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ETCS in PS-mode
GPRS/EGPRS Guideline

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1 INTRODUCTION

1.1 Purpose

One of the major milestones in the evolution of GSM-R is the introduction of General Packet Radio Services (GPRS) to complement current CS-mode services by packet oriented data transmission.

GPRS/EGPRS (Enhanced Data Rates for GPRS) bearer service is considered for the evolution of the transmission of European Train Control System (ETCS) Level 2, with the objective to transport ETCS signalling data sharing at least one traffic channel on the GSM-R air interface.

Up to now, GPRS/EGPRS has been used for non-safety related applications like railway infrastructure related data recording tasks, track information for driver or train scheduling information that can cope with the “Best Effort” approach.

Many dense railway hubs in Europe are facing air interface capacity bottlenecks due to the narrow 4 MHz frequency band available for GSM-R. Due to the limited number of frequencies that are available within the GSM-R band, GSM-R circuit switched data as a bearer for ETCS does not provide sufficient capacity in dense railway hubs.
Hence, GPRS/EGPRS is a major milestone from current circuit switched (CS-mode) based technology, as a complete timeslot is dedicated to one data call, towards the use of packet oriented data transmission (PS-mode) to enable IP based technology, the standard in data communication networks.
The efficient transmission resource allocation in GPRS allows a sharing of one traffic channel between several users. If transmission resources are not needed any longer by the user, the network will release and reallocate those freed resources to other users which demanding data transmission capabilities.
The introduction of ETCS in PS-mode taking into account GPRS/EGPRS as a bearer also serves as a vehicle to develop and implement value-added applications in PS-mode for railway undertaking in order to improve operational efficiency and safety.

The present document provides a guideline about the mandatory GSM-R PS-mode network extensions, system features, necessary planning tasks and the parameters dedicated to GPRS/EGPRS used as a bearer for the ETCS application.

In detail:

- Necessary GSM-R and IP network extensions,
- Engineering recommendations,
- Guidelines to set GPRS system parameters in an ETCS context.

The necessary extensions, features and the related parameter settings are listed at the end of each chapter/subchapter if necessary. Depending on the impact to the ETCS-application or network setup the listed items are either required as mandatory (M), conditional (C) or optional (O).
A mandatory classification denotes a basic network extension or the feature/parameter providing a broad effect to the GPRS transmission system behaviour that is related to ETCS PS-mode QoS requirements.

An optional classification denotes either a network availability improvement or a limited effect to the GPRS/EGPRS transmission system behaviour that is related to ETCS PS-mode QoS requirements.

A conditional classification denotes a network extension/functionality that can be used by the GSM-infrastructure operator but includes mandatory requirements.

Recommendation denotes GPRS/EGPRS specific timer, counter and specific network settings.

1.2 References

[1] 3GPP TS 23.003: “Numbering, addressing and identification”

[2] 3GPP TS 23.060: “General Packet Radio Service (GPRS); Service description; Stage 2”

[3] 3GPP TS 23.107: “QoS Concept and Architecture”

[4] 3GPP TS 23.207: “End-to-end Quality of Service (QoS) concept and architecture”

[5] 3GPP TS 24.008: “Mobile radio interface Layer 3 specification; Core network protocols;”

[6] 3GPP TS 27.007: "AT command set for User Equipment (UE)"

[7] 3GPP TS 29.060: “GPRS Tunnelling Protocol (GTP) across the Gn and Gp interface”

[8] 3GPP TS 43.064: "Overall description of the GPRS radio interface; Stage 2"

[9] 3GPP TS 44.018: “Radio Resource Control (RRC) protocol”

[10] 3GPP TS 44.060: "Radio Link Control/Medium Access Control (RLC/MAC) protocol"

[11] 3GPP TS 44.064: "General Packet Radio Service (GPRS); Mobile Station - Serving GPRS Support Node (MS-SGSN) Logical Link Control (LLC) layer specification".

[12] 3GPP TS 45.002: "Multiplexing and multiple access on the radio path"

[13] 3GPP TS 45.003: “Radio Access Network; Channel coding”

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[28] RFC 2474: “Definition of the Differentiated Services Field (DS Field) in the IPv4 and IPv6 Headers”

[29] ITU-T Y.1540 “Internet protocol data communication service – IP packet transfer and availability performance parameters”

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[31] EIRENE SRS applicable version (PS-mode included)

[32] Subset-026 applicable version (PS-mode)

[33] Subset-037 applicable version (PS-mode)

[34] Subset-093 applicable version (PS-mode)

[35] Radio Transmission FFFIS for EuroRadio applicable version (PS-mode)
[36] IR.34 GSMA Association Inter-Service Provider IP Backbone Guidelines 5.0
[37] 3GPP TS 23.236 Intra-domain connection of Radio Access Network (RAN) nodes to multiple Core Network (CN) nodes

1.3 *Abbreviations and definitions*

Abbreviations

AGCH	Access Grant Channel
APN	Access Point Name
ARQ	Automatic Repeat Request
ASCI	Advanced Speech Call Item
AuC	Authentication Centre
BCCH	Broadcast Control Channel
BEP	Bit Error Probability
BG	Border Gateway
BLER	Block Error Rate
BSS	Base Station Sub-System
BSSGP	Base Station System GPRS Protocol
BTS	Base Transceiver Station
BVCI	Base Station Virtual Connection Identifier
C/I	Carrier to Interference
CBCH	Cell Broadcast Channel
CCN	Cell Change Notification
CCCH	Common Control Channel
CDF	Charging Data Function
CGF	Charging Gateway Function
CIR	Carrier to Interference Ratio
CS	Circuit Switched
CSD	Circuit Switched Data
DCCH	Dedicated Control Channel
DI	Disconnect Indication
DL	Downlink
DSCP	Differentiated Services Code Point
DTM	Dual Transfer Mode
DTX	Discontinuous Transmission
EDGE	Enhanced Data for GSM Evolution
EDOR	ETCS Data Only Radio
EIRENE	European Integrated Railway Radio Enhanced Network
ETCS	European Train Control System
E2E	End-to-End
EGPRS	Enhanced GPRS (EDGE)
FACCH	Fast Associated Control Channel
FCCH	Frequency Correction Channel
FEC	Forward Error Correction
FH	Frequency Hopping
FQDN	Full Qualified Domain Name
FW	Firewall
GERAN	GSM EDGE Radio Access Network
GGSN	GPRS Gateway Support Node
GM	General Message
GMM	GPRS Mobility Management
GMSK	Gauss Minimum Shift Keying
GPRS	General Packet Radio Service
GSM	Global **S**ystem for Mobile Communications
GSN	Gateway Support Node
GTP	GPRS Tunnelling Protocol
HLR	Home Location Register
IMSI	International Mobile Subscriber Identity
IETF	Internet Engineering Task Force
IP	Internet Protocol

IR	Incremental Redundancy
LA	Location Area
LLC	Logical Link Control
LTE	Long Term Evolution
MA	Movement Authority
MAC	Medium Access Control
MCS	Modulation and Coding Scheme
MG	Multiplexing Gain
MGW	Media Gateway
MM	Mobility Management (GSM)
MS	Mobile Station
MSC	Mobile Switching Centre
MSS	MSC Server
MT	Mobile Terminal
MTU	Maximum Transmission Unit
NACC	Network Assisted Cell Change
NCn	Network Control Order (n:0-2)
NCH	Notification Channel
NI	Network Identifier
NSAPI	Network layer Service Access Point Identifier
NMO1	Network Mode of Operation 1
NMO2	Network Mode of Operation 2
NSS	Network Sub-System
NSE	Network Service Entity
OBU	On board Unit
OI	Operator Identifier
OSI	Open Systems Interconnection Reference Model
PACCH	Packet Associate Control Channel
PaCo	Packet Core (Network)
PAGCH	Packet Access Grant Channel
PCCC	Packet Cell Change Continue
PCCN	Packet Cell Change Notification
PCH	Paging Channel
PCO	Point of Control and Observation
PCU	Packet Control Unit
PDP	Packet Data Protocol
PDU	Protocol Data Unit
PDN	Packet Data Network
PDCH	Packet Data Channel
PFC	Packet Flow Context
PDTCH	Packet Data Traffic Channel
PFI	Packet Flow Identifier
PLPMN	Public Land Mobile Network
PNCD	Packet Neighbour Cell Data
PS	Packet Switched
PSK	Phase-shift keying
PSn	Puncturing Scheme (n: 1-3)
PSCD	Packet Serving Cell Data
P-TMSI	Packet – Temporary Mobile Subscriber Identity
PtM	Point to Multipoint
PtP	Point to Point
QoS	Quality of Service
RA	Routing Area
RACH	Random Access Channel
RAN	Radio Access Network
RBC	Radio Block Controller

RLC	Radio Link Control
RR	Radio Resource
SACCH	Slow Associated Common Control Channel
SaPDU	Safe Software Protocol Data Unit
SCH	Synchronisation Channel
SDCCH	Standalone Dedicated Common Control Channel
SGSN	Serving GPRS Support Node
SNDCP	Subnetwork Dependent Convergence Protocol
SM	Session Management
SMS	Short Message Service
TBF	Temporary Block Flow
TCCC	Traffic Capability Cell Configuration
TCH	Traffic Channel
TCP	Transmission Control Protocol
TDM	Time Division Multiplex
TE	Terminal Equipment
TFI	Temporary Flow Identity
TID	Tunnel Identifier
TLLI	Temporary Logical Link Identity
TMSI	Temporary Mobile Subscriber Identity
TRAU	Transcoder and Rate Adaption Unit
TS	Timeslot
TTD	Transmission Transfer Delay
TTI	Transmission Time Interval
UDP	User Datagram Protocol
UL	Uplink
UNISIG	Union Industry of Signalling
UMTS	Universal Mobile Telecommunications System
VBS	Voice Broadcast Service
VGCS	Voice Group Call Service
VLR	Visitor Location Register
XID	eXchange IDentification frame

Symbols and Definitions

Byte	1 start bit + 8 data bits + 1 stop bit
G_i	Reference point between a GGSN and an external packet data network.
G_p	Interface between a SGSN and a packet gateway/GGSN in different PLMNs. The Gp interface allows support of GPRS network services across areas served by the co-operating GPRS PLMNs.
I_{FIX_PS}	(Trackside) Reference point between ETCS trackside equipment and the fixed packet data network.
I_{GSM}	(Train borne) Interface between ETCS and GSM-R on mobile side
I_{Um}	The GSM-R radio interface that corresponds to the U_m interface
Octet	8 data bits
NMO	Network Mode of Operation in GPRS/EGPRS
MT0	Includes functions belonging to the functional group MT that are needed for network access arrangements, with support of no terminal interfaces.
MT2	includes functions belonging to the functional group MT that are needed for network access arrangements with an interface that complies with the 3GPP TS 27.00z series Terminal Adaptation Function specifications. Accordingly, the interchange circuit mapping at the MT2 to TE interface shall comply with the ITU-T V.24 [42] recommendation; while the physical implementation shall conform to the ITU-T V.28 electrical specifications.
Ratio	Unit less, e.g. percentage
Rate	Value per time unit, e.g. per hour

2 GSM REFERENCE

2.1 Network Architecture [1]

2.1.1 Reference Architecture

As an overview a GSM-R network consist of a base station subsystem (BSS), the network switching subsystem (NSS) and the mobile station. With the introduction of GPRS the existing network architecture will be expanded, since both types of application – Circuit Switched (CS) and Packet Switched (PS) – run via the mutual GSM-R/GPRS network.

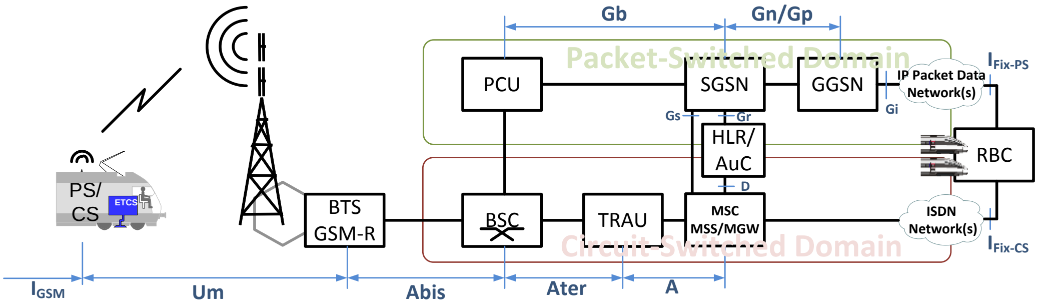

Figure 2-1 GSM-R logical network architecture including CS- and PS-Domain

The BSS consist of a larger number of base transceiver stations (BTSs) which enables a wireless connection between the mobile station(s) and the network. A BTS assumes all layer 1 functions between the mobile and the network that include channel coding, interleaving, ciphering (only CS-mode) and burst generating. Others are GMSK and 8-PSK (assuming EGPRS higher coding schemes are enabled) modulation and demodulation that are processed by the base transceiver station.
A number of BTSs are controlled by the BSC that include the evaluation of measurement results from the BTS and mobile station during a dedicated connection (signalling, voice, data or messaging) and the necessary handover and power control adjustments from this. The BSC as such further exchange in order to relieve the MSC/MSS from wireless related tasks like the Radio Resource Management (RR) and the resource administration on the Abis and the air interface (Um).

The third network element in the BSS is the TRAU which provides speech compression, comfort noise generation while DTX is in operation and the conversion of fax, speech, data information into TRAU frames.

For GSM(-R) PS-mode purposes the BSS has been enhanced by the packet control unit (PCU), which can be installed as part of the BSS at different locations in the network. PCU responsibility is to take care about GPRS (only) radio resource management functions while the BSC takes care of administrating circuit switched radio resources. The second task of the PCU is to convert data packets into PCU frames that are forwarded transparently through the BSC to the BTS. Additional processing in the BTS is necessary to apply channel coding, interleaving etc. For CS-mode purposes 16kbps channels are used between the TRAU and the BTS and this channel rate is used for lower GPRS/EGPRS coding schemes (channel coding). To achieve higher bandwidth with GPRS, i.e. coding schemes 3 and 4 (CS-3/CS-4), and EGPRS, i.e. modulation coding schemes MCS-3 up to MCS-9, more bandwidth (>16kbps) on the Abis is required. The efficient usage of this additional bandwidth is as well an important topic that is in most of the cases vendor implementation specific.

As aforementioned PCU frames are forwarded transparently though the BSC to the BTS for further processing. BSC and PCU share the timeslots and resources on the Abis and air interface (Um). Both, BSC and PCU need to be coordinated in order to prevent BSC and PCU allocating timeslots that are already occupied by the other.

The NSS consists of one or more home location registers (HLR) including the authentication centre (AuC), various Media Gateways and MSS as part of 3GPP Release 4 or MSCs in 3GPP Release 99 core network architecture. The visitor location register (VLR) is an autonomous function but in most of the cases it is connected to the MSC/MSS. Parts of the NSS are used as well by GSM PS-mode (GPRS) like for subscription purposes (HLR) and for combined mobility functions the MSC/MSS.

The PS-mode Packet Core (PaCo) network is the counterpart to the CS-mode NSS and consists of serving (SGSN) and gateway (GGSN) functions. Simply, the serving GPRS support node (SGSN) inside the PaCo network takes over the function that is performed by the MSS/MSC and VLR in GSM. In addition to these functions, SGSN has to perform additional task which are GPRS specific.

The GGSN - gateway GPRS support node is essentially the interface between the GPRS network and external packet data network networks. It is necessary to recognize that the GGSN externally looks like a router that has been modified for additional functions in the GPRS network.

2.1.2 Network Architecture Requirement(s):

Number of requirement	**Description**	**Mandatory - M Optional – O**
2.1.2.1	The BSS need to be extended depending on the cell quantity by one or more Packet Control Unit(s) for PS-mode.	M
2.1.2.2	A Packet Core Network that has to consists at least of one SGSN and GGSN that need to be added to the GSM-R network infrastructure (M). (1), (2)	M
2.1.2.3	RAN-Flex (Intra-domain connection of Radio Access Network nodes to multiple Core Network) [37] for GSM PS-domain including the necessary function in the BSS and Packet Core network should be considered to improve GSM-R PS-domain network availability.	O
2.1.2.4	TRAU format is specific to the BSS network supplier. The conversion of packet data into something that is the same as the TRAU frame format is a BSS network supplier specific choice. Hence, the PCU and the BSS has to be provided by the same BSS vendor.	M
2.1.2.5	The network operator has to determine how many GPRS/EGPRS resources (timeslot(s)) in the applicable GSM-R cells shall be allocated (minimum/maximum). For further details refer to chapter 3.1.3.	M

Table 2-1 PS-mode - Network Architecture requirements

Note 1: Necessary LAN switches or routers are out of scope due to vendor specific Packet Core network implementation.
Note 2: Packet latency inside the Packet Core Network (SGSN←→GGSN) shall be treated in the End to End performance context.

2.2 GPRS bearer protocol stack (A/Gb mode) [2]

2.2.1 GPRS protocol stack

GPRS requires new protocols which apply to the interfaces between mobile station and BSS (PCU) and also to the Packet Core network. The protocol stack (see Figure 2-2) comprises User Plane (user data) and Control Plane (Network registration, Mobility and Session Management). It is noticeable in Figure 2-2 that there is no circuit switched MSC/MSS+MGW in the User Plane protocol stack. BTS and BSC are illustrated completely transparent.

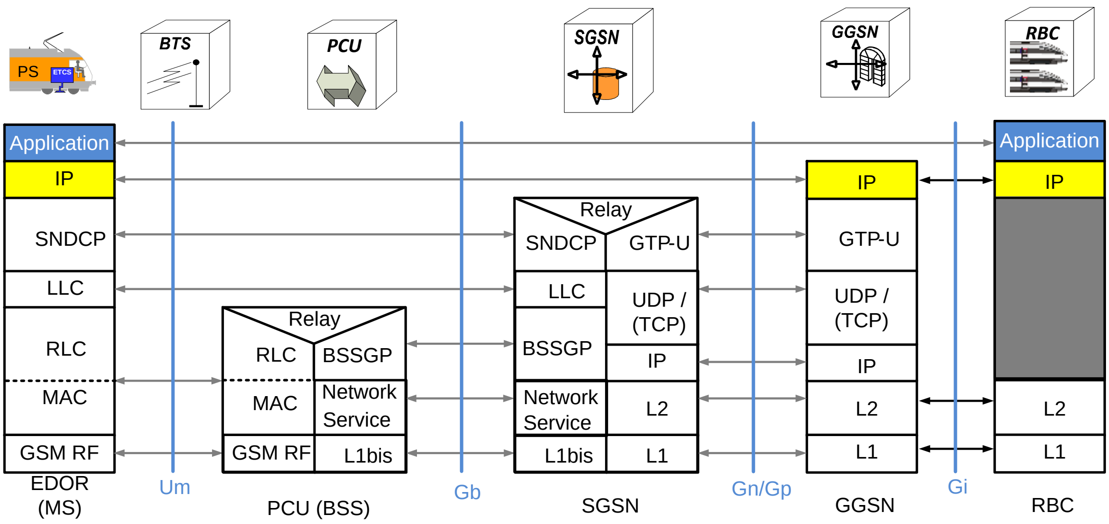

Figure 2-2 Overview GPRS protocol stack – User Plane

Between all GPRS support nodes, SGSNs and GGSNs, User Datagram Protocol (UDP) or Transmission Control Protocol (TCP) are shown as possibilities below the **GPRS Tunnelling Protocol (GTP)**. Both transport layer protocols are only possible with 3GPP R97and R98. From 3GPP R99 onwards, only UDP is supported. GTP is used to transport GPRS in GSM, UMTS and LTE and consists of separate protocols, GTP-C, GTP-U and GTP'. GTP-C is used in the packet core network between the SGSN and GGSN for signalling purpose i.e.to activate/deactivate a PDP context. To transport user data GTP-U is used for this in the packet core network. The user data transported can be packets in IPv4, IPv6 and PPP format. GTP' can be used for carrying charging data from the "Charging Data Function" (CDF) of the SGSN/GGSN to the "Charging Gateway Function" (CGF).
GTP version 0 was specified for 3GPP Release 97/R98 networks, version 1 shall be operational from Release 99 in GERAN and UMTS networks. Together with the introduction of 4G mobile communication, GTP version 2 has been specified.

SNDCP provides services to the higher layers which include multiplexing, segmentation and encapsulation i.e. IP frames into sub-network format (SNPDUs). In addition SNDCP performs multiple PDP context PDU transfer and ensures that network protocol data units are transmitted to the LLC layer in time respecting the QoS requirements.

Note: SNDCP protocol layer has a header size of 4 bytes.

LLC transports the protocol data units (PDU) from all higher layers, mobility management (GMM), session management (SM), IP packets and short messages (SMS). The PDU are pre-processed in the SNDCP layer and prepared for transfer via LLC. LLC transmission parameters between mobile station and SGSN are exchanged by exchange identification frames (XID).

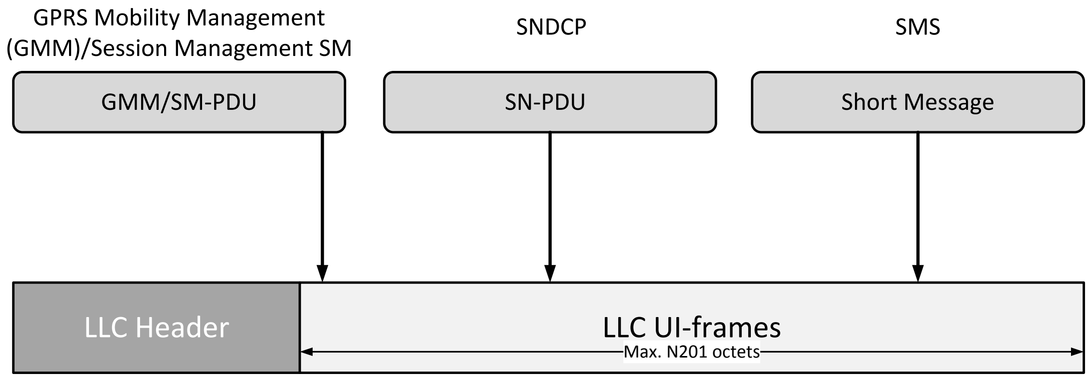

Figure 2-3 GPRS Protocol Stack - LLC transport functions

In addition LLC supports Ciphering/Deciphering of user data between the mobile station and the SGSN.

Note: LLC protocol layer has a header size of 6 bytes in LLC unacknowledged mode operation.

BSSGP is used to provide radio related QoS- and routing information that are required to exchange user data between the PCU (BSS) and the SGSN. The user data as such are transparent and the BSSGP does not provide forward error correction to the user data.

Radio resource allocation mechanism belongs to the **RLC/MAC** in the protocol stack and is composed of two individual protocols, radio link control and medium access control.

The main functions of the **MAC** are:

1.) Controlling network resource access (medium access)
2.) Allocation of available resources among several mobile station (medium sharing)
3.) Controlling network resource release (medium release)

For completion the **RLC** functions are:

1.) Setup of acknowledged/unacknowledged operation
2.) Segmentation/De-segmentation of LLC frames into/from RLC/MAC transport format

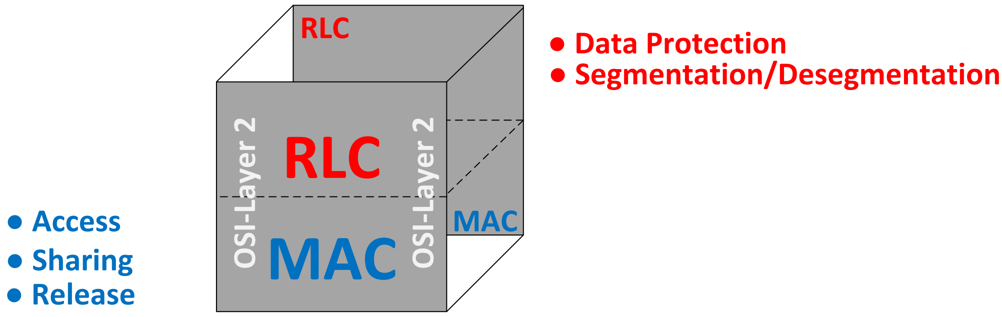

Figure 2-4 GPRS Protocol Stack - RLC/MAC transport functions

2.2.2 Interface Mode between radio access and core network

A/Gb mode indicates to make use of A- or a Gb-interface between the radio access and the core network. With the introduction of Gb interface in 3GPP Release 97 all the GSM standard releases (Release 98-Release 4) have been based on the assumption that a dedicated A interface between the BSS and the MSC/MSS for CS-mode services and a dedicated Gb interface between PCU(BSS) and the SGSN for PS-mode service are used.
UMTS starting with 3GPP Release 99 introduced a functional split between the access and the core network. The relevant interfaces between the radio access and the core network are Iu-cs for CS-mode and Iu-ps for PS mode services. One major key point for operators who are deploying both GSM/EDGE and UMTS was to have a similar set of services that could be provided through both radio access technologies. The adoption of the Iu interface to GSM/EGDE (GERAN), namely the **Iu mode,** embodies the necessary changes of signalling to the 3GPP specification starting in Release 5. Apart the improvements of **Iu mode,** railways do not operate GSM-R and UMTS in parallel. Therefore the use of A/Gb mode is sufficient.

2.2.3 Specific Protocol Requirements

Number of requirement	**Description**	**Mandatory - M Optional – O**
2.2.3.1	SGSN and GGSN have to support GTPv1.	M
2.2.3.2	LLC has to be operated in unacknowledged mode. (1)	M
2.2.3.3	LLC Ciphering/Deciphering may be applied depending on the infrastructure operator rules.	O
2.2.3.4	A/Gb mode is applicable for mobile stations.	M
2.2.3.5	A/Gb mode is applicable for the GPRS network.	M

Table 2-2 PS-mode - protocol layer requirements

Note 1: Subscriber QoS subscription profile settings can impact the operation mode (acknowledged/unacknowledged) of (a) specific protocol layer(s). It is recommended applying the proposed QoS settings that can be found later in this document.

2.3 Interfaces

The previous two subchapters within this chapter introduced the new network architecture and the related protocol extensions. Instead specifying interface specific packet latency requirements 3GPP [3] follows the approach to provide QoS attribute

control on a peer to peer basis between the mobile station and gateway support node (GSN) at the Gi reference point (see Figure 2-2).
Hence, specific PS-domain interface packet latency requirements are out of scope also in this document except the packet data networks attached to the Gi reference point.
This chapter as such describe requirements and practical advices that shall be taken into account during network planning phase.

2.3.1 Um Interface

In GPRS/EGPRS mobile stations are able to support multi timeslot operation that allows a combination of multiple timeslots for data transmission purposes (see in [12]).
Type 1 multi slot class is not able to transmit and receive at the same time. Hence half-duplex operation is supported due to the missing duplexer to enable simultaneous transmission and reception via the same antenna.
In contrast to type 1, type 2 multi slot class allows simultaneous reception and transmission in the same mobile and contains either a duplexer or two antennas. It is obvious that type 2 mobile stations are more expensive but are indispensable for high throughput.
Today mobile stations are supporting mainly type 1 multi slot class 10 enabling maximum (DL+UL) 3+2 or 4+1 multi slot operation. To benefit from multi slot operation at least class 3/type 1 is required.

2.3.2 Abis Interface

Necessary 3GPP compliancy (see in [19]) for Abis layer 1 remains un-changed. Care should be taken if Abis over IP or Abis Circuit emulation are already or become part of the network deployment. Especially the transfer delay aspect is of interest.

Lower coding schemes, in GPRS CS-1/CS-2 and EGPRS MCS-1/MCS-2 (see in [8]), are compliant to the CS-mode TRAU channel bandwidth of 16kbps. In the opposite higher GPRS/EGPRS channel coding require multiple of 16kbps TRAU channels to benefit from the extended radio interface bandwidth. GSM-R network suppliers pursue different implementation strategies to provide the necessary Abis bandwidth for higher coding schemes. It is recommended to refer to the relevant network supplier feature description.
If the infrastructure provider considers making use of higher GPRS/EGPRS coding schemes i.e. CS-3/CS-4 or MCS-3 – MCS-9 additional 16kbps channels inside the Abis interface need to be taken into account.

2.3.3 Gb-interface

The Gb-interface, located between the PCU and the SGSN (see Figure 2-2), can be established based on Frame Relay [17] or GboverIP [17]. Frame Relay integration is available since 3GPP R97 while GboverIP has been introduced in 3GPP R4.
A Gb-interface integration based on Frame Relay may be sufficient for GPRS purposes but with the introduction of EGPRS and a broader scope of applications GboverIP provide the better scalability.
Depending on the IP transport strategy, e.g. direct IP based SDH links or MPLS network etc., a specific service classification for Gb-interface is necessary to avoid further packet delay due to above average loaded transport networks. For traffic classification purposes the DS -Differentiated services field in the IP header (IPv4/IPv6) can be used to assign a specific traffic category for Gb-interface traffic based on the DSCP-DiffServ Code Points [28]. Based on the DSCP the IP based transport network can apply the valid rules for the specific traffic category.

The Maximum Transmission Unit MTU is the size of the largest protocol data unit without fragmentation including the IP header. It is recommended to make use of the largest possible MTU size. In addition adjacent network elements and their related IP based network interface(s) attached to the same logical interface need to be aligned to the have same MTU size to avoid segmentation that can generate further processing delay.

2.3.4 Packet Core Network (Gn/Gp)

IP transport network and service for Gn interface
Packet Core network elements SGSN and GGSN can be installed either collocated or geographically distributed. In the latter case an IP transport network is necessary to provide the interconnectivity between the network elements. To be able to differentiate between ETCS and non-ETCS traffic within the IP transport network GPRS/EGPRS bearer QoS attributes may be used to map them to different DSCP categories.
Alike to the Gb-interface recommendation (see chapter 2.3.3) IP transport network can apply the specific traffic category treatment rules.

Also the MTU size of the nodes belonging to the same logical interface should be aligned to avoid unnecessary segmentation. In addition and the largest possible MTU size should be part of the network planning.

2.3.5 Interface requirements

Number of requirement	Description	Mandatory - M Optional – O
2.3.5.1	Mobile Multislot operation according to [12] should be taken into account e.g. if the ETCS traffic model (packet size/frequency) requires more radio transmission bandwidth.	O
2.3.5.2	If optional higher coding schemes, GPRS (CS-3/CS-4) and EGPRS MCS-3 – MCS-9 are used, then it requires additional Abis capacity.	M
2.3.5.3	If IP based interfaces are part of the GSM-R PS-domain network design and the transport network may share transport capabilities a specific QoS class according to ITU-R specification ([29], [30]) should be part of the IP network implementation.	O
2.3.5.4	If IP based interfaces are part of the GSM-R PS-domain network design, the MTU size of the interfaces that are belonging to the same logical network should be aligned.	O

Table 2-3 PS-mode - Interface requirements

2.4 IP addressing

2.4.1 General Aspects

IP addressing scheme of the Packet Core Network (GGSN, SGSN), RBC and the end system e.g. OBU is the matter of the subsequent chapters. First an introduction is given about the available IP address ranges.

IPv4 consists of different network classes:

Class A	0.0.0.0 – 127.255.255.255	network mask: 255.0.0.0
Class B	128.0.0.0 – 191.255.255.255	network mask: 255.255.0.0
Class C	192.0.0.0 – 223.255.255.255	network mask: 255.255.255.0
Class D	224.0.0.0 – 239.255.255.255	reserved for Multicast
Class E	240.0.0.0 – 255.255.255.255	reserved for future purposes

In IPv4, the different network classes are assigned for public and private purposes. The public part follows a strict unique address allocation to the hosts. However the private IP address part can be reused in different networks. Network address translation from private to public (or v.v.) and different tunnelling approaches guarantee the communication between private IP networks using e.g. the Internet. IPv4 comprises 2^{32} IP addresses.
Due to the limited public IPv4 address space IPv6 has been specified that comprises an address space of 2^{128}. IPv6 shall solve the lack of IPv4 address space limitation.

2.4.2 Principles

IP address allocation principles focus is to guarantee interoperability between the involved networks in case of border crossing and RBC reselection (handover) scenarios. Especially the fact that same OBU IP addresses can be allocated from different GSM-R networks may require a dual IP OBU-RBC stack implementation in the OBU.

Following definitions are taken into account for further consideration and requirements:

Uncoordinated IP address allocation follows a local or national IP address allocation scheme. The involved communication entities and related transport networks allocate IP addresses from a national private IP address pool. It comprises the IP address allocation to the EDOR during PDP context activation and the specific RBC IP address allocation.

Coordinated IP address allocation follows a global and international agreed IP address allocation scheme. IP address allocation can result from a coordinated private or a public IP range. It comprises the IP address allocation to the EDOR during PDP context activation and the specific RBC IP address allocation.

OBU IP address (es): An OBU IP address can be allocated a static IP address as part of the subscription per APN or from an IP address pool that is applicable for the specific APN and the attached PDN (see
Figure 2-5 yellow IP block). In case of dynamic IP address allocation, the IP address assignment shall be permanent until the PDP context will be deactivated.

RBC IP address allocation (see
Figure 2-5 yellow-green shade) shall be permanent to prevent communication loss due to IP address reallocation etc.

Physical IP address is an IP address allocation to a specific network interface card. A host, having more than one network interface card, may have different physical IP addresses of different IP (sub) networks.

Logical IP address is an IP address allocation (e.g. loopback) for a host which is independent from a physical (network interface card) IP addresses. An outage of one physical interface due to whatever reason may guarantee a seamless failover of the IP based communication between the OBU and the applicable RBC.

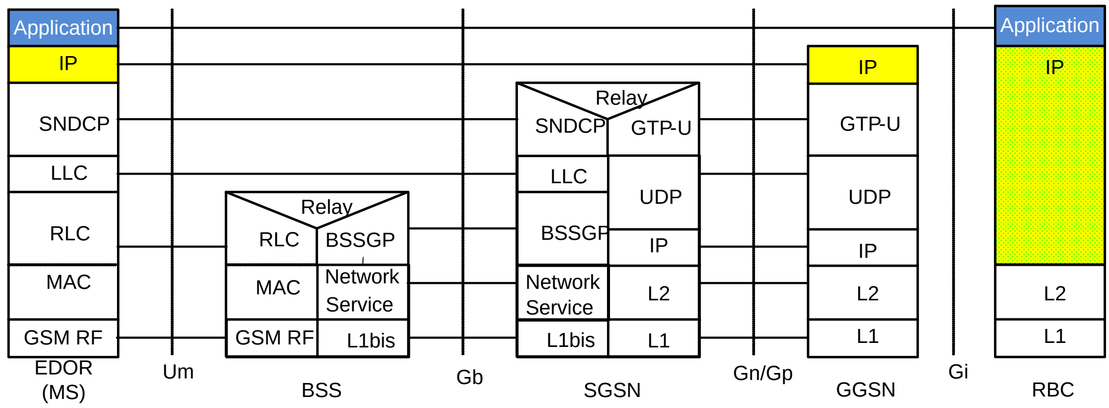

Figure 2-5 GPRS User Plane protocol stack

2.4.3 Packet Core Network

SGSN, GGSN, GNS functions and, if necessary, at least one layer 3 switch constitutes the Packet Core network, that interworks locally via the Gn interface and for national respective international interworking purposes, the Gp interface is used. Refer to Figure 2-1 for the specific location of the aforementioned interfaces.

For ETCS purposes, Gp based interworking between different Packet Core networks is not required, because always the visited GGSN shall be used to establish the bearer service between the OBU and the applicable RBC. Thus in ETCS only operation, any IP network of Class A, B or C (see [23]) is applicable for Layer 3 – IP addressing purposes.

If the GSM-R Packet Core network shall provide as well service access when abroad, GSMA IR.34 [36] guideline chapter 7.1.2 shall be applied. This is the case in national and international roaming scenarios and the Home-GGSN provides the service access. Then public IPv4 addressing shall be applied in all Service Provider/Infrastructure Operator IP Backbone network elements, which are advertised or visible to other Service Providers/Infrastructure operators. Using public addressing means, each Service Provider/Infrastructure Operator has a unique address space that is officially reserved from the Internet addressing authority. However, public addressing does not mean that these addresses should be visible to the Internet.

2.4.4 OBU IP address pool

OBU IP addresses shall be dynamically assigned during the PDP context activation procedure and the allocated IP address is valid during the entire live time of the PDP context. Actually the mobiles (EDOR) are compliant to IPv4 only. In the midterm IPv6 need to be studied and the necessary precautions need to be taken into account. At this point it need to be noted that the use of IPv6 may require at least header compression. Such functionality need to be supported by the network and the mobile.

The size of an OBU IP address pool shall take into account following conditions:

- Only one APN is used for all applicable RBC inside a country
- Number of mobiles per train that have an active PDP context (PDP_n)

The necessary IP address pool size can be estimated by the Erlang B formula, because the Erlang equation applies to any time scale. Instead considering the number circuits the number of IP addresses are taken into account. The grade of service is the

probability P_b that a new PDP context activation request to the “etcs” APN is rejected because all IP addresses of the pool are occupied.
To calculate the maximum number of IP addresses in the pool depends as well on the strategy having a PDP context active. Here, there are several approaches:

- PDP context is always active after powering up the train and the equipped EDORs
- Train is instructed by a balise to activate the PDP context

However, the estimation of the maximum required IP addresses for the APN “etcs” yields into following equation:

$$\max IPpoolsize = NoT * PDP_n$$

NoT *number of trains during “etcs” APN PDP context busy hour*
PDPn *number of EDORs per train that can have an active PDP context*

2.4.5 RBC IP addressing

ETCS over GPRS principles states that only one IP address is applicable for the communication between OBU and RBC. An RBC HW platform can make use at least of one or more than one network interface cards for redundancy reasons. In case more than one network interface cards are used in a RBC a logical IP address need to be considered. In any case, the use of a logical RBC IP address decouples this address from the physical network interface IP address which enables a seamless ETCS session changeover to another RBC network interface if the former interface is in degraded service state (faulty).

2.4.6 IP addressing requirements

Number of requirement	**Description**	**Mandatory - M Optional – O**
2.4.6.1	Only IPv4 shall be provided to the OBU.	M
2.4.6.2	OBU IPv6 is for further study.	N/A
2.4.6.3	An RBC shall be accessible by only one logical IP address.	M
2.4.6.4	Crossing border operation requires IP address coordination to prevent IP address duplication during RBC to RBC communication between adjacent countries.	M

Table 2-4 PS-mode IP addressing requirements

2.5 Mobile Classes

2.5.1 GPRS/EGPRS Mobile Classes

GPRS/EGPRS mobile station are classified into classes A, B and C [2].

Class A mobile stations can simultaneously connect to the CS-mode core network (MSC or MSS/MGW) and to the packet switched core network (SGSN), through A and Gb interfaces. The class A mobile user can make/receive CS-mode calls and is able to receive/transmit PS-mode data. Due to uncoordinated radio resource allocation for CS-mode and PS-mode connections which implies a duplication of some mobile key parts i.e. transceiver the implementation of Class A mobiles are impractical.

Practical low cost implementation of Class A mobiles are based today on Dual Transfer Mode – DTM. Due to the fact that ETCS Data only radio are in focus Class A mobiles using DTM are for further study.

Class B mobile stations are attached simultaneous to packet (GPRS) and circuit switched mode service (GSM). It can only operate one set of services at a time, in which the CS-mode suspends PS-mode data transmission.

Note: Incoming CS-mode services suspend GPRS data exchange while using a class B mobile. Therefore care need to be taken to prevent this scenario during the operation of ETCS. The necessary ETCS subscriber subscription alignment is part of chapter 5.7.10.

Class C mobile stations are restricted even more in its capabilities to operate simultaneous CS-mode and PS-mode services. It can be attached either to the CS-domain (GSM) or to the PS-domain (GPRS). The domain selection is done manually and does not allow simultaneous operation.

Note: Due to the increased time duration to change between CS-mode and PS-mode and the necessary external control for example a balise, Class C mobile stations may be applicable in ETCS PS-mode only operation!

2.5.2 Requirements Mobile Classes

Number of requirement	**Description**	**Mandatory - M Optional – O**
2.5.2.1	The use of a class A mobile is for further study.	N/A
2.5.2.2	Class B mobile stations are required in mixed CS-mode/PS-mode ETCS operation.	M
2.5.2.3	Class C mobile stations are not applicable in ETCS PS-mode only operation.	N/A

Table 2-5 PS-mode - Mobile -Class requirements

2.6 Channel Coding [13], [14]

2.6.1 General Aspects

GPRS/EGPRS achieves higher transmission rate than in GSM (CS-mode) because of the possible Multislot operation (see chapter 2.3.1). More important is that GPRS and EGPRS provide higher payload rates per timeslot.

GSM achieves a maximum transmission rate of 22.8 kbps. This is derived from the 26 multiframes with a period of 120 milliseconds. A normal burst has a payload of 57*2bits and the product of the 26 multiframe payload [12] and a normal burst (26-2)*114 yields into 2736 bits. This result divided by the period of the 26 multiframe (120 milliseconds) yields into 22.8 kbps maximum transmission rate. A 9.6kbps CS-mode bearer consists of only 192 data bits and 48 synchronisation/signalling bits. The gap between the normal burst capability of 456 bits and the real data bits is accordingly large. The difference between payload and normal burst bit capability are used for forward error correction (FEC). If more payload bits and less redundant bits are transmitted via the radio channel its more likely that transmission errors occur and results into a reduction of the payload rate.

Taking into account that a radio channel achieves often sufficient quality then it can reduce partially or totally forward error correction (FEC). This may applies if i.e. train is not in motion, moves slowly and continues under high speed conditions.
GPRS/EGPRS provide such adaptive algorithm to choose flexibly, the degree of forward error correction depending on the radio channel quality and the resulting bit error rate. With the introduction of the GPRS coding schemes CS-1 to CS-4 respectively EGPRS modulation and coding schemes MCS-1 to MCS-9 the wireless transmission system is able to react quickly to changing reception conditions including a stepwise change between FEC and non FEC. The Figure 2-6 and Figure 2-7 illustrate the link between channel data rate and FEC.

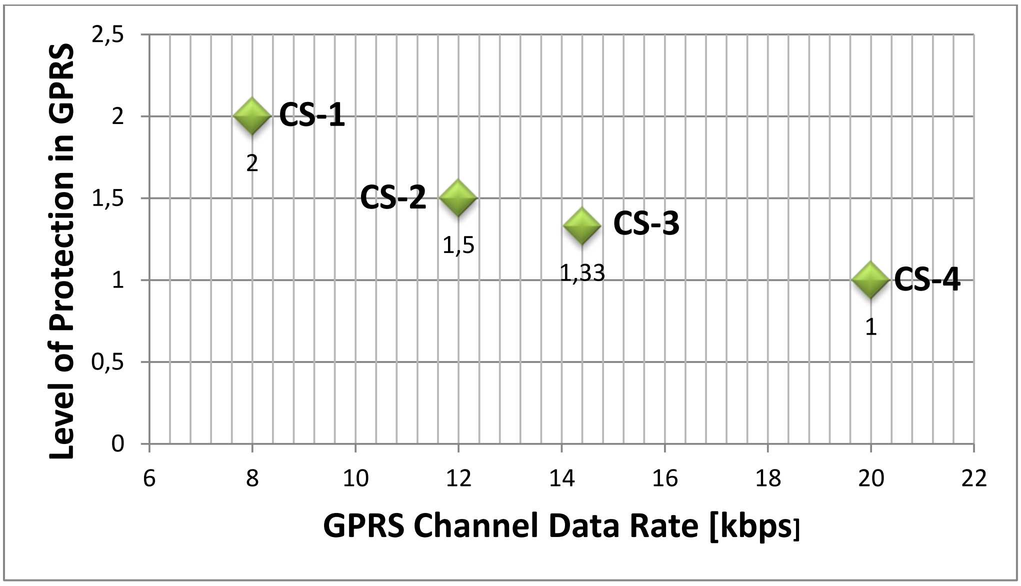

Figure 2-6 Link between FEC and the resulting Channel Data rate in GPRS

CS-1, MCS-1and MCS-5 provides the highest FEC protections level, while CS-4, MCS-4 and MCS-9 have no form of FEC. Hence transmission errors can be corrected only by a retransmission of the affected radio blocks.

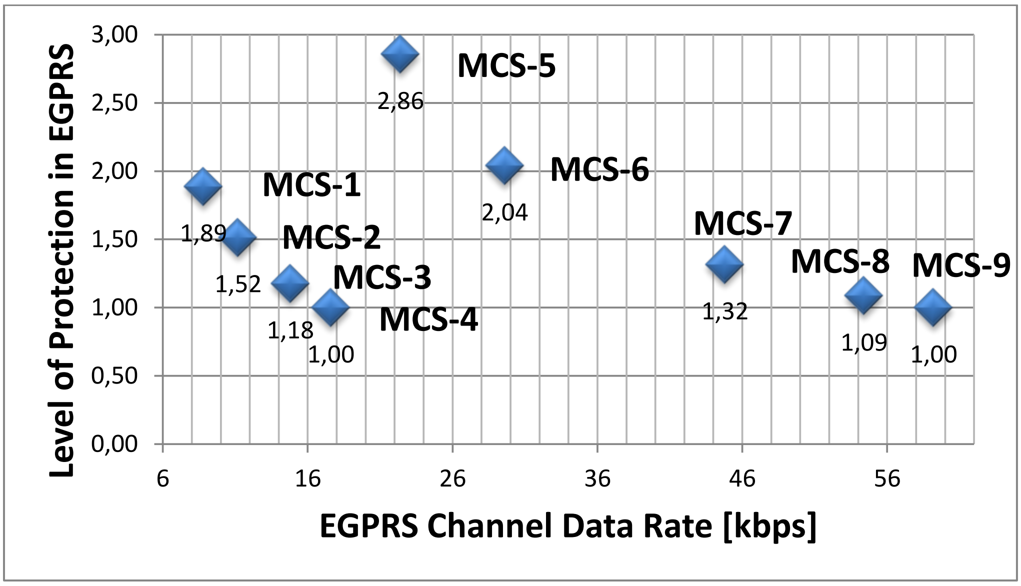

Figure 2-7 Link between FEC and the resulting Channel Data rate in EGPRS

The data channel rate in CS-1/MCS-1 restricted but can be used even under poor radio channel conditions.

Apart the different level of protection levels of GPRS and EGPRS the mobile station will indicate the support of GPRS/EGPRS in the relevant classmark information towards the network. The network takes into account classmark information to be able to command the appropriate channel coding.

2.6.2 GPRS channel coding

The four GPRS coding schemes, CS-1 to CS-4, are defined for user data blocks using GMSK modulation. In CS-1 up to CS-3 forward error correction applied by half convolutional coding that is punctured to have the desired coding rate. CS-4 does not foresee forward error correction. Table 2-6 provide an overview about the GPRS coding schemes. For further details about coding parameters consult the relevant 3GPP specification in [8].
The channel coding of CS-1 is not new and is being used for SDCCH and AGCH in GSM. The channel coding for logical GPRS channels (PACCH, PAGCH etc.) that are used for signalling purposes is the same as CS-1.

Note: GPRS coding schemes are applicable at GMSK modulation for MS power class 2 (nominal output power 8Watt - 39dBm) and MS power class 4 (nominal output power 2 Watt – 32dBm see in [15]).

	Coding Scheme	Modulation	Coding Rate	RLC/MAC Segment Size - User bits /20ms and time slot	RLC data block Bit Rate/ time slot [kbps]	Family
GPRS	CS-1	GMSK	1/2	160	8	N/A
	CS-2		33/50	240	12	N/A
	CS-3		3/4	288	14.4	N/A
	CS-4		1	400	20	N/A
EGPRS	MCS-1	GMSK	53/100	176	8.8	C
	MCS-2		33/50	224	11.2	B
	MCS-3		17/20	296	14.8	A
	MCS-4		1	352	17.6	C
	MCS-5	8-PSK	37/100	448	22.4	B
	MCS-6		49/100	592	29.6	A
	MCS-7		19/25	448+448	44.8	B
	MCS-8		23/25	544+544	54.4	A
	MCS-9		1	592+592	59.2	A

Table 2-6 GPRS/EGPRS important channel coding parameters

2.6.3 EGPRS channel coding

EGPRS is specified in a way to enhance the transmission bandwidth per timeslot and lowers the transmission transfer delay on the radio interface. The enhancement behind the extended data rate is the introduction of 8-PSK modulation in addition to GMSK. EGPRS has a major impact on the physical layer of the radio interface and the RLC/MAC protocol, but less to the subsequent higher protocol layers.
EGPRS consist of nine modulation and coding schemes MCS-1 to MCS-9. MCS-5 to MCS-9 uses 8-PSK modulation while MCS-1 to MCS-4 is based on GMSK. Latter coding schemes are different from GPRS CS-1 to CS-4 which was necessary to support incremental redundancy (IR).

The principle of channel coding compared to GPRS remain unchanged but in EGPRS RLC/MAC header (1/3 code 8-PSK/ 1/2 code GMSK) and the payload become differently coded. Also this was necessary to allow reliable decoding of the header in incremental redundancy operation. EGPRS modulation coding schemes are arranged in families according to their RLC data block sizes (see Table 2-6). The numbers of payload bits of the lower coding schemes inside the families are submultiples of the higher coding schemes that enable retransmission of erroneous data blocks with the more robust coding scheme within the same family if necessary. One exception is the switching from MCS-8 to MCS-6 or MCS-3 padding octets added to data octets.

Note: EGPRS modulation coding schemes are applicable at GMSK modulation for MS power class 2 (nominal output power 8Watt - 39dBm) and MS power class 4 (nominal output power 2 Watt – 33dBm). 8-PSK based modulation coding schemes are applicable for MS power class E1 (nominal output power 2 Watt – 33dBm see [15]).

2.6.4 Retransmission algorithm(s)

General Aspects

Erroneous radio blocks or data need to be retransmitted until the success of retransmission. For this reason the applicable protocol has to acknowledge successful transmitted data and request retransmission by a negative acknowledgment indication. The algorithms described subsequently are part of 3GPP specification in [10] and are only applicable in RLC acknowledged mode of operation (see chapter 3).

Automatic Repeat Request (ARQ)

The transfer of GPRS RLC data blocks in acknowledged mode is controlled by selective type I ARQ mechanism as the sending instance, mobile or network, transmitted a number of frames or radio blocks in a specific window size without a need to wait for an individual acknowledgement of the receiver. Latter may reject a single radio block or frame, which can be retransmitted alone. The receiver accepts out of order frames and is able to buffer them.

This selective type I ARQ is part of the GPRS RLC/MAC specification. Every retransmission of an erroneous RLC radio block in GPRS has to be performed within the same coding scheme as the original transmission. The explanation for this behaviour can be found in Table 2-6 and it becomes obvious that GPRS RLC block segment size of the different coding schemes are not multiples or submultiples.

This fact is a certain risk of stalling the transmit window which may create additional delay.

In EGPRS retransmission of an RLC block with different coding schemes is part of the specification and can be used if it is part of the network implementation.

Incremental Redundancy

With incremental redundancy each retransmission within an EGPRS coding scheme does not have to be identical to the original transmission. Multiple sets of coded bits are generated and each set is representing the same set of information bits. In case a retransmission is required, the retransmission uses a different set of coded bits than the previous transmission. The receiver combines the retransmission with a transmission attempt prior to that of the same frame. Typically for incremental redundancy is that the different redundancy version of one information frame are generated by puncturing schemes PS1, PS2, PS3 (see Figure 2-8). The initial transmission is sent with one of the initial code rates; initial data are punctured with puncturing scheme 1 (PS1) of the selected MCS. If the received RLC radio block is

erroneous, the first retransmission contains additional coded bits punctured with PS2 of the prevailing MCS, which are sent and decoded together with the previously received code words until error free decoding succeeds. After all code words (initial transmission to second retransmission using PS1- PS3) have been sent, the code word used during initial transmission using PS1 is sent.
In incremental redundancy, the different redundancy version are typically generated through puncturing and the resulting coding protection of PS1, PS2, and PS3 having similar performance. The whole process of incremental redundancy scheme is called type-II Hybrid ARQ.

Only EGPRS is supporting the incremental redundancy mode that can improve packet transfer delay and the robustness for varying radio channel conditions and erroneous measurements. Incremental redundancy (IR) is mandatory for mobile station and optional for the network.

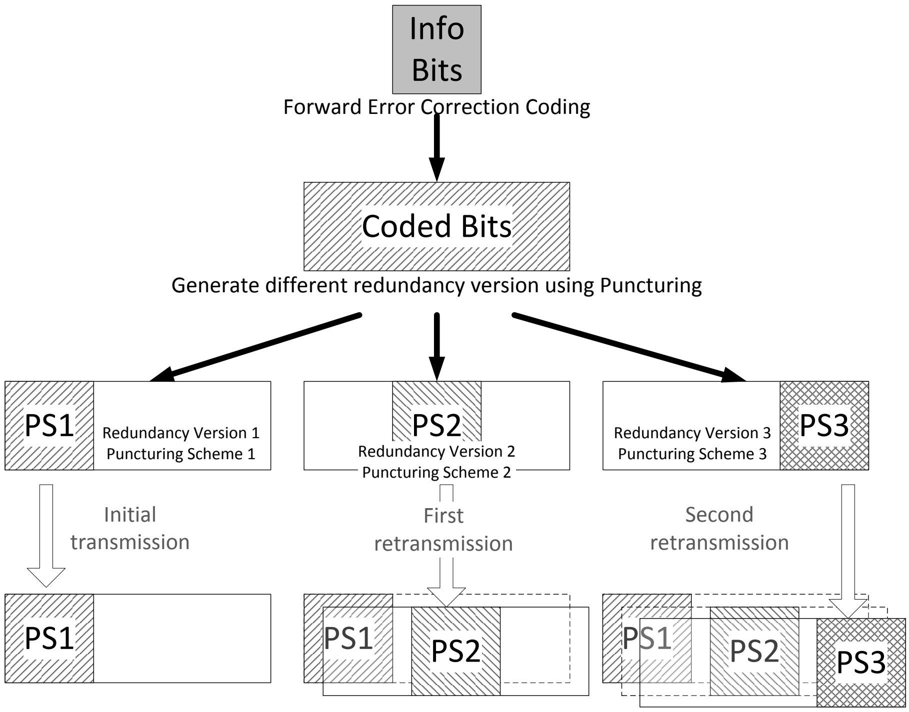

Figure 2-8 Incremental redundancy principle

Link adaptation

Chapter 2.6.1 highlighted that GSM CS-mode data transmission is unable to adapt the radio transmission protection level. (E)GPRS introduces such functionality by increasing the amount of redundancy that the error correction can be improved and reduces at the same time the net bit rate of the traffic channel resource (timeslot). In order to minimise the transfer delay or to maximise the throughput, robust coding schemes should be used in poor radio condition and coding schemes having less protection in good radio conditions. Figure 2-6 and Figure 2-7 provided an overview about the protection levels of each (modulation) coding scheme in (E)GPRS.

Link adaptation algorithms are used to apply the optimum channel coding as a function of the radio channel conditions. Typical link adaptation implementations take into account the carrier to interference ratio or the bit error/radio block error rate and compute an estimate for the radio channel quality within a specific time interval. The link adaptation algorithm provides the decision about the appropriate coding scheme by comparing the channel quality estimation to certain threshold values. There are different link adaptation algorithms which are depending on the available channel quality estimates i.e. BLER etc.

In GPRS/EGPRS radio link measurements are autonomous to RLC mode of operation (see chapter 3). GPRS channel quality reporting contains interference levels of the serving cell, the received signal quality (RXQUAL in DL) and an averaged variance of the received signal level. EGPRS reports provide similar information, apart from the Bit Error Probability (BEP) which is included instead of the received signal quality and received signal level. Based on the channel coding specific information the network is able to select the optimal coding scheme for DL transmission.
In UL transmission direction, the network commands the mobile which coding scheme shall be used. The specific selection of channel coding in UL is typically based on the same LA algorithm used in DL taking into account measurements performed by the applicable base transceiver station.

Retransmissions with different coding schemes is not possible in GPRS but EGPRS provides this functionality due to the RLC/MAC block re-segmentation possibilities within the MCS families (A, B, C see Table 2-6). Depending on the GPRS implementation LA can be provided as well.
In order to allow retransmissions in other coding schemes re-segmentation and padding can be used (see in [8]), but IR combining is not possible in these cases. In principle re-segmentation and padding are beneficial, when there is a need to retransmit the same radio block using a lower coding scheme due to changing radio link conditions.

2.6.5 Requirements Channel Coding and Retransmission algorithms

Number of requirement	Description	Mobile Mandatory – M Conditional - C Optional – O	Network Mandatory – M Conditional - C Optional – O
2.6.5.1	GPRS channel coding support of CS-1/CS-2	M	M
2.6.5.2	GPRS channel coding support of CS-3/CS-4	M	O
2.6.5.3	EGPRS channel coding support of MCS-1 to MCS-4	M	O
2.6.5.4	EGPRS channel coding support of MCS-5 to MCS-9	M	O
2.6.5.5	Mobile Station/EDOR support of MS Power Class 2 for GMSK modulation	M	N/A
2.6.5.6	Mobile Station/EDOR support of MS Power Class E1 for other modulation (8-PSK)	C	N/A
2.6.5.7	Type I ARQ support	M	M
2.6.5.8	Type II Hybrid ARQ support	C	$C_{(1)}$
2.6.5.9	Link Adaptation support for GPRS	N/A	O
2.6.5.10	Link Adaptation support for EGPRS	N/A	O

Table 2-7 PS-mode - Channel Coding and retransmission requirements

Note 1: Type II Hybrid ARQ is only supported and required if EGPRS is enabled in the network.

2.7 GSM-R - Radio Network Architecture

2.7.1 General Aspects

GSM-R radio network architecture is a matter of availability and maintainability requirements. Each GSM-R infrastructure operator decides about the coverage scenario that is necessary for e.g. track or high train density area deployment. Such possible radio coverage architecture scenarios are subsequently introduced.

The different radio coverage design scenarios may require specific GSM-R PS-mode system features which are considered in chapter 4 later in this document.

2.7.2 Single Radio Layer architecture - limited adjacent cell overlapping

A single radio layer is the basic coverage architecture which comprises one layer of cells along a railway track or single layer structure in a high train density area without any redundancy (see

Figure 2-9). The overlapping characteristic between adjacent cells is very limited and the radio coverage elements (BTS) are connected to one controller element (BSC/PCU).

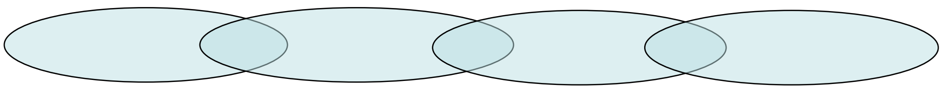

Figure 2-9 Single radio layer architecture – limited adjacent cell overlapping

2.7.3 Single Radio Layer Coverage – extended

This coverage architecture consists as well of a single radio layer and take into account a much shorter distance up ~50% overlapping between adjacent cells. In every point of the track, the mobile get at least under nominal conditions two radio signals. This architecture requires at least one controller element (BSC/PCU) but it is also possible to connect adjacent cells to different controller elements (BSC/PCU).

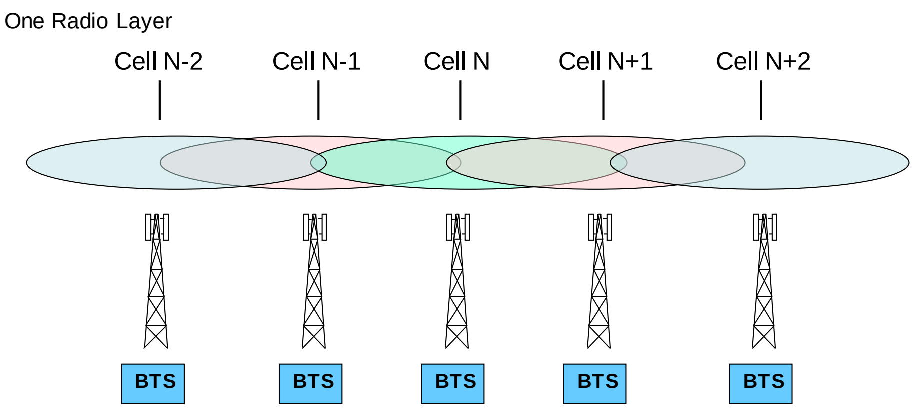

Figure 2-10 Single radio layer architecture – extended adjacent cell overlapping

2.7.4 Dual Radio Layer Coverage- no layer offset

A double coverage without offset between the coverage layers consists of two autonomous radio layers and the base stations of each layer are connected to different controller elements (BSC/PCU). The overlapping characteristic between adjacent cells inside one layer is very limited, but always two base stations of the different layers are covering almost one track segment.

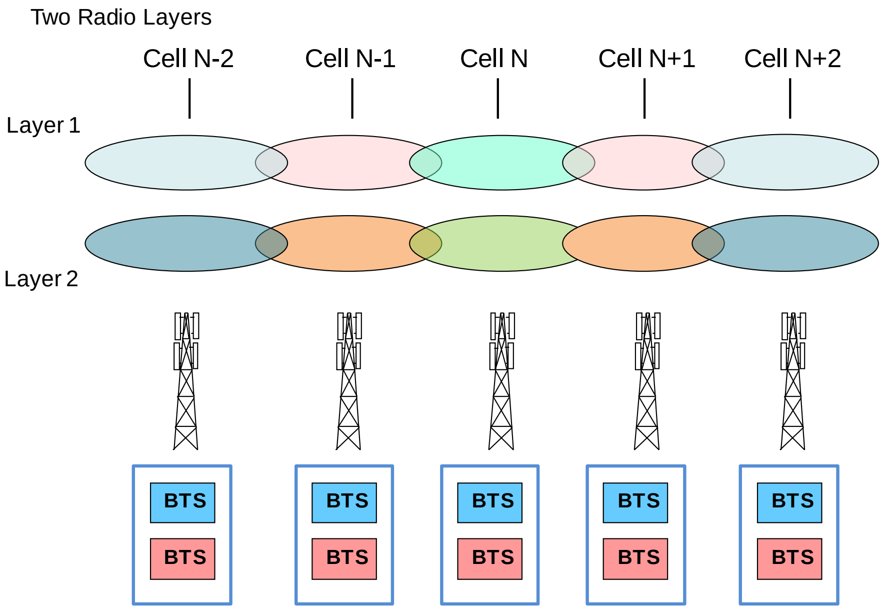

Figure 2-11 Dual Radio Layer architecture – no layer offset

2.7.5 Dual Radio Layer Coverage - with layer offset

This architecture contains as well two autonomous radio layers and the base station is connected to different controller elements (BSC/PCU). The difference to the architecture approach in 2.7.4 is an offset of ~50% between the two radio coverage layers as illustrated in Figure 2-12.

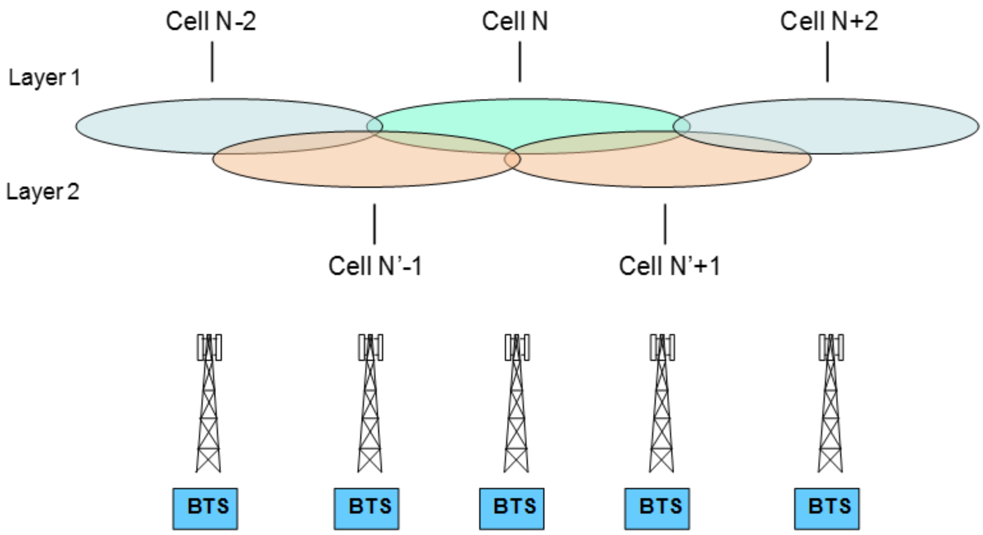

Figure 2-12 Dual Radio Layer Coverage – with layer offset

2.8 GSM-R Radio Network planning

2.8.1 General Aspects

The trackside GSM-R signal/field strength requirement according to EIRENE [31] for ETCS remains unchanged.

Due to the limited GSM-R spectrum it can be assumed that the networks are interference limited as the same frequencies are reused in different cells. Interference limited networks can be considered as capacity limited. For GPRS/EGPRS the interference level is setting the limits of the spectral efficiency and the wide use of the available coding schemes.
In GSM specification [15] the minimum BTS and mobile station performance for GPRS/EGPRS are specified and comprise the receiver sensitivity and the minimum CIR (Carrier to Interferer Ratio for a reference (radio) block error ratio [BLER]). Different channel models including mobile speed and the channel type (typical urban etc.) are as well subject of this specification [15] and need to be considered during GSM-R radio planning process.

2.8.2 Requirements GSM-R Radio Network planning

Number of requirement	**Description**	**Mandatory - M Optional – O**
2.8.2.1	EIRENE SRS [31] GSM-R signal/field strength requirements are as well applicable for GPRS/EGPRS deployment.	M
2.8.2.2	To guarantee specific use of GPRS channel coding minimum CIR requirements according to 3GPP 45.005 [15] for GPRS channel coding shall be part of radio network planning and trackside deployment respecting the MS-power class.	M
2.8.2.3	To guarantee specific use of EGPRS channel coding minimum CIR requirements according to 3GPP 45.005 [15] for EGPRS channel coding should be part of radio network planning and trackside deployment respecting the MS-power class for higher coding schemes.	C

Table 2-8 PS-mode – radio planning requirements

2.9 Control Channels

2.9.1 General Aspects

GSM uses TDMA as the multiple access formats and each physical channel (frequency) is subdivided into eight timeslots. Logical channels are cyclic mapped to the physical channel based on the GSM radio interface multi frame pattern. A specific synchronisation algorithm between mobile and BTS guarantees the exact position of the cycles. Different types of logical channels are placed onto the individual timeslots, that each timeslot is occupied by different logical channel types in sequence. This principle applies to the different signalling channels (e.g. SDCCH), the traffic channel and their associated control channels (SACCH). The logical channel types that are applicable for GSM-R are summarised in Figure 2-13.

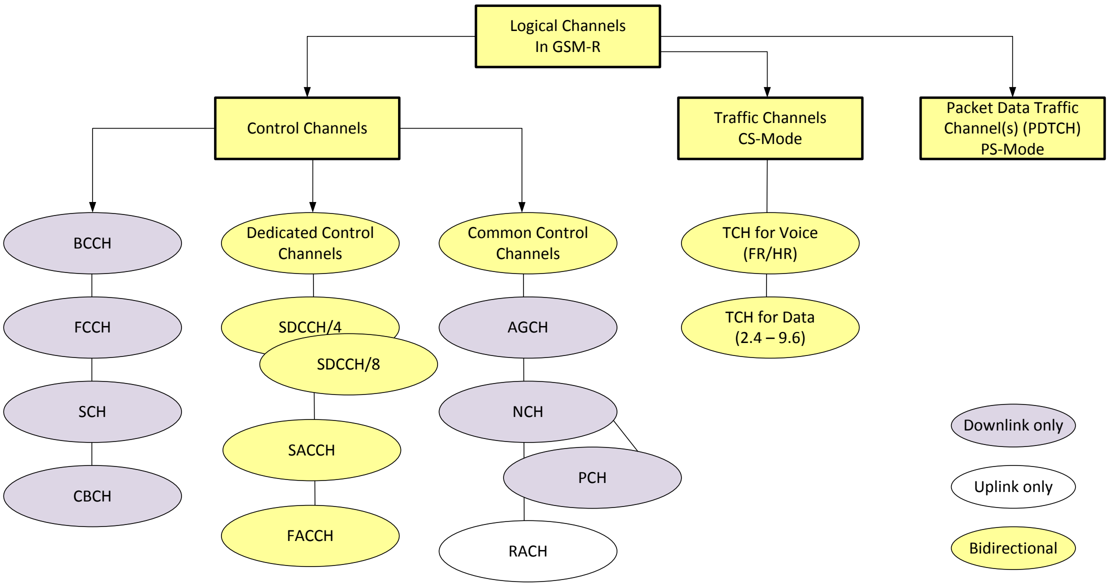

Figure 2-13 Logical Channel Types applicable for GSM-R

Control channel across the mobile-BTS interface are used to provide all active mobiles necessary system information (unidirectional) and the transport of signalling information for mobility, connection and radio resources management (bidirectional). The different types of logical channel are placed onto the individual timeslots, as each timeslot is not occupied by the same logical channel type every time but is occupied by different logical channel types in sequence according to [12] (see Figure 2-14).

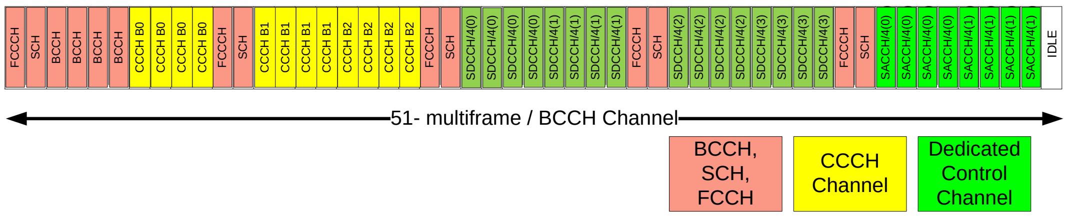

Figure 2-14 Logical Channel sequence using combined channel setup - Downlink

The logical channels divide into traffic and control channels (see Figure 2-13) that are used circuit or packet switched mode. TCH carry circuit switched speech or user data and a PDTCH packet switched user data.

GSM control channels divide into three groups (see Figure 2-13):

> **Broadcast Channel** are the frequency correction channel (FCCH), synchronisation channel (SCH) and the broadcast control channel (BCCH) that are used to continuously broadcast frequency reference, time an system information.
>
> **Common Control Channel** category consists of the random access channel (RACH), paging channel (PCH), access grant channel (AGCH) and the notification channel for ASCI services only. These channels are used to establish radio resource (RR) links that the network can exchange signalling and radio link control messages with the mobile station on the dedicated control channels.
>
> **Dedicated Control** channels are the standalone control channel (SDCCH), fast associated control channel (FACCH) and slow associated control channel (SACCH)

Note: Control channels use always Gaussian minimum shift keying modulation (GMSK).

GSM control channels are mapped onto physical channels according to the 51-multiframe structure as depicted in Figure 2-14. The physical channel that transports the broadcast information is designated as BCCH and occupies always timeslot 0 of a dedicated carrier in the cell, and the broadcast channel uses 14 frames in each of the 51-multiframe. The remaining frames are allocated to the common and dedicated control channels. A network operator can use either a **combined** or **non-combined** [12] channel/multiframe configuration depending on the cell traffic capacity.

In a **combined** channel configuration the BCCH channel comprises four SDCCH sub channels with their SACCHs in the Downlink. Three blocks of four frames are then allocated for the CCCH (see Figure 2-14). PCH and AGCH share these CCCH on a block by block basis. The infrastructure operator may reserve a fixed number of CCCH blocks for NCH and AGCH that may not be used for the PCH. For GPRS purposes, the AGCH capacity can impact the performance of GPRS radio resource allocation (i.e. Immediate Assignment). As a consequence of less AGCH resources TBF establishment can be delayed (see chapter 2.9.2).

In non-combined channel configuration all blocks left from broadcast channel are reserved for the CCCH, and depending on the cell traffic capabilities one or more timeslot(s) need(s) to be allocated for the SDCCH usage (see Figure 2-15).

In the uplink 51 RACH frames are allocated in a non-combined configuration, and 27 RACH frames plus four SDCCH blocks and their associated SACCH share the 51-multiframe structure in a combined configuration (see in [12]).

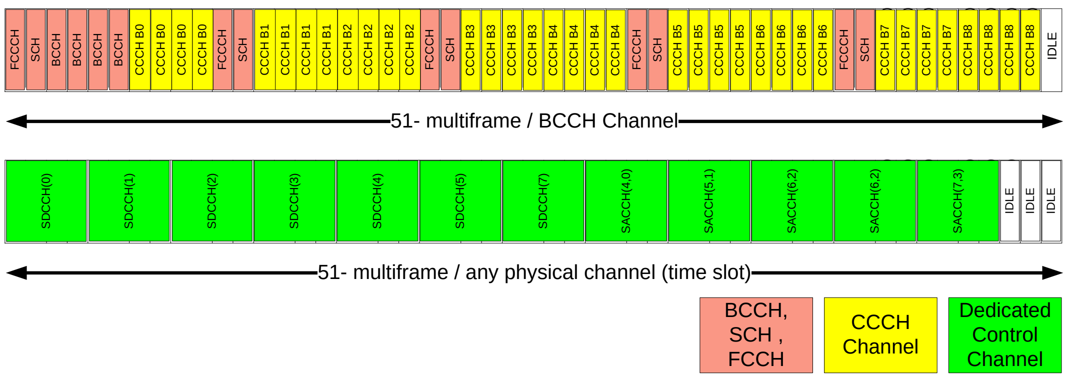

Figure 2-15 Logical Channel sequence non-combined channel setup - Downlink

2.9.2 GSM-R Signalling channel capacity limitations

GSM-R ASCI services, Voice Broadcast- and Voice Group Call, use the notification channel (NCH) to inform the subscriber about on-going group calls. Per definition the NCH belongs to the category of common control channels (CCCH) and has to share CCCH block capacity among the other logical channels (PCH and AGCH).

Inside a GSM 51-multiframe, which has duration of 235ms, 9 blocks are dedicated to broadcast one message.

In the non-combined 51-multiframe structure, up to 7 NCH blocks can be configured (see Figure 2-14), while in the combined multiframe structure (see Figure 2-15), up to 2 NCH blocks can be configured.

However, NCH dimensioning, i.e. how many CCCH blocks are dedicated to VBS and VGCS notification, has an impact on CS-mode call setup and PS-mode session establishment performance: The more NCH are configured, the less AGCH blocks are available for CS call and TBF establishment.

Table 2-9 and Table 2-10 summarize the maximum additional delay during TBF establishment, induced by the number of NCH blocks configured. (Time values are rounded). The delay is the direct consequence of the fact that the TBF resource allocation message sent to the mobile on AGCH during TBF establishment can be delayed if the current CCCH block broadcast on the radio is not an AGCH i.e. is an NCH block. In this case, the values in tables 2-9 and 2-10 indicate the maximum time needed to wait for the next occurrence of the AGCH block, necessary to send the relevant message to the mobile.

Note: During the lifetime of the TBF, this number of NCH blocks has no influence to the packet transfer delay performance at all.

non combined channel combination	
number of NCH blocks/remaining AGCH blocks	**additional delay on TBF establishment [milliseconds]**
1/8	28
2/7	47
3/6	74
4/5	93
5/4	120
6/3	139
7/2	167

Table 2-9 TBF establishment delay- non combined channel combination

combined channel combination	
number of NCH blocks/remaining AGCH blocks	**additional delay on TBF establishment [milliseconds]**
1/3	28
2/2	47

Table 2-10 TBF establishment delay - combined channel combination

2.10 ETCS application characteristics

ETCS application and the related protocol stack is transaction based which follows a typical interactive characteristic. The responsible ETCS protocol instance at the train borne side sends e.g. a measurement report about the actual train location and the trackside EuroRadio protocol instance acknowledges its reception and may provide permission back to the train borne side communication instance. Resulting frequency of ETCS messages and the ETCS/EuroRadio message size(s) are planning parameter which shall be part of the track/high density area planning process.
Table 2-11 provide a summary about the typically used ETCS messages (see [22].

	OBU to RBC	RBC to OBU	SaPDU size	Message Frequency [seconds]			Total packet size + header Uplink [octets]	Total packet size + header Downlink [octets]	Message Overhead type	Header Size [octets]
ETCS Message	Uplink	Downlink	[octets]	min	max	Typical				
Authentication Message 1, AU1	X		13	1	1		73		Adaptation Layer	10
Authentication Message 2, AU2		X	21	1	1			81	Transport Layer (TCP)	20
Authentication Message 3, AU3	X		9	1	1		69		Network Layer protocol (IP)	20
Authentication Response, AR		X	9	1	1			69	SNDCP	4
Disconnect, DI	X		9	1	1		69		LLC (UI frame)	6
Initiation of a Communication Session,	X		19	1	1		79		**Sum headers**	60
Configuration Determination,		X	20	1	1			80		
Session Established, (only max packet size)	X		43	1	1		103			
Validated Train Data,	X		60	1	1		120			
Ack. of Train Data,		X	23	1	1			83		
General Message + extra packet(s), entry		X	50	2	2			110		
General Message + extra packet(s), Full supervision		X	19	3	40			79		
General Message + extra packet(s), exit		X	23	1	1			83		
Acknowledgement of GM	X		23	3	40		83			

ETCS Message	OBU to RBC	RBC to OBU	SaPDU size [octets]	Message Frequency [seconds]			Total packet size + header Uplink [octets]	Total packet size + header Downlink [octets]	Message Overhead type	Header Size [octets]
	Uplink	Downlink		min	max	Typical				
Movement Authority + extra packet(s), 100-500		X	500	6	120	20		560		
Request to shorten MA + options	X		40	1	1		100			
Acknowledgement of MA	X		23	6	120	20	83			
Train Position Report	X		33	3	120		93			
Termination of Communication Session	X		19	1	1		79			
Ack. of Termination,		X	19	1	1			79		
MA Request, 20-60	X		60	6	120		120			
TCP acknowledgement	X		20	10	10		80			
TCP acknowledgement		X	20	10	10			80		

Table 2-11 Typical ETCS messages

It is obvious that size of the SaPDUs is quite small except the maximum size of the Movement Authority. This fact is also illustrated in Figure 2-16 that depicts the ETCS message including all headers on the radio link (Um interface). In general ETCS messages are in its entirety small with one exception.

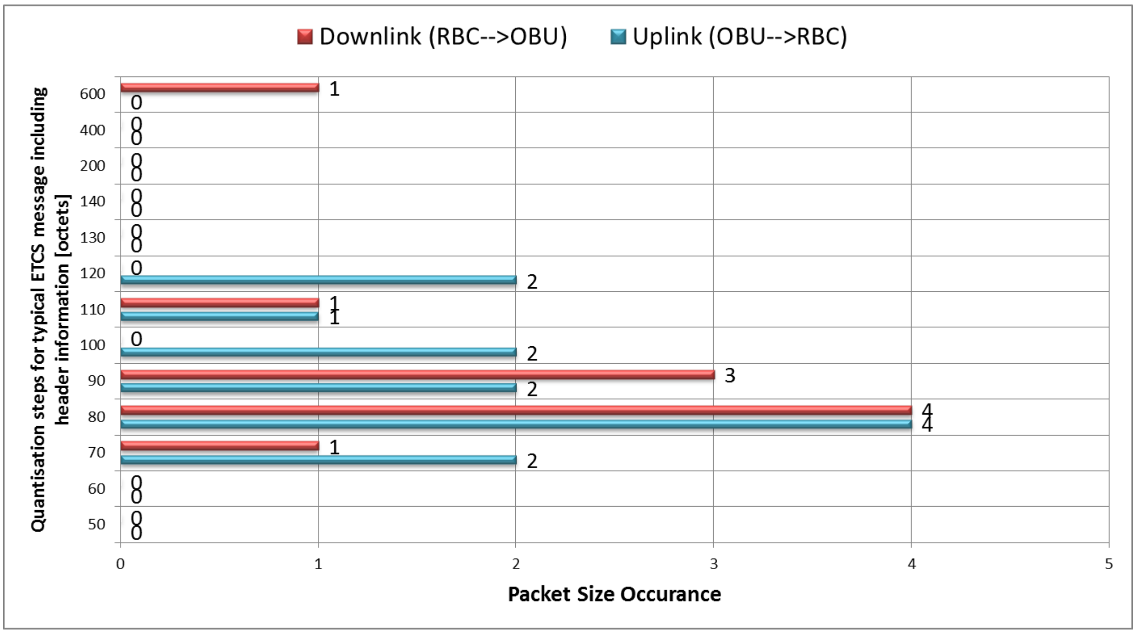

Figure 2-16 ETCS message size occurrence Uplink/Downlink

Also the frequency of the entire ETCS messages portion is divergent. Some messages are sent only once, at the beginning or the end of ETCS session, which is an important input parameter to the lower transport layers i.e. MAC (see chapter 2.2.1) in GSM-R PS-mode. Bear in mind most wireless access systems allocate resources on demand and mainly the network controls resource utilisation for a specific subscriber. If the network detects that allocated resources are not utilised any longer by the subscriber these resources are released and can be allocated to other subscribers.

ETCS application message size comprises the number of an ETCS application message octets including all necessary header information to transport the message by the GPRS/EGPRS bearer service over the air interface at RLC/MAC level (see chapter 2.1). Mainly the air interface is the limiting fact in terms of transmission bandwidth and the resulting delay of an application packet. Transmission bandwidth limitations can have different reasons e.g. system depended or external and thus the GSM-R system responsible has to gather information about the maximum ETCS application packet size to be used and the highest frequency of the packets to be exchanged.
The available bandwidth at the air interface allows different resource allocation and release pattern. If sufficient bandwidth is available, e.g. in EGPRS MCS-6 – MCS-9, the ETCS packet size + headers is insignificant compare to the time duration need for user identification and resource allocation. This topic will be taken into account later in chapter 3.3.

3 RADIO LINK OPERATION

3.1 *Transmission channel allocation*

3.1.1 General Aspects

Radio channel allocation algorithms are responsible for assigning a physical transport channel to a GPRS/EGPRS mobile station. Assuming that CS-mode and PS-mode have to share the same physical resources (timeslots), different strategies is possible. First option provides a sharing of all available resources between CS- and PS-mode. A second option considers separate resource pools for both transmission modes. Also a combination of both options is realisable.
Two pools of transmission resources imply a dedicated pool for PS- and one for CS-mode transmission resources. Voices, including PtP and PtM, and CS-data connections are allocated to transmission channels that belong to the CS-mode pool while GPRS/EGPRS connections are allocated to the resources inside the PS-mode pool. Transmission resource reallocation (Upgrade/Downgrade) between the pools is possible depending on the traffic load conditions.
A common pool of transmission resources consists in forming a pool of timeslots in which CS-mode and PS-mode connection are allocated as both traffic mode types have to compete for the use of resource in the cell.

GSM specification [8] stated that higher priority service may take precedence over PS data channel allocation. Most implementations of channel allocation algorithms prioritise CS-mode services to guarantee a stable timeslot allocation and a continuous traffic flow. In the worst case all traffic resources can be allocated to CS-mode services which can be interpreted as PS-mode service unavailability.
Thus, the infrastructure operator needs to allocate at least one traffic channel (timeslot) to the PS-mode pool which can't be reallocated to any CS-mode services.

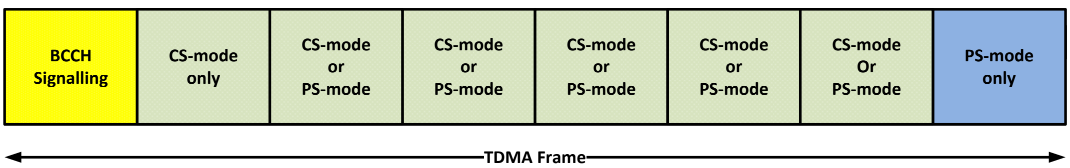

Figure 3-1 Example CS- and PS-mode transmission resource pool allocation

Any kind of rail emergency call, which has the highest priority in the radio access network, is not able to pre-empt dedicated PS-mode pool traffic channel allocation within a cell!

Further dedicated or shared transmission channel allocations to the PS-mode pool are depending mainly on the expected traffic load caused by the different application and their corresponding QoS requirements and the impact on transfer delay of data packets. Also specific impairments of the radio channel due to high train speed etc. may require further channel allocations to the PS-mode pool.

3.1.2 GPRS/EGPRS Capacity dimensioning principles

GPRS/EGPRS bandwidth dimensioning is the result of the computation of several inputs like radio environment and infrastructure operator strategy. When the required

bandwidth is known, the number of dedicated packet data traffic channel to be configured on the radio interface can be calculated.
To dimension the radio interface capacity for the ETCS application the following inputs are required:

- Maximum number of users (train(s), other potential PS-mode application users) per cell
- Transport channel performance for ETCS purposes according to subset-093 [34] and according to the environment of the cells (urban / rural)
- ETCS application message size/message sequence model (see chapter 2.10) result into a specific throughput per train in a cell along the track or dense area
- Traffic model of non-ETCS applications that are used in a cell together with the ETCS application

Note: If the infrastructure operator plans to use its GPRS/EGPRS network also for other data applications than ETCS, it needs to be taken into account in the bandwidth dimensioning!

The three first inputs aforementioned provide the minimum transport capacity requested. The infrastructure operator can also decide to allow more bandwidth than the minimum required. In addition, the fourth input allows defining the most suitable radio GPRS/EGPRS channel coding to compute the number of packet data traffic channels configured and dedicated on the radio interface.
At the end, the result has to be compliant with the GSM/GPRS system limitations in terms of maximum number of mobiles per packet data traffic channels.
The configuration of the total dedicated and dynamic timeslot quantity requires considerable analysis of consequences before any recommendations can be made. At least one dedicated timeslot (PDTCH) shall be allocated per cells. Otherwise there is a risk that ETCS data traffic can be pre-empted by any kind of CS-mode calls.

3.1.3 Requirements transmission channel allocation

Number of requirement	**Description**	**Mandatory - M Optional – O**
3.1.3.1	If the GSM-R cell is used to transport the ETCS application in PS-mode sufficient, but at least one dedicated GPRS traffic channel (timeslot) shall be provided.	M
3.1.3.2	To guarantee the QoS of voice calls (e.g. Rail Emergency Call) sufficient, but at least one dedicated traffic channel should be allocated to CS-mode.	O
3.1.3.3	Depending on the traffic load in a cell (an) additional traffic channel(s) can be allocated to CS- or PS-mode.	O
3.1.3.4	Depending on the CS-mode and PS-mode traffic load in a cell, (an) additional traffic channel(s) can be shared between the CS-mode and the PS-mode pool. Sharing of traffic resources between CS- and PS-mode can impact the QoS e.g. slow connection setup.	O

Table 3-1 PS-mode – Cell specific traffic channel allocation

Note: The assignment of traffic channels to the PS-mode pool has no impact on specific radio coverage architecture according to chapter 2.7.

3.2 Radio Link Control (RLC) operation mode

3.2.1 General Aspects

The main functions of RLC have been already outlined in chapter 2.3. This chapter will have closer focus on the RLC operation modes and the recommendation for the operation of ETCS application. The operating mode required for a PDP context is determined by the subscriber APN QoS profile that is located in the subscribers HLR. Precisely the parameters SDU error ratio and Residual bit error ratio (see in [3]) decide about RLC unacknowledged or acknowledge mode of operation.

3.2.2 Unacknowledged Mode

The transfer of RLC data blocks in the unacknowledged RLC/MAC mode is controlled by the numbering of the RLC data blocks within one Temporary Block Flow and does not include any retransmissions between mobile and PCU. Radio impairments may cause erroneous user data packets which have to be corrected necessarily at higher (end to end) protocol layers. The impact on ETCS message delay can be significant.

3.2.3 Acknowledged Mode

In the acknowledged operating mode, the sending entity (mobile or PCU) expects a confirmation from the receiver after a certain number of data blocks (window) which is different between GPRS and EGPRS. In GPRS the receiving entity has to acknowledge latest after 64 data blocks while in EGPRS it depends on the channel coding used during data transmission.
GPRS makes use of the Automatic Repeat Request (ARQ) while EGPRS uses more enhanced retransmission algorithms type I/II Hybrid ARQ (see chapter 2.6.4).
GPRS optimisation outlined that the RLC acknowledge operation mode reduces the impact of degraded radio degradation to the end- to-end transfer delay performance. Erroneous radio blocks are much faster retransmitted at the lower layer than using end-to-end error correction.

Number of requirement	**Description**	**Mandatory - M Optional – O**
3.2.3.1	GPRS/EGPRS radio bearer service for ETCS purposes shall be operated in RLC acknowledged mode.	M
3.2.3.2	Applicable QoS Profile settings shall be according to FFFIS for EuroRadio [35]	M

Table 3-2 PS-mode – RLC operation mode settings

3.3 Temporary Block Flow

3.3.1 General Aspects

In GPRS/EGPRS several users can use the same timeslot uplink or downlink simultaneously, every user can transmit and/or receive on several timeslots at the same time. Moreover, uplink and downlink are independent from another.
GPRS/EGPRS introduces a TBF - Temporary Block Flow to identify all data packets that belong to the same uplink or downlink dataflow. A TBF encompass all data packets unidirectional from mobile to the PCU or vice a versa. In order to be able to allocate every data packet on every timeslot to a TBF the TFI – Temporary Flow Identifier (5 bit) identifies the TBF unambiguous. Each data packet is coded using the TFI in order to be allocated to the individual TBF. Up to 32 TBFs can be differentiated to each transmission direction per timeslot.

3.3.2 TBF resource allocation [10]

Radio interface transmission resources are allocated in GPRS/EGPRS based on the ”resource on demand principle”, thus network resources are only allocated to a subscriber for as long as they are required for user data exchange i.e. between client and server. This requires as well instant access to the radio transmission resources without any long identification and authentication procedures prior the allocation of these.

There are several variations of network access in GPRS/EGPRS but finally the network decides about the access criterions to be used. The network access variations are:

One-phase packet access can be proposed by the mobile while the network, particularly the PCU, decides whether one-phase packet is possible or two-phase packet access has to be enforced. In RLC unacknowledged mode (see chapter 3.2) the mobile cannot propose one-phase packet access.
The procedure is called one-phase access because after reception of access information in form of access bursts, PCU allocates immediately uplink resources to the mobile. If the RACH is used to initiate the one-phase access, only one single timeslot can be allocated, because multi slot capabilities of the mobile are still unknown in the network.
Due to the limited bit quantity of an access burst (8 or 11 bit) the mobile cannot be identified with absolute certainty. This requires the execution of the contention resolution procedure using the established uplink data transfer to identify the mobiles with absolute certainty inside the applicable SGSN area.

Two-phase packet access has to be used in RLC unacknowledged mode only. The mobile can neither identify itself using the access burst, nor is the resource quantity communicated exactly. Due this reason, the network only allocates a single block during the first phase of the two phase packet access that can be used for further communication by the mobile towards the network. With the subsequent resource request (second phase) the mobile can be identified in the radio access network. Respectively the contention resolution procedure is also present in the two-phase packet access. When the transmission resources are used by the mobile, the applicable SGSN has as well the absolute certainty about the mobile identity.

Note: GPRS/EGPRS access phase will cause almost additional delay for the first data packet to be exchanged. The access delay value depends on the implementation of the necessary procedure.

Downlink resource allocation is carried out if the PCU receives data from higher layer levels for transmission to the mobile in GSM. For this reason a DL-TBF must be activated. A TBF for a particular mobile is identified by the TFI (see 3.3.1) for each timeslot or even a group of timeslots. The mobile should search for data packets with its allocated TFI. Thus all radio blocks on the assigned timeslots must be received and at least the TFI must be decoded before a data block has to be processed or rejected.

Uplink resource allocation: If a Mobile receives the request for data from higher layers to be transmitted towards a communication entity in the network, the PCU will process the allocation of uplink resources to the requesting mobile. In this document the "Dynamic Allocation" method is in focus. Thus the other specified uplink resource allocation methods can be retrieved from applicable 3GPP specification [10].

The **Dynamic Allocation** as one possible algorithm of the uplink resource allocation procedures is based on the "Uplink State Flag - USF" which forms the first 3 bits in each RLC downlink radio block (see in [10]). Therefore eight different values can be distinguished via the USF. Hence, the mobile receives the timeslot(s) to be used for uplink data transmission and one USF per timeslot and monitors the downlink direction of the timeslot(s) allocated. In case the mobile recognizes its USF in a downlink block, the mobile should use based on a specific block pattern, the same timeslot(s) for the transmission of the next uplink radio block.

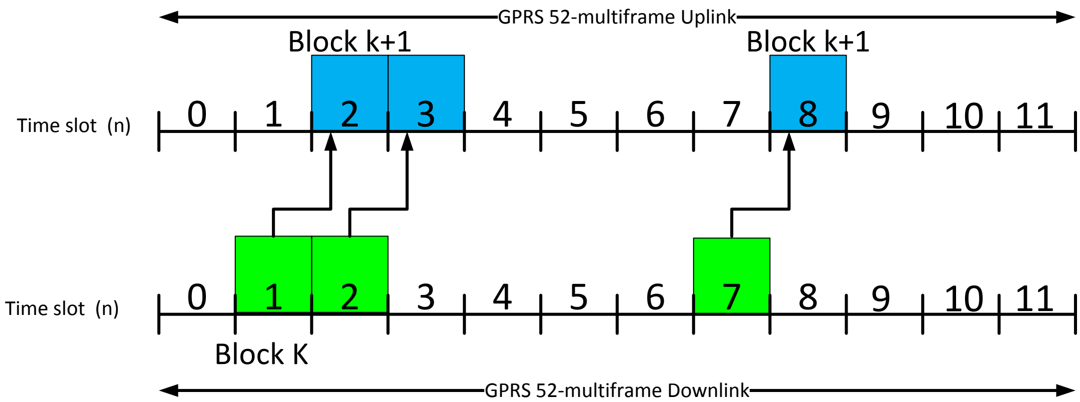

Figure 3-2 Uplink block allocation principle using USF

A 3 bit USF addressing field in the header limits the multiplexing of one timeslot to eight concurrent uplink resource allocations to mobiles. On a PDCH not carrying the packet oriented CCCH (PCCCH); the eight USF values are used to reserve the uplink for different mobiles (see in [8]). However, one USF value shall be used to prevent collision on uplink channel, when MS without USF is using the uplink channel [11]. It allows the conclusion that up to seven concurrent users can be multiplexed to one transport resource (timeslot).

Note: The previous described procedures may cause an additional delay to the first data packet in uplink direction up to 300 milliseconds depending on the implementation and the number of concurrent users sharing a resource (timeslot).

3.3.3 TBF termination - resource release

The previous chapter concentrated on the allocation on UL and DL resources. Now the question remains how resources can be released as quickly or even more delayed and without excessive signalling. Also the autonomous treatment between uplink and downlink remains unchanged.

DL TBF termination
Downlink TBF termination is as simple given that the last data block transmitted by the PCU is indicated as the final block. In RLC acknowledged operation mode the transmitted data blocks need to be positively acknowledged. In unacknowledged mode of operation the mobile sends control message to the PCU based on last block indication.
Each release and establishment of a downlink TBF will bring additional transfer delay to the transport of the ETCS application data packets if the available bandwidth is limited. In other words, the frequency of ETCS application messages affects the release and establishment behaviour of the downlink TBF.

When the network exhausts its supply of downlink LLC frames (ETCS application data) for a downlink TBF, it may release the TBF. If the downlink TBF shall not be instantly released, the network can continue the downlink TBF awaiting new downlink LLC frames. After a specific period of inactivity, no further downlink LLC frames, the TBF shall be released at a point determined by the network. Once the release of a downlink TBF is initiated, the TBF shall not be continued.

The inactivity period before downlink TBF release can be implementation specific. Therefore ETCS application message frequency between RBC and OBU shall be taken into account. A delayed downlink TBF timer range of a couple of second up to 60 seconds is sufficient for ETCS purposes.

Note: The impact to the mobile power consumption to mobiles that are operating other application than ETCS has to be taken into account during the system engineering process.

UL TBF termination
The termination of the uplink TBF is usually initiated by the mobile by starting the countdown process. Countdown procedure (see in [10]) is based on 4 bit countdown value (CV). This CV is counted down to 0 by the mobile and informs the PCU in advance that a mobile will shortly no longer require any additional transport resources. The countdown process cannot be cancelled also when additional data are placed in the mobile output buffer after the countdown process started.
If the network has received all RLC data blocks when it detects the end of the TBF (i.e.CV=0), it demands the mobile to acknowledge the termination of the uplink TBF.

An instant uplink TBF resource release after successful data transmission causes an additional delay to the next packet to be transmitted in the uplink direction. In case only ETCS “Position Reports” are considered, each Position Report will get additional delay due to necessary access phase as it has been elaborated in chapter 3.3.2.
To prevent additional delay to ETCS OBU→RBC application messages the TBF resources shall be allocated to the mobile taking into account an inactivity period between consecutive ETCS OBU→RBC messages. The feature **extended UL-TBF** provides such an extended inactivity period to the uplink TBF and is a part of the *GERAN Feature Package 1*.

An inactivity period exists when there is no RLC data block ready to send for any TBF, the mobile station shall send an (dummy) control block in each uplink radio block allocated by the network, unless indicated otherwise.
An extended UL-TBF inactivity timer range is implementation depended and varies between couple of second up to maximum 30 seconds for ETCS purposes.

Note: The impact to the mobile power consumption to mobiles that are operating other application than ETCS has to be taken into account during the system engineering process.

Track and High density area GPRS/EGPRS resource allocation
The ETCS application is impacted differently during the operation on the track or in stations. More robust channel coding shall be used on the track while less robust channel coding can be used in big railway stations. It is obvious that the stationary environment e.g. a big railway station may favour the use of higher bandwidth like it is supported by EGPRS channel coding MCS-8 or MCS-9 which bring significant more bandwidth per timeslot than CS-2/MCS-2. However, ETCS application messages are in most of the cases less than 100 octets including higher and lower layer headers (see chapter 2.10). Together with the higher available bandwidth and improved retransmission algorithms, the ETCS message transport delay becomes negligible compared to the resource allocation delay described in chapter 3.3.2.
The available bandwidth of EGPRS higher coding schemes can partly compensate the USF limitation of seven concurrent ETCS sessions per timeslot, by reducing i.e. the inactivity timer for the uplink. With that in mind the 5 bit range of the TFI can be more widely used to host more than seven ETCS sessions in one timeslot. This approach requires a case by case study and the support of EGPRS by the mobiles and the GSM-R network.

3.4 Requirements/Recommendations Temporary Block Flow

Number of requirement	**Description**	**Mandatory - M** **Optional – O** **Timer/Counter**
3.4.1	It is recommended to activate the uplink TBF establishment in one phase. (reference in [10])	O
3.4.2	It is recommended to set timer **T3168** to its minimum value: 500ms. This helps to decrease the duration of the uplink TBF establishment in case of TBF establishment failure. (reference in [10])	Recommendation: 500 milliseconds
3.4.3	To prevent the occurrence of abnormal TBF release in Uplink direction caused by transient radio failures, it is recommended to make use of a large value for the N3103 parameter. (reference in [10]) Please refer to the GSM-R network supplier documentation.	Recommendation: 8
3.4.4	The network shall support the feature “Delayed DL TBF”. (reference in [10])	M

Number of requirement	Description	Mandatory - M Optional – O Timer/Counter
3.4.5	Delayed DL-TBF setting – inactivity timer It is recommended to set inactivity timer for Delayed DL-TBF to value greater than the maximum time interval of two subsequent RBC→OBU messages. No generic 3GPP parameter! Refer to your network supplier documentation.	Recommendation: greater than the maximum time interval of two subsequent downlink application messages (RBC→OBU)
3.4.6	Downlink DL-TBF setting – N3105 To prevent the occurrence of abnormal TBF release during downlink TBF inactivity period caused by e.g. transient radio failure, it is recommended to make use of a large value for counter N3105 parameter that corresponds to a timeframe of ~3-5 seconds. (reference in [10])	~3-5seconds
3.4.7	The mobile(s) shall support the feature “extended UL TBF” as part of the GERAN feature package 1. (reference in [10])	M
3.4.8	The network shall support the feature “extended UL-TBF” (reference in [10])	M
3.4.9	It is not required to activate extended uplink TBF no data functionality as part of the extend UL-TBF feature. (reference in [10])	M
3.4.10	Extended UL-TBF setting It is recommended to set inactivity timer for extended UL-TBF greater than maximum time interval between two subsequent OBU→RBC messages. (reference in [10])	Recommendation: greater than the maximum time interval of two subsequent uplink application messages (OBU→RBC)
3.4.11	UL-TBF setting (reference in [10]) To prevent the occurrence of abnormal TBF release during uplink TBF inactivity period cause by e.g. transient radio failure for example), it is recommended to use a large counter number for the N3101 parameter, that corresponds to a timeframe of ~3 seconds.	~3seconds

Table 3-3 PS-mode - TBF handling requirements/recommendations

4 GPRS/EGPRS MOBILITY

4.1 General Aspects

GSM CS-mode has clear differentiation between a cell change known under the term idle mode, and a handover during an active connection (dedicated mode) with allocated radio resources.
In idle mode, the mobile carry out a cell reselection procedure which can lead as well to location update scenario. The mobile decides autonomously about the possible cell reselection in regard to the power level measurements of the serving and adjacent cells.
During an ongoing connection (dedicated mode), the mobile performs as well power level measurements of the serving and adjacent cells, but the change to the adjacent cell is commanded by the network, explicitly by the serving cell. The aforementioned principles works perfectly in CS-mode, but in GPRS following difficulties arise.

Due to the transparency of GPRS in the BSC (see chapter 2.1), the BSC cannot be used as GPRS radio resource function. Thus the BSC cannot be entrusted with the GPRS handover.
In consequence of active and inactive GPRS data transmission phases it is difficult to distinguish if a handover or cell reselection criterion is fulfilled. Such a distinction in GPRS makes no sense. Instead of having CS-mode idle/dedicated mode behaviour, GPRS defines the cell update scenario, which can be monitored either by the mobile or by the network.

4.1.1 Cell Update

Cell update is always performed between mobile and the network when the mobile carries out a cell reselection. Such a procedure would cause a heavy signalling load. Thus another method has been specified.

In GPRS **READY state** (see Figure 4-1), the mobile may send and receive data and every time the SGSN receives data from the particular mobile, the corresponding ready timer (T3314) is restarted in the mobiles as well as in the SGSN. While the mobile is in this state, cell updates procedures executed when the mobile reselect to another cell. In case the mobile changes the routing area during the process of cell reselection, a routing area update is performed instead of a cell update. Always in ready state the mobile is attached to the GPRS mobility management (GMM) [2] in the corresponding SGSN.
If the ready timer (MS or SGSN) expires, the MS will move to STANDBY state.

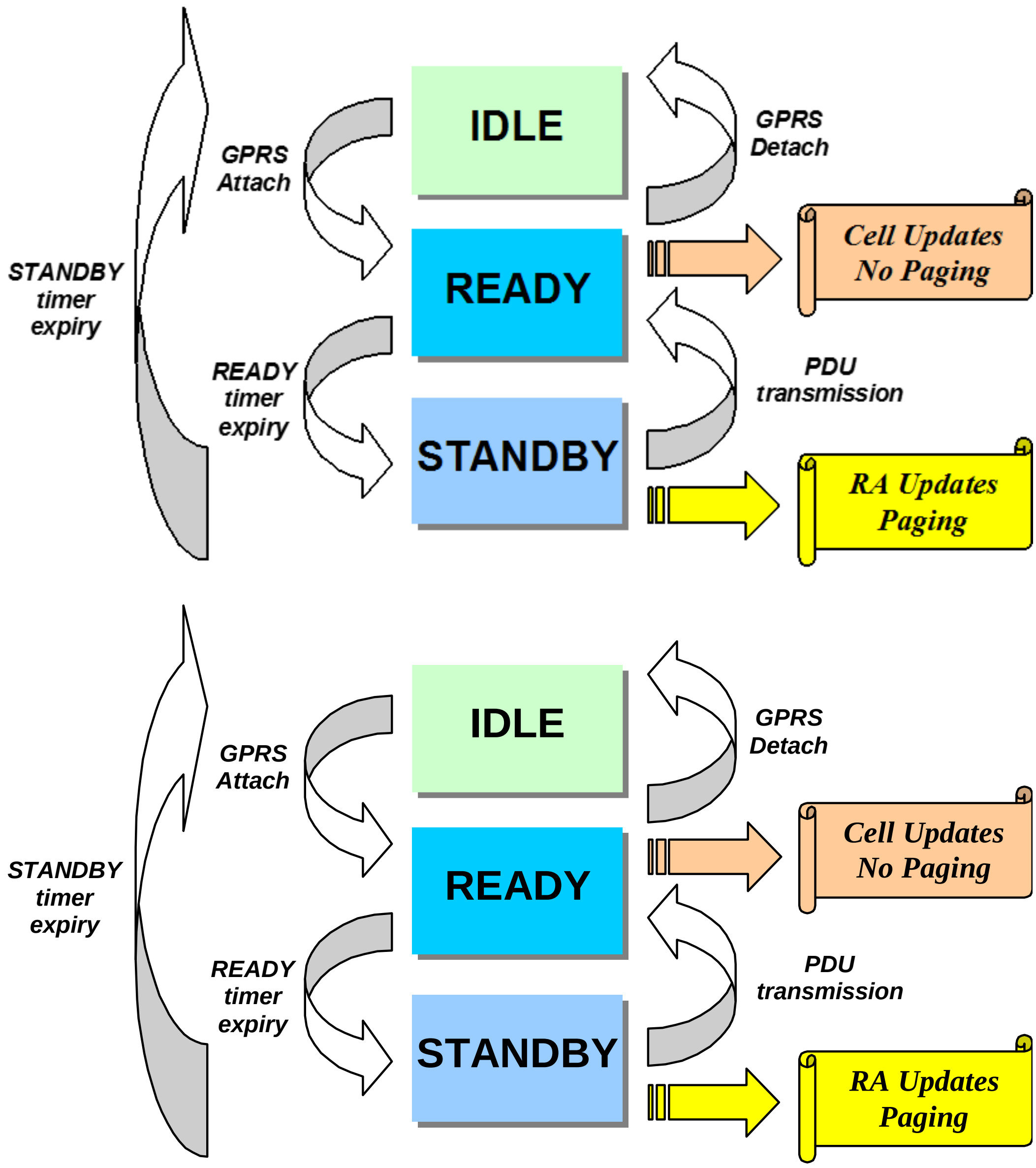

Figure 4-1 Mobile GMM state model

In GPRS **IDLE state,** the subscriber is not attached to the GMM. Data transmission to and from the MS as well as the paging of the subscriber is not possible. So, the GPRS MS is not reachable and a *GPRS Attach procedure* must be performed in order to allow data communication.

In GPRS **STANDBY state**, the subscriber is attached to the GMM. If data has to be sent to the subscriber, PS-paging procedure will be initiated by the SGSN.
When the MS enters a new RA, it shall inform the SGSN carrying out the GMM *Routing Area update* procedure. At this point, if the subscriber wants to request a data transfer, a PDP context must be activated before data transfer is possible. If the standby timer (MS or SGSN one) expires, the MM contexts both in MS and in SGSN shall be deleted and the MS returns to IDLE state.

Associated timers:
The MS GPRS mobility is managed at SGSN side. This management is associated with several SGSN timers.

The MS remains in the **GMM Ready state** during a period of time defined at SGSN side by the **ready Timer** T3314 [5].

On **ready Timer** expiry, the MS shall go through the **GMM Standby state**.

- In UL direction, the MS may send data and then, **GMM state** returns to **Ready,**
- In DL direction, to be able to receive data, the MS has to be PS paged by the SGSN.

Upon transition from **GMM Ready state** to **GMM Standby state**, the **Periodic Routing Area update timer function (Timer T3312)** [5] is started. The subscriber remains attached to GPRS MM and is known in accuracy of the Routing Area. The mobile performs locally the GPRS Routing Area update and GPRS cell selection and cell reselection.

Mobile Reachable Timer function monitors the periodic Routing Area (RA) update process in the SGSN. The associated timer shall be slightly longer than the periodic Routing Area update timer (**T3312)**

Upon expiry of **mobileReachableTimer**, several events are triggered:

- In Downlink direction, PS paging is internally forbidden by the SGSN
- SGSN shall start the **implicitDetachTimer** [5] parameter. When the **implicit DetachTimer** expires, the mobile is detached from the GPRS network and shall go to the **GMM Idle state**. As the **implicitDetachTimer** default value is equal to 0 min, this means that the mobile will be detached at **mobileReachableTimer** expiry. The mobile is not anymore attached to the GPRS MM and cannot send or receive any data.

When the mobile is in **GMM Standby state**, the mobile performs periodic routing area updates according to T3312 setting. Therefore, under normal conditions the **mobileReachableTimer** never expires, because the timer is restarted at each periodic successful periodic routing area update.

4.1.2 Cell Change

The conventional cell reselection (see in [16]) procedure allows the mobile to change between adjacent cells either in standby or ready state. In standby state the mobile cell reselection is carried out autonomously by the mobile- mobile controlled cell reselection, while in ready state cell reselection can be initiated either by the mobile or the network. At this point it can be concluded that a conventional cell reselection procedure is unsuitable for services that require a seamless cell change operation, because conventional cell reselection is performed autonomously by the mobile without any notification to the network. The mobile cannot request a random access to resume the data communication/TBF in the new serving cell until a defined minimum set of system information of the target cell has been correctly received. The resulting service interruption time that arises during the process of cell reselection is depending on how quickly the minimum set of system information can be acquired by the mobile. This process can take a few seconds, which makes the conventional cell reselection unsuitable for more delay-sensitive services, like the operation of ETCS Level 2 is.

To support these services in GPRS/EGPRS, some enhancements to the present conventional cell change algorithm were necessary. The NACC – Network Assisted Cell Change feature was introduced in 3GPP Release 4, which can reduce the service outage time for a mobile in packet transfer mode from a few seconds to less than one

second. To achieve a less service interruption the network assists the mobile during the cell change by the sending of adjacent cell system information together with the introduction of new procedures.
Basically, NACC [8], [10] introduced in 3GPP Release 4 to cover the intra-PCU cell reselection case (Figure 4-2). In order to support NACC as well for the inter-PCU case (Figure 4-2), the RAN Information Management (RIM) was introduced [18]. The aim of RIM in a context of NACC functionality is to support the interrogation of the necessary system information of cells managed by adjacent PCU (BSC) in order to provide this system information for the NACC supported cell change.

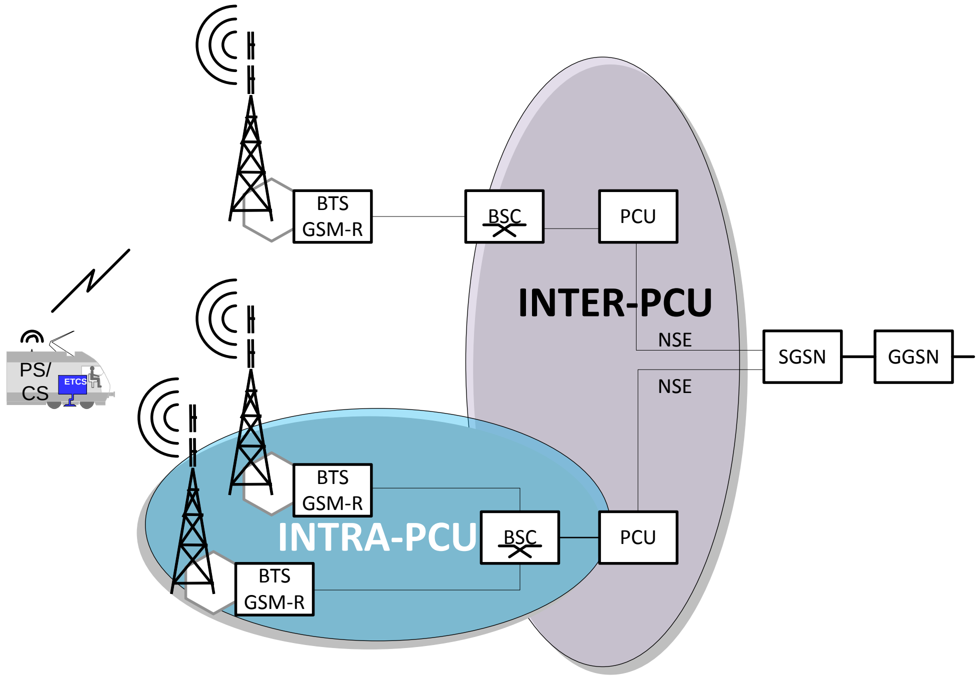

Figure 4-2 PS-mode - Intra/Inter PCU architecture schematic

The overall target of NACC is to minimise the data service interruption for all QoS traffic classes when a mobile reselect between GSM/GSM-R cells. NACC provide two independent mechanisms:

- Adjacent Cell System Information arrangement to assist the mobile with the necessary adjacent cell system information required for initial access after the cell change. The mobile may use this information when accessing the target cell without scanning the BCCH channel of the new cell. After the successful access to the new cell, the mobile asks for missing system information by using Packet SI status procedures.
- Secondly, the network may order the mobile to enter into the Cell Change Notification (CCN) mode before cell reselection. While the mobile is CCN mode, it notifies the network about fulfilment of reselection criterions and delays the execution of cell reselection that the network is able to respond with the adjacent cell information.

By providing system information of the target cell still on the dedicated link in the source cell, the service interruption time due to cell reselection can be significantly reduced. For the operation of the network assisted cell change (NACC) feature NETWORK_CONTROL_ORDER [16] NC0, mobile performs autonomous cell reselection, is required. Other NETWORK_CONTROL_ORDER modes like NC1 and NC2 are related to other network assisted/controlled cell change functionalities, which are not part of this document.

Note: In case of Inter Routing Area change, data service interruption may get even longer, because of the necessary routing are update procedure that suspends the data transfer completely.

Packet Forwarding (logical link procedures) after Cell Change

It has been already mentioned in this chapter, that the mobile carry out a cell change autonomously without any notification to the network except when it asks for adjacent cell information prior the cell reselection. During the process of cell change, the packet core network meanwhile continuous to forward downlink LLC data frames for the particular mobile to the known cell routing entity (BVCI) inside the corresponding PCU. It is obvious, that these downlink LLC frames cannot be delivered completely to the mobile while it was in the previous serving cell. Thus the undelivered downlink LLC frames either flushed or forwarded to the new cell routing entity (BVCI) inside the same PCU (intra-PCU) or a different PCU (inter-PCU) after reception of the cell update information including the new cell identification.

A flush of undelivered LLC frames can cause a retransmission of the entire (service) data unit (data packet), which needs to be ordered by higher layer end-to-end protocols. The consequence is obvious; a retransmission will add delay to the downlink data transfer. If undelivered LLC frames can be rerouted to the new serving cell, then the LLC frame delay can be reduced to the duration of the cell change and the time endurance of the TBF allocation in the new cell.

3GPP specification includes such a LLC frame rerouting/forwarding functionality and distinguishes between intra-PCU and an inter-PCU case.

In an intra-PCU case (see Figure 4-2), adjacent cells belong to one PCU, which is connected by the same (same) logical network service entity towards the relevant SGSN. The opposite scenario is called inter-PCU (see Figure 4-2), when adjacent cells are allocated and controlled by different PCU which are connected also by different network service entity (NSE) towards the SGSN. Latter case is only supported if the old cell indicates the support of “Inter-NSE rerouting”.

Note: The intra- and inter-PCU LLC frame forwarding scenarios require always that the cells are belonging to the same routing area. If cells are belonging to different routing areas, undelivered LLC frames assigned to the old cell are deleted.

The impact of cell change to the duration of data service interruption is depending on the chosen GSM-R coverage scenario. Chapter 2.7 introduced the potential GSM-R radio coverage scenarios in the context of availability and maintainability. These scenarios may require specific NACC and LLC frame forwarding feature support. Table 4-1 outlines NACC and LLC frame feature requirements in correspondance to the GSM-R coverage scenarios.

GSM-R track coverage scenario	**NACC (Intra PCU)** M- Mandatory O- Optional NA- not applicable	**NACC (Inter PCU including RIM)** M- Mandatory O- Optional NA- not applicable	**LLC forwarding Intra-PCU**	**LLC forwarding Inter-PCU**
Single Radio Layer Coverage - limited adjacent cell overlapping (see chapter 2.7.2)	**M**	**NA**	**M**	**NA**
Single Radio Layer Coverage – extended (~50%) adjacent cell overlapping Intra PCU (BSC) case (see chapter 2.7.3)	**M**	**NA**	**M**	**NA**
Single Radio Layer Coverage – extended (~50%) adjacent cell overlapping Inter PCU (BSC) case (see chapter 2.7.3)	**O**	**M**	**M**	**O**
Dual Radio Layer Coverage- no layer offset (see chapter 2.7.4)	**M**	**O**	**M**	**O**
Dual Radio Layer Coverage - with layer offset (see chapter 2.7.5)	**M**	**O**	**M**	**O**

Table 4-1 PS-mode – NACC versus GSM-R coverage scenario

Note: Table 4-1 *presumes that the cells as part of the GSM-R track coverage are belonging to one routing area*!

4.1.3 Cell Reselection Criterions

As discussed in the previous chapters, cell reselection process is controlled autonomously by the mobile (conventional case) or can be assisted by the network (network case). The mobile constantly measures the received power of the serving and surrounding cells in conventional and network assisted case to be able to compute path loss criterion C1 and the cell reselection criterion C2 [16]. Received power measurements are applicable whether the mobile is in packet transfer mode or not.

The CELL_RESELECT_HYSTERESIS [16] parameter can prevent frequent cell reselection between GSM cells belonging to different location areas while the mobile is idle.

As aforementioned GPRS/EGPRS makes use as well of the conventional cell reselection procedure taking into account C1 and C2 formulas and in addition CELL_RESELECT_HYSTERESIS parameter is used to compute C2 criterion as follow:

C2 (neighbour) > C2 (serving) + CELL_RESELECT_HYSTERESIS (dB)

So, **CELL_RESELECT_HYSTERESIS** parameter adds a margin (dB value) to advantage the serving cell to prevent frequent cell reselection between adjacent cells, but this parameter is only taken into account while the mobile is in READY state (see chapter 4.1.1.).
Cell reselection mechanism also has to deal with various speed profiles of the active users (mobiles) that can produce different behaviour pattern. The TEMPORARY_OFFSET parameter as part of C2 formula can be used to prevent undesired cell reselection to a cell while the train is at high speed condition and e.g. local constructions teams may use voice group calls for communication purposes.

The purpose of TEMPORAY OFFSET is to apply a negative offset to C2 criterion to the undesired adjacent cell for the duration of the PENALTY_TIME. If the PENALTY_TIME expires, TEMPORARY_OFFSET become "0" in C2 criterion computation.

A possible use of TEMPORARY_OFFSET is given in the following example.
Trains which are passing the station without stop must stay on the **purple** layer and shall not select the "**station** cell". When applying a sufficient TEMPORARY_OFFSET to the station cell for the duration of the PENALTY_TIME, which can vary between 20 and 620 seconds at 20 seconds steps, the (high speed) train remains on the purple layer (see Figure 4-3). The range of PENALTY_TIME also allows different speed levels to prevent cell reselection to the station cell.

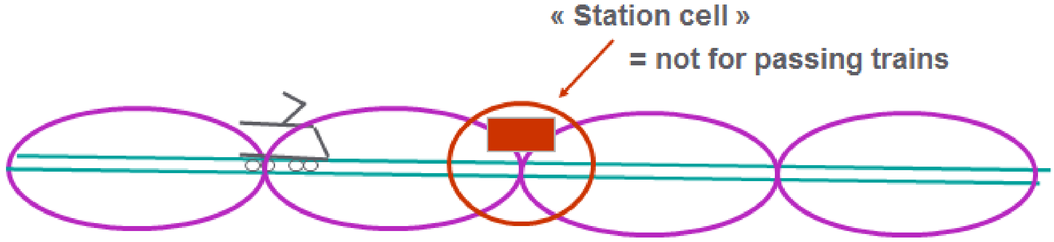

Figure 4-3 PS-mode - Temporary Offset impact

4.1.4 Requirements/Recommendation GPRS Mobility

Number of requirement	**Description**	**Mandatory - M Optional – O Timer/Counter**
4.1.4.1	To reduce the duration of service interruption due to cell reselection while the mobile is in packet transfer mode the use of Network Assisted Cell Change (NACC) is required in the network.	M
4.1.4.2	NACC feature shall be supported by the mobile.	M
4.1.4.3	NACC requires NETWORK_CONTROL_ORDER operation of NC0 – mobile autonomous cell reselection.	M
4.1.4.4	To guarantee the performance of ETCS operation in PS-mode considering different track coverage scenarios in chapter 2.7, some enhancements of NACC shall be taken into account. Table 4-1 contains the link between coverage scenarios and the required/recommended NACC feature (enhancements).	M
4.1.4.5	Downlink LLC frame rerouting shall be supported by the GSM-R GPRS/EGPRS network.	M
4.1.4.6	Specific coverage scenarios require some LLC rerouting enhancements to guarantee the necessary performance of ETCS operation. Table 4-1 contains the link between coverage scenarios and the required/recommended LLC features.	M

Table 4-2 PS-mode - GPRS mobility requirements/recommendations

5 QUALITY OF SERVICE

5.1 General Aspects

Quality of Service can be summarised as an effect of service performance which determines the degree of satisfaction of a service user. QoS management in mobile networks is based on the fact that the user expectations vary a lot depending on the application type and that different performance levels are required by the users of different services. Basic criterions for the service differentiation are reliability (transmission link erroneousness) and throughput/delay requirements. Services having strict delay and less reliability requirements are regarded to real time class, while services characterised by high reliability and relaxed delay requirements are categorised as non-real time services. Real time traffic classes can ask for guaranteed bitrate to ensure required service performance while non-real time traffic classes cannot.

The operation of the ETCS application has strict delay and high reliability requirements which looks apparently contradicting to the aforementioned definition of real and non-real time service classification, but the QoS specification in subset-093 PS-mode amendment requires such a classification.

QoS management includes measures to negotiate the quality to be provided, to prioritize particular connections and to guarantee certain performance of higher priority data flows at the expense of lower priority data flows.

However, QoS mechanisms allow infrastructure operators to realise the operation of ETCS in PS-mode and other application at the same time, but should be not considered as a remedy for lack of network capacity.

In the context of end-to end QoS (see in [4]); the network may be regarded as the sub-system that provides data connectivity between the mobile terminal and the external IP-based network. The end-to-end transmission path between mobile terminal and RBC consists of three segments (see Figure 5-1):

- Radio Access Network
- Packet Core Network
- External IP based Packet Data Network

Different QoS mechanisms are used along the whole chain and it is necessary to coordinate the QoS management between all domains. For example in the external IP network can be realised by using Differentiated Services etc. which can be applied as well in the Packet Core Network. In the GPRS/EGPRS network, the GGSN may utilise QoS attributes to configure the differentiated edge functionality to provide the interworking between the GPRS/EGPRS and the external IP based data network.

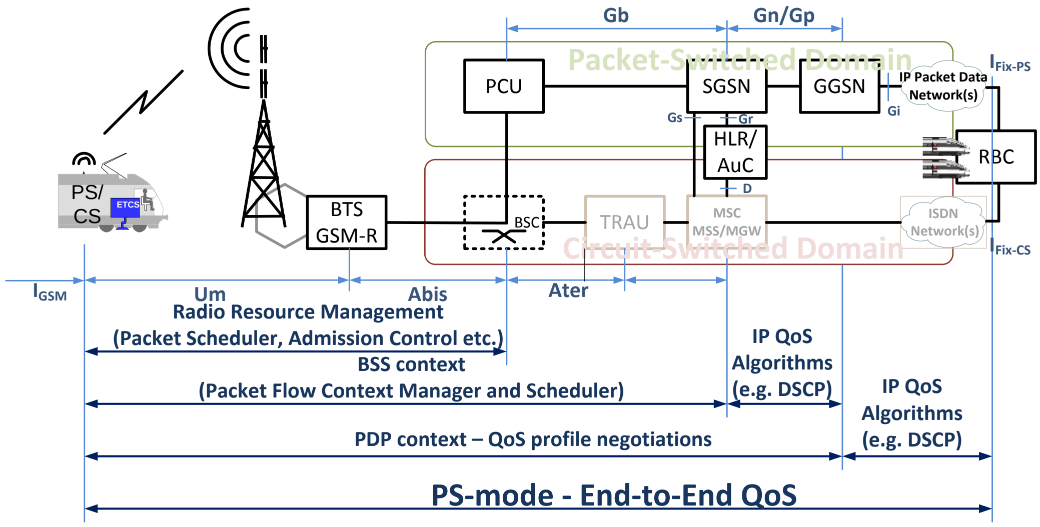

Figure 5-1 PS-mode - End-to-End Quality of Service

The concept of GPRS/EGPRS QoS architecture was standardised in 3GPP Release 97/98. Together with the PDP context the mobile is visible in the external packet data network and allows a QoS profile for a data transfer session to be negotiated between mobile and the network.

A PDP context is the essence of service differentiation based on the requested QoS parameter inside the PDP context. The subscriber subscription may contain one or several APNs which are linked to a QoS profile. This contains information about reliability requirements (RLC acknowledged/unacknowledged operation see chapter 3.2), the traffic class etc. If the subscriber requested QoS attributes exceeds the upper limits defined in the HLR profile, the values from the HLR subscription are used. A mobile that requires streaming or conversational QoS, then the mobile shall at least explicitly request the traffic class and should explicitly request the guaranteed bit rate and the maximum bit rate [2].
If the negotiated QoS parameters are unacceptable the mobile may terminate the session by deactivating the PDP context.
3GPP Release 97/98 QoS architecture supports only non-real time services, while 3GPP Release 99 [3] introduced real time QoS real time support. The mechanism that has been specified in Release 99 allows the SGSN to check with associated BSS whether the requested QoS can be provided by the radio access network before the context is admitted to the requesting mobile. After resource availability verification, the BSS creates the Packet Flow Context (PFC) for the PDP Context. PFC parameters are negotiated between the SGSN and the associated BSS based on the PDP Context QoS attributes.

The QoS concept in 3GPP Release 99 introduced a new set of QoS parameters. Four new traffic classes have been introduced to differentiate between the various service characteristics.
Conversational traffic class is meant for services sensitive to delay and delay variations while streaming class can compensate delay variations with the use of buffering mechanisms. Interactive class is meant for applications that are sensitive to delay but less sensitive to delay variations. The reliability requirements in interactive and background class are higher than in conversational and streaming. The ranking between the four traffic classes is obvious, background data flows have the lowest priority and will have less resources assigned than conversational or streaming or interactive. Not all

attributes are applicable to all traffic classes. Traffic handling priority [3] is only applicable to interactive traffic flows while the guaranteed bit rate attribute is only applicable to streaming and conversational data flows.

5.2 ETCS QoS Profile subscription

Already today, several Railway undertakings or infrastructure managers use GPRS/EGPRS to carry different operational services. These need to be maintained when ETCS over GPRS/EGPRS is introduced. The transport of the ETCS application is however delay sensitive and therefore requires higher priority.
Therefore it is strongly recommended to provide the HLR QoS profile to be used for ETCS as stated below in Table 5-1. The values in this table are sufficient to meet the most demanding requirements that the ETCS application could impose and to meet the performance requirements of the ETCS application. Other applications should be provided with lower priority QoS profiles. It is then a network intrinsic decision how the QoS requirements for ETCS are implemented: for example the local network (SGSN or GGSN) may downgrade to interactive traffic class while still maintaining highest traffic handling priority (THP=1), or to optimize network capacity by lowering guaranteed or maximum bit rates to reflect local ETCS traffic requirements.

3GPP ETCS QoS profile parameters(s) [3], [35]	**Maximum QoS parameter settings**
SDU error ratio	10^{-4}
Residual bit error ratio	10^{-5}
Delivery of erroneous SDUs	No
Traffic class	Streaming
Traffic handling priority (THP)	1 (1)
Transfer delay (milliseconds) (2)	N/A
Allocation/Retention priority (ARP)	1
Delivery order	Yes
Maximum SDU size [octets]	1500
Maximum bitrate [kbps]	64
Guaranteed bit rate [kbps] applicable to Uplink and Downlink	4 (3)

Table 5-1 PS-Mode - ETCS QoS Profile as registered Profile

Note 1: Traffic Handling Priority is only applicable in interactive traffic class, if streaming traffic class cannot be allocated by the network (degraded condition).
Note 2: Currently not used in GPRS/EGPRS. It is for future ETCS radio access technologies which provide a lower air interface Transmission Time Interval (TTI) than GPRS/EGPRS.
Note 3: Chosen GBR value is according to the common ETCS traffic (message sequence) model and reflects the upper limit. Lower GBR values can be applied by the packet core network entities.

5.3 BSS QoS Management

BSS Packet Flow Context (PFC) was specified to improve QoS handling in GSM-GPRS/EGPRS networks. The mechanism allows the exchange of radio bearer QoS information between SGSN and PCU (BSS) already during PDP context activation phase. The SGSN defines the QoS requirements for the given Packet Flow Context and initiates BSS PFC setup procedure (see in [2]). A Packet Flow Identifier (PFI) will be assigned to the PFC according to the QoS parameters (see Figure 5-2). If the available resources in the BSS satisfy the QoS requirements, the PCU will accept the PFC request.

If the available BSS resources are insufficient to meet the QoS requirements, the BSS may restrict QoS parameter values. The agreed QoS parameters are sent by the applicable SGSN to the mobile within the PDP context accept.
A PFC may be modified during its lifetime. For example if the agreed QoS parameters can no longer be sustained by the BSS.

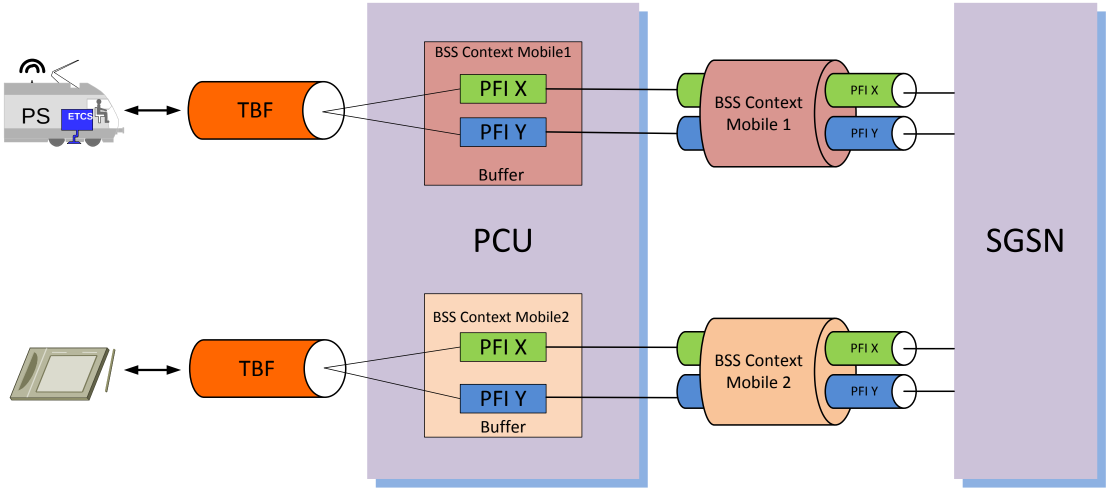

Figure 5-2 PS-mode - BSS context principle

A BSS packet flow timer indicates the maximum time that the BSS may store the BSS packet flow context. The BSS packet flow timer shall not exceed the value of the READY timer (see chapter 4.1.1) for this MS. The BSS packet flow timer is started when the BSS packet flow context is stored in the BSS and when an LLC frame is received from the MS. When the BSS packet flow timer expires, the BSS shall delete the BSS packet flow context. If the BSS receives a new request of uplink or downlink user data after READY timer expired, the BSS establish again a BSS context by asking the SGSN. Until the BSS receives the BSS packet flow context, the BSS will handle uplink and downlink transfers according to a default BSS QoS profile.
The BSS can at any time request modification of the contents of an existing packet flow context, e.g. due to a change in the resource availability at the BSS.

A PFC can be assigned to one or more application using the same PDP context. The Packet Flow Identifier is used then to differentiate between the applications (see Figure 5-2).

In case of cell reselection, an active BSS context of a mobile will be transferred to the new cell taking into account the negotiated QoS parameters. The BSS context is also transferred when the available resources cannot be accepted in the new cell. QoS parameters are then modified based on the available resources in the new cell. The BSS may resume the transfer of downlink packets before the BSS context modification is completed.

Packet flow management using PFC ensures the right treatment of the ETCS application while other applications are in operation at the same time. GPRS/EGPRS narrowband characteristics which depend on the resource quantity (timeslot) and the used channel coding, the BSS can be the bottleneck in the overall transport chain. From system point view PFC is strongly recommended when the ETCS application has to share same GSM-R radio resources at the same time.

5.4 Packet Core and external IP network QoS Management

In IP Networks, it is also necessary to perform resource management to ensure that resources required for a service are available. Where the resources for the IP Bearer Service to be managed are not owned by the GPRS/EGPRS network, the resource management of those resources need to be performed through an interaction between the GPRS/EGPRS network and that external network.

Whenever resources are required to provide QoS but these are not owned or controlled by the GPRS/EGPRS network, it is necessary to interwork with the external network that controls those resources. Interworking (see in [4]) can be realised by packet marking or labelling along the flow path using e.g. DiffServ or MPLS.

DiffServ networks classify packets into one of a small number of aggregated flows or "classes", based on the DiffServ code point (DSCP) in the packet's IP header. Interaction between GPRS/EGPRS bearer services and IP bearer services shall only occur at the translation function in the GGSN which is called **DiffServ Edge Function**.

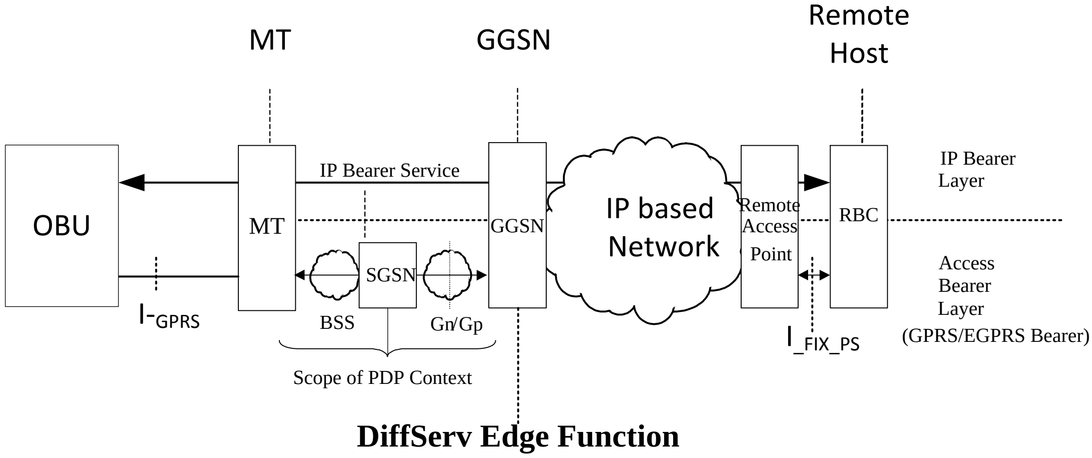

Figure 5-3 PS-mode - QoS mapping between GPRS and IP based networks

At this point it can be concluded that the GGSN shall support DiffServ edge functionality. There are a number of other mechanisms provided to support inter-operator interworking, some of which are given below.

- **Signalling along the flow path:** Resource requirements are explicitly requested and either granted or rejected through the exchange of signalling messages between network elements along the path of the IP packet flow.

- **Interaction between network management entities:** Traffic resource requirements need to be explicitly negotiated and provisioned through network management entities. The results of this exchange are then enforced in the border nodes separating DiffServ administrative domains.

- **Service Level Agreements enforced by the border routers between networks:** Traffic resources are allocated along the path based on agreements between the network operators. The border routers along the path flow are provisioned with the characteristics of the aggregated traffic that is allowed to flow between systems.

Note: This listing is not exhaustive. Other options are possible.

The DiffServ function shall be aligned on the basis of PDP Context QoS parameters that a user data packet between OBU and RBC contains QoS marking.

5.5 Roaming and QoS settings

ETCS operations shall be based on the unambiguous APN Network Identifier "ETCS" using always the HLR QoS profile in Table 5-1. If the train is abroad always it shall make use of the "ETCS" APN but the local QoS settings may be different. Therefore the QoS may be overruled by the visited GPRS network during the PDP QoS parameter negotiation phase with the GGSN. The reason to do so is a careful handling with scarce BSS transmission resources if less guaranteed bit rate is required than subscribed. The GPRS Network operator may then configure and apply the compatible QoS profile during PDP context activation phase.

5.6 Mobile terminated traffic

GPRS allows the operation of different mobile classes (see chapter 2.5). The use of a class B mobile does not allow a simultaneous operation of CS- and PS-mode services while class a mobile does. A class B mobile suspends GPRS/EGPRS based data exchange while a CS-mode call is established. Also the transmission and reception of a SMS message can suspend the GPRS/EGPRS data transmission.

This behaviour affects the operation of ETCS using GPRS/EGPRS radio access bearer service. Any incoming CS-mode call (voice, data, and fax) suspends the GPRS/EGPRS based data exchange for the duration of the CS-mode call. Also the reception of a SMS that is delivered via the CS-domain (MSC or MSS / VLR) can suspend the GPRS/EGPRS based data transmission while the delivery using the PS-domain (SGSN) is not affected. For the use of a class B mobile some preventive measures shall be taken into account to suppress the reception of incoming calls and Mobile Terminated Short Message Service (SMS).

5.7 Requirements QoS management

Number of requirement	**Description**	**Mandatory - M Optional – O**
5.7.1	ETCS mobile subscriber QoS profile located in the HLR shall be according to Table 5-1.	M
5.7.2	If ETCS and other applications operated simultaneously, the PS-mode QoS profile for the non-ETCS applications shall be subscribed having less traffic treatment preferences in the network. The upper QoS profile limit for non ETCS applications shall not exceed "Interactive" traffic class" including traffic handling priority "2".	M
5.7.3	The ETCS mobile shall support PFC feature.	M
5.7.4	If the infrastructure provider operates ETCS and other applications at the same time, the feature Packet Flow Context (PFC) – BSS context shall be used to differentiate between traffic types.	M
5.7.5	In any other cases the operation of PFC is strongly recommended.	O
5.7.6	The GPRS network operator shall be able to override the subscribed QoS profile during PDP context negotiation to adapt to the local or	M

Number of requirement	Description	Mandatory - M Optional – O
	visited network requirements.	
5.7.7	GGSN should provide at least the DiffServ Edge Function	O
5.7.8	The fixed IP network should provide QoS performance to guarantee the mapping between Fixed IP network and mobile network. DSCP (IETF RFC 2474) shall be used to guarantee the interoperability between the network types.	M
5.7.9	For an ETCS subscription that is supporting CS- & PS Mode and mobile class B is used, the reception of incoming calls shall be prevented by barring of all incoming calls for the bearer services listed as follows: BS24: Asynchronous data 2.4 kbps BS25: Asynchronous data 4.8 kbps BS26: Asynchronous data 9.6 kbps	M
5.7.10	For an ETCS subscription that is supporting CS- & PS-mode and mobile class B is used, the reception of incoming (mobile terminated-T21) SMS, if the delivery of the message passes through the CS-domain (VLR), shall be prevented during the operation of ETCS.	M

Table 5-2 PS-mode - QoS requirements

6 POWER CONTROL [16]

6.1 General Aspects

RF power control is employed to minimize the transmit power required by the mobile or BSS whilst maintaining the quality of the radio links. By minimizing the transmit power levels, interference to co channel users is reduced.
The power level to be employed by the BTS or the mobile is a matter of Power Control which is based on the measurement results reported by the mobile/BTS and various parameters set for each cell. The exact strategy is to be determined by the network operator.
Power control algorithm and the related parameters are different in GPRS/EGPRS compared to the GSM CS-mode. In PS-mode, Power Control is more challenging due to the burstiness nature of packet data.

6.2 Uplink Power Control

The main purpose of UL power control is to save mobile battery consumption, but this aspect is insignificant to railways because of the permanent mobile power supply.
Another non-negligible aspect is the reduction of interferences.

The mobile follows in Uplink a flexible power control algorithm that is used in open and closed loop power control. The mobile shall calculate the RF output power value, P_{CH}, to be used on each individual uplink PDCH assigned to the MS:

$P_{CH} = \min((\Gamma_0 - \Gamma_{CH} - \alpha * (C + 48), PMAX)$

Γ_{CH} is a mobile and channel specific power control parameter, which is sent to the mobile in any resource assigning message. Further, the network can, at any time during a packet transfer, send new Γ_{CH} values to the mobile on the downlink PACCH; (BSS parameter having a range between 0 and 62dB)

Γ_0 is a frequency band dependent constant.
39dBm for GSM 400, GSM 700, GSM 850 and GSM900

$\alpha \in [0, 1]$ is a system parameter. Broadcast on PBCCH or optionally sent to the mobile in an RLC control message. Mobile and channel specific values can be sent to the mobile together with Γ_{CH}.

C is the normalised received signal level at the mobile for each radio block.
Packet Idle and Packet Transfer Mode are computed differently
(see 45.008[16] chapter 10. The forgetting factor b is part of the C value computation for Packet Idle respective Packet Transfer Mode. For further information please refer to the applicable supplier documentation.

PMAX is the maximum allowed output power in the serving cell.

The parameter Γ_{CH} determines the minimum mobile output power while α determines how much an alteration in the received power level may change mobile output power.
When the mobile receives new Γ_{CH} or α values, the MS shall use the new value to update P_{CH} according to equation in this chapter.
The mobile may round the calculated output power to the nearest nominal output power value (see in [16]) although a higher resolution is preferred. The output power actually transmitted by the MS shall fulfil the absolute accuracy as specified in 45.005. In

addition, the transmitted power is a monotonic function of the calculated output power and any change of 2 dB in the calculated value corresponds to a change of 2 ± 1.5 dB in the transmitted value.
The MS shall use the same output power on all four bursts within one radio block.

6.3 Downlink Power/Power Control

This chapter just informs about the use of Downlink Power while GPRS/EGPRS is used as bearer service for ETCS.

For the downlink, the power control is performed in the BTS. 3GPP does not specify any specific algorithms, but the information about the downlink performance is needed. For that purpose the mobiles have to transfer Channel Quality Reports to the BTS.
Downlink power control can only be used when the serving BCCH and the used packet data traffic channel frequencies are in the same frequency band which is the case for GSM-R.
Packet data traffic channel that carries user data, downlink power control can be used. Then the BTS uses the same output power on all four bursts within one radio block except for bursts transmitted on the BCCH carrier. To control the output power of the downlink transmission, the BTS has to process Channel Quality Reports sent by the mobile.
Basically, the BCCH is transmitted without variation of RF level in case all timeslots on BCCH carrier are GMSK modulated and else in case of different modulated timeslots with minimum variation of RF level as specified in 3GPP 45.008 [16].

For timeslots on the BCCH carrier which are transmitted with modulations other than GMSK, the output power (as defined in 3GPP TS 45.005) may be lower than the output power used for GMSK modulated timeslots. In the case of EGPRS that uses 8-PSK, the output power is decreased at 4dB.

If downlink power control is used, the BTS shall limit its output power on blocks addressed to a particular mobile i.e. USF or RLC blocks to levels between (BCCH level – P0dB) and (BCCH level – P0dB – 10dB). The output power must be sufficient for the mobile for which the RLC block is intended as well as the mobiles for which the USF is intended (see in [10]).

Note: P0 is defined as a power reduction relative to BCCH

If packet data traffic channel that do not use downlink power control (as indicated in the assignment message), the BTS shall use a constant output power with the exception that it is not required to transmit on every block.

7 DOMAIN NAME SERVICES

7.1 General Aspects

Domain Name Services are used to resolve logical network node names into IP addresses or vice a versa. ETCS in PS-mode using GPRS/EGPRS requires the resolution of the applicable APN [2] and the RBC identification.

DNS for IPv4 shall make use of an A resource record to define IPv4 host address corresponding to fully qualified name of the host as defined in RFC 1035 [25] while a AAAA resource record is used to define IPv6 host address corresponding to fully qualified name of the host as defined in IETF RFC 3596.

In DNS either A or AAAA host names represent a node name, but rather a set of "equivalent" interfaces. A node may need to have more than one host name for the simple reason that it can have different interfaces for different purposes.

7.2 GPRS Name Service - GNS

GPRS Name Services are required to resolve the APN and routing area identification into the applicable GGSN or SGSN node (IP) address [2]. The GNS function is part of the Packet Core network and is located at Gn-interface (see Figure 2-1).

APN encoding shall follow the Name Syntax defined in RFC 2181 [27], RFC 1035 [25] and RFC 1123 [26]. An APN can consist of one or more labels. Each label is coded as a one octet length field followed by that number of octets coded as 8 bit ASCII characters. The labels shall consist only of the alphabetic characters (A-Z and a-z), digits (0-9) and the hyphen (-). Following the RFC labels shall begin and end with either an alphabetic character or a digit. The case of alphabetic characters is not significant.

The APN structure consists of two parts [1]:

> **APN Network Identifier (NI)**: Defines to which external packet data network the GGSN is connected. This part of the APN is mandatory. An APN corresponds to a FQDN of a GGSN. The Network Identifier can consist of 3 or more labels and starting with a Reserved Service Label, or an APN Network Identifier consisting of a Reserved Service Label alone.
>
> For ETCS purposes a unique APN-NI has been agreed across Europe called ***"etcs"***.
>
> **APN Operator Identifier (OI)**: Defines in which Land Mobile Network the GPRS backbone GGSN is located. This part of the APN is optional.
> The APN Operator Identifier is composed of three labels. The last label (or domain) shall be "gprs". The first and second labels together shall uniquely identify the EIRENE (GPRS) Land Mobile Network.
> A default APN Operator Identifier is derived from the IMSI as follows:
>
> **"mnc<MNC>.mcc<MCC>.gprs"**
>
> <MNC> and <MCC> are derived from the components of the IMSI.
>
> In the roaming case, if the GGSN from the Visiting EIRENE network is to be selected, the APN Operator Identifier for the mobile is constructed from the serving EIRENE Land Mobile Network ID. In this case, the APN-OI replacement field, if received, shall be ignored.

In order to guarantee GNS translation, the <MNC> and <MCC> coding used in the "mnc<MNC>.mcc<MCC>.gprs" format of the APN OI shall be:

<MNC> = 3 digits
<MCC> = 3 digits

Note: The configuration of the A resource records for GNS may depend on the network supplier implementation. Please refer to applicable network supplier documentation.

7.3 Domain Name Service for ETCS

The Domain Name Service for ETCS is responsible to resolve RBC identification (see subset-026) into one IPv4 address. An RBC identification is part of the applicable FQDN to be used for ETCS purposes and the encoding of any identifier used as part of a Fully Qualified Domain Name (FQDN) shall follow the Name Syntax defined in RFC 2181 [27], RFC 1035 [25] and RFC 1123 [26]. The RBC FQDN consists of one or more labels and each label is coded as a one octet length field followed by that number of octets coded as 8 bit ASCII characters.
For the purpose of presentation, identifiers are usually displayed as a string in which the labels are separated by dots (e.g. "Label1.Label2.Label3").

The RBC FQDN is composed of three labels as the last label (or domain) shall be "etcs". The first and second labels together shall uniquely identify the RBC identity.
Then a FQDN to be used to uniquely identify an RBC shall comply with the format (M):

{“Ty<ETCS-ID Type>.id<unique ETCS-ID>.etcs”}

ETCS ID Type shall be according to subset-037 [33]

Unique ETCS ID shall be according to subset-026 [32]

The ETCS Name Service is located beyond the Gi-interface (see reference network architecture in Figure 2-1) and due to its high relevance to establish the ETCS service certain availability ETCS Name Service need to be taken into account. Only one ETCS Name Service IPv4 address shall be provided to the OBU. For that reason, the necessary ETCS Name Service IP layer redundancy shall be established in the network.

In order to comply with the ETCS over GPRS principles, ETCS DNS shall make use of IPv4 addressing scheme.

According to 3GPP specification, an A resource record shall be used to define the IPv4 host address that is corresponding to FQDN of the host (RBC) [1]. The configuration of the resource records for ETCS DNS purpose depends on the network supplier implementation. Please refer to applicable network supplier documentation.

7.4 Requirements Domain Name Service(s)

Number of requirement	Description	Mandatory - M Optional – O
7.4.1	GPRS Name Service need to be established to be able to resolve an APN into the applicable GGSN IP addresses (es).	M
7.4.2	GPRS Name Service needs to be established to be able to resolve a routing area into the applicable SGSN IP address (es).	M

Number of requirement	**Description**	**Mandatory - M Optional – O**
7.4.3	Each GPRS infrastructure operator has to maintain its own zone that is composed of the APN - Operator Identifier. **mnc<MNC>.mcc<MCC>.gprs.**	M
7.4.4	For ETCS purposes, APN-NI "**etcs**" shall be used and configured in the applicable GNS function.	M
7.4.5	While the train is abroad and has to use the visiting GGSN to get secured by ETCS, the APN Operator Identifier for the mobile shall be constructed from the serving EIRENE Land Mobile Network ID.	M
7.4.6	A Domain Name Service function for ETCS purposes (ETCS –DNS) shall be provided as part of the packet data network behind the Gi-interface (see Figure 2-1)	M
7.4.7	ETCS-DNS availability is mission critical to establish the ETCS Service setup. Thus, a certain availability of the ETCS-DNS should be taken into account.	O
7.4.8	Only one ETCS-DNS IP address shall be returned to the OBU.	M
7.4.9	The ETCS-DNS IP address shall be of the IPv4 format.	M
7.4.10	The ETCS DNS shall make use of an A resource record to be able to configure the IPv4 RBC IP address (es)**.**	M
7.4.11	To prevent unnecessary ETCS DNS signalling, the total live time (time to live) of an RBC IP address, returned to the OBU, should be according to the ETCS service session live time within a RBC area.	O
7.4.12	An RBC FQDN shall be of the format: **{"Ty<ETCS-ID Type>.id<unique ETCS-ID>.etcs"}.** ETCS ID Type according to subset-037 [33] ETCS ID according to subset-026 [32]	M

Table 7-1 PS-Mode - Requirements Domain Name Service

8 MISCELLANEOUS

8.1 General Aspects

The following chapter covers additional GPRS/EGPRS system aspects, which have informational character. If specific network settings are necessary, please consult the specific network supplier system documentation and the references indicated in the relevant chapters.

8.2 GPRS/EGPRS interaction with eMLPP

The eMLPP feature works independently from the fact that there is GPRS/EGPRS bearer access service activated on the cell. Pre-emption still applies on the same criterions:

- Pre-emption Vulnerability Indicator (PVI)
- Pre-emption Capability Indicator (PCI)
- Priority level given by the MSC.

3GPP does not explicitly specify how to manage the priority between CS-mode and PS-mode resources. With eMLPP one CS-mode call can be pre-empted by another CS-mode call, while the priority between different PDP contexts can be managed by the feature Packet Flow Context (see chapter 5).

8.3 Session Management

Session Management is in charge of PDP context activation and deactivation. A PDP context is used for routing purposes inside the GPRS/EGPDS network.
A GPRS subscription can contain one or more PDP addresses (IP address). Each PDP (IP) address is described by an individual PDP context in the mobile, SGSN and GGSN. The PDP state indicates whether the PDP address is activated for data transfer or not. All PDP contexts of a subscriber are associated with the same MM context.

3GPP specifies [2] two possible PDP states, **INACTIVE** and **ACTIVE**:

The **INACTIVE state** characterizes the data service for a certain PDP address of the subscriber as not activated. So, no data can be transferred. The mobile moves from INACTIVE to ACTIVE state by initiating the PDP context activation [5], [7].

In **ACTIVE State**, the PDP context for the PDP address in use is activated in the mobile, SGSN and GGSN. The PDP state ACTIVE is permitted only when the GMM state of the subscriber is STANDBY or READY (see chapter 4). An ACTIVE PDP context for a mobile is moved to INACTIVE state when the PPD context deactivation procedure is initiated. All active PDP contexts of a mobile are moved to INACTIVE when the GMM state changes to IDLE. If a PDP context is deactivated by error, all data are flushed and the IP address becomes available to another user.

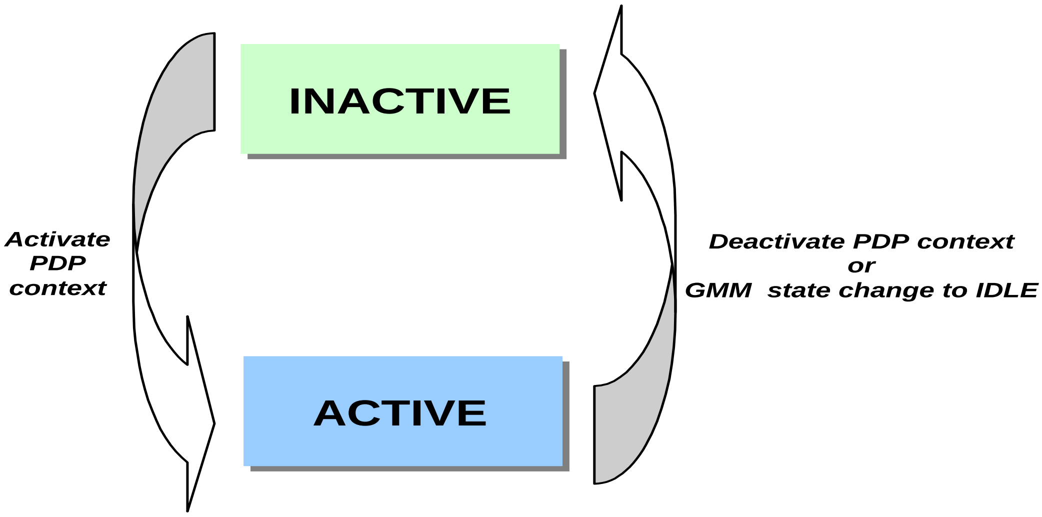

Figure 8-1 PS-mode - Functional PDP state model

8.4 Location Area and Routing Area design

Chapter 4 elaborated about the different states while the mobile is attached to the GPRS mobility management. When the mobile has an ongoing PS-mode session using GPRS/EGPRS, it has to perform location area or routing area updates. The on-going data transfer get suspended during several seconds of the update procedure to allow the mobile to inform the GSM-R circuit switched and packet switched core network about the new location/routing area it is entering. ETCS messages are delayed during the duration of the location/routing update procedure.
To secure a level of transfer delay performance for the ETCS application it is recommended to limit the number of location/routing areas along a track during the radio design.
A location/routing area size (number of cell) is dimensioned according to the estimated/required amount of CS and PS paging commands. The number of the possible paging commands per second depends on the channel combination which has been described in chapter 2.9.

The number of location/routing areas within a network should be limited and designed with great care, as significant delays due to RA updates would require for example the ETCS application and the chosen T_NVcontact settings to cope with that.

8.5 Network Modes of Operation

Network mode of operation (NMO) [2], [5] defines the way a GPRS/EGPRS mobile shall perform network registration (IMSI attach) for CS and PS (GPRS attach) radio access bearer services and periodic/normal location/routing update procedures:

- In NMO-II, CS-mode and PS-mode procedures are managed without coordination between MSC and SGSN, i.e. mobile uses dedicated CS-mode transaction to maintain Mobility Management (MM) and dedicated PS-mode transactions to maintain GPRS Mobility Management (GMM).
- In NMO-I, there is coordination between the CS-domain (MSC) and the PS-domain (SGSN) and the mobile makes use of combined CS-mode and PS-mode transactions between the MS and SGSN. The SGSN forwards/receives information of the concerned MSC/VLR via the Gs-interface (see figure 5). PS-

mode mobility procedures are equivalent in NMO-I and NMO-II. CS-mode mobility procedures are then managed by PS-mode mobility timers in NMO-I.

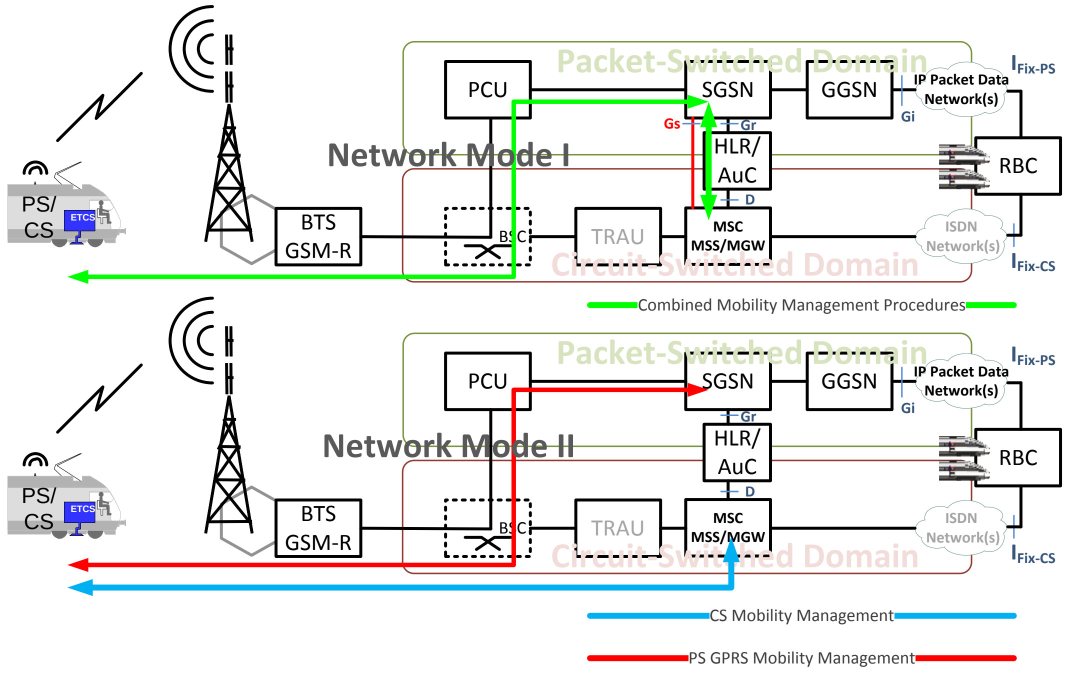

Figure 8-2 GPRS Network Modes of Operation

A class B mobile suspends the GPRS service (packet data transmission and reception is suspended) to perform a normal/periodic location area update procedure or the mobiles enters into dedicated mode to answer to a CS-mode paging.

Table 8-1 summarises the typical mobile and network mode dependent transactions and their impact to ETCS session performance.

	Impact on ETCS Level 2 GPRS performance	
Mobility Management (MM/GMM)) Procedure	**NMO-I**	**NMO-II (reference)**
IMSI Attach & GPRS Attach	Combined CS-mode and PS-mode Attach procedure (see upper part of Figure 8-2) but does not improve GPRS user plane procedure (delay etc.)	Dedicated IMSI Attach procedure that only involves CS-Domain Dedicated GPRS Attach procedure that only involves PS-Domain
Periodic Location Area Update	Managed by the periodic routing area update timer (T3312 see Figure 8-3). In ETCS Level 2 scenario T3312 [5] should never expire, because the mobile remains in ready state (see chapter 4). In case the mobile is in standby state (no PS data traffic during “ready timer” seconds),	Managed by periodic location area update timer T3212[9]. On expiry of T3212, mobile data flow is suspended and will be resumed after successful location area update. The duration of data flow suspension can be up to several seconds.

	T3312 can expire if no PS data traffic is exchanged between OBU and RBC during T3312 seconds: In this case, mobile has to perform a periodic location/routing area update and GPRS service is not suspended.	
Normal Location Area Update	GPRS based data flow will not experience a suspension, because it is managed by T3312 (see Figure 8-3) [5] again while the mobile remains in ready state (see chapter 4).	Managed by periodic location area update timer T3212 [9]. On expiry of T3212, mobile data flow is suspended and will be resumed after successful location area update. The duration of mobile data flow suspension can be up to several seconds.

Table 8-1 GPRS Network Mode of Operation

T3212 = “0” implies that no periodic location update is requested and can prevent mobile data flow interruption due to timer expiry (see Figure 8-3). If T3212 has specific value ≠0 up to the specified limit in 3GPP [9], the mobile will periodically update the location based on the frequency specified in T3212 while Network Mode of Operation mode II is active. In NMO-I, the mobile data flow is not suspended, because the mobile remains in ready state (see chapter 4) during an ETCS session. Due this reason T3312 (periodical routing area update timer) does not expire. In that sense, the mobile remains in ready state (see chapter 4) and prevent periodical and normal location/routing area update timer expiry. Only on T3312 expiry a periodical routing area update procedure is carried out.

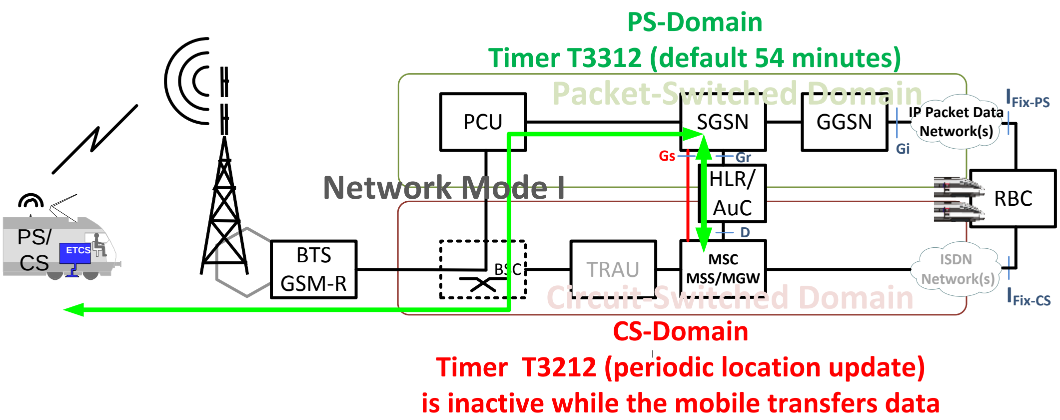

Figure 8-3 Mobility Management timer association to CS- and PS-domain

Concluding this chapter, the infrastructure operator has to consider their strategy of periodic location/routing area update timer settings and location area /routing area design having in mind the use of mobile class B (see chapter 2.5).

To be independent form the location area design and to prevent mobile data flow suspension during an ETCS session, NMO-I is the right choice. If NMO-II becomes part of the GSM-R network integration, the location/routing area design and the T3212 setting in the CS-domain need to be carefully planned. For example, location/routing area borders shall be not part of the ETCS track or high train density area while NMO-II is the design choice. A mixture between NMO-1 and NMO-II operation in the network is also possible, but increases the complexity. In case NMO-I/II operation, the mobile has to adapt their CS-domain/PS-domain registration according to the broadcasted NMO, which causes additional signalling.

NMO-1 requires the introduction of Gs-interface between the SGSN and the MSC/MSS (see Figure 8-2). Special attention might be paid for voice services if the Gs-interface is unavailable. Alternative routing scenario via the A-interface due to Gs-interface unavailability is not part of 3GPP specification. Thus, it is network supplier implementation specific.

NMO is broadcasted in the relevant system information (SI13) to instruct the mobile if dedicated or combined mobility management procedure shall be used. Following settings are applicable for the BSC:

To activate NMO1:

NMO (3GPP name) parameter = “0”

To activate NMO2:

NMO (3GPP name) parameter = “1”

8.6 Interaction with VGCS/VBS

VBS/VGCS calls and GPRS/EGPRS data sessions can be established within the same cell. A mobile in an on-going VBS/VGCS call can be notified by PS-mode paging while the PDP context is active.

Table 8-2 summarises GPRS/EGPRS and VGCS/VBS interactions that are applicable for class B mobile only. The first column of each row indicates a given mobile state (see chapter 4) and the next columns indicate whether the mobile is able to be notified by a group call or a packet switched paging (PS-paging).

Note: ETCS subscription suppresses the usage of VBS/VGCS service as indicated in FFFIS for EuroRadio [35].

Incoming Call →	VBS/VGCS call	GPRS call (PS paging/Subscriber is already attached)
MS State ↓	*Mobile terminated call/service notification*	
Idle	**Yes** (NCH reading to get group call details)	**Yes**, PS-paging
Dedicated mode	**Yes**	**No** because the packet service has been suspended (class B see chapter 2.5).
Group transmit mode	**Yes**	**No** because the packet service has been suspended (class B see chapter 2.5).
Group Receive mode	**Yes**	**No**
Packet Idle	**Yes** (NCH reading to get group call details)	**Yes**
Packet transfer	Mobile vendor dependent.	**Not applicable**. Network will automatically allocate TBF blocks for incoming PS call.

Table 8-2 VGCS/VBS and GPRS/EGPRS interaction

Generally, GPRS/EGPRS introduction has no impact on the VBS/VGCS behaviour.

8.7 Security

Security is a broad subject and therefore this chapter outlines the basic security principles that need to be considered during ETCS PS-mode integration.
The GGSN is the gateway which can be interconnected to several IP packet data networks. Beside the ETCS based signalling other application can be operated at the same time by using the GSM-R PS-mode infrastructure (see Figure 8-4).

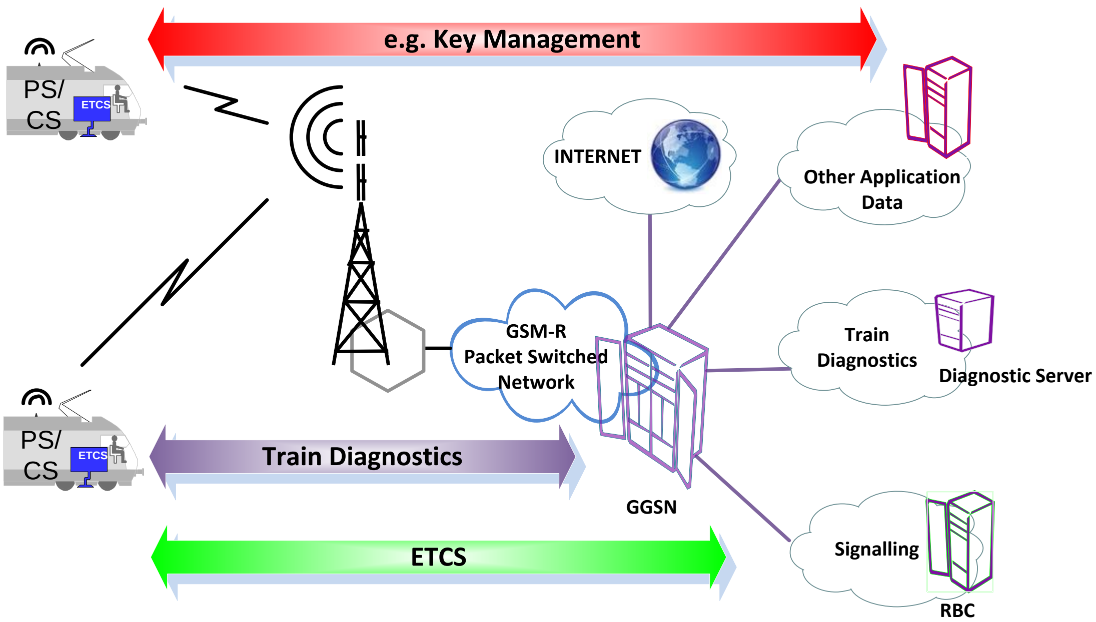

Figure 8-4 Basic Security in PS-mode

Table 8-3summarises the basic security advisements which is not exhaustive. An infrastructure operator security assessment for the operation of ETCS in PS-mode is in any case recommended.

Number	Security Advise
1	The "ETCS" APN shall be used only for ETCS purposes.
2	Other data traffic using the GSM-R PS-domain infrastructure shall use (a) different APN(s).
3	IP domain(s) for ETCS purposes (IP address assignment trainborne and trackside) shall be strictly separated from any other application e.g. office, internet etc.
4	To reduce the impact of broadcast storms IP address network size that is used for ETCS purposes (trainborne/trackside) shall be limited.
5	Different physical interfaces or at least a separation at layer 2 (VLAN) including transmission bandwidth reservation to each APN at the Gi reference point need to be considered. This can prevent bandwidth flooding caused by other application.
6	The integration of a RBC should take into account a physical interface separation of OBU- RBC and RBC to RBC traffic.
7	To prevent any radio access bandwidth allocation by unwanted packet traffic, IP communication between trains using the ETCS APN shall be prohibited.
8	GSM-R PS-domain shall be not accessible from the Internet. This is also valid, if the Gp interface becomes part of the packet core network integration.

Table 8-3 Security Advices

8.8 Signalling System Handover

8.8.1 General Aspects

ETCS Signalling System Handover involves two adjacent RBCs. Either one mobile provides the transport capabilities to each RBC subsequently or two mobiles are involved simultaneously in the RBC System Handover procedure. Latter case requires inside the RBC System Handover zone sufficient GPRS/EGPRS radio resources to cover the simultaneous RBC sessions per train. Bandwidth estimation shall take into account the possible number of trains inside the RBC System Handover zone, the ETCS traffic model including packet sizes as well as message periodicities.

8.8.2 RBC handover (national)

The general procedure and the related engineering of RBC System Handover remain unchanged compared to CS-mode. In PS-mode, also one mobile can simultaneously cover both RBC sessions. If only one mobile is involved, the two RBC sessions requires additional bandwidth that can exceed maximum guaranteed bit rate of the PDP context (see Table 5-1). Then care should be taken that in general sufficient radio access bearer bandwidth, in particular the timeslot quantity respecting the GPRS/EGPRS channel coding, is available.

8.8.3 Crossing border- RBC handover (international)

The general procedure of RBC System Handover while crossing a border remains unchanged. Two mobiles are recommended to achieve the best performance in time changing between the two mobile networks and RBCs.

9 ANNEX – 3GPP PARAMETERS FOR GPRS/EGPRS

This chapter provides the list of 3GPP parameters involved in the GPRS/EGPRS implementation.

9.1 BSS Parameters

3GPP name	BEP_PERIOD
Definition	When EDGE is activated in the cell, the field broadcast and indicates the BEP filter averaging period to the MS

3GPP name	BS_CV_MAX
Definition	Indicates when to start countdown procedure in UL: the countdown starts when the remaining RLC blocks will be sent in (bsCvMax * 20ms), i.e. when (bsCvMax * Nb_UL_TS_Allocated) blocks are left. bsCvMax also indicates when the MS should accept a NACK from the PCU.

3GPP name	BSS_PAGING_COORDINATION
Definition	Activation parameter of BSS Cs paging coordination feature.

3GPP name	CELL_RESELECT_HYSTERESIS
Definition	Hysteresis to reselect towards a cell: When the MS is in GSM IDLE mode and reselects a cell with a different LA (Location Area). When the MS is in GMM Standby state and reselects a cell with a different RA (Routing Area). When the MS is in GMM Ready state and reselects a different cell.

3GPP name	DRX_TIMER_MAX
Definition	Duration of non-DRX mode. When switching to packet Idle mode, the MS shall: Only listen to the CCCH blocks belonging to its paging group in DRX mode (“sleep mode”) Listen to all the CCCH channels in non-DRX mode.

3GPP name	EXT_UTBF_NODATA
Definition	Flag used to allow the mobile station to refrain from sending Packet Uplink Dummy Control blocks during inactivity periods. It is only taken into account when Extended UL TBF is activated.

3GPP name	N3103
Definition	Maximum number of repetition of final PUAN with FAI=1 without reception of a PCA.

3GPP name	NW_EXT_UTBF
Definition	Enables / disables Extended Uplink TBF feature

3GPP name	SI_STATUS_IND
Definition	Flag used to indicate the support of Packet SI Status feature in the target cell.

3GPP name	PAN_DEC
Definition	The MS counter N3102 is decremented by panDec each time T3182 expires.

3GPP name	PAN_INC
Definition	The MS counter N3102 is incremented by panInc each time a PUAN message which allows the transmit window to go forward is received.

3GPP name	PAN_MAX
Definition	Maximum value of the counter N3102. N3102 is set to panMax by the MS at each cell reselection. N3102 is used in case of block acknowledgment timeout when the transmit window on MS side is stalled.

3GPP name	PFC_FEATURE_MODE
Definition	The parameter is used to activate PFC in the cell.

3GPP name	RA
Definition	Defines the Routing Area Code. It is one of the attributes constituting the GPRS Cell Global Identifier (locationAreaCode + cellIdentity + routingArea).

3GPP name	SGSNR
Definition	The parameter is set to ‘0’ when the SGSN supports rel’98 or older and set to ‘1’ when the SGSN supports rel’99. Set the “SGSNR” bit of the SI13 to “0” or “1”.

3GPP name	T3168
Definition	This timer is used at the MS side to define when to stop waiting for the PUAS message after sending either a PRR message or a Channel Request in a PDAN.

3GPP name	T3192
Definition	Wait for DL TBF release after reception of the final block. This timer is used on the MS side to define when the MS received all the RLC data blocks. When the timer expires, the MS releases the resources associated with the TBF and begins to monitor its paging group.

3GPP name	T6
Definition	pfcT6 is the guard timer for the Download PFC procedure

3GPP name	T8
Definition	pfcT8 is the guard timer for the Modify PFC procedure.

3GPP name	N3105
Definition	Maximum number of consecutive polling requests without answer from MS.

Table 9-1 3GPP BSS Parameter

9.2 Packet Core Parameters – GMM

3GPP name	pagingTimer (t3313)
Comment	Network dependent

3GPP name	pagingRetries (n3313)
Comment	3GPP default value
Value	1

3GPP name	nwkInitiatedDetachTimer (t3322)
Comment	3GPP default value
Value	6 s

3GPP name	nwkInitDetachRetries (n3322)
Comment	3GPP default value
Value	4

3GPP name	idRequestTimer (t3370)
Comment	3GPP default value
Value	6 s

3GPP name	idRequestRetries (n3370)
Comment	3GPP default value
Value	4

3GPP name	ptmsiReallocTimer (t3350)
Comment	3GPP default value
Value	6 s

3GPP name	ptmsiReallocRetries (n3350)
Comment	3GPP default value
Value	4

3GPP name	authCipheringTimer (t3360)
Comment	3GPP default value
Value	6 s

3GPP name	authCipheringRetries (n3360)
Comment	3GPP default value
Value	4

3GPP name	t3302
Comment	3GPP default value

Value	12 min
3GPP name	periodicRaUpdateTimer (t3312)
Comment	3GPP default value
Value	54 min
3GPP name	Mobile reachable timer
Comment	T3312 + 4 min = 3GPP default value
Value	58 min
3GPP name	implicit detach timer
Comment	Starts at mobile reachable timer expiry
Value	0
3GPP name	ready timer (T3314)
Comment	44 s = 3GPP default value. Ready timer must be > maximum duration between 2 ETCS2 uplink messages.
Value	44 s

Table 9-2 3GPP GPRS Mobility Management Parameter

9.3 Packet Core Parameters – SM

3GPP name	nwkPdpDeactTimer (t3395)
Comment	3GPP default value
Value	8 s

3GPP name	nwkPdpDeactRetries (t3395Retry)
Comment	3GPP default value
Value	4

3GPP name	nwkPdpModifyTimer (t3386)
Comment	3GPP default value
Value	8 s

3GPP name	nwkPdpModifyRetries (n3386)
Comment	3GPP default value
Value	4

Table 9-3 3GPP Session Management Parameter

9.4 Packet Core Parameters – BSSGP

3GPP name	T3 (suspend guard timer)
Comment	-

3GPP name	pdu lifetime
Comment	-

3GPP name	T4 (resume guard timer)
Comment	-

3GPP name	T6 (download bss pfc guard timer)
Comment	-

3GPP name	T7 (create BSS PFC guard timer)
Comment	-

3GPP name	T8 (modify BSS PFC guard timer)
Comment	-

3GPP name	PacketFlowTimer (T9)
Comment	Rule: T9 <= ready timer. PFT must ne > maximum duration between 2 ETCS2 uplink messages.

Table 9-4 3GPP BSSGP Parameter

END OF DOCUMENT.