

# Survey of General Packet Radio Service

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RESEARCH PAPER  
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This paper provides a high level view of the major components of a GPRS system as it relates to GSM. In order to facilitate this, a brief overview of the GSM system is given. Next the overall architecture of a GPRS extended GSM system is shown, with emphasis on the two new GPRS Support Nodes, device types available and Quality of Service offered. Afterwards, registration and session management is discussed, along with an example of routing between an external network and a mobile station. The critical subject of mobility management is discussed in the context of maintaining packet deliverability. Finally a summary is provided and references are given.

Categories and Subject Descriptors: G.4 [General Literature]: Introductory and Survey;  
General Terms: GPRS Mobile Data Network  
Additional Key Words and Phrases: GSM extension

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## 1. INTRODUCTION

Until the late nineteen-nineties wireless mobile networks focused primarily on voice service, evolving from the well known “bag telephone” in the late eighties to the newer, clearer digital networks, such as GSM. With the advent of smaller, more powerful devices, user sophistication has grown and with it the demand for faster wireless data services has also grown. In an attempt to address this, the ETSI<sup>1</sup> developed a new wireless data network, designed to integrate with existing digital networks, known as General Packet Radio Service or GPRS.

GPRS offers speeds from 9 to 115 kilobits/second and support for multiple bandwidths, make it an ideal solution for carriers on the path to the 3G<sup>2</sup>. In fact, GPRS can be added to a network incrementally, allowing the total capacity to be increased as needed. This approach has two advantages, it minimizes the risk on the investment required to deploy a GPRS network, and allows the users to drive the deployment<sup>3</sup>.

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<sup>1</sup> European Telecommunications Standards Institute. <http://www.etsi.org/>

<sup>2</sup> 3G is an acronym for Third Generation mobile networks which promise on demand video, and other high bandwidth content wirelessly.

<sup>3</sup> This is a standard supply and demand model; the carrier can deploy a “limited GPRS network” and allow the user uptake to decide future enhancements/deployments.

This paper gives an overview of the GPRS architecture, as it relates to existing networks, specifically GSM<sup>4</sup>. Followed by an explanation of how a mobile station registers with the network and how those sessions are managed. An example of routing packets to and from an external network and a GPRS mobile station is given. Of course packets cannot be routed to a mobile station if its location is unknown. Therefore tracking the location of a mobile station as it moves is very important. Preceding this is a brief overview of GSM, required to fully understand the architecture of GPRS.

## 2. ARCHITECTURE

GPRS is a packet switched network designed to enrich existing digital cellular networks, such as GSM. It has many advantages over circuit switched data services, including a major boost in bandwidth and allowing the user to be billed by the amount of data sent rather than the length of the data call. In addition, the two streams of data (uplink and downlink) can be allocated independently, allowing more efficient use of the physical/link layer. However, before we get to the specifics of GPRS, a quick summary of GSM is required.

### 2.1 GSM ARCHITECTURE

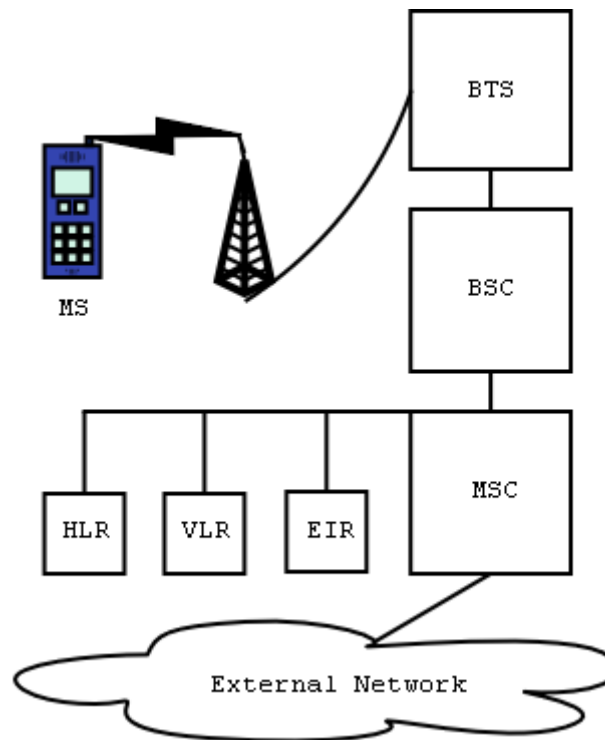
Figure 1 gives a broad overview of a typical GSM network<sup>5</sup>. A mobile station (MS), as the diagram depicts, is the actual user equipment, identified by an International Mobile Equipment Identity (IMEI). However, this identifier is only for the device, the user of the device is identified by a Subscriber Identification Module (SIM)<sup>6</sup>. Multiple MSs connect wirelessly to a Base Transceiver Station (BTS) creating a “cell” of users. The BTS is responsible for translating data coming from and destined for the MSs. From the BTS the data is sent to the Base Station Controller (BSC), capable of handling hundreds of cells and responsible for registration, handover and other functions (all of these combined create a very computationally expensive task). The next link in the chain is the Mobile Switching Centre (MSC), an

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<sup>4</sup> GSM is an acronym for Global System for Mobile Communications; a voice oriented wireless network standard.

<sup>5</sup> Aside from being a broad overview it is also a simplistic overview, including only relevant information from the point of view of GPRS. For example, the links between components are very well defined in the standards, but not covered here.

upgraded switch used to bridge networks, mobile phone network to the standard telephone system. Since large numbers of MS's may be attached to each BSC, there are usually only a few BSCs controlled by each MSC.<sup>7</sup>



**Figure 1: GSM Architecture Overview.**

Available to the MSC are various databases (only the relevant ones are shown), such as the Equipment Identity Register (EIR) used to store the IMEI of each MS on the network. This can be used to exclude certain MSs from the network or even for notification when stolen MSs are registering on the network. The two other databases shown on the diagram, the Home Location Register (HLR) and Visitor Location Register (VLR), are used to track and record the location of the mobile stations.

In the next section, GPRS will be overlaid on this GSM, elaborating on the parts of the GSM system that need to be extended to facilitate GPRS service.

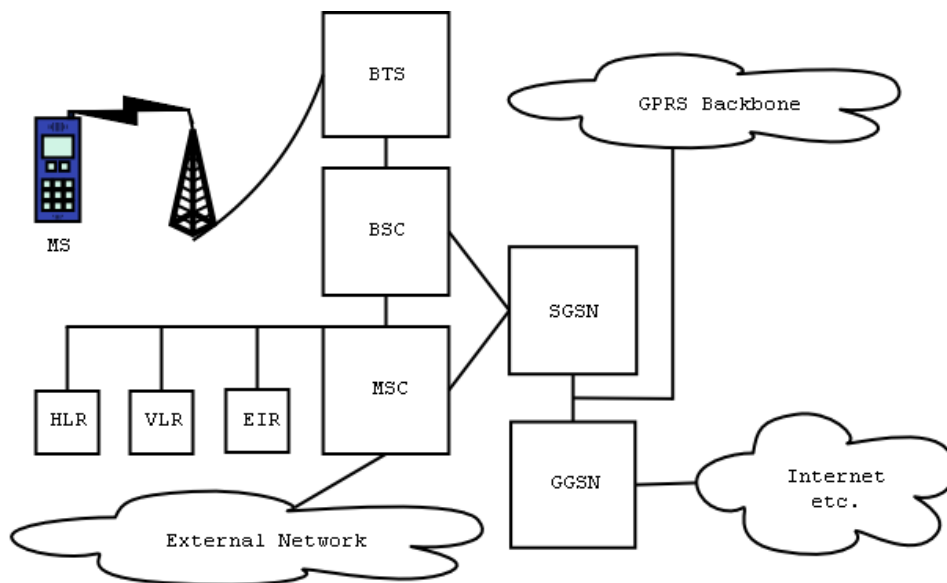
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<sup>6</sup> A SIM card is a smartcard (standardized by the ISO) cut to specific dimensions, capable of securely storing the unique data required to identify a user of the network.

## 2.2 GPRS ARCHITECTURE

An overview of a GPRS extended GSM system, as shown in Figure 2, adds two new components, the Serving GPRS Support Node (SGSN) and the Gateway GPRS Support Node (GGSN). Both of these are part of a class of nodes known as GPRS Support Nodes (GSN), collectively responsible for delivering packets from MSs to external networks, such as the Internet. The SGSN is also responsible for tracking the location of the MSs as they move around inside the network.

The SGSN is a proxy between the MS and the GPRS backbone, responsible for delivering packets to and from the MS, monitoring traffic for billing, location tracking, and other functions (not addressed in this paper). This node also represents the sole integration point between the GSM network and the GPRS addition, although the integration occurs with both the BSC and MSC.



**Figure 2: GPRS Architecture Overview**

The GGSN, like any gateway, acts as a bridge between external networks and the MSs via the SGSN. Delivering packets from the MSs, via the SGSN, to the

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<sup>7</sup> It should be noted that several sources note that while the standard is very complete there are ambiguities in the management that cause carriers to buy all the equipment from

external network and vice versa. As part of this task the GPRS standard defines a GPRS Tunneling Protocol (GTP) that is used to forward the IP packet onto the MS intact.

The roles of the two GSNs will be discussed in more detail in the following sections of this paper. To finish the architectural overview we discuss the three classes of devices defined by GPRS and the Quality of Service (QoS) provided.

### 2.3 MOBILE STATION CLASSES AND QUALITY OF SERVICE

GPRS provides for three classes of mobile stations,

1. Class A: The most robust device class, this type can use GSM and GPRS services simultaneously.
2. Class B: Able to register for both services simultaneously, but only able to use one service at a time.
3. Class C: Can register for only one service at a time, either GSM or GPRS<sup>8</sup>.

In addition to a choice of device types, there is also a choice of quality of service. A QoS profile is negotiated between the mobile station and the network during registration (explained later). The required QoS depends on the intended use. For example, checking your e-mail can be accomplished using so-called “best-effort”, meaning the packets are delivered as quickly and reliably as possible, but that other data may take precedence. However, a live data feed, such as audio/video, will require timely delivery of in-sequence packets otherwise the user experience is diminished.

During the negotiation of a QoS profile four criterion are considered<sup>9</sup>, precedence, reliability, delay and throughput. The MS will notify the network with the requested QoS parameters which will either be accepted or the network will offer another profile (if the requested parameters cannot be accommodated). All of the GSNs are involved in providing QoS throughout the transmission of the data. It

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one manufacturer to avoid operational conflicts.

<sup>8</sup> One exception to this is the ability to send SMS messages which can be transmitted at anytime.

<sup>9</sup> If you are interested in reading further about the QoS profiles and parameters offered by GPRS, the specification (listed in the references), has much more information than the condensed version provided here.

should be noted here that traffic bound for external networks is subject to the QoS available on that network, regardless of the negotiated profile. It is worth noting that the higher the QoS requested the more costly the connection, this gives the carrier the opportunity to properly assign charges to those users placing the most demand on the network.

### 3. REGISTRATION

Before a MS can use the GPRS functionality on a given network it must first attach to the SGSN. When an attachment request is received from a MS, the SGSN will check to make sure the user is authorized<sup>10</sup>. If authorization succeeds the user's profile is then copied from the HLR to a temporary location on the SGSN. This process can only be initiated by a MS, and can happen (for those devices that support it) at the same time as registration on the GSM network.

Conversely, when a MS is finished using the network it must send a detach request to release allocated resources on both sides of the connection. Unlike the attach process, the detach process can be initiated by both sides, the SGSN or the HLR can initiate the detach process if required.

#### 3.1 SESSION MANAGEMENT

After a MS has "attached" to the GPRS network and made itself known to the SGSN it is still unable to communicate with external Packet Data Networks (PDN), such as the internet. Before using a PDN the MS needs to create a session for that specific PDN, obtaining a Packet Data Protocol (PDP) address in the process. Incidentally, a MS is not limited to one session, it may have several sessions to multiple PDNs if necessary.

For each session a PDP context is created containing the PDN type, such as IPv4, the PDP address assigned to the MS, the QoS parameters (as negotiated) and the address of the GGSN, necessary to access the PDN. Once this context is created the MS is free to exchange data with the PDN.

The PDP address obtained during session creation can be either statically or dynamically assigned, depending on the user account. This type of address

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<sup>10</sup> Remember the user is not the same as the device, the ID of the user is stored on the SIM and may be used in multiple devices (at different times).

assignment is prevalent in many other networks, and is nothing new. If the address is statically assigned to the user account, it will receive the same PDP address every time a session is created<sup>11</sup>. Otherwise, the address will be dynamically assigned from a pool of available addresses, similar to DHCP in an IP based network.

In addition, GPRS supports the notion of anonymous and non-anonymous context creation. The preceding paragraphs assume non-anonymous access, meaning that the user has a subscription and is known to the network. However, anonymous access does not require a subscription. There are anonymous access cases, such as pre-paid services. In these cases the MS is not required to attach to the SGSN before creating a PDP context, but the mobility of the MS is limited to the current Routing Area (RA)<sup>12</sup> and the network has no knowledge of the user (but does obviously know the IMEI of the MS).

To conclude, regardless of the address type or access method, all MSs with an active session are able to send and receive data packets and the interface between the network and the PDN remains the same. In the next section, routing a packet from the PDN to the MS is discussed, with an example using the Internet.

### 3.2 ROUTING

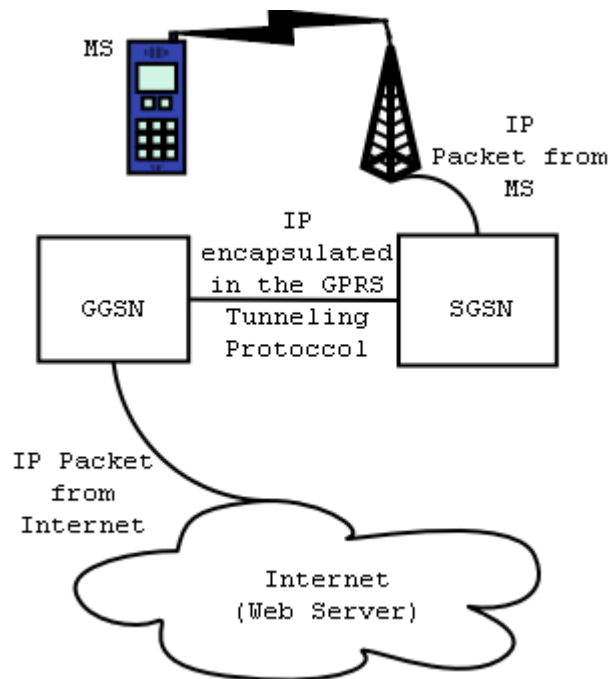
To illustrate the routing of packets between an external PDN and a mobile station on a GPRS network lets consider the case of a mobile browser communicating with a server on the internet, as in Figure 3. First, the MS attaches to the GPRS network and obtains a PDP address, in this case an IP address accessible on the internet. Once the context has been created, the MS sends IP packets to the web server. Clearly, IP packets can not pass through the GPRS network without some assistance, therefore the SGSN intercepts the outgoing IP packets, checks the PDP context, encapsulates the IP packet (using GTP) and routes it through the GPRS network to the GGSN. Once at the GGSN, the packet is decapsulated and forwarded to the Internet and onto the server.

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<sup>11</sup> For networks such as the internet this would seem like a waste since the device would not be permanently online, and would most likely act as a client (rather than server). However, consider a closed network, such as VPN, and having a static address for each device may make sense.

<sup>12</sup> Routing Area is a GSM term, and it typically refers to a group of several cells controlled by one BSC.

After the server has processed the request, it sends the response back to the mobile node using the IP (PDP) address of the MS. Since the GGSN and MS share the same subnet the packet will be routed to the GGSN<sup>13</sup>. When the packet arrives, the HLR is consulted to find the current location of the MS<sup>14</sup>. The packet is then encapsulated and forwarded on to the appropriate SGSN, where it is decapsulated and the original IP packet is sent to the MS.



**Figure 3: Packets being routed from the Internet to a mobile station.**

The main thing to remember from this section is the GGSN acting as “proxy” for the MSs on the external PDN. Obviously, this example can be extrapolated to provide access to multiple networks, of differing types. In fact, many carriers use this functionality as a way to provide companies secure access to their VPN.

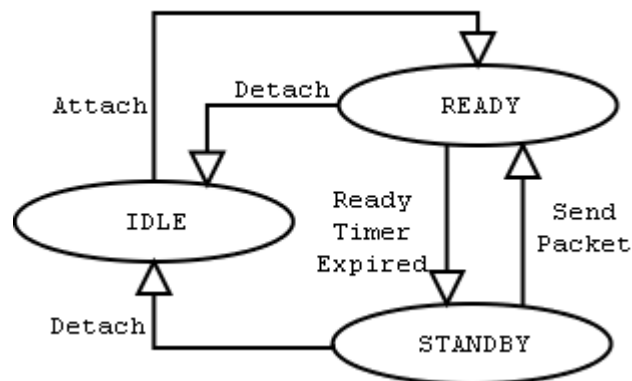
#### 4. MOBILITY MANAGEMENT

<sup>13</sup> The GGSN is a bridge between two network types, in this case IP and GPRS.

<sup>14</sup> See section 4 for an explanation of Mobility Management, which explains how the HLR and VLR are updated when a MS moves around in the network.

As with all mobile networks, tracking a mobile station as it moves around the network is imperative to the proper routing of traffic. The physical detection of cell change is handled by the GSM network, it is sufficient here to say that the MS “knows” when it has changed cells and so on (this paper sticks to the updates required for GPRS, rather than giving a detailed explanation of GSM). Just how often does this cell change occur? Well, it has been estimated that a typical user may change cells every thirty to forty seconds or almost a thousand times in an eight hour work day.

As a MS moves around it periodically sends “location update” messages to its current SGSN. If these messages are too frequent it wastes valuable resources such as bandwidth<sup>15</sup> and battery power. However, if the location update messages are too infrequent then the current SGSN will have to send paging packets, to find the exact location of the MS, before delivering the actual packet causing unnecessary overhead. To avoid this, the GPRS specification has devised a state machine to control the transmission of location messages (a compromise of the two extremes), see Figure 4.



**Figure 4: MS State Diagram (Used to determine location update messages).**

Starting in the IDLE state, when data is ready to be sent a MS attaches to the network and transitions to the READY state. In the READY state a timer is created, if data is sent/received before the timer expires it is reset, otherwise when the timer runs out the MS transitions to the STANDBY state. From the STANDBY state, a timer is once again created, if the MS transmits data before the timer runs out the MS moves to the

<sup>15</sup> In GPRS, the bandwidth is shared between all MSs on the cell, so preserving these resources when possible is important.

READY state once again, otherwise the MS detaches from the GPRS network and goes to the IDLE state.

So how do all these states help with the location message problem? Simple, the frequency of the location update messages is determined by the current state of the MS. In the IDLE state, location update messages are only sent if the MS is moving between areas controlled by differing SGSNs. Conversely in the READY and STANDBY states, the location is updated for every cell change, providing location information with cellular precision, and avoiding the need for paging while the MS is receiving packets.

During the MS handover process, from one SGSN to another, the old SGSN is required to forward any packets sent for the MS (it also buffers all packets until they are acknowledged). This guarantees delivery of all packets, even during handover.

## 5. SUMMARY

GPRS is a wireless data network, designed to be integrated with existing digital networks, to provide an enhanced data network. Advantages include things such as faster connection times, faster data speeds and more accurate billing (to the kilobyte generated and consumed).

When integrating with GSM, GPRS requires very little new equipment. First, a SGSN to provide logistic and encapsulation support for the MSs. A GGSN, is also needed to provide a gateway with external packet data networks, such as the Internet. Routing of external packet types through the network is facilitated by the GTP or GPRS Tunneling Protocol, and occurs between the two types of GSNs, SGSN and GGSN.

Finally, the importance of mobility management was discussed as it relates to the delivery of packets. If a MS moves between SGSNs while transmitting data the system needs to be able to deliver the packets seamlessly and reliably. This happens on two levels. First, if the MS is in the READY or STANDBY states, all movements trigger a location update message. However, if the MS is in the IDLE state, a location update message will only be sent if the MS moves between cells controlled by differing SGSNs, also known as Routing Areas (RA) in GSM.

This paper has endeavored to provide a high level introduction to the fundamental features of GPRS, including registration, routing and mobility management. GPRS is a very complex and involved specification for wireless data specification with multiple extension and integration points. Therefore this paper should not be taken as a comprehensive guide to GPRS, but rather a cursory introduction. In addition, much of the

underlying physical and link layer activities, such as detecting movement between cells is provided by the underlying network and not GPRS specifically.

## 6. REFERENCES

1. BETTSTETTER, CHRISTIAN, AND VOGEL, HANS-JORG, AND EBERSPACHER, JORG. 1999. GSM PHASE 2+ GENERAL PACKET RADIO SERVICE GPRS: ARCHITECTURE, PROTOCOLS AND AIR INTERFACE. *IEEE COMMUNICATIONS SURVEYS VOL 2 NO 3*.
2. CAI, J., AND GOODMAN, D. J., 1997. GENERAL PACKET RADIO SERVICE IN GSM, *IEEE COMMUNICATIONS VOL 35 NO 10, 122-131*.
3. GSM 03.60, GPRS, SERVICE DESCRIPTION, STAGE 2.
4. SALKINTZIS, APOSTOLIS K. 1999. A SURVEY OF MOBILE DATA NETWORKS. *IEEE COMMUNICATIONS SURVEYS VOL 2 NO 3*.

In addition to these references, there are several websites with helpful information (cited as of April 1, 2003):

- <http://www.gsmworld.com/technology/gprs/index.shtml>
- [http://www.cs.hut.fi/~hhk/GPRS/gprs\\_own.html](http://www.cs.hut.fi/~hhk/GPRS/gprs_own.html)
- <http://www.willassen.no/msl/index.html>
- <http://www.business2.com/webguide/0,1660,61346,00.html>