The Evolution and Future of Mobile Communication Systems

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Chapter 3 : EDGE (Enhanced Data rates for GSM Evolution)

3.1 The Evolution of the GSM Network

The existing mobile digital communications network continues to develop, in order to increase capacity, coverage, quality and data transmission rates. There have been a series of developments that are now starting to be deployed with the aim of enhancing the GSM network functionality.

Figure 3.1 shows the enhancements planned for the next few years, starting off with High Speed Circuit Switched Data (HSCD). The next development is General Packet Radio Services (GPRS), this is a packet-switched service that allows full mobility and wide-area coverage. Enhanced Data rates for GSM Evolution (EDGE) will use enhanced modulation and related techniques, further improving local mobility. Universal Mobile Telecommunications System (UMTS) will include second and third generation services.

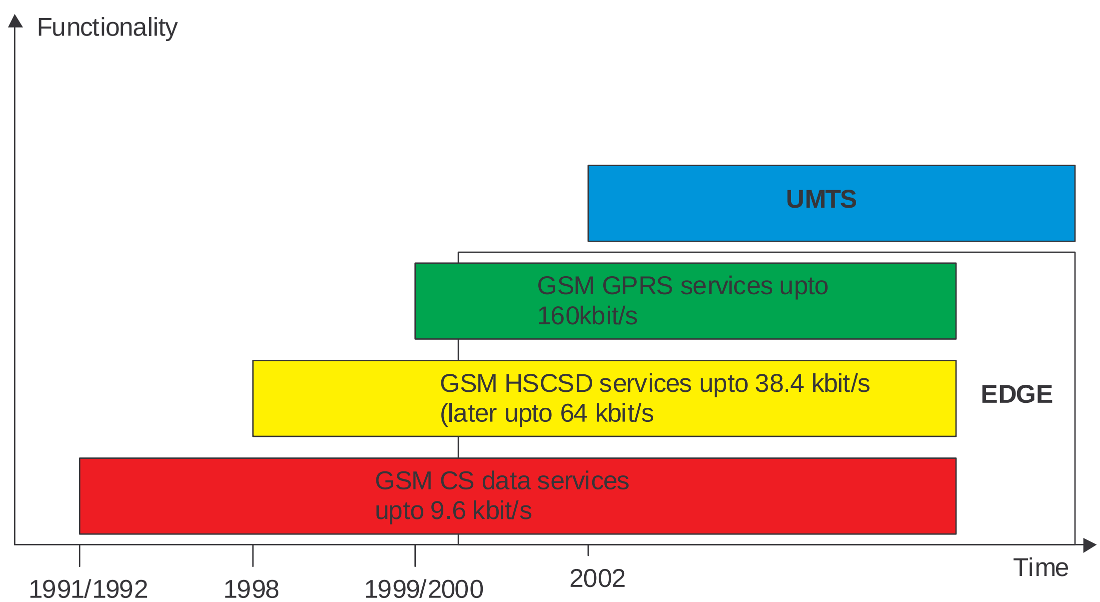

Figure 1 Evolution of GSM Data Service

(Adapted from Ericsson Document EN/LZT 123 5374 R1B)

3.2 High Speed Circuit Switched Data (HSCSD)

HSCSD is basically an upgrade of the original GSM CS data transmission system, by using HSCSD the speed at which data is transmitted is greatly improved. The higher data transmission rates are achieved by making use of bundled Traffic Channels (TCH). The way that this works is the MS requests one or more TCHs from the GSM network, in other words the MSC will allocate TDMA slots within a TDMA frame. This allocations do not need to be asymmetrical i.e. more slots can allocated downlink than the uplink, this fit the behavior of most users, typically the user will download more than they will upload. HSCSD requires software upgrades in an MS and MSC, this is because both have to be able to split a single traffic stream into several traffic streams, each using a TCH, and then to combine the streams again.

In theory a single MS could use all eight time slots within a TDMA frame to achieve an Air Interface User Rate (AIUR), for example 8 TCH/F14.4 channels or 115.2 kbit/s (ETSI 1998) TR 101 186. One major problem with this configuration is that the MS is required to send and receive at the same time. However standard GSM does not support this, uplinks and down links are always shifted for three slots. ESTI, (1997) EN 301 344, specifies that the AIUR available at 57.6 kbit/s (duplex) using four time slots and four time slots for the downlink, the table on the next page shows the allowable combinations of TCHs and allocated slots for non-transparent services.

AIUR	TCH/F4.8	TCH/9.6	TCH/14.4
4.8 kbit/s	1	-	-
9.6 kbit/s	2	1	-
14.4 kbit/s	3	-	1
19.2 kbit/s	4	2	-
28.8 kbit/s	-	3	2
38.4 kbit/s	-	4	-
43.2 kbit/s	-	-	3
57.6 kbit/s	-	-	4

Table 4.1(Available Data Rates for HSCSD)

(Adapted from Ericsson Document EN/LZT 123 5374 R1B)

Although HSCSD delivers major advantages in data transmission over GSM CS it does have several major disadvantages, it still uses a connection-orientated mechanisms of GSM, these mechanisms are not very efficient when it comes to computer data traffic, which typically uses bursts of data. If a large file is being downloaded HSCSD may require all channels to be reserved, where as typical web browsing would leave the channels idle most of the time. The allocation of channels is reflected directly in the service cost, as once the channels have been reserved by one HSCSD user other users can not use them, even if they are idle.

HSCSD was not used by any of the UK operators, this was because of the disadvantages stated above and the fact that GPRS came along so fast.

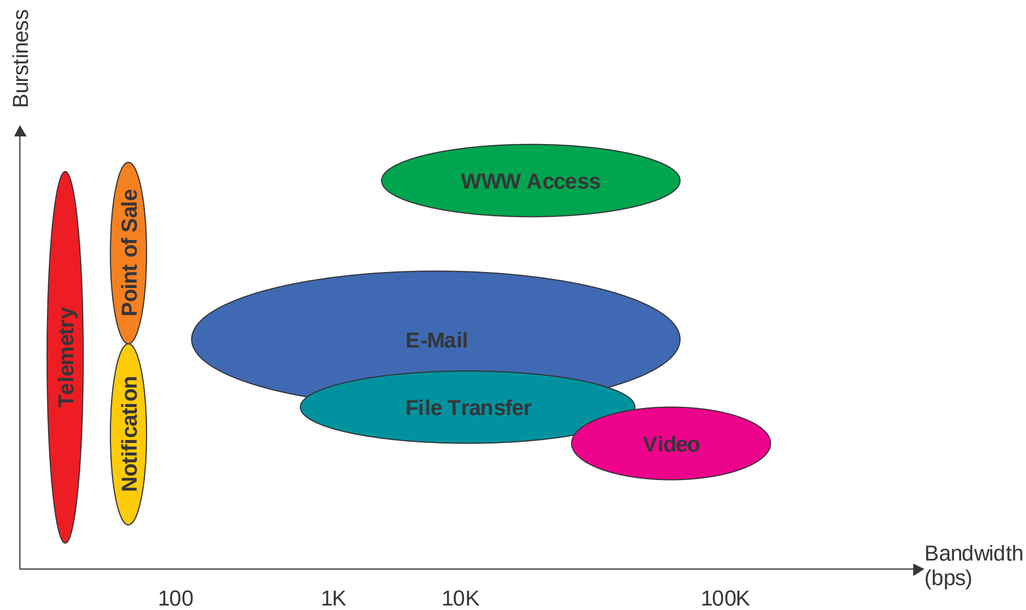

Figure 2 Areas of Bursty and/or bandwidth consuming communications

(Adapted from Ericsson Document EN/LZT 123 5374 R1B)

There are two main ways of transmitting data, Circuit-Switched (CS) and Packet-Switched (PS) communication, this is sometimes referred to packet data communication).

Figure 19 illustrates areas of bursty and/or bandwidth consuming communications. Burstiness and bandwidth requirements affect the type of communication chosen – circuit-switched, packet-switched, or e.g. SMS (Short Message Service) communication. However it should be noted that when choosing the manner of communication for an application the cost should be considered.

3.3 General Packet Radio Service (GPRS)

3.3.1 System Overview

The parts of the GPRS system that carry out the switch of packet data are called the Serving GPRS Support Node (SGSN) and the Gateway GPRS Node (GGSN). The SGSN provides a packet routing to and from the geographical SGSN service area. The GGSN makes up the interface towards the external IP packet networks, the SGSN.GGSN is physically separated from the circuit-switched part of the GSM system. The other parts of the GPRS architecture utilize the current GSM network elements.

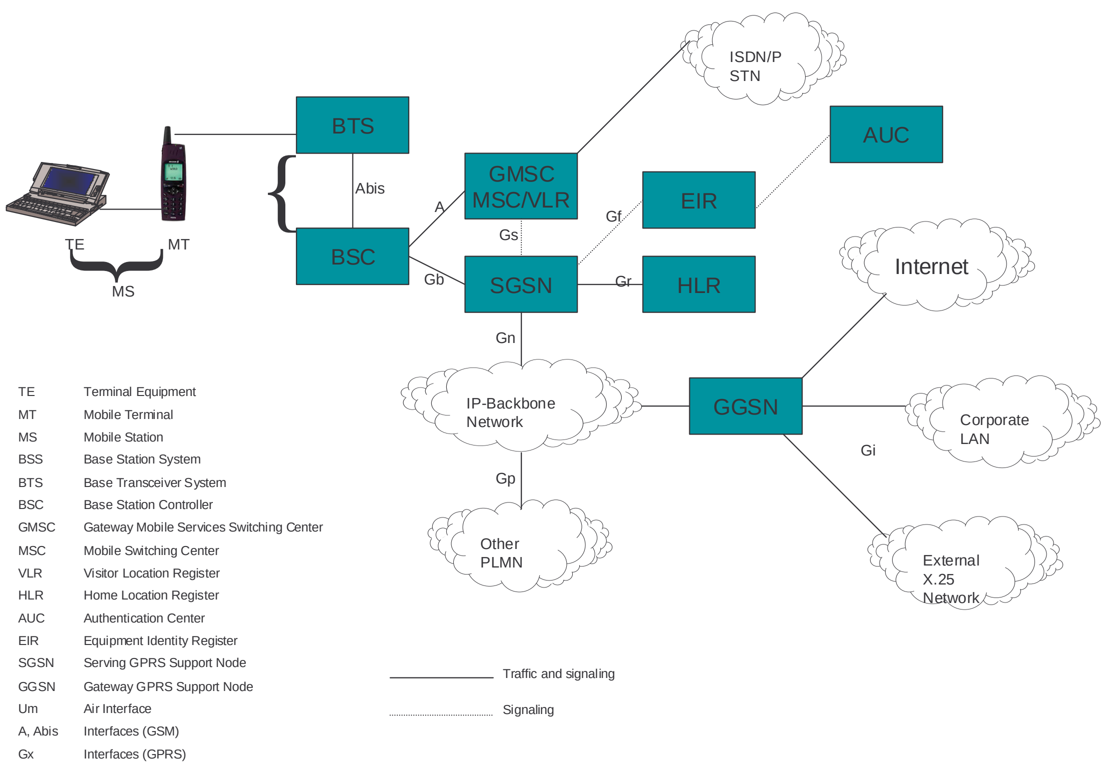

Figure 3 GPRS Logical Architecture

(Adapted from ETIS 1998 EN 301 344)

Terminal Equipment (TE)

The TE is the computer terminal that the end user uses. This is the component used for the GPRS system to transmit and receive end user packet data. For example, the TE could be a laptop computer. The GPRS system provides for IP connectivity between the TE and an Internet Service Provider (ISP), or a Corporate Local Area Network (LAN) connected to the GPRS system. From the users point of view the MT could be compared to a conventional modem.

Mobile Terminal (MT)

The MT communicates with a TE, and over the air with the BTS, the MT must be equipped with software for GPRS functionality when used in conjunction with the GPRS system. The MT is associated with a subscriber in the GSM system, the MT established SGSN. Channel reselection is provided at the radio link between the MT and the SGSN, the IP connection is static from the TE point of view, that is, the TE does not know it is mobile and retains its assigned IP address until the MT detached.

Base Station System (BSS)

The BSS consists of a Base Station Controller (BSC) and a Base Transceiver Station (BTS). The BTS is the radio equipment, that transmits and receives information over the air to let the BSC communicate with MSs in the BSCs service area. A group of BTSs is controlled by the BSC, however for GPRS to work on the BTS it must have the GPRS specific software.

The BSC provides all the radio related functions. The BSC can set up, supervise and disconnect circuit switched and packet switched calls, it has a high capacity switch, this provides function such as handover decisions, cell configuration data and channel assignment. The BSC must also be equipped with both the GPRS hardware and software when used for GPRS, one or several BSCs are served by an MSC, and a number of BSCs are served by an SGSN.

The BTS separates the MS originated circuit switched calls from the packet switched data communications, before the BSC forwards a circuit switched calls to the MSC/VLR, and packet switched data to the SGSN.

The standard GSM protocols are used with the BSC to achieve the desired compatibility.

Mobile Services Switching Center (MSC)

The MSC performs the telephony switching functions of the GSM circuit switched system, like the SGSN switches the GSM packet switched traffic, it controls calls to and from other telephony and data systems, such as the PSTN, ISDN, PLMN, Public Data Networks and possibility some private networks.

The SGSN Routing Area (RA)

The SGSN Routing Area (RA) is a subset of the MSC (CS) Location Area (LA). An MSC Location Area is a group of BSS cells, the system uses the Las to search for subscribers in the active state. An LA is the part of the network in which an MS may move around with out reporting its location to the network.

One MSC/VLR Service Area (SA) is made up of a number of LAs, the SA is the part of the network that is covered by one MSC. However there can be more than one MSC corresponding to one SGSN, one MSC can also be connected to several SGSNs.

Gateway Mobile Services Switching Center (GMSC)

The GMSC switches the circuit switched calls between GSM circuit switched network and the PSTN which is the fixed telephony network, hence it serves the function of routing incoming calls to the MSC where the mobile subscriber is currently registered, it is normally integrated in the same node as the MSC/VLR. The GMSC does not need any upgrading for GPRS.

The Home Location Register (HLR)

As stated in the section about the GSM Network the HLR is the database that holds all the subscription information for every person who has bought a from the GSM operator. The HLR stores information for the CS and PS communication, information stored the HLR includes, for example supplementary services, authentication parameters, Access Point Name (APN) such as subscribers ISP, and whether a static IP address is allocated to the MS. In addition, the HLR also includes information about the location of the MS. The main difference between this and the GSM system is that the information from the HLR is exchanged between the HLR and the SGSN.

The information that is exchanged between the HLR and the SGSN has been set up by the operator for the user, this information transfer is done when the operator changes the subscriber information, or when a new SGSN needs to have data for a subscriber after the MS has connected or in roaming, the old SGSN is also informed if the MS is roaming. The information that is going from the HLR to the SGSN is basically the routing information that is transferred upon an MS action, e.g. attach or roaming. For a roaming MS, the HLR may be in a different PLMN that the SGSN that is serving the MS.

Visitor Location Register (VLR)

The VLR database contains all the information about all MSs that are currently located in the MSC LA or the SGSN routing area respectively. The SGSN actually contains the VLR functionality for packet-switched communications, similarly, the circuit-switched VLR is an integrated component of the MSC. Another function of the VLR is that it contains the temporary subscriber information needed by the MSC or SGSN to provide services for visiting subscribers.

For MSs that support GPRS (PS) and GSM (CS), both the SGSN and the MSC will obtain location information from the HLR when the MS is combined-attached, i.e. both GPRS- and IMSI/CS-attached.

The GPRS VLR consists of software in a serving GRPS Support Node, the VLR contains information about the SGSN that is used.

The MSC/VLR is connected to the SGSN directly using the Gs interface, and indirectly via the BBS using the A and the Gb interfaces.

Serving GPRS Support Node (SGSN)

For the upgrading of the GSM network to cope with GPRS the SGSN is the primary component, and the SGSN is a new component in GSM. The SGSN forwards all incoming and outgoing IP packets addressed to/from an MS that is attached within the SGSN service area. The SGSN provides packet routing and transfer to and from the SGSN service area. SGSN serves all GPRS subscribers that are physically located within the geographical SGSN service area. A GPRS subscriber may be served by any SGSN in the network, all depending on the geographical location. The traffic is routed from the SGSN to the BSC, via the BTS to the MS. Also the SGSN provides:

Ciphering and Authentication

Session Management

Mobility Management

Logical Link Management toward the MS

Connecting to HLR, MSC, BSC, GGSN and other nodes

Output of billing data

Gateway GPRS Support Node (GGSN)

As with the SGSN the GGSN is a new primary component in the GSM network when using GPRS. The GGSN provides the following functions:

The interface toward the external IP packet networks, the GGSN therefore contains access functionality that interfaces with an external ISP, functions such as, routers and RADIUS (Remote Dial-In User Services) servers. From and external IP networks point of view the GGSN is acting as a router for the IP addresses of all subscribers served by the GPRS network. So the GGSN exchanges routing information with the external network.

GPRS session management, communication setup toward external network.

Functionality for associating the subscribers with the right SGSN.

Output billing data, the GGSN collects information for each MS, related to the external data network usage. Both the GGSN and the SGSN collect billing information on the usage of the GPRS network resources.

Equipment Identity Register (EIR)

See GSM section 2.1.2.3 (Page 25)

Authentication Center (AUC)

The AUC is a GSM component that provide triplets to the authentication and ciphering process used within GSM, the authentication for GPRS is the same as for GSM users, the only change is in the security for GPRS is related to ciphering, however this change does not require any change in software or hardware.

3.4 Traffic Cases

3.4.1 IMSI attach

In order to make or receive calls on the GSM system an MS needs to perform one procedure, an IMSI attach. The IMSI attach is shown in Figure 21, at IMSI attach a connection between the MS and the GSM network is established. The end user does not need to specify which fixed networks he wants to use because all fixed networks follow the same numbering plan (E 164), it should be noted that the MSISDN is always the same no matter which country and to whom it calls.

Figure 4 IMSI Attach

3.4.2 GPRS Attach

In order for the GPRS MS to receive or transmit data the end user needs to perform a two-step procedure, GPRS attach (Figure 21) ND PDP context activation (Figure 22)

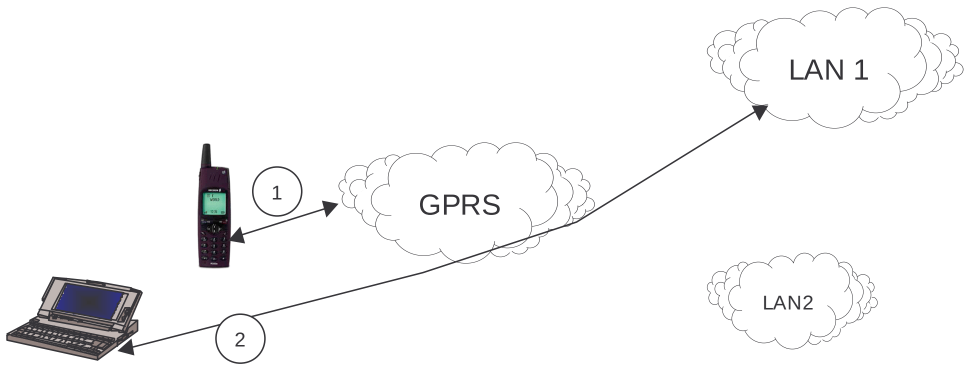

Figure 5 GPRS attach (1) and PDP context activation (2)

At GPRS attach a logical link is established between MS and SGSN, the GPRS attachment procedure in Figure 23.

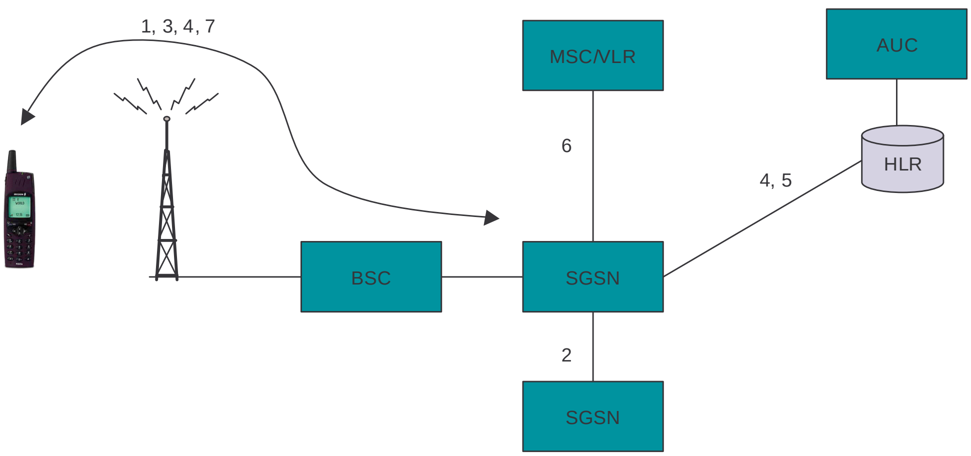

Figure 6 GPRS Attach

MS sends message to SGSN: “attach request”.

If the MS is not known by the SGSN it asks the old SGSN about the IMSI and triplets.

If the MS is not known by the old SGSN it sends an error message to the new SGSN and the new SGSN asks MS about IMSI.

SGSN authenticates MS.

Update HLR (if new SGSN service area).

Update MSC/VLR (only necessary if new LA).

SGSN tell the MS about new TLLI (Temporary Location Link ID).

3.4.3 Combined GPRS/IMSI Attach

In a combined GPRS/IMSI attach, both of the previous procedures are carried out simultaneously, shown in Figure 24.

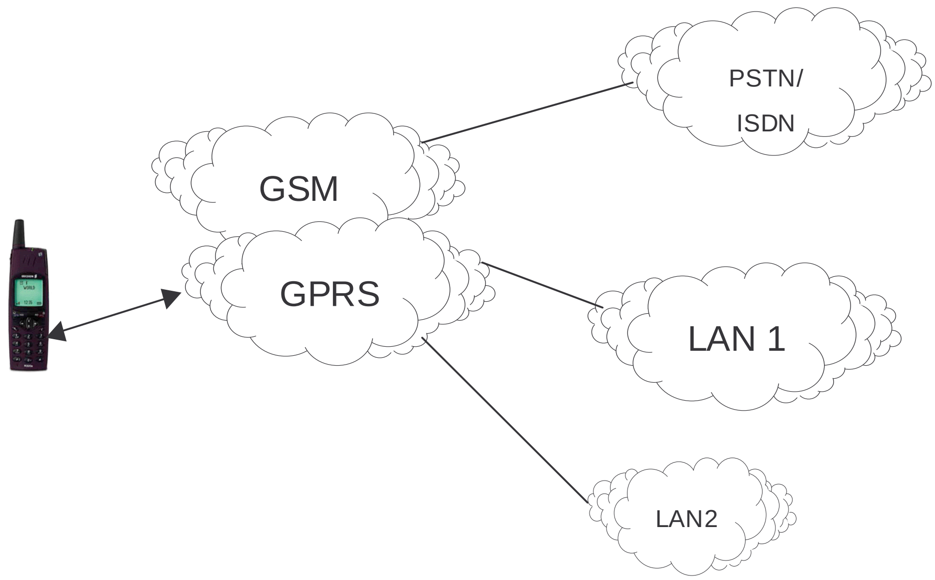

Figure 7 Combined GPRS/IMSI attach

3.4.4 PDP Context Activation and Deactivation

In order for the MS to send and receive GPRS data the MS must perform a PDP context activation after the GPRS attach (Shown in Figure 23). The PDP context activation makes the MS known in the concerned GGSN and communication to external networks is made possible.

The PDP context activation corresponds from the end users perspective to “Logging On” to an external network.

The difference from using a dial-up connection over circuit switched is that in GPRS the end user can have several PDP contexts activated simultaneously if the terminal supports several IP addresses.

3.5 GPRS Air Interface

The air interface (Um) is the logical link between the MS and the BSS. Figure 25 shows the GPRS Protocol Stack from the perspective of the BSS

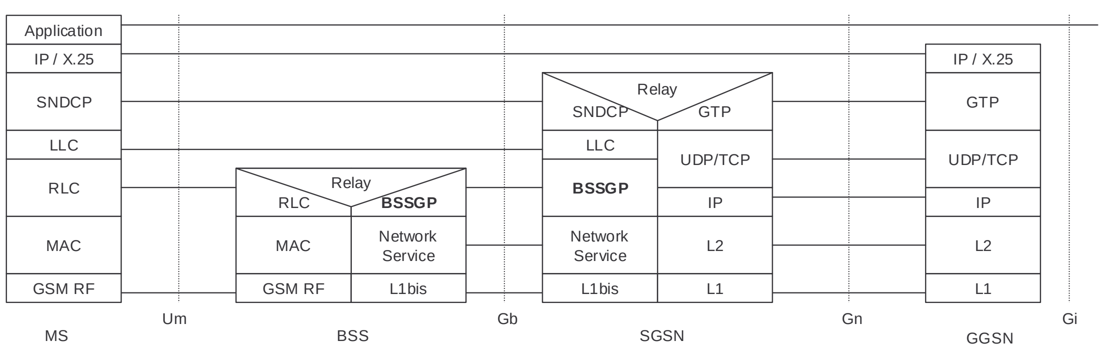

Figure 8 GPRS Protocol Stack

(Thomas, R, et al, 1999, France Telecom)

The Layers are described in Appendix 1.

3.6 Logical Channels

Within GPRS there are a number of new logical channels, similar to the existing ones, but these are only for GPRS. (NB These logical channels have been standardized.) The new logical channels have been mapped onto the physical channels that have been assigned for packet data, the physical channels denoted as Packet Data Channels (PDCH), the logical channels that are mapped onto these are :

Packet Common Control Channels

PRACH : Packet Random Access Channel (Uplink)

PPCH : Packet Paging Channel (Downlink)

PAGCH : Packet Access Grant Channel (Downlink)

PTCCH : Packet Timing advance Control Channel (Up/downlink)

PNCH : Packet Notification Channel (Downlink)

Broadcast Channel

PBCCH : Packet Broadcast Control Channel (Downlink)

Packet Traffic Channels

PDTCH : Packet Data Traffic Channel (Up/downlink)

PACCH : Packet Associated Control Channel (Up/downlink)

3.7 PDCH Allocation

The following section will explain how the PDCH is allocated. Traffic Channels and packet data channels basically create a common pool of resources, utilizing the existing resources in an efficient way. See Figure 26

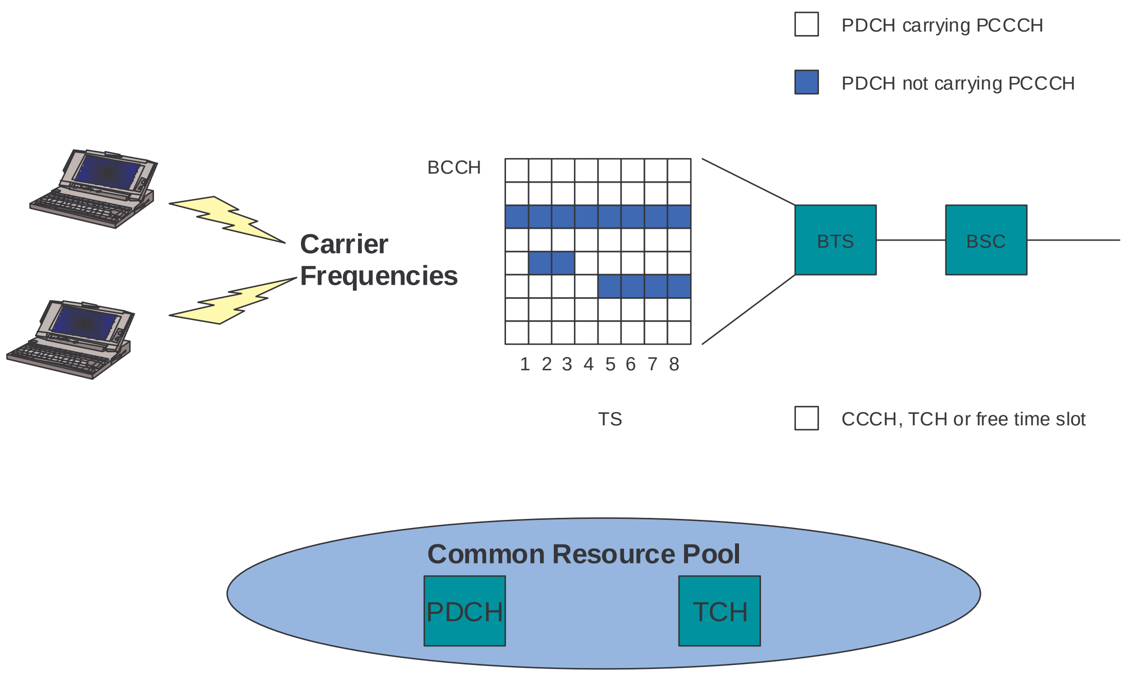

Figure 9 Common Recourse Pool

The PDCHs are allocated to the PCU, the PCU is responsible for assigning channels to different GPRS MSs. The PDCHs can be allocated in different ways:

Dedicated PDCHs are allocated and released by operator command.

On-demand PDCHs, serving as temporary dynamic GPRS recourses, are allocated and released depending on GPRS traffic demand.

The channels that are allocated for GPRS (PDCH) are allocated in sets of maximum four consecutive time slots, such a set is called a PEST (Shown in Figure 27), a PEST can consist of both dedicated and on demand PDCH. All PESTS are on the same frequency or hop the same frequency hopping set. An MS can only be assigned PDCHs from one

PEST, at present this limits the maximum number of assigned time slots to four, there is no additional limit on the number of PDCHs that can be allocated in a cell, except the number of available TCHs.

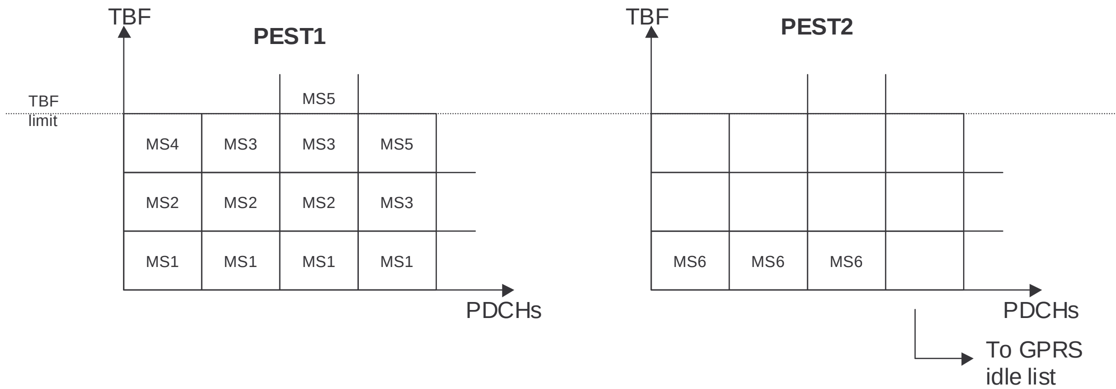

Figure 10 Channel Reservation (PESTs)

3.7.1 Dedicated PDCH

Dedicated PDCHs can only be used for GPRS, the operator can specify between zero and eight dedicated PDCHs per cell, the reason for dedicated PDCHs is to ensure that there is always the GPRS resources in a cell. To some extent the operators can specify to where they dedicated PDCH(s) to be located. However from a radio point of view, non hopping channels on the BCCH carrier are generally not equivalent to traffic channels on other frequencies. The operator can decide if the PDCH shall be allocated on the non-hopping BCCH frequency as primary or secondary choice, or with no preference.

3.7.2 On-demand PDCH

On-demand PDCH can be pre-empted by incoming circuit switched calls in congested cells, it should be noted that in a HSCSD, a user can never get more than a single channel through the pre-emption procedure.

There is no physical limit on how many on-demand PDCHs there can be in a cell. However the number of on-demand PDCHs depends on how much packet switched traffic there is, upto the limit where circuit switched traffic starts

3.7.3 Master PDCH

A master PDCH (MPDCH), is a PDCH carrying a PBCCH and PCCCH, as well as GPRS traffic. The PCCCH carries all the necessary control signaling to initiate packet traffic. In the standard, the MPDCH is called “the PDCH carrying the PBCCH”. NB the abbreviation MPDCH is only used within Ericsson systems.

The first directed PDCH that is allocated according to the operator’s preferences regarding non-hopping BCCH will be configured as an MPDCH. The following PDCHs that are allocated will only carry GPRS traffic and associated signaling. However in a cell with no MPDCH (i.e. no dedicated PDCH allocated) the ordinary control channels such as the BCCH, RACH etc, will handle the broadcasting and signaling to the GPRS mobiles.

3.8 Cell Selection and Reselection

Comparing GPRS with circuit switched

In a GSM network the BSC governs the cell selection behavior of the MS when in idle and active mode by different methods. Idle mode MSs autonomously performs cell reselection by using the C1/C2 criteria.

In active mode, non-GPRS MSs are steered by the locating functionality implemented in the BSC. So this means that the BSC initiates the handovers to other cells. With GPRS, the MS determines the base station with which it will communicate, Figure 28 shows the handover procedures for both Circuit Switched and Packet Switched. The GPRS MS manages both the idle packet and transfer packet mode behaviors.

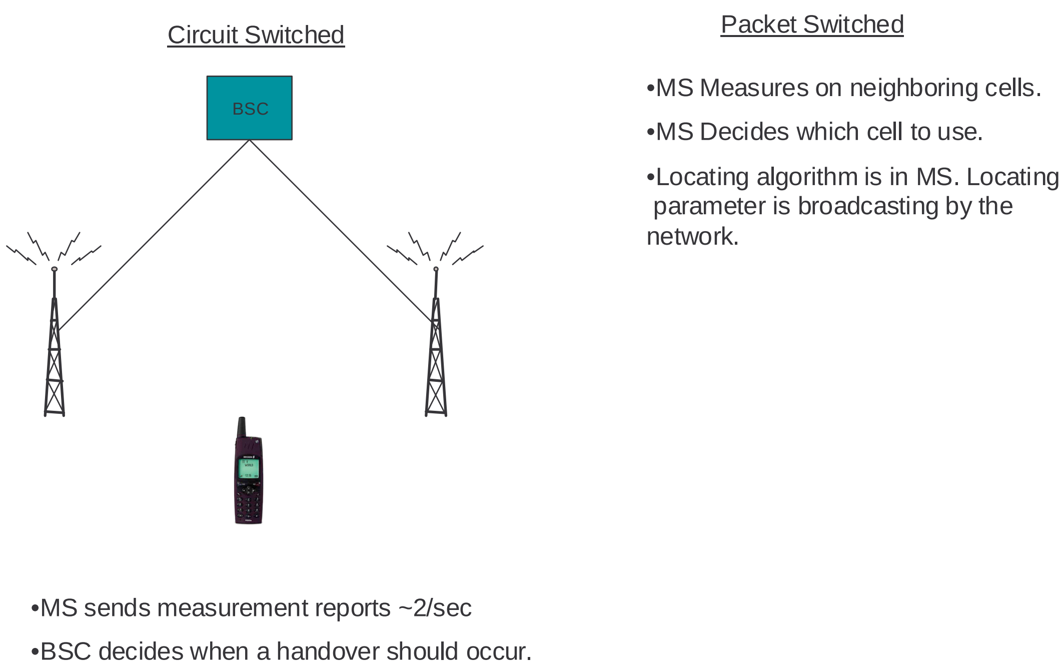

Figure 11 Handover, comparison between CS and PS

The cell selection and reselection algorithm used for controlling the idle/transfer mode behaviors are governed by the GPRS cell selection and reselection parameter setting broadcast in the packet system information on the PBCCH in each GPRS capable cell with an allocated PBCCH (MPDCH). If no PBCCH has been allocated in a cell, the GPRS MS will read the system information broadcast on BCCH and use the C1/C2 criteria for cell selection and reselection as in the circuit switched idle mode case.

So as you can see the GPRS cell selection and reselection algorithms are governed by parameter settings. These parameters C31 and C32 are different to the corresponding parameters for the circuit switched system. However with some GPRS systems GPRS cell section parameters are automatically mapped on those for cell selection/locating known from the circuit switched case. The reason for this is to achieve the same cell selection behavior for GPRS, as with GSM, this will enable an easy rollout of GPRS in the network.

The GPRS standard allow the network to take over cell reselection for a specific MS or for all MSs. This is called Network Controlled Cell Reselection and have not yet been implemented in any UK or European GPRS systems.

3.8.1 GPRS Support Node (GSN)

The GSN is a general purpose, high-performance packet switching platform, the GSN combines features usually more associated with data communications (features such as compactness and high functionality) with features from telecommunications such as robustness and scalability. The GSN is designed for non-stop operation, the platform incorporates 1+n redundant hardware, and also the software is of a modular design enabling individual modules to be upgraded with out causing any interference to the traffic.

3.9 Interconnection Principles.

In this section the connection between GSNs and their operating environment, the interfaces used in the GPRSN network and the GSNs, and their contexts are shown in Figure 29, the interface names are part of the ETSI GSM standard for GPRS.

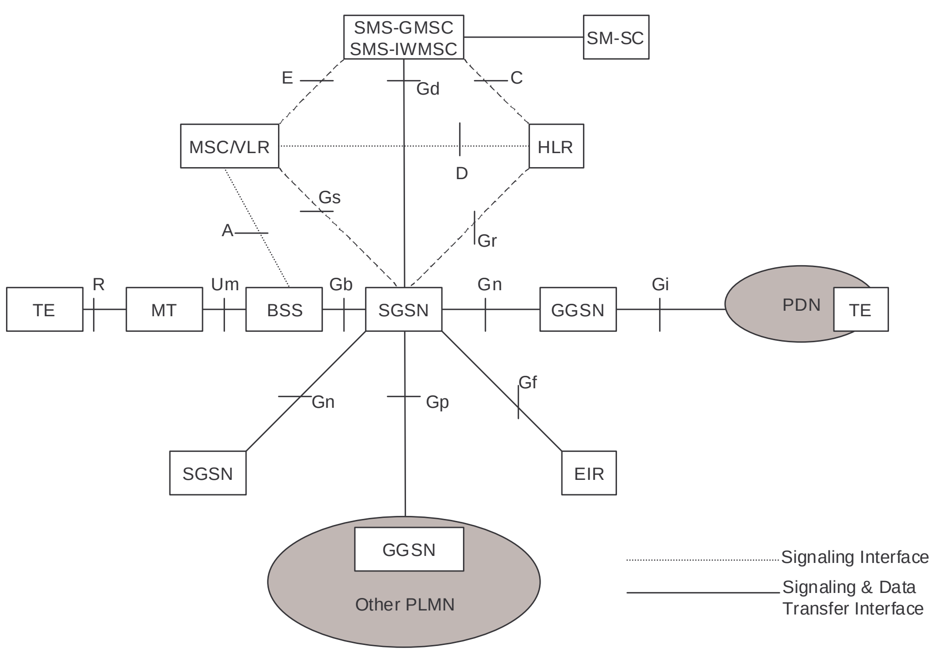

Figure 12 GPRS Logical Architecture

(Adapted from ESTI 301 344 V6.3.2 (1999))

3.10 GPRS IP Connectivity

One of the main advantages of GPRS is that it provides IP connectivity, this means that communication between the different parts of the operators GPRS system, the GGSN, administrative hosts and hosts providing Internet Services. Further more the IP connectivity enables easy communication with the Internet. However is should be noted that GPRS has two different types of communications, represented with two different levels of IP communication:

The IP communications within the GPRS network. This is for signaling, management etc.

3.11 The users IP communication.

The latter is the communication between a GPRS MS and an ISP, for example. The GPRS system provides IP connectivity between MS and ISPs, using the GSM standard, data transfer is based on the common internet protocol (IP), which means that packet data transmission is carried out on an end-to-end basis (including the air interface). From the users point of view a modem connection to the internet is provided when using an GPRS MS.

An interface that communicates using the IP protocol must have an IP address and identifier, now since the GPRS system uses the IP protocol for both the end-user traffic and the system user traffic, both MSs and system components need IP addresses.

The IP addresses used in the GPRS system, for system and for end-user communication, can be public, dynamic or static.

Chapter Summary and Key Points

In GSM Circuit switched data, the typical maximum data rate of data throughput was officially 9.6 kbit/s, however when the overhead of control, guard data, encryption keys and error correction, are taken into account the typically user data throughput was only 1 – 1.5 kbit/s.

The first phase of the GSM evolution to higher speed data was the introduction of High Speed Circuit Switched Data (HSCSD). This gave the user the potential of data rates up to 38.4 kbit/s, which after the overhead was accounted for allowed a user data rate of 14 kbit/s. This improvement in data throughput was achieved by the use of multiple time slots, but was at the expense of the main revenue earning service (speech).

Due to the fact that data is tolerant to delays in transmission, as opposed to speech a new technique utilizing packet switching was developed (GPRS)

GPRS differs significantly from HSCSD in that it is not permanently connected to a single physical channel. Like HSCSD, GPRS utilizes multiple time slots, but the network has the ability to reduce the number of time slots used so that speech traffic is given priority. The disadvantage to the data user is that during peak hour traffic data throughput will be significantly reduced by the network in order to accommodate the higher revenue potential of speech traffic.

To the network operator the introduction of GPRS has meant a significant modification of the existing GSM network infrastructure. The advantage to the network operator is that they can now use a packet switched network for data transmission instead of dedicated circuit switched network. This has major economic advantages for the network operator. During speech transmissions, there are many instances of no information being transmitted but with data, transmission is continuous. It is for this reason that data does not need to be permanently connected as the data can always be re-arranged at the terminal end.

With users requiring faster and faster data speeds and even the ability to download multimedia applications, a new technology had to be developed due to the fact that GSM had reached it's maximum data throughput. Also the network had to consider whether it was connected to a data or speech call. So the next step in the evolution was the development of Wideband CDMA, leading to UMTS.