GPRS

General Packet Radio Service

White Paper by

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GPRS

GPRS is expected to profoundly change the mobile data services that GSM, CDMA and TDMA (ANSI-I36) network operators can offer. GPRS will increase opportunities for higher revenues and enable new, differentiated services and tariff dimensions to be offered (such as a charge for the number of kilobytes of data transferred). GPRS combines mobile access with Internet protocol (IP)-based services, using packet data transmission that makes highly efficient use of radio spectrum and enables high data speeds. It gives users increased bandwidth, making it possible and cost-effective to remain constantly connected, as well as to send and receive data as text, graphics and video.

What is GPRS?

GPRS (general packet radio service) is a packet-based data bearer service for wireless communication services that is delivered as a network overlay for GSM, CDMA and TDMA (ANSI-I36) networks. GPRS applies a packet radio principle to transfer user data packets in an efficient way between GSM mobile stations and external packet data networks. Packet switching is where data is split into packets that are transmitted separately and then reassembled at the receiving end. GPRS supports the world's leading packet-based Internet communication protocols, Internet protocol (IP) and X.25, a protocol that is used mainly in Europe. GPRS enables any existing IP or X.25 application to operate over a GSM cellular connection. Cellular networks with GPRS capabilities are wireless extensions of the Internet and X.25 networks.

GPRS gives almost instantaneous connection set-up and continuous connection to the Internet. GPRS users will be able to log on to an APN (Access Point Name) and have access to many services or an office network (without the need to dial-up) and remain continuously connected until they log off, only paying when data is actually transmitted. A physical end-to-end connection is not required because network resources and bandwidth are only used when data is actually transferred. This makes extremely efficient use of available radio bandwidth. Therefore, GPRS packet-based services should cost users less than circuit-switched services since communication channels are being shared and are on a ‘as-packets-are-needed’ basis rather than dedicated to only one user at a time. It should also be easier to make applications available to mobile users because the faster data rate means that middleware currently needed to adapt applications from fixed line rates to the slower speed of wireless systems will no longer be needed.

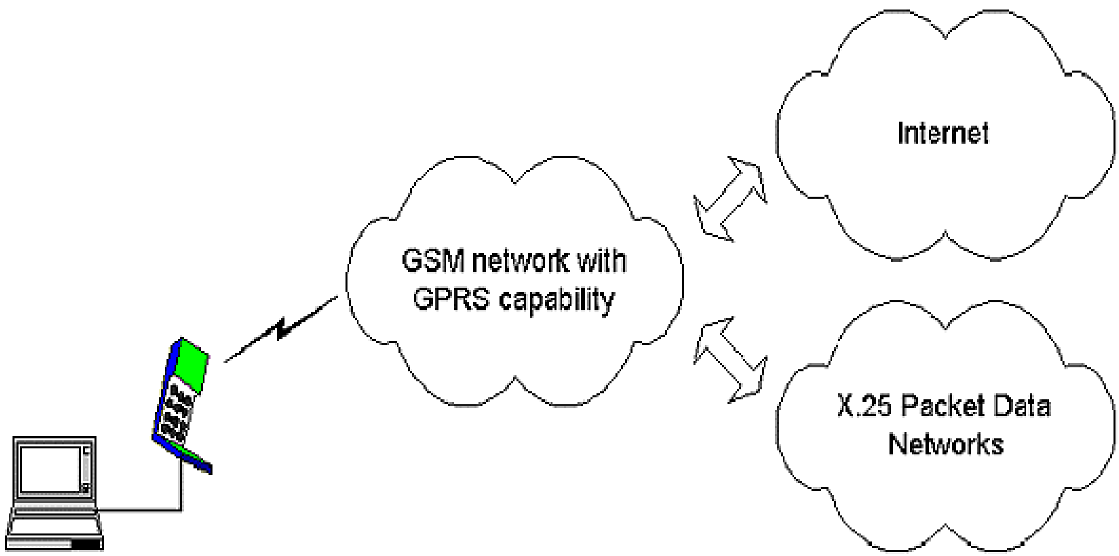
GPRS data speeds will range from 14.4 kbit/s (using one radio timeslot) to 115kbit/s (by amalgamating timeslots) and offer continuous connection to the Internet for mobile phone and computer users. GPRS data speeds are likely to average at about 56 kbit/s, with between 28 and 40 kbit/s initially. The higher data rates will allow users to take part in video conferences and interact with multimedia web sites and similar applications using mobile handheld devices as well as notebook computers.

The key drivers for operators to evolve to GPRS networks are to:

- increase revenues by moving into the mobile data market, especially since the voice market has had profit margins squeezed with the commoditization of voice services
- gain new subscribers who require mobile data services or do not want to invest in a PC to gain Internet access
- retain current subscribers by offering new services
- reduce costs due to the efficient use of network resources
- ease of adapting applications for mobile users because high data speeds mean that middleware is no longer required to convert fixed applications for mobile use.

The overall benefits of GPRS networks for mobile operators are discussed below.

Figure 1 – GPRS Network (1)



Ref: Peter Rysavy, Rysavy Research 1998

GPRS is based on GSM communication and will complement existing services such as circuit-switched cellular phone connections and the Short Message Service (SMS). It will also complement Bluetooth, a standard for replacing wired connections between devices with wireless radio connections.

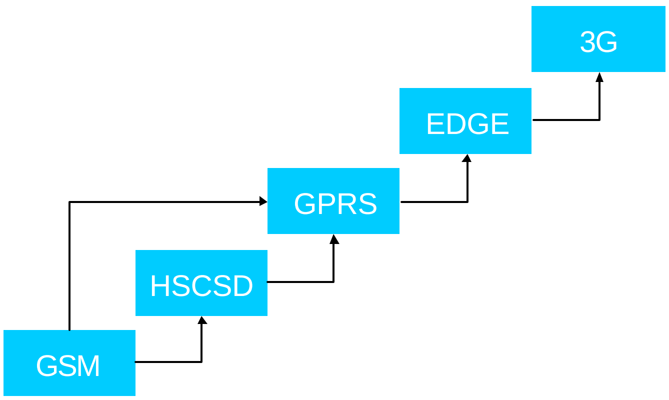
How is GPRS different to GSM?

GPRS is different to GSM because it offers the following key features:

- higher bandwidth and, therefore, data speeds
- seamless, immediate and continuous connection to the Internet – 'always on-line'
- new text and visual data and content services (due to data speeds and the Internet), such as email, chat, still and moving images, information services (stock prices, weather reports, train times), video conferencing, e-commerce transactions (buying flight and cinema tickets) and Internet-based remote access to corporate intranets and public networks (rather than dial-up remote access which incurs long distance phone calls)
- packet-switching rather than circuit-switching, which means that there is higher radio spectrum efficiency because network resources and bandwidth are only used when data is actually transmitted even though it is always connected
- different mediation, rating and billing requirements such as collecting records from GPRS and IP networks, charging for volumes of data transferred rather than connection time and new and multiple members of the billing value chain
- support for leading Internet communications protocols - Internet protocol (IP) and X. 25
- additional components and protocols to the GSM network – the key elements are SGSN (serving GPRS support node), GGSN (gateway GPRS support node) and a charging gateway
- different devices (not GSM phones) - GPRS will be available from laptops or handheld computers that are either connected to GPRS-capable cellular phones, external modems or that have PC card modems, smart phones that have full screen capability and cellular phones that have WAP microbrowsers. All of these devices have user interfaces that will allow users to utilise GPRS services
- the first important step on the path to 3G.

The Big Picture - The evolutionary path from GSM to 3G

Figure 2 – GSM to 3G



GSM (Global System for Mobile) – is known as a 2G (second generation) digital. GSM has maximum data speeds of 9.6 kbit/s and is based on circuit switching technology.

HSCSD (High Speed Circuit Switched Data) – the first step towards faster data speeds on GSM circuit switched networks. HSCSD concentrates up to four GSM timeslots and allows data speeds of up to 64 kbit/s (mostly aimed at the corporate market). However, mobile terminals supporting HSCSD are not currently available. It is primarily used for notebooks with a data card. Operators will need to decide if they will offer this service or GPRS or both. HSCSD is being installed in markets that are highly competitive where differentiation is key, such as Finland, as well as where data services have been particularly successful such as Norway and Hong Kong.

GPRS – the introduction of packet switching technology to GSM, CDMA and TDMA (ANSI-I36) mobile networks, making it easier to integrate with other packet-based protocols such as IP or X.25. GPRS is the first important step on the path to 3G, hence GPRS also being known as 2.5G. The announcements of GPRS data speeds vary from up to 115 kbit/s to up to 117 kbit/s, but is likely to average at 56 kbit/s, with between 28 and 40 kbit/s initially. If GPRS usage is mainly text based, it will meet many wireless Internet service requirements from the outset. Trials of GPRS services will occur in 2000, but it is unlikely that commercial usage will be significant before 2001. GPRS is being deployed in mobile networks today to provide the core network packet data handling capabilities that 3G will need, whether delivered using WCDMA or EDGE (see below).

EDGE (Enhanced Data for GSM Evolution) – the second step towards 3G for GSM/GPRS networks. EDGE will increase data rates on GSM to 384 kbit/s by bundling up to eight channels or 48 kbit/s per channel. Analysts suggest that indoor EDGE speeds will drop outside of the urban areas to 115 kbit/s, but that EDGE will be able to offer outdoor rates of 450-550 kbit/s. EDGE is unlikely to emerge until 2002 and is an attractive option for operators that do not have a UMTS licence. GPRS is based on a modulation technique known as Gaussian minimum-shift keying (GMSK). EDGE is based on a new modulation scheme that allows a much higher bit rate across the air interface - this is called eight-phase-shift keying (8 PSK) modulation. Since 8 PSK will also be used for UMTS, network operators will need to incorporate it at some stage to make the transition to third generation mobile phone systems.

3G (third generation mobile) – 3G is also often referred to as IMT-2000, WCDMA and UMTS. IMT-2000 (International Mobile Telecommunications 2000) is the ITU (International Telecommunications Union) initiative for a service that will provide radio access to the global telecommunications infrastructure, through both satellite and terrestrial systems, servicing fixed and mobile users in public and private networks. 3G standards have regional names such as UMTS (universal mobile telecommunications system) in Europe and Core-A in Japan. In the USA (any some parts of Japan and South Korea) 3G is referred to the evolution form cdmaOne to cdma2000. The global standard for the 3G radio link between the user's terminal and the operators network is very likely to be WCDMA (wideband code division multiple access). The WCDMA method applies a user-specific code to separate the signals transmitted via a given channel. A channel does not occupy a specific frequency, instead, several hundred channels can share a frequency corridor of five MHz, which results in high data speeds.

UMTS is the direct evolution for GSM/GPRS networks. The UMTS Forum defines UMTS as ''a mobile communications system that can offer significant user benefits including high-quality wireless multimedia services to a convergent network of fixed, cellular and satellite components. It will deliver information directly to users and provide them with access to new and innovative services and applications. It will offer mobile personalised communications to the mass market regardless of location, network or terminal used.'' UMTS will become the most flexible broadband access technology, because it allows for mobile, office and residential use in a wide range of public and non-public networks. UMTS can support both IP and non-IP traffic in a variety of modes including packet, circuit switched and virtual circuit.

UMTS seeks to build on and extend the capability of today's mobile, cordless and satellite technologies by providing increased capacity, data capability and a far greater range of services using an innovative radio access scheme and an enhanced, evolving core network. In 1998 ETSI selected a new radio interface for UMTS called UMTS Terrestrial Radio Access or UTRA, as the basis for a global terrestrial radio access network. UTRA is a combination of two technologies – W-CDMA for paired spectrum bands and TD-CDMA for unpaired. A UMTS network will incorporate new UTRA base stations as well as standards, infrastructure and services from GPRS. UMTS will offer data rates up to 2 Mbit/s (megabits per second) for stationary wireless terminals. These speeds will probably drop to a maximum of 384 kbit/s for pedestrians and 144 kbit/s for moving vehicles. UMTS will arrive commercially in 2002/3.

Japan was the first to select and announce specific plans to introduce wideband radio networks based on WCDMA (wideband code division multiple access) technology. In Japan NTT DoCoMo is very successful with its i-mode technology (not GPRS). It is expected that 3G services using WCDMA will be in service in Japan in 2001. This technology is optimised to allow very high-speed multi-media services such as full-motion video, Internet access and videoconferencing.

GPRS Today

It is expected that half of all network operators will have introduced packet-switched services by the end of 2000. Network operators are in the process of awarding trial and full contracts with GPRS vendors such as Nokia, Ericsson, Siemens, Alcatel, Nortel and Motorola.

Ericsson is promoting the development and testing of GPRS applications, in conjunction with software companies, through the GPRS Application Alliance (GAA), which it formed last June. The GAA provides centres in Sweden, the United States and Singapore where operators can try out new applications across pilot GPRS networks.

The European Telecommunications Standards Institute (ETSI), operators and billing companies are working to develop billing systems that will enable operators to bill in real-time according to volumes of data and other new tariff plans, rather than by the duration of the call.

Omnipoint in the USA, SmarTone in Hong Kong and BT Cellnet in the UK have announced plans to launch commercial GPRS services during 2000. BT Cellnet is conducting a trial for a 500-user corporate service and believes GPRS is the best 2.5G mobile data platform. It claims that it is superior to alternative technologies, specifically HSCSD, which has been favoured by its UK rival, Orange. BT Cellnet has not revealed its tariffing plans, although the operator confirmed that it would not be on a per-minute basis, but would be based on the type and amount of data accessed.

Sonera in Finland has stated that it will use HSCSD for video pictures and GPRS for bursty data such as web surfing and email.

Benefits of GPRS

Operators/ICPs (Integrated Communication Providers):

- Offer new and improved data services to residential and business markets to aid retention and loyalty
- Increase revenues from data services
- Opportunity to increase subscriber numbers - there are more mobile phones in general use than there are PCs in people's homes. This means that the potential market for GPRS is high and that new Internet users are more likely to upgrade to a GPRS handset rather than making a larger investment in a PC
- Offer innovative tariffs based on new dimensions such as the number of kilobytes or megabytes
- Return on investment - investment in GPRS will be twofold since the new network infrastructure pieces will be used as part of the UMTS network requirements as well as GPRS
- GPRS provides an upgrade path and test bed for UMTS
- Control of large content portals
- Access to the key member of the value chain – the customer
- Cost effectiveness through spectrum efficiency – with packet-switching radio resources are used only when users are actually sending or receiving data. This efficient use of scarce radio resources means that large numbers of GPRS users can potentially share the same bandwidth and be served from a single cell. GPRS spectrum efficiency means that there is less need to build in idle capacity that is only used in peak hours. GPRS therefore lets network operators maximise the use of their network resources in a dynamic and flexible way.

End-users:

- New data services
- Speed – higher levels of bandwidth means higher speeds for data transactions
- Cost-effectiveness – only charged when data is transmitted and not for the duration of the connection
- Constant connectivity – GPRS enables instant connections and the ability to remain logged-on at all times (Internet or corporate virtual private networks (VPN)). For example, a user with a laptop computer could be working on a document and automatically receive new e-mail which could be responded to then or later. The user has had a network connection throughout, but has not had to dial-in, as is necessary with circuit–switched connections. The immediacy of access to services is highly desirable and critical for some applications, such as remote credit card authorization where it would be unacceptable to delay customer service for several minutes
- Simultaneous voice and data communication - the user can receive incoming calls or make outgoing calls while in the midst of a data session.

Applications for GPRS

There are many residential applications that can applied to GPRS, but there is call for a greater number of valuable corporate applications. Analysts predict that between 30%-50% of business-to-business use of the Internet will be carried out on mobile devices by 2004 and that the real demand for wireless data is likely to come from applications that can be transformed by mobile. If, for instance, a company has a centralised ordering system but is able to speed up and make the process more flexible by submitting order information through mobile devices, it is likely to build a specific mobile extension.

IBM's Wireless Group is working on an application that will enable companies to track the time employees spend with their customers. The application is designed for workers such as engineers and repair people, who can enter details about the task performed, customers and the time spent with them, directly into a mobile device. This would enable companies both to cut down on paper work, because the information would be sent directly to a database, as well as more closely compare the performance of different employees.

A wide range of corporate and consumer applications are enabled by non-voice mobile services such as GPRS. Mobile Lifestreams, a UK-based consultancy firm, has identified the following applications:

- **chat** - GPRS is an extension of the Internet, it will allow mobile users to use existing Internet chat groups rather than needing to set up their own groups dedicated to mobile users. GPRS will not support point to multipoint services in its first phase, hindering the distribution of a single message to a group of people
- **information services as text or graphics** - information content includes services such as share prices, sports scores, weather reports, news headlines, flight information, news headlines, traffic reports, maps, graphs and lottery results. GPRS is likely be used for qualitative information services when end users have GPRS capable devices, but SMS (which is limited to 160 characters) is likely to continue to be used for delivering most quantitative information services
- **still images** - such as photographs (either scanned or from a digital camera), pictures, postcards, greeting cards and presentations
- **moving images** - such as video messages, movie previews, security camera images, patient images (eg from a crash site to a hospital) and video conferencing
- **web browsing**
- **document sharing and remote collaborative working** - which lets different people in different places work on the same document in a problem solving exercise, such as medical treatment, journalism, advertising copy and fire-fighting
- **audio reports** - for broadcasting or analysing. For example, high quality voice clips for television and radio or sounds for police to use as evidence, occupy large file sizes that need high speed mobile data rates such as GPRS
- **job dispatch** – such as advising a mobile engineer where their next job is, providing full briefing details and images, as well as enabling the engineer to report back to head office
- **corporate email** – allowing mobile employees to access their internal email system from their local area network (LAN) in the office
- **LAN applications** – mobile employees can access any applications normally available on their PC at the office
- **Internet email** – most Internet email users do not get notified of new email on their mobile phone. When they are out of the office, they have to dial in speculatively and periodically to check their mailbox contents. However, by linking Internet email with an alert mechanism such as SMS or GPRS, users can be notified when a new email is received
- **vehicle positioning** – an application that integrates a satellite positioning systems that tells people where they are with non-voice mobile services that lets people tell others where they are
- **file transfer** – downloading sizeable data across the mobile network such as a presentation for a sales person or a manual for a service engineer or a software application such as Adobe Acrobat Reader to read documents.

The general information services such as train timetables will be provided via a WAP server to the mobile phone. Broadcasting services such as live news reports will only be able to be transmitted by GPRS.

To use GPRS applications, users require:

- a mobile phone or terminal that supports GPRS (existing GSM phones do not support GPRS)
- a subscription to a mobile telephone network that supports GPRS and for access to be activated. Automatic access to GPRS may be allowed by some mobile network operators, others will require a specific opt-in
- knowledge of how to send and/or receive GPRS information using their specific model of mobile phone, including software and hardware configuration
- a destination to send or receive information through GPRS. Whereas with SMS this was often another mobile phone, in the case of GPRS, it is likely to be an Internet address, since GPRS is designed to make the Internet fully available to mobile users for the first time.

GPRS Challenges

Operators have many issues to consider:

- Few defined or proven tariffing schemes exist for GPRS data services and there is a user expectation that prices will be lower than voice. However, there could be a shortage of mobile bandwidth that limits the extent to which that bandwidth is viewed as a commodity, so prices will not be heavily reduced (especially with the short to medium term customer care and billing complexities)
- No proven business model or system architecture for GPRS mediation, rating and billing systems
- Gaining customer interest, understanding and increased usage in GPRS services
- Developing valued GPRS applications for the corporate market
- Overcoming issues that may arise from subscriber services varying according to the capabilities of the terminal used
- Developing partnerships with content providers to provide unique service combinations to users, such as banks, news services and entertainment providers
- Availability of GPRS-enabled mobile devices by handset and terminal manufacturers who have found it difficult to produce high volume, high quality handset to the standards needed
- How to encourage users (both residential and corporate) to subscribe to WAP and then GPRS services if they will need to purchase a new handset for each. Will operators subsidise the cost of new phones or upgrades?
- Security and roaming. The solutions for these issues are not yet clear. Security issues are particularly significant to corporate intranet access
- Difficulties associated with ensuring quality of service on GPRS. Guaranteed quality of service will be a major challenge in the evolution from GPRS to UMTS. VOIP over GPRS is not likely to become a reality, but will become possible with EDGE and UMTS because quality of service will be stabilised. However, QoS guarantees are likely to apply to only the GPRS network and not the IP network since delays in downloading web pages may be caused by an overloaded web server which is beyond the operators control
- Limited cell capacity - GPRS does impact a network's existing cell capacity (ie the geographic area covered by a cellular transmitter – the cell site). There are only limited radio resources. Voice and GPRS calls use the same network resources, which can not be used for both services simultaneously. The extent of the impact depends upon the number of timeslots, if any, that are reserved exclusively for GPRS. However, SMS uses a different type of radio resource and more cell sites so will continue to be used as a complementary bearer to reduce the potential scarcity of radio resources for GPRS services
- IP mediation - identifying the content and value of packets (ie images, email etc.), so that the appropriate rating plans can be applied and bills can detail the applications used. IP networks typically record network-level information and not application-level detail
- Creating compatible and comparable data records for events that occur across both circuit and packet-switched networks to enable accurate billing

- Limited speeds **-** The likelihood of a user achieving 115kbit/s is low because the user would need to take over 8 timeslots without errors. It is unlikely that a network operator will allow all timeslots to be used by a single GPRS user. Additionally, the initial GPRS terminals are expected be severely limited - supporting only one, two or three timeslots. The maximum GPRS speeds should be checked against the reality of constraints in the networks and terminals
- Transit Delays - GPRS packets are sent in all different directions to reach the same destination. This opens up the potential for one or some of those packets to be lost or corrupted during the data transmission over the radio link. However, the result is that potential transit delays can occur. Applications requiring broadcast quality video may well be implemented HSCSD. HSCSD is simply a circuit-switched data call in which a single user can take over up to four separate channels at the same time. Because of its characteristic of end to end connection between sender and recipient, transmission delays are less likely
- Interconnect tariffs between operators for GPRS services are yet to have regulatory standards set.

Introduction to GPRS Billing

Technologies such as WAP, GPRS and 3G are revolutionising the mobile industry. The size of the market and the potential revenue from new data services means that the stakes are high. However, there is a fundamental issue that needs to be addressed. How do you bill for these services, who do you bill and can your current billing and operational support systems handle it?

Chorleywood Consulting Ltd, an international telecommunications management consultancy, states that billing for transport will give way to billing for content, which will in turn entail passing fees to content providers. Usage based bills will need to draw upon new types of detailed information about applications, quality of service, time of day and other parameters. Maintaining control over revenue collection will become both more difficult and more important at the same time.

GPRS Mediation

With mobile Internet a ‘call’ only travels across the telephony network (GSM and GPRS) until it reaches the Internet gateway, at which point it converts into IP network traffic. Operators will need to handle mediation and billing for multiple record formats such as voice calls as CDRs, data transfer as GPRS data records, IP event records and content event records of various kinds (including WAP).

This means that it must handle files from circuit-switched networks and transactions from packet-switched networks. Whereas a telephone call travels over a single route, each IP event must be reconstructed by piecing together information about multiple packets travelling via multiple routers. IP networks are composed of multiple components that interact with each other in a complex way and record large quantities of network information (at least 10 times more than voice). IP records are not attached to a switch or generated in a single, identifiable and centralised place, like a voice record. Therefore, IP mediation requires the correlation of data - including accounting and performance data – to be collected from some or all of these devices in real-time and to be stored until it is processed. This could be managed in a number of ways, but whatever strategy an operator uses it is the IP mediation function that makes it possible.

A network typically records network-level data regarding packets and not user-level data such as which services and applications have been used. However, this information is needed to have a bill that is intelligible to the customer. Therefore IP mediation is a more complex task.

A single mediation system or two mediation modules could be used, but ultimately mediation must be able to collect and consolidate all records from both GPRS and IP networks in order to send one service-related record to the billing system. See Table 1 for a comparison of mediation for voice and IP.

Analysts have stated that GPRS services will produce 15-20 times the number of CDRs that a GSM network produces, however, many of these may not be of any real value and need to be filtered out. Therefore, mediation systems will need to handle a huge volume.

Why is it important to collect everything if much of it may not be used?

- To enable the full range of current billing scenarios and cross-service packages and discounts to be offered. Many of the records will be required to understand and charge for bundled and individual services. If mediation systems only collect records from the charging gateway nodes in the GPRS network, and not from the IP network, it will not be possible to determine what services have been used or to differentiate the billing of specific services (such as the various WAP offerings)
- To support future billing requirements that are not yet defined, but may need additional data from the mediation system
- To add usage data to other operational support systems such as fraud, data warehouse and marketing.

Table 1 – Comparison of Mediation for Voice and IP Services

Features of Mediation	Voice Telephony	IP Services
Network architecture	Static circuit switches, well defined, hard wired information sources. Still largely a mix of proprietary systems.	No unified architecture, dynamic and distributed information sources. Open systems platform based.
Billing related information sources	Telephone switches.	Multiple network devices, including gateways, servers, proxies, routers, firewalls, as well as PCs and TVs.
Scheduling	True real-time collection is not usually supported.	Real-time collection and correlation is key.
Key functions	Data collection, buffering, filtering, reformatting, forwarding to multiple systems.	Collection, buffering, correlation and consolidation, filtering, reformatting and forwarding to multiple systems.
Typical information contained in a CDR	Call start and finish times and date. Caller and called party ID. Trunk information for interconnect accounting.	Volume in terms of packet or byte count. Transmission start and end times. Applications and content related information. Quality/class of service and type. Transit, routing and peering information from multiple partners.
Requirements for billing	Log file collection. Reformatting CDRs from fixed voice, mobile, cable etc. to uniform format recognized by billing system. High volumes of billing data.	Event-based collection for usage and content based billing. Support for reconciliation with content providers and advertisers. Higher volumes of billing data.

Ref: Chorleywood Consulting Ltd

How are GPRS data records collected?

Information about the usage of the GPRS network is recorded at the SGSN (serving GPRS support node) which is the point of access to the GPRS network and the GGSN (gateway GPRS support node) which connects the GPRS network to the IP network. The information from the SGSN and the GGSN is consolidated at the charging gateway that provides a mechanism to transfer charging information to the network operators mediation/billing system.

Figure 3: GPRS Data Records

The information held in the charging gateway's log has to be converted to event data records, EDRs, by a mediation system. The criteria and frequency for this conversion (eg each time a user requests a service or at set time periods such as every hour) will depend upon the operators business model, but will affect the flexibility of pricing and the number of EDRs that must be processed by the billing system.

Events should be sent immediately for rating so that users and operators have a real-time view of usage charges, however, the network infrastructure may not support the real-time delivery of EDRs to the billing system. (See further information regarding pre-paid in the section entitled *What are the key GPRS convergent billing and customer care requirements?*

GPRS Tariffing

GSM circuit-switched based voice services are charged mainly on duration of calls and time of day. GPRS packet-based charging will be based on totally different and many more dimensions because the user is always 'logged-on' to the network, whether they are actively using it or not. Some of the tariff dimensions that could be used for GPRS subscribers are as follows:

- number of packets transported (price per packet), although the cost of counting the number of packets may be greater than their value
- volume in terms of kilobytes (kbit/s) and megabytes (mbit/s) of data transferred
- uplink/downlink volume – GPRS has the flexibility to monitor data going from the user to the network and vice versa. This enables tariffs such as free access for surfing and payment for downloading
- type of content
- value of content
- e-commerce/m-commerce – transactions and content that are not delivered by the mobile network but is charged to the mobile bill. For example, mobile phones can be used to purchase items from vending machines, juke boxes and car washes (as offered by Sonera and Radiolinja in Finland). In this scenario a user dials a particular number which activates the machine to dispense a cold drink and the charge appears on the user's phone bill. In Austria, Mobilkom lets subscribers request railway schedules and buy train tickets
- number of messages
- time delay - charge more for a real-time stock quote than for a delayed one
- quality of service(QoS) – users can be charged for the class of service they opt for, such as priority, mean throughput or delayed. Discounts will have to be offered by operators for shortfalls in the QoS
- type of device used (subscriber services may vary according to the GPRS mobile device)
- transaction fees - it is highly likely that a transaction fee may be the most applicable tariff for messaging or WAP services such as a traffic query. The transport fee would be bundled into the transaction fee of the content service

- number of emails sent and received
- mailbox size
- number of web page hits
- time of day – peak or off-peak
- location - although distance has no significance in the IP world (users do not pay different rates to download web pages depending on the geographic location of the web server) operators may still wish to offer location-based pricing. For example a tariff for an area within a radius of the office or home, based on nominated cells, to encourage GPRS usage on the operators network. Once roaming is supported on GPRS networks, charges for roaming would be higher than for the home-network
- monthly subscription fee
- location-specific (billing according to the location of the originating call)
- terminal-specific (subscribers with different terminal capabilities will experience different services and will have different usage patterns).

A business tariff example:

Operator X offers a mobile office tariff for business users to connect to their office network via GPRS to download email and to use the corporate intranet and public Internet to download files and potentially use a videoconferencing facility. The user would probably use a laptop PC with a GPRS radio card or connected to a GSM/GPRS handset. The operator could offer a basic price per MB during business hours, an off-peak price per MB rate to transfer data when the network is less busy, a subscription charge for the mobile office tariff, that includes 25 MB of data transfer in peak hours, and a discount when the user is in a particular location. Cross-service discounting may be applicable on certain tariff packages where a discount on GSM voice calls is made if a certain number of mbit/s were transferred over GPRS in a month.

Mobile Lifestreams, a UK-based consultancy firm, believes that the optimal GPRS pricing model will be based on two variables - time and packet – where a flat rate charge applies during off-peak times and a price per packet charge during peak times. Time and packet related charging will encourage applications such as remote monitoring, meter reading and chat to be used overnight when spare network capacity is available. However, the cost of counting the number of packets may be greater than their value and, therefore, time and volume of packets may be the best way forward so that heavier users of bandwidth are charged more at peak hours.

As yet, most operators do not know how they will bill for GPRS. The only agreement seems to be that duration tariffing is unfair and that flat rate billing and data volume transferred would be the first tariffs implemented. The residential market may continue to have flat rate charges for some services for longer than the business market, which can have more complex tariffs and service level agreements (SLAs). Corporate clients will probably purchase so many megabytes of data transfer, but the mass market is viewed, by some, as not ready for this. However, in Japan NTT DoCoMo charge in terms of data transfer and not call duration to the mass market and is very successful with its i-mode technology (not GPRS).

Some analysts foresee the end of usage billing as the cost of bandwidth decreases. Users will pay for the value of what is transmitted with the cost of transport absorbed as a small percentage of the overall charge. However, currently bandwidth remains at a premium and therefore is likely to remain for the foreseeable future.

In March 2000 an article in Mobile Communications raised the question – does the average consumer understand packet switching and does the operator want them to? The most important thing an operator can do is to create service portfolios that the customer understands and trusts if it is to succeed. The customer does not have to understand detailed network logistics, but should have simply defined tariffs – even if they are in new dimensions.

In addition, operators need to charge advertisers linked to content that are downloaded and content providers. This is discussed below entitled *Billing the Value Chain for Mobile Content Services.*

GPRS Billing

The billing system will apply single and cross-service convergent discounts for volume usage and adjustments for any reduced quality of service, for example.

Bill presentation is key to avoiding confusion that will lead to increased customer care calls and subsequently increased costs and churn.

WAP and GPRS services also make greater demands on convergent billing since the user has the option to purchase items such as cinema tickets and have the cost charged back to the mobile phone bill which need to be presented clearly. This will also be possible on prepaid mobile phones. The cinema represents another member of the value chain (see below) that will have to be monitored and paid (similar to interconnect) and for whom the billing system will have to contend with.

Usage billing for WAP and GPRS is further complicated by the fact that interconnect billing in IP is not fully regulated and difficult to calculate and enforce, but operators need to maintain interconnect agreements and have billing systems to cater for this.

Billing the Value Chain for Mobile Content Services

Mobile content is bringing the e-commerce business model to the mobile telecommunications industry – m-commerce. ICPs (integrated communication providers) need to provide for multi-party content billing down through the value chain. Mobile operators have an opportunity to take greater control of the m-commerce value chain than in the original wireline e-commerce scenario.

In the wired world, the content value chain comprises the customer, the network operator, the Internet service provider (ISP), the content brokers (ISPs with portals) and content providers (who may have a chain of their own that includes publishers, writers, artists etc.). A user would access the Internet through their ISPs point of presence (POP) via dial-up lines (PSTN or ISDN) through their network operator. In this scenario ISPs are usually unable to take a share of e-commerce because the customer purchases goods from the content provider by credit card directly, as well as not having any control or understanding of their customers' spending habits. Therefore, they have established their own web sites or portals as the main point of access. It is from this portal that they broker a range of content and take commissions on content purchased from their portal along with advertising revenue, due to so many users visit their site (eg Freeserve and AOL). Many ISPs now offer free Internet access to attract as many customers as possible. Fixed line operators' only revenue is from the local call charge for the time taken to browse and download (and this is reduced with faster modems). Therefore, there are an increasing number of operators installing IP network capability so that they can become an ISP and mergers between operators, ISPs and content providers in order to gain revenues and customer information.

In the wireless world, mobile operators that have a GPRS network will automatically be ISPs because GPRS is a wireless extension of the Internet. Operators are signing up content partners in order to set-up their own WAP-portals. For example, BT Cellnet's Genie Internet service offers email, web browsing and other WAP services.

Operators have several choices for billing the value chain:

- firstly the operator could bill its customers directly for the content purchased, so one section of the bill will be much like a credit card bill. The operator will pay the content providers minus a commission

- secondly, the operator may charge a commission for purchases made via its WAP portal where the customer pays the content provider directly
- thirdly, the operator could bill advertisers for sponsoring content and pass on a share of the revenue to its content partners. However, the opportunities are limited for WAP devices due to screen size.

All three of these billing scenarios could be employed simultaneously by an operator. Billing becomes more challenging when each event incurs a different type of billing scenario for all the parties involved. For example a transaction fee or MB download for information requested by the user, a fee for the content provider and charges for companies advertising with that content, depending on the number of downloads per month that include their advertising.

Customer Care

Value-added network services such as mobile data and mobile Internet generate specific customer problems and requirements. Therefore, an operator will need to train customer service personnel to be aware of these issues and know how to solve them. The reality in the short and medium term is that the need for customer support for value-added services will increase, not decrease, as awareness of services and their usage increases and as new services and terminals come onto the marketplace.

Web self-care, where customers can solve their own billing enquiries, for example, is a customer benefit and a cost-saving opportunity for operators. The promotion of web self-care for basic enquiries will be particularly important so that CSRs (customer sales representatives) in call centres are only dealing with complex enquiries.

The user interfaces both internally and externally will need to be well designed to enable a clear understanding and management of the information in the customer care and billing system.

What are the key GPRS convergent billing and customer care requirements?

- cross-product packages and discounts for mobile voice, data and content
- rapid and flexible product and service definition and rating schedule development to enable fast time-to-market for new services and immediate changes to rating schedules that the market is not responding to. This is achieved via rules-based systems that enable new products and services to be set-up without expensive and time consuming customization to the application
- support for new tariff dimensions
- understand and monitor customer requirements and usage to help define products and services and devise relevant promotions
- analyze the profitability of individual and packaged products and services
- a single view of the customer, which requires a customer care system that can access and process information regarding all of the services offered
- web self-care so that customers can solve their own billing enquiries, for example
- multi-party content billing down through the value chain
- independent mediation device that can collect and format data records from various sources in multiple formats that contain new attributes that are not associated with voice telephony
- real-time and pre-paid capabilities for users and operators. Users want to have immediate access to up-to-date charges for usage, immediate activation of account detail changes, immediate provisioning of new services and immediate top-up facilities for prepaid services, for example. Operators need to have instant electronic payment processing and real-time (or very near real-time) mediation, provisioning, rating and billing. However, this may not be possible due to the hardware required to cater for peak periods and is not worthwhile unless all elements are in real-time. It is no good rating in real-time if the records are not sent from the mediation system in real-time to start with. IP mediation must be in real-time, whether pre or post paid, since collection of chargeable IP events must be at the time they occur. It will

be important to offer real-time functionality for prepaid customers but real-time rating and billing for post-paid customers will not be necessary. In the pre-paid WAP and GPRS billing scenario the WAP gateway and SGSN/GGSN respectively, will receive requests for pre-pay services and ask the pre-pay server or billing system if credits exist. If so, the gateway or service node will be authorized to open service for 15 minutes for example. Similar issues occur in GPRS as GSM voice pre-pay, such as fraud and credit exposure

- convergent pre-pay for voice, data and content across GSM, WAP and GPRS. However, this is currently difficult to achieve and current IN platforms may not this. Operators may choose to use existing pre-pay servers and interface to the GPRS environment. It is possible that billing systems may come to the fore more in this area by offering a single credit limit across all services and be able to calculate whether a desired transaction can be permitted with the current credit limit
- scalability and performance. Some operators have estimated a 10-fold increase in the number of records to be processed per product per day compared to voice telephony.

Migration to GPRS Billing

Operators have several potential migration options to take them from billing GSM to GPRS. A convergent billing system that supports mobile and IP (and fixed) enables cross-service packages and discounts to be more easily implemented, as well as reducing the integration effort. Options for migration:

Option 1: Implementing a convergent billing solution for billing packet switched content and data and leave legacy system to bill for circuit-switched voice. This option will not allow for a single convergent bill. This option is a low risk strategy.

Option 2: Integrating a convergent solution for billing voice, data and content for customers who take all three services and leave the legacy system to bill those customers that are voice-only. This option provides a convergent bill for those who require it and is a relatively low risk strategy.

Option 3: Integrating a convergent solution for both rating and billing of data and content services, as well as pure billing of voice calls. The legacy system would rate all of the voice calls and pass rated voice events to Unicorn for customers that have services in addition to voice, but bill those customers that have only voice services. This provides a convergent bill for those who require it and is relatively low risk.

Option 4: Implementing a convergent solution for the billing of all services. The legacy system would not be required. This approach has a relatively higher risk factor than options 1 – 3 due to a big-bang approach to migration, since project management of this type of project is more complex. However, Usha Communications Technology has migration expertise and experience with this type of migration and does not regard it as high risk.

How does GPRS work?

In order to offer GPRS services operators must install a new network overlay to allow migration to packet switching. The key new elements in a GPRS network are:

- **SGSN -** the node within the GSM infrastructure that sends and receives packet data to and from the mobile stations and keeps track of the mobiles within its service area. SGSNs send queries to Home Location Registers (HLRs) to obtain profile data of GPRS subscribers and detects new GPRS mobile stations in a given service area. The SGSN performs the functions include mobility management (tracking a mobile location), user verification and collection of billing data
- **GGSN** – the node that interfaces to external public data networks (PDNs) such as the Internet and X.25. GGSNs maintain routing information that is necessary to tunnel the

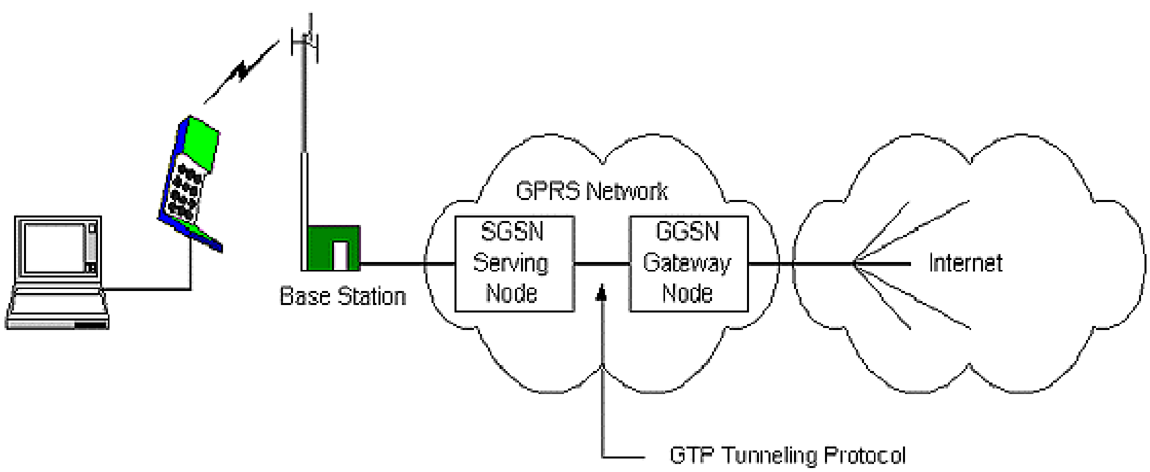
Protocol Data Units (PDUs) to the SGSNs that service particular mobile stations. Other functions include network and subscriber screening and address mapping.

- **Charging Gateway** - an interface between the charging gateway functionality and the billing system. The charging gateway makes a log entry whenever there is network activity such as data being transferred, the charging terms changing (peak/off-peak), an alteration in the quality of service or if a GPRS session ends (known as a packet data protocol (PDP) context). The main functions of the charging gateway are the collection of GPRS data records from the GPRS nodes, intermediate data record storage, buffering and transfer of data records to the mediation/billing systems.
- **GPRS Tunnelling Protocol (GTP)** – a specialized protocol that operates over the top of standard TCP/IP protocols to encapsulate IP or X.25 packets so that they can be forwarded between the SGSN and GGSN (more information below)

In addition two network elements must also be enhanced in order to support GPRS:

- **Base Station System (BSS)**: must be enhanced to recognize and send user data to the SGSN that is serving the area
- **Home Location Register (HLR)**: must be enhanced to register GPRS user profiles and respond to queries originating from SGSNs regarding these profiles.

Figure 4 – GPRS Network (2)



Ref: Peter Rysavy, Rysavy Research 1998

To provide an overview of how these elements fit together it is useful to use an example of a business person with a laptop connected to a GPRS cellular phone. The GPRS phone communicates with a GSM base station that sends the data packets to the SGSN (whereas a circuit-switched data calls is connected to voice networks by the mobile switching centre.) The SGSN communicates with the GGSN, a system that maintains connections with other networks such as the Internet, X.25 networks or private networks. A GPRS network can use multiple serving nodes, but requires only one gateway node for connecting to an external network such as the Internet. IP packets from the Internet addressed for the mobile station are received by the GGSN, forwarded to the SGSN and then transmitted to the mobile station.
To forward IP or X.25 packets between each other, the SGSN and GGSN encapsulate these packets using a specialized protocol called the GPRS tunnel protocol (GTP) which operates over the top of standard TCP/IP protocols. The user experiences a straightforward IP or X.25

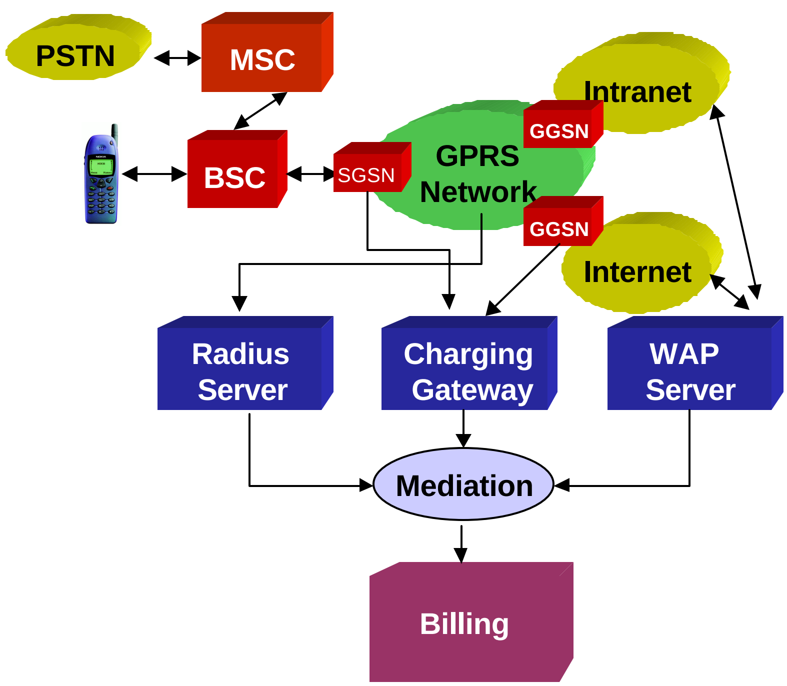
connection, but a network connection is actually established for each transaction and released once the transaction is completed (see below for further information).

How does GPRS achieve high data speeds?

GPRS uses the same radio channel as voice calls, a channel that is 200 kHz wide. This radio channel carries a raw digital radio stream of 271 kbit/s which, for voice calls, is divided into 8 separate data streams, each carrying approximately 34 kbit/s. After protocol and error correction overhead, 13 kbit/s is left for each voice connection or about 14 kbit/s for data. Circuit-switched data today uses one voice channel. GPRS can combine up to 8 of these channels, and since each of these can deliver up to 14 kbit/s of data throughput, the net result is that users will be able to enjoy rates over 100 kbit/s. But not all eight-voice channels have to be used. In fact, the most economical phones will be ones that are limited to 56 kbit/s. The GPRS standard defines a mechanism by which a mobile station can request the amount of bandwidth it desires at the time it establishes a data session.

GPRS Architecture

Figure 5 - GPRS Architectural Components



Note: Radius Server = Remote access dial-in user server

Charging Gateway

The charging gateway is a single logical interface between the charging gateway functionality and the billing system. The charging gateway functionality can be either a separate centralised network element or a distributed resident in SGSN and GGSN.

GPRS Tunnelling Protocol (GTP)

GTP is the protocol that tunnels the protocol data units through the IP backbone by adding routing information. GTP operates on top of TCP/IP. ETSI has defined the functions of the GTP as:

- CDR transfer mechanism between GPRS nodes generating CDRs and the charging gateway functionality
- redirection of CDR transfer to another CGF (charging gateway functionality)
- ability to detect communication failures between the CDR handling GPRS network elements by echo messaging.
- ability of a CDR handling node to advertise the peer CDR handling GPRS network elements about its CDR transfer capability (e.g. after a period of service downtime).
- ability to prevent duplicate CDRs that might arise during redundancy operations. If so configured, the CDR duplication prevention function may also be carried out by marking potentially duplicated CDR packets and delegating the final duplicate deletion task to CGF or Billing System (instead of handling the possible duplicates solely by GTP' messaging).
- the aim of the duplication prevention support of GTP' is to reduce the number of duplicated CDRs sent towards the billing system and to support the billing system in keeping the efforts for duplicate CDR checking as small as possible.

Additional GPRS Network Protocols

There are several protocols used in the GPRS network equipment besides GTP. The following is a brief description of each protocol layer:

- **Sub-Network Dependent Convergence Protocol (SNDCP)** – a protocol that maps a network-level protocol, such as IP or X.25, to the underlying logical link control. SNDCP also provides other functions such as compression, segmentation and multiplexing of network-layer messages to a single virtual connection
- **Logical Link Control (LLC)** - a data link layer protocol that assures the reliable transfer of user data across a wireless network
- **Base Station System GPRS Protocol (BSSGP)** - BSSGP processes routing and quality of service (QoS) information for the BSS. BSSGP uses the Frame Relay Q.922 core protocol as its transport mechanism
- **GPRS Mobility Management (GMM)** - protocol that operates in the signalling plane of GPRS and handles mobility issues such as roaming, authentication and selection of encryption algorithms.
- **Network Service** - protocol that manages the convergence sub-layer operating between BSSGP and the Frame Relay Q.922 core by mapping BSSGP's service requests to the appropriate Frame Relay services
- **BSSAP+** - protocol that manages paging for voice and data connections and optimises paging for mobile subscribers. BSSAP+ is also responsible for location and routing updates as well as mobile station alerts.

Data transmission in a GPRS network

Although a user experiences a continuous connection, a network connection needs to be opened and closed for each transaction. Data transmission in a GPRS network requires several steps to be undertaken (in the context of the protocol layers described above):

- **Network Access** - once a GPRS mobile station is switched on, it 'introduces' itself to the network by sending a 'GPRS attach' request. Network access can be achieved from either the fixed side or the mobile side of the GPRS network - point-to-point, point-to-multi-point or anonymous connections are then available. As in cellular networks, several administrative functions are performed to validate a user, including :

- User Registration - associates the mobile ID with the user's PDP (packet data protocol) and address within the PLMN (public land mobile network). Within the home area of the mobile station, traditional HLRs are enhanced to reference GPRS data. Outside the home area, dynamically allocated records are referenced in VLRs (visitor location registers)
- Authentication - ensures the validity of the GPRS mobile station and its associated services. Mobility management functions (GMM protocol stack) are used for this part of the signalling
- Call Admission Control (CAC) - determines the required network resources for the quality of service (QoS) that is requested. If these resources are available, they will be reserved

- **Routing and Data Transfer -** once a mobile station begins data transmission, routing is performed by the GSNs on a hop-by-hop basis through the mobile network using the destination address in the message header. Routing tables are maintained by the GSNs utilising the GTP layer which may carry out address translation and mapping functions to convert the external PDN (public data network) addresses to an address that is usable for routing within PLMNs. The data itself will go through several transformations as it travels through the network. Depending on the destination PDN, the data can be:

  - Forwarded - using the relay function, to go from one node to the other in the route
  - Tunnelled - to transfer data from one PLMN to another
  - Compressed - to use the radio path in an efficient manner (compression algorithms may be used for manufacturers to differentiate themselves, however, they may face interoperability issues in heterogeneous networks)
  - Encrypted - to protect the mobile station from eavesdropping (encryption algorithms can also be used as a differentiating factor).

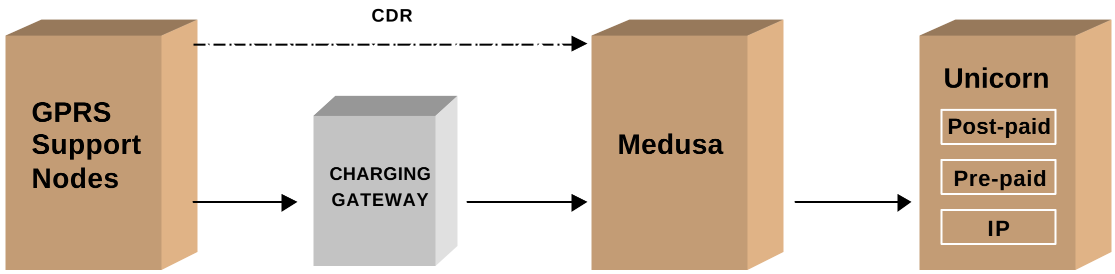
- **Mobility Management** - as a mobile station moves from one area to another, mobility management functions are used to track its location within each PLMN. SGSNs communicate with each other and update the user location. The mobile station's profiles are preserved in the VLRs that are accessible to SGSNs via the local MSC (mobile services switching centre). A logical link is established and maintained between the mobile station and the SGSN at each PLMN. At the end of transmission or when a mobile station moves out of the area of a specific SGSN, the logical link is released and the resources associated with it can be reallocated.

Usha Communications Technology's GPRS Solutions

Usha Communications Technology offers a GPRS-compliant mediation system, Medusa, and Unicorn, a convergent GPRS-compliant billing system that offers post-paid, pre-paid and IP billing. Unicorn is a rules-based system that enables a fast time-to-market for new GPRS services, without the need for customization, and a technology-independent architecture for ease of integration both now and into the future.

Medusa, can collect records from the charging gateway or from the SGSNs and GGSN directly, see Figure 6.

Figure 6 – Medusa GPRS data record collection



The Future for GPRS

GPRS is set to revolutionise mobile telecommunications by further enabling mobile Internet services and opportunities for operators to offer differentiated packages and tariffs. It will improve the current WAP services over GSM by providing greater bandwidth and, therefore, data speeds. However, there are a number of challenges that need to be overcome, as indicated above, but manufacturers, billing system suppliers, ETSI and network operators are continuously tackling and solving these issues.

GPRS will evolve to EDGE and 3G in the next few years that will offer a significant advantage in terms of the enhanced delivery speeds (up to 2 megabit/s) and, therefore, multi-media services that can be offered.

Conclusion

GPRS will promote integrated and seamless advanced services and enable mobile operators to combine wireless networks with public and private/corporate networks. GPRS paves the way for migration to 3G that will enable high speed, universal communication services regardless of the terminal, network, or location.

Usha Communications Technology is committed to GPRS and 3G. For further information please send an email to info@ushacomm.com.

Usha Communications Technology offers a range of solutions that cover the needs of next generation communication providers, both emerging and well established. At the centre of this suite is Unicorn, a highly flexible next generation convergent Customer Care and Billing System. A comprehensive suite of solutions and applications are tightly integrated with Unicorn, ensuring smooth operation, rapid implementation, added value and next generation convergence. This means that we can execute high velocity implementations and offer smoother, more effective business processes. The benefits include lower costs, lower risks and more flexible systems.

Usha Communications Technology products include:

- Billing – Postpaid and Prepaid
- IP Billing
- Customer Care Plus
- Mediation and Provisioning
- Business Performance Monitoring
- Intelligent Network Platforms
- Short Message Service Platforms
- WAP Applications

Glossary

8PSK – 8 phase shift keying (modulation scheme for EDGE)

Air Interface – the radio interface between a mobile communications handset and a base station.

ANSI-I36 – American National Standards Institute, the standards body for North America.

APN - Access Point Name

BSC - Base Station Controller

BSS - Base Station System, comprising the BTS and BSC

BSSGP - Base Station System GPRS Protocol

BTS - Base Transceiver Station

Bearer - the underlying network through which messages are transported between physical devices. A bearer service is a type of telecommunication service that provides the capability for the transmission of information between user-network interfaces. A bearer is an air interface such as short message service (SMS), circuit switched data (CSD) and unstructured supplementary services data (USSD) which may run on the same and different networks such as GSM.

CDMA – Code Division Multiple Access. A multiple access technique used for cdmaOne, cdma2000 and WCDMA air interfaces.

CDR – Call Data Record

CGF – Charging Gateway Functionality

EDR – Event Data Record

ETSI – European Telecommunications Standards Institute

GGSN – Gateway GPRS Support Node, connecting the GPRS network to the IP network

GMM - GPRS Mobility Management

GPRS - General Packet Radio Service. A packet-based wireless communication service that, when available in 2000, promises data rates from 56 up to 114 kbit/s and continuous connection to the Internet for mobile phone and computer users. The higher data rates will allow users to take part in video conferences and interact with multimedia Web sites and similar applications using mobile handheld devices as well as notebook computers. GPRS is based on Global System for Mobile (GSM) communication and will complement existing services such circuit-switched cellular phone connections and the Short Message Service (SMS).

GSM - Global System for Mobile

GTP - GPRS Tunnel Protocol

HLR – Home Location Register

HSCSD – High Speed Circuit Switched Data

IMT-2000 - International Mobile Telecommunications 2000. The ITU (International Telecommunications Union) initiative for a service that will provide radio access to the global telecommunications infrastructure, through both satellite and terrestrial systems, servicing fixed and mobile users in public and private networks.

IP – Internet Protocol

ITU - International Telecommunications Union

LAN – local area network

LLC - Logical Link Control

MSC - Mobile Services Switching Centre

PDC – personal digital cellular. A generic term for a mass-market mobile personal communications service, independent of the technology used to provide it.

PDN – Public Data Network eg the Internet

PDP context – packet data protocol context. This is the name given to a user session on the GPRS network.

PDU – protocol data unit

PLMN – Public Land Mobile Network. A network that is established and operated by an administration or by a recognized operating agency (ROA) for the specific purpose of providing land mobile telecommunications services to the public. Note: A PLMN may be considered as an extension of a fixed network, e.g. the Public Switched Telephone Network (PSTN) or as an integral part of the PSTN. The GSM PLMN supports a wide range of voice and non-voice services in the same network.

PSTN – Public Switched Telephone Network

QoS – quality of service

Radius - Remote access dial-in user server

SGSN – Serving GPRS Support Node, the point of access to the GPRS network, there can be many SGSNs but only one GGSN

SLA – Service level agreement

SNDCP - Sub-Network Dependent Convergence Protocol

TCP - the Internet's Transmission Control Protocol (TCP). TCP/IP is the standard connection-oriented transport protocol for the Internet.

TDMA – time division multiple access. A technique used for current GSM, TDMA (ANSI-I36) and PDC air interfaces.

UMTS – Universal Mobile Telecommunications System. A system for delivering third generation services, being developed under ETSI (European Telecommunications Standards Institute). ETSI's purpose is to define standards that will enable the global market for telecommunications to function as a single market.

VLR – Visitor Location Register

VPN – Virtual Private Network

WAP – Wireless Application Protocol

WCDMA – Wideband Code Division Multiple Access. A multiple access technique used for cdmaOne, cdma2000 and WCDMA air interfaces.