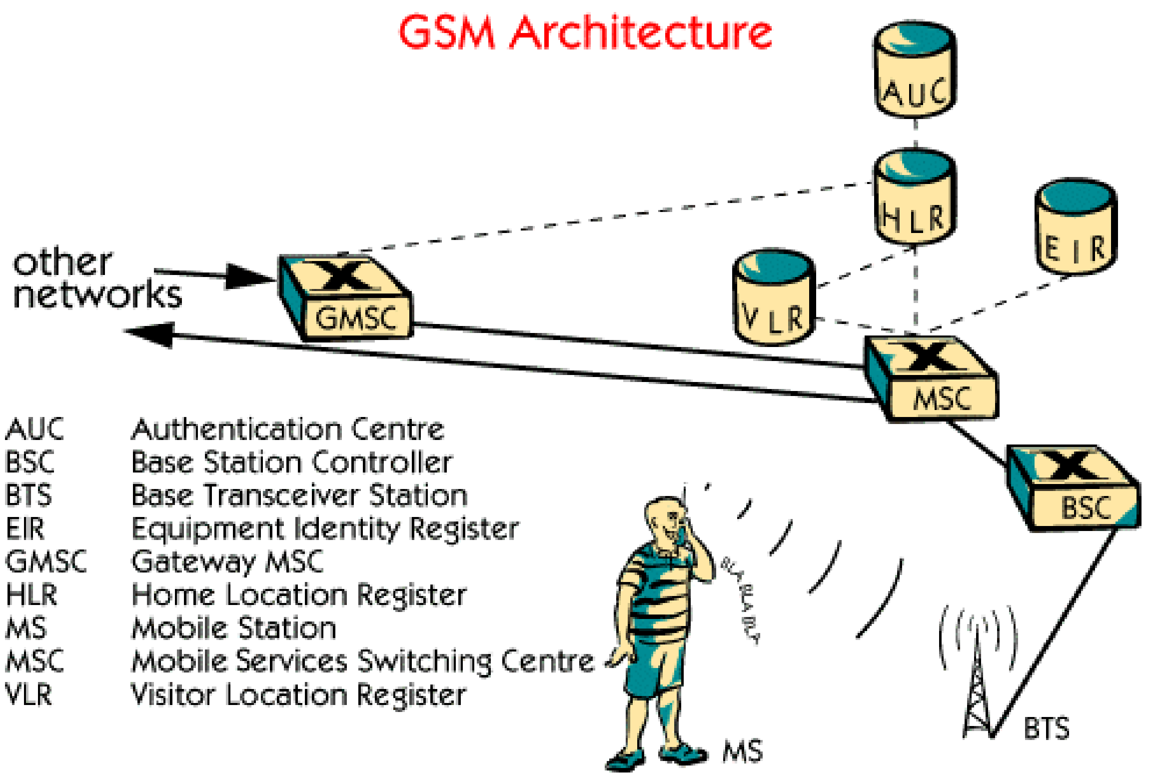
Ch.15 - GSM and GPRS

In the next few slide we're going to look at GSM, the Global System for Mobile communications. GSM is the European standard for mobile telephony and is currently implemented in over 80 countries from Albania to Zimbabwe, with a rapidly growing subscriber base - in fact current rates of growth mean that there is a new subscriber added every second!



GSM is a digital, circuit switched system developed for mobile telephony which has been in commercial operation since 1991. The channel access is TDMA with 8 time slots and the operating frequency is 900 MHz. The new DCS operates at 1800 MHz and PCS at 1900 MHz. Both DCS and PCS are extensions to the original GSM specification.

The architecture shown here can be split into 2 main parts, the basestation system and the switching system. The Operation and Maintenance system isn't shown in this picture, as it's not relevant to this discussion.

The Mobile Station is used by a mobile subscriber to communicate with the cellular system.

The Base Transceiver Station handles the radio interface for a cell. Mobile Stations communicate with the BTS using a radio channel.

The Base Station Controller establishes, supervises and releases channels for a BTS. It is also responsible for handovers between base transceiver stations. One BSC can be connected to several BTSs.

The Mobile Services Switching Center performs telephony switching within the network. It is responsible for call establishment and handovers between base station controllers. One MSC can be connected to several BSCs. Ericsson's MSCs are based on AXE technology.

The Gateway Mobile Service Switching Center handles incoming calls from external networks. Any MSC can act as a GMSC.

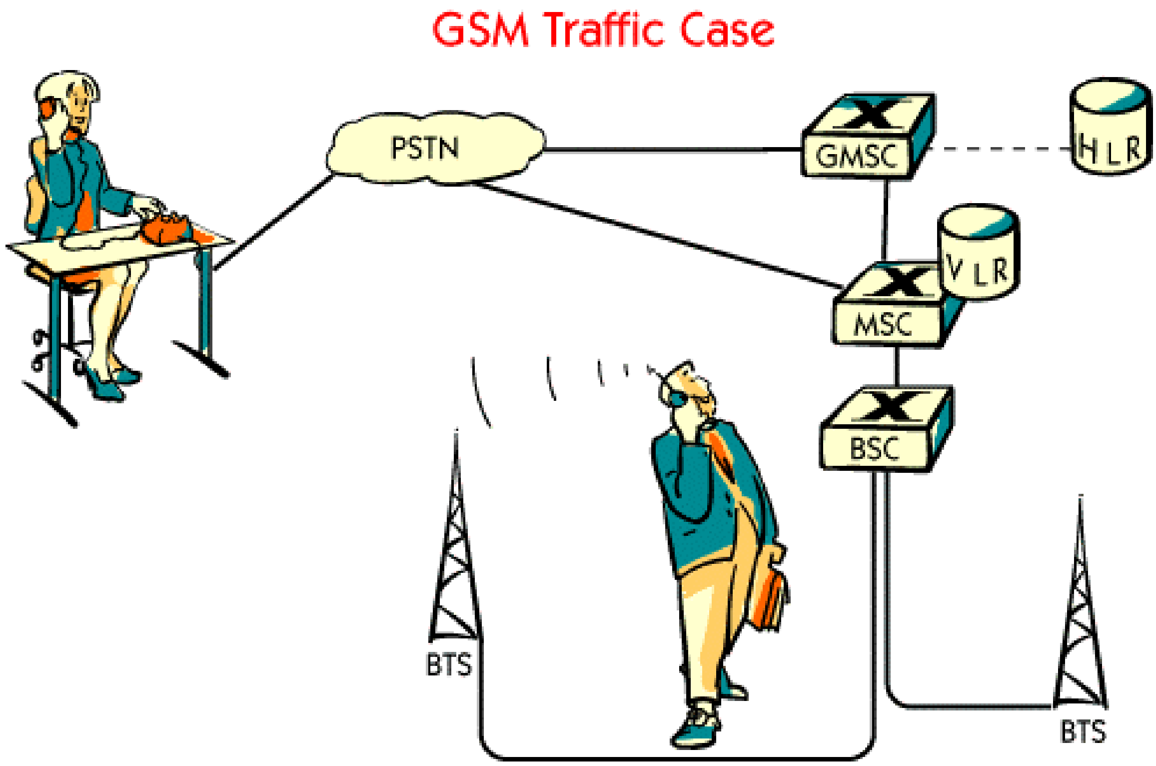
The Home Location Register stores and manages all the subscription information for a single network. The information stored includes a subscribers supplementary services, location information and authentication parameters.

The Visitor Location Register contains information about all the mobiles currently under a single MSC. The VLR can be seen as a distributed HLR. Ericsson's VLR is integrated into the MSC.

The Equipment Identity Register contains details of MS hardware numbers and their status. This means that faulty or stolen mobiles can be barred from the network regardless of the subscription they are using.

The Authentication Center is a database connected to the HLR. Its purpose is to provide authentication parameters and ciphering keys to the HLR to help protect network operators and subscribers from fraud.

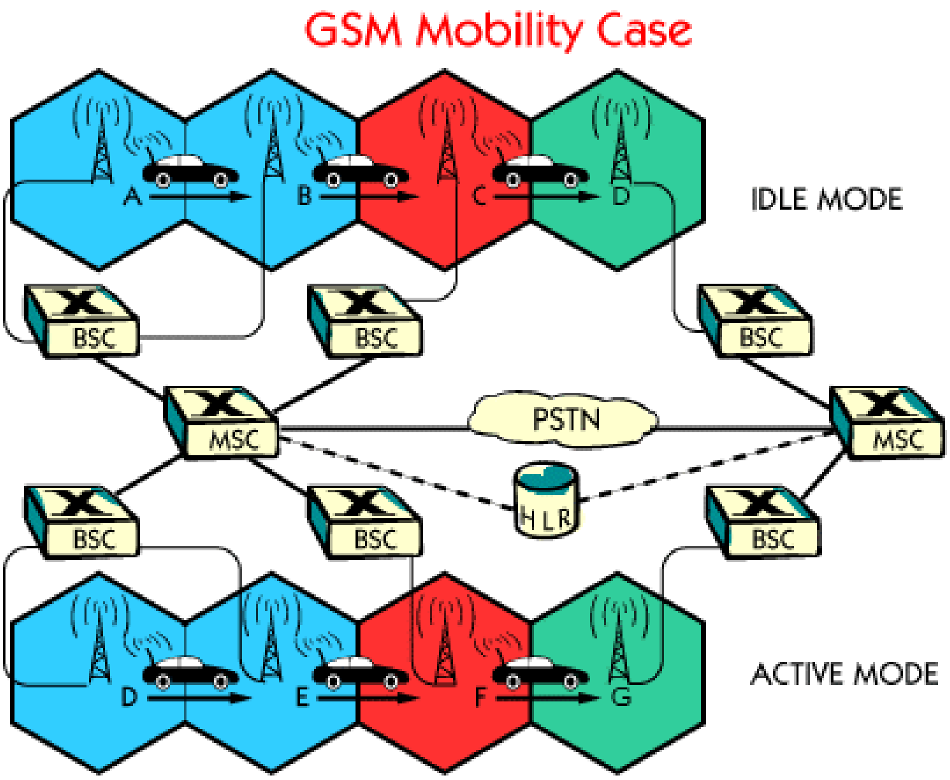
Another important concept in the GSM infrastructure is that of a Location Area. An LA is a collection of cells where an MS can move around without having to report its new position. An incoming call for an MS means that a paging message is broadcast in all the cells in the MS's Location Area.



Here we can see what happens when an MS receives a telephone call.

A user in the fixed telephone network dials the number for a mobile subscriber. This is routed via the PSTN to the Gateway MSC. The GMSC queries the HLR for the mobile subscriber's serving MSC/VLR. The call is then routed to correct MSC/VLR. The MSC queries the VLR for the MS's current Location Area. A paging message is broadcast to the MS's Location Area, which the mobile receives and responds to. The MSC now knows the actual cell the mobile is located in and can route the call to the correct BSC. The BSC selects the traffic channel on the relevant BTS and orders the mobile to tune to the correct channel. The Mobile Station then generates a ring signal and when the subscriber answers the call is connected.

What happens when a mobile subscriber makes a telephone call?
First the subscriber dials the number which results in an access request message being sent to the serving MSC. The MSC queries the VLR to verify that the MS is allowed to perform this action. If the mobile is authorized then the MSC initiates a call set-up to the PSTN network. The MSC also asks the BSC to allocate a free traffic channel. The BTS is informed of the selected traffic channel and the MS is ordered to switch to that channel. The person receiving the call answers and the connection is established.



What happens when a mobile moves around the GSM network? The exact chain of events depends on the state of the mobile - firstly we'll look at what happens when the mobile is in the idle mode - that is the mobile is turned on but there is no telephone call in progress.

As we said earlier, an idle mobile is not particularly interested in the exact cell location. It is only tracked on the Location Area level. So, when the mobile moves from cell A to cell B, which are within the same Location Area, no update messages are required. If we imagine that cell B and cell C are in different Location Areas, when the mobile moves from B to C it notices that the Location Area has changed. So, the mobile transmits a Location Area update to inform the MSC and VLR that it has entered a new Location Area. The MSC performs some authentication procedures (for example, to check if the mobile is allowed to use the new Location Area) and then informs the mobile that the update request was successful. As the Location Area is under the same MSC the HLR does not need to be informed.

The process is similar when the mobile roams to a new cell under a different MSC, for example moving from C to D. As the cell is under a different MSC it is also in a different Location Area. Again the mobile sends a Location Area update message to the new MSC which again performs some authentication procedures. Because the Location Area is under a new MSC the HLR is also informed of the new serving MSC. When this is done the mobile is informed that the Location Area update was successful.

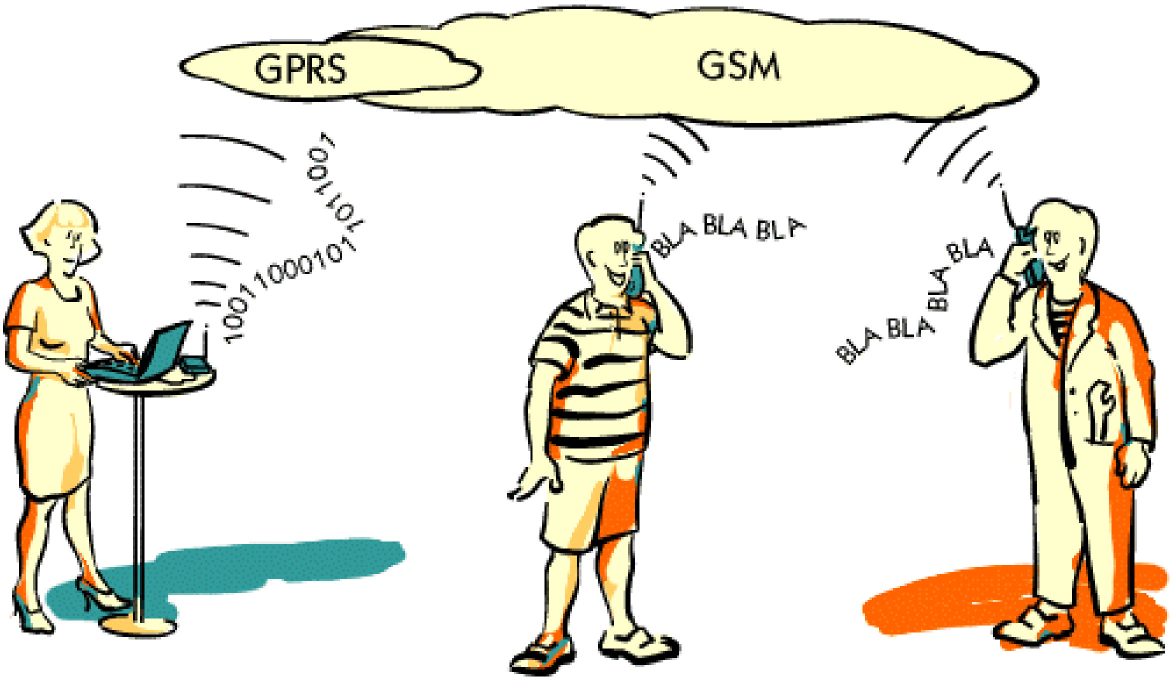
When a mobile is in the active state (that is, there is a circuit switched call ongoing) the process is slightly different. In this case the mobile is tracked on the cell level. So, when an active mobile moves from cell D to E (both under the same BSC), it is the BSC that decides a

handover should take place. This decision is based on measurements supplied by the BTS and the mobile. The BSC sends a message to the new BTS to allocate a new radio channel for the mobile. It then sends a message to the mobile, using the old BTS, to inform the mobile of the channel to use in the new BTS cell. The mobile then tunes to the new channel and transmits a small message informing the BSC that the handover is complete. The BSC then instructs the old BTS to release the now unused radio channel. Note that no Location Area updates are issued while the mobile is active.
If the two cells happen to be in different Location Areas, the mobile will send a Location Area update message when the call is completed.

What happens when an active mobile moves from a cell which is under the control of a different BSC? This case can be seen when the mobile moves from cell E to cell F. The procedure is almost exactly the same as for handover between two cells under the same BSC, except that messages between the new and old BSCs must be sent via the MSC.

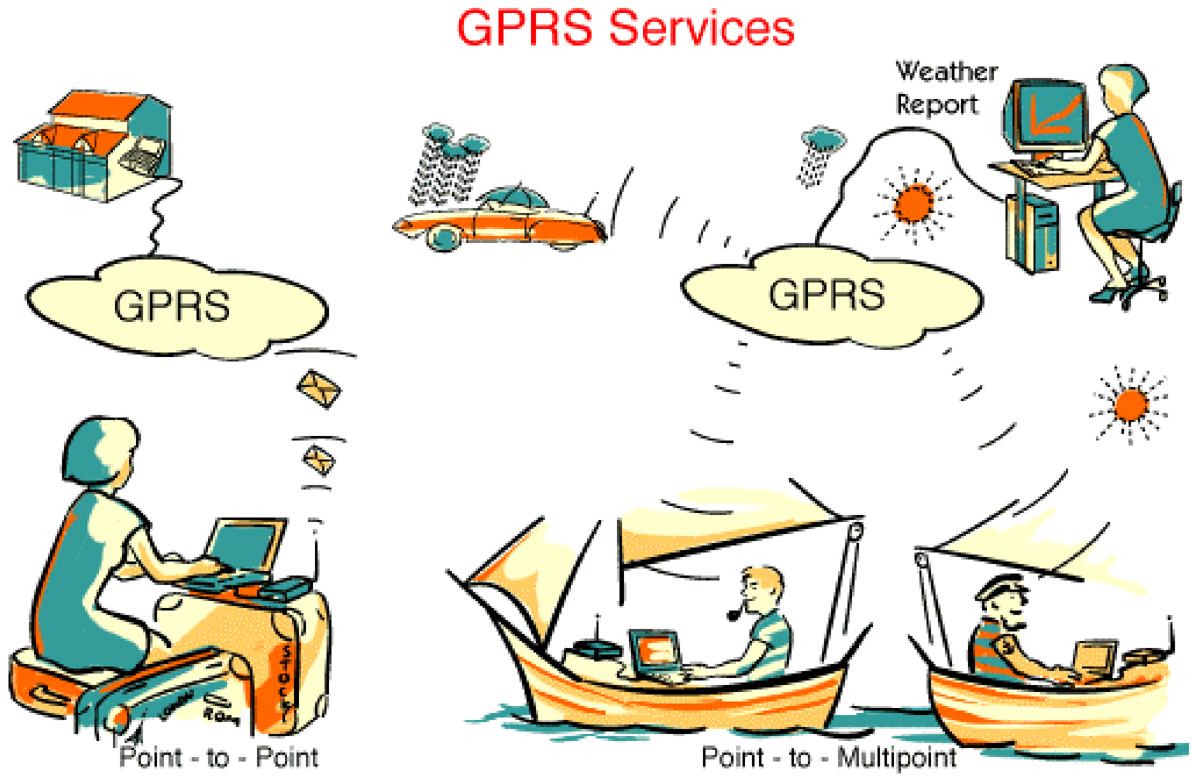
Handovers between cells under different MSCs (for example, when the mobile moves from cell F to G) are a little more involved. When the mobile realizes a handover is necessary it sends a handover request up to the BSC. The BSC realizes that the new cell is not in its jurisdiction and sends the request up to the MSC. Similarly the old MSC realizes that the new cell lies under another MSC. The handover request message is forwarded by the new MSC which forwards it to the correct BSC and the process is the same as for the handover between two BSC. However, when the mobile tunes to the new channel under the new BSC and sends the message informing the BSC that the mobile is now under its control, the call is routed from the old MSC to the new MSC, possibly via the PSTN. This means that for the duration of the call the circuit goes through the old MSC, the PSTN and the new MSC before reaching the BSC, BTS and ultimately the mobile.

GPRS Introduction



GPRS, General Packet Radio Service, allows network operators to offer a packet-oriented data communications service using the current GSM infrastructure. GPRS is an addition to GSM, not a replacement.
Network operators will continue to offer circuit switched services alongside the new packet switched service.

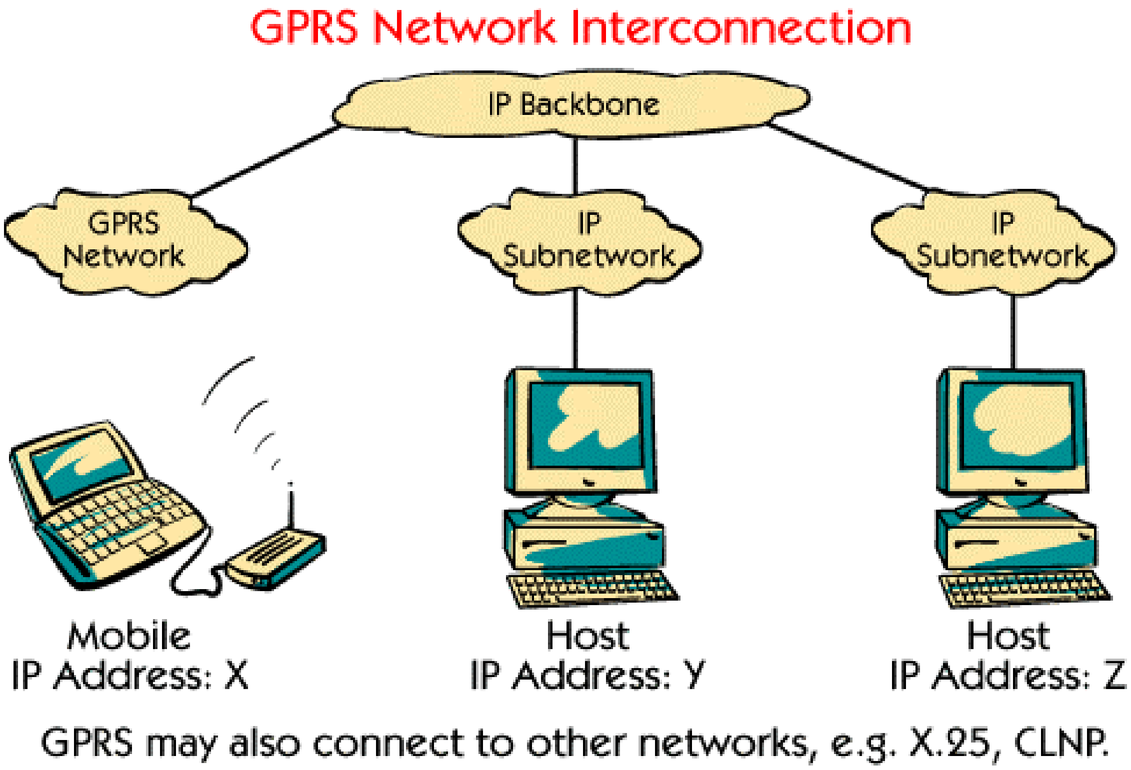
The GPRS standardization is currently ongoing within ETSI (European Telephony Standardization Institute) and phase 1 of the standard was ready in the spring of 1998. More services will be introduced in the 2nd phase of standardization.



GPRS will offer 2 types of services - Point-to-Point and Point-to-Multipoint.

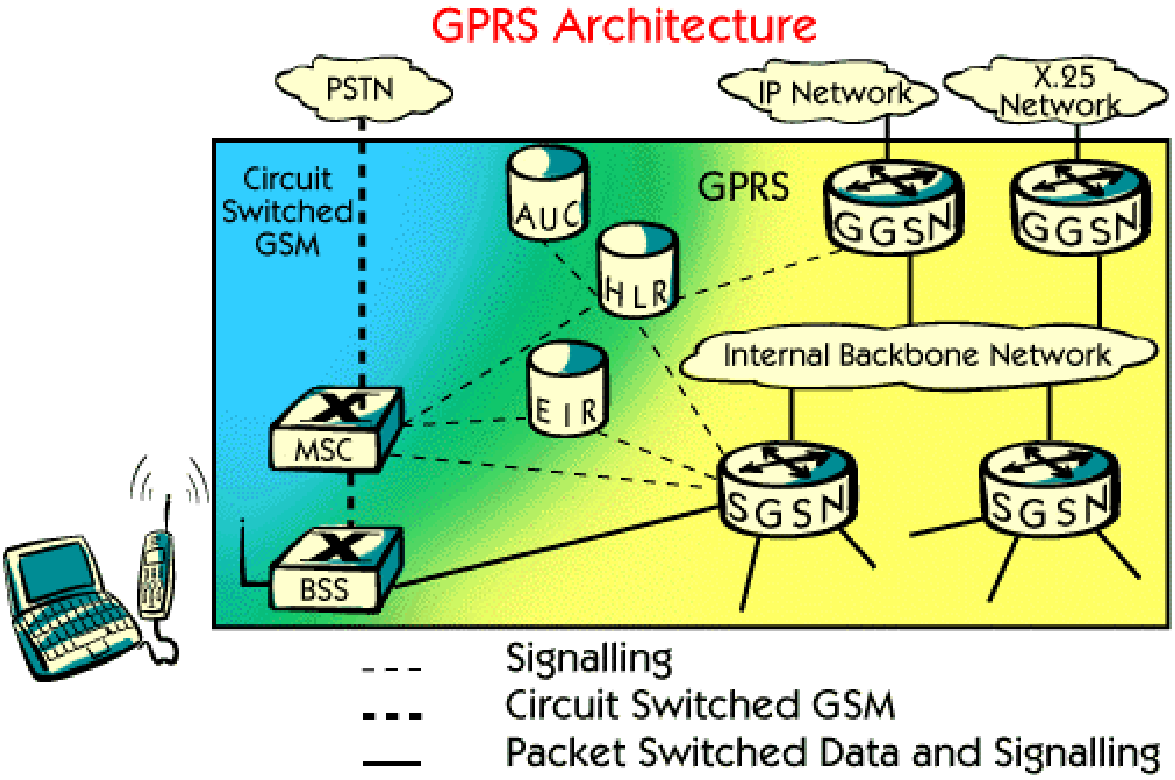
Point-to-Point concentrates on a traditional data communications idea; packets are transferred between two distinct points in the network. The applications for this service are the usual suspects e-mail, web browsing, ftp etc. The Point-to-Point service is defined in phase 1 of the GPRS standardization.

Point-to-Multipoint is used when a single user wants to broadcast data to several users simultaneously. Example applications are weather reports, stock market information, and sports results. The Point-to-Multipoint service will be defined in phase 2 of the GPRS standardization.



When two different, interconnected hosts wish to communicate they address each other using IP addresses. So, for example, when host Y wishes to send packets to host Z then Z is addressed using its IP address. A GPRS network should appear to other networks as just another IP subnetwork where mobiles are addressed using IP addresses.
So, when host Y wants to send packets to host X on the GPRS subnetwork, Y is oblivious to the fact that X is a GPRS mobile.
Packets sent to X are addressed using X's IP address.

GPRS also has the ability to connect to other networks. Phase 1 of the standardization process specifies connections to IP and X.25 networks. Other network standards may be added in phase 2.



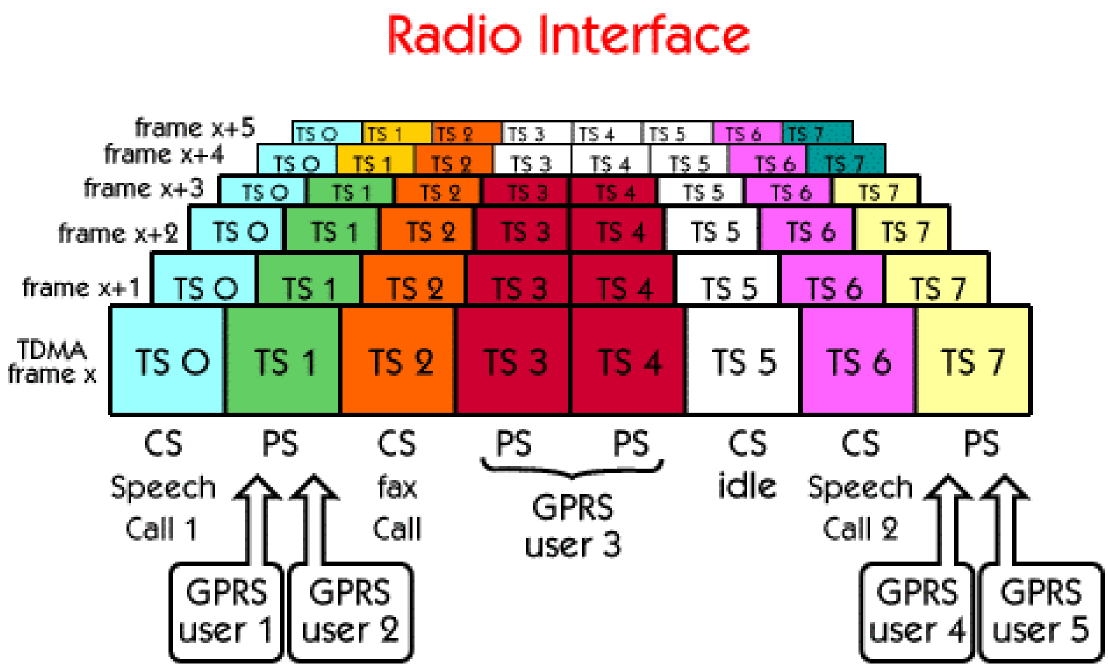
GPRS builds upon the existing GSM infrastructure to provide a packet data service. The parts of the system shown in blue here are those that are part of the traditional GSM system. Those parts in green are the parts of GSM that currently exist but require changes for GPRS. For the BSS it is envisaged that the BTSs will require only a software upgrade. BSCs will probably require both new software and hardware. Those parts shown in yellow are completely new for GPRS these are the GPRS Support Nodes and the internal backbone.

The Gateway GPRS Support Node acts as an interface and a router to external networks. The GGSN contains routing information for GPRS mobiles, which is used to tunnel packets through the IP based internal backbone to the correct Serving GPRS Support Node. The GGSN also collects charging information connected to the use of the external data networks and can act as a packet filter for incoming traffic.

The Serving GPRS Support Node is responsible for authentication of GPRS mobiles, registration of mobiles in the network, mobility management, and collecting information for charging for the use of the air interface.

The internal backbone is an IP based network used to carry packets between different GSNs. Tunneling is used between SGSNs and GGSNs, so the internal backbone does not need any information about domains outside the GPRS network. Signaling from a GSN to a MSC, HLR or EIR is done using SS7.

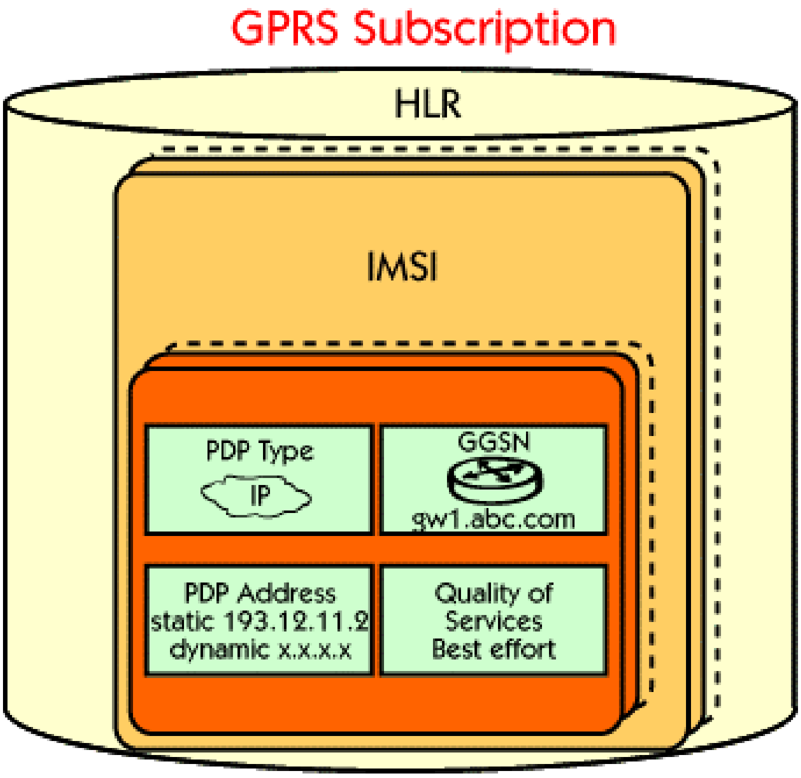
GPRS introduces the concept of a routing area. This is much the same as a Location Area in GSM, except that it will generally contain fewer cells. Because routing areas are smaller than Location Areas, less radio resources are used when a paging message is broadcast.



GPRS and GSM use the same physical interface for the radio link, which is based on TDMA with 8 time slots per frame. Each frame is approximately 4.6ms in length.

A normal circuit switched telephone call uses the same slot in consecutive frames. Here you can see two speech calls in timeslots 0 and 6, and a fax call in timeslot 2. All are circuit switched and occupy the same slot in every frame. These slots are occupied until the call is cleared.

Channel allocation in GPRS is slightly different. A GPRS user is allocated a block, which consists of four timeslots in consecutive frames. Here you can see GPRS user 1 who uses TDMA slots x to x+3, a block of 4 timeslots in consecutive frames. After those slots are used, the same timeslot is allocated to GPRS user 2 who then has access to four slots in frames x+4 to x+7. GPRS user 3 has requested and been allocated two GPRS channels, meaning that double the bandwidth is available to that user. Even so, the channel access is still limited to four timeslots in consecutive frames.

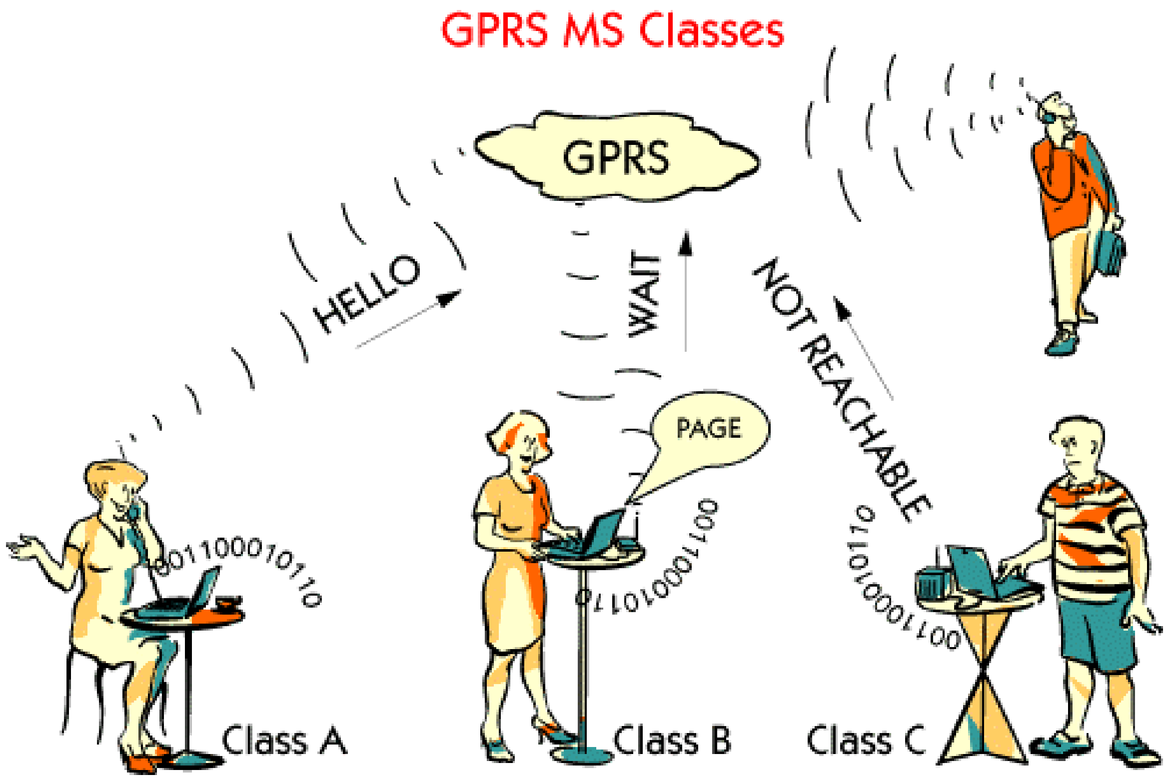


GPRS subscribers need extra information stored in the Home Location Register. The most important new parameters are shown here. The PDP Type holds the packet data protocol that is currently being used, which can be either IP or X.25. The PDP address contains the address of the mobile which can either be static of dynamic. In the case of dynamic addresses, the address is allocated to the mobile when it first activates a context.

The GGSN address is the address of the Gateway GSN that the mobile is currently using. It is possible for operators to have more than one GGSN in the network.

Finally there is a quality of service parameter. Exactly how this parameter functions is still subject to a great deal of discussion.

The key to a users context is the International Mobile Subscriber Identity. It should also be noted that each user can have several different contexts activated simultaneously, thus allowing the same mobile to operate in different modes if required. For example, one mobile may wish to use IP one day and X.25 the next. After a mobile has attached to the network the context can be chosen with the activated PDP context message.

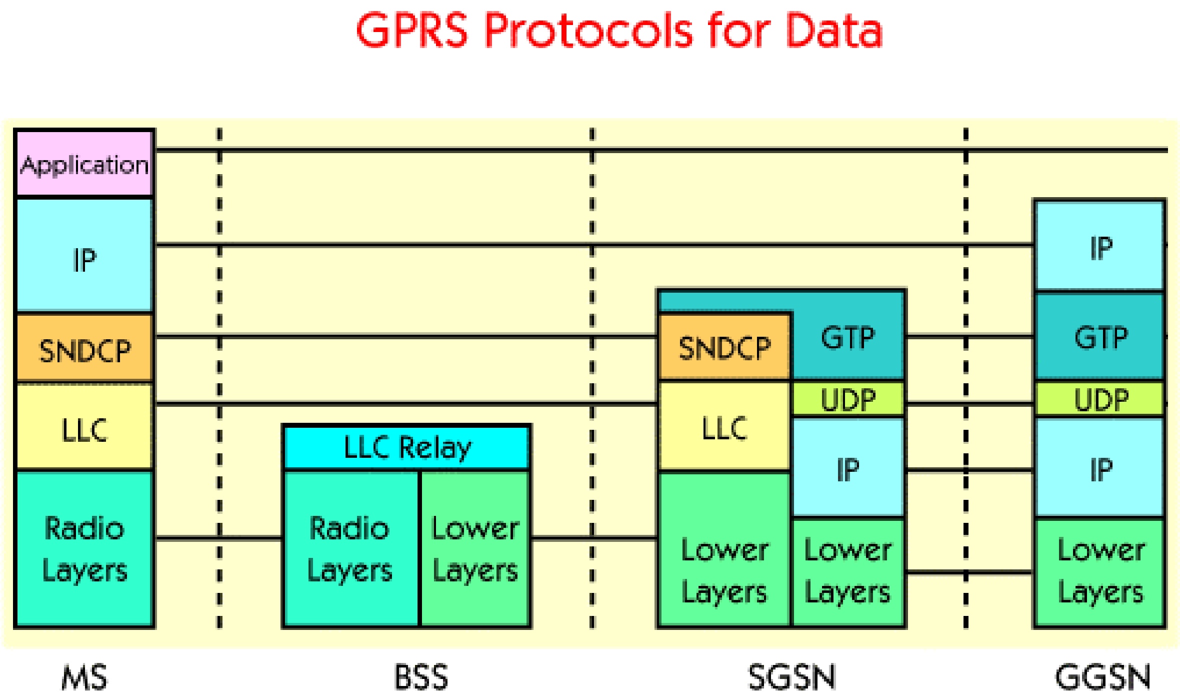


There are three different classes of GPRS mobiles.

Class A mobile can handle circuit switched and packet switched data simultaneously. This means a user can receive and transmit data whilst receiving circuit switched telephone calls.

Class B mobiles can also connect to both GSM and GPRS and listen for pages from both systems simultaneously. Should the user be operating in packet switched mode, a page for a circuit switched call can still be received. The user then has the choice to switch from one mode to another or ignore the page and return a busy signal.

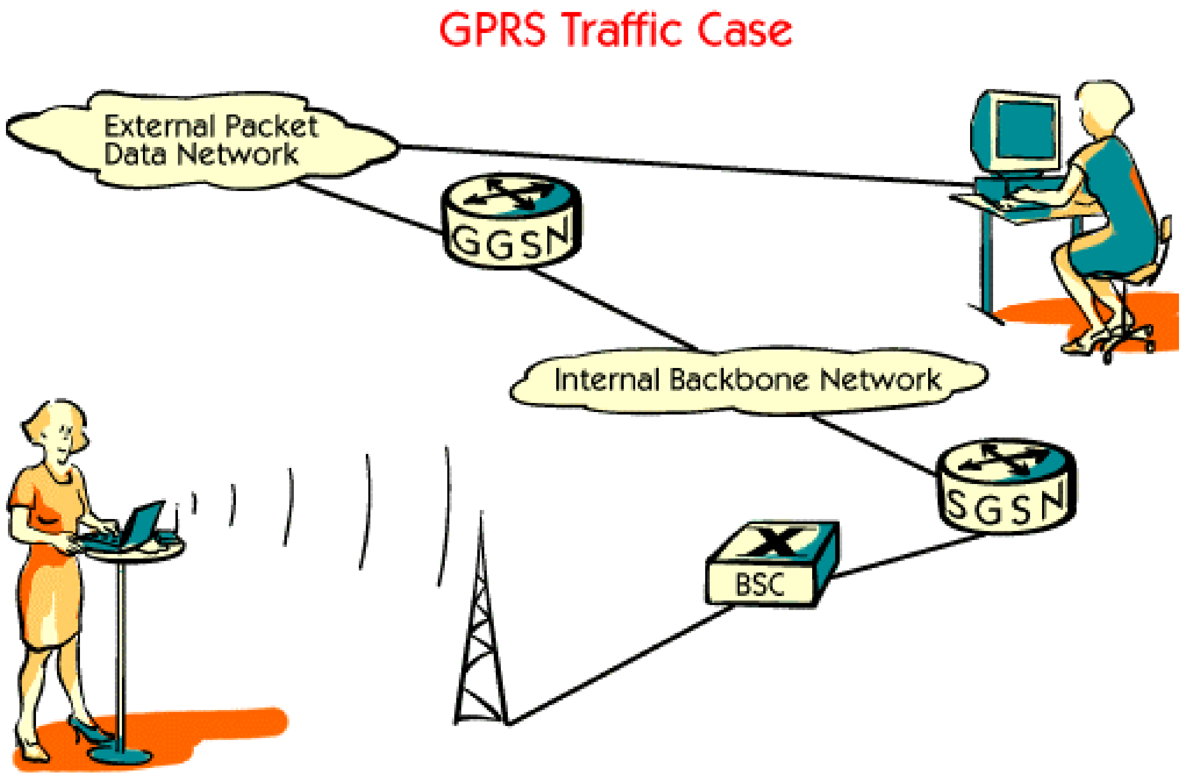
Class C mobiles can only connect to one system at a time. If the user wishes to accept circuit switched calls then they must first remove their connection to the GPRS system and reconnect to GSM. As long as they are operating in packet switched mode no pages for circuit switched calls can be received.



One of the most important things to note here is that the application communicates via standard IP, which is carried through the GPRS network and out through the gateway GPRS looks like a normal IP sub-network to users both inside and outside the network.

Also notice that packets travelling between the GGSN and the SGSN use the GPRS tunneling protocol so the internal backbone network does not have to deal with IP addresses outside the GPRS network. This GTP is run over UDP and IP.

Between the SGSN and the MS a combination of SubNetwork Dependent Convergence Protocol and Logical Link Control is used. SNDCP compresses data to minimize the load on the radio channel. The LLC provides a safe logical link by encrypting packets. The same LLC link is used as long as a mobile is under a single SGSN. When the mobile moves to a routing area that lies under a different SGSN the LLC link is removed and a new link is established with the new Serving GSN X.25 services are provided by running X.25 on top of TCP/IP in the internal backbone.

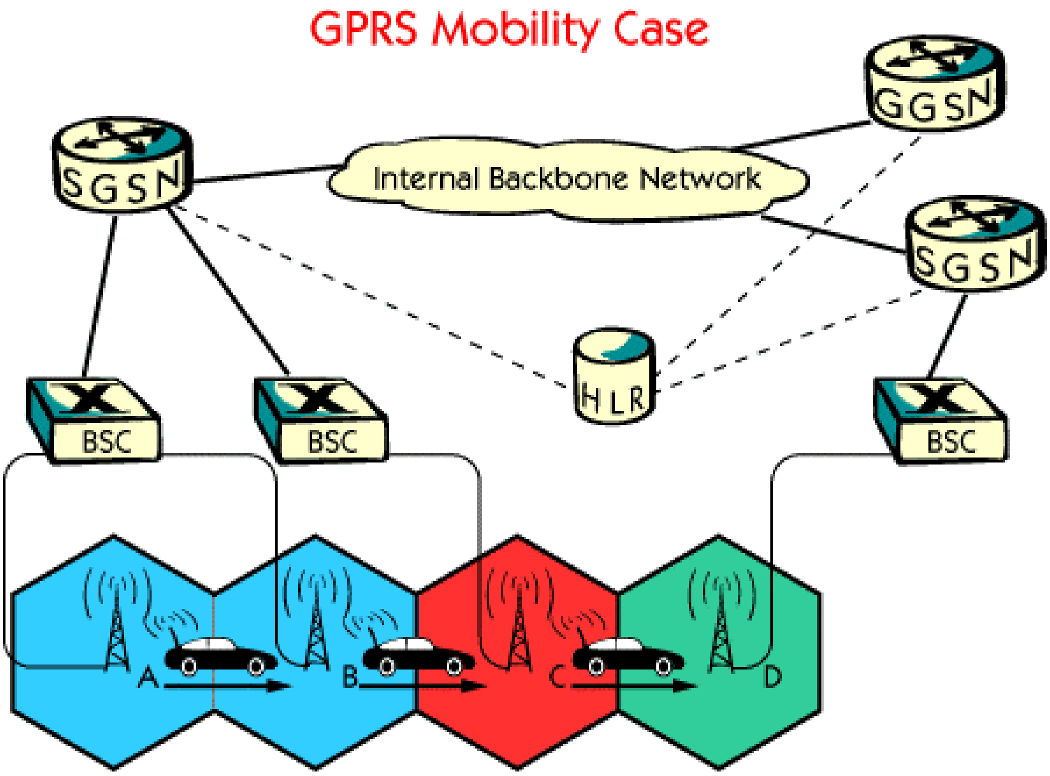


Here we can follow what happens when a user sends or receives data.

A user wishing to send data does not need to perform any call set-up procedures, remember it's a packet switched network. The data is simply sent to the BTS, which forwards it to the SGSN. The SGSN encapsulates the data and sends it to the GGSN via the internal backbone. Recall that data sent between SGSNs and GGSNs uses tunneling over the internal backbone The GGSN receives the users data packets and forwards it to the external network. The external network then routes it to the destination address.

When data is sent from an external user to a GPRS user it arrives at the GGSN via the external network. The GGSN examines the IP address in the incoming packet and uses that to find the address of the Serving GSN. The packet is then tunneled over the internal backbone to the correct SGSN. At this point two things can happen. If the mobile is in a ready state, then the SGSN knows exactly which cell to send the packet to. The packet is simply forwarded to the correct BSC, BTS and finally the GPRS user.

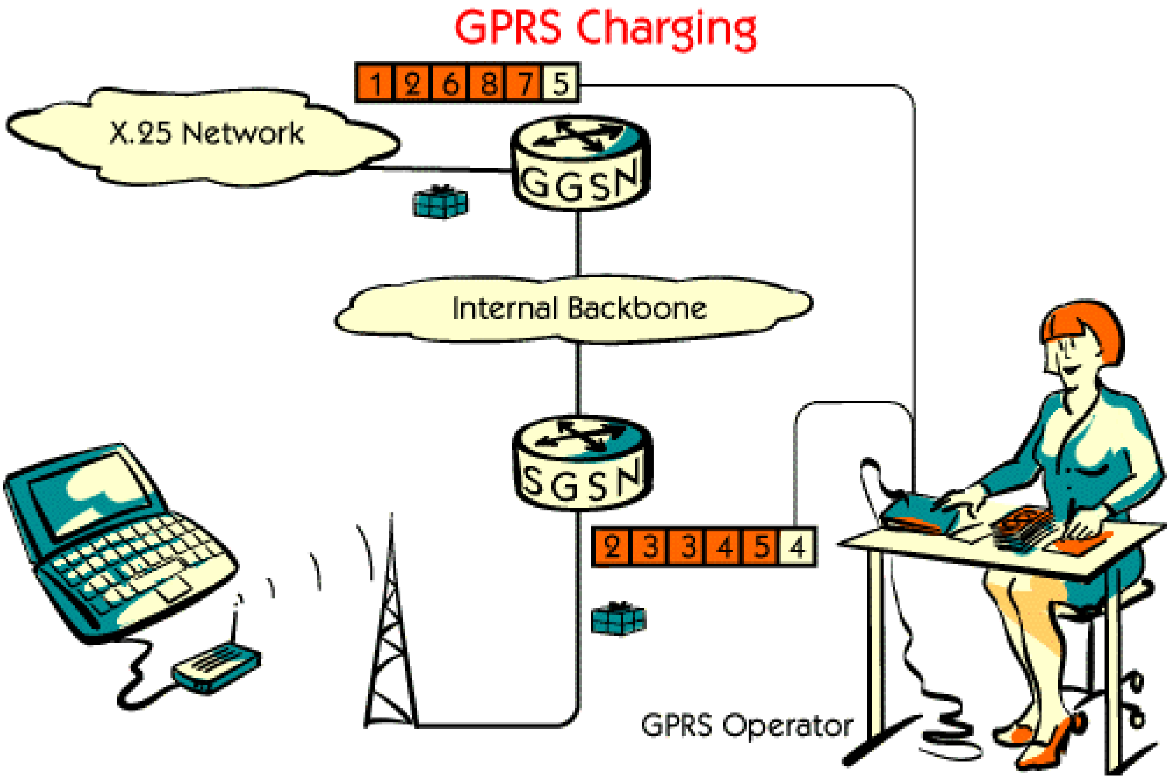
If the mobile is in the standby state the SGSN does not know which cell the mobile is in only the routing area is known. In this case a paging message is sent out in the routing area. The mobile responds to the paging message which allows the SGSN to narrow down the MS's location to a single cell. The packet can then be forwarded to the correct BSC, BTS, and finally the user.



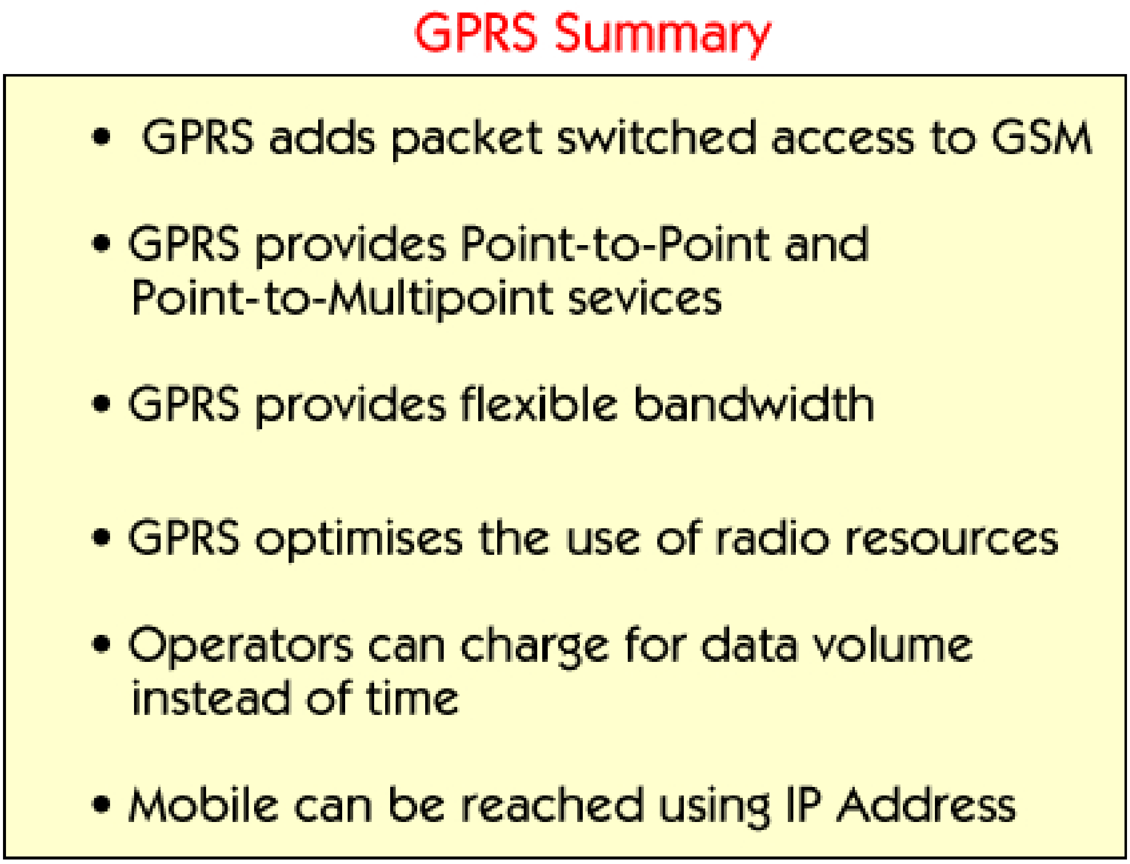
Mobility management in GPRS depends on the current state of the MS.
Firstly we'll look at the case when the MS is in the ready state.

In the ready state the SGSN knows which cell the MS is in. The mobile knows when it moves from cell A to B and notifies the SGSN of the change. The same process happens when the MS moves from cell B to C as both are under the same SGSN. When the MS moves from cell C to D it also changes SGSN. The mobile marks the change in cells and sends a routing area update to the new SGSN. This routing area update contains the identity of the old routing area, which allows the new SGSN to identify the old SGSN. The new SGSN sends a message to the old SGSN informing it that the MS has changed routing area and is now reachable at the new SGSN address. The old SGSN starts a timer and will forward all packets for the MS to the new SGSN until the timer expires. This prevents any packets from being lost in the handover process. Next the new SGSN informs the GGSN that the MS is now under a new SGSN so new packets can be tunneled to the correct place. The HLR is also informed of the new Serving GSN.

For a mobile in the standby state the process is similar. The difference here is that when the MS moves from one cell to another within the same routing area then no updates need to be sent a mobile in the standby state is tracked only on the routing area level. So, the MS is free to move from cell A to B without updating the SGSN as cells A and B are in the same routing area. When the MS moves from cell B to C, which are in different routing areas, then a routing area update is sent to the SGSN.



Charging in GPRS is based on the amount of radio resources used and traffic to external networks. The amount of traffic sent inside the GPRS network is tracked by the SGSN. The amount of traffic to and from external networks is tracked by the GGSN. This allows the network operator to charge subscribers for the total network usage.



To summarize this last chapter:

We have seen that GPRS is not a replacement for GSM. GPRS adds packet switching capabilities to the existing GSM infrastructure. This allows more efficient use of the scarce radio resources.

There are two services available in GPRS. The Point-to-Point service is included in the phase 1 specification. The Point-to-Multipoint service will be included in the phase 2 specification.

Because bandwidth is dynamically allocated, users can access one or more time-slots simultaneously. This means that a users bandwidth can grow and shrink as traffic and network conditions dictate.

Circuit switched data transfers take up a full channel in GSM. Typical data communications is bursty in nature and does not generally need a permanently allocated channel. By using a packet switched system the scarce radio resources of the physical layer are much more efficiently utilized.

Users may pay only for the volume of data they send. This means a user can be attached to the network all day and yet only pay for the data that they send or receive.

To external networks, a GPRS network appears as another IP sub-network. This means that users are reached using IP addresses, not telephone numbers.