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X.25 data services in GSM: GSM–PSPDN interworking

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Acknowledgements

The PTT wants to use existing networks for the integration of services within digital networks, e.g. ISDN. This is realized by interworking between the networks. One part of this 'interworking by integration of networks (services)' is performed in this report: a description of the interworking between GSM and PSPDNs in order to support data services within GSM.

I accepted this graduation assignment offered to me by prof.ir. J. de Stigter, Departmental manager of the communications research and systems department of PTT research Neher laboratories, and professor at the Eindhoven University of Technology, faculty of Electrical Engineering.

I would like to thank prof.ir. J. de Stigter for the opportunity given to perform this graduation assignment. I also thank ir. A.J.J. Kerkhof for his great (correctional) support, ir. Anton Halderen for being always ready to assist (especially the support of computer technology) and ir. Jan v.d. Graaf for his deeper understanding in how to deliver a lecture.

Summary

This report describes how the cellular radio system GSM[1] can support data services. An introduction of GSM is given to show the GSM capability to support data services. Some limitations in contrast to ISDN have been found on the user network interface (radio interface) of GSM.

A closer look to *mobile* data services is performed to give more insight into the requirements which are needed to support these services in GSM.

It is proposed in this report to implement the packet switching functionality, for supporting data services in GSM, in a PSPDN[2]. This is also performed for ISDN and the description can be found in CCITT Recommendation X.31.

An implementation of X.31 within ISDN can be found in the description of the ETSI PHI (see [8]). In this report an ETSI PHI implementation for a GSM variant of X.31 case B is described as a solution for GSM to support data services. Two functional models of the ETSI PHI implementation for GSM are examined. The remote access model for GSM is further described.

The applicability of X.31 case B services in GSM is examined. The main conclusion from this was a packet mode bearer service on a Dm channel cannot be offered.

Some 'problems' are identified:

- access of X.31 case B services in GSM (e.g. with an ISDN packet terminal)
- numbering plan interworking
- the support of multiplexing functions in GSM
- call control interworking

These problems are elaborated.

Finally, conclusions are given. The main conclusion in this report is that the ETSI PHI implementation can be used to support data services in GSM. No changings are needed on the PHI, but some functions are introduced in GSM to support the X.31 case B services.

[1]Groupe Spéciale Mobile

[2]Packet Switched Public Data Network

Samenvatting

In dit verslag wordt beschreven hoe het cellulaire communicatie systeem GSM[3] datadiensten kan leveren. Allereerst wordt een introductie van GSM gegeven om na te gaan welke mogelijkheden GSM daartoe bezit. De meeste beperkingen t.o.v. ISDN zijn gevonden op de 'user network interface' (radio interface) van GSM.

Een uitgangspunt in dit verslag is dat de pakket geschakelde functie van GSM neergelegd wordt in speciale datanetwerken (PSPDN), zoals het Nederlandse Datanet 1. Dit is al reeds eerder gedaan voor ISDN. Een beschrijving kan gevonden worden in de CCITT aanbeveling X.31.

Een implementatie van X.31 case B in ISDN is met behulp van een Packet Handler Interface (PHI) gerealiseerd. Deze PHI is gestandaardiseerd door ETSI en wordt gebruikt in dit verslag om een implementatie van een variant op X.31 in GSM te realiseren. Hiertoe zijn twee modellen opgesteld: een basis model en een 'remote access model'. Het 'remote access model' is verder uitgewerkt.

De diensten gebaseerd op X.31 case B zijn bestudeerd op toepasbaarheid in GSM. De belangrijkste conclusie hieruit is dat het niet mogelijk is om een 'packet mode bearer service' aan te bieden over een Dm kanaal.

Enkele problemen hebben zich voor gedaan:

1. toegang tot de X.31 diensten m.b.v. een ISDN 'packet terminal'
2. samenwerking tussen nummerplannen en routering
3. hoe kan GSM multiplexing functies ondersteunen
4. de opbouw van een verbinding tussen GSM en een PSPDN

Deze problemen zijn in het verslag verder uitgewerkt.

Uiteindelijk zijn de conclusies beschreven. De belangrijkste conclusie in dit verslag is dat de ETSI PHI beschrijving gebruikt kan worden voor GSM zonder verandering van de PHI, alleen in GSM zijn een aantal functies toegevoegd om X.31 case B te kunnen ondersteunen.

[3]Groupe Spéciale Mobile

Contents

Chapter 1

Introduction

1.1 The formulation of a problem

The intention of this report is to describe how GSM can support data services. If packet functions of GSM are concentrated in special data networks it is necessary to describe an integration/interface between the GSM system and a PSPDN[1], like the Dutch Datanet 1.

GSM is a cellular radio system for the whole of Western Europe which has, as far as can be, full compatibility with the services offered in ISDN. The most restrictive factor is the Radio interface which has only a 'Bearer' capability with *Bm(12kbit/s) + Dm(0.7kbit/s)* compared with the 'Bearer' capability in ISDN (*2B(64kbit/s) + D(16kbit/s)*). There are also some special characteristics due to the cellular structure in the GSM system, like ***handover***, ***routing*** and the *access* to the system. One has to deal with these qualities in searching for the right interworking scenario because it can cause some problems, like getting out of synchronization, relative long interruptions of the data communication connection and problems with routing (in reference to a Packet Handler Interface).

A PSPDN is a public packet switched data network with an X.25 user network interface. It is a standardized interface, so one has deal to with the corresponding protocol model and the access to the data network.

The Bearer services which are possible in the interworking situation are the X.25 services, but because of the limitations of the radio interface in the GSM system a refinement of this X.25 service is inevitable.

The Teleservices which are possible are, first of all, the user applications based upon the X.25 service and it is likely that these applications use the special mobile possibilities of the GSM system. Secondly are the teleservices delivered by the telephone company, e.g., facsimile service.

When solving the problem, an interworking scenario must be found which can deliver a flexible service towards the users and a simple network implementation

[1]Packet Switched Public Data Network

towards the telephone company.

1.2 The structure of this report

Chapter 2 is an introduction in GSM to show the GSM capability to support data services. It can be skipped, except for the conclusions, if the reader is familiar with the GSM system.

Chapter 3 is an introduction into Packet Switched Public Data Networks (PSPDNs). It can also be skipped, except for the conclusions, if the reader is familiar with Datanet 1, the Dutch packet switched data network.

Chapter 4 describes the data services which are possible in the interworking situation of GSM and PSPDNs. A closer look to mobile data services is performed to give more insight into the requirements which are needed to implement these services in GSM.

Chapter 5 describes the general interworking aspects between GSM and PSPDNs. It gives an overview of the interworking scenarios which can be used for GSM to support data services. A variation on the CCITT X.31 case B is indicated to be further elaborated. A closer look to numbering plan interworking and routing is also performed to identify problems which these subjects might cause.

Chapter 6 describes the GSM variant of X.31 case B. It is shown how the ETSI PHI can be used in the GSM environment, especially the functions which are needed in GSM. Furthermore, it is shown how an existing ISDN terminal for X.31 case B services can be connected to a GSM mobile station thus providing an access to the GSM packet mode service.

Chapter 7 describes the call control procedures which are needed for setting up a connection between data terminals, i.e. of different networks (GSM, ISDN and a PSPDN). First the protocol layer model is discussed to give an overview of the protocols which are used in the different networks. Based upon these protocols the call control procedures are described.

Chapter 8 describes the conclusions.

Chapter 2

The GSM system, a short introduction

This chapter is an introduction into the GSM system. It contains only information out of the GSM recommendation which is needed to understand the remainder of this report. It can be skipped, except for the conclusions, if the reader is familiar with the GSM system.

First the possible services of the system are briefly overviewed. Secondly, the several parts of the GSM system and their interconnections are explained. Finally, the functions of the system will be discussed. More information can be found in [2], [15] and [9].

Cellular radio systems are now an established part of many telecommunications networks throughout the world, giving the facility of mobile communications to many millions of subscribers. The Groupe Spéciale Mobile (GSM) digital cellular radio system, to be introduced into Europe in 1991, is the first standardized cellular radio system to use digital transmission. The GSM system is intended to provide a common cellular radio communications system for the whole of Western Europe and a better capability for the use of the radio channels, to satisfy the constantly growing demand for new cellular capacity. It is also intended to provide higher quality service both for speech and data (e.g., a lower error rate), with, as far as possible, full compatibility with the ISDN.

Since 1982 GSM, as a working group established by CEPT, has been very active in drawing up the standard for the common European system, resulting into more than one hundred recommendations making up the GSM specifications. The work is now largely complete with most of the recommendations stable in their final draft form. CEPT is the Conference of European Posts and Telecommunications administrations. Since 1989 these responsibilities have been transferred to the European Telecommunications Standards Institute (ETSI).

2.1 GSM services

The GSM services are based on ISDN services and have a mobile character, see [12].

The telecommunication services in the GSM system are, as in ISDN, divided in three broad categories, according to GSM Recommendation 02:

1. **Bearer services**
   Bearer services are services providing the capability of transmission of signals between access points (called user-network interfaces in ISDN).

2. **Teleservices**
   Teleservices are services providing the complete capability, including terminal equipment functions, for communications between users according to protocols established by agreement between network operators.

3. **Supplementary services**
   A supplementary service modifies or supplements a basic telecommunication service (a basic set including bearer- and tele- services). Consequently, it must be offered together or in association with a basic telecommunication service.

Figure 2.1 gives an overview of the most likely services which are also indicated in the GSM recommendations.

The next sections clarify how GSM supports these services. These sections can be seen as background information to understand the remainder of this report. It will become clear that GSM cannot support all the ISDN services.

2.2 The elements of GSM

The GSM system is a sophisticated system. It can be globally subdivided into two parts: the network part (architecture, functions) and the radio part.

2.2.1 Network part

The network part can be subdivided into the network architecture and the network functions.

2.2.1.1 The network architecture

The GSM system has three main elements, according to GSM Recommendation 01.02:

- Mobile Stations (MS)

Teleservices
Initial Services Basic service: Normal duplex telephone communication between public land mobile network subscribers or between these subscribers and fixed public network subscribers Emergency call: telephone teleservice as normal call. Emergency service routing is handled by the mobile services switching centre according to call origin, using special tables *Future Services* Short messages to mobiles Access to message handling system Fax3: this service requires implementation of an interworking function to provide input signal conversion in the base station subsystem into fixed network frequencies and vice versa
Bearer services
Initial services Data transparent service at 300 bit/s and 1200 bit/s duplex, in asynchronous transparent mode *Future services* Nontransparent data service: for such services mobile and interworking function units are equipped with the appropriate radio link protocol defined by GSM in order to achieve error-free transmission High speed data transfer (up to 9.6 kbit/s) Synchronous services
Supplementary services
Initial services Call forwarding Call barring (outgoing, international outgoing, incoming) Call holding Call waiting *Future Services* Call barring (outgoing from home mobile network, outgoing calls directed to non-CEPT countries) Conference call and most other fixed network telephone supplementary services

Figure 2.1: The most likely telecommunication services in GSM.

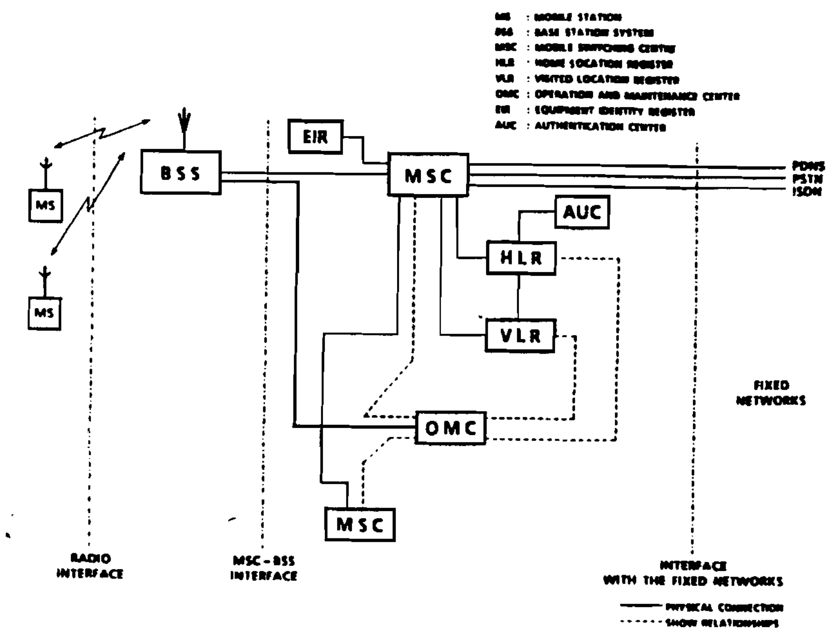


Figure 2.2: The functional entities of the GSM system and their interconnection.

- Base Stations Systems (BSS)
- Mobile Switching Centers (MSC)

These are arranged as shown in Figure 2.2. Some other functional elements are illustrated in this figure:

- Visited Location Register (VLR)
- Home Location Register (HLR)
- Operation and Maintenance Center (OMC)
- Authentication Center (AUC)
- Equipment Identity Register (EIR)

The elements of the GSM system will briefly be explained:

MS

The mobile station consists of the physical equipment used by the subscriber to a GSM PLMN[1] to gain access to the telecommunications services offered.

Various types of MSs exist, such as: vehicle mounted stations, portable stations or hand-held stations.

BSS

The Base Station System is the physical equipment used to give radio-electrical coverage to a determined geographical zone called a cell, and to

[1]Public Land Mobile Network

contain the equipment needed to communicate with the MSs attached to the Base Station.

A number of mobile stations can be connected to the base station over the air interface. The base station can switch any radio channel to a PCM[2] channel of the MSC-BSS interface and vice versa.

MSC

The Mobile Switching Center is a switching center that holds all the switching functions needed for mobile communication, located in an associated geographical area, called a MSC area. It should take into account the mobile nature of its subscribers and be able to manage the necessary radio resources, especially those procedures required to handle and update the location registration and procedures required to carry out the ***handover***. *Handover* occurs when someone passes the border of a cell and enters a new cell, see Section 2.2.1.2.

MSCs retrieve all the data needed to treat subscriber call requests from three databases: the HLR, VLR, and the AUC (authentication center). In turn, the MSC updates the databases with the latest information on subscriber location and status.

Also interworking with other networks (PSTN[3] or PSPDN[4]) needs the presence of specific functions associated with the MSC, known as interworking functions (IWF).

HLR

The Home Location Register is a database used for the management of mobile subscribers. Two types of basic information are stored in the HLR:

- Subscriber information (e.g., IMSI: International Mobile Subscriber Identity)
- Part of the mobile location information allowing incoming calls to be routed to the MSC for the called mobile station (e.g., the MS Roaming number, the VLR address, the MSC address).

The database contains other information such as:

- Teleservices and bearer services subscription information
- Service restrictions (e.g., roaming limitations)
- Supplementary services, a table contains the parameters attached to these services

[2]A 2048 kbit/s multiplexed bitstream according to CCITT Recommendation G.705
[3]Public Switched Telephone Network
[4]Packet Switched Public Data Network

- When applicable (e.g., for MSs with built-in identity), the characteristics of the mobile equipment used by the subscriber[5]

VLR
: The Visitor Location Register is the functional unit that dynamically stores subscriber information, such as the location area, when the subscriber is located in the area this VLR is in charge of. When a roaming mobile enters a MSC area, this MSC warns the associated VLR of this situation.

  The VLR also contains other information needed to handle incoming or outgoing calls. This information is gathered by the VLR via a dialogue with the HLR associated with the mobile subscriber.

OMC
: The Operation and Maintenance Center is the functional entity through which the Network Operator can monitor and control the system.

AUC
: The Authentication Center stores any information that is needed to protect communications through the air interface against intrusion, to which they are vulnerable.

EIR
: A mobile station's IMEI (International Mobile Equipment Identity) can be checked against a list of unauthorized equipment (e.g., stolen mobile stations) which is stored in the Equipment Identity Register (EIR).

2.2.1.2 Network functions

In any radio system the resource that has the primary influence on the system design is the available spectrum. Cellular radio attempts to make maximum use of this resource by restricting the coverage area of a BSS and then reusing the frequencies at some distant BSS. The area covering all MSs which are currently being served from one BSS is called a cell. Cells are then arranged in clusters and the total spectrum (a total number of radio channels) is then divided between the cells in the cluster. Regular patterns of clusters are then used to give total area coverage. As an example, a seven cell cluster is shown in Figure 2.3.

The main functions of a GSM PLMN are strongly related to the fact that mobile subscribers are inside the cellular system. This leads to the following functions:

- Authentication
  For avoiding misuse of the network each user is identified and authenticated

[5]This information can also be saved in a 'smart card'.

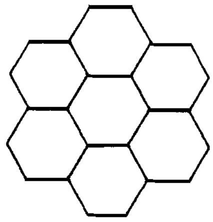


Figure 2.3: A seven cell cluster.

on accessing the network. The claimed identity of a user is checked by an authentication mechanism.

- Paging
On incoming calls into a cell, a broadcast signal will be sent in the cell. The subscriber called to (or his MS) must response on the broadcast signal. After the response a univocal relation exists between the subscriber and the network in which it is possible to set up a connection.

- Location registration
A subscriber can roam in all of Europe. Due to the enormous bandwidth needed to page for all incoming calls, directed towards subscribers all over Europe, Europe has been split up in many location areas. The network keeps up to date in which location area a subscriber is located. If a subscriber is moving to another area, the MS detects this situation by means of listening to the Common Control Channel (CCCH). After this detection a location updating procedure will be invoked.

- Handover
The fundamental process of cellular radio is that MSs should have their calls established to the BSS which gives them the best communication link. This is usually the nearest BSS. Therefore as an MS moves it must be reassigned to new BSSs and its call rerouted appropriately. This is called the handover process.

- Identification
A difference exists within the telephone network between a subscriber number (telephone number) and the number of the telephone line towards the subscriber (see also [17]). GSM subscribers have also subscriber numbers (see Section 5.3.1). However, within the GSM PLMN no fixed connection exists, but it is desirable to indicate the roaming subscribers with fixed universal identities. This is a welcome help for the procedures inside the system. For example, it is desirable that the allocation of international mobile station identities should be independently of the numbering plans used

for accessing mobile stations from the different public networks. This will enable Administrations to develop their own (national) numbering plans for land mobile stations for different services without the need for coordinating them with other countries. An identity of a GSM subscriber is named an IMSI, International Mobile Subscriber Identity.

For more information, see CCITT Recommendation E.212, E.213 and E.214, GSM Recommendation 03.03.

- Encryption
  It is possible to use a secure encryption mechanism for data and speech transmission across the radio-interface.

2.2.2 Radio part

The radio part of GSM involves the whole of the technology used in GSM to support radio functions, e.g., transmission of data over the radio interface. For a complete description, see GSM Recommendation 04.

An introduction of this radio part is necessary to understand the remainder of this report. The most important issue in this report is the radio interface and the structures used on the radio interface. These structures are the GSM frame structure, channel structures and data structures. Some functions also exist, e.g. channel coding and modulation, which are needed for the transmission of data over the radio interface.

The GSM system is required to be able to operate

- over the band 890–915 MHz for MS transmit and BSS receive (the uplink)
- and over the band 935–960 MHz for BSS transmit and MS receive (the downlink)

with a carrier spacing of 200 kHz. This means that 124 carriers are possible, also indicated as Radio carrier Frequencies (RF). The modulating bit rate for a carrier is 270.838 kbit/s.

The GSM MS, although capable of operating over the full 25 MHz bands, will only use that part of the band assigned to the system in which it is operating as this information is signalled to it from the BSS.

2.2.2.1 TDMA structures

Each of the RF channels is divided into timeslots of approximately 577 μs duration. This means that the timeslots correspond to 156.25 bit durations. These timeslots are grouped together in sets of eight consecutive timeslots as one Time

Division Multiple Access (TDMA) frame. A physical channel is defined by specifying a RF channel **and** a TDMA frame timeslot number. Hence for a given RF channel the system has available to it eight physical channels. Each of these channels is full duplex allowing simultaneous transmission and reception by both MS and BSS. To avoid the requirement for the MS to transmit and receive simultaneously, a staggering of the TDMA frames is employed[6]. A graphical explanation of the TDMA frame structure is given in Figure 2.4, see also GSM Recommendation 04.03 and [10]. The TDMA frames are grouped together in one out of two ways as multi-frames:

- A 26-frame multiframe with a duration of 120 ms, comprising 26 TDMA frames, see Figure 2.5. This multiframe is used to carry *traffic channels* and their associated *control channels*. The differentiation per multiframe is 24 traffic channels, 1 control channel and 1 idle frame.
- A 51-frame multiframe with a duration of approximately 235.4 ms, comprising 51 TDMA frames, see Figure 2.6. This multiframe is exclusively for control channels.

The frame structure used on each physical channel is independent of those on the other channels.

The multiframe structure is built up to produce superframes with a duration of 6.12 s. A superframe can thus consist of 51 of the 26-frame multiframes or 26 of the 51-frame multiframes. Simple arithmetic dictates that the multiframe type used on a physical channel is only permitted to change at superframe boundaries.

The final level of the frame structure is termed the hyperframe, consisting of 2048 superframes and has a duration of 12533.76 s.

The structure of a timeslot (burst) is also briefly described to explain in more details how data is transmitted on the radio interface.

Bursts

A burst consists of 156.25 bit durations and is made up of a transmission part and a guard period. The transmission part, as its name suggests, contains the data to be transmitted (user part), a midamble (or training sequence) and tail bits (for more information, see [10]). In the guard period nothing is transmitted and its purpose is to allow a variation in the arrival time of the burst without adjacent (in time) received bursts having their useful parts overlapped.

2.2.2.2 The basic speech and data link

The primary elements of a speech and data link for a call established over the GSM system are shown in Figure 2.7. A short explanation of some elements:

[6]The GSM MS times its transmit bursts to be 3 timeslots after the received bursts from the BSS.

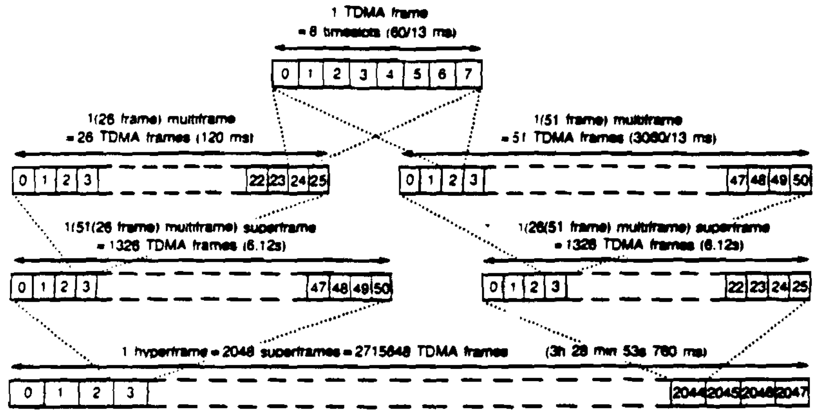


Figure 2.4: GSM frame structure, (Figure 3a from [10]).

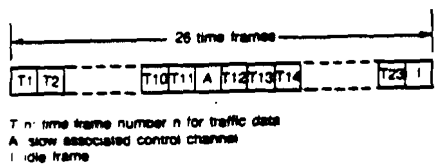


Figure 2.5: Traffic channel multiframe, (Figure 3b from [10]).

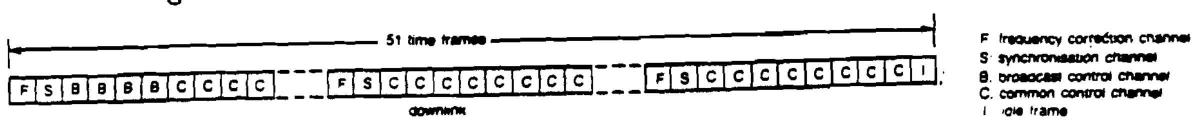


Figure 2.6: Control channel multiframe, (Figure 3c from [10]).

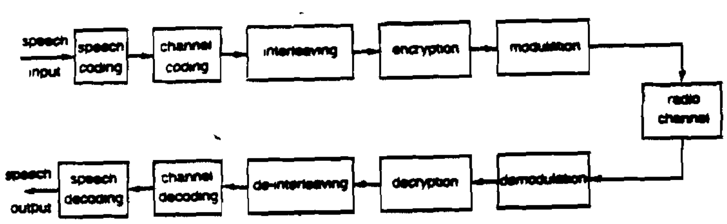


Figure 2.7: The basic speech and data link.

Channel coding

To protect the transmission against errors, forward error correction (channel coding and decoding) is used in the GSM system. This can be simply described as the addition of redundant parity check bits to the transmitted data so that errors can be detected. Obviously a penalty is paid in increasing the bit rate by this added redundancy and GSM has been designed to achieve an 'optimum' compromise.

Interleaving

Errors are generated in mobile radio systems largely due to signal fading. The fades occur at a much slower rate than the 270 kbit/s transmission rate of GSM and hence errors tend to occur in bursts. Indeed fades lasting a whole TDMA burst (approximately 4.6 ms) are likely. Hence the channel errors are characterized by periods of high error rates with longer gaps of very low error rates. For an error correcting code to work efficiently the errors must be evenly distributed in time. Interleaving over TDMA frames are ways in which this is achieved in GSM.

Modulation

Modulation can be simply viewed as the process which converts the data to be transmitted into a form which matches both the transmission requirements of the medium used and any requirement imposed by the system design and operation. The following are the main requirements of the GSM modulation scheme:

- Frequency translation into the correct band.
- Relatively narrow bandwidth to allow good spectrum efficiency.
- Constant envelope to allow the use of simple and efficient power amplifiers.
- Low out-of-band radiation so that adjacent channel interference is low.

These requirements are achieved by Gaussian MSK (GMSK)[7].

2.3 MS access capability of GSM

The user network interface (radio interface) is an important interface because it must be identical for the whole of Europe. An important issue of this user network interface for this report is the access capability because many services, offered in GSM, are dependent of the channel structures which are possible on this interface.

The description of the various channel types preceeds the discussion of the access capability.

[7]Minimum Shift Keying with a Gaussian pre-modulation filter.

2.3.1 Channel types

A mobile station access capability is the description of the set of its possible channel configurations. Two channel types are possible, according to GSM Recommendation 04.03: traffic channel and a control channel.

2.3.1.1 Traffic channels

Traffic channels are fixed physical gross rate channels, intended to carry encoded speech or user data. Two general forms are defined:

- Full rate traffic channels at a gross coded[8] bit rate of 22.8 kbit/s[9] (TCH/F, Traffic Channel/Full rate). These channels are called Bm channels. They are coded by the channel coder, see also Figure 2.7.

- Half rate traffic channels at a gross coded bit rate of 11.4 kbit/s (TCH/H, Traffic Channel/Half rate). These channels are called Lm channels. They are coded by a channel coder.

Bm channel

A Bm channel is a traffic channel able to carry:

1. A 13 kbit/s rate bit stream[10] and an error structure intended to carry voice encoded according to GSM Recommendation series 06.

2. A bit stream at a rate of 12, 6 or 3.6 kbit/s, and an error structure intended to use it for data transmission (e.g., X.25 packet service).

Lm channel

Lm channels are traffic channels with a carrying capability lower than a Bm channel. The highest net bit rate of these channels is 6 kbit/s.

2.3.1.2 Control channels (Dm channels)

A Dm channel is a term to refer to the possible control channels used by a mobile station. These channels carry:

1. Signalling information for circuit and packet switching, mobility management and access management.

2. Packet switched data, including those relating to short message services.

[8]Coded by a channel coder, see Figure 2.7.

[9]This bit rate is based on speech frames which are 20 ms. These frames consist of 456 coded bits, coded by a channel coder.

[10]This is performed by the speech encoder, see Figure 2.7.

The net rate of a control channel is, as it is used in combination with a traffic channel, approximately 700 bit/s (maximum). These bits are needed for associated signalling to maintain a connection. Due to this low signalling capacity only short message services are possible, see GSM Recommendation 03.40. A packet switched data service on a D channel will not be assumed.

To describe the access capability it is necessary to split up the Dm channel into the following three control channel types, according to the function of the information that each carries, see also GSM Recommendation 04.03:

1. **Broadcast channels**
   A broadcast channel is a point-to-multipoint unidirectional control channel from the BSS to the mobile stations. A broadcast channel is intended to broadcast a variety of information to MSs. The following broadcast channels are defined:

   - **FCCH**
     A Frequency Correction CHannel (FCCH) is for mobile station frequency correction
   - **SCH**
     A Synchronization CHannel (SCH) is for frame synchronization of the mobile station and identification of the base station
   - **BCCH**
     A Broadcast Control CHannel broadcasts general information on an individual basis. This includes general information about the base station and some details on the precise control channel organization within the current cell.

2. **CCCH**
   A Common Control CHannel (CCCH) is a point-to-multipoint bi-directional control channel. A CCCH is primarily intended to carry signalling information necessary for access management functions (e.g., allocation of dedicated channels). Several parts of the CCCH exist, related to the context in which they are used:

   - **RACH**
     The Random Access CHannel (RACH) is the uplink (MS to network) part of the CCCH. It is used to request allocation of a SDCCH (Stand alone Dedicated Control Channel, see below).
   - **AGCH**
     The Access Grant CHannel (AGCH) is part of the downlink (network to MS) part of the CCCH. It is used to allocate a SDCCH or directly a TCH.

- **PCH**
  The Paging CHannel is the remaining part of the downlink part of the CCCH. It is used to page mobile stations in a certain MSC-area to look for the called subscriber, on incoming calls into an area.

3. **DCCH**
   A Dedicated Control CHannel (DCCH) is a point-to-point bi-directional control channel to carry signalling data used for registration, location updating, authentication and call setup. DCCHs are further classified according to some technical particularities:

   - **SDCCH**
     A Stand alone DCCH (SDCCH) is a DCCH whose allocation is not linked to the allocation of a TCH. It is used, after initial connection between base station and mobile station, for authentication, ciphering request and traffic channel assignment messages. SDCCHs exist with bit rates of 781 (approximately), 4600 or 9200 bit/s.
   - **FACCH**
     A Fast Associated DCCH (FACCH) is a DCCH obtained by preemptive dynamic multiplexing on a Bm or a Lm channel. The allocation of a FACCH is obviously linked to the allocation of a TCH. The bit rate of a FACCH is 9200 or 4600 bit/s. It carries the same information as the SDCCHs. It is used when a dedicated channel is not available, and steals frames from the channel it is associated with. It will be used in situations that require fast responses, e.g., immediate handover to another cell.
   - **SACCH**
     A Slow Associated DCCH (SACCH) is a DCCH with a rate of 390 bit/s (approximately). An independent SACCH is always allocated together with a TCH or a SDCCH. It carries information such as signal strengths measured at the mobile station to the base station. It may be considered a 'housekeeping' channel.

2.3.2 MS access capability

A Mobile Station accesses, at one point in time, only a limited number of the channels appearing on its radio interface. Different compositions for the accessed channels set are identified, and specified below:

1. BCCH
2. CCCH
3. CCCH + BCCH + SCH + FCCH

4. SDCCH + SACCH
5. Bm + FACCH + SACCH
6. Lm + FACCH + SACCH
7. Lm + Lm + FACCH + SACCH

Configuration '1' is normally used only in the phase when the physical connection is not set (e.g., just after switch-on, or after a too long interruption of the physical connection). Configuration '2' or '3' are used by active but idle MS (e.g, no circuit or packet switched communication is in progress, but the network can reache the MS). Configuration '4' is used in phases when only a dedicated control channel is needed (e.g, for authentication). Configuration '5', '6' and '7' are used in particular when a circuit or packet switched communication is in progress.

2.4 Conclusions

This introduction of GSM already leads to some important conclusions. Most of these conclusions lead to limitations of the services offered in ISDN:

1. **Only one traffic channel (Bm)**
   In contrast to ISDN (two B channels) only one traffic channel (Bm) can be used on the user network interface of GSM (radio interface).

2. **A channel on the radio interface (Bm or Dm) is not always available**
   In contrast to a D channel in ISDN, a channel on the radio interface is not always available. Some reasons are:

   - The capacity within a cell is not sufficient.
   - Significant breaks in transmission as a result of shadowing or handover.
   - Severe fading and interference likely on these channels.

3. **The net bit rate of 13 kbit/s for full rate channels**
   The net bit rates of the channels on the radio interface are low compared with the channels used in ISDN (B(64 kbit/s) and D(16 kbit/s)). This applies for channels used for packet data. Speech channels are using a speech codec to overcome the low bit rate.

4. **Packet switched data services on a D channel are not assumed**
   Due to the low signalling capacity (approximately 700 bit/s) packet switched data services on a Dm channel are not assumed in this report.

Chapter 3

Introduction of Packet Switched Public Data Networks (PSPDNs)

This chapter is an introduction into Packet Switched Public Data Networks. It can be skipped, except for the conclusions, if the reader is familiar with Datanet 1, the Dutch packet switched data network.

It is important, for this report, to be well informed about the protocols used on the user network interface of a PSPDN (CCITT X.25) and the protocols on the interface towards other networks (for this report, CCITT X.75), see Figure 3.1. It will be beyond the scope of this report to give an introduction of these protocols. The reader is referred to the many existing reports which deal with these protocols.

This introduction of PSPDNs is based on the Datanet 1, aiming to give insight into the services supported by Datanet 1. First, an introduction of the network system is given. Secondly, the functions of the network elements are described. Finally, the data services and access capabilities are discussed.

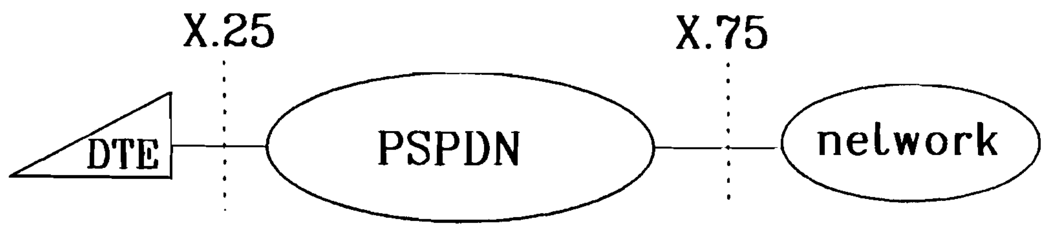


Figure 3.1: A PSPDN with an X.25 interface towards the users and a X.75 interface towards other networks.

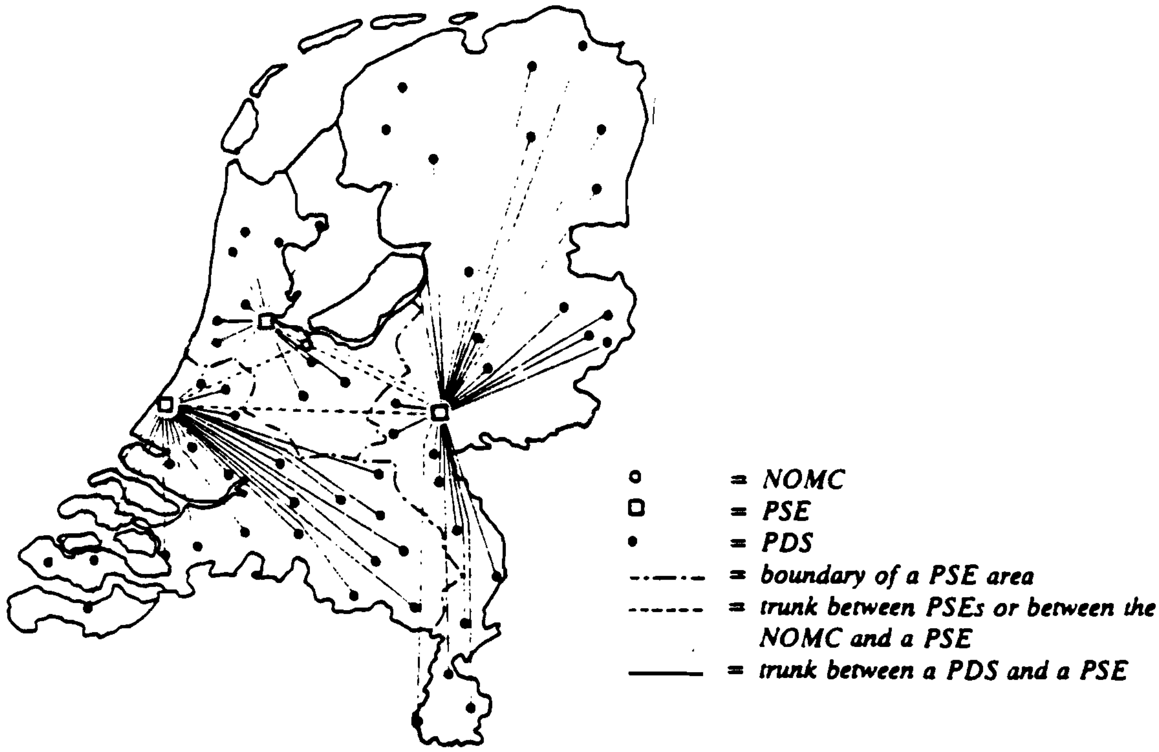


Figure 3.2: The Dutch datanetwork, (Figure 1 of [21])

3.1 The network system of Datanet 1

Datanet 1 is a public packet switched data network with an X.25 user network interface, see [21]. The network consists of an operation and management centre (NOMC[1]), three exchanges (PSE[2]) and 60 satellites (PDS[3]), see Figure 3.2. The NOMC is located in Bussum while the PSEs are in Amsterdam, Arnhem and Den Haag. The PDSs are distributed throughout the country. Connections between PSEs are by means of three geographically separate 64 kbit/s links. Connections between a PSE and the NOMC are by two such links. Each of the three PSEs covers a part of the country, and the PDSs in each part are connected by two or more geographically separate 64 kbit/s links, see figure 3.3. Each PDS covers in turn a particular area, in which all the subscribers are connected to the PDS by dedicated lines with line speeds of 2.4, 4.8, 9.6 or 48 kbit/s. The division of the country into PSE areas is such that each of the three PSEs covers a comparable sector.

[1] Network Operation and Management centre
[2] Packet Switching Exchange
[3] Packet Data Satellite

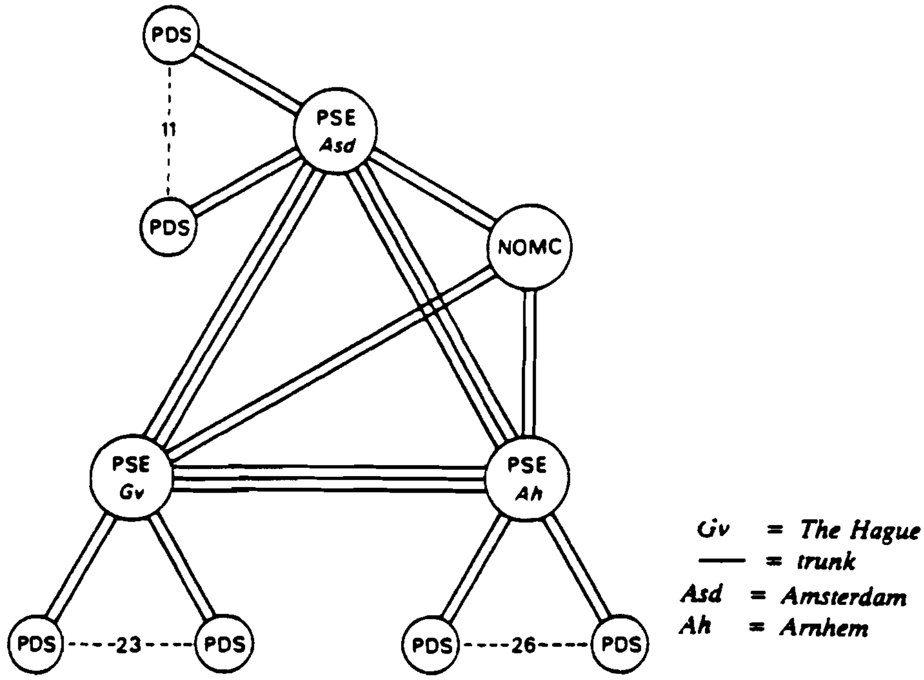


Figure 3.3: Topology of the Dutch data network, (Figure 2 of [21])

3.2 Functions of the network elements

The functions of the network elements mentioned earlier can be briefly outlined as follows:

- **NOMC**
  The NOMC is the central network management point. All management information, either in response to operator actions or generated by the network itself, is sent here. This can be categorized into:

  1. Technical management:
     - The maintenance of the system.
     - The correction of failures in the system.
     - The extension of Datanet 1.
  2. Administrative management:
     - The assignment of numbers to new subscribers.
     - To carry out possible changes in the facilities used by a subscriber.
  3. Helpdesk:
     A facility to support users which use Datanet 1. Users can consult the 'helpdesk' of the NOMC 24 hours a day.

- **PSE**
  A PSE performs the switching functions with the aid of routing tables and

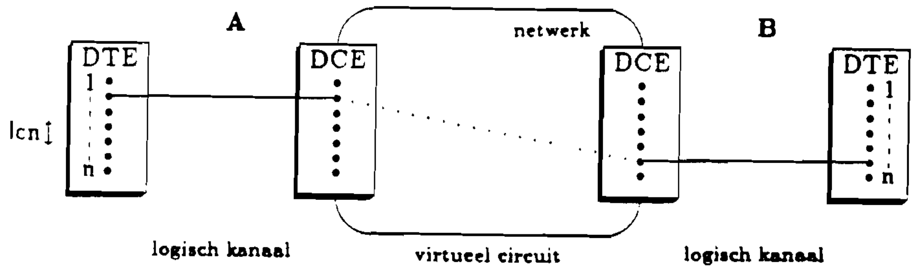


Figure 3.4: A virtual circuit and a logical channel are elements of an X.25 layer 3 connection.

during connection set-up validates the subscribers concerned. Subscriber information, like extra facilities, can be found here in a DTE[4]-profile. A DTE-profile determines the actual DTE-capabilities in terms of the CCITT Recommendation X.25 optional user facilities.

- **PDS**
  A PDS is a multiplexer/concentrator for subscriber terminal connections and also translates the interface protocol between network and subscriber into an internal network protocol and vice versa.

  The charging is performed here and the charging information will be sent to the PSE after call termination.

3.3 Services and access capabilities

In this section services supported by Datanet 1 are described. This is necessary because the services which are possible in the interworking situation between Datanet 1 and other networks depend on the services supported by Datanet 1.

First, the network connections and the network services are briefly discussed. Secondly, the supplementary services are described.

3.3.1 Network connections of a PSPDN

An introduction into network connections is given to understand the terminology used to describe the access capabilities (next section). More information can be found in [18]

The X.25 layer 3 connection between two DTEs consists out of two elements, see Figure 3.4:

[4]Data Terminal Equipment

1. **A virtual circuit**
   A virtual circuit is a logical end-to-end connection, across the packet switched network, between two DTEs.

2. **A logical channel**
   A logical channel is local logical connection between a DTE and a DCE.

The logical channels on both sides are connected together by a virtual circuit. Theoretically 4095 virtual circuits can be managed on a X.25 interface. Each virtual circuit can be subdivided into *Virtual Calls (VC)*, established by a subscriber, and *Permanent Virtual Circuits (PVC)*, established by the network operator. However the sum of the rates of the simultaneous calls cannot exceed the transmission rate. This limits the number of virtual circuits.

A VC is a temporary- or switched- virtual circuit that has to be set up by an exchange of packets before information transfer can take place.

A PVC is a permanent association between two DTEs which is analogous to a leased telephone line.

3.3.2 Network services and access capabilities

The basic network service is the CCITT X.25 protocol. It is a standardized protocol, so all the users of the network are depended of this protocol. According to OSI[5] X.25 consists out of three layers, see [18]. An user can develop his own protocols (layer 4 to 7) based upon these three layers to make his own application.

The network services supported by Datanet 1 are illustrated by the description of the access possibilities to the system:

1. **The normal 'direct access' X.25 connection**
   - Direct access: direct connection with PDS.
   - User rates: 2400, 4800, 9600, 48000 and 64000 bit/s.
   - Two kinds of connections are possible: Virtual Call (VC) and Permanent Virtual Circuit (PVC).

2. **The X.25 network connection**
   - Connection with PDS through Concentrator.
   - User rates: 2400, 4800 and 9600 bit/s.
   - Connections: VC and PVC (see above).
   - The subscriber gets 7 access switches to Datanet 1 through a 'standard X.25 switch', each having his own connection number.

[5] Open Systems Interconnection

- It is possible to have internal data communication among the 7 access switches (free of charge).

3. **A partial X.25 connection**

   - Connection with PDS through Concentrator.
   - User access: maximum of 2400 kbit/s.
   - Only one virtual circuit can be managed.
   - Only Virtual Calls (VCs) are possible on this virtual circuit.

4. **Switched access through a PAD[6]**

   - This is needed for asynchronous terminals and videotex terminals.
   - Only one Virtual Call is possible.
   - PTT delivers the following PAD facilities:
     - Telepad 1 for ASCII services (asynchronous X.28 protocol)
     - Telepad 2 for videotex services.
   - User access rates: 300/300, 1200/75, 1200/1200 and 2400/2400 bit/s.
   - Two applications for using a PAD are defined:
     - Identified use of the normal data-network service.
     - Non identified use for switching to a Value Added Service, like Memocom.
   - A PAD-subscriber is not accessible for incoming calls.

5. **Switched access based on X.32 procedures**

   - The X.32 non identified service, (in which the network forces the facility 'reverse charging'), for the users of X.25 terminals.
   - It is possible for an X.25 terminal user to access Datanet 1 through a modem and PSTN[7] to make a connection with any Datanet subscriber which has the facility 'reverse charging acceptance'.
   - The X.25 terminal caller does not have to be a subscriber of Datanet 1.

It can be concluded that the network service in Datanet 1 is the X.25 protocol. However the supplementary services, delivered by the telephone company, are the more attractive services for the subscribers.

[6] Packet Assembler Disassembler, CCITT X.28/X.29

[7] Public Switched Telephone Network

3.3.3 Supplementary services

Datanet 1 is a Value Added Network (VAN) because of the rate adaptation and the protocol conversion inside the network. It has also some optional facilities (supplementary services) which subscribers might use (e.g., closed user groups).

It will be out of the scope of this report to describe them all, but a few which are regularly used are given:

1. **Standard facility, identification presentation**
   The supplementary service which provides to the connected party the calling subscriber's number and vice versa. This is standard in Datanet 1.

2. **Closed user group (CUG)**
   The supplementary service which provides the possibility for a group of subscribers, connected to Datanet 1, to intercommunicate only amongst themselves and, if required, one or more subscribers may be provided with incoming/outgoing access to subscribers outside this group.

3. **Reverse charging**
   The supplementary service allowing a called subscriber to be charged for the usage-based call on a per call basis, at the calling subscriber's request and with the called subscriber's permission.

4. **Advice of charge**
   The supplementary service which provides the possibility for a subscriber who pays for the use of telecommunications services to receive charging information related to the telecommunication services used.

5. **Barring of all outgoing or incoming calls**
   The supplementary service which makes it possible for a subscriber to prevent all incoming or outcoming calls to be terminated at her directory number (incoming situation) or to be set-up by means of her subscription (outcoming situation).

6. **Call redirection, (Call forwarding unconditional)**
   The supplementary service which permits a called DTE to have the network send all incoming virtual calls, addressed to the called DTE-number to another DTE-number.

3.4 Conclusions

Summarizing, this brief introduction into PSPDNs leads to some conclusions:

1. The basic network service in Datanet 1 is based on the X.25 protocol. This service is of major importance to get a 'basic' connection between two subscribers (e.g., to deliver the data-packets in an orderly way).

2. Based upon the X.25 protocol one can develop its own application protocols, considering the X.25 characteristics, e.g., packet size (see also [18]).

3. Several supplementary services are available. These services have to be considered in an interworking situation between Datanet 1 and other networks, like GSM. This is not fulfilled in this report and is for further study.

Chapter 4

Data services in GSM and in PSPDNs

4.1 Introduction of data services

The specification of data services in GSM has been of lower importance than speech services, but that is now outdated because the use of mobile radio for data services has been increased alongside the growth in data communications generally.

Support of many data services in the future will be based on packet switching protocols both using ISDN and a PSPDN (e.g., Datanet 1). The type of services involved are: facsimile group 4, Teletex, Videotex, Message Handling Systems (MHS X.400), etc.

Data services are of major importance, so the aim of this report is to find a solution to support data services in GSM. This can be realized to describe a GSM–PSPDN interworking situation. This is described in the following chapters. In this chapter a closer look to mobile data services is performed to give more insight into the requirements which are needed to implement these services in GSM.

The GSM network will provide a wide variety of data services. These services may be either teleservices or bearer services. Most of these services can be recognized as bearer services. A short overview of data services which can be found in the GSM recommendations is given. Most of these services are only described on general level. Data services which are possible for an interworking situation between GSM and PSPDN are examined by looking to potential market categories for mobile data services.

4.2 Data services in the GSM recommendation

Data services in GSM are categorized into bearer services and teleservices.

4.2.1 Data services categorized as bearer services

The data services supported by GSM consist of:

- The standard asynchronous rates up to 9.6 kbit/s (i.e., 300 bit/s, 600 bit/s, 1200 bit/s, 1200/75 bit/s, 2400 bit/s, 4800 bit/s, 9600 bit/s, all duplex).
- The same rates from 1200 bit/s upward for synchronous service.

The asynchronous services are for circuit mode or PAD access, and the synchronous services are for circuit mode or packet mode service.

The 9.6 kbit/s service uses a full rate traffic channel, see Section 2.3.1. All the rates lower than 9.6 kbit/s can use a full rate or a half rate channel.

4.2.2 Data services categorized as teleservices

The data services supported by GSM consist of:

- Access to message handling systems, like X.400, described in GSM recommendation 03.42.
- Facsimile services (e.g., alternate speech and facsimile group 3), described in GSM recommendation 03.45.
- Videotex service, described in GSM recommendation 03.43.
- Teletex service, described in GSM recommendation 03.44.
- Short message service to mobiles. With this service a short message (180 characters) can be sent to a user. The message is stored in a Service Center (SC) and forwarded to the user when he is ready to receive. This is described in GSM recommendation 03.40 and 03.41.

These data services, except for the short message service, are described on general level and scenario level.

4.3 Data services in the interworking situation

Mobile data services are examined by looking to the potential market categories.

4.3.1 The GSM market for data services

Some potential market categories for data services are possible. A differentiation is made on the mobile character of a data service to find similarities within these categories.

1. **Data traffic with a strong mobile character**
   - International goods carriage
     Example: Information exchange about cargo, weather, traffic information and strike actions.
   - International business traffic
     Example: To have everywhere: information exchange with the company (hand on latest meeting news with Facsimile service), ask for stock market news on a database, et cetera.
   - Public motor traffic
     Example: car navigation systems or access to public databases (teletex) or Facsimile service.
   - Air traffic
     Example: Information exchange about control, weather or public possibilities to get information.
   - Railway traffic
     Example: Information exchange about time-reports, railway (connection), rail freight or public possibilities.
2. **Data traffic with a local mobile character**
   - Public services
     - Ambulance
       Example: Access to a Medical information database.
     - Fire brigade
     - Police
       Example: Access to databases for personal identification.
     - Taxi
       Example: Taxi-fleet management system.
     - Emergency service
   - Inland navigation
     Example: Ask for information about water level, locks, cargo through databases or to have data communication with a company.
   - Shopping centre or warehouse
     Example: A salesman for instance can check immediately whether the warehouse can supply his client's order and an extra printing attachment makes it possible for him presenting the invoice at the same time, providing an efficient and fast service.
   - Industrial park (local traffic)
     Example: Remote control, alarm systems or access to the data communication facilities on unusual work stations.

- Airport (local traffic)
  Example: Information exchange about planes, cargo and control.

3. **Data traffic from a fixed point or with a less mobile character**

   - Gas station
     Example (fixed point): On the end of a day, the turnover can be sent to the company or data terminal for public services.
   - Media (the press, TV)
     Example (less mobile): A news reporter, for instance, can type his story on the spot and transmit it instantly to his news desk, ensuring his company is first with the headlines.
   - Industrial traffic
     Fixed point terminals on important places, for instance outside a building on a work station.

4.4 Conclusions on data services

From Section 4.3.1, it is clear that the use of mobile radio for data services has many possibilities. A great part of all these services can be handled by the GSM system. Interworking with a PSPDN will be assumed because many data services are supported by this network and also many companies have already a network infrastructure based on a PSPDN. Only the nature of the service support within the GSM network imposes some limitations and constraints, already mentioned in Chapter 2.

The mobile data services mentioned in Section 4.2 are possible for the interworking situation. A further distinction is PAD access to a PSPDN or Packet mode service with an interworking unit. From Section 4.3.1 it is concluded that:

- Many mobile data services are based on accessing databases which are connected to PSPDNs, so many call set-ups will be MS originated. In those cases PAD access to a PSPDN will be sufficient. This solution for interworking (see also Section 5.2.1) is important to consider because PAD access is a cheap solution.

- If one wants to have full service compatibility (as far as possible) within GSM according to ISDN and PSPDNs it is necessary to have an interworking unit to support packet mode services. This is described in the following chapters.

Chapter 5

General interworking aspects between GSM and PSPDNs

This chapter gives an overview of the interworking possibilities between the mobile cellular communication system GSM and X.25 packet switched networks, like the Dutch Datanet 1. An introduction into numbering plan interworking and routing is also given to give insight in the problems these subjects can cause.

5.1 Introduction into interworking

The GSM system is a network, like ISDN, that provides end-to-end digital connectivity to support a wide range of services, including voice and non-voice services, to which users have access by a limited set of standard multi-purpose user network interfaces. In contrast, existing dedicated networks have always been developed for specific services. Therefore, especially in the initial phase, the GSM system may support data services which in principle are still observed in a dedicated network (PSPDN), but it is also preferable to support data services between two GSM subscribers or between a GSM subscriber and a ISDN subscriber. Thus, it is necessary to provide interworking between the GSM system and PSPDNs to allow data communication between terminals belonging to equivalent services offered through different networks.

InterWorking Functions (IWF) are needed between the two systems to cope with the different environments given by the various networks.

5.2 Interworking scenarios

An interworking scenario describes the general arrangements for interworking between different networks. GSM Recommendation 03.70 identifies various scenarios for connecting a GSM PLMN to a PSPDN. These scenarios are based on either a direct connection to a PSPDN or via a transit network (ISDN/PSTN). A

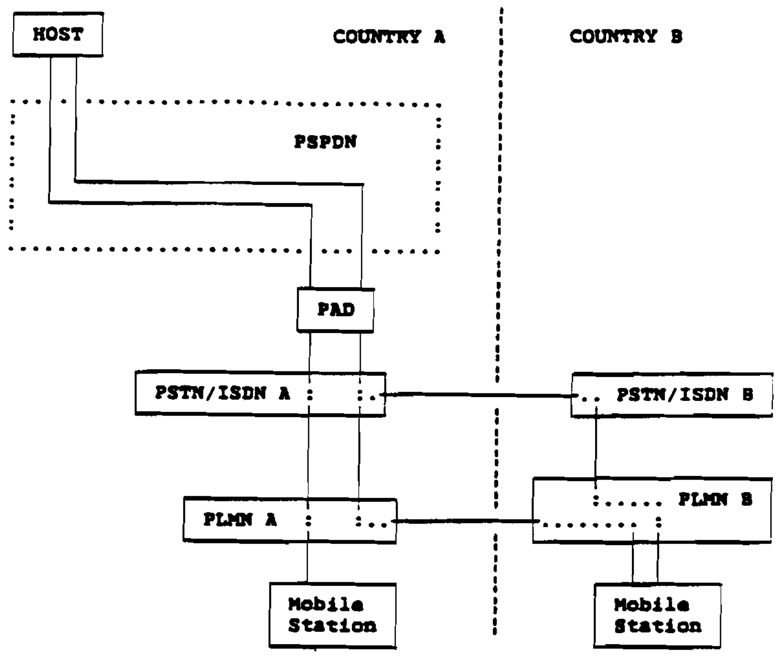


Figure 5.1: Packet service access by PAD

number of current standards are worth considering. The current standards within the ISDN/PSTN are the CCITT X.32 standard and X.31 case A. The standard for handling packet data in ISDN is still X.31 case A, but in future X.31 case B is recommended[1]. The scenarios identified in GSM Recommendation 03.70 are based on these standards.

In addition to these standards some other considerations are noticed. These considerations are identified in this report as mobile ISDN scenarios. These mobile ISDN scenarios are not fully described. However, an introduction is given to mention the main possibilities to reduce the limitations of the radio interface.

The various scenarios are briefly explained in this section.

5.2.1 Packet service access by PAD

In this case the user's terminal is a fairly simple one with an asynchronous access capability. The PAD performs the conversion from asynchronous characters to the X.25 packet format for onward routing of traffic in the PSPDN. For this type of service two networks with differing capabilities are involved in the call. First PSTN and ISDN, with its circuit switching type access and charging capability, and second PSPDN with its packet switching and time/volume related charging capability, see Figure 5.1.

It is only possible to make calls into the PAD from the PSTN/ISDN based customer. Calls are not possible from the PSPDN out towards the PSTN/ISDN.

[1] A development of a Packet Handler Interface (PHI) according to ETSI is based on the X.31 case B, see Chapter 6 of this report.

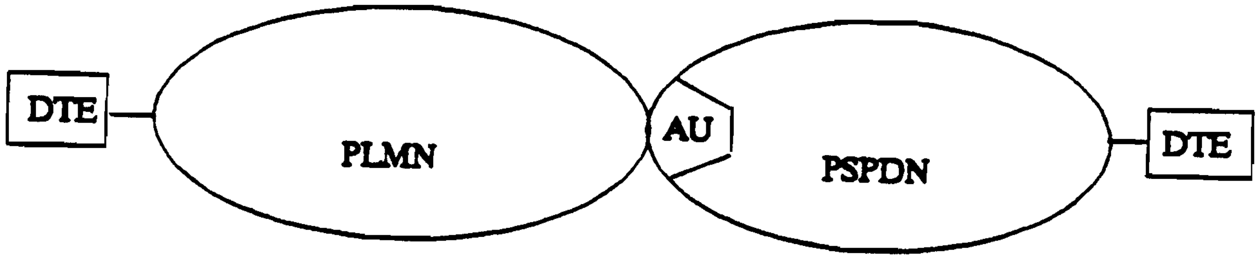


Figure 5.2: Direct interworking PLMN to Datanet 1, based on accessing PSPDN services (X.31 case A/X.32)

Two types of PAD access are examined:

1. **Basic PAD access**
   The basic PAD access refers to the use of existing PADs in PSPDN via one or more transit PSTN or ISDN networks. Call setup is done in two stages. First the PAD is addressed with a directory number (E.164 numbering plan[2]) and a circuit switched PSTN connection is established to the PAD. Secondly the called subscriber is addressed with an X.121 address which will be transmitted through the PAD.

2. **Dedicated PAD access**
   The dedicated PAD access refers to the use of a PAD whereby the mobile subscriber does not hold a NUI[3] on that PAD and it is accessed by means of a special short code. It is not accessed by a directory number as for the basic access.

5.2.2 Variation on CCITT X.31 Case A

A variation on circuit switched access to PSPDN services (X.31 case A) is possible, see Figure 5.2. In this scenario an access unit (AU) is considered to be part of the PSPDN (Datanet 1). Connection between the DTE and the AU is established through the MSC by means of a circuit switched path either on demand or permanently. In the case of the demand access the AU has an E.164/E.163 address and the terminal indicates this address in the initial call set up procedure. The network provides the necessary resources to establish the connection to the access unit. This connection may be initiated by the mobile station or the AU.

Additional terminal identification procedures to those required for the ISDN and PSTN may be necessary, particularly for charging purposes, because the AU

[2]Presently, this is still the E.163 numbering plan.
[3]Network User Identification

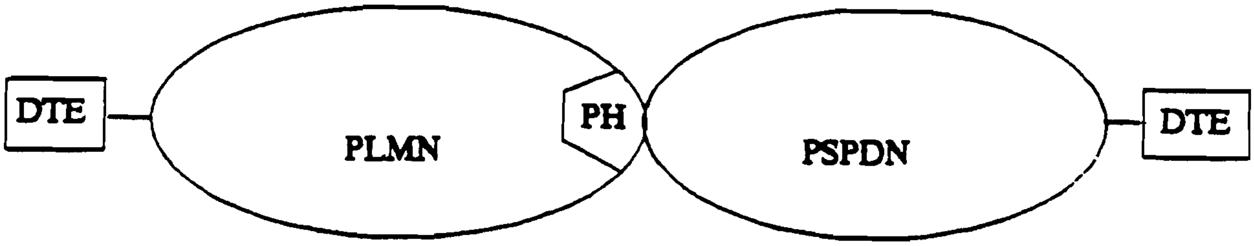


Figure 5.3: Direct interworking PLMN to Datanet 1 based on accessing ISDN Virtual Circuit Bearer Service (X.31 Case B), prerequisite is the availability of the PH according to X.31 Case B, allotted to the PLMN.

is the port to the 'additional' PSPDN service and common for both ISDN/PSTN and PLMN subscribers. To cater for this, Recommendation X.32 identifies a number of options to establish terminal identification. Once this terminal identification procedure has been successfully passed, the AU handles the X.25 procedures, whereas the 'own' numbering plan referred to in the CRP[4] is the X.121 one, and establishes the connection within the PSPDN. This two stage call setup is, as far as addressing is concerned, similar to the case of Basic PAD access.

5.2.3 Variation on CCITT X.31 Case B

This scenario, in its ISDN X.31 purity, considers the Packet Handler (PH) being part of the ISDN. Connection to this Packet Handler is provided and operated by the ISDN either on the B channel (64 kbit/s) or on the D channel (16 kbit/s). The PH does not have a unique address, but is identified by additional out-of-band signalling information. The PH is then able to pass information either to the PSPDN or to other ISDN terminals, dependent upon the subscriber number required. The internetwork protocol X.75 is used on the interface between the PH and the PSPDN.

This scenario is applicable for the interworking situation between GSM and PSPDNs, see Figure 5.3. The following characteristics are identified:

- In contrast to the two B channels on the S interface only one Bm channel can be used on the radio interface.
- Packet data on the D-channel (ISDN terminal) is mapped through a PLMN adaptation function on the Bm channel.
- Data rates are limited to 9.6 kbit/s.

[4]Call Request Packet

- Numbering plan interworking is necessary because of the different numbering plans used in GSM (CCITT E.164) and PSPDNs (CCITT X.121).

Some considerations are possible for the network operator and these considerations are also discussed in Chapter 6:

- Static or statistical multiplexing of data on the packet channels?
- In which part of the network will multiplexing be done?
- In the case of statistical multiplexing: Remote control of multiplexing by MSC will be needed and interworking must be possible with the PH.
- How will data terminals be supported? For example a standard terminal interface which can support ISDN terminals with a Terminal Adapter and specialized mobile data terminals.

Two types of case B are examined in GSM Recommendation 09.06:

5.2.3.1 Basic Packet Access

In this case the mobile subscriber accesses the packet service of that service provider to which he is individually registered, via the transit network of the home/visited GSM PLMN. This means that no Packet Function exists within the PLMN. The GSM PLMN shall use the Packet Function of ISDN, if present.

Furthermore, terminal identification procedures are limited to the availability of ISDN-type Virtual Circuit Bearer Service (VCBS), which entails out-of-band terminal identification, see GSM Recommendation 09.06.

The basic packet access will not further be discussed, because in GSM Recommendation 09.06 it is stated that the basic packet access for X.31 case B is limited to those PLMNs, where access to the ISDN-type VCBS is available and the mobile subscriber is registered to that service, so it is not possible to have a direct interworking situation with the PSPDN.

5.2.3.2 Dedicated Packet Access

In this case the PLMN provides the functionality of a PH. This PH may then be connected directly to a PSPDN, or via the ISDN/PSTN.

The important difference between this and the basic access, is that connection establishment and any necessary identification procedures outside the PLMN are invisible to the mobile subscriber. More details can be found in Chapter 6.

The advantage of this procedure to the mobile subscriber is that the service offered by the PLMN PH for the PSPDN access is completely compatible irrespective of the nature of the packet service in any transit or terminating network of the PLMN.

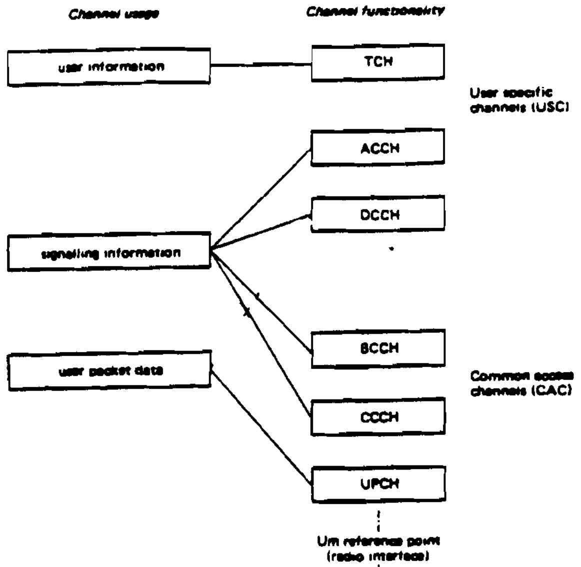


Figure 5.4: A User Packet Channel fitted in the existing channel structure.

In this report the dedicated packet access is elaborated, but with more possibilities. In GSM Recommendation 09.06 it is assumed that only a circuit switched connection to a PH is possible in the GSM system, but other possibilities exist as well, see Chapter 6.

5.2.4 Mobile ISDN scenarios

The mobile ISDN scenarios are other considerations to realize data communication in GSM with a capability to support more ISDN services. Compared with other scenarios there are no great differences in the interworking unit, like a Packet Handler, but most of the differences are located in the user-network interface. Since available radio spectrum is very limited, it is difficult to offer mobile ISDN service at a data rate of 144 kb/s (2B + D interface) or more. Instead, within the literature (see [6] and [16]) two approaches of a new radio channel structure are proposed:

1. **User Packet Channel (UPCH)**
   In this case an extension of the recommended GSM channel structure is suggested; a User Packet Channel which is a point-to-multipoint, bi-directional control channel, see also [6]. A UPCH is primarily intended to support user packet data. In particular, the UPCH is a common resource available to more than one MS within a specific geographic area. In this way the UPCH is managed and allocated based on specific random access techniques. It can be fit in the existing channel structure in the GSM recommendations, see Figure 5.4. On the UPCH the existing signalling protocols on the radio interface (described in the GSM recommendation) can be used for handling the transport of packet data. This solution is worth considering because it

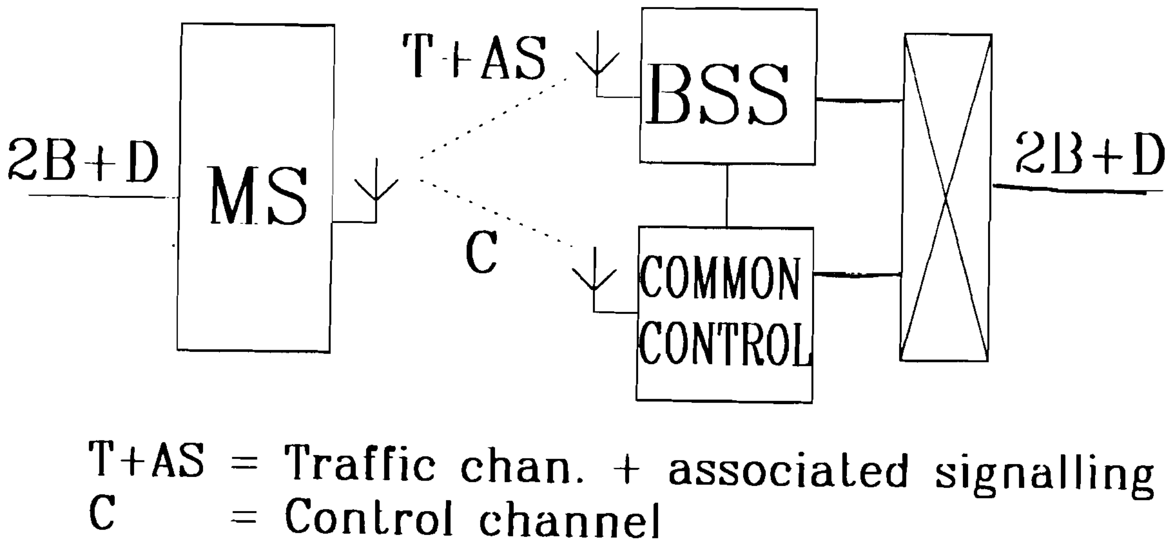


Figure 5.5: The GSM system as a mobile interface to ISDN.

can use existing protocols and it demands only a small modification of the existing channel structure.

2. **An ISDN-like structure**
   In this case a change in the existing channel structure is necessary, see [16]. The aim is to continue the '2B + D' channel structure of the S interface on the radio interface of the GSM system. This can be realized if different radio carriers are used for the common signalling channel and the user channel, see Figure 5.5. The consequence is that packet data traffic might also be handled by the common signalling system in GSM, like in ISDN (D-channel). The proposed channel structure, see Figure 5.5, is organized in such a way that on the network side of the base station the '2B + D' structure of the S interface is maintained. The result is that the GSM system has become a mobile interface to ISDN. Of course, special treatment for Mobility Management (MM), e.g., handover of location registration, and special treatment for Radio Transmission (RT) will be necessary.

   A description on general level can be found in [16]. A more detailed description has not been found in the literature.

5.2.5 Conclusions on interworking scenarios

Some conclusions can be made:

- **Existing scenarios**
  In the GSM recommendation several interworking scenarios are described on general level. These scenarios are all variations on PAD access, X.31 Case A or X.31 Case B.

- **Change of channel structure**
  It is necessary to extend or to change the existing channel structure of the radio interface if the premise is GSM services to be more compatibel with ISDN services.

- **Important considerations**
  Some considerations are noticed, i.e., for X.31 Case B, which are also discussed in chapter 6:

  - Static or statistical multiplexing within GSM?
  - How are data terminals supported, primarily ISDN terminals with a capability to support data services?
  - Numbering plan interworking is needed.

5.3 Numbering plan and Routing

This section is only an introduction of numbering plan interworking and routing. It is based on GSM Recommendation 03.70 which is a first attempt to describe numbering plan interworking and routing for the use in GSM. It is examined to give insight into the problems these subjects can cause, especially for the interworking scenario X.31 case B with a situation that ISDN and GSM use the same PH, see Chapter 6. The problems which are identified are not indicated in the GSM recommendation but can be found in the conclusions, see Section 5.3.4.

The GSM system uses another numbering plan then the one used in the PSPDN. If data communication is needed between terminals belonging to these systems, numbering plan interworking is necessary.

5.3.1 Numbering plan of GSM

The numbering plan of GSM is based on CCITT E.164. When developing the numbering plan of the GSM network some requirements were identified (see also GSM Recommendation 03.03):

1. It should be possible for any mobile station in a GSM PLMN to call any subscriber of the ISDN or PSTN.

2. It should be possible for any subscriber of the PSPDN to call any mobile station in a GSM PLMN or vice versa. This implies that it may be necessary for an MS to have an X.121 number.

3. It must be possible to change the IMSI[5], which is used for identification within the GSM system, without changing the ISDN number or X.121 number.

[5]International Mobile Subscriber Identity

```
[     CC     ]    [    NDC    ]    [     SN     ]
                 |National (significant)       >|
                 |<      mobile number
|<     Mobile station international            >|
               ISDN number
           - Number Structure
```

Figure 5.6: The structure of the mobile station international ISDN/PSTN number

4. The numbering plan should not limit the possibility for mobile stations to roam among GSM PLMNs.

5. To know where a mobile station is situated, interrogation with the databases HLR and VLR is necessary. This implies that the composition of the numbering plan should be such that it can be used within the Signalling System no.7 (SS no.7). The number must be used as a global title address in the Signalling Connection Control Part (SCCP) for routing messages to the databases, see also CCITT Recommendation E.213.

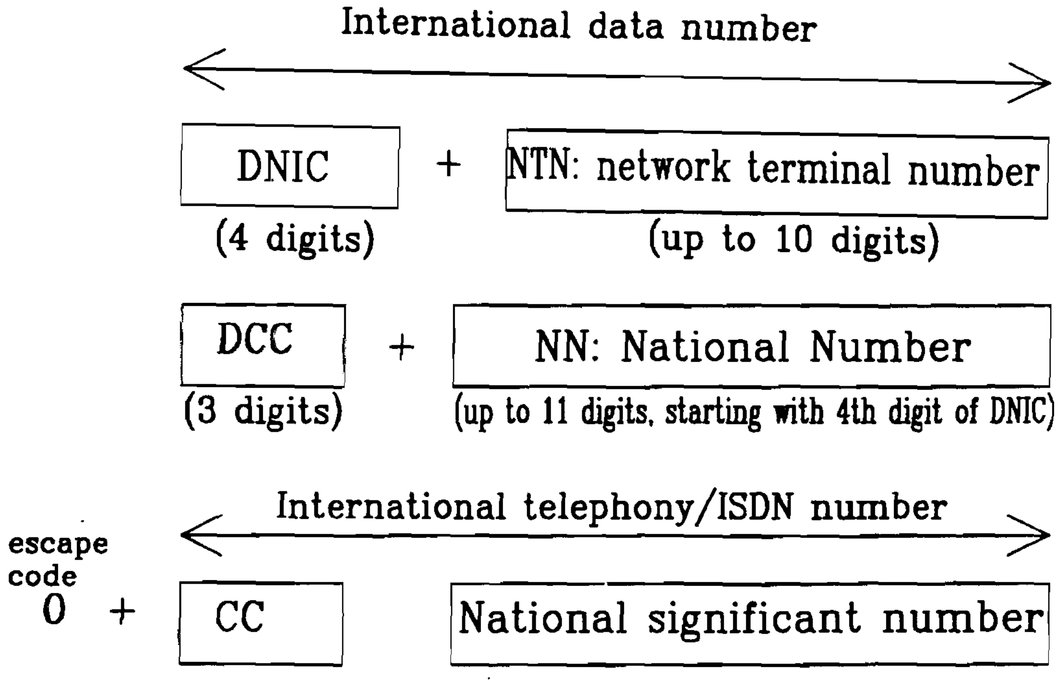
In the GSM system a numbering plan is chosen which complies with the ISDN numbering plan because it is better to have one uniform numbering plan than several different numbering plans. See Figure 5.6 for the structure of the numbering plan. It also satisfies the routing possibilities in the signalling system no.7. A specific ISDN number for the GSM system is called a Mobile Station International ISDN number (MSisdn). The number consists of:

- Country Code (CC) of the country in which the mobile station is registered, followed by

- National (significant) mobile number which consists of National Destination Code (NDC) and Subscriber Number (SN). In some countries more than one NDC may be required for each GSM PLMN.

5.3.2 Numbering plan of the PSPDN

The numbering plan of a PSPDN is described in CCITT recommendation X.121. It is intended to be used for public data networks. It is designed for international purposes and it has unique numbers on national level. It must also be possible to interwork with other numbering plans. See Figure 5.7 for the structure of the X.121 number. A data terminal on a public data network when called from



CC = Country code as defined by Rec. E.163/164
DCC = Data Country Code
DNIC = Data network identification code

Figure 5.7: The international X.121 number format

another country should be addressed by the international data number assigned to its DTE/DCE interface. The international data number should consist of the data network identification code (DNIC) of the called public data network, followed by the network terminal number (NTN) of the called DTE/DCE interface, or where an integrated numbering scheme exists within a country, the data country code (DCC) followed by the National Number (NN) of the called DTE/DCE interface. So there are two possibilities:

- International X.121 = DNIC + NTN or
- International X.121 = DCC + NN.

A part of the X.121 number does not belong to the international X.121 number, see Figure 5.7. This is called a prefix and it is used to allow the selection of different types of address formats. It is only used on national level, (i.e., to distinguish between national and international numbers). In Figure 5.7 an ISDN number is used as an example to show the use of a prefix.

5.3.3 Requirements for numbering plan interworking

The requirements for numbering plan interworking can be approached from two sides: PSPDN and GSM. It is assumed in this report only to look on international

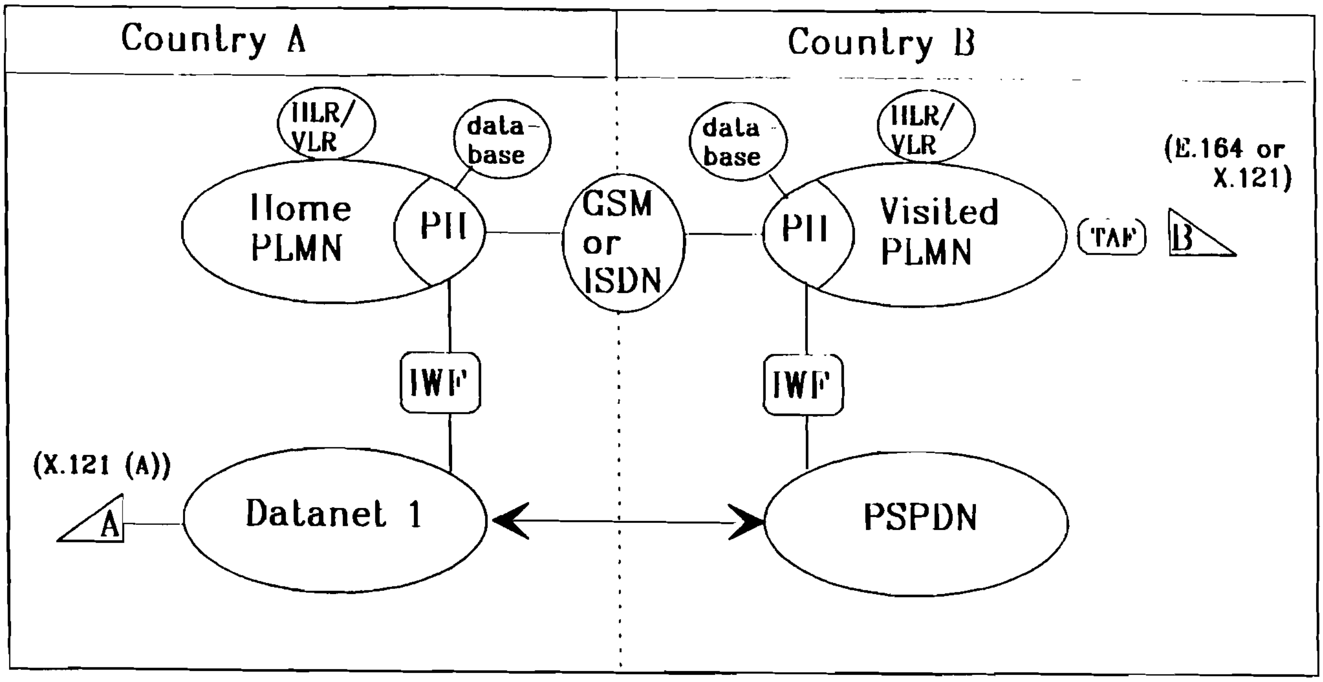


Figure 5.8: A sketch of the interworking situation GSM, ISDN and PSPDN

level because it is possible to roam in the GSM system and a GSM subscriber does not have to know where he is situated in Europe. If a GSM subscriber has an X.121 number in addition to the MSisdn number it is also assumed that this is an international X.121 number because of the same reasons, see above.

The interworking possibilities between the numbering plans, described in this section, are based on the Recommendations E.166, X.122, GSM Recommendation 03.70 and [13].

5.3.3.1 PSPDN originated and GSM terminated calls

In this case the following questions can be asked, see Figure 5.8 for a sketch of the interworking situation:

1. How to handle an international X.121 number which is given to a GSM subscriber?

2. How to handle an E.164 MSisdn number?

3. How to distinguish MSisdn numbers from ISDN numbers?

4. How to route a data call to a foreign GSM subscriber?

GSM Recommendation 03.70 identifies some ways to handle different numbering plans (other than X.121), see Figure 5.9. Two possibilities which can be used for X.31 case B are given.

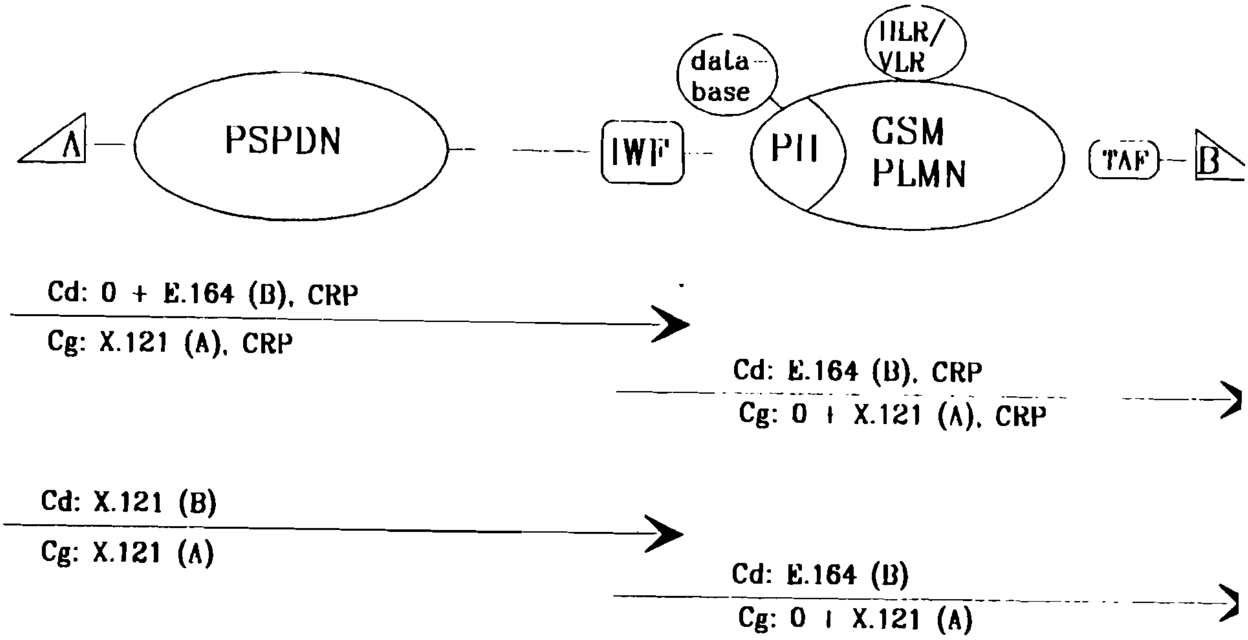


Figure 5.9: Two ways how to realize interworking between the X.121 and the E.164 numbering plan (PSPDN originated call set up).

1. **Escape codes**
   An escape code is an indicator consisting of one digit. It indicates that the following digits are a number from a different numbering plan. The escape code has to be carried forward through the originating network and can be carried across internetwork and international boundaries. The escape code is a part of the international data number, see Figure 5.7. The '0' indicates that the digits which follow belong to the E.164 numbering plan and that a digital interface between the data network and the destination network (GSM or ISDN) is requested. The Interworking Function (IWF), which can be situated in the PH, will take care of the removal of the escape code. If a GSM subscriber has an X.121 number then the IWF might search into a list to look for the E.164 number which belong to the X.121 number, so the call can be routed in GSM to the called subscriber. The IWF might also transform the X.121 number into an E.164 number. This implies that the X.121 numbering plan should best be a part of the E.164 numbering plan.

   In Recommendation E.165 it is determined that the use of an escape code can only be used until 1997.

2. **Escape code with additional number analysis**
   The PSPDN handles the E.164 numbers on the basis of the CCITT defined concept of escape codes, but it is suggested in GSM Recommendation 03.70 that the PSPDN is also capable of analyzing up to the first six digits for routing. These six digits contain the information: escape code, country

code and a part of the national destination code of the national mobile number. Calls are routed from the PSPDN to the PLMN after analysis of the six digits indicating that the call is for a mobile subscriber.

The question how to route a data call to a foreign GSM subscriber can be answered if one realizes that the nature of the call is an X.25 data call. This means that it is better to remain as long as possible in the PSPDN than to take the nearest PH and route the call in the GSM system. However, a GSM subscriber can roam, so the PSPDN needs some 'location' information of the GSM subscriber. This information is found in the HLR or VLR of GSM. The procedure to interrogate these databases to get the location information will be for further study.

ISDN and GSM use the same numbering plan (E.164). If they also use the same PH[6], then it is necessary for the PH to distinguish between these systems[7] and their part of the numbering plan. This may cause a problem if each country develops his own mobile numbering scheme. The PH must, in that case, know all these schemes, because a GSM subscriber can roam. It would be preferable to develop one unique solution (for Europe) to distinguish between GSM and ISDN.

5.3.3.2 GSM originated and PSPDN terminated calls

In this case the following questions can be asked, see again Figure 5.8 for a sketch of the interworking situation:

1. How to route a call to a foreign PSPDN subscriber (international X.121 number)?

2. When will routing take place: before setting up a signalling link to a PH or after setting up a signalling link to the nearest PH? This PH now decides how to progress the routing of the call.

An existing solution is identified for X.31 case B to handle interworking between the numbering plans, see Figure 5.10. GSM will be able to determine that a connection needs to be established to a PSPDN by analysis of the bearer capability = 'packet' in the call set up message[8]. An escape code is inserted by the IWF for the calling address to indicate in a PSPDN an E.164 number is used.

Some routing possibilities exist, it depends on the called number in the X.25 Call Request Packet (CRP):

1. **An international X.121 number (PSPDN subscriber)**:
   It is assumed in this report only to use international X.121 numbers because a GSM subscriber can roam. Now some situations exist:

[6]For example: the ETSI PHI implementation in this report, see Chapter 6.

[7]The PH wants to set up a channel to a MSC (GSM) or to an ISDN exchange.

[8]This applies for CCITT X.31 case B, see Chapter 6.

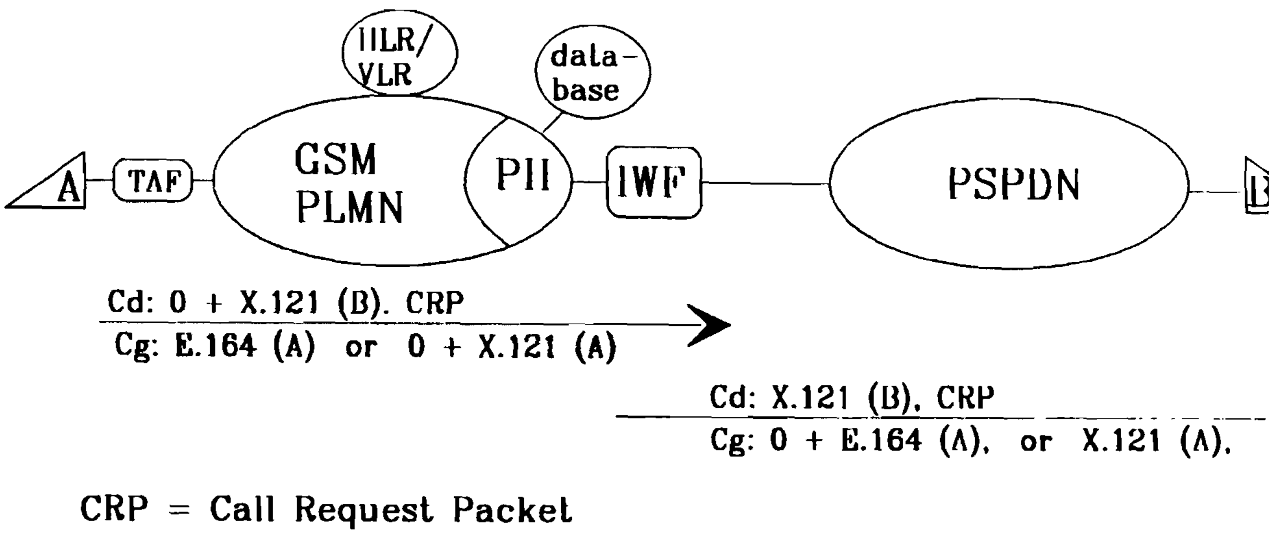


Figure 5.10: The escape code as a solution to realize interworking between the E.164 and the X.121 numbering plan (GSM originated call set up).

- **Registration for using a PSPDN by a GSM subscriber is performed in a database of the PH**
  This situation must be avoided because a GSM subscriber can roam and it is almost impossible to perform registration in each PH. To avoid a situation that a foreign PSPDN cannot be used, see the following situation.
- **GSM subscriber may have a standard access to a PSPDN**
  The PH could take a standard user profile if the called subscriber is not registered in the PH, and will sent the call along with this information to the PSPDN. This requires that the PSPDN must recognize the international X.121 address. This requires also that the PSPDN must have agreements with GSM that the status of an authorized PLMN GSM subscriber is supported within the administration of the PSPDN. This will be a good solution because the nature of the call is a X.25 packet call.

2. **An X.121 number of a GSM subscriber**:
   If it is allowed to have an X.121 number in addition to the E.164 number, no terminated PSPDN call exists, but a GSM originated GSM terminated call, see Section 5.3.3.1.

3. **an E.164 number**:
   This is not a PSPDN terminated call, but a GSM originated and GSM or ISDN terminated call. The PH recognizes that this is a GSM or ISDN packet subscriber number and will send a SETUP message back to the GMSC with the E.164 number, if this number is a mobile Station ISDN

number, used in the GSM system. This assumes that it must be possible to distinguish the GSM numbers from the ISDN numbers. It would be preferable to have one unique solution for the whole of Europe.

5.3.4 Conclusions on numbering plan interworking and routing

- **GSM numbering plan**
  The numbering plan of GSM is based on E.164. The E.164 numbers are called Mobile Station ISDN (MSisdn) numbers. It may be necessary to give an X.121 number in addition to a MSisdn number.

- **Uniform solution to distinguish between ISDN and GSM**
  It is preferable to have one unique solution to distinguish between ISDN and GSM numbers. A shared PH for ISDN and GSM means that a PH must determine which E.164 number is a GSM or an ISDN number. An unique solution for the whole of Europe avoids that a PH must know all the national solutions.

- **Interworking function needed**
  An interworking function is needed (e.g., situated in a PH) if in addition to the E.164 number an X.121 number is used for a GSM subscriber. This function must translate the GSM X.121 number into a Mobile Station ISDN number (E.164). The easiest translation will be possible if the X.121 numbering plan is a part of the E.164 numbering plan.

- **Routing with the use of PSPDN**
  It is preferable for a data call in GSM to remain as long as possible in PSPDN because the nature of the call is an X.25 connection. As an example, a PSPDN originated international call for a GSM subscriber could better be routed within PSPDNs until the GSM PLMN is reached in which the called GSM subscriber is situated. This implies that the PSPDN needs some location information of the GSM subscriber. This information is found in the databases of GSM (HLR and VLR). A procedure to interrogate these databases is for further study.

Chapter 6

The ETSI PHI implementation of X.31 case B within GSM

In Chapter 5 some interworking scenarios were given. It was indicated that a variation on the CCITT X.31 case B would be elaborated, this is realized in this chapter.

The ETSI PHI was developed as the solution for X.31 case B, thus providing packet mode services in ISDN, see [8]. In this chapter it is shown how the ETSI PHI can be used in the GSM environment, especially the functions which are needed. Furthermore, it is shown how an existing ISDN terminal for X.31 case B services can be connected to a GSM mobile station thus providing an access to the GSM packet mode service.

Additional reasons for studying the ETSI PHI implementation of the GSM X.31 case B variant are:

- If the ETSI PHI implementation can be used within GSM, it will be another argument to recommend the ETSI PHI.
- It is possible to use existing PSPDNs which is preferable, because in many companies PSPDN operators have made investments in X.25 network elements.
- GSM and ISDN can use the same PH, so it is possible for data communication to have a direct connection between GSM and ISDN.
- It is possible with the ETSI PHI to use a remote access model, see Section 6.2.3.

First, a brief description of the ETSI PHI will be given (architecture and functional model). Secondly, two models of the ETSI PHI implemented in the GSM system are proposed. Several functional elements are proposed in this section to handle the X.31 case B services, e.g. a GSM-FH (GSM Frame Handler) and a RCMU (Remote Controlled Multiplexing Unit). Finally, some 'problems' are discussed: access of the X.31 case B services and multiplexing in GSM.

The procedures which are needed (e.g. call control) for the X.31 case B variant are described in Chapter 7.

6.1 Interworking network architecture GSM, ISDN and the ETSI PHI

The network architecture is the physical framework to offer services to the subscribers of that network. Figure 6.1 gives an interworking situation between GSM, ISDN/PSTN and PSPDN (Datanet 1). This figure reflects the case that ISDN and GSM use the same ETSI PHI to implement X.31 Case B. An advantage, which can be concluded out of this figure, is that it is possible to set up a direct data connection between GSM and ISDN via the ETSI PHI.

The ETSI PHI implementation is described in the following sections.

6.2 The functional model of the ETSI PHI

Two functional models of the ETSI PHI for GSM are proposed in this section, but first an introduction of the ETSI PHI is given.

6.2.1 The functional model of the ETSI PHI for ISDN

The ETSI PHI describes the interface between ISDN and PSPDN for the provision of packet mode services. Figure 6.2 gives a reference configuration for the Case B implementation with the PHI in ISDN. Some definitions in this figure are:

- The Connection Related Functions (CRF):
  The functional abstraction of the circuit switched part of ISDN.
- The Packet Handler (PH):
  The functional abstraction of the packet switched part of ISDN.

These functional abstractions contain the following functions, see Figure 6.3:

- Frame Handler (FH): Layer 2 functionality for multiplexing subscriber D-channel links used for packet mode services (SAPI[1] = 16) onto channels of the PHI.
- PHI signalling: Signalling functionality across the PHI. This includes call control and interface management functions.

[1]Service Access Point Identifier

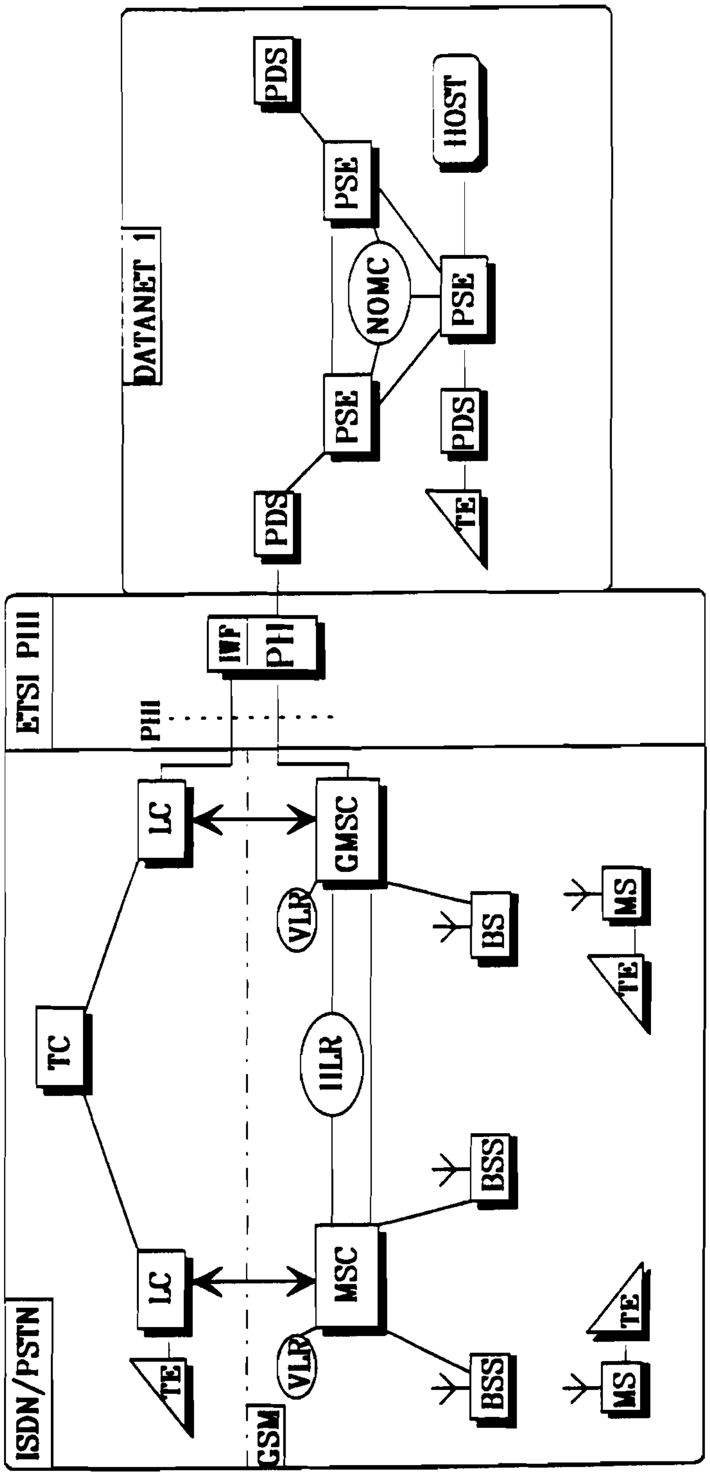
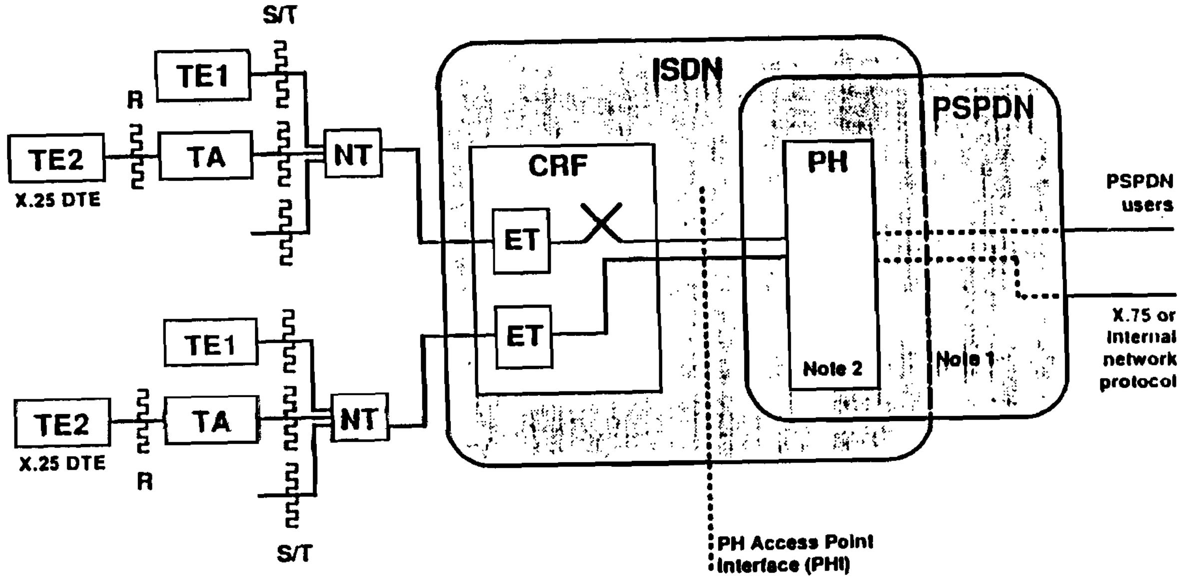


Figure 6.1: Interworking network architecture with the ETSI PHI.



NOTE 1 : If X.75 is chosen as the protocol between PH and PSPDN, the PSPDN does not extend into the ISDN. If, on the other hand, an internal network protocol is used between the PH and the PSPDN and the packet switching part of the ISDN may be viewed as a single entity.

NOTE 2 : In the case that the PHI supports Case A services in addition to Case B, the PH assumes the role of the access unit (AU).

NOTE 3 : The user arrangement shown in this figure is only an example. For other possibilities refer to prETS 300 007.

Figure 6.2: The reference configuration of the case B implementation with the PHI in ISDN

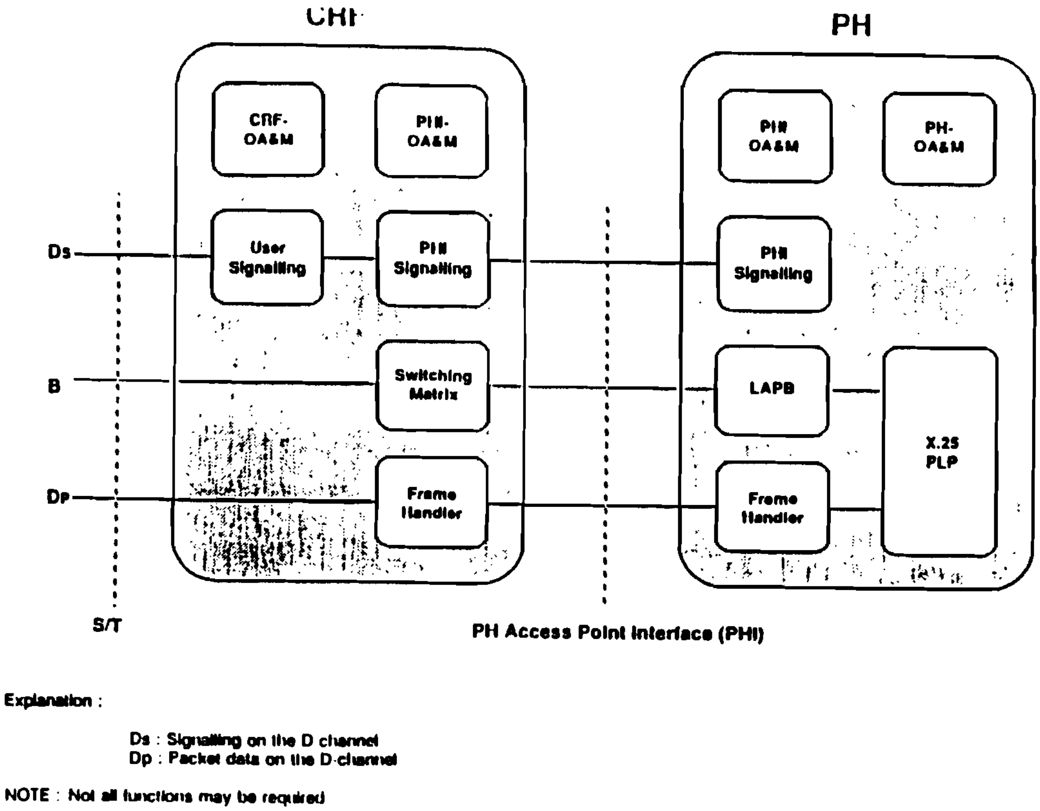


Figure 6.3: A Basic functional model for the PHI within ISDN.

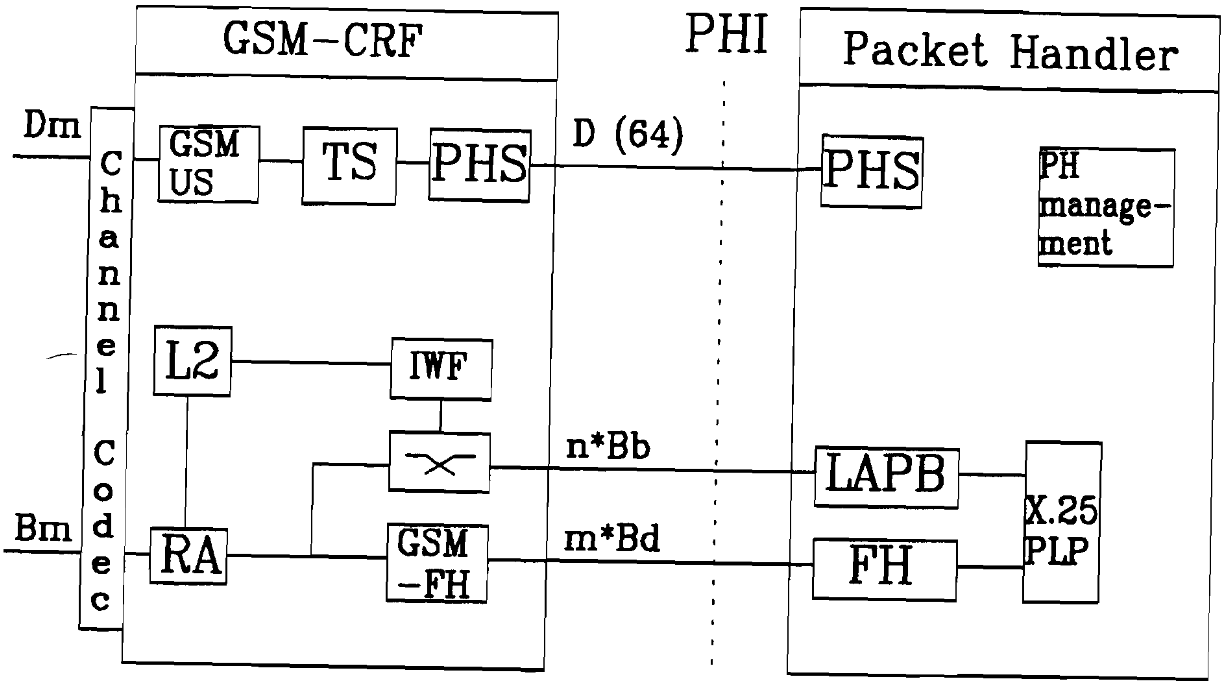
- Switching Matrix: Circuit switching capability of the local exchange, being used primarily for connecting subscriber B channels used for packet mode services. But it is also involved in the support of D-channel services.
- CRF related OA&M[2] functions: OA&M functionality related to the subscriber connection (e.g., administration of user profile data related to the connection and to circuit switching services).
- PHI OA&M: OA&M functionality related to the PHI.
- PH related OA&M functions: OA&M functionality related to packet switching services (e.g., administration of user profile data related to packet switching services).

In the next sections, this basic functional model is used for handling packet services in the GSM system.

6.2.2 A basic functional model for the GSM system

Figure 6.4 gives a basic functional model for the GSM system to use the ETSI PHI. In this figure some other functional blocks are visualized which are not part

[2]Operation, Administration and Maintenance



TS = Transit Signalling
PHS = PHI signalling
FH = Frame Handler

Figure 6.4: A basic functional model for the GSM system to use the ETSI PHI.

of the basic model of the ETSI PHI:

- **GSM-FH:** It is proposed in this report to use a GSM Frame Handler, see Section 6.3.1.3. This FH has the functionality to multiplex packet data of several Bm channels (radio interface) to a Bd channel which is used on the PHI and vice versa.

- **Rate Adaptation:** It shall be necessary to have Rate Adaptation functionality to handle the various rates within the GSM. More details can be found in Section 6.5.1.1.

- **L2:** As outlined earlier, the GSM radio interface may cause excessive error rates, or short term breaks during handover. The normally used Forward Error Correction (FEC) provides considerable improvement to the average bit error rate, but cannot always reduce it to acceptable levels. A Layer 2 functional block is needed to overcome the data errors which cannot be corrected by the FEC. A feature of FEC is that no possibilities exist for retransmission of data if an error occurs which the FEC cannot detect. In that case the connection is called transparent. If the L2 block is used the connection is called non-transparent, according to the definitions of the GSM recommendations.

If the Layer 2 functionality is used then it is proposed in this report to introduce an Interworking function (IWF) which can convert the Layer 2 protocol into the LAPB protocol and vice versa. More details can be found in Section 6.3.1.2.

- **GSM User Signalling (GSM US):** Signalling functionality within GSM needed for call control and management functions, e.g. the management of mobile functions in GSM. More details of signalling can be found in Chapter 7.

- **Packet Handler Signalling (PHS):** Signalling functionality across the PHI. This includes call control and interface management functions. A mapping possibility must exist from Transit Signalling[3] (TS) to PHS and vice versa.

6.2.3 A Remote access model for GSM

The basic model for GSM gives no answers to the question where all the functional blocks are situated within GSM, the PH included. The remote access model is more detailed. In this model it is assumed that there is no need to have a PH connected to each MSC because the traffic density may vary in different areas. The MSCs which have a PHI will be called Gateway MSCs (GMSC). Other MSCs will have a switched connection to a GMSC and use a channel on the PHI, see Figure 6.5.

A connection between a Bm channel (radio interface) and a Bb channel (PHI) will now use a terrestrial (64 kbit/s) channel between the MSC and the GMSC. So there will be a need for additional transit ('SS7') signalling.

The remote access model gives an answer to the question where a PH is situated, but not to the question where exactly a functional block in the GSM system is situated. The following section, which handles the Case B service, will give some answers to this question.

6.3 The implementation of X.31 Case B services

In this section a variant of the X.31 Case B service is described for the GSM system with the ETSI PHI. This will be done with an increasing level of complexity. The implementation of the X.31 case B service in GSM is described in accordance with the ETSI PHI recommendation. This means that functions which are needed in GSM to support the X.31 case B service are similar with the functions described in the ETSI PHI recommendation, see [8].

[3] Signalling System no.7 (SS7).

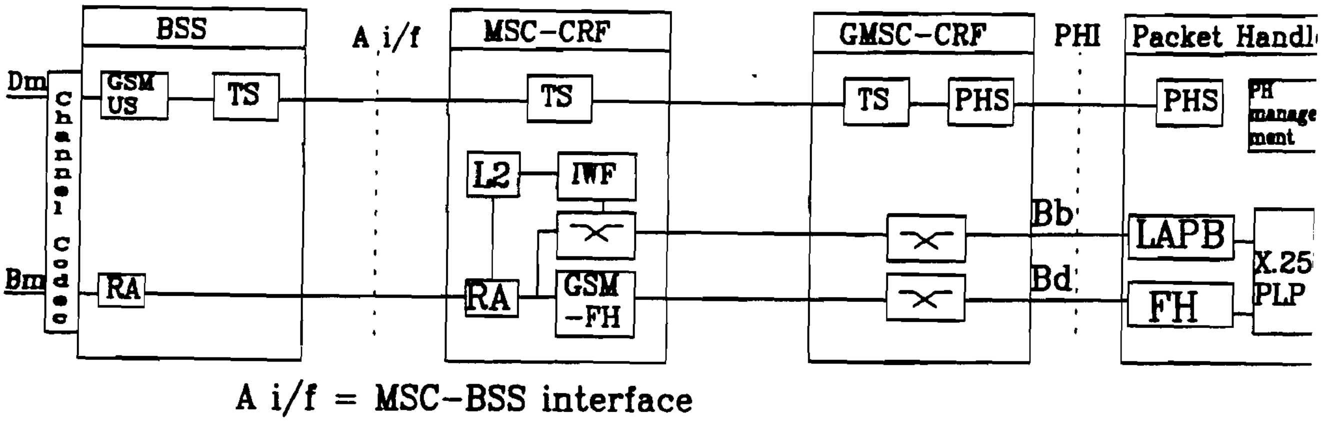


Figure 6.5: Access to a PH, according to the remote access model.

6.3.1 X.31 case B services within GSM

In the GSM recommendation it is outlined that an ISDN terminal with a packet mode capability must be one of the possibilities to access the GSM system, see also Section 6.4. This means that one can request a packet service via the D channel for handling packet data on a B or a D channel, according to X.31 case B. This is called B channel service when a B channel is used on the user network interface (S interface) and D channel service when a D channel is used on the S interface. The aim is to offer these services also in GSM. Three conclusions can now already be made:

1. A first conclusion can be made out of the preceding chapters: the D channel service cannot be offered in GSM. The reasons for this conclusion can be found on the user network interface (radio interface) of GSM:

   - It is not possible to use the Dm channel of the radio interface for X.25 packet data, so a Bm channel must be used. This means that the packet data on the D channel must be mapped on a fixed traffic channel (Bm channel). As a consequence, if a subscriber wants a packet mode bearer service and his ISDN terminal is trying to set up for this purpose a special layer 2 (SAPI = 16) connection to the PH on the D channel, this action must be transformed in the mobile station to a Bm channel request (bearer capability = packet), see Section 6.4 for more information.

- It is not possible to have two connections[4] on the radio interface at the same moment, e.g. a channel used for speech and a channel used for data, because only one Bm channel can be set up by a subscriber.
- A D channel in ISDN is always available, but a Bm channel on the radio interface in the GSM system is not always available, because of the characteristics of the radio interface, see Chapter 2.

As a consequence, no advantages of having a D channel access to the packet service exist anymore.

2. A second conclusion is also related to the radio interface. The error performance of the packet service in the GSM system is poor in contrast to the desired error performance in the PSPDN, because of the radio transmission. A Layer 2 function is needed in the GSM system to overcome this poor error performance. So, a distinction can be made between a transparent Bm channel service and a non-transparent Bm channel service.

3. A third conclusion can be made by looking to the PHI. On this interface two channels are possible for data: a Bb channel and a Bd channel. A Bb channel can be compared with an ISDN B channel. A Bd channel is used for statistical multiplexing of data links. So, it is possible to use this Bd channel if GSM supports statistical multiplexing. An advantage of this multiplexing is the more optimal use of channel capacity.

Summarizing, the following X.31 case B services can be offered in GSM: *B channel* or *D channel* used on the S interface for packet data with,

- *transparent Bm channel* transport in GSM to a GMSC and a Bb channel on the PHI to the PH or,
- *non-transparent Bm channel* transport in GSM to a GMSC and a Bb channel on the PHI to the PH or,
- (non-)transparent Bm channel on the radio interface and *statistical multiplexing* on a Bd channel to the PH.

The access of the X.31 case B services on the S interface is described in Section 6.4 and the service possibilities of X.31 case B in GSM are further described in the following sections.

[4]Note, that more tan one X.25 connection will be possible over the Bm channel.

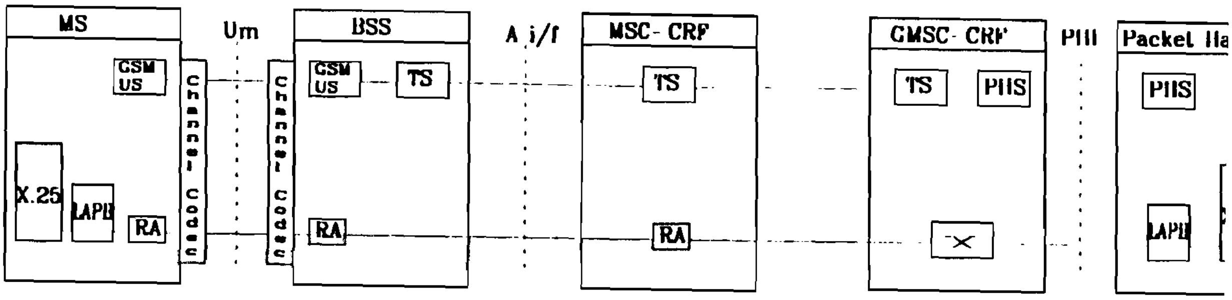


Figure 6.6: Case B with a transparent Bm channel transport to a PH.

6.3.1.1 Transparent Bm channel transport to PH

Offering this service in the GSM system means that packet data on the B or D channel must be mapped on a Bm channel (radio interface). On the network side of the Base Station data on the Bm channel is mapped on a terrestrial channel towards the MSC and GMSC. The GMSC maps the packet data on a Bb channel of the PHI, see Figure 6.6 for the case a **B channel** is used on the S interface.

This figure visualizes the easiest way (for the network manager) to handle the Case B service. A subscriber uses a B channel for packet mode service. In the GSM system a Bm channel on the radio interface will be used. Only Forward Error Correction (FEC) and rate adaptation functions for flow control of data traffic are used.

The disadvantage of this minimal Case B service is that as a result of shadowing or handover (poor radio conditions), burst of errors[5] may significantly degrade the service.

6.3.1.2 Non-transparent Bm channel transport to PH

In addition to the Bm channel transport a solution exists to upgrade the poor error performance. This could be provided by a specifically designed Layer 2 link protocol (L2), see Figure 6.7 for the added functionality (a B channel is used on the S interface). The L2 consists of two parts: the radio link protocol and the layer 2 relay function.

The Radio Link Protocol function (RLP) performs grouping of user data for the purpose of implementing error control and retransmission mechanisms in the case of non-transparent low layer capabilities, see GSM Recommendation 04.22.

The Layer 2 Relay function (L2R or L2RBOP[6]) performs protocol conversion

[5] FEC cannot correct burst of errors.

[6] L2R Bit Oriented Protocol

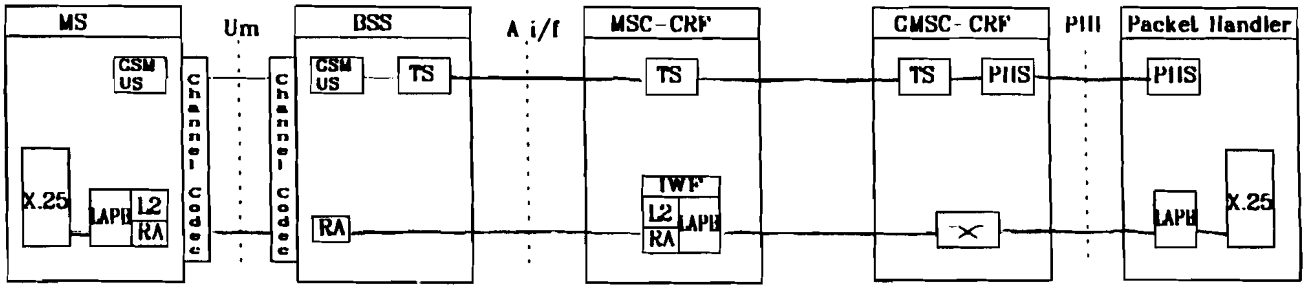


Figure 6.7: Case B with a non-transparent Bm channel transport to a PH.

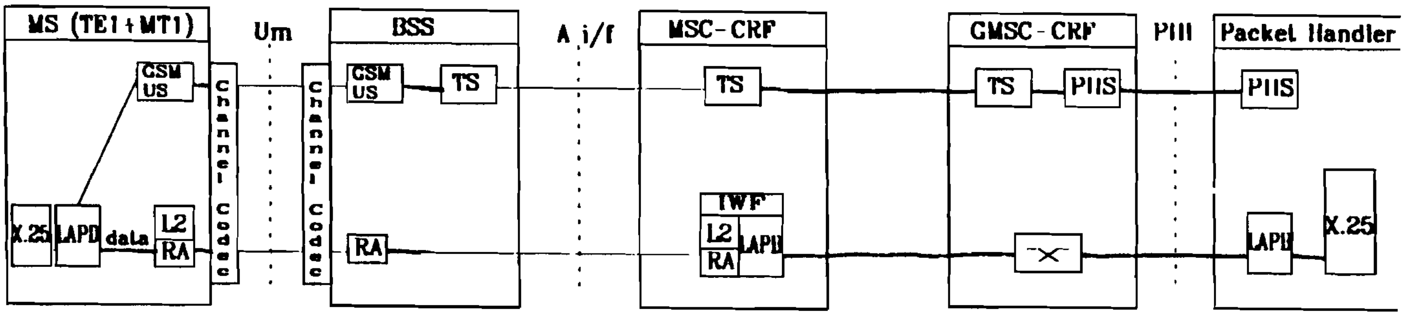


Figure 6.8: B channel service (non-transparent case) in GSM with a D channel used on the S interface.

between the user data structure (e.g., X.25 layer 2 frames) and a structure more adapted to the radio link protocol, see GSM Recommendation 07.03.

To implement this special layer 2 protocol, the MS (TE1 + MT1) must convert the LAPB protocol of X.25 into the layer 2 protocol and vice versa. Furthermore it is important to have an InterWorking Function (IWF) in the MSC to convert the special layer 2 link protocol back to LAPB which is used on the Bb channels of the PHI.

If a D channel is used for packet data on the S interface the MS must convert the LAPD protocol to the layer 2 protocol. This is presented in Figure 6.8. The Layer 2 relay function (part of the special layer 2 protocol) is designed to convert LAPB messages, so LAPD parameters must correspond with LAPB parameters.

The LAPD protocol is converted, through the special layer 2 protocol, to the LAPB protocol, see also Figure 6.8. This conversion is possible if one takes special care for the parameters in those protocols:

- **Frame size**
  The LAPB protocol does not have segmentation capabilities, so the LAPB frame size approaches[7] the packet size of the X.25 PLP[8]. The default maximum frame size is 128 octets, but can be ranged from 16 octets to 4096 octets. In the LAPD (Q.921) protocol the maximum frame size is 260 octets. So the frame size in the LAPB protocol can not be larger than 260 octets.

- **Address size**
  The LAPD address, used on the D channel, is the DLCI and consists out of a SAPI and a TEI[9]. The DLCI has a length of 2 octets, one for the SAPI and one for the TEI. In the normal case it is possible to have more than one Q.921 data link at the same moment.

  The X.25 LAPB address, used on the PHI, has a length of one octet, because there is only one data link possible which is only used for packet data, so there is no need for a SAPI.

  It is clear that, because of the LAPB protocol, only one data link can exist at the same moment. The Interworking Unit in the MSC must take care of the mapping of the data link addresses.

- **Window size**
  The default window size of the LAPD protocol is 2. The window size of the X.25 LAPB protocol can range from 1 and 7. The window size can be established on each interface.

6.3.1.3 Bm channel and statistical multiplexing of data towards the PH

A more general approach of multiplexing (statical or statistical) can be found in Section 6.5, but in this section it is proposed to implement a GSM- FH to perform statistical multiplexing of data links in GSM, see Figure 6.9.

Now the Interworking Function in the MSC is replaced by a GSM-FH. This FH must perform a translation of the special layer 2 protocol to a special Q.921* (LAPD*) link, which is used on the PHI. This Q.921* protocol is specially made for use on the Bd channels of the PHI. It is an extension of the LAPD protocol (Q.921). The Q.921* protocol normally multiplexes D channel packet data of different subscribers onto a Bd channel towards the PH. It also performs additional PHI signalling to exchange information (inband signalling) before a Q.921* link is set up. This information is:

[7] X.25 PLP frame size + LAPB overhead = LAPB frame size

[8] X.25 Packet Level Protocol (layer 3).

[9] Terminal Endpoint Identifier

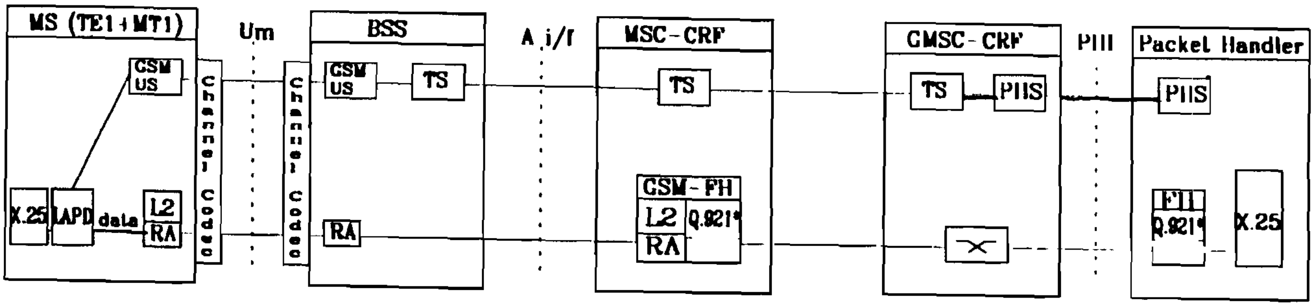


Figure 6.9: Statistical multiplexing in GSM.

- The DLCI which is selected by the MSC-CRF. Each data link on the Bd channel of the PHI is identified by a data link address. This Data Link Connection Identifier (DLCI) must be agreed on between the PH and the MSC- CRF.
- A selected Bd channel by the PH.

The reason for this exchange is that the Bd channel to be used is determined by the PH but the DLCI to be used on that Bd channel is determined by the Bd link management in the MSC-CRF (thus at the other side of the PHI). Before a data link can be established the information must be exchanged for which an extra signalling procedure is used. This extra signalling procedure is used to transfer the desired information via the special Q.921* link.

6.3.2 Conclusions on X.31 case B services within GSM

It is concluded that the D channel service is not possible. The B channel service is possible with three categories:

1. **Transparent Bm channel in GSM**
   This implementation provides a minimal service. This service can only be a service with a less mobile character, because burst of errors cannot be detected and corrected on the radio radio interface.

2. **Non-transparent Bm channel in GSM**
   This is a better implementation of the B channel service, due to the additional error correction on the radio interface. This error correction is performed by a special layer 2 protocol. An interworking function is needed in the MSC to convert this special layer 2 protocol on the radio interface to the LAPB protocol on the PHI and vice versa.

3. **Statistical multiplexing in GSM**
   This implementation delivers no improved service, compared with the non-transparent case of GSM, towards the users. It is only an improvement from a point of view of the network manager because channel capacity is more optimally used. A penalty is paid in complexity because a GSM-FH is needed to multiplex data links on Bd channels of the PHI.

Access of these X.31 case B services is handled in the following section. A general approach to implement multiplexing functions in GSM is handled in Section 6.5.

6.4 Access of X.31 case B services in GSM

In the following sections one can find some more details about network elements which are needed for accessing the X.31 case B services in GSM. First the access reference configuration is described. Secondly the terminal equipment and terminal interfaces are introduced. Finally the Call Control Adaptation Unit is introduced.

6.4.1 Functional description of the access reference configuration

The GSM PLMN supports a wide range of voice and non-voice services in the same network. In order to enable non-voice traffic in the GSM PLMN there is a need to connect various kinds of terminal equipment to the Mobile Termination (MT). Figure 6.10 presents the reference configuration for access to a GSM PLMN (see also GSM 04.02).

Recommendation CCITT Q.1061 and Q.1062 emphasize that a digital PLMN supports the same wide range of service capabilities as the ISDN concept and that the digital PLMN user-network interface should provide flexibility for separate user terminal evolution and PLMN technology evolution. These recommendations define the mobile ISDN user network interface function as having four functional entities: radio frequency transmission management (RT), mobility management (MM), PLMN call control adaptation and ISDN call control, as shown in Figure 6.11. These functional entities are briefly described:

- **Radio Transmission (RT):** RT includes functions required to provide radio subscriber lines. These functions include layer 3 functions such as channel allocation controls, and layer 1 functions such as selecting the channel coding and controlling transmitter power.

- **Mobility** MM has functions for supporting the mobility of the user terminals in the GSM system, such as location updating, handover and user authentication.

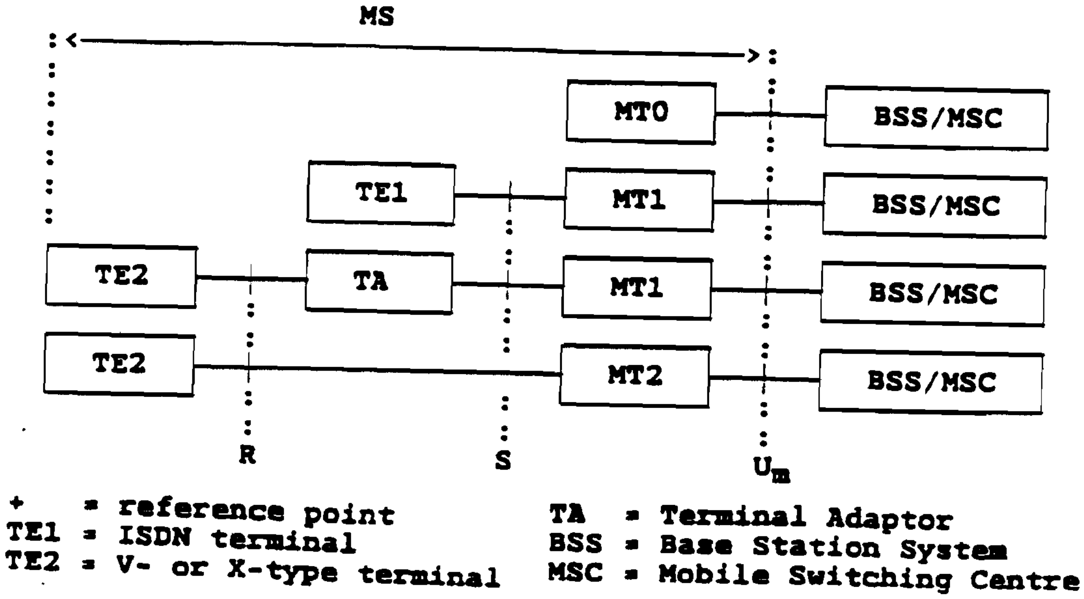


Figure 6.10: GSM PLMN Access Reference Configuration.

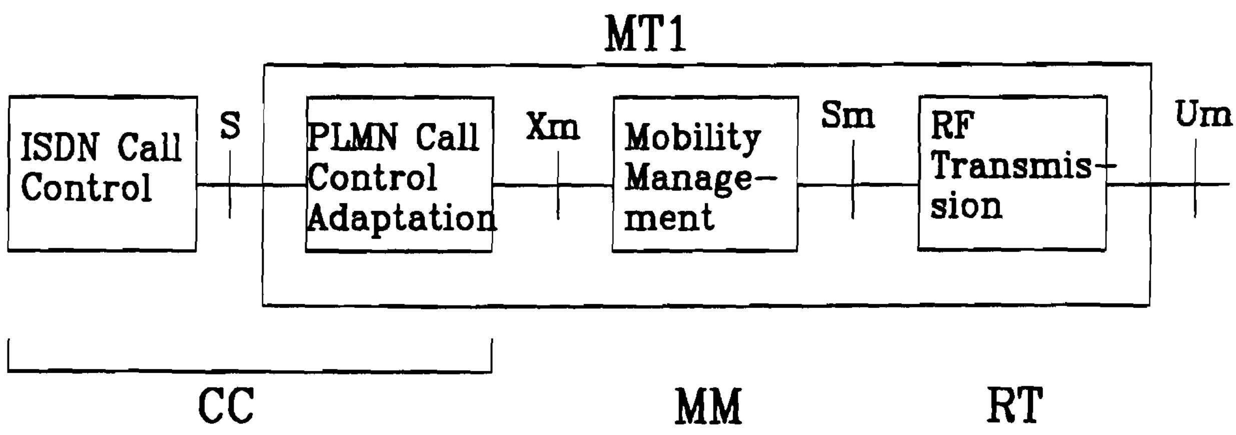


Figure 6.11: Signalling reference points and configuration

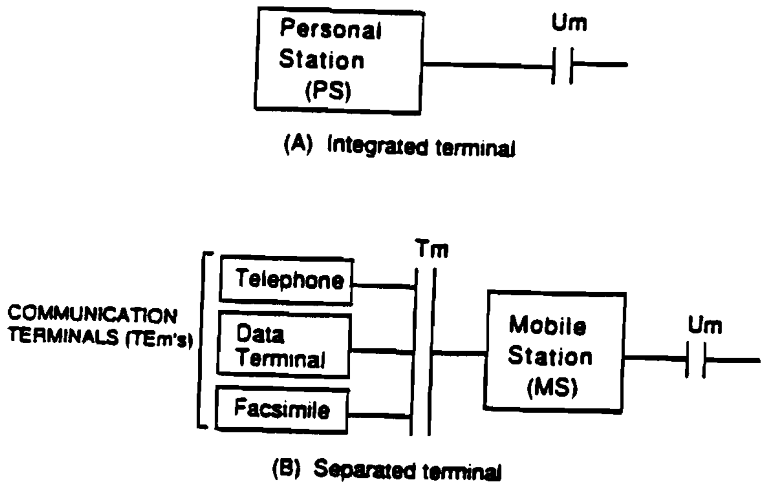


Figure 6.12: Physical configuration of terminal equipment

- **PLMN call control adaptation** is required to convert standard CCITT call control signalling into call control signalling appropriate to the GSM system.

S, Xm, Sm and Um are defined as reference points. **S** is the ISDN user- network interface. The **Xm** reference point is the demarcation between MM and call control (CC) which is defined as a function combining both PLMN GSM call control adaptation and ISDN call control. The Um reference point is the mobile station (MS) to the base station (BS) interface (also radio interface).

6.4.1.1 Terminal equipment and interfaces

The users of the GSM system might use a physically integrated terminal equipment type such as a personal station (PS) or a physically separated terminal equipment type in which various kinds of mobile specific terminal equipment (TEm's) can be connected to a mobile station (MS) by the same connectors, as shown in Figure 6.12. Therefore, the Um and Tm reference points can be candidates as a terminal equipment interface for the MS/PS and TEm, respectively.

6.4.1.2 Functional description of a PLMN Call Control Adaptation unit and user channel mapping functions

The case B scenario requires the Mobile station to contain the following functions:

1. PLMN Call Control Adaptation functions:

   - Convert User signalling on the S interface (i.e., Q.931 call control signalling) into call control signalling appropriate to the GSM system (GSM recommendation 04.08) and vice versa.

- To handle a request, received on the S interface (D channel), for a packet mode bearer service on a B channel towards a Packet Handler and vice versa. This is called the B channel service, see Section 6.3.1.
- To handle a request, received on the S interface (D channel), to request a packet mode bearer service on the D channel towards a Packet handler and vice versa. This is realized by setting up a data link (layer 2) on the D channel. However only a Bm channel can be used in GSM, see Section 6.3.1.

2. User channel mapping functions:

- To map data on a B channel (S interface) to a Bm channel (radio interface) and vice versa. This is performed by Rate Adaptation (RA) functions.
- To map data packets on the D channel (S interface) to a Bm channel (radio interface) and vice versa. This is realized by rate adaptation functions and a B-map procedure.
- To handle special layer 2 protocols used on the radio interface for additional error correction, see Section 6.3.1.2.

These functions are subdivided into functional entities, as can be seen in Figure 6.13. A FH is introduced to handle packet calls (SAPI=16) on the D channel towards the network or vice versa. The D mapping procedure, see above, and rate adaptation functions are also used to handle packet calls (SAPI=16) on the D channel.

A Frame handler (FH) has, in the ISDN situation, a layer 2 functionality for multiplexing subscriber D-channel links used for packet mode services (SAPI=16) onto channels of the PHI. In the GSM situation, the Frame Handler (FH) within the PLMN CCAU must end this functionality, because this function cannot be supported on the channels of the radio interface, see Section 6.3.1. A D mapping procedure must be started and X.25 data must be mapped on a Bm channel. It is not possible to keep the multiplexing functionality on the radio interface, but on the network side of the radio interface this functionality can be introduced again, see Section 6.5.

The User signalling (US) must be mapped onto User signalling in GSM, where also Mobility Management (MM) and Radio Transmission (RT) is needed. Rate Adaptation (RA), L2 and Channel codec procedures are handled in Section 6.3.1.2 and 6.5.1.1.

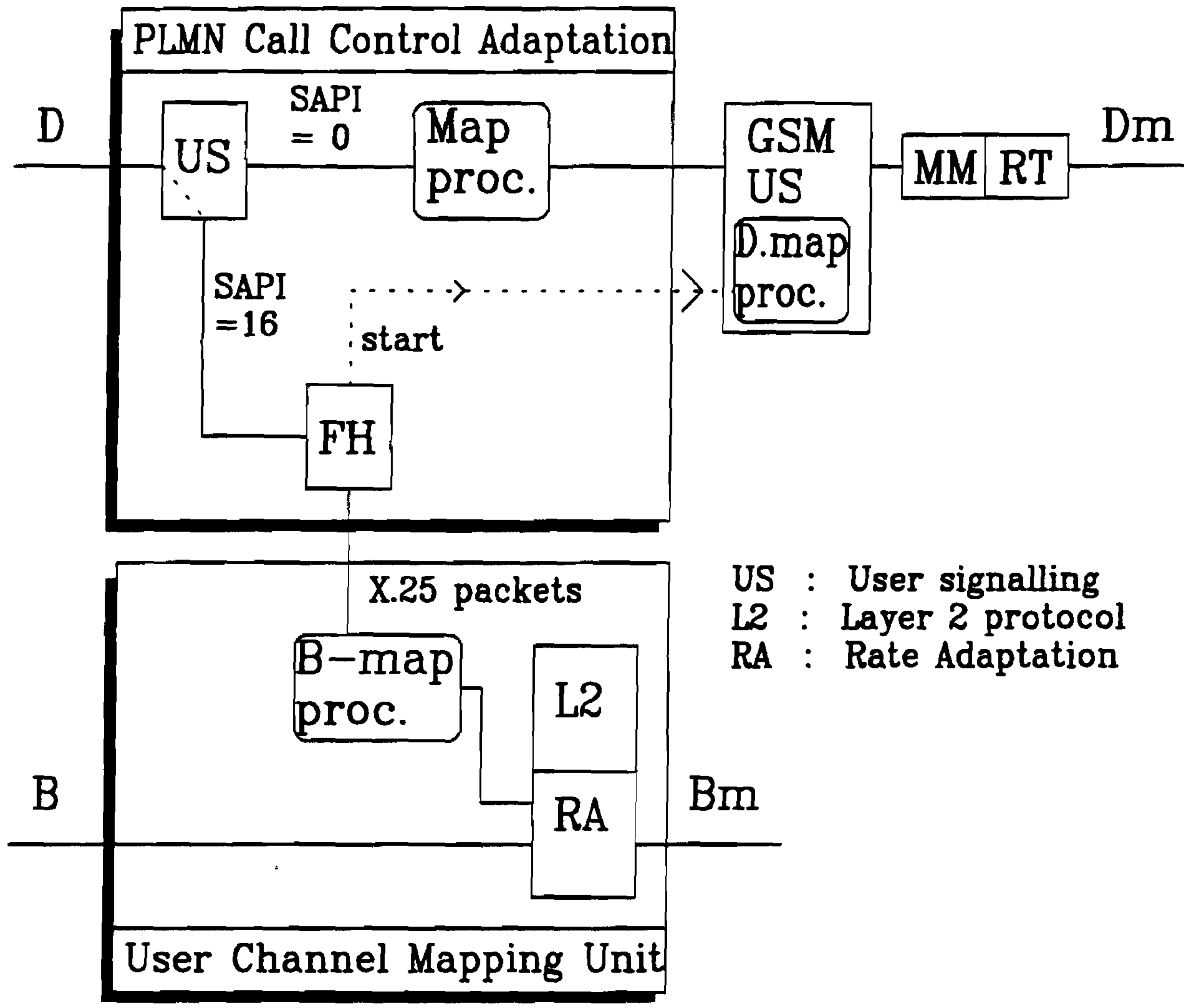


Figure 6.13: PLMN call control adaptation and User channel mapping

6.5 Multiplexing and Rate adaptation of user data

In this section a general approach for implementing multiplexing functions is given. It is stated in Section 6.3.1 that statistical multiplexing could be useful because multiplexing of user data is an economic way for transporting the data on the available resources. In this section statical multiplexing is also described because this is an alternative method for an optimal use of the channel capacity. However, statistical multiplexing is more useful for implementing the functions which are needed to support X.31 case B, see Section 6.3.1.

The GSM system has to deal on the radio interface with a low channel rate (less than 13 kbit/s) and on the BSS-MSC interface with normal 64 kbit/s channels. To overcome this difference, three possibilities are presented:

1. **Rate Adaptation (RA).** This can be found in the GSM Recommendation 4.21 and 8.20.

2. **Statical multiplexing and remote control of Rate Adaptation.** This can be found in the GSM Recommendation 08.60.

3. **Statistical multiplexing and remote control of Rate Adaptation.** This is not supported or handled in the GSM recommendation.

These possibilities are described in the following sections. First, it is needed to give a functional description of the base station because this leads to an implementation of statical multiplexing.

6.5.1 Functional description of the base station

The base station can be subdivided into two functional entities, see Figure 6.14:

1. **Base Transceiver Station (BTS)**
   The base transceiver station contains all the radio frequency transmit and receive equipment, channel coders, and control logic. It handles layers 1 and 2 of the air interface.

2. **Base Station Controller (BSC)**
   The base station controller deals with most of the radio management functions in layer 3. Some important functions are:

   - to provide 2 Mbit/s PCM interfaces towards the MSC and base transceiver station.
   - to switch user channels between the MSC-BSC interface and the BTS-BSC interface (A and Abis interface).

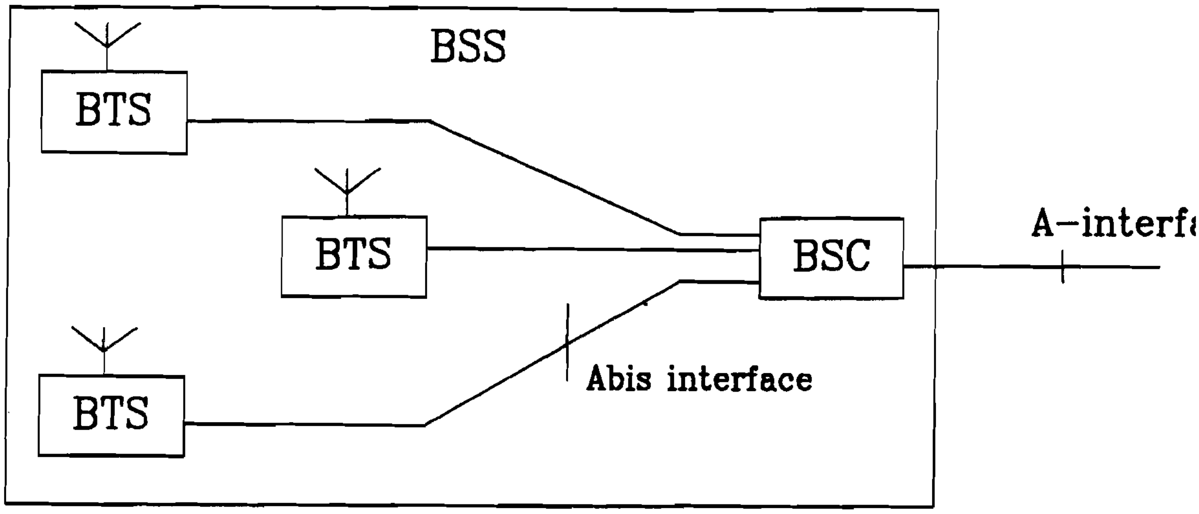


Figure 6.14: The base station, described as a star configuration, with the interfaces in the GSM system.

- to terminate and process protocols based on the CCITT No.7 signalling system (MSC interface) and LAPD (base transceiver station interface). More information can be found in Section 7.1.1.2.
- transparent transfer of call control signalling information between mobile station and MSC.
- operations and maintenance functions.

The controller and transceiver can be collocated or separated. In the latter case they are connected over digital trunks. A number of configurations are possible, but the most common used configuration (GSM recommendation) is the star configuration, the one in Figure 6.14.

The separation of the BSS functions into BTSs functions and a BSC functions is useful for implementing static multiplexing functions, but first it is needed, as an introduction to static multiplexing, to explain how rate adaptation is used in GSM.

6.5.1.1 Rate Adaptation

The general approach in the GSM recommendation has been to follow CCITT X.30/V.110 principles wherever possible. However, in order to accommodate channel rates over the radio interface of considerably less than 64 kbit/s, certain modifications to the rate adaptation process were necessary. CCITT considers a three stage process, see Figure 6.15: (A complete description in GSM 04.21)

1. If the user interface is asynchronous, this is converted to a synchronous stream at 2 times 300 bit/s.

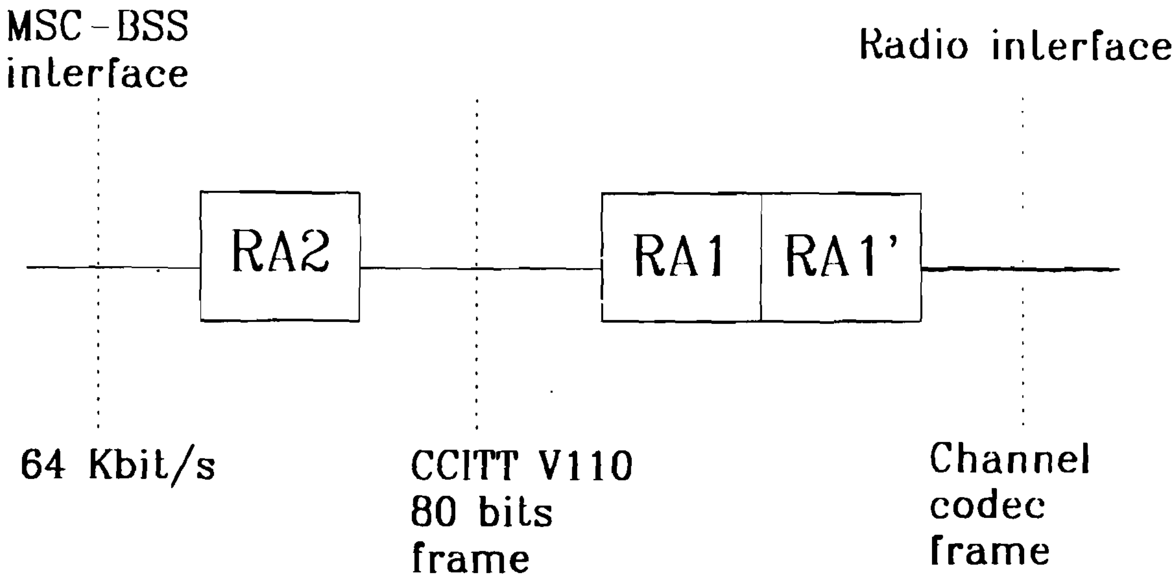


Figure 6.15: Rate adaptation on the radio interface and BSS-MSC interface

2. This stream (or a direct synchronous stream) along with information reflecting the state of the user interface, certain control information and synchronization pattern, is multiplexed (by repeating data bits where necessary) to 8 or 16 Kbit/s (the "Intermediate rate") in the form of 80 bit frames.

3. These frames are then bit stuffed to 64 kbit/s.

Within the mobile termination and in the GSM network, GSM have adopted the first function (RA0) without change. The second stage (RA1) has been modified by removal of the synchronization and the control information related to data speed (the speed is passed explicitly in the Dm channel signalling) to fit the radio rates of 12 kbit/s, 6.0 kbit/s and 3.0 kbit/s. This function is referred to as RA1' in Figure 6.15. The third stage is a standard RA2 function to produce a 64 kbit/s output which is suitable for switching by the MSC.

6.5.2 Statical multiplexing within GSM

Separation of the RA2 function, see Figure 6.16; and the channel coder allows a manufacturer to multiplex several data and speech circuits onto a single 64 kbit/s bearer.

The general approach by GSM is to position the transcoders (for speech) and rate adapters (for data) remote to the BTS, e.g. within the BSC or MSC. The information between the Channel Codec Unit (CCU, on the radio interface side) and the remote Transcoder/Rate Adapter Unit (TRAU) is transferred in frames with a fixed length (TRAU frames). Within these frames both the speech/data and the TRAU associated control signals are transferred. These associated control signals are necessary to give the TRAU knowledge of some radio parameters

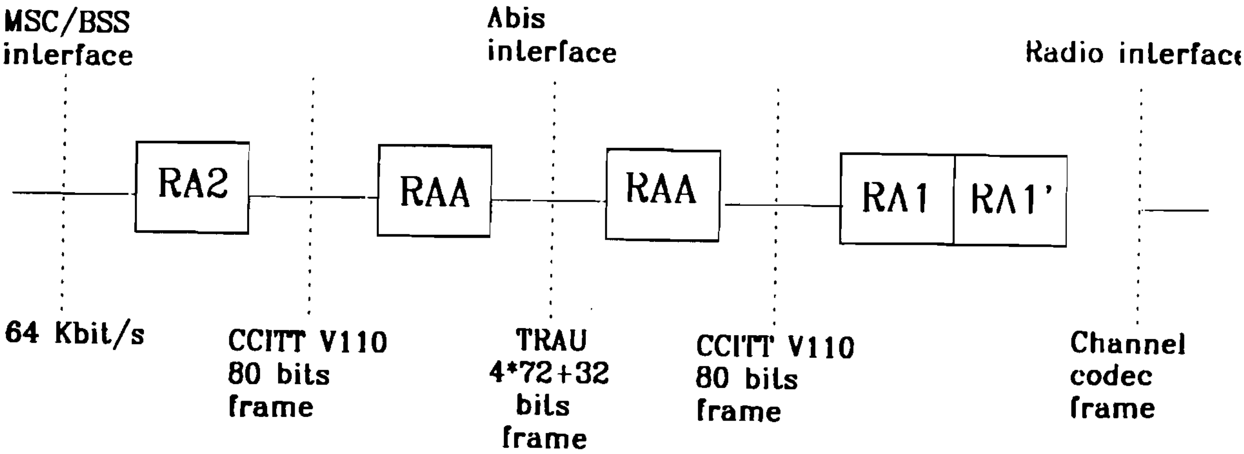


Figure 6.16: Static multiplexing and Rate adaption

for an efficient decoding (speech). As an example, timing parameters are necessary to align the timing of the transcoder with the transmission of data frames over the radio interface.

TRAU is considered a part of the BSC, but may also be situated on the MSC-side before switching is done.

When data is adapted to the fixed length frames (320 bits) on the Abis interface, a conversion function (RAA) is required in addition to the conversion/rate adaptation specified for the BSS-MSC interface. These 320 bits (20 mS) entails a transmission speed of 16 kbit/s. So, when sub-64 kbit/s traffic channels are used, up to four data frames are transferred in each TRAU frame.

In Figure 6.17 a possible configuration of the TRAU and the CCU is shown. The functions inside the TRAU are:

- Remote Transcoder and Rate Adapter Control Function (RTRACF).
- Remote Speech Handler Function (RSHF). (Remote control of the transcoder function).
- The RAA function.
- The RA2 function.
- The transcoder function

The functions inside the CCU are:

- Transcoder and Rate Adapter Control Function. (TRACF).
- Speech Handler Function (SHF).

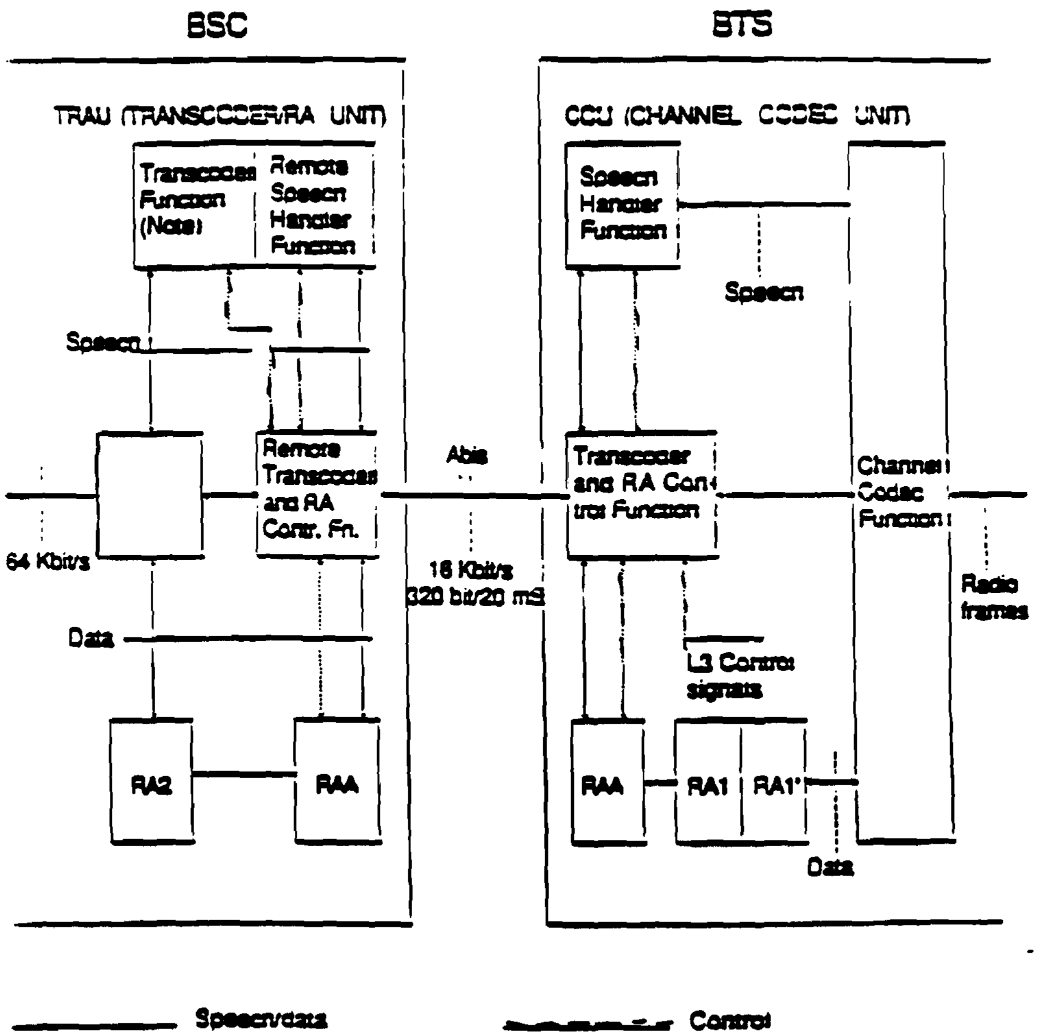


Figure 6.17: A possible configuration of the TRAU and the CCU

- The RAA function.
- The RA1/RA1' function.
- The channel codec function.

The Channel Codec Unit (CCU) in the BTS has to control some of the functions in the remote Transcoder/Rate Adapter Unit (TRAU) in the BSC or on the MSC-side of the BSS-MSC interface. This remote control is performed by inband signalling carried in the TRAU frame. The following functions in the TRAU, which are necessary for data traffic, are remotely controlled by the CCU:

- Shift between speech decoding and data rate adaptation.
- Shift between half and full rate radio channels.
- Control of the rate adaptation functions for the data calls.

More information can be found in GSM Recommendation 08.60.

6.5.3 Statistical multiplexing in GSM

Statistical multiplexing will sometimes be advantageous. The main purpose of introducing such functionality is to reduce the number of terrestrial circuits needed, but statistical multiplexing could also be implemented to make use of the Bd channels on the PHI, see Section 6.3.1. (Based on GSM Recommendation 08.02.)

Statistical multiplexing functionality could be implemented as a relative simple line concentrator between BSS sites and a MSC for signalling and traffic circuits, but it could also be implemented as a unit which performs interworking with other networks, e.g. a PSPDN.

It is proposed in this report to use a Remote Controlled Multiplexing Unit (RCMU). This unit must perform the statistical multiplexing. The RCMU will be regarded as a remotely controlled part of the MSC.

Some functions, which the RCMU may perform:

- It might contain the GSM-FH functions, mentioned in Section 6.3.1.3, like statistical multiplexing of special data links used on the Bd channels of the PHI.
- Setting up and clearing of circuits to the BSS and the MSC or to the PH, remotely controlled by the MSC.
- Switching of the circuits between MSC and the various BSSs or between the PH and the various BSSs.
- Operation and maintenance functions of the RCMU.

A few requirements to realize these functions are:

- Before a RCMU can be used, a signalling connection must be set up between a MS and a MSC, because the MSC handles call control signalling. If this connection exists the MSC can introduce the RCMU during the call set up phase. The MSC must perform remote control of the RCMU as long as a connection exists because the RCMU cannot handle call control signalling needed to maintain the connection. This means that the interface between the BSS and the RCMU must be the same as the interface between the BSS and the MSC.

- The use of a RCMU is not without risk, because the RCMU handles more subscribers than a single BSS. If the RCMU fails or the signalling link to the MSC is down then this will have serious impact on the mobile service in a large area.

The benefits of introducing statistical multiplexing will depend on:

- the costs of implementing this extra functionality

- the costs involved in operating the multiplexing

- the complexity of a multiplexing unit (RCMU), which must perform this statistical multiplexing. This complexity will grow if interworking is needed with, for example, PSPDN.

- the reducing of terrestrial circuits.

- the possible use of the RCMU as a frame handler to perform statistical multiplexing of data links on a Bd channel of the PHI.

6.6 Conclusions on the ETSI PHI implementation

In this report the GSM variant of X.31 Case B, a scenario to provide packet mode services, is described. The X.31 Case B is implemented using the ETSI PHI.

Two functional models of the ETSI PHI for GSM are proposed: a basic model and a remote access model. The remote access model is further described.

Several conclusions are made on the implementation of the X.31 case B services (B channel service and the D channel service):

- The D channel service cannot be offered in GSM.

- A Layer 2 function is needed in the GSM system to overcome the poor error qualities of the radio interface.

- It is possible to use this Bd channel of the PHI if GSM supports statistical multiplexing. An advantage of this multiplexing is that channel capacity is only used if necessary.

As a consequence, the following X.31 case B services are possible in GSM: The B channel service is possible with three categories:

1. **Transparent Bm channel in GSM**
   This implementation provides a minimal service. This service can only be a service with a less mobile character, because burst of errors cannot be detected and corrected on the radio radio interface.

2. **Non-transparent Bm channel in GSM**
   This is a better implementation of the B channel service, because of the additional error correction on the radio interface. An interworking function is needed in the MSC to map a special layer 2 protocol on the radio interface to the LAPB protocol on the PHI.

3. **Statistical multiplexing in GSM**
   This implementation provides no improved service, compared with the non-transparent case of GSM, towards the users. It is only a improvement from a point of view of the network manager because channel capacity is more utilized. A penalty must be paid in complexity because a GSM-FH is needed to multiplex data links on Bd channels of the PHI.

Related to the access of the X.31 case B services and the implementation of multiplexing functions in GSM, the following can be concluded:

- **PLMN Call Control Adaptation Unit**
  It must be possible to use a ISDN terminal with a capability to support packet data. In that case a PLMN Call Control Adaptation Unit is needed. The most important task is to translate the B and D channel service in ISDN into appropriate services in GSM and vice versa. In this report a description of this unit is proposed.

- **Statical multiplexing**
  It is possible to statically multiplex traffic (speech or data) or signalling channels. To implement this, remote control out of the BTS is needed.

- **Statistical multiplexing within GSM: GSM-FH**
  A solution to statistically multiplex data within GSM is given in this chapter. However this is only possible on the network side of the radio interface[10], otherwise the channel structure on the radio interface has to be changed. A GSM-FH is proposed in this report to implement statistical

[10] No common access channel exists on the radio interface.

multiplexing in GSM. The GSM-FH multiplexes data links on a Bd channel of the PHI. This FH must perform a conversion of a special layer 2 protocol, needed to overcome data errors made on the radio interface, to a special data link protocol (Q.921* data link) used on the PHI and vice versa.

- **Remote Controlled Multiplexing Unit (RCMU)**
  A RCMU is proposed in this chapter to implement statistical multiplexing between Base Stations and their MSC. This RCMU must also interwork with the protocols used on the PHI. As an example the RCMU can include the GSM-FH functions. A RCMU is controlled by the MSC.

Chapter 7

Call control signalling

In this chapter call control signalling is handled which is needed for setting up a connection between data terminals, i.e. of different networks (GSM, ISDN and PSPDN). First the protocol layer model is discussed to give an overview of the protocols which are used on the interfaces of the different networks. Secondly, the call control procedures are described, based on the protocols.

7.1 Protocol layer model

The Protocol layer model describes the protocols which are needed for data communication between users of communication networks. In this report two networks are involved: GSM and a PSPDN. The protocols used on the user network interface of PSPDN (CCITT X.25) and on the interface towards other networks (CCITT X.75) are not described but can be found in the many existing reports which deal with these protocols. Now the user network interface protocols of ISDN and the ETSI PHI protocols in relation with the GSM protocols are discussed.

The GSM system uses out-of-band signalling, so a model exists for the signalling protocols and a model exists for the data transfer protocols.

7.1.1 Signalling protocol model

The signalling protocol model can be subdivided into sub-models which have their own specific functions and protocols:

1. Access reference configuration and protocols

2. GSM network signalling protocols

3. PHI signalling protocols

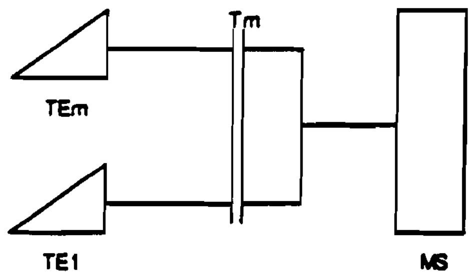


Figure 7.1: Adaption of ISDN terminal (TE1) at the TM interface point.

7.1.1.1 Access reference configuration and protocols

The Tm interface signalling protocol, see Section 6.4, is similar to the interface signalling protocol of the Xm reference point because the Tm signalling protocol supports functions selectable by end users.

The Tm interface structure should be based on the ISDN basic interface structure. As a result, the ISDN basic interface terminals can be directly connected to the MS at the Tm interface point, as illustrated in Figure 7.1. In this case, the Tm interface structure is as follows:

- Layer 1: 2B + D (I.430)
- Layer 2: LAPD (Q.921)
- Layer 3: Q.931 or I.450 (general aspects), I.451 (detailed specification) and PLMN GSM service protocols.

The PLMN GSM service protocols (layer 3 protocols, GSM Recommendation 04.08) can be identified by protocol discrimination fields. In the following sections a ISDN terminal is used for accessing the GSM system.

7.1.1.2 GSM network signalling protocols

The signalling link between the MS and the MSC consists of two parts as shown in Figure 7.2.

The MS-BSS part

The MS-BSS part consists of three layers:

1. Layer 1: Dm channel, see Section 2.3.1.2.

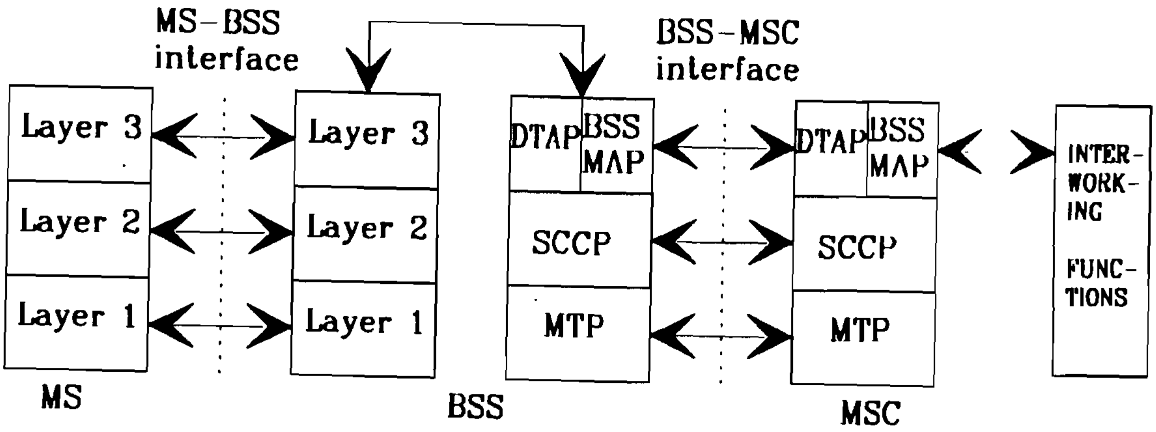


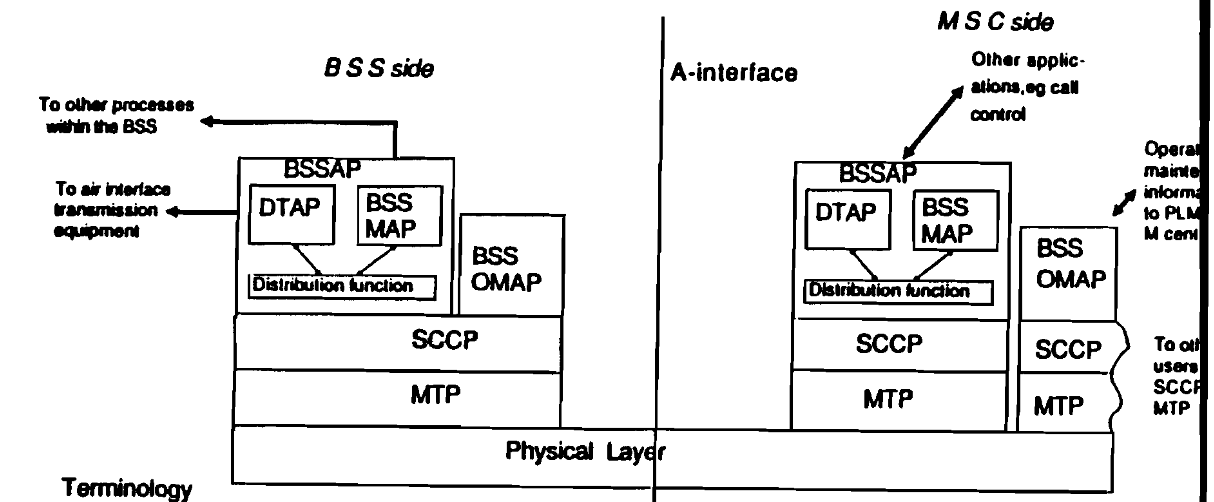
Figure 7.2: The two parts of the signalling link between MS and MSC.

2. Layer 2: LAPDm (GSM Recommendation 04.05).
   The purpose of LAPDm is to convey information between layer 3 entities across the GSM PLMN radio interface using the Dm channel. Specifically LAPDm will support:
   - multiple layer 3 entities.
   - multiple physical layer entities.
   - Signalling of the broadcast control channel (BCCH), paging channel (PCH), access grant channel (AGCH) and dedicated control channels (DCCH).
3. Layer 3: (GSM Recommendation 04.07) Connection management (CM) functions, the mobility management (MM) functions and the radio resource management (RR) functions. The purpose is to provide functions to establish, maintain and terminate circuit and packet switched connections across a GSM PLMN and other networks to which the GSM PLMN is connected.

The BSS-MSC part

The BSS-MSC section utilizes Signalling System No. 7, see Figure 7.3. It consists basically of a physical layer and two parts upon this layer:

1. Physical layer: This layer shall utilize digital transmission at a rate of 2048 kbit/s with a frame structure of 32 * 64kbit/s time slots, as specified in recommendation CCITT G.705 section 3. A predetermined number of the 64kbit/s timeslots may be used for signalling, to one or more base station systems.
2. The Message Transfer Part (MTP, Q.701-Q.707): it is the common transport system for all signalling messages. The MTP consists of three levels:
   (a) MTP level 1: The signalling Data link.



Terminology

DTAP ; direct transfer application part
BSSMAP : BSS management application part
BSS OMAP : Operation and maintenance application part
SCCP : signalling connection control part
MTP : message transfer part
BSS : Base station system
MSC : Mobile services switching centre

Note: X.25 can be used for transferring O and M information

Figure 7.3: The BSS-MSC signalling part, based on SS. no.7

(b) MTP level 2: Link Control functions (e.g, error correction protocol).

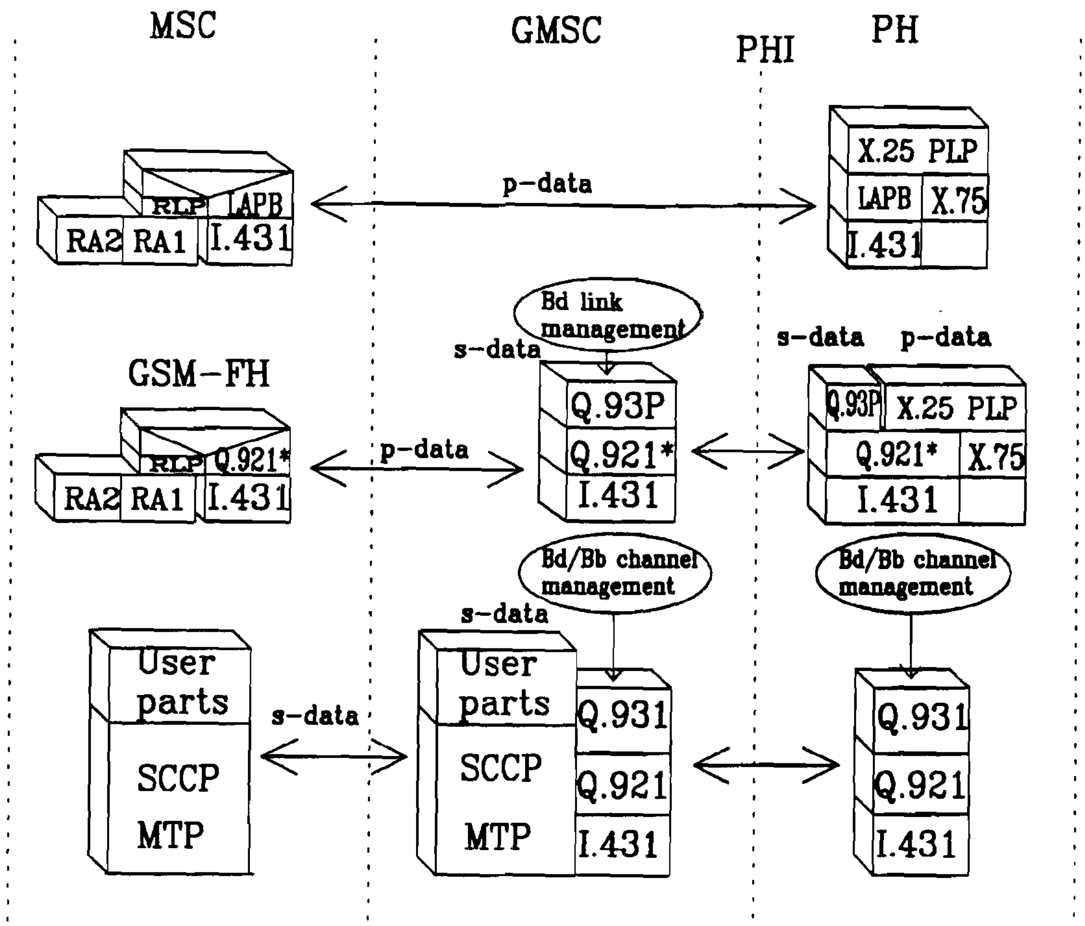
(c) MTP level 3: Common Transfer functions (i.e., message routing function).

3. The Signalling Connection Control Part (SCCP, Q.711-Q.714): It is a supplemented part for the MTP part, in the case of information exchange without a user channel connection (known as logical or virtual signalling connections).

The Radio Subsystem Application Part (BSSAP, GSM Recommendation 08.06) is an user function of the SCCP and MTP. The BSSAP uses one signalling connection per active Mobile Station having one or more active transactions[1], for the transfer of Layer 3 messages related to this transaction. The BSSAP user function is further subdivided into two separate functions:

1. The Direct Transfer Application sub-Part (DTAP) is used to transfer call control and mobility management messages to and from the MS; the Layer-3 information in these messages is not interpreted by the BSS.

[1]For example handover signalling and transfer of call control signalling at the same time.



p-data = packet data
s-data = signalling data

Figure 7.4: The protocols used on the PHI between the GMSC and the PH.

2. The BSS Management Application sub-Part (BSSMAP) supports other procedures between the MSC and the BSS related to the MS (handover), or to a cell within the BSS.

7.1.1.3 PHI signalling protocols and how to handle these in a GMSC

It is assumed in Chapter 5 that the ETSI PHI will be used in the GSM system. This means also the protocols, belonging to the PHI. The GMSC must perform these protocols towards the PH. Figure 7.4 gives an overview of the used signalling protocols and data transfer protocols. A complete description of the protocols on the PHI will not be given, because this is done in the [8] and in [14]. A short explanation of the protocols on the GMSC-side of the PHI is given.

The GSM system must use the protocols belonging to the PHI, the signalling protocols are:

- **layer 1: PCM 30 multiplex**
  This is the same interface as the ISDN primary rate interface. The specifi-

cations can be found in the CCITT G 705 recommendation. The bitrate is 2048 kbit/s. It is possible to have 30 speech or data channels of 64 Kbit/s. Besides these channels a common signalling channel (64 kbit/s) exists and another one for operation and maintenance of the interface.

- **layer 2: LAPD (Q.921) and LAPD* (Q.921*)**
  The LAPD is needed for the signalling of the PHI (this is the normal use, like setting up a datalink). The specification can be found in the Q.921 recommendation. LAPD* is needed for the Bd channels. This protocol is specially designed for use on the Bd channels and multiplexes D-channel packet data of several subscribers. It also transports additional PHI signalling (see Section 6.3.1.3).

- **Layer 3: Q.931***
  This protocol is also specially designed for the use on the PHI. This includes, first of all, a subset of Q.931, only needed to set up and to release Bb or Bd channels in the PHI. Furthermore this includes additional signalling needed to set up a Bd channel (see Section 6.3.1.3), this is called the Q.93P protocol.

If a GMSC uses the same PHI interface there are some requirements:

1. **Bd/Bb channel management**
   This concerns the normal signalling protocols. Translation is needed from the signalling system no.7 to the PHI protocols (Q.931, Q.921) and vice versa.

2. **Bd link management**
   The additional signalling (Q.93P, described above) must be transferred on Q.921* datalinks as inband signalling. The Q.921* datalinks are also needed for multiplexing of datalinks. The exact procedures are described in the ETSI PHI recommendation, see [8].

7.1.2 Data transfer protocols and error protection

The basic data transfer protocol in the interworking situation between a PSPDN and GSM is of course the X.25 protocol, but some modifications are needed because of the limitations of the radio interface in GSM. In Figure 7.5 the data transfer protocols are visible which are needed in GSM. There are some important protocols:

- **Forward Error Correction (FEC)**

- **Rate Adaptation protocols**
  These protocols (RA2, RA1 and RA1') are described in Section 6.5.1.1.

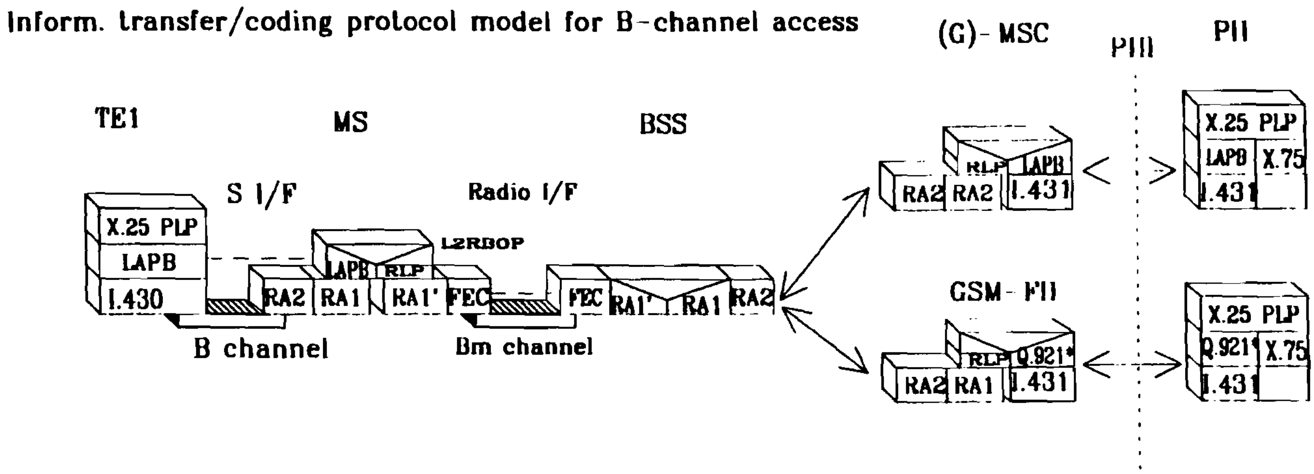


Figure 7.5: The data transfer protocols in the GSM system.

- **Special Layer 2 protocols**
  These protocols (RLP and L2RBOP) are described in Section 6.3.1.2.

It is possible to choose for statistical multiplexing in which case a GSM-FH is needed, see Section 6.3.1.3. In Figure 7.5 it is assumed that the special Layer 2 protocol will be used (non-transparent case).

7.2 Access procedures and call control

The most important procedures for call control are:

- MS originated and MS terminated call establishment.
- Call maintaining during data transfer phase.
- Call termination.
- Call related Supplementary Services Support.

Call establishment means for the GSM system, compared to the ISDN, to handle some special procedures: to set up a signalling link, identification, authentication, ciphering and TMSI reallocation procedures. These procedures are independent of who requested the call set up, and are described in Appendix A.

Procedures in the GSM system for call maintaining are focused on the radio interface, because significant breaks in transmission are possible as a result of shadowing or handover.

7.2.1 GSM specific call control procedures

The GSM system uses out-of-band signalling for call control, just like in ISDN, but a Dm channel must be set up when a subscriber wants access to GSM. Some procedures, which use this Dm channel, are also necessary. These procedures are described in Appendix A.

Now it is necessary to focus on the call control procedures. The procedures mentioned above are called 'GSM setup procedure' in the following sections.

7.2.2 Call control procedures for B channel access on the S interface

In this section the complete call setup will be handled for Packet bearer requests on a B channel (S interface) with a ISDN terminal.

There are two directions, MS originated call set up and MS terminated call set up.

7.2.2.1 MS originated calls

Figure 7.6 visualizes the general procedure to realize MS originated call set up for a B or D channel (Bm channel in GSM) with a packet bearer capability.

When a X.25 Call Request is sent by a TE2 terminal on the R interface to the Terminal Adapter, it will be saved until a Bm channel in GSM to the PH is established. But first B or D channel service procedures have to be translated into GSM call control procedures ('Bm channel service procedures') by the GSM PLMN Call Control Adaptation unit. After this translation, the GSM setup procedure starts to establish a signalling link to the MSC. Via this signalling link a Bm channel to a PH is requested.

More details can be found in Figure 7.7 (MS originated call with a ISDN terminal):

1. If the packet terminal wants to set up an X.25 connection, it must for that purpose set up a LAPB datalink to a PH (DCE), and send an X.25 Call Request packet across the datalink. However, first the terminal must set up a layer 1 connection to the PH.

2. The terminal sends an ISDN B-channel SETUP Request across the D- channel with a bearer capability = 'packet' to set up a layer 1 connection to the PH. No called party number is sent along with this Request because addressing will take place during X.25 call set up. The PH will take care of the number when the X.25 call request message is sent to the PH.

   For the purpose of identification and charging, the calling party number will be sent along with the Request.

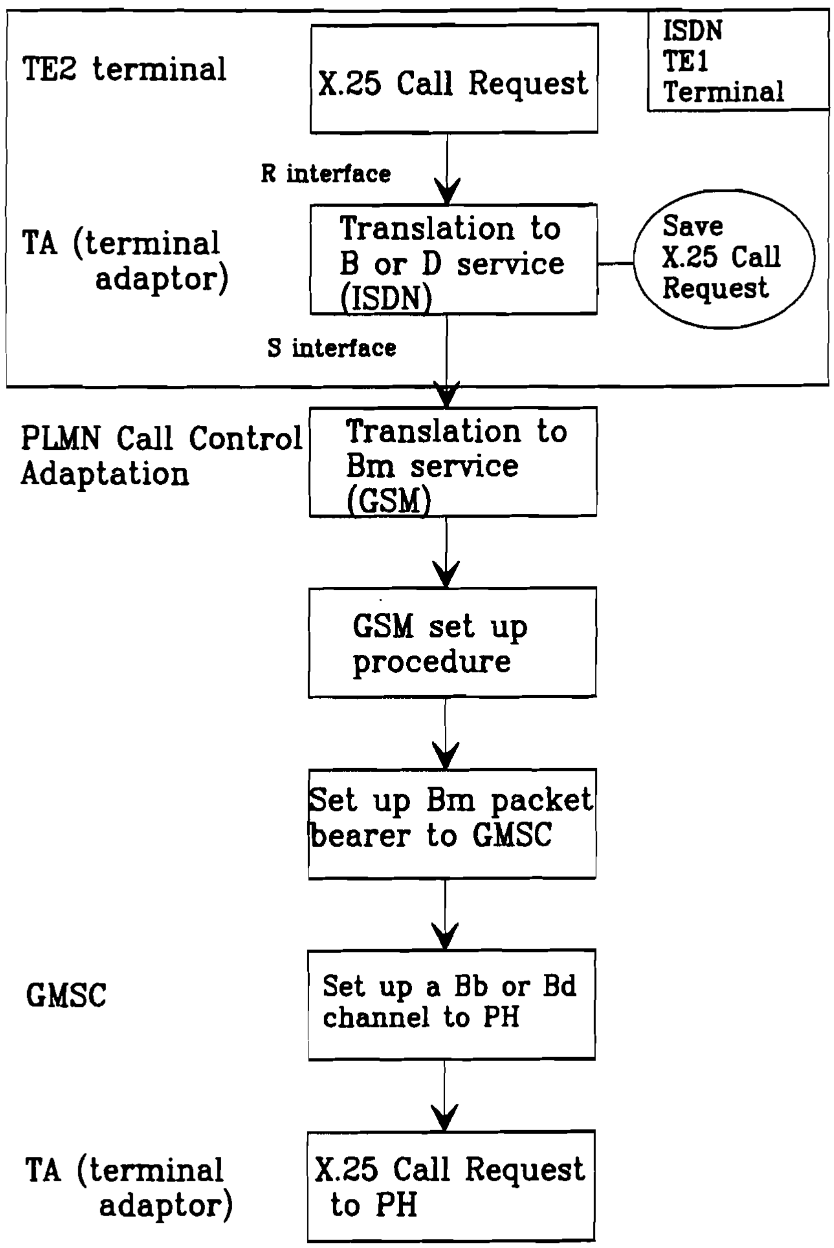
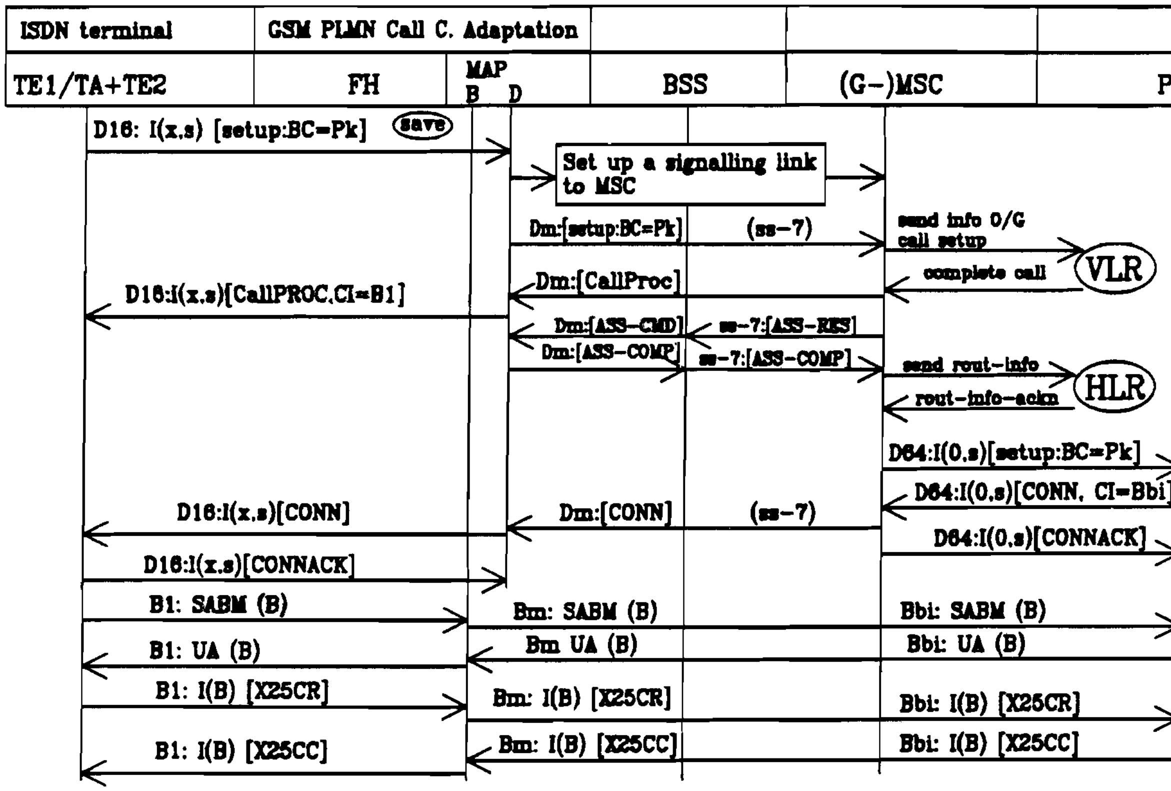


Figure 7.6: The general procedure for MS originated call set up, packet bearer request on D channel for B or D packet service



Layer 2 Address Indication

DLCI	for subscriber data link on Bd channel SAPI=16, LIC link specific
0,s	D channel signalling link PHI SAPI=0, TEI=0
GTEI,s	broadcast on subscriber access SAPI=0, TEI=127
x,s	signalling link for specific TE SAPI=0, TEI link specific
x,p	data link for specific TE SAPI=16, TEI link specific

Channel Indication

B1,B2	B channel user access
D64	D channel on PHI
D16	D channel user access
Bbi	B channel on PHI for B channel service
Bdi	B channel on PHI for D channel service
Bds	B channel on PHI for D channel service with signalling data link

(DSS1) Information Elements

CI	Channel Identification §4.5.13
CI=anyB	Channel Identification §4.5.13 no channel indicated or prefered channel indicated
CI=B1,Bi	Channel Identification §4.5.13 exclusive B channel, no D channel
BC=Pk	Bearer Capability §4.5.5 packet mode

X.25 Call Control Packets

X25CR	Call Request
X25CC	Call Connected
X25IC	Incoming Call
X25CA	Call Accepted
X25CLR	Clear Request
X25CLI	Clear Indication
X25CLC	Clear Confirmation

Q.931 Messages

CALLPROC	Call Proceeding
CONN	Connect
CONNACK	Connect Acknowledge
DISCONN	Disconnect
REL	Release
RELCOMP	Release Complete
SETUP	Setup

Figure 7.7: MS originated call set up to PH with a ISDN data packet terminal

3. The PLMN Call Control Adaptation unit maps the B channel SETUP Request to a Bm channel request with a bearer capability ='packet', but first a GSM setup procedure is started by the MS to set up a signalling link (Dm channel) to the MSC and to start some procedures which need this signalling link, see Appendix A. After this action the Bm channel Request is sent across the Dm channel to the MSC.

4. The connection Request is routed through C7 to the GMSC (Gateway MSC). This is a MSC (home or visited PLMN) with a PH interface (PHI) to the PH. The GMSC must now set up a Bb channel to the PH. Normal ISDN procedures will be followed, but only those who are necessary to set up a channel. The GMSC sends a SETUP message to the Packet Handler across the D64 channel. A Channel identification 'any B' is sent along with the Request to indicate that a Bb channel is needed (this is because of the difference between Bb and Bd channel request procedures).

5. A Bd channel could also be chosen, but this requires a GSM Frame Handler, see Section 6.3.1.3. It is the choice of the network manager to make use of the Bd channels on which statistical multiplexing is possible. The procedures to set up a Bd channel can be found in [8].

   For now it is assumed that a Bb channel is requested.

6. The Packet Handler chooses a free Bb channel of the PHI and sends a 'CONNECT' message to the GMSC along with the chosen Bb channel. The GMSC connects this Bb channel with the Bm channel in the switch matrix.

7. The channel establishment is signalled through C7 to the BSS, and further as a "CONNECT" message on the Dm channel to the Mobile Station.

8. The D-Mapping procedure translates this message and sends also a 'CONNECT' message on the D16 channel to the ISDN terminal. The terminal has now a transparent traffic channel to the PH.

9. The subscriber is now able to set up an X.25 LAPB link with the PH, on which the saved X.25 Call Request Packet can be sent to become a X.25 Virtual Call. The User Channel Mapping Unit (UCMU) takes care of mapping the X.25 packets on the B channel to the Bm channel and vice versa, see Section 6.13.

7.2.2.2 MS terminating calls

Figure 7.8 visualizes the general procedure to realize MS terminated call set up with a packet bearer capability.

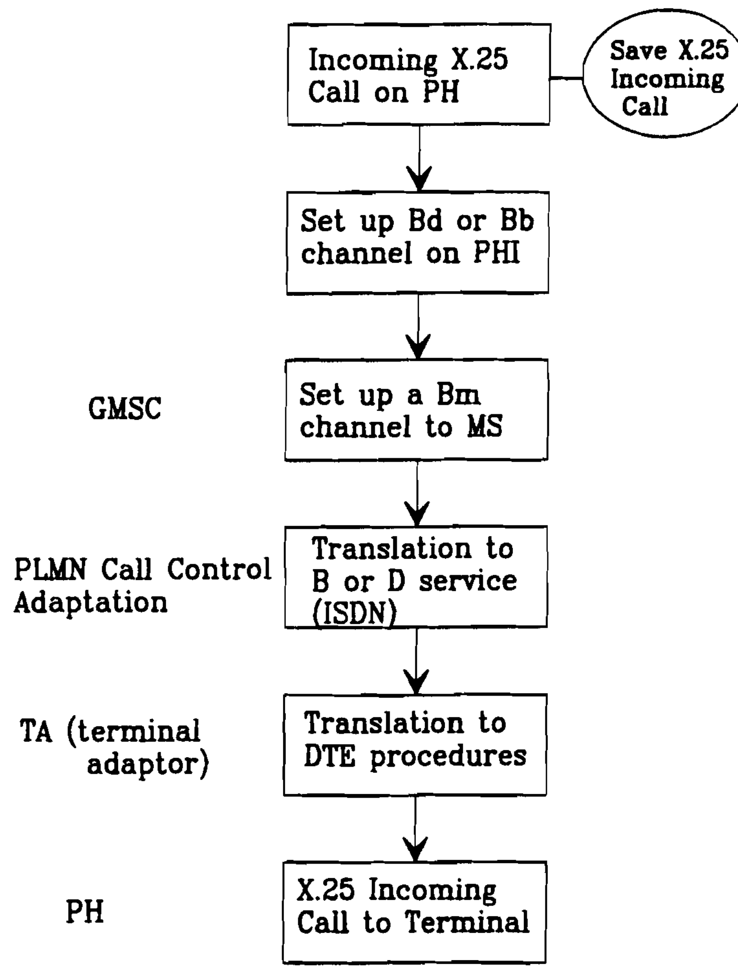


Figure 7.8: The general procedure for MS terminated call set up, packet bearer request on the ISDN D channel for B or D packet service

On an X.25 Incoming Call for a packet GSM subscriber the PH wants to set up an X.25 connection with the terminal of the called subscriber. This is realized by setting up a Bb or Bd channel on the PHI to the GMSC. The GMSC sets up a traffic channel to the MS, but before a traffic channel can be requested by the GMSC (and a Bm channel on the radio interface), a signalling link must be set up between the GMSC and the MS. On the S interface the B or D channel service is possible (see Section 6.4).

More details can be found in Figure 7.9:

1. The Packet Handler must send an X.25 Incoming Call packet to a GSM (or ISDN) packet subscriber if the Incoming Call has an E.164 number as the called address. It is also possible in some situations to address a GSM packet subscriber with an X.121 number, see Section 5.3.1.

   But first, a connection must be made with the terminal (layer 1 and 2).

2. Based on the address in the X.25 Incoming Call packet a database, alloted to the PH, might be scanned, looking for the user profile of the calling subscriber. If the calling subscriber is a GSM subscriber, the user profile could also be found in the VLR or in the HLR if it is chosen to save the user profiles here.

3. The Packet Handler maps the called address of the X.25 message to a called party number and maps the calling address to a calling party number.

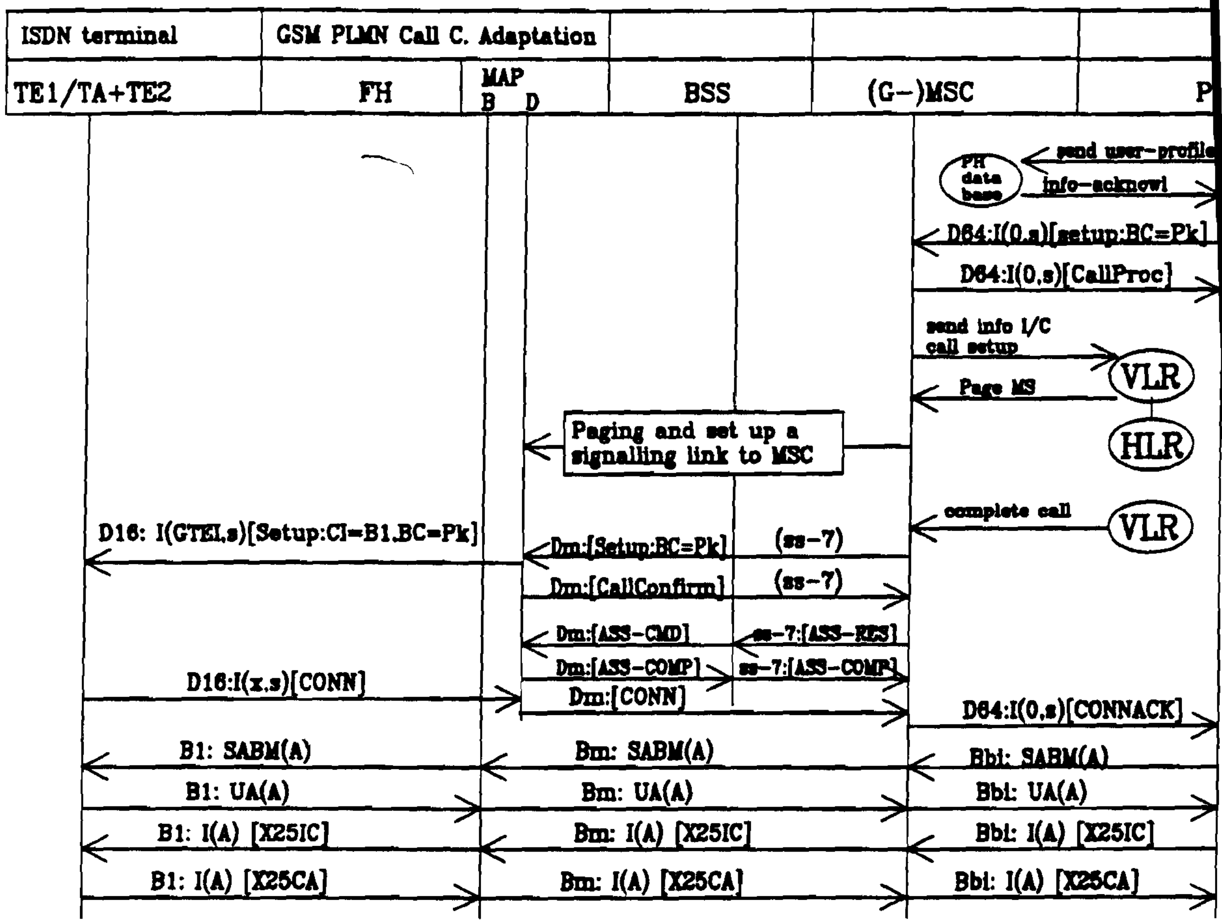
4. The Packet Handler chooses now a Bb channel[2] on the PH interface, and starts the call set up by sending a SETUP message on the D64 channel of the PHI to the GMSC[3]. The addresses, extracted from the X.25 message, will be filled in in this SETUP message. Furthermore, the channel indication is the chosen Bb channel and the bearer capability = 'packet'.

5. The GMSC interrogates the VLR to receive information of the called subscriber, e.g. user profile. This is done by sending the message 'send info for I/C call setup'. If no information of the called subscriber is available, the VLR must get the information from the HLR of the home PLMN of the called subscriber.

6. Before the VLR sends back the desired information, it first sends a request for recovering the location of the called subscriber. This is done by sending a 'Page MS' message to the GMSC.

[2] A Bd channel can also be chosen, it depends on the possibilities in GSM, e.g. if a GSM-FH exists.

[3] If the called subscriber is an ISDN subscriber, a SETUP will be sent to ISDN, if ISDN has the capability to handle these calls, see [8].



Layer 2 Address Indication

DLCI	for subscriber data link on Bd channel SAPI=16, LIC link specific
0,s	D channel signalling link PHI SAPI=0, TEI=0
GTEI,s	broadcast on subscriber access SAPI=0, TEI=127
x,s	signalling link for specific TE SAPI=0, TEI link specific
x,p	data link for specific TE SAPI=16, TEI link specific

Channel Indication

B1,B2	B channel user access
D64	D channel on PHI
D16	D channel user access
Bbi	B channel on PHI for B channel service
Bdi	B channel on PHI for D channel service
Bds	B channel on PHI for D channel service with signalling data link

Figure 7.9: MS terminated call set up if a PH receives an Incoming X.25 Call with the purpose to use the B channel on the S interface.

7. In response to this message, the MSC will receive the outcome of the page MS procedure. If the radio connection (signalling link) is successfully established, the MSC will receive the 'call complete message', which may provide, for example: bearer service information, teleservice information and information as required for handling the incoming call.

8. The MSC, of the MSC area where the called subscriber is situated, sends a SETUP message to the MS. The D-Mapping procedure of PLMN CCAU in the MS sends a Call Confirm message back to the MSC and sends a SETUP message to the ISDN terminal on the D channel with a bearer capability = 'packet' and with a Channel identification (in this case) a B1 channel.

9. If the ISDN terminal accepts the call, a 'CONNect' message is sent back via the D channel. This message will be saved until the network is ready to accept it. In the meantime the MSC sends an 'Assignment' message to set up a Bm channel to the MS.

10. If the Bm channel is set up the MSC connects the Bm channel with a terrestrial channel used on the MSC-GMSC interface and the GMSC connects the terrestrial channel to the Bb channel of the PHI. Now the D mapping procedure sends a 'CONNect' message on the Dm channel to the MSC. The GMSC sends a 'CONNACK' message on the D64 channel of the PHI.

11. The PH is now able to set up an X.25 LAPB link with the terminal of the called subscriber, via which the saved X.25 Incoming Call Request can be sent, resulting in an X.25 Virtual Call. The User Channel Mapping Unit takes care of mapping X.25 packets on the Bm channel to the B channel and vice versa (see Section 6.13).

7.2.3 Call control procedures for D channel access on the S interface

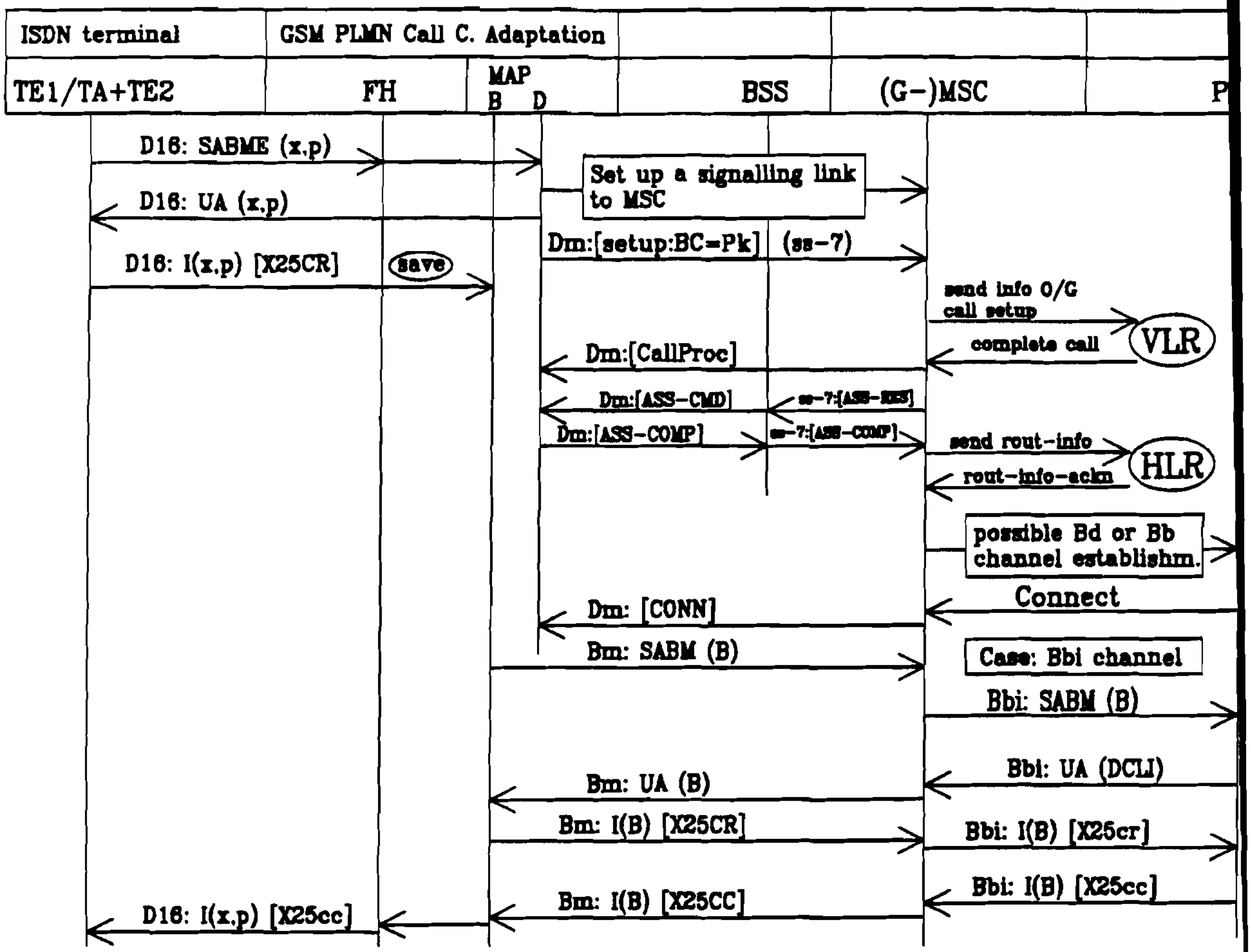
In this section the complete call setup will be handled for X.25 Packet call requests on a D channel (S interface) using the D channel for the transport of packet data.

There are two directions, MS originated call set up and MS terminated call set up.

7.2.3.1 MS originated calls

Figure 7.6 reflects the general procedure to realize MS originated call set up for handling packet mode bearer service requests. A D channel on the S interface can be used for transporting X.25 packet data. However in GSM, a Bm channel on the radio interface must be used for transporting X.25 packet data.

More details can be found in Figure 7.10:



Layer 2 Address Indication

DLCI	for subscriber data link on Bd channel SAPI=16, LIC link specific
0,s	D channel signalling link PHI SAPI=0, TEI=0
GTEI,s	broadcast on subscriber access SAPI=0, TEI=127
x,s	signalling link for specific TE SAPI=0, TEI link specific
x,p	data link for specific TE SAPI=16, TEI link specific

Channel Indication

B1,B2	B channel user access
D64	D channel on PHI
D16	D channel user access
Bbi	B channel on PHI for B channel service
Bdi	B channel on PHI for D channel service
Bds	B channel on PHI for D channel service with signalling data link

Figure 7.10: MS originated call set up to PH with a ISDN data packet terminal on a D channel

1. The subscriber wants an X.25 service and the subscriber's terminal[4] sends for this purpose an X.25 Call Request using, in contrast to the B channel service, a data link with SAPI = 16. The aim is now, for the X.31 terminal, to set up a data link to the PH across the D channel, instead of setting up a B channel to the PH. The terminal sends a SABME frame with SAPI=16 (into the addressing field) to the network (in this case the Mobile station).

2. This SABME frame is received by the GSM PLMN Call Control Adaptation unit of the Mobile station. It will be handled by the Frame Handler (FH) in this unit because the SABME message is sent with SAPI=16. The FH starts the D Mapping procedure because receiving of the SABME message implicates that the D channel service is requested, see Section 6.4. The D Mapping procedure requests a Bm channel with a packet capability because the Dm channel on the radio interface cannot be used for X.25 packet data.

3. The D mapping procedure handles the Bm channel request, but first a signalling link will be set up between the MS and the MSC (GSM setup procedure, see Section A). On this link a Bm channel is requested with a Bearer Capability = 'packet' by the D Mapping procedure.

4. The connection request is routed to the GMSC (Gateway MSC[5]) using SS no.7. According to the D channel packet service in ISDN a Bd channel must now be requested on the PH interface. However the Bm channel is used in GSM for packet data, so that also a Bb channel can be requested (the choice of a GSM network operator). If a Bd channel is used a GSM-FH is needed to multiplex data links on a Bd channel, see Section 6.3.1.3. The signalling procedures which handle the Bd channel request can be found in [14] or [8].

   In this case a Bb channel request is handled to simplify the setup procedure.

5. The GMSC must now set up a Bb channel to the PH. Normal ISDN procedures will be followed, but only those who are necessary to set up a channel, like in the case of B channel service. The GMSC sends a SETUP message to the Packet Handler across the D64 channel. A Channel identification 'any B' is sent along with the Request to indicate that a Bb channel is needed (this is because of the difference between Bb and Bd channel request procedures).

6. The Packet Handler chooses a free Bb channel of the PHI and accepts the call with a 'Connect' message, and sends this to the GMSC along with the indication of the chosen Bb channel. The GMSC now knows which Bb

[4]ISDN TE1 = data terminal (TE2) with X.31 Terminal Adaptor (TA)

[5]A GMSC is a MSC with a PH interface (PHI) to the PH.

channel it can use, and connects this channel with the Bm channel in the switch matrix.

7. The channel establishment is signalled to the BSS using SS.no.7, and further as a 'CONNECT' message on the Dm channel to the Mobile Station. The D mapping procedure is now finished.

8. The User Channel Mapping Unit in combination with the FH in the PLMN CCAU must take care of further X.25 procedures. First an X.25 LAPB link must be established with the PH, via which the saved X.25 Call Request Packet can be sent to become an X.25 Virtual Call.

9. When the X.25 Virtual Call set up is completed an X.25 Call Connect message is sent back to the ISDN terminal.

10. The User Channel Mapping Unit also takes care for X.25 packet data to be handled properly: data packets on the D channel will be mapped on the Bm channel and vice versa.

7.2.3.2 MS terminating calls

Figure 7.8 visualizes the general procedures to realize MS terminated call set up for an Incoming X.25 call on a PH. In this case a D channel is used on the S interface for packet data.

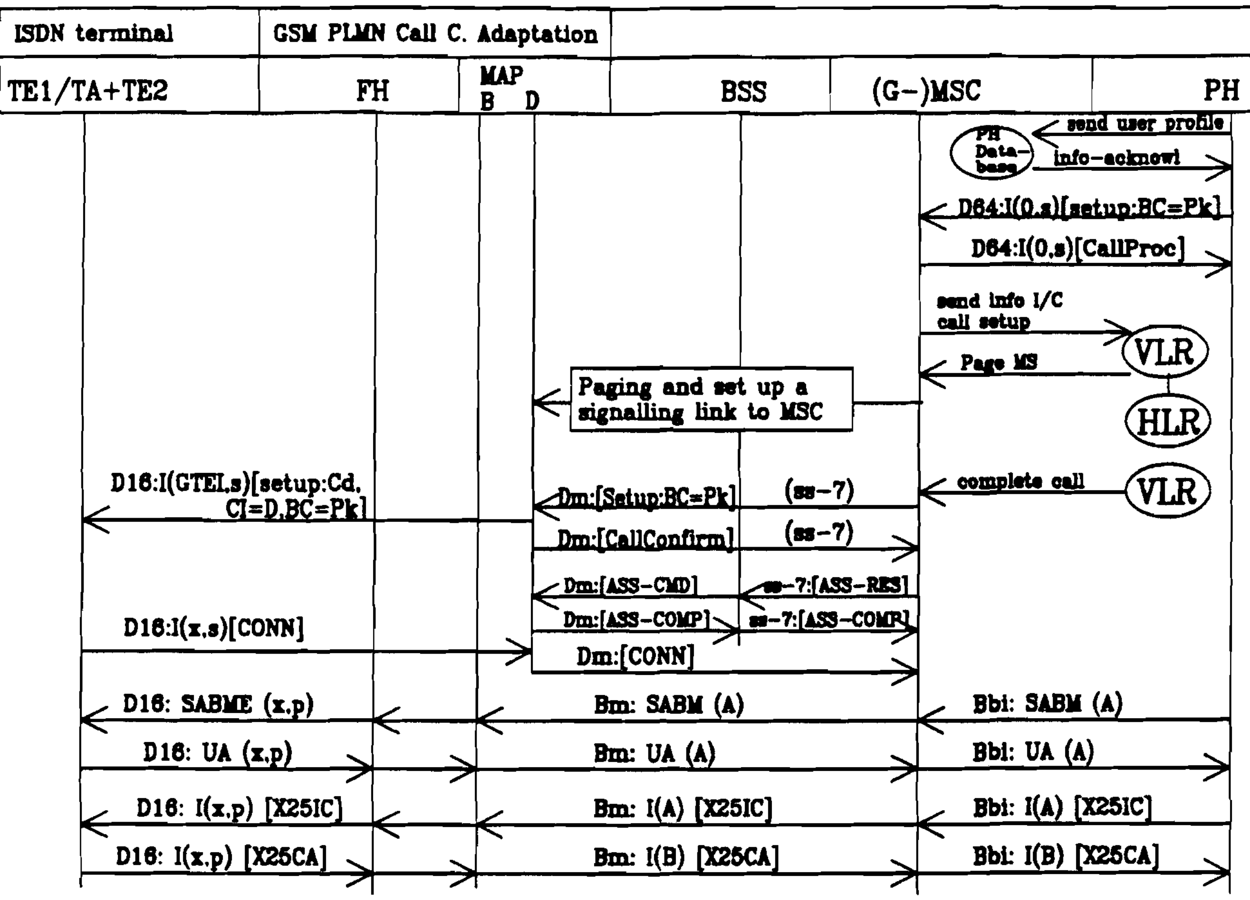
More details can be found in Figure 7.11:

1. If the PH wants to use a Bb channel on the PH interface towards the GMSC, steps 1 to 8 can be followed in Section 7.2.2.2. The only difference is that the D mapping procedure of the GSM PLMN Call Control Adaptation unit sends a SETUP message with a channel identification = D channel to the ISDN terminal.

   If the PH wants to use a Bd channel, like is done in the ISDN-PH case (see [8]), the GMSC must have the capability to handle the PHI signalling protocols for this case. Therefore, that a GSM-FH is needed, see Section 6.3.1.3.

   This is not necessary if no need exists in the GSM system for statistical multiplexing. However if X.25 packet data, after the transport on the fixed Bm channel (radio-interface), will be statistically multiplexed, then a FH in the MSC (GSM-FH) is needed. A Remotely Controlled Multiplexing Unit (RCMU) between the BSS and the MSC can also be used if it supports the GSM-FH functions, see Section 6.5.3. If statistical multiplexing is used in GSM it is attractive to use the Bd channels on the PHI.

2. If the ISDN terminal accepts the call a 'CONNect' message will be sent to the MS. The following steps are the same as steps 9 to 11 in Section 7.2.2.2



Layer 2 Address Indication

DLCI	for subscriber data link on Bd channel SAPI=16, LIC link specific
0,s	D channel signalling link PHI SAPI=0, TEI=0
GTEI,s	broadcast on subscriber access SAPI=0, TEI=127
x,s	signalling link for specific TE SAPI=0, TEI link specific
x,p	data link for specific TE SAPI=16, TEI link specific

Channel Indication

B1,B2	B channel user access
D64	D channel on PHI
D16	D channel user access
Bbi	B channel on PHI for B channel service
Bdi	B channel on PHI for D channel service
Bds	B channel on PHI for D channel service with signalling data link

Figure 7.11: MS terminated call set if a PH receives an Incoming X.25 Call Request with the purpose to use the D channel on the S interface

with the only difference that a D channel is used on the S interface. The FH and the User Channel Mapping Unit handle the mapping of the Bm channel to the D channel and vice versa.

3. If statistical multiplexing is used in the GSM system, the mapping of packet data from the D channel on the Bm channel of the radio interface is the same as if no statistical multiplexing is used, but on the network side of the radio interface, a channel must be set up between the GSM-FH (situated in the MSC) to the FH in the PH (Bd channel) and the Bm channel must be switched to this channel via a terrestrial channel. The MSC could also decide to introduce a RCMU, it will be the choice of the GSM network operator. The signalling procedures of the ETSI PHI report (see [14] and [8]) can be used as a basis to handle the Bd channel set up procedures.

7.3 Conclusions on call control signalling

If the ETSI PHI will be used then it is necessary to map call control signalling from Transit Signalling[6] in the GSM system to PH signalling and vice versa. On the user network interface of GSM it is necessary to map call control signalling of ISDN to call control signalling of GSM and vice versa.

In this report all the call control possibilities for the GSM variant of X.31 case B services have been described. Some conclusions:

- **User network interface protocols for packet calls**
  In this report the user network interface protocols for packet calls in GSM are introduced and described.

- **PLMN call control mapping**
  The signalling procedures are described to map call control signalling of ISDN to call control signalling of GSM and vice versa.

- **PHI protocols without changings**
  The PHI protocols out of the ETSI PHI recommendation (see 7.1.1.3) can be used without changings. This implies that the CC7 signalling in GSM must be mapped on PHI signalling.

[6] Signalling system no.7.

Chapter 8

Conclusions

In this report it is described how GSM can support data services.

A closer look to mobile data services is performed to give more insight into the requirements to implement these services in GSM.

An introduction of GSM is given in this report to show the GSM capability to support data services.

The ETSI PHI implementation of a X.31 case B variant for GSM is described as a solution for GSM to support data services.

Some 'problems' are identified: access of X.31 case B services in GSM (e.g. with an ISDN terminal), numbering plan interworking, multiplexing functions in GSM and call control interworking.

Finally, conclusions are given and can be found in the following sections. The main conclusion is that the ETSI PHI implementation can be used in GSM to support data services. No changings are needed on the PHI, but some functions are introduced in GSM to support the X.31 case B services.

8.1 Data services

- **Growing market**
  Data services are a constantly growing part of the telecommunication market. Most of the data services are at this moment obtainable from the fixed X.25 based data networks[1]. Most of the European countries have such networks and communication is possible between those data networks.

- **Mobile services**
  A growing interest in *mobile* data services exists. A reason for this interest is that many applications, which are categorized as data services with a mobile character, are possible.

[1]Packet Switched Public Data Networks (PSPDN).

- **Interworking needed**
  If mobile subscribers of GSM want to have data communication with subscribers of existing data networks[2] and vice versa then interworking between these networks is needed. Many mobile data services are based on this interworking, e.g., a mobile subscriber wants to access a database which is connected with a data network.

8.2 The capability to support data services in GSM

- **Data services compatible with ISDN**
  The GSM system is optimized for speech services. The interest to implement data services has grown because of the importance of data services (explained above). One of the premises of GSM was to support services which are compatible with ISDN. As a consequence, the data services offered in GSM system have the same structure as the data services offered in ISDN. This also means that if interworking is needed with a data network, the X.25 service must be possible in GSM.

- **Reachability**
  The GSM network is designed to get access to telecommunication services independent of the subscriber's location in Europe. This makes the GSM network suitable to implement *mobile* data services.

- **The limitations of mobile services**
  The nature of the service support within the GSM network imposes some limitations and constraints, some of which relate to air interface factors and some to network issues:

  - **Air interface**
    The channel structure on the radio interface is optimized for speech services. Some important factors of the radio interface are:

    1. The net bit rate of 13 kbit/s for full rate channels.
    2. Severe fading and interference likely on these channels.
    3. Significant breaks in transmission as a result of shadowing or handover.

  - **Network issues**

    1. Routing via different network nodes (Base stations and switches) during the progress of a single call.

[2]For example the Dutch Datanet 1. Many companies have investments in fixed data networks.

2. Different charging regimes for Datanet 1 subscribers to those of the GSM system. This is not described in this report.
3. Different network numbering schemes between Datanet 1 (X.121) and GSM (E.164).
4. Traffic handling for roaming subscribers.

8.3 The interworking scenarios

The interworking scenarios which are examined are all based on the assumption that the packet functionality of GSM is implemented in packet switched data networks (PSPDNs). The following conclusions are made:

- **Direct interworking**
  The GSM system will sooner be operational than ISDN. As a consequence, if a GSM subscriber wants to have a full duplex data communication connection with a fixed data network then direct interworking with the data network is needed. Otherwise one has to wait for an ISDN solution. In that case the GSM network must support data services via a GSM-ISDN interface.

- **Cheap solution**
  A cheap solution is possible with existing network elements. This solution is based on a PAD access via PSTN to a PSPDN. Now it is only possible to perform mobile station originated call set up to establish a connection.

- **ISDN solutions**
  A solution in ISDN to support data services already exists: X.31 Case A and Case B. This solution could be applicable for the GSM system, because GSM comforms to the description of data services with ISDN[3] and X.31 case B is already recommended to be the solution for ISDN in future.

- **Full X.31 implementation**
  If GSM wants a full implementation of X.31 it is necessary to change or to extend the channel structure of the GSM radio interface, because the proposed channel structure in GSM recommendation limits the possibilities for data services. In this report two new channel structures are briefly described, however these channel structures are not fully described because the GSM recommendation is handled as stable information.

[3] Sometimes GSM is called mobile ISDN.

8.4 The ETSI PHI implementation of X.31 case B in GSM

The ETSI PHI implementation of an X.31 case B variant is described as a solution for GSM to support packet mode services. The following conclusions are made:

- **The importance of Case B**
  One of the most important applications of Case B in the ISDN situation is the possibility to multiplex data if the D channel is used as a packet data communication channel. This D channel service can only be offered with Case B.

- **Implementation X.31 Case B: the ETSI PHI**
  The ETSI PHI was developed as the solution for X.31 case B, thus providing packet mode services in ISDN. In this report it is shown how the ETSI PHI can be used in the GSM environment. Additional benefits of the GSM X.31 case B variant are:

  - If the ETSI PHI implementation can be used within GSM, it will be another argument to recommend the ETSI PHI.
  - It is possible to use existing PSPDNs which is preferable, because in many companies PSPDN operators have made investments in X.25 network elements.
  - GSM and ISDN can use the same PH, so it is possible for data communication to have a direct connection between GSM and ISDN.
  - It is possible with the ETSI PHI to use a remote access model. This means a flexible solution in sense of dimensioning the available X.25 resources.

- **The D channel service cannot be offered in GSM**
  The reasons for this conclusion can be found on the user network interface (radio interface) of GSM, see Section 6.3.1.

- **The B channel service is possible**
  The B channel service is possible with three categories:

  1. **Transparent Bm channel in GSM**
     This implementation provides a minimal service. This service can only be a service with a less mobile character, because burst of errors cannot be detected and corrected on the radio interface.
  2. **Non-transparent Bm channel in GSM**
     This is a better implementation of the B channel service, because of the additional error correction on the radio interface. An interworking

function is needed in the MSC to map a special layer 2 protocol on the radio interface to the LAPB protocol used on the PHI.

3. **Statistical multiplexing in GSM**
   This implementation provides no improved service, compared with the non-transparent case of GSM, towards the users. It is only an improvement from a point of view of the network manager because channel capacity is more optimally used. A penalty is paid in complexity because a GSM-FH is needed to multiplex data links on Bd channels of the PHI.

- **PLMN Call Control Adaptation Unit**
  It must be possible to use an ISDN terminal with a capability to support packet data. In that case a PLMN Call Control Adaptation Unit is needed. The most important task is to translate the B and D channel service in ISDN into appropriate services in GSM and vice versa. In this report a description of this unit is introduced.

- **Statical multiplexing**
  It is possible to statically multiplex traffic (speech or data) or signalling channels. To implement this, remote control out of the BTS[4] is needed.

- **Statistical multiplexing within GSM: GSM-FH**
  A solution to statistically multiplex data within GSM is given in this chapter. However this is only possible on the network side of the radio interface[5], otherwise the channel structure on the radio interface has to be changed. A GSM-FH is proposed in this report to implement statistical multiplexing between a MSC and a PH. This FH must perform a translation of a special layer 2 protocol, needed to overcome data errors made on the radio interface, to a special data link (Q.921* data link) on the PHI and vice versa.

- **Remote Controlled Multiplexing Unit (RCMU)**
  A RCMU is proposed in this report to implement statistical multiplexing between Base Stations and their MSC. This RCMU must also interwork with the protocols used on the PHI. As an example the RCMU can include the GSM- FH functions. A RCMU is controlled by the MSC.

[4] Base Transceiver Station, a part of the Base Station.
[5] No common access channel exists on the radio interface.

8.5 Call control interworking

If the ETSI PHI will be used then it is necessary to map call control signalling from Transit Signalling[6] in the GSM system to PH signalling and vice versa. On the user network interface of GSM it is necessary to map call control signalling of ISDN to call control signalling of GSM and vice versa.

In this report all the call control possibilities for the GSM variant of X.31 case B services have been described. Some conclusions:

- **User network interface protocols for packet calls**
  In this report the user network interface protocols for packet calls in GSM are introduced and described.

- **PLMN call control mapping**
  The signalling procedures are described to map call control signalling of ISDN to call control signalling of GSM and vice versa.

- **PHI protocols without changings**
  The PHI protocols out of the ETSI PHI recommendation (see 7.1.1.3) can be used without changings. This implies that the CC7 signalling in GSM must be mapped on PHI signalling.

8.6 Numbering plan interworking and routing

- **GSM numbering plan**
  The numbering plan of GSM is based on E.164. The E.164 numbers are called Mobile Station ISDN (MSisdn) numbers. It may be necessary to give a X.121 number in addition to a MSisdn number.

- **Uniform solution to distinguish between ISDN and GSM**
  It is preferable to have one unique solution to distinguish between ISDN and GSM numbers. A shared PH for ISDN and GSM means that a PH must determine which E.164 number is a GSM or an ISDN number. A unique solution for the whole of Europe avoids that a PH must know all the national solutions.

- **Interworking function needed**
  An interworking function is needed (e.g., situated in a PH) if in addition to the E.164 number an X.121 number is used for a GSM subscriber. This function must translate the GSM X.121 number into a Mobile Station ISDN number (E.164). This assumes that the X.121 numbering plan must be a part of the E.164 numbering plan.

[6] Signalling system no.7.

- **Routing with the use of PSPDN**
  It is preferable for a data call in GSM to remain as long as possible in PSPDN because the nature of the call is an X.25 connection. As an example, a PSPDN originated international call for a GSM subscriber could better be routed within PSPDNs until the GSM PLMN is reached in which the called GSM subscriber is situated. This implies that the PSPDN needs some location information of the GSM subscriber. This information is found in the databases of GSM (HLR and VLR). A procedure to interrogate these databases is for further study.

8.7 For Further Study

Some interworking items are not fully covered in this report and are for further study:

- **Handover problems**
  It might be a problem if the following three conditions are satisfied: a connection is made to a PH, statistical multiplexing is used and a handover procedure must be performed.

- **New channel structures of the radio interface**
  In Chapter 5 it was suggested to change the channel structure to get a better implementation of the services offered in recommendation X.31. A first attempt to describe these channel structures is given, but a full description is for further study.

- **New developments**
  This report describes how GSM can support data services which are based on the X.25 protocol, but new developments must be considerated to make the right decision how data services can be offered in future. This is not performed in this report. Some new developments are:

  - **Frame mode services**
    Frame mode bearer services are ways to perform packet switching according to the ISDN-method: separation of signalling procedures and data transfer procedures. The reader is referred to a PTT Research report 622/90 ('frame mode: wat is het en wat kan ermee', ir. A.J.J. Kerkhof).

  - **The introduction of B-ISDN**
    With the introduction of the Broadband ISDN, a lot of new services will be offered, e.g. multimedia services. The reader is referred to the many existing reports which deal with this subject.

- **A separation of call control and connection control**
  A flexible and efficient control of multimedia calls is enabled when control of the connections and control of the call are separated. The reader is reffered to a PTT Research report 1110/90 ('the separation between Call Control and Connection Control in the B-ISDN', ir. P.F.C. Blankers).

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- I.510: 'Definitions and general principles for ISDN interworking'
- I.550: 'General arrangements for interworking between packet switched public data networks (PSPDNs) and integrated services digital networks (ISDNs) for the provision of data transmission'

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- E.166: 'Numbering plan interworking in the ISDN era'
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- 02.03: 'Teleservices'
- 03.10: 'Connection Types'
- 09.03: 'Signalling interworking'
- 03.03: 'Numbering'
- 04.21 & 08.20: 'Rate Adaptation'
- 04.22: 'Radio Link Protocol'
- 03.70: 'Routing'
- 07.01 to 07.03: 'Terminal adaptation functions'
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- 08.60: 'Inband control of remote transcoders and rate adaptors'
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Abbreviations

AGCH	Access Grant Channel
AU	Access Unit
AUC	Authentication Center
BCCH	Broadcast Control Channel
BSC	Base Station Controller
BSS	Base Station System
BSSAP	Radio Subsystem Apllication Part
BSSMAP	BSS Management Application sub-Part
BTS	Base Transceiver Station
CCCH	Common Control Channel
CCU	Channel Codec Unit
CRF	Connection Related Function
CRP	Call Request Packet
DCC	Data Country Code
DCCH	Dedicated Control Channel
DLCI	Data Link Connection Identifier
DNIC	Data Network Identification Code
DTE	Data Terminal Equipment
DTP	Direct Transfer Application sub-Part
EIR	Equipment Identity Register
ETSI	European Telecommunication Standards Institute
FACCH	Fast associated DCCH
FCCH	Frequency Correction Channel
FEC	Forward Error Correction
FH	Frame Handler
GSM	Groupe Spéciale Mobile
HLR	Home Location Register
IC	Incoming Call
IMEI	International Mobile Equipment Identity
IMSI	International Mobile Subscriber Identity
IWF	Interworking Function

L2R	Layer 2 Relay function
L2RBOP	L2R Bit Oriented Protocol
MM	Mobility Management
MS	Mobile Station
MSC	Mobile Switching Center
MSisdn	Mobile Station ISDN number
MTP	Message Transfer Part
NN	National Number
NTN	Network Terminal Number
NOMC	Network Operation and Management Center
NUI	Network User Identification
OA&M	Operation, Administration and Maintenance
OMC	Operation and Maintenance Center
PAD	Packet Assembler Disassembler
PCH	Paging Channel
PDS	Packet Data Satellite
PH	Packet Handler
PHI	Packet Handler access point Interface
PHS	Packet Handler Signalling
PLMN	Public Land Mobile Network
PLMN CCAU	PLMN Call Control Adaptation Unit
PRA	Primary Rate Access
PSE	Packet Switching Exchange
PSPDN	Packet Switched Public Data Network
PSTN	Public Switched Telephone Network
PVC	Permanent Virtual Circuit
RA	Rate Adaptation
RACH	Random Access Channel
RCMU	Remote Controlled Multiplexing Unit
RLP	Radio Link Protocol function
RT	Radio Transmission
SAPI	Service Access Point Identifier
SACCH	Slow Associated DCCH
SCCH	Signalling Connection Control Part
SCH	Synchronization Channel
SDCCH	Stand alone DCCH
SS7	CCITT Signalling System no.7

TCH	Traffic Channel
TDMA	Time Division Multiple Access
TE	Terminal Equipment (TE-1: ISDN, TE-2: non ISDN)
TEI	Terminal Endpoint Identifier
TRAU	Transcoder/Rate Adapter Unit
UCMU	User Channel Mapping Unit
UPCH	User Packet Channel
US	User Signalling
VC	Virtual Call
VLR	Visited Location Register

List of figures

Appendix A

GSM setup procedures for call control

Call establishment means for the GSM system, compared to the ISDN, to handle some special procedures: to set up a signalling link, identification, authentication, ciphering and TMSI reallocation procedures. These procedures are independent of who requested the call set up, and are described in this appendix.

Figure A.1 gives an overview of the procedures needed in the GSM system before a 'call setup' can be handled. These procedures are described in the following sections. A complete description can be found in the GSM recommendation 08.08, 09.02, 04.08 and 09.09.

A.1 Setting up a signalling link between a MS and a MSC

The GSM system uses out-of-band signalling for call control, just like in ISDN, but the Dm channel must be set up when a user wants access to the GSM system. The procedure to set up a signalling link can be split in four parts, see Figure A.2.

1. First of all the MS requests a signalling link on the Random Access channel with a 'random access message' which is a layer 3 message, see Figure A.3. A successful Random Access channel request will be confirmed by the network with an 'Immediate Assignment message'. A SDCCH (Stand Alone DCCH) has now been allocated to the MS. This SDCCH is used for further signalling procedures described in this appendix.

2. Next a data link (layer 2) will be set up by sending a 'Set Asynchroon balanced mode (SABM) message'. A data link layer entity in the BTS confirms acceptance of a SABM command by the transmission at the first opportunity of an Unnumbered Acknowledge response (UA) response.

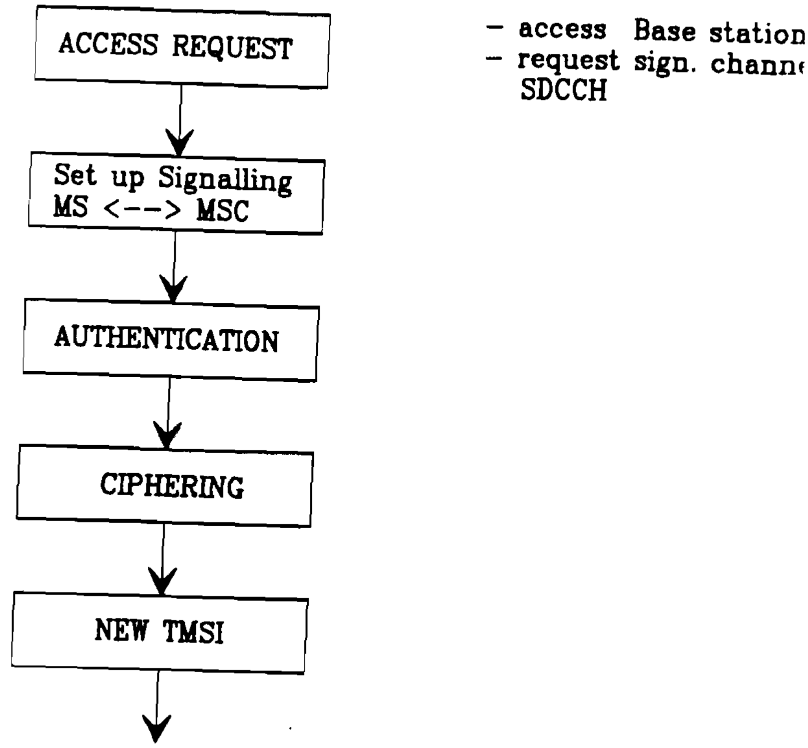

Figure A.1: The GSM set up procedures before call request handling.

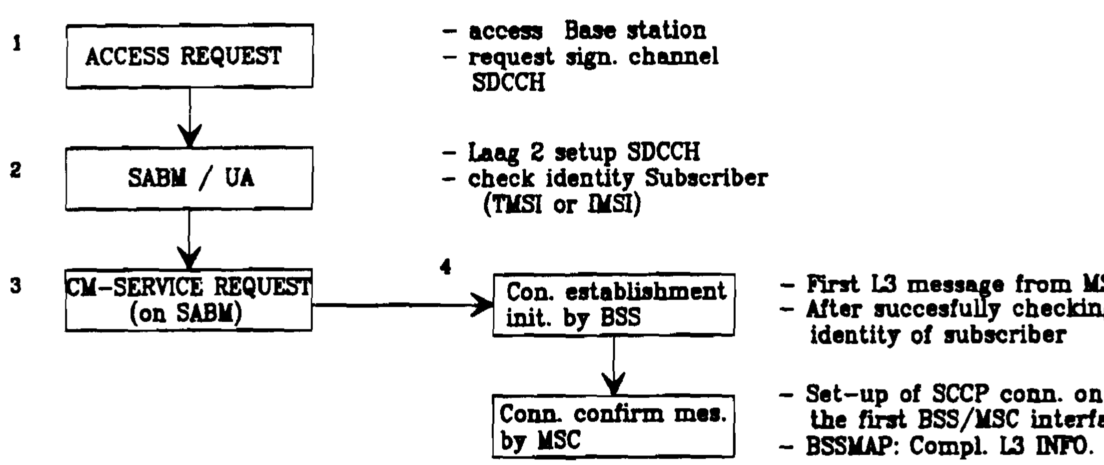

Figure A.2: Procedures to set up a signalling link in the GSM system.

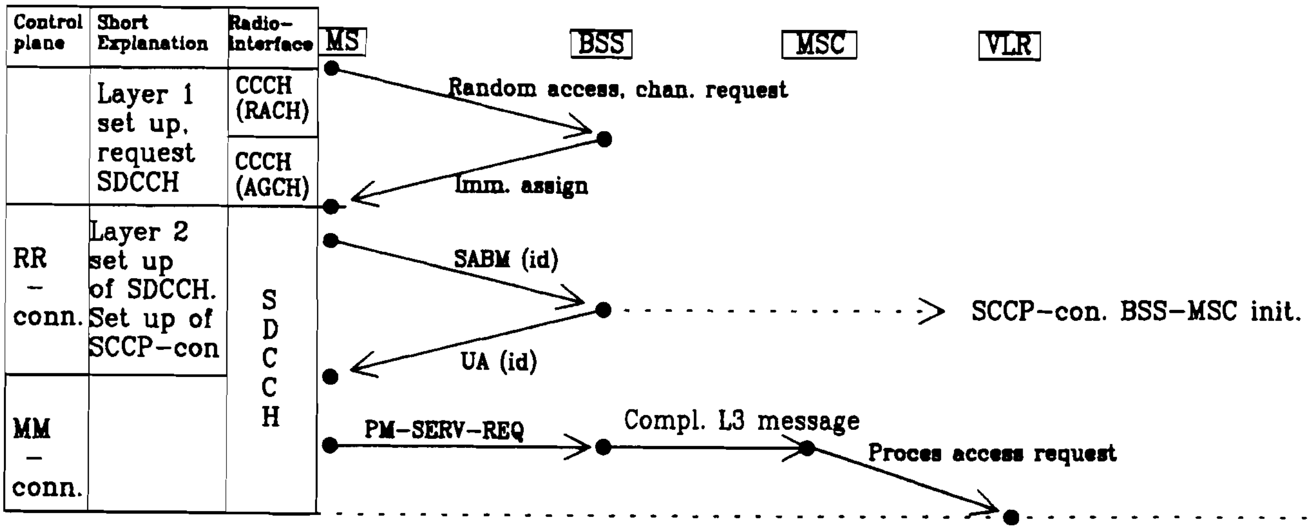

Figure A.3: The MS requests access to the network

3. The PM-Service-Request[1] can now be transferred over the control channel and will be kept in the BSS until a MM[2] sub-layer connection is established. The PM-Service-Request contains service identity and mobile identity. On receiving this message the BSS, after successfully having checked the identity of the MS, initializes a SCCP connection to the MSC.

4. After setting up a signalling link to the MSC, the PM-Service- Request is sent to the MSC as part of 'Complete Layer 3 information' message.

A.2 Identification

A unique IMSI (International Mobile Subscriber Identity) is allocated to each Subscriber. For card operated MSs an IMSI is allocated to the card. It is only used for the internal operation of the GSM system, and not for dialing. Optional a TMSI (Temporary Mobile Subscriber Identity) is used instead of the IMSI. The TMSI is allocated to the MS by the VLR and is changed at least after every authentication procedure. If a TMSI is used instead of an IMSI the VLR maps the TMSI to the IMSI.

Identification of the MS is controlled first in the 'Random Access/Immediate Assignment' procedure and is finished in the 'SABM/UA' procedure (see above).

[1]Packet Mode Service Request: it is assumed that this message is possible, because normally a CM-SERVICE- REQUEST is used. However, it makes no difference for the procedures in this appendix.

[2]Mobility Management

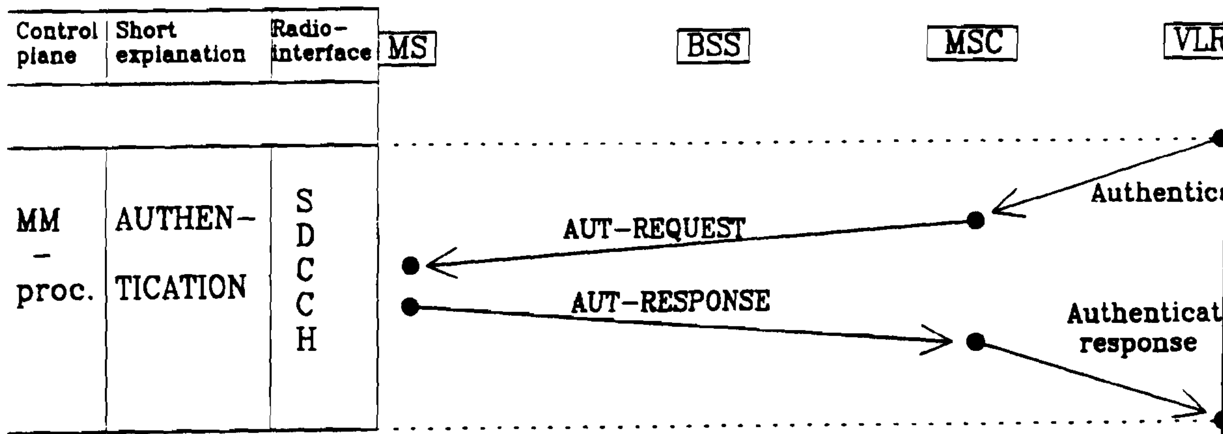

Figure A.4: The Authentication procedure

A.3 Authentication

The purpose of authentication is to check whether or not the identity provided by the Mobile Station is authorized. After receiving the 'Complete Layer 3 information' message the MSC sends a 'process access request' to the VLR, see Figure A.4. In the normal case, if the VLR knows the TMSI of the originating subscriber, the authentication procedure will know be started with the 'authenticate' message, send from the VLR to the MSC. The MSC converts the MAP authentication message to layer 3 message of the MS-MSC interface. The MS sends back an 'Authentication Response' message to the network to deliver a calculated response (with a secret key) to the network (see GSM Recommendation 04.08). The MSC changes the message to the MAP authentication response for authentication checking.

A.4 Ciphering

If authentication was successful, the VLR requests the MSC to start ciphering procedures with the message 'start ciphering', see Figure A.5. The message contains ciphering information and it also indicates whether ciphering is used or not. This information is sent to the BSS and MS with a 'Cipher Mode Command' message. The 'Cipher Mode Complete' message will be sent back as an indication that appropriate action on enciphering and deciphering has been started by the MS and the BSS.

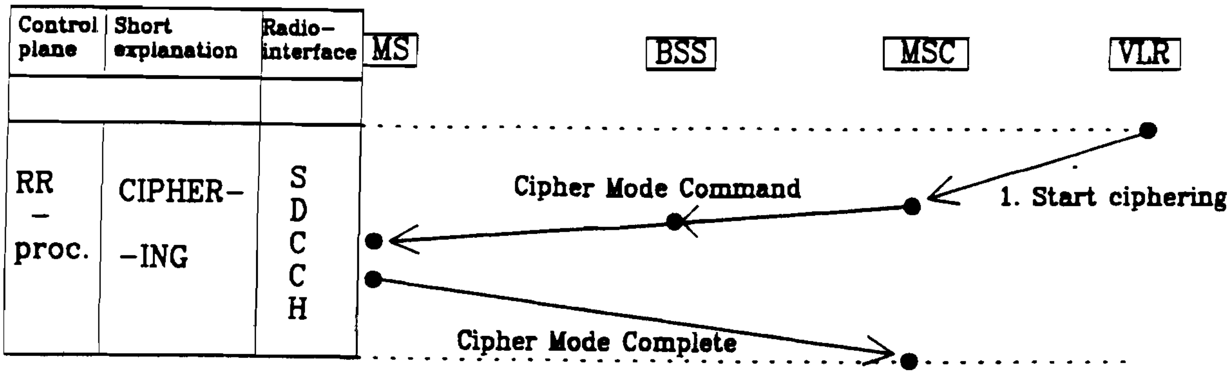

Figure A.5: The Ciphering procedure

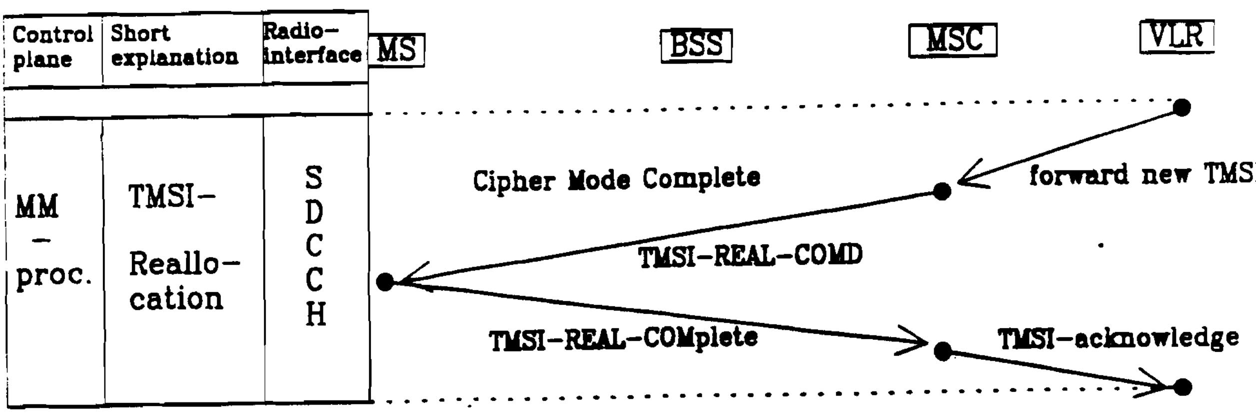

Figure A.6: The TMSI Reallocation procedure.

A.5 TMSI reallocation

The purpose of the TMSI reallocation procedure is to provide identity confidentiality, e.g. to protect a user against being identified and located by an intruder. The TMSI reallocation procedure must be performed at least at each change of a location area, because the TMSI has only local significance within a location area. The procedure is started, see Figure A.6, with the 'TMSI Reallocation Command'. This message is sent by the network to the mobile station to reallocate a new TMSI and it is using a RT connection in ciphered mode. A reaction is the command 'TMSI Reallocation Complete'. This message is sent by the mobile station to the network to indicate that reallocation of a new TMSI has taken place.