Solution provided by Ericsson’s proposed QoS management mechanisms:

The answer is similar to the one given for the GPRS (Release 1998) QoS management mechanism.

Solution provided by the GPRS (Release 1999) QoS management mechanisms:

The answer is similar to the one given for the GPRS (Release 1998) QoS management mechanism.

Q6. Is the mechanism able to respond to queries about available resources?

Solution provided by the GPRS (Release 1998) QoS management mechanisms:

According to [GSM 03.64] it shall be possible for the network to order the mobile stations to send measurement reports to the network and to suspend its normal cell re-selection, and instead to accept decisions from the network. However, these reports will not contain information about available resources but only on the Radio Frequency signal strength of the serving and neighboring cells.

Solution provided by Ericsson’s proposed QoS management mechanisms:

It has not yet been specified.

Solution provided by the GPRS (Release 1999) QoS management mechanisms:

The answer is similar to the one given for the GPRS (Release 1998) QoS management mechanism.

Q7. Is the mechanism able to guarantee an upperbound for the delay (Guaranteed Service)?

Solution provided by the GPRS (Release 1998) QoS management mechanisms:

The delay GPRS QoS profiles are mainly qualitative and they are not specifying quantitative (deterministic) service guarantees on maximum delays, but only on mean delays. Note that the Delay QoS profile is specifying statistical guarantees on delays, i.e., 95 percentile of Delay. However, due to the fact that the RLC/MAC layer is capable of reserving resources on dedicated channels, it can be claimed that the mechanism is able to guarantee an upperbound for the delay in the radio access part. Regarding the IP subnetwork that is interconnecting the SGSN with the GGSN, it can be claimed that it will only be able to guarantee an upperbound in the delay only if one of the solutions listed in the answer to question Q1 is applied.

Solution provided by Ericsson’s proposed QoS management mechanisms:

This mechanism is enhanced in such a way that it has similarities with the Integrated Service concept (see [ZeAi99]). Therefore it should be possible to guarantee an upper bound on delay. However, regarding the IP subnetwork that is interconnecting the SGSN with the GGSN, it can be claimed that it will only be able to guarantee an upperbound in the delay only if one of the solutions listed in the answer to question Q1 is applied.

Solution provided by the GPRS (Release 1999) QoS management mechanisms:

Similar to the QoS Management mechanisms provided by the Ericsson proposals, this mechanism has been enhanced in such a way that it has similarities with the Integrated Service concept. Similar to GPRS Release 1998, the delay GPRS QoS profiles are still mainly qualitative and they are not specifying quantitative service guarantees on maximum delays, but only on mean delays. However, statistical delay bounds are specified as 95 percentiles of the delay. Furthermore, regarding the IP subnetwork that is interconnecting the SGSN with the GGSN, it can be claimed that it will only be able to guarantee an upperbound in the delay only if one of the solutions listed in the answer to question Q1 is applied.

5.4 Flow Separation and Scheduling

Flow separation is required when a preferential treatment has to be given to some applications, e.g., real-time services, over other applications, e.g., best effort applications. Furthermore, this treatment can be further enforced by scheduling the flows used for the different applications according to their requirements.

Three questions created in [ZeAi99] are used to test if the GPRS wireless technology is capable of supporting flow separation and scheduling.

Q8. Is the mechanism able to distinguish between flows belonging to different service classes?

Solution provided by the GPRS (Release 1998) QoS management mechanisms:

In Sections 4.3 and 4.3.3.1 is shown that GPRS supports a relative ordering of application flows belonging to different QoS profiles, e.g., precedence. However, the limitation is that each QoS profile is assigned to one PDP address. If two application flows must use two different QoS profiles, then two different PDP addresses, one for each flow, will have to be used.

Solution provided by Ericsson's proposed QoS management mechanisms:

The Ericsson's proposed QoS management mechanism, as described in Section 4.3.3.2, provides a relative ordering of flows. For this situation the limitation related to the relation between the QoS profile and the PDP address described above is not applicable.

Solution provided by the GPRS (Release 1999) QoS management mechanisms:

Similar to the solution provided by Ericsson's proposed QoS management mechanisms.

Q9. Does the mechanism offer opportunities to implement scheduling?

Solution provided by the GPRS (Release 1998) QoS management mechanisms:
In GPRS scheduling mechanisms are required especially, for the downlink direction to implement the required medium access control functionality (see [GSM 03.64]).
In general, in order to provide the different QoS precedence classes, scheduling mechanisms are also required in the MS, SGSN and GGSN. However, the implementations of these mechanisms are not specified in the GPRS standards.

Solution provided by Ericsson's proposed QoS management mechanisms:

It should be possible but it is not yet specified.

Solution provided by the GPRS (Release 1999) QoS management mechanisms:
The GPRS Release 1999 has to support different QoS service precedence classes. Therefore, scheduling mechanisms are required in the MS, SGSN and GGSN. However, in [3PGG 23.060] is mentioned that these scheduling algorithms are implementation dependent and are not specified in the GPRS standards.

Q10. Does the mechanism use power-saving techniques?

Solution provided by the GPRS (Release 1998) QoS management mechanisms:

In GPRS (see [GSM 02.60], [GSM 03.60]) power saving techniques are used for the extension of the battery life by allowing the MS to reduce its current drain; e.g., by using a discontinuous reception (DRX) strategy. Note that when an MS is in DRX mode it is only required to monitor the radio blocks defined by its paging group. Also Power control techniques are used ([GSM 03.64 and [GSM 05.08] to improve spectrum efficiency and reduce power consumption in the MS. This algorithm is active in the MS and is used for PTP uplink transmission. Power control is not applicable to point-to-multipoint multicast services.

Solution provided by Ericsson's proposed QoS management mechanisms:

Not specified.

Solution provided by the GPRS (Release 1998) QoS management mechanisms:

The solutions are similar to the ones provided in GPRS Release 1998.

5.5 Policing and shaping

The conformance of the traffic to negotiated traffic parameters is ensured by using among others shaping and/or policing mechanisms.

Two questions created in [ZeAi99] are used to test if the GPRS wireless technology is capable of supporting policing and shaping.

Q11. Is policing in the mobile or wireless access point possible?

Solution provided by the GPRS (Release 1998) QoS management mechanisms:

The policing procedure will have to be used at the R (between TE and MT) and Gi (Between the external PDN and GGSN) interfaces such that the peak throughput is policed.

Additionally, a policing procedure is used at the Gb interface. This policing procedure can be accomplished in GPRS by using a flow control mechanism. A flow control conformance definition for the downlink Gb (SGSN to BSS) interface of GPRS is described in [GSM 08.16] and is based on [ITU-TQ.922]. Note that the Gb interface is considered in GPRS to be the User-to-Network (UNI) interface. The flow control uses a leaky bucket that is described in e.g., [Zhan95]. Its main functionality is to ensure that the traffic transmitted over an interface is limited by some predefined parameters. These parameters are the "bucket size" and the "leaky" rate. A bucket counter increases whenever a packet arrives at the leaky bucket. The counter is decreased according to a "leaky rate". The leaky bucket algorithm passes a packet of traffic flow as long as the bucket counter does not exceed the maximum "bucket size". If the bucket counter exceeds the maximum bucket size then the packet is delayed until the bucket is emptied by the leaky rate so much that the packet can flow through.

The policy control uses the BSSGP flow control described in [GSM 08.16]. The downlink flow control should be able to work as well on MS level as on cell level. On MS level the flow control is handled very dynamically, considering that the TBF should not be released because of the low incoming traffic load from SGSN. On cell level the traffic flow is considered to be more static and well dimensioned such that it will not limit the traffic flow on an MS.

Providing these considerations the bucket size will be large enough to prevent that the buffers get emptied because of normal variations in the leaky rate.

Solution provided by Ericsson's proposed QoS management mechanisms:

In the Ericsson's proposal policing is controlled by using the information set contained in Traffic Flow Templates (TFT) that specifies how to identify traffic and rules for policing.

As can be seen in Figure 5-3 the new functional decomposition of the MS is shown. This functionality is decomposed in the TE and the MT and is used for the uplink transmission. Note that the definitions of the entities used in [SMG12 C-99-462] are given in Section 2.1. The Application entity can exchange signaling messages, e.g., QoS requirements, with its peers located in remote hosts. Alternatively, this entity can use a separate signaling protocol to exchange QoS parameters for a given session. The ReSource reserVation Protocol (RSVP), (see e.g., [RFC2205], [Whi97], [ZeAi99]) is such an signaling protocol. The TE independently of the used signaling protocol, is expected to determine the QoS attributes, the flow records and the policing behavior. The Mapper/translator performs the translation between the external QoS requirements carried by the signaling protocol, e.g., RSVP into the GPRS QoS attributes. The packet classifier is used to identify the incoming flows. In order to do that the classifier needs some classification rules. These rules are stored in flow records. These records are a part of the TFT to both the MT and GGSN (see Section 4.3.3.2). An other component of the TFT is the policing behavior. The selected default policing behavior is sent to the GGSN via the MT. Note that this policing behavior may be either be provisioned by all MS with active contexts at a given GGSN or be stored in the HLR as the part of their subscription profiles.

It is proposed that the signaling exchange between the TE, MT and GGSN is a part of the PDF context signaling. The TE will have to define when to activate or re-negotiate a PDF. The TE protects the GPRS network from excessive amount of signaling by using a flow control mechanism (this is not yet defined). This mechanism is included in the policer. In addition the MT has to regulate the amount of PDF context signaling.

By using the flow record the MT maps the user plane uplink packet sent from the TE, to the right PDF context. In [SMG12 C99-461] a procedure to map the external to GPRS flows to different PDF contexts is described. This can be achieved by using:

- The Multi-Class Multi-Link (MCML) PPP identifiers. MCML PPP (see [RFC1990], [RFC2686]) that is a link layer framing, can be used to separate QoS flows (see Figure 5-1). This protocol supports multiple levels of priorities;
- By using other multi-link protocols between the TE and MT;
- By analyzing the TOS byte in the MT (see Figure 5-2). The TOS byte of the IP header is used to separate the QoS flows in uplink direction. First of all, in the TE the different QoS flows are identified. Afterwards, according to these QoS flows the TOS fields of the IP packets are set. The MT by looking to the TOS byte in the IP packet will be able to map the flows to the correct uplink PDF context.

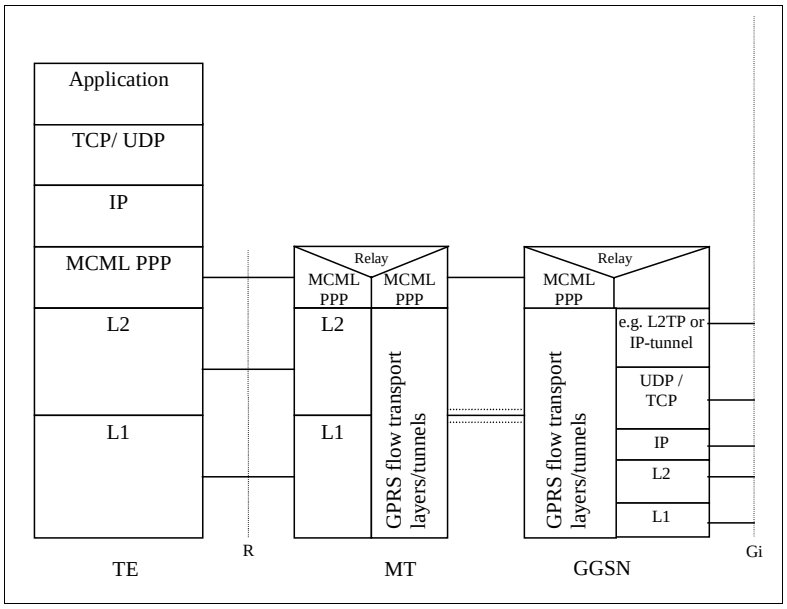

Figure 5-1: User plane Protocol stacks for the MCML PPP option (from [SMG12 C-99-461])

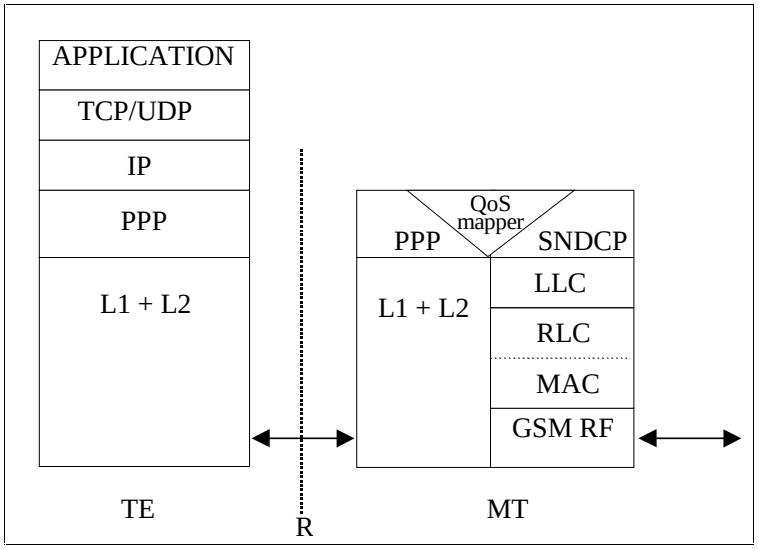

Figure 5-2: User plane protocol stacks for the "MT terminated PPP" option (from [SMG12 C-99-461])

Due to the fact that the radio link scheduling executes an implicit form of policing, this is not needed in the MT. However, policing in the TE is still required and provided.

In Figure 5-4 the functional decomposition of the GGSN is shown. The operations performed by the GGSN for the downlink direction are similar to the ones performed by the MS for the uplink direction, with the exception of translation of the external QoS requirements and the GPRS QoS attributes. The packet classification and the policing procedures performed in the GGSN are based on the TFT information sent by the MT. The mapping on the user plane of the external to GPRS flows to different PDF contexts for downlink direction at the GGSN (see [SMG12 C-99-461]) can be provided by:

- Parts of the header of the received IP packet are matched to the available flow template that is associated to a certain PDF context;
- Based on local flow analyses in the GGSN, the received packets are mapped to the available PDF contexts.

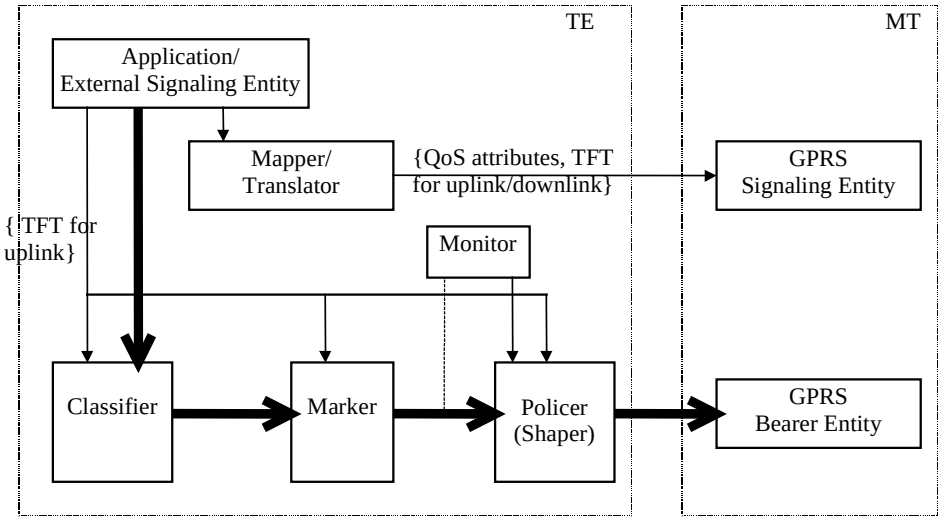

Figure 5-3: Functional decomposition of the MS (from [SMG12 C-99-462])

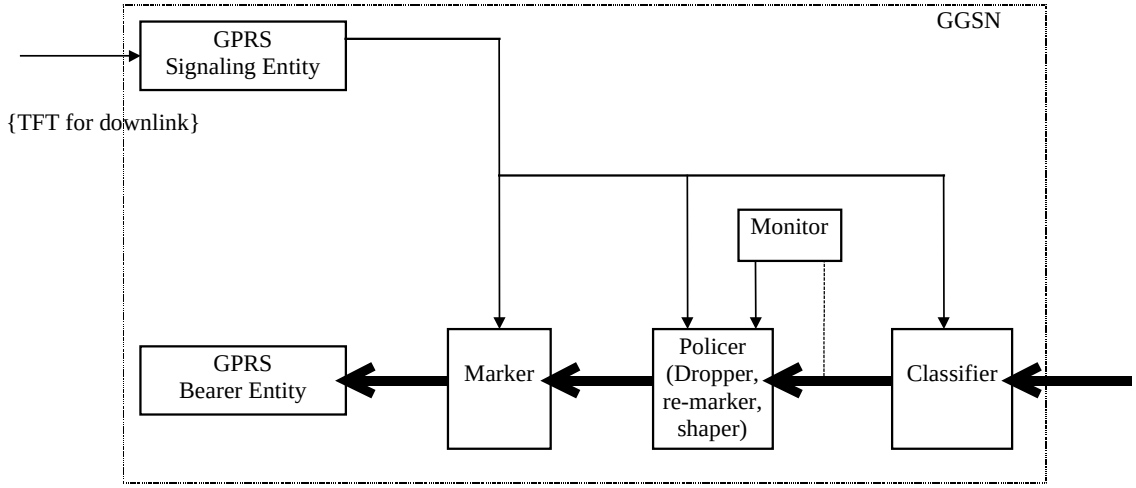

Figure 5-4: Functional decomposition of the GGSN (from [SMG12 C-99-462])

Solution provided by the GPRS (Release 1999) QoS management mechanisms:
The GPRS Release 1999 is capable of using the QoS mechanisms defined by the Ericsson proposals in [SMG12 C-99-461] and [SMG12 C-99-462]. The GPRS Release 1999 user plane protocol stacks used in a Mobile Station and described in [3GPP 270.60] are identical to the ones explained in [SMG12 C-99-461]. Apparently, the QoS functional decomposition in the MS and the GGSN that will have to be used in Release 1999 is not completely specified. A starting point has been made in [3GPP23.907]. However, the QoS functional decompositions for MS and GGSN depicted in Figure 5-3 and Figure 5-4 could also be used in the GPRS Release 1999.

Q12. Does the mechanism offer opportunities to implement shaping?

Solution provided by the GPRS (Release 1998) QoS management mechanisms:

Shaping is not specified by the GPRS standards.

Solution provided by Ericsson's proposed QoS management mechanisms:

Shaping is supported by the Ericsson's proposal (see answer of question Q.11 and [Tdoc SMG12 C-99-462]).

Solution provided by the GPRS (Release 1998) QoS management mechanisms:

Not yet specified, but due to the similarities between the QoS mechanisms proposed by Ericsson and the GPRS Release 1999, we think that shaping will be supported in Release 1999.

5.6 Soft State

In the IntServ framework, the information related to the accomplished reservations is maintained using the soft state concept.

One question created in [ZeAi99] is used to test if the GPRS wireless technology is capable of supporting the soft state concept.

Q13. Does the mechanism offer opportunities to maintain soft states?

Solution provided by the GPRS (Release 1998) QoS management mechanisms:

The GPRS standards do not mention that soft states are maintained.

Solution provided by Ericsson's proposed QoS management mechanisms:

Not yet specified.

Solution provided by the GPRS (Release 1999) QoS management mechanisms:

The GPRS 1999 standards do not mention that soft states are maintained.

5.7 Scalability

A disadvantage of the IntServ framework is that it is not able to scale to the largest expected number of users.

One question created in [ZeAi99] is used to test if the GPRS wireless technology is capable of supporting the largest possible number of users when implementing the IntServ framework.

Q14. Is the mechanism scalable to the largest possible number of users when implementing Integrated Services?

Solution provided by the GPRS (Release 1998) QoS management mechanisms:

The GPRS system may create a PDP context per one application flow. This is similar to the disadvantage that the Intserv framework has. However, GPRS does not use the concepts of soft state refreshing and multifield classification that are certainly used in Intserv infrastructures. Regarding scalability, this is an advantage compared to Intserv. Thus we can conclude that GPRS scales beter than Intserv.

Solution provided by Ericsson's proposed QoS management mechanisms:

In the Ericsson's proposal is mentioned that a PDF context may be created per GPRS flow. However, the proposal does not focus in detail on this issue. Therefore, we could not deduce if this flow will introduce soft states procedures, that are similar to the Intserv concept. Therefore we do not know if this concept will be more scalable than the Intserv concept.

Solution provided by the GPRS (Release 1999) QoS management mechanisms:

The GPRS Release 1999 system may create a PDP context per GPRS flow. This is similar to the disadvantage that the Intserv framework has. However, GPRS Release 1999 does not use the concepts of soft state refreshing.

5.8 Fault Tolerance and Recover

A network is fault tolerant when it is able to function under the presence of failures. Moreover, in some situations the network should be able to recover from local failures.

Two questions created in [ZeAi99] are used to test if the GPRS wireless technology is capable of providing fault tolerance and recovery.

Q15. Is the mechanism able to inform end users about the quality of the link?

Solution provided by the GPRS (Release 1998) QoS management mechanisms:

All Mobile Stations will be capable of measuring the RF quality of the link they are using. Thus the answer is yes.

Solution provided by Ericsson's proposed QoS management mechanisms:

All Mobile Stations will be capable of measuring the RF quality of the link they are using. Thus the answer is yes.

Solution provided by the GPRS (Release 1999) QoS management mechanisms:

All Mobile Stations will be capable of measuring the RF quality of the link they are using. Thus the answer is yes.

Q 16. Is the mechanism able to select a particular route in the case where repeaters are used?

Solution provided by the GPRS (Release 1998) QoS management mechanisms:

This is not applicable for GPRS.

Solution provided by Ericsson's proposed QoS management mechanisms:

This is not applicable for GPRS.

Solution provided by the GPRS (Release 1999) QoS management mechanisms:

This is not applicable for GPRS.

5.9 Independence from Higher Layer Protocol

This issue focuses on the availability of an access network to support the IntServ framework well even when other resource reservation protocols than RSVP are used.

One question created in [ZeAi99] is used to test if the GPRS wireless technology is capable to support the IntServ framework well even when other resource reservation protocols than RSVP are used.

Q17. Is the mechanism able to provide Integrated Services even when other resource reservation protocols are used?

Solution provided by the GPRS (Release 1998) QoS management mechanisms:

This can be accomplished by using the PDP context management procedures explained in Section 4.3.3.1.

Solution provided by Ericsson's proposed QoS management mechanisms:

This can be accomplished by using the PDP/PDF context management procedures explained in Section 4.3.3.2.

However, for an end to end resource reservation provisioning the PDP/PDF context management and the IntServ external signaling, e.g., RSVP signaling have to interwork. In other words new end to end QoS interworking procedures have to be provided.

Solution provided by the GPRS (Release 1999) QoS management mechanisms:

Same as the solution provided by the QoS mechanisms specified in the Ericsson proposals.

5.10 Interworking between GPRS QoS management and Intserv concept

The GPRS Release 1998 QoS management mechanism can interwork with an IntServ external signaling, e.g., RSVP, only if a number of functionality enhancements will be introduced into the MS and GGSN. Note that many of these enhancements are already introduced in GPRS Release 1999.

5.10.1 QoS end to end interworking at the MS

The additional enhancements to be introduced in the GPRS Release 1999 are similar to the ones introduced in Figure 5-3 for MS and Figure 5-4 for the GGSN. The mapping in the user plane of the IntServ flows to the PDP contexts can be achieved by using one of the methods described in the answer given to question Q11, that is still applicable for this situation, e.g., at MT: local flow analysis is used for this mapping.

[SMG12 C-99-461] describes an end to end QoS interworking that is mainly accomplished in the MS (in the TE). Figure 5-5 depicts the message sequence for the situation that the QoS reservation is initiated by the MS (TE). Note that this is done for bi-directional PDP (“first” or Secondary) flows. The following steps are performed:

[..

1. The TE may forward a RSVP PATH message via IP towards the remote host. The message is carried with the QoS of the “first” PDP context
2. Assuming the receiving node is capable of RSVP message processing and is willing to receive traffic from the TE, a RSVP RESV message is forwarded from the remote host back to the TE.
3. The TE then initiates the activation of a new “Secondary” PDP Context or the modification of an existing one to satisfy the requirements of the traffic. Since, it is desirable to avoid Micro Flow analysis in the MT, the PDP context used by the TE has to include:
   - The MCML PPP class id for the designated traffic, used in case of MCML PPP or
   - The TOS Byte used in case of ‘PPP with TOS Byte marking’
4. The TE sends a new PATH message with updated QoS requirements according to the negotiated QoS with the network.] (based on [SMG12 C-99-461])

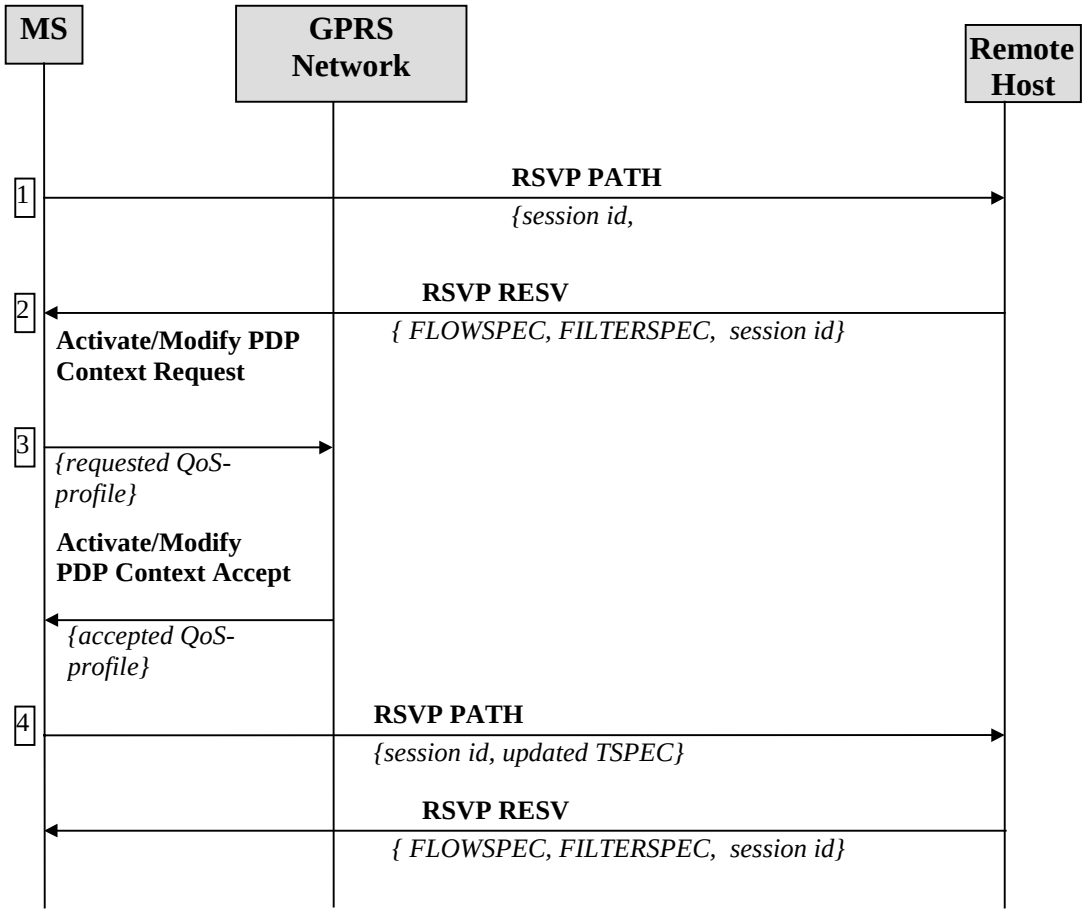

Figure 5-5: Message sequence for QoS reservation, MS (TE) originating case (based on [SMG12 C-99-461])

Figure 5-6 depicts the message sequence for the situation that the QoS reservation is originated by the remote host. Note that this is done for bi-directional PDP flows. The following steps are performed:

1. A RSVP PATH message is received by the MS (TE), via the GPRS network from the remote host. This message is carried with the QoS profile of the “first” PDP Context.
2. The requested QoS is negotiated between the MS (TE) and the network;
3. The MS (TE) finally sends the RESV message.

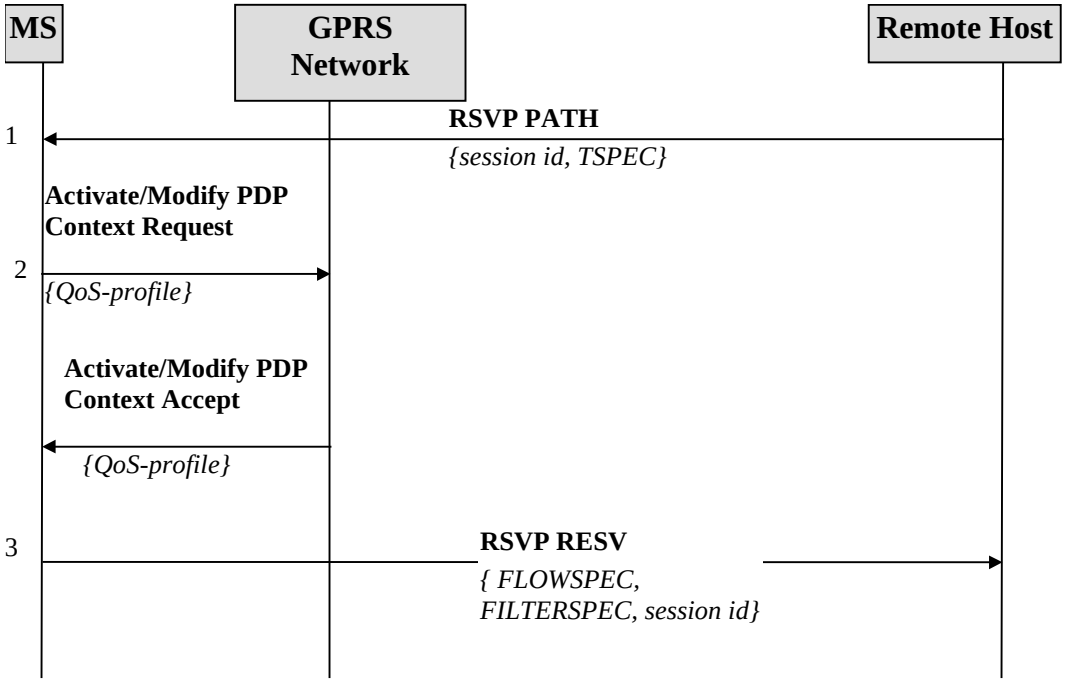

Figure 5-6: Message sequence for QoS reservation, Remote Host originating case (based on [SMG12 C-99-461])

The main advantage of this scheme is that applications that are able to use the QoS IntServ framework, will also be supported by an GPRS MS. However, the main disadvantage of this End to end QoS interworking scheme is that the edge nodes (the TE in the MS) will have to support two QoS concepts, i.e., the Intserv framework and the PDP context framework. Compared to an MS that does not provide end to end QoS interworking, the complexity and probably the cost of an MS that provides this interworking will increase.

5.10.2 Proposed QoS end to end interworking at the GGSN

We propose a solution to the above given disadvantage, by providing a specification for the end to end QoS interworking at the GGSN. Note that this solution can only be provided for the situation that the QoS management is accomplished by using the PDP management context specified for GPRS Release 1999.

In this proposal, depending on the MS capabilities, the end to end QoS interworking can be accomplished either in the MS or in the GGSN.

In the PDP context stored in the GGSN, information must be available to specify that the MS is capable to provide end to end QoS interworking. If that is the case then the QoS interworking will be accomplished using the method described in 5.10.1. Otherwise, the end to end QoS interworking is accomplished in the GGSN. In this situation it is considered that the GGSN will be able to perform a RSVP proxy functionality [GaDu00].

The functional decomposition of the MS and GGSN depicted in Figure 5-3 and Figure 5-4 should be modified. The new functional decomposition for the MS is shown in Figure 5-7 wherein the TFT for the uplink direction is specified by the GGSN. Furthermore, the Mapper /Translator entity is not anymore required and is not used. For the GGSN the new functional decomposition is shown in Figure 5-8. In this decomposition a mapper/translator is required to translate in the uplink direction the PDP contexts to RSVP QoS information, i.e., included in RESV and PATH messages. For the downlink direction, the RSVP QoS information, i.e., included in the RESV and PATH messages are translated to PDP contexts.

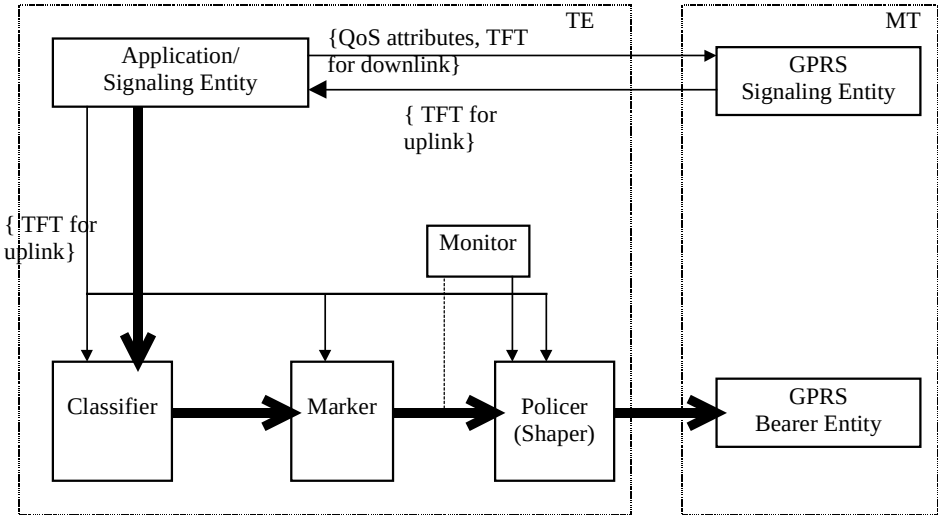

Figure 5-7: New proposed functional decomposition of the MS

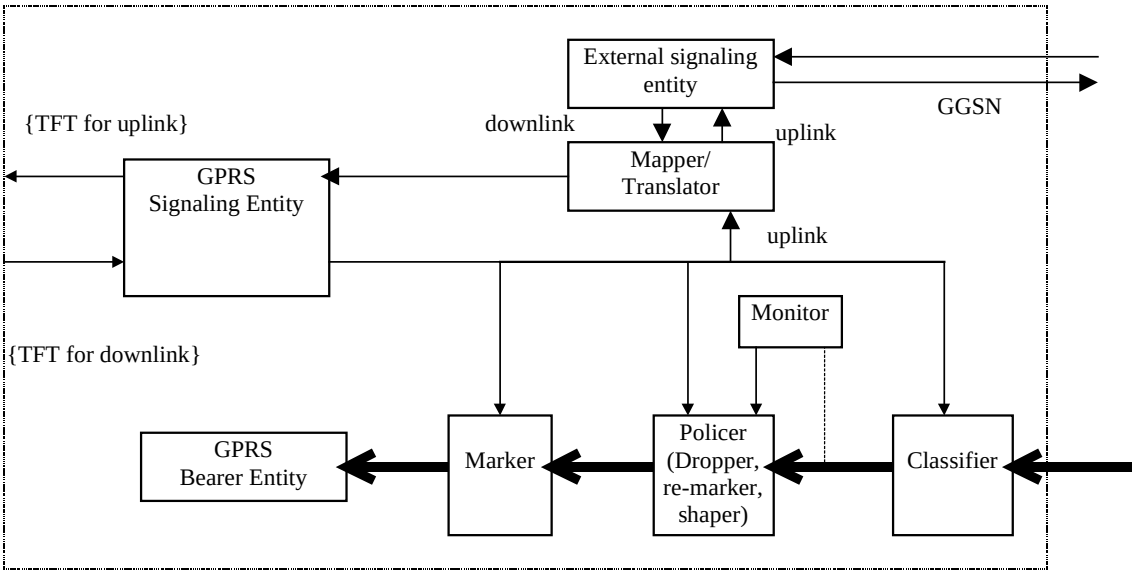

Figure 5-8: New proposed functional decomposition of the GGSN

The mapping in the user plane of the IntServ flows to PDP contexts for the downlink direction in the GGSN is similar to the mapping that is described in Section 5.10.1 for the uplink direction in the MS (i.e., TE). For the uplink direction in the GGSN, the mapping of the PDF contexts to the IntServ flows the inverse functionality of the downlink mapping in GGSN should be used.

Figure 5-9 depicts the message sequence for the QoS reservation procedure initiated by the MS. This is accomplished in the following sequential steps (Note that the messages that are used in the GPRS PDP management are discussed in Section 4.3.3.3):

1. The MS sends an Activate PDP Context Request to SGSN that includes one QoS profile identifying, a maximum value.
2. SGSN if is accepting the request it sends a Create PDP Context Request to GGSN.
3. The GGSN after receiving the “Create PDP Context Request” will have to translate the GPRS QoS profile into the Source traffic characteristics (Tspec) of a RSVP PATH message (see [ZeAi99]). Furthermore, the PDP Context ID is translated to an RSVP session ID. In this document, we propose that the “mapper” function, located in the GGSN, can use a predefined algorithm or additional information stored in its data base to define the minimum QoS profile that is related to the application that the MS is supporting.
4. If the receiving Remote Host (RH) is RSVP capable and is willing to receive traffic form the MS (TE) then a RSVP RESV message is send by the RH back to the GGSN.
5. The RESV message sent by the receiving RH is received by the GGSN. This message contains among others the RSPEC, FILTERSPEC and FLOWSPEC and the Session ID information fields.. The session ID is translated to the PDP Context ID and the RSPEC, FILTERSPEC and FLOWSPEC are translated to a QoS profile. It is possible that the new uplink QoS profile, i.e., QoS negotiated, is different, i.e, less, then the maximum QoS profile that was sent by the GGSN to the receiving RH. If the value of the QoS negotiated is in the region defined by the minimum (see step 3) and maximum QoS profiles, then the GGSN will not reject the RESV message and a “Create PDP Response” message is sent to the SGSN.
6. The SGSN sends an Activate “PDF Context Accept” message to the MS.

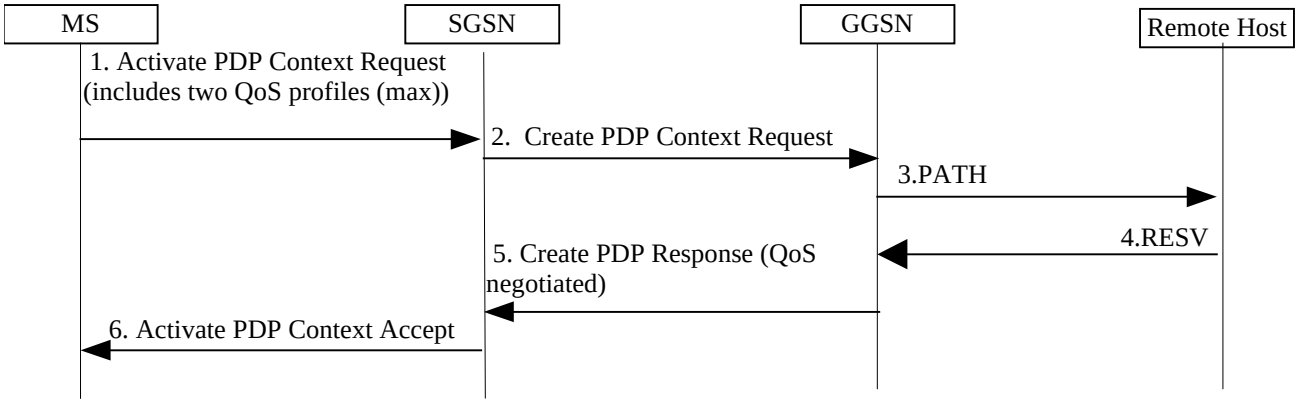

Figure 5-9: Message sequence of QoS interworking at GGSN; Ms originated

Figure 5-10 depicts the message sequence for the QoS reservation procedure originated by the Remote Host. This is accomplished in the following sequential steps.

1. The RH sends a PATH message to the MS via GGSN. This PATH message specifies the QoS on the MS downlink direction and it includes among others, a Session ID and the required TSPEC for the QoS in the MS downlink direction.

2. The GGSN translates the Session ID to the PDF context ID and the TSPEC to a QoS profile used for the MS downlink direction. Afterwards, the GGSN sends a “Create PDF Context Request” message to the SGSN.
3. If the SGSN agrees with the request, then it sends an “Activate PDF Context Request” message to the MS;
4. If the MS accepts the request then an “Activate PDF Context Accept” message is sent to the SGSN.
5. SGSN sends a “Create PDF Context Response” message to the GGSN.
6. GGSN translates the received QoS profile into the RESV RSPEC, FLOWSPEC and FILTERSPEC information. The PDF Channel identifier is mapped to the RESV Session Id information filed. The RESV message is sent to the RH.

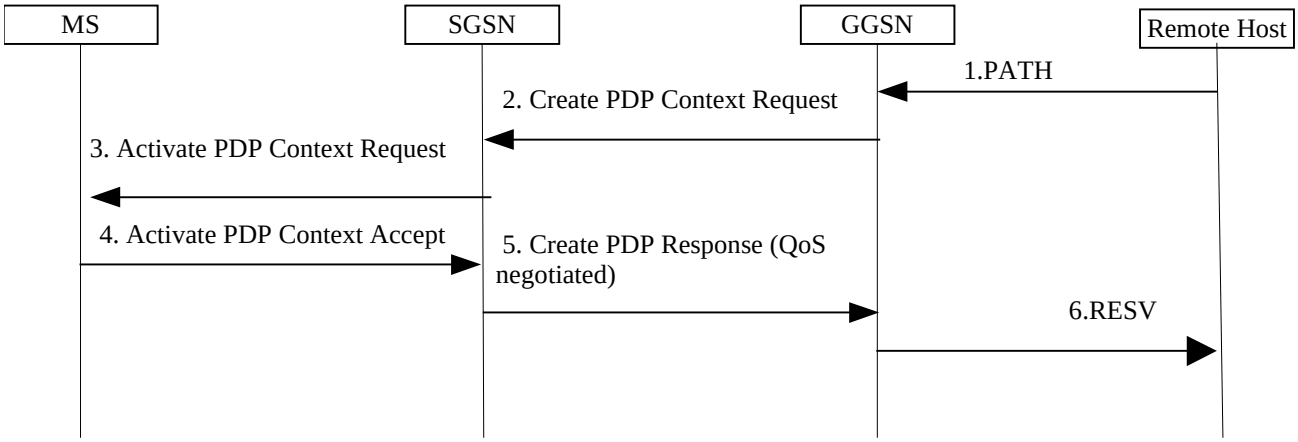

Figure 5-10: Message sequence of QoS interworking at GGSN; originated by Remote Host

5.11 Receiver Heterogeneity

In the situation of a multicast communication, the GPRS wireless access concerning the same flow must be able to provide different QoS levels to the multicast group receivers. One question created in [ZeAi99] is used to test if the GPRS wireless technology supports the receiver heterogeneity.

Q18. Is the mechanism able to provide different QoS, concerning the same flow, for different receivers?

Solution provided by the GPRS (Release 1998) QoS management mechanisms:

The PTM-M and PTM-G communication is not specified. However, in [GSM 02.60] is mentioned that the subscriber who receives the PTM-M data is passive and cannot affect the PTM-M QoS parameters;

Solution provided by Ericsson’s proposed QoS management mechanisms:

Not yet specified.

Solution provided by the GPRS (Release 1999) QoS management mechanisms:

The GPRS Release 1999 supports the PTM-G (see [3GPP22.060]) QoS profile negotiation. However, the procedures that will have to be used are not yet specified.

5.12 Support for different Filter Styles

In the IntServ framework, RSVP defines three different filter styles (see [ZeAi99]). These are the Fixed Filter (FF) where one specific sender is specified, the Shared Explicit (SE) filter where any of two or more senders are specified and the Shared Wildcard filter where any sender in a group is selected. The GPRS wireless access should be able to support these filter styles.

Q19. Is the mechanism able to support the different filter styles?

Solution provided by the GPRS (Release 1998) QoS management mechanisms:

It is not supported by the GPRS access system. However FF is always supported.

Solution provided by Ericsson's proposed QoS management mechanisms:

Not yet specified.

Solution provided by the GPRS (Release 1999) QoS management mechanisms:

Not yet specified.

6 Differentiated Services in GPRS

6.1 Introduction

The Differentiated Services (DiffServ) framework (see [RFC2475], [Difframe]) is a method of distinguishing different flows of packets, which requires some policing, but does not necessarily require the state information associated with the flows defined by integrated services.

This Section describes how the DiffServ QoS requirements, specified in [ZeAi99], are supported by the GPRS technology. Note that this description is provided for the GPRS QoS management contexts discussed in Section 4.3.3.1, i.e., the GPRS (Release 1998) QoS management mechanisms, in Section 4.3.3.2, i.e., Ericsson's proposed QoS management mechanisms and Section 4.3.3.3, i.e., the GPRS (Release 1999) QoS management mechanisms.

6.2 Service Level Agreements

The Service Level Agreement (SLA) [RFC2475] specifies the negotiated contract between adjacent domains. This contract can be either static or dynamic. The technical part of the SLA is called Service Level Specification that specifies the forwarding service to be provided to a client, with the accompanying parameters such as peak rate, burst size. The Traffic Conditioning Agreement (TCA) defines which actions the client must do to obtain the desired service and which actions the service provider will take to enforce the predefined limits. This subsection discusses the possibility of the GPRS access network to establish SLS's with an interconnection network.

Solution provided by the GPRS (Release 1998) QoS management mechanisms:

As described in Section 4.3.3.1, the PDP context management procedures can be used to establish different QoS profiles. The PDP context is used to store the information required for a certain QoS profile. An SLA is a concept that stores also information that is required to support QoS. However, the information stored by the SLA is different then the one stored by a PDP context. The GPRS will be able to establish SLA only if a number of additional information fields, similar to the ones included in the SLA, will be included in the PDP context.

Solution provided by Ericsson's proposed QoS management mechanisms:

The SLA information fields have to be added to the PDP context described in Section 5.10.2.

Solution provided by the GPRS (Release 1998) QoS management mechanisms:

The SLA information fields have to be added to the PDP context described in Section 5.10.2.

6.3 Marking of IP packets

This Issue is related to the possibility of marking of IP packets i.e. setting the DSCP (DiffServ Code Point) byte. The DSCP is used to select a Per Hop Behavior (PHB) at each Diffserv aware node. The PHB describes the externally observable behavior at a node.

Solution provided by the GPRS (Release 1998) QoS management mechanisms:

This function is not supported in the GPRS (Release 1998) QoS management mechanism.

Solution provided by Ericsson's proposed QoS management mechanisms:

The marking function is provided by the Ericsson's proposal (see Section 5.5, Figure 5-3 and Figure 5-4).

Solution provided by the GPRS (Release 1999) QoS management mechanisms:

See the answer given in "*Solution provided by Ericsson's proposed QoS management mechanisms".*

6.4 Classification, policing and re-shaping

Possibility of Classification, policing and (re-)shaping incoming traffic, into the DiffServ domain, at the ingress node based on the SLA.

Solution provided by the GPRS (Release 1998) QoS management mechanisms:

The classification and policing functions are supported in GPRS. However, these classification and policing functions are quite different from the ones required in the DiffServ framework (see [RFC2475]). Therefore, these functions can be used to co-operate with the DiffServ network only if their functionalities are enhanced (see e.g., Section 5.5). Re-shaping is not supported by the GPRS (Release 1998).

Solution provided by Ericsson's proposed QoS management mechanisms:

All three functions are supported by the Ericsson's proposal (see Section 5.5 and 5.10.2). However, functionality enhancements are required.

Solution provided by the GPRS (Release 1999) QoS management mechanisms:

See the answer given in "*Solution provided by Ericsson's proposed QoS management mechanisms".*

6.5 Admission control

In case of dynamic SLAs and Bandwidth Brokers (BB), an admission control function for resource requests should be available.

The admission control functions that are supported in GPRS are discussed in Section 5.3.

6.6 Implement a Per-Hop-Behavior

The Differentiated Services framework uses a concept at each node that describes the externally observable behavior, e.g., delay, delay jitter, drop priorities, at that node. This concept is called "Per Hop Behavior" (PHB) (see [RFC2475]). An wireless access technology should be able to support PHB's. This section discusses this issue focussing on the GPRS technology.

Solution provided by the GPRS (Release 1998) QoS management mechanisms:

The current GPRS (Release 1998) network does not support Diffserv PHB's. However, similar functionalities can be achieved.

Furthermore, Section 6.7 discusses a way of partially providing Diffserv PHB's in the GPRS network.

Solution provided by Ericsson's proposed QoS management mechanisms:

Similar, to the GPRS (Release 1998) system, the Ericsson's proposal is not able to support the Diffserv PHB concept. However, by configuring the Mapper/Translator this could be done.

Solution provided by the GPRS (Release 1999) QoS management mechanisms:

See the answer given in "*Solution provided by Ericsson's proposed QoS management mechanisms".*

6.7 Proposed mechanism for interworking between GPRS QoS management and the Diffserv concept

By enhancing the functionality of the GPRS Release 1999 nodes, i.e., GGSN, the interworking between the GPRS QoS management procedures and a Differentiated Service domain will be enabled.

The Diffserv concept as specified in [Difframe] can be implemented in different ways depending on which entity is providing the control to share the available DiffServ resources, e.g., by individual entities or Bandwidth Brokers (BBs), and on how the SLA is configured, i.e., statically or dynamically. In general, the BB (see [NiJa97], [TeHa99]) is used to control the internal to a Diffserv domain demands and the resources based on a local policy database. Furthermore, the BB is used to set up and maintain bilateral agreements that are reflecting the traffic policies with neighboring domains.

In Figure 6-1 we propose a BB architecture that can be used in an access DiffServ domain. This consists of:

Aggregation (see [BaIt00]): aggregates different E2E (end to end) microflow (RSVP) reservations into one “aggregate” (RSVP) reservation. In [Balt00] is mentioned that the aggregator is the first router in the aggregation region that it processes the different E2E (end to end) PATH message. The aggregator is able to set and manage the “aggregate” RSVP state into a node. In our situation, in the GPRS domain the aggregator can aggregate several GPRS QoS reservations into one “aggregate” (RSVP) reservation.

Deaggregation (see [BaIt00]): is the other end point of an aggregation region. An aggregation region is a region that is able to process the “aggregate” RSVP messages. In [BaIt00] is mentioned that the deaggregator is the last router in the “aggregation region” that processes the E2E PATH message. The deaggregator is able to set and manage the “aggregate” RSVP state into a node.

External signalling, e.g., RSVP, with neighboring domains: this entity manages the bilateral agreements reflecting traffic policies with the BBs of the neighboring domains. Note that the BB of the neighbouring domains should be able to handle reservation aggregates.

DiffServ local resource allocation: manages internal demands and resources based on a local policy database. Note that this entity is capable to intercommunicate via e.g., RSVP, COPS or SNMP, with internal and boundary Diffserv routers.

PDP (Policy Decission Point): is responsible for determining the actions that are applicable to packets. The PDP is used to control the actions that are performed by the Policy Enforcement Points (PEP). PEP is usual located in a Diffserv node and is responsible for the enforcement and execution of the policy actions.

Policy Repository: is the data base that stores all the policies defined in the domain.

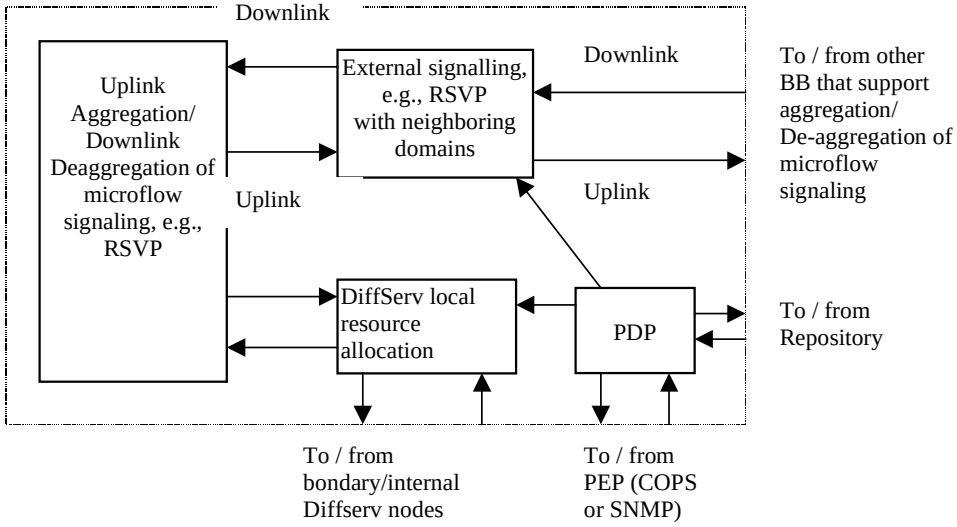

Figure 6-1: Possible architecture of a BB in an access Diffserv network

A Diffserv domain consists of DiffServ boundary nodes and interior nodes. The boundary nodes are used to inter-connect the DiffServ domain to other DiffServ or non-Diffserv domains. The Diffserv boundary node can function both as a Diffserv ingress node or Diffserv egress node for different directions of traffic. The ingress node ensures that the traffic entering the DiffServ domain satisfies and conforms to any TCA settled with a neighbor domain. The egress node may perform traffic conditioning functions, such as metering, shaping, policing and/or remarking, to the traffic that exits the domain.

The architecture of a boundary node can be seen in Figure 6-2. It consists of the following functions:

- Classifier that directs a stream of packets to the Traffic conditioner. The classification can be achieved either based on the DSCP, called Behavior Aggregate (BA) classification, or based on a set of fields in the packet, called Multi-Fields (MF) classification;
- Meter profile that measures the traffic against a predefined profile;
- Marker that possibly based on metering it sets the DSCP;
- Shaper/Dropper is delaying or dropping packets to conform to a TCA.

The DiffServ interior nodes are the ones that are located in a Diffserv domain and that are able to communicate to other interior nodes or boundary nodes.

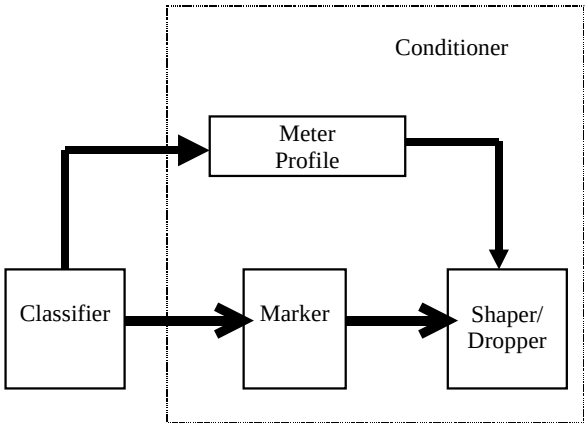

Figure 6-2: DiffServ boundary node architecture

Both the boundary nodes and interior should be able to select a PHB based on the DSCP. The interior nodes may provide limited traffic conditioning functions such as DSCP re-marking.

In our proposal we assume that the control of the sharing of the resources is accomplished by the BB's and the SLA is dynamically configured. Furthermore, we consider that the GPRS network is a non-diffserv domain and that the GGSN is used to interconnect the GPRS (non-DiffServ-capable domain) to a Diffserv domain. GGSN will be ale to employ traffic conditioning to pre-mark the traffic before it reaches the DiffServ domain. Moreover, GGSN will be seen by the BB that manages the neighbouring DiffServ domain as a BB. As GPRS QoS management procedures we use the GPRS Release 1999 procedures described in Section 4.3.3.3. Furthermore, all the mechanisms introduced in the Ericsson proposal will have to be applied.

Due to the reasons mentioned in Section 5.10.2 we will assume that the interworking between the GPRS network and the Diffserv domain will be accomplished in the GGSN. Therefore, we will assume that the GGSN will be used as a boundary node. Furthermore, the GGSN must be able to perform a limited BB functionality. The architecture that can be used for the MS is similar to the one depicted in Figure 5-7. The proposed architecture for the GGSN node is depicted in Figure 6-3 for the downlink direction and in Figure 6-4 for the uplink direction.

For the downlink direction (see Figure 6-3) the functional entities Monitor, GPRS marker, GPRS policer, GPRS signalling entity and GPRS bearer entity are similar to the ones discussed in Figure 5-8.

The **external signalling entity** manages the bilateral agreements that are reflecting traffic policies with the BB of the neighboring domains.

The **deaggregator/PDP/translator** based in a certain predefined policy should be able to divide the "aggregated" reservations into per flow GPRS QoS reservations, i.e., PDF context activations. The user plane Diffserv packets are mapped to GPRS packets that are using a certain PDF context. This mapping is similar to the one described in the answer of Q11 in Section 5.5. The difference is that the based on a predefined policy stored into the PDP, the DSCP is mapped into a certain PDF context.

The **"aggregate" RSVP data base** manages the "aggregated" reservations.

The Diffserv to GPRS **classifier** uses information from the translator to classify the Diffserv packets based on the mapped DSCP to PDF context elements.

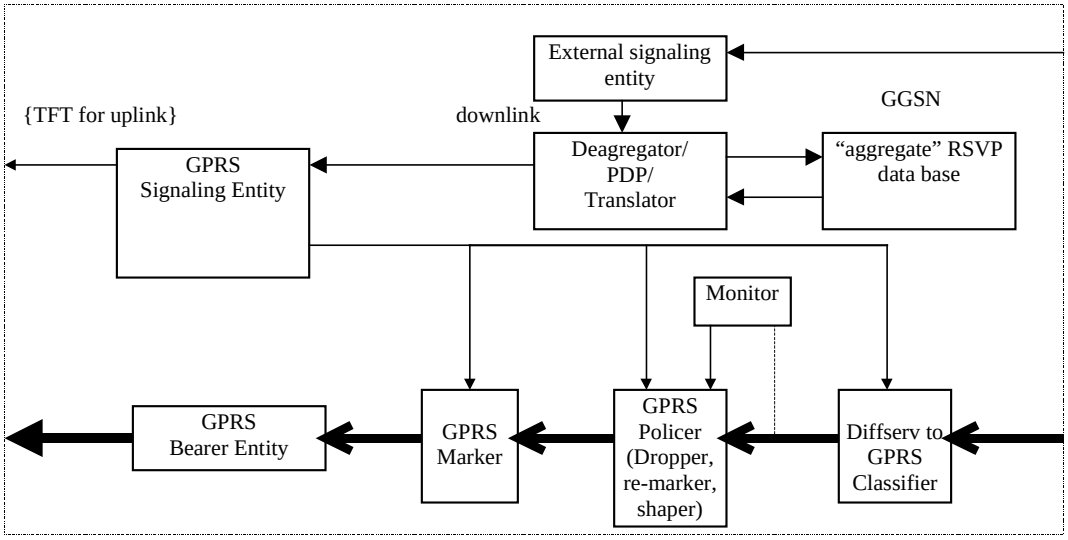

Figure 6-3: Functional decomposition of the GGSN to be used for GPRS/DiffServ interworking in downlink direction

For the uplink direction (see Figure 6-4) the functional entities GPRS signalling entity and GPRS bearer entity are similar to the ones depicted in Figure 5-8.

The **external signalling entity** has the same functionality as the same entity used for the downlink direction.

The **translator/PDP/aggregator** based on a predefined policy (stored in the PDP) it aggregates several GPRS QoS reservations, i.e., PDP context activations, into one "aggregate" (RSVP) reservation. Furthermore, on the user plane the translator maps the PDP context into the DSCP. This mapping is similar to the one described for the downlink direction. The difference is that the mapping is from the PDF context to a DSCP element.

The **"aggregate" RSVP data base** manages the "aggregated" reservations.
Based on the information obtained from the translator, the GPRS to Diffserv **classifier**, classifies the GPRS packets based on the PDF context to DSCP elements.

The rest of the entities are similar to the ones depicted in Figure 6-2.

In subsection 6.7.1 the proposed message sequence charts for the QoS end to end interworking between a GPRS access network and several Diffserv domains are discussed.

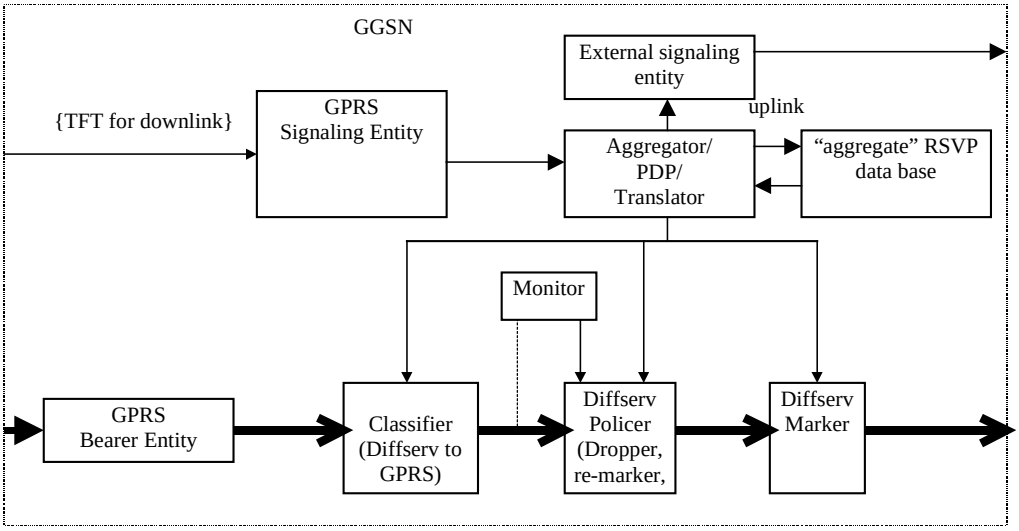

Figure 6-4: Functional decomposition of the GGSN to be used for GPRS/DiffServ interworking in uplink direction

6.7.1 GPRS/Diffserv QoS interworking message sequence charts

The proposed message sequence chart that can be used to provide the end to end GPRS/Diffserv QoS interworking for the situation that the MS is the originating entity is depicted in Figure 6-5. The interworking between the GPRS network and the Diffserv domain will be accomplished in the GGSN. The communication between MS and GGSN is similar to the one discussed in Figure 5-9. In this scenario it is assumed that at the moment the "Create PDP Context request" message arrives at the Aggregator, i.e., GGSN, there are no aggregate path states available (see [BaIt00]). The sequential steps 3 to 15 are accomplished in the following way:

3. The GGSN after receiving the "Create PDP Context Request" message it will translate it into an E2E RSVP microflow PATH message. This message will be used as an RSVP E2E PATH (end to end) message as defined in [BaIt00]. In other words this is a microflow RSVP PATH message that will be used to communicate the QoS request from one end point, in our case the aggregator, to the other end point, in our case the deaggregator via e.g., an IP over IP tunnel. Furthermore, it will find out if a QoS profile can be included in an aggregate path state that exists from the aggregator to deaggregator for a session with an appropriate DSCP. The created E2E message is sent to the deaggregator, i.e., ABB. The main information elements contained in this message are the session_ID and the SENDER_TSPEC.
4. In this scenario we considered that there are no aggregated states. Therefore, the Deaggregator will send an E2E PATHErr message to the Aggregator (see [BaIt00]). The aggregator, subsequently creates an aggregated path state. Only the required resources from the current flows will be included. An AggrPATH message will be sent to NBB.
5. The neighboring NBB is consider to be an interior node of the aggregated region. An interior node in an aggregated region handles the "aggregated" RSVP messages as normal RSVP messages. After receiving the "aggregated" PATH message, it performs the normal RSVP procedures, i.e., an aggregated path state is created, and it sends the "aggregate" PATH message to the ABB that is managing the access network wherein the Remote Host (RH) is located.

6. At the moment that the ABB receives the AggrPATH message and depending on the signalling protocols that will be used in the access network, e.g., COPS (Common Open Policy Server) [BoCo99] or SNMP (Simple Network Management Protocol), the ABB will translate the earlier arrived E2E PATH message into an reservation request message.
7. Considering that the COPS protocol is used then, a COPS DEC (Decision) message will inform the RH that is able to use a certain amount of resources to communicate with the MS.
8. Simultaneously ABB sends an AggrRESV message to NBB.
9. NBB after updating its “aggregate” RSVP data PATH state it forwards the “aggregate” RESV message to GGSN. GGSN assigns the MS requested QoS profile to the subsequent message sent to the SGSN.
10. GGSN will receive the AggrRESV message and it will update its aggregate data PATH state. Furthermore it will create a new message AggRESVConfirm that will be send to the NBB;
11. NBB wil forward the AggRESVConfirm message to the deaggregator, i.e., ABB.
12. RH will report to the ABB if this reservation is possible by sending e.g., a COPS RPL (reply) message.
13. The ABB will translate the received COPS RPL message into an microflow RSVP RESV E2E message, and it will send it to the aggregator GGSN. The created RSVP E2E RESV message it will be tunnelled and sent to the aggregator (GGSN), that is the exit point of the tunnel.
14. The exit point of the tunnel, i.e., GGSN will decapsulate the packet and it will translate it in an Create PDP Response message. Furthermore this message will be send to the SGSN.
15. SGSN generates an Activate PDP Context Accept message and sends it to the MS.

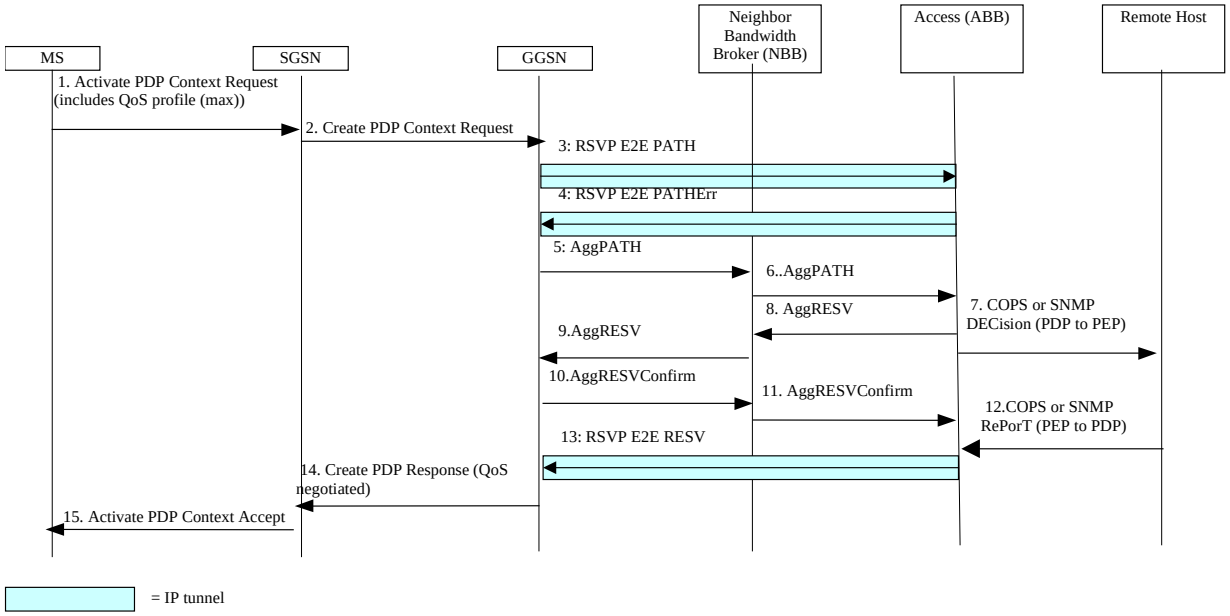

Figure 6-5: Message sequence of QoS interworking (GPRS/Diffserv) at GGSN; MS originated *(no aggregated states available at the moment that the initial E2E PATH message arrives at the aggregator.)*

Figure 6-6 shows the message sequence charts used for the GPRS/Diffserv QoS interworking for the sitiuation that the Qos resource reservation request is originated by the remote host.

The communication between MS and GGSN is similar to the one discussed in Figure 5-10. The sequential steps 1 to 2 and 7 to 9 are accomplished in the following way:

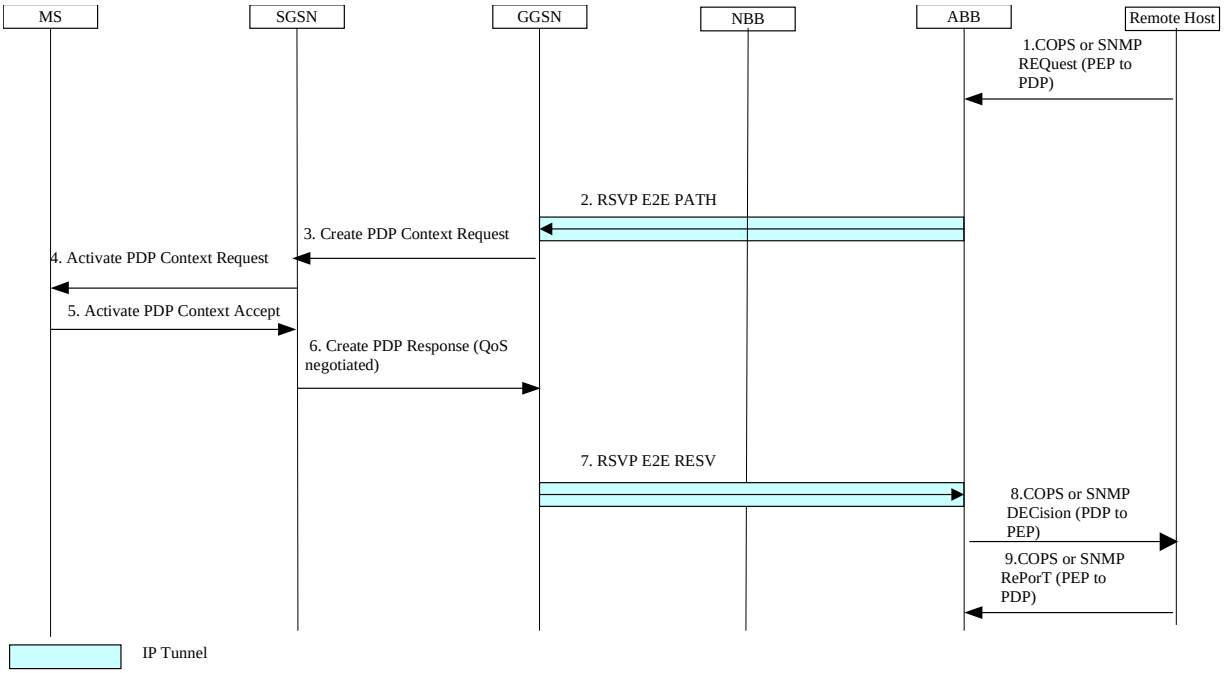

Figure 6-6: Message sequence of QoS interworking (GPRS/Diffserv) at GGSN; Remote Host originated *(it is assumed that all routers in the aggregated region have aggregated PATH states; furthermore there is no need for aggregated reservation resising)*

1. The RH wishes to reserve an amount of resources to use them for an application that requires a certain level of QoS. The request is sent to the ABB by using a signaling protocol, e.g., COPS or SNMP. If COPS is used then RH sends a COPS REQ message to ABB.
2. The ABB after receiving the e.g., COPS REQ it will translate it into an RSVP microflow E2E PATH message.). The E2E PATH message as defined in [BaIt00] will be created. Furthermore, ABB will find out if a QoS profile can be included in an aggregate path state that exists from the aggregator (ABB) to deaggregator (GGSN) for a session with an appropriate DSCP. For this example it is considered that such and aggregated PATH state exists. The main information elements contained in the E2E PATH message are the session_ID and the SENDER_TSPEC.
3. The GGSN receives the RSVP E2E PATH message and it will translate it into an “Create PDF context Request” message. GGSN communicates with the MS in similar way as depicted in Figure 5-10.
6. After the GGSN /MS communication is completed, the GGSN receives a “Create PDP response” message from the SGSN. Furthermore, the GGSN will translate the received “Create PDP response” message into an RSVP E2E RESV message.
7. The created RSVP RESV E2E message it will be tunneled and sent to the aggregator (ABB), that is the exit point of the tunnel.
8. ABB will translate the received RSVP RESV E2E message into e.g., COPS DEC message and informs the RH, that a certain amount of resources should be reserved.
9. If the RH agrees, then it sends a e.g., COPS RPL message to ABB.

7 Conclusions

The European Telecommunications Standards Institute (ETSI) developed the General Packet Radio Service (GPRS), that is a new packet switched data service for GSM, that can allow bitrates, theoretically up to 170 kbit/s per user. However, commercially GPRS systems will support bitrates up to 115 kbit/s.

The main goal of the GPRS technology is to provide access to Internet applications. By converging the Internet and GPRS technologies, it is expected that significant QoS requirements will be imposed on the GPRS technology. In the Internet technology, IETF (Internet Engineering Task Force) specified two frameworks that can be used to support QoS in IP networks. These are the Integrated Services (IntServ) and Differentiated Services (DiffServ) frameworks. The IntServ framework requires some protocol, e.g., Resource reSerVation Protocol (RSVP), to communicate with the IP routers, along the path of the intended flow and reserve the resources necessary for the QoS provisioning. The Differentiated Services (DiffServ) framework is a method of distinguishing different flows of packets, which requires some policing, but does not necessarily require the state information associated with the flows defined by integrated services.

In this document current developments and research activities in the area of Quality of Service (QoS) provisioning in GPRS Release 1998 and Release 1999 are discussed. The main difference between GPRS Release 1998 and GPRS Release 1999 is that the first one is capable of supporting GPRS access networks while the later one additionally is capable of supporting Universal Mobile Telecommunications System (UMTS) access networks. Furthermore, the QoS management principles used for GPRS Release 1999 are similar to the ones used for UMTS Release 1999.

Moreover, this document describes how the GPRS technology supports the QoS requirements that result from the convergence of the Internet and GPRS technologies when either the IntServ or the Diffserv frameworks are used.

It can be concluded that the GPRS Release 1998 technology is able to support different QoS classes, but is unable to support neither the IntServ nor DiffServ frameworks without QoS functionality enhancements.

In May 1999, Ericsson proposed to ETSI a number of QoS functional enhancements for GPRS Release 1998. These functional enhancements after minor modifications are introduced in the GPRS Release 1999. By implementing these enhancements, the GPRS technology becomes capable of supporting the QoS Intserv framework. In the Ericsson proposal the required GPRS to/from IntServ QoS interworking has to be accomplished in the Mobile Station. In this document we propose that the end to end QoS interworking, depending on the MS capabilities, could be accomplished either in the MS or in the GGSN.

Regarding the GPRS to/from Diffserv QoS interworking none solutions were found. In this document we propose a solution on this issue. In particular, we considered that in the near future the dynamic resource allocation becomes an important Diffserv challenge. Moreover, we consider that the inter-Diffserv domain communication is still a challenge. Therefore, we considered that the Diffserv framework uses Bandwidth Brokers to accomplish the inter-Diffserv domain communication. Moreover, we considered that the resource allocation in the DiffServ domain is dynamic. In this document we proposed a number of QoS functional enhancements for the GPRS technology, such that GPRS will be capable of supporting the DiffServ framework.

8 References

All the ETSI GPRS specifications used in this document are referring to the GPRS Release 1998. The 3GPP GPRS specifications are referring to the GPRS Release 1999.

8.1 By alphabet

[3GPP22.060] Title: General Packet Radio Service (Release 1999); Service Description stage 1
Author: 3rd Generation Partnership Project,
Doc. no.: 3G TS 22.060,
Date: March 2000.

[3GPP23.060] Title: General Packet Radio Service (Release 1999); Service Description stage 2
Author: 3rd Generation Partnership Project,
Doc. no.: 3G TS 23.060,
Date: January 2000.

[3GPP23.078] Title: General Packet Radio Service (Release 1999); Customised Applications for Mobile Network Enhanced Logic (CAMEL) Phase 3 –Stage 2
Author: 3rd Generation Partnership Project,
Doc. no.: 3G TS 23.078,

[3GPP23.907] Title: General Packet Radio Service (Release 1999); QoS Concept
Author: 3rd Generation Partnership Project,
Doc. no.: 3G TS 23.907,

[3GPP27.060] Title: General Packet Radio Service (Release 1999); Supporting Packet Switched Services
Author: 3rd Generation Partnership Project,
Doc. no.: 3G TS 27.060,
Date: March 2000.

[3GPP29.060] Title: General Packet Radio Service (Release 1999); GPRS Tunnelling Protocol (GTP) across the Gn and Gp Interface
Author: 3rd Generation Partnership Project,
Doc. no.: 3G TS 29.060,
Date: January 2000.

[ArBi98] Title: GPRS Delay and Capacity Analysis for Web Browsing Application
Author: Y. Argyropoulos, A. Bigloo, J. van Peursem,
Doc. no.: ICT '98. International Conference on Telecommunications, Vol. 2, pp. 32 –36,
Date: 1998.

[BaIt00] Title: RSVP Reservation Aggregation,
Author: F. Baker, et al.,
Doc. no.: Internet Draft, draft-ietf-issll-rsvp-aggr-02.txt,
Date: 2000.

[BrWa97] Title: Concepts, Services, and Protocols of the New GSM Phase 2+ General packet Radio Service,
Author: G. Brasche and B. Walke,
Doc. no.: IEEE Communications Magazine, pp. 94 - 104,
Date: August 1997.

[BoCo99] Title: The COPS (Common Open Policy Service) protocol

Author: J. Boyle, et al.,
Doc. no.: Internet draft, draft-ietf-rap-cops-08.txt,
Date: 1999.

[BuWa96] Title: Random Access Algorithm for Multicast Users,
Author: T. Buol, F. Wattanabe,
Doc. no.: submitted as Tdoc 02/96 to ETSI SMG2 GPRS ad hoc, Tampere, Finland,
Date: Jan 1996.

[CaGo97] Title: General Packet Radio Service in GSM
Author: J. Cai, D. J. Goodman,
Doc. no.: IEEE Communications Magazine, pp. 122 - 131,
Date: October 1997.

[Call95] Title: Call Admission Control for PRMA-based multiservice cellular networks,
Author: F. Callegati,
Doc. no.: Proceedings Australian Telecommunication Networks and Applications Conference, Vol. 1, pp. 485 – 489,
Date: 1995.

[Difframe] Title: An Architecture for Differentiated Services,
Author: Y. Bernet et al,
Doc. no.: Internet Draft, draft-ietf-diffserv-framework-02.txt,
Date: 1999.

[Diffserv] Title: Charter of the Differentiated Services WG,
Author: IETF,
Doc. no.: http://www.ietf.org/html.charters/diffserv-charter.html

[FrBr98] Title: Prioritised random access for GPRS with pseudo Bayesian broadcast control, exponential backoff and stack based schemes,
Author: C. Fresco Diez, A. E. Brand, A. Hamid Aghvami,
Doc. no.: Proceedings of ICT'98 - International Conference on Telecommunications, qvol.1, pp. 24 28,
Date: 1998.

[GaDu00] Title: RSVP proxy,
Author: S. Gai, D. G. Dutt, N. Elfassy, Y. Bernet
Doc. No.: Internet draft, draft-ietf-rsvp-proxy-01.txt,
Date: July 2000.

[GSM 02.60] Title: Digital cellular telecommunications system (Phase 2+); General Packet Radio Service (GPRS); Service description; Stage 1
Author: ETSI,
Doc. no.: ETSI GSM 02.60 GPRS standard,

[GSM 03.20] Title: Digital cellular telecommunications system (Phase 2+); Security related network functions
Author: ETSI,
Doc. no.: ETSI GSM 03.20 GPRS standard,

[GSM 03.22] Title: Digital cellular telecommunications system (Phase 2+); Functions related to Mobile Station (MS) in idle mode and group receive mode
Author: ETSI,
Doc. no.: ETSI GSM 03.22 GPRS standard,

[GSM 03.60] Title: Digital cellular telecommunications system (Phase 2+); General Packet Radio Service (GPRS); Service Description; Stage 2,
Author: ETSI,
Doc. no.: ETSI GSM 03.60 GPRS standard,

[GSM 03.61] Title: Digital cellular telecommunications system (Phase 2+); General Packet Radio Service (GPRS); Point to Multipoint Multicast Service Description; Stage 2
Author: ETSI,
Doc. no.: ETSI GSM 03.61 GPRS standard,

[GSM 03.62] Title: Digital cellular telecommunications system (Phase 2+); General Packet Radio Service (GPRS); Point to Multipoint Group Call Service Description; Stage 2
Author: ETSI,
Doc. no.: ETSI GSM 03.62 GPRS standard,

[GSM 03.64] Title: Digital cellular telecommunications system (Phase 2+); Overall description of the General Packet Radio Service (GPRS) Radio interface; Stage 2
Author: ETSI,
Doc. no.: ETSI GSM 03.64 GPRS standard,

[GSM 04.08] Title: Digital cellular telecommunications system (Phase 2+); Mobile radio interface layer 3 specification
Author: ETSI,
Doc. no.: ETSI GSM 04.08 GPRS standard,

[GSM 04.60] Title: Digital cellular telecommunications system (Phase 2+); General Packet Radio Service (GPRS); Mobile Station (MS) - Base Station System (BSS) interface; Radio Link Control / Medium Access Control (RLC/MAC) protocol
Author: ETSI,
Doc. no.: ETSI 04.60 GPRS standard,

[GSM 04.64] Title: Digital cellular telecommunications system (Phase 2+); General Packet Radio Service (GPRS); Logical Link Control (LLC)
Author: ETSI,
Doc. no.: ETSI GSM 04.64 GPRS standard,

[GSM 04.65] Title: Digital cellular telecommunications system (Phase 2+); General Packet Radio Service (GPRS); Subnetwork Dependent Convergence Protocol (SNDCP),
Author: ETSI,
Doc. no.: ETSI GSM 04.65 GPRS standard,

[GSM 05.01] Title: Digital cellular telecommunications system (Phase 2+); Physical Layer on the Radio Path (General Description)
Author: ETSI,
Doc. no.: ETSI GSM 05.01 GPRS standard,

[GSM 05.05] Title: Digital cellular telecommunications system (Phase 2+); Radio Transmission and Reception
Author: ETSI,
Doc. no.: ETSI GSM 05.05 GPRS standard,

[GSM 05.08] Title: Digital cellular telecommunications system (Phase 2+); Radio Subsystem Link Control
Author: ETSI,
Doc. no.: ETSI GSM 05.08 GPRS standard,

[GSM 08.14] Title: Digital cellular telecommunications system (Phase 2+); General Packet Radio Service (GPRS); Base Station System (BSS) - Serving GPRS Support Node (SGSN) interface; Gb interface layer 1
Author: ETSI,
Doc. no.: ETSI GSM 08.14 GPRS standard,

[GSM 08.16] Title: Digital cellular telecommunications system (Phase 2+); General Packet Radio Service (GPRS); Base Station System (BSS) - Serving GPRS Support Node (SGSN) interface; Network Service
Author: ETSI,
Doc. no.: ETSI GSM 08.16 GPRS standard,

[GSM 08.18] Title: Digital cellular telecommunications system (Phase 2+); General Packet Radio Service (GPRS); Base Station System (BSS) - Serving GPRS Support Node (SGSN); BSS GPRS Protocol (BSSGP),
Author: ETSI,
Doc. no.: ETSI GSM 08.18 GPRS standard,

[GSM 09.02] Title: Digital cellular telecommunications system (Phase 2+); Mobile Application Part (MAP) specification
Author: ETSI,
Doc. no.: ETSI GSM 09.02 GPRS standard,

[GSM 09.18] Title: Digital cellular telecommunications system (Phase 2+); General Packet Radio Service (GPRS); Serving GPRS Support Node (SGSN) - Visitors Location Register (VLR); Gs interface layer 3 specification
Author: ETSI,
Doc. no.: ETSI GSM 09.18 GPRS standard,

[GSM 09.60] Title: Digital cellular telecommunications system (Phase 2+); General Packet Radio Service (GPRS); GPRS Tunnelling Protocol (GTP) across the Gn and Gp Interface

Author: ETSI,

Doc. no.: ETSI GSM 09.60 GPRS standard,

[HoMe98] Title: A performance Evaluation of Internet Access via the General Packet Radio Service of GSM
Author: S. Hoff, M. Meyer, A. Schieder,
Doc. no.: VTC'98, Vol. 3, pp. 1760-1764,
Date: 1998.

[Intserv] Title: Charter of the Integrated Services WG,
Author: IETF,
Doc. no.: http://www.ietf.org/html.charters/intserv-charter.html

[ITU: Q.701] Title: Functional description of the Message Transfer Part (MTP) of Signalling System No. 7

Author:ITU

Doc. no.:ITU-T Recommendation Q.701

[ITU: Q.711] Title: Signalling System No.7 - Functional description of the signalling connection control part
Author: ITU
Doc. no.: ITU-T Recommendation Q.711

[ITU: Q.712] Title: Signalling System No.7 - Definition and function of SCCP messages

Author: ITU
Doc. no.: ITU-T Recommendation Q.712

[ITU: Q.713] Title: Signalling System No.7 - SCCP formats and codes.
Author: ITU
Doc. no.: ITU-T Recommendation Q.713

[ITU: Q.714] Title: Signalling System No.7 - Signalling connection control part procedures
Author: ITU
Doc. no.: ITU-T Recommendation Q.714

[ITU: Q.771] Title: Signalling System No.7 - Functional Description of Transaction Capabilities
Author: ITU
Doc. no.: ITU-T Recommendation Q.771
Date: 1993

[ITU: Q.772] Title: Signalling System No.7 - Transaction Capabilities Information Element Definitions
Author: ITU
Doc. no.: ITU-T Recommendation Q.772
Date: 1993

[ITU: Q.773] Title: Signalling System No.7 - Transaction Capabilities Formats and Encoding
Author: ITU
Doc. no.: ITU-T Recommendation Q.773
Date: 1993

[ITU: Q.774] Title: Signalling System No.7 - Transaction Capabilities Procedures
Author: ITU
Doc. no.: ITU-T Recommendation Q.774
Date: 1993

[ITU-TQ.922] Title: ISDN data link layer specification for frame mode bearer services
Author: ITU,
Doc. no.: ITU TQ.922,
Date: 1992.

[Kar99] Title: Mobile IP
Author: G. Karagiannis,
Doc. no.: QWING State of the Art Report, located at:
http://w3-emn.ericsson.se/project_ING/INGpublic/
Date: 1999

[KAMe99] Title: Wireless Internet Access based on GPRS
Author: R. Kalden, I. Merick, M. Meyer,
Doc. no.: Ericsson document, *Has been submitted for acceptance in special issue of IEEE Communication Magazine - The Evolution of Mobile Data Networking - Februrary 2000. Located at:*
http://research.eed.ericsson.se/gprs_simul/papers/CommMag/CommMag_v4.pdf
Date: 1999.

[NiJa97] Title: A Two-bit Differentiated Services Architecture for the Internet,
Author: K. Nichols, V. Jacobson, and L. Zhang,
Doc. no.: Internet draft, located at:
ftp://ftp.ee.lbl.gov/papers/dsaarch.pdf
Date: Nov. 1997.

[Ostro96] Title: Efficient Transmission of Integrated Voice and Data in Wireless Networks,
Author: M. Ostrowski,
Doc. no.: ICC International Conference on Communications, Vol. 2, pp. 721 –727,
Date: 1996.

[RaJo90] Title: Performance Evaluation of Slotted Aloha with Generalized Retransmission Backoff
Author: D. Raychaudhuri, K. Joseph,
Doc. no.: Proc. IEEE Transactions on Communications, vol. 38, no. 1, pp. 117 – 122,
Date: Jan 1990.

[RFC768] Title: User Datagram Protocol
Author: J. Postel,
Doc. no.: IETF RFC768,
Date: 1980.

[RFC791] Title: Internet protocol
Author: DARPA INTERNET PROGRAM,
Doc. no.: IETF RFC791,
Date: 1981.

[RFC793] Title: Transmission Control Protocol
Author: DARPA INTERNET PROGRAM,
Doc. no.: IETF RFC793,
Date: 1981.

[RFC1990] Title: The PPP Multilink Protocol (MP)
Author: K. Sklower, et, al,
Doc. no.: IETF RFC 1990,
Date: 1996.

[RFC2002] Title: IPv4 Mobility Support,
Author: Charles Perkins (Editor),
Doc. no.: IETF RFC 2002,
Date: 1996.

[RFC2131] Title: Dynamic Host Configuration Protocol,
Author: IETF,
Doc. no.: IETF RFC 2131,
Date: 1997.

[RFC2205] Title: Resource ReSerVation Protocol (RSVP) – Version 1,
Author: R. Braden, et al.,
Doc. no.: IETF RFC 2205,
Date: 1997.

[RFC2460] Title: Internet Protocol, Version 6 Sepecification
Author: S. Deering, R. Hinden,
Doc. no.: IETF RFC 2460,
Date: 1999.

[RFC2475] Title: An Architecture for Differentiated Services
Author: S. Blake, et, al,
Doc. no.: IETF RFC 2475,
Date: 1998.

[RFC2686] Title: The Multi-Class Extension to Multi-Link PPP
Author: C. Bormann,

Doc. no.: IETF RFC 2686,
Date: 1999.

[Rive97] Title: Network Control by Bayesian Broadcast,
Author: R. L. Rivest,
Doc. no.: Proc. IEEE Transactions on Infrom. Theory, vol. IT-33, no. 3, pp. 323 - 328,
Date: May 1987.

[QWING] Title: The Internet NG Project –
WU4: QoS over wireless and mobile access networks
Author: Internet NG WU4 members,
Doc. no.: , located at: http://w3-emn.ericsson.se/project_ING/INGpublic/
Date: 2000.

[ShBu97] Title: Analysis of integrated services in GPRS cellular systems
Author: Y. Shaokai; T. Buot,
Doc. no.: Proceedings APCC'97. Third Asia-Pacific Conference on Communications. Incorporating, Vol. 1, pp. 474 – 478,
Date: 1997.

[SMG12 C-99-460] Title: PDP context and Packet Data Flow context handling for different QoS profiles
Author: Ericsson,
Doc. no.: ETSI STC SMG12 QoS Ad-hoc, Tdoc SMG12 C-99-460,
Date: May 1999.

[SMG12 C-99-461] Title: QoS in GPRS phase 2 – Edge Node QoS interworking
Author: Ericsson,
Doc. no.: ETSI STC SMG12 QoS Ad-hoc, Tdoc SMG12 C-99-461,
Date: May 1999.

[SMG12 C-99-462] Title: Traffic flow templates used for edge node QoS functionality
Author: Ericsson,
Doc. no.: ETSI STC SMG12 QoS Ad-hoc, Tdoc SMG12 C-99-462,
Date: May 1999.

[TeHa99] Title: Internet 2 Qbone: Building a Testbed for Differentiated Services
Author: B. Teitelbaum, S Hares, et al.,
Doc. no.: IEEE Network Magazine, pp. 8 - 16,
Date: September/October 1999.

[X25] Title: Interface between data terminal equipment (DTE) and data circuit-terminating equipment (DCE) for terminals operating in the packet mode and connected to public data networks by dedicated circuit,
Author: ITU,
Doc. no.: ITU Recommendation X.25,

[Whi97] Title: RSVP and Integrated Services in the Internet: A Tutorial,
Author: P. P., White,
Doc. no.: IEEE Communications Magazine, pp. 100 - 106,
Date: May 1997.

[Zhan95] Title: Service Disciplines For Guaranteed Performance Service in Packet-Switching Networks
Author: H. Zhang
Doc. no.: Proceedings of the IEEE, 83(10)
Date: October 1995

[ZeAi99] Title: Quality of Service over Specific Link Layers
Author: M. van der Zee, R. Ait Yaiz,
Doc. no.: QWING State of the Art Report, located at:

http://w3-emn.ericsson.se/project_ING/INGpublic/
Date: 1999

8.2 By category

In this section the "by alphabet' listed references are categorised into different types, i.e., ETSI GPRS documents, IETF documents and reports & articles. Note that all the ETSI GPRS specifications used in this document are referring to the GPRS Release 1998. The 3GPP GPRS specifications are referring to the GPRS Release 1999.

8.2.1 3GPP GPRS documents

[3GPP22.060] Title: General Packet Radio Service (Release 1999); Service Description stage 1
Author: 3rd Generation Partnership Project,
Doc. no.: 3G TS 22.060,
Date: March 2000.

[3GPP23.060] Title: General Packet Radio Service (Release 1999); Service Description stage 2
Author: 3rd Generation Partnership Project,
Doc. no.: 3G TS 23.060,
Date: January 2000.

[3GPP23.078] Title: General Packet Radio Service (Release 1999); Customised Applications for Mobile Network Enhanced Logic (CAMEL) Phase 3 –Stage 2
Author: 3rd Generation Partnership Project,
Doc. no.: 3G TS 23.078,

[3GPP23.907] Title: General Packet Radio Service (Release 1999); QoS Concept
Author: 3rd Generation Partnership Project,
Doc. no.: 3G TS 23.907,

[3GPP27.060] Title: General Packet Radio Service (Release 1999); Supporting Packet Switched Services
Author: 3rd Generation Partnership Project,
Doc. no.: 3G TS 27.060,
Date: March 2000.

[3GPP29.060] Title: General Packet Radio Service (Release 1999); GPRS Tunnelling Protocol (GTP) across the Gn and Gp Interface
Author: 3rd Generation Partnership Project,
Doc. no.: 3G TS 29.060,
Date: January 2000.

8.2.2 ETSI GPRS documents

[BuWa96] Title: Random Access Algorithm for Multicast Users,
Author: T. Buol, F. Wattanabe,
Doc. no.: submitted as Tdoc 02/96 to ETSI SMG2 GPRS ad hoc, Tampere, Finland,
Date: Jan 1996.

[GSM 02.60] Title: Digital cellular telecommunications system (Phase 2+); General Packet Radio Service (GPRS); Service description; Stage 1
Author: ETSI,
Doc. no.: ETSI GSM 02.60 GPRS standard,

[GSM 03.20] Title: Digital cellular telecommunications system (Phase 2+); Security related network functions
Author: ETSI,
Doc. no.: ETSI GSM 03.20 GPRS standard,

[GSM 03.22] Title: Digital cellular telecommunications system (Phase 2+); Functions related to Mobile Station (MS) in idle mode and group receive mode
Author: ETSI,
Doc. no.: ETSI GSM 03.22 GPRS standard,

[GSM 03.60] Title: Digital cellular telecommunications system (Phase 2+); General Packet Radio Service (GPRS); Service Description; Stage 2,
Author: ETSI,
Doc. no.: ETSI GSM 03.60 GPRS standard,

[GSM 03.61] Title: Digital cellular telecommunications system (Phase 2+); General Packet Radio Service (GPRS); Point to Multipoint Multicast Service Description; Stage 2
Author: ETSI,
Doc. no.: ETSI GSM 03.61 GPRS standard,

[GSM 03.62] Title: Digital cellular telecommunications system (Phase 2+); General Packet Radio Service (GPRS); Point to Multipoint Group Call Service Description; Stage 2
Author: ETSI,
Doc. no.: ETSI GSM 03.62 GPRS standard,

[GSM 03.64] Title: Digital cellular telecommunications system (Phase 2+); Overall description of the General Packet Radio Service (GPRS) Radio interface; Stage 2
Author: ETSI,
Doc. no.: ETSI GSM 03.64 GPRS standard,

[GSM 04.08] Title: Digital cellular telecommunications system (Phase 2+); Mobile radio interface layer 3 specification
Author: ETSI,
Doc. no.: ETSI GSM 04.08 GPRS standard,

[GSM 04.60] Title: Digital cellular telecommunications system (Phase 2+); General Packet Radio Service (GPRS); Mobile Station (MS) - Base Station System (BSS) interface; Radio Link Control / Medium Access Control (RLC/MAC) protocol
Author: ETSI,
Doc. no.: ETSI 04.60 GPRS standard,

[GSM 04.64] Title: Digital cellular telecommunications system (Phase 2+); General Packet Radio Service (GPRS); Logical Link Control (LLC)
Author: ETSI,
Doc. no.: ETSI GSM 04.64 GPRS standard,

[GSM 04.65] Title: Digital cellular telecommunications system (Phase 2+); General Packet Radio Service (GPRS); Subnetwork Dependent Convergence Protocol (SNDCP),
Author: ETSI,
Doc. no.: ETSI GSM 04.65 GPRS standard,

[GSM 05.01] Title: Digital cellular telecommunications system (Phase 2+); Physical Layer on the Radio Path (General Description)
Author: ETSI,
Doc. no.: ETSI GSM 05.01 GPRS standard,

[GSM 05.05] Title: Digital cellular telecommunications system (Phase 2+); Radio Transmission and Reception
Author: ETSI,
Doc. no.: ETSI GSM 05.05 GPRS standard,

[GSM 05.08] Title: Digital cellular telecommunications system (Phase 2+); Radio Subsystem Link Control
Author: ETSI,
Doc. no.: ETSI GSM 05.08 GPRS standard,

[GSM 08.14] Title: Digital cellular telecommunications system (Phase 2+); General Packet Radio Service (GPRS); Base Station System (BSS) - Serving GPRS Support Node (SGSN) interface; Gb interface layer 1
Author: ETSI,
Doc. no.: ETSI GSM 08.14 GPRS standard,

[GSM 08.16] Title: Digital cellular telecommunications system (Phase 2+); General Packet Radio Service (GPRS); Base Station System (BSS) - Serving GPRS Support Node (SGSN) interface; Network Service
Author: ETSI,
Doc. no.: ETSI GSM 08.16 GPRS standard,

[GSM 08.18] Title: Digital cellular telecommunications system (Phase 2+); General Packet Radio Service (GPRS); Base Station System (BSS) - Serving GPRS Support Node (SGSN); BSS GPRS Protocol (BSSGP),
Author: ETSI,
Doc. no.: ETSI GSM 08.18 GPRS standard,

[GSM 09.02] Title: Digital cellular telecommunications system (Phase 2+); Mobile Application Part (MAP) specification
Author: ETSI,
Doc. no.: ETSI GSM 09.02 GPRS standard,

[GSM 09.18] Title: Digital cellular telecommunications system (Phase 2+); General Packet Radio Service (GPRS); Serving GPRS Support Node (SGSN) - Visitors Location Register (VLR); Gs interface layer 3 specification
Author: ETSI,
Doc. no.: ETSI GSM 09.18 GPRS standard,

[GSM 09.60] Title: Digital cellular telecommunications system (Phase 2+); General Packet Radio Service (GPRS); GPRS Tunnelling Protocol (GTP) across the Gn and Gp Interface

Author: ETSI,

Doc. no.: ETSI GSM 09.60 GPRS standard,

[SMG12 C-99-460] Title: PDP context and Packet Data Flow context handling for different QoS profiles
Author: Ericsson,
Doc. no.: ETSI STC SMG12 QoS Ad-hoc, Tdoc SMG12 C-99-460,
Date: May 1999.

[SMG12 C-99-461] Title: QoS in GPRS phase 2 – Edge Node QoS interworking
Author: Ericsson,
Doc. no.: ETSI STC SMG12 QoS Ad-hoc, Tdoc SMG12 C-99-461,
Date: May 1999.

[SMG12 C-99-462] Title: Traffic flow templates used for edge node QoS functionality

Author: Ericsson,
Doc. no.: ETSI STC SMG12 QoS Ad-hoc, Tdoc SMG12 C-99-462,
Date: May 1999.

8.2.3 IETF documents

[BaIt00] Title: RSVP Reservation Aggregation,
Author: F. Baker, et al.,
Doc. no.: Internet Draft, draft-ietf-issll-rsvp-aggr-00.txt,
Date: 2000.

[BoCo99] Title: The COPS (Common Open Policy Service) protocol
Author: J. Boyle, et al.,
Doc. no.: Internet draft, draft-ietf-rap-cops-08.txt,
Date: 1999.

[Difframe] Title: An Architecture for Differentiated Services,
Author: Y. Bernet et al,
Doc. no.: Internet Draft, draft-ietf-diffserv-framework-02.txt,
Date: 1999.

[Diffserv] Title: Charter of the Differentiated Services WG,
Author: IETF,
Doc. no.: http://www.ietf.org/html.charters/diffserv-charter.html

[GaDu00] Title: RSVP proxy,
Author: S. Gai, D. G. Dutt, N. Elfassy, Y. Bernet
Doc. No.: Internet draft, draft-ietf-rsvp-proxy-01.txt,
Date: July 2000.

[Intserv] Title: Charter of the Integrated Services WG,
Author: IETF,
Doc. no.: http://www.ietf.org/html.charters/intserv-charter.html

[NiJa97] Title: A Two-bit Differentiated Services Architecture for the Internet,
Author: K. Nichols, V. Jacobson, and L. Zhang,
Doc. no.: Internet draft, located at:
ftp://ftp.ee.lbl.gov/papers/dsaarch.pdf
Date: Nov. 1997.

[RFC768] Title: User Datagram Protocol
Author: J. Postel,
Doc. no.: IETF RFC768,
Date: 1980.

[RFC791] Title: Internet protocol
Author: DARPA INTERNET PROGRAM,
Doc. no.: IETF RFC791,
Date: 1981.

[RFC793] Title: Transmission Control Protocol
Author: DARPA INTERNET PROGRAM,
Doc. no.: IETF RFC793,
Date: 1981.

[RFC1990] Title: The PPP Multilink Protocol (MP)

Author: K. Sklower, et, al,
Doc. no.: IETF RFC 1990,
Date: 1996.

[RFC2002] Title: IPv4 Mobility Support,
Author: Charles Perkins (Editor),
Doc. no.: IETF RFC 2002,
Date: 1996.

[RFC2131] Title: Dynamic Host Configuration Protocol,
Author: IETF,
Doc. no.: IETF RFC 2131,
Date: 1997.

[RFC2205] Title: Resource ReSerVation Protocol (RSVP) – Version 1,
Author: R. Braden, et al.,
Doc. no.: IETF RFC 2205,
Date: 1997.

[RFC2460] Title: Internet Protocol, Version 6 Sepecification
Author: S. Deering, R. Hinden,
Doc. no.: IETF RFC 2460,
Date: 1999.

[RFC2475] Title: An Architecture for Differentiated Services
Author: S. Blake, et, al,
Doc. no.: IETF RFC 2475,
Date: 1998.

[RFC2686] Title: The Multi-Class Extension to Multi-Link PPP
Author: C. Bormann,
Doc. no.: IETF RFC 2686,
Date: 1999.

8.2.4 Reports and articles

[ArBi98] Title: GPRS Delay and Capacity Analysis for Web Browsing Application
Author: Y. Argyropoulos, A. Bigloo, J. van Peursem,
Doc. no.: ICT '98. International Conference on Telecommunications, Vol. 2, pp. 32 –36,
Date: 1998.

[BrWa97] Title: Concepts, Services, and Protocols of the New GSM Phase 2+ General packet Radio Service,
Author: G. Brasche and B. Walke,
Doc. no.: IEEE Communications Magazine, pp. 94 - 104,
Date: August 1997.

[CaGo97] Title: General Packet Radio Service in GSM
Author: J. Cai, D. J. Goodman,
Doc. no.: IEEE Communications Magazine, pp. 122 - 131,
Date: October 1997.

[Call95] Title: Call Admission Control for PRMA-based multiservice cellular networks,
Author: F. Callegati,
Doc. no.: Proceedings Australian Telecommunication Networks and Applications Conference, Vol. 1, pp. 485 – 489,
Date: 1995.

[FrBr98] Title: Prioritised random access for GPRS with pseudo Bayesian broadcast control, exponential backoff and stack based schemes,

Author: C. Fresco Diez, A. E. Brand, A. Hamid Aghvami,

Doc. no.: Proceedings of ICT'98 - International Conference on Telecommunications, qvol.1, pp. 24 28,

Date: 1998.

[HoMe98] Title: A performance Evaluation of Internet Access via the General Packet Radio Service of GSM
Author: S. Hoff, M. Meyer, A. Schieder,
Doc. no.: VTC'98, Vol. 3, pp. 1760-1764,
Date: 1998.

[ITU: Q.701] Title: Functional description of the Message Transfer Part (MTP) of Signalling System No. 7

Author:ITU

Doc. no.:ITU-T Recommendation Q.701

[ITU: Q.711] Title: Signalling System No.7 - Functional description of the signalling connection control part
Author: ITU
Doc. no.: ITU-T Recommendation Q.711

[ITU: Q.712] Title: Signalling System No.7 - Definition and function of SCCP messages
Author: ITU
Doc. no.: ITU-T Recommendation Q.712

[ITU: Q.713] Title: Signalling System No.7 - SCCP formats and codes.
Author: ITU
Doc. no.: ITU-T Recommendation Q.713

[ITU: Q.714] Title: Signalling System No.7 - Signalling connection control part procedures
Author: ITU
Doc. no.: ITU-T Recommendation Q.714

[ITU: Q.771] Title: Signalling System No.7 - Functional Description of Transaction Capabilities
Author: ITU
Doc. no.: ITU-T Recommendation Q.771
Date: 1993

[ITU: Q.772] Title: Signalling System No.7 - Transaction Capabilities Information Element Definitions
Author: ITU
Doc. no.: ITU-T Recommendation Q.772
Date: 1993

[ITU: Q.773] Title: Signalling System No.7 - Transaction Capabilities Formats and Encoding
Author: ITU
Doc. no.: ITU-T Recommendation Q.773
Date: 1993

[ITU: Q.774] Title: Signalling System No.7 - Transaction Capabilities Procedures
Author: ITU
Doc. no.: ITU-T Recommendation Q.774
Date: 1993

[ITU-TQ.922] Title: ISDN data link layer specification for frame mode bearer services
Author: ITU,
Doc. no.: ITU TQ.922,
Date: 1992.

[Kar99] Title: Mobile IP
Author: G. Karagiannis,
Doc. no.: QWING State of the Art Report, located at:
http://w3-emn.ericsson.se/project_ING/INGpublic/
Date: 1999

[KAMe99] Title: Wireless Internet Access based on GPRS
Author: R. Kalden, I. Merick, M. Meyer,
Doc. no.: Ericsson document, *Has been submitted for acceptance in special issue of IEEE Communication Magazine - The Evolution of Mobile Data Networking - Februrary 2000. Located at:*
http://research.eed.ericsson.se/gprs_simul/papers/CommMag/CommMag_v4.pdf
Date: 1999.

[Ostro96] Title: Efficient Transmission of Integrated Voice and Data in Wireless Networks,
Author: M. Ostrowski,
Doc. no.: ICC International Conference on Communications, Vol. 2, pp. 721 –727,
Date: 1996.

[RaJo90] Title: Performance Evaluation of Slotted Aloha with Generalized Retransmission Backoff
Author: D. Raychaudhuri, K. Joseph,
Doc. no.: Proc. IEEE Transactions on Communications, vol. 38, no. 1, pp. 117 – 122,
Date: Jan 1990.

[QWING] Title: The Internet NG Project –
WU4: QoS over wireless and mobile access networks
Author: Internet NG WU4 members,
Doc. no.: , located at: http://w3-emn.ericsson.se/project_ING/INGpublic/
Date: 2000.

[ShBu97] Title: Analysis of integrated services in GPRS cellular systems
Author: Y. Shaokai; T. Buot,
Doc. no.: Proceedings APCC'97. Third Asia-Pacific Conference on Communications. Incorporating, Vol. 1, pp. 474 – 478,
Date: 1997.

[TeHa99] Title: Internet 2 Qbone: Building a Testbed for Differentiated Services
Author: B. Teitelbaum, S Hares, et al.,
Doc. no.: IEEE Network Magazine, pp. 8 - 16,
Date: September/October 1999.

[X25] Title: Interface between data terminal equipment (DTE) and data circuit-terminating equipment (DCE) for terminals operating in the packet mode and connected to public data networks by dedicated circuit,
Author: ITU,
Doc. no.: ITU Recommendation X.25,

[Whi97] Title: RSVP and Integrated Services in the Internet: A Tutorial,
Author: P. P., White,
Doc. no.: IEEE Communications Magazine, pp. 100 - 106,
Date: May 1997.

[Zhan95] Title: Service Disciplines For Guaranteed Performance Service in Packet-Switching

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Networks
Author: H. Zhang
Doc. no.: Proceedings of the IEEE, 83(10)
Date: October 1995

[ZeAi99] Title: Quality of Service over Specific Link Layers
Author: M. van der Zee, R. Ait Yaiz,
Doc. no.: QWING State of the Art Report, located at:
http://w3-emn.ericsson.se/project_ING/INGpublic/
Date: 1999