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An Overview of GPRS Technology Concepts

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presented by:

Evelio Sotolongo

This paper presents an overview of GPRS technology concepts. The intention is to provide a basic understanding of GPRS rather than an in-depth training. The concepts will provide adequate background material to better understand the application papers that are typically presented afterwards.

For in-depth training, contact your Agilent Technologies sales representative to learn more about the training classes that are available.

Key Objectives

At the end of this presentation you will better understand:

- GSM/GPRS network architecture differences
- GSM/GPRS RF interface differences
- Key GPRS signaling procedures
- How data is transferred from the Public Internet to the GPRS network

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The key objectives for this presentation are listed here. At the end of this presentation you will hopefully have a better understanding of the network architecture differences between GSM and GPRS. These include new network elements like the GGSN and SGSN.

While the GPRS network uses the same base stations, antennas, and towers as GSM, there are some subtle differences including multiplexing of multiple users per timeslot and new logical channels. These will be briefly covered.

New GPRS signaling procedures like GPRS attaches and PDP context activations will also be described.

Finally, a discussion of the protocols used to transfer data from external networks like the Public Internet to the Wireless Operator’s GPRS network will be illustrated.

Contents

- GPRS highlights
- GSM background
- GPRS network architecture
- GPRS attach and PDP context activation
- GPRS protocols and coding schemes
- GPRS logical channels

The agenda for today's paper is provided here. A brief overview of the highlights of GPRS will first be presented. Since GPRS uses the existing GSM network, a short review of GSM concepts will be given. Then, the network architecture for GPRS will be described. To obtain GPRS service, a GPRS attach and PDP context activation are required. These concepts will be addressed. The GPRS protocol stacks, coding schemes, and logical channels will then be presented.

Let's start with some of the key GPRS highlights.

General Packet Radio Service - Highlights

- Works on existing GSM Network
- Packet Switched Data
- Multiplexing of many users
- Interworks with TCP/IP, X.25 networks

- Requires GPRS capable Phones
- New Transmission and Signaling Procedures
- High Data Rates - 171.2 kbps (max-theoretical)
  40-56 kbps (practical)
- Applications: e-mail, Internet, ftp, etc.

- Billing based on throughput (data transfer)

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GPRS stands for General Packet Radio Service. We will discuss the key highlights and differences which GPRS brings to the existing GSM network.

First, GPRS uses existing data communication technologies and networks to achieve datacomm applications like Intranet access, e-mail, etc. GPRS users require new mobile phones that operate either for GSM voice calls or GPRS data calls. GPRS adds hardware and software upgrades to the existing GSM networks. This provides GSM users with always-on packet data communication.

GPRS uses packet switched data. This means no dedicated circuit needs to be assigned to a mobile. A physical channel is only assigned when data transfer is required. As a result of this one resource (timeslot on air interface) can be shared by multiple users. This multiplexing of several users shares the limited resources.

When packet switched data leaves the GSM network it is received by existing outside world TCP-IP networks like Internet, Intranet, X.25 etc. Hence GPRS provides Interworking protocols for working with standard external packet data networks.

GPRS phones are required to handle both GSM and Packet switched communication. Hence, the existing phones cannot be used (not even with external laptop communication). In the future GPRS phones might be built inside the laptops, etc.

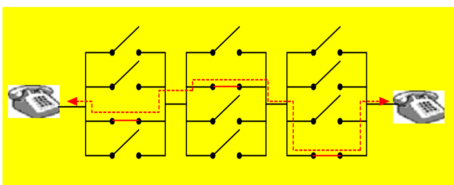
GPRS has new transmission techniques and Interworking with the IP world. This allows new transmission and signaling procedures to be introduced in the existing GSM networks

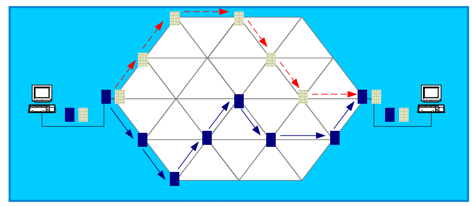
GPRS supports high data rates. This is done by changing the air interface error coding schemes and by using multiple timeslots, similar to HSCSD (High Speed Circuit Switched Data). We can get a maximum 171.2 kbps data rate theoretically by using 8 timeslots. In practice this is probably not feasible due to design challenges of the mobile phone and the quality of the air interface due to spectrum limitations. Use of packet switched communication allows non-continuous assignment of resources to a user. Hence billing does not occur on time basis. Most of the tariffs for GPRS usage will be based on usage.

GPRS Provides ‘always on’ Packet Switched Data

- 2G technologies are circuit switched
- Dial-up type connections
- A single user occupies a channel for the entire transmission
- Requires time-oriented billing
- Data transmissions are bursty

- GPRS is packet switched technology
- More appropriate for data services
- Continuous flow is not required
- Access is based on demand only
- Several users can be multiplexed
- Billing based on negotiated QoS and usage





GPRS is a packet-based technology which is optimized for data services. While GSM also provides data services, it is circuit-switched and data speeds are much slower.

Circuit-switched data only allows one user to occupy a channel at one time. Since data is very bursty, this method is not as efficient from a capacity point of view. The user also must pay for the entire connection time regardless of what percentage of that time was spent actually transferring data.

Packet-switched technologies like GPRS are more appropriate for data. Once the mobile is attached to the network, it is ‘always on’. Billing is based on the amount of data transferred, rather than the overall connect time. Several users can be multiplexed, enabling higher capacity for wireless operators.

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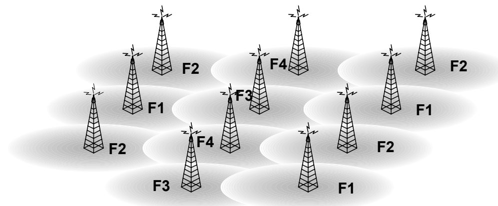
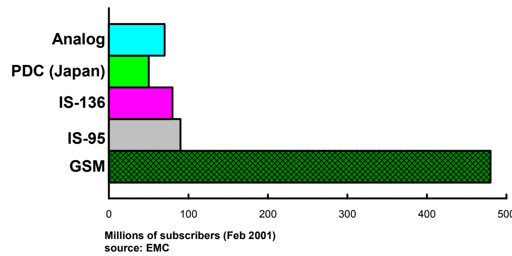
Prior to introducing the GPRS network architecture, let's first review some of the basic GSM concepts on which the GPRS network is based.

GSM Background

- Second Generation Technology
- International wireless standard developed by ETSI
- Frequency reuse implementation
- Over 480 million subscribers
- GSM900, DCS1800, PCS1900, GSM850, R-GSM



N=4 Frequency Reuse Concept



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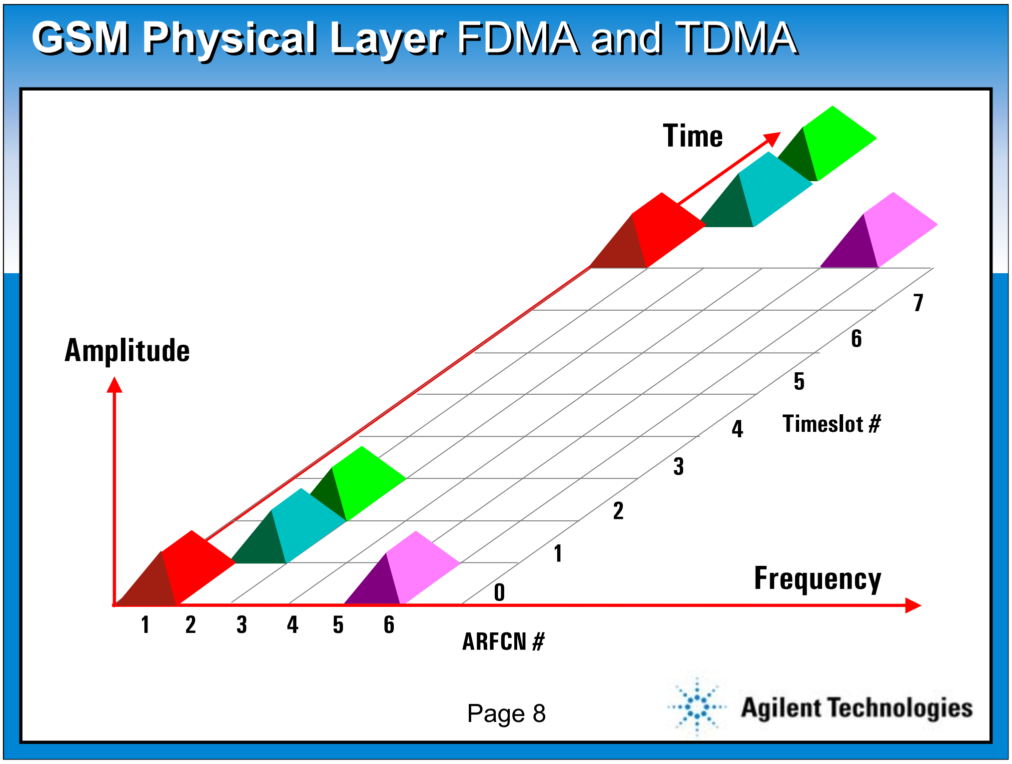
GSM is the most popular air interface standard in the world with over 480 million subscribers.

GPRS uses the same radio network as GSM. The air interface is identical. Therefore, the same same concepts apply. For example, individual frequency channels (ARFCNs, or Absolute Radio Frequency Channel Numbers) and eight timeslots are used to carry voice and data traffic. Since frequency spectrum is limited, channels must be reused to cover the footprint of the network. However, care must be taken to avoid co-channel and adjacent channel interference. Frequency reuse planning is done during the early system designs to minimize this interference. Later, drive testing is used to troubleshoot and optimize the network for interference that might occur.

Several bands are used for GSM and GPRS including GSM900, DCS1800, PCS1900, GSM 850, and Railway-GSM.



GSM uses TDMA (Time Division Multiple Access) and FDMA (Frequency Division Multiple Access). The slide shows part of one of these bands. Each band is divided into 200 kHz slots called ARFCN's (Absolute Radio Frequency Channel Numbers).

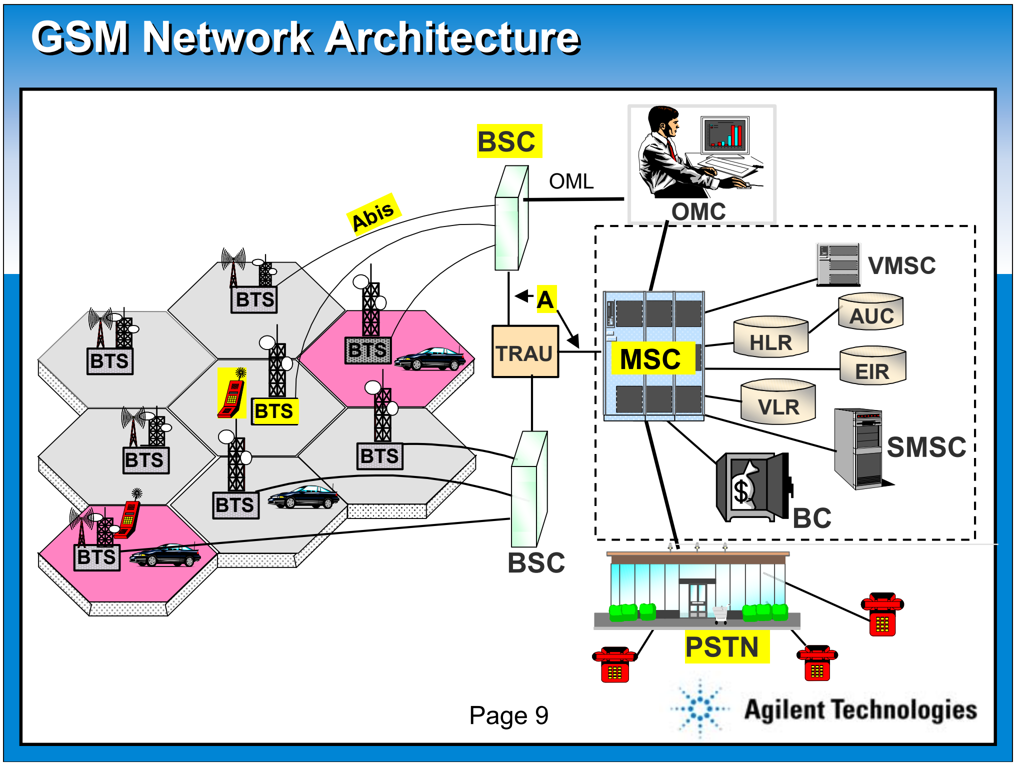
Each ARFCN is also divided in time into 8 Timeslots (TS), each TS being used in turn by a different MS. The 8 TS's together are known as a Frame.

The slide illustrates 4 TCH's (Traffic Channels). Each one of the TCH's uses a particular ARFCN and Timeslot. Two of the TCH's are on the same ARFCN, using different timeslots, the other two are on different ARFCN's.

The combination of a TS number and ARFCN is called a physical channel.

Frequency-division duplex spacing is used between downlink (higher frequency) and uplink pairs; 45MHz spacing for GSM900 and 95MHz for 1800 and 1900MHz bands.

An acceptable standard of voice communication requires a minimum Signal-to-Noise Ratio of 11dB (reducing to 9dB when frequency Hopping is enabled). This minimum requirement increases to 14dB for data transactions with GPRS.



Here is a diagram of a GSM network. The mobile transmits and receives over the air interface. Each base station serves a cell, and handovers occur as the mobile moves from cell to cell. The BTS is connected to the BSC over an Abis link. The BSC connects to the MSC over the A interface. The circuit-switched voice or data calls are then connected to the PSTN.

As we'll see next, the GPRS network adds new network elements to the existing GSM network to provide packet-based data services.

Here are some definitions of the acronyms shown in the diagram:

BTS : Base Transceiver Station

BSC : Base Station Controller

MS : Mobile Station

TRAU : Transcoder Rate Adaptation Unit

MSC : Mobile Switching Center

HLR : Home Location Register

VLR : Visiting Location Register

AUC : Authentication Centre

EIR : Equipment Identity Register

SMSC : Short Message Service Center

VMSC : Voice Mail Service Center

BC : Billing Center

OMC : Operations and Maintenance Center

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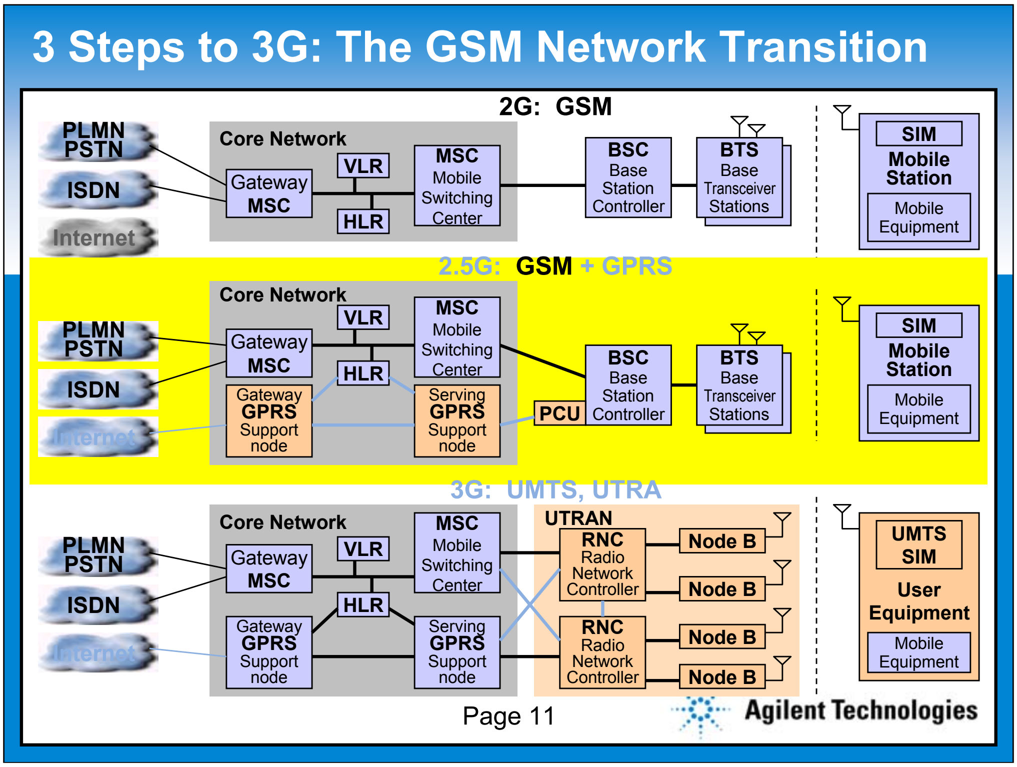
Now let's see what changes must be made to the GSM network to provide higher speed packet-based GPRS data services. The GPRS network architecture will be presented next.



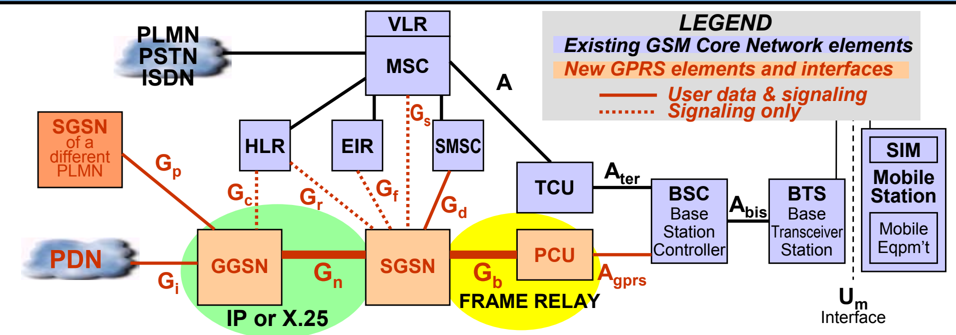
The migration from GSM to GPRS and then to UMTS are shown here.

To transition from GSM to GPRS requires the addition of new hardware and software. New hardware elements include the GGSN, SGSN, and PCU. The GGSN is the Gateway GPRS Support Node. The SGSN is the Serving GPRS Support Node. The PCU is the Packet Control Unit.

Notice that the voice calls still go through the GSM circuit-switched network using the MSC. Data calls are routed through the new PCU, SGSN, and GGSN on their way to the Internet.

We will only include the UMTS diagram for completeness. It is covered in more detail in another paper. Just note that a new set of network elements is added to provide higher speed data services. The UMTS Radio Access Network includes new Node B’s (base stations) and Radio Network Controllers.

New GPRS Network Elements and Interfaces



- Gb between SGSN-PCU uses Frame Relay protocols
- Gn between SGSN-GGSN uses IP routing, GPRS Tunnel Protocol
- Gr between SGSN-HLR is an extension of MAP
- Gi between GGSN and PDNs uses IP and X.25
- Gd between SGSN-SMSC delivers SMS messages using MAP
- Gc between GGSN-HLR is optional, uses MAP
- Gs between SGSN-MSC/VLR is optional, uses BSSMAP

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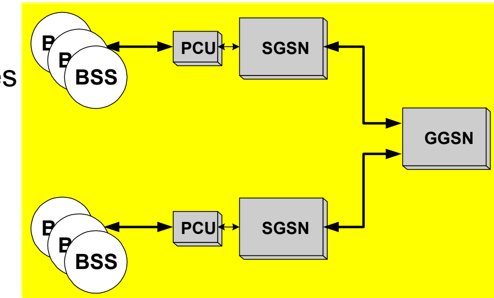
Here's a more detailed look at the GPRS network architecture, including the new network elements and network interfaces.

The new GPRS network elements are the GGSN (Gateway GPRS Support Node), the SGSN (Serving GPRS Support Node), and PCU (Packet Control Unit). Each of these will be described in more detail in the next several slides.

Some of the new interfaces include the Gb (PCU to SGSN), the Gn (SGSN to GGSN), and Gi (GGSN to Public Data Internet).

GPRS Network Architecture - SGSN

- Serving GPRS Support Node
- Delivers data packets to mobiles
- Each SGSN is assigned to a specific service area
- Allows for very little change in the BTS and BSC



- All mobile stations communicate to the SGSN in the area
- Provides authentication and ciphering
- Handles mobility management
- Introduction of the routing area - RA
- Also responsible for billing over the air interface

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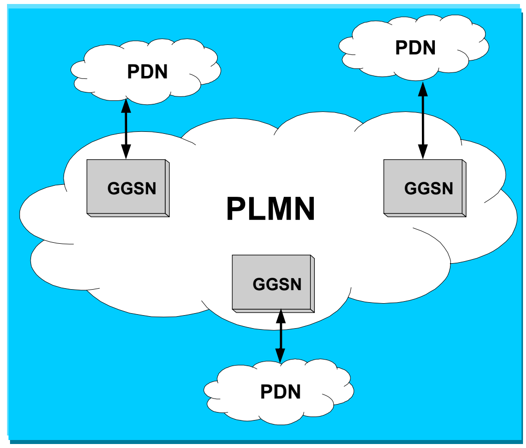
The SGSN is similar to the MSC/VLR (in GSM) because it controls all aspects of the connection between the network and mobile by providing Session Management (SM) and GPRS Mobility Management (GMM) functions such as handovers, paging, attach/detach etc. It manages packet communication sessions between individual mobile stations and the GGSN. The SGSN also interacts with the GSM databases to achieve mobility management functions and get subscription information to offer desired services to the mobile station. It is also involved in the counting of data packets for billing. It is responsible for packet delivery to mobiles in its area.

Data is "tunneled" from the GGSN to the SGSN using GTP, GPRS Tunneling Protocol, encapsulating packets de-encapsulating on delivery. A typical PLMN network will start with only one SGSN. Each BSC has a Packet Control Unit (PCU).

GPRS Network Architecture - GGSN

- Gateway GPRS Support Node
- Allows the GPRS network to communicate with external PDNs
- Routes all packet data units through the corresponding SGSN
- Whereas the SGSNs can change during cell reselections, the GGSN remains the same during an ongoing packet transaction
- Responsible for billing related to connections with external PDNs

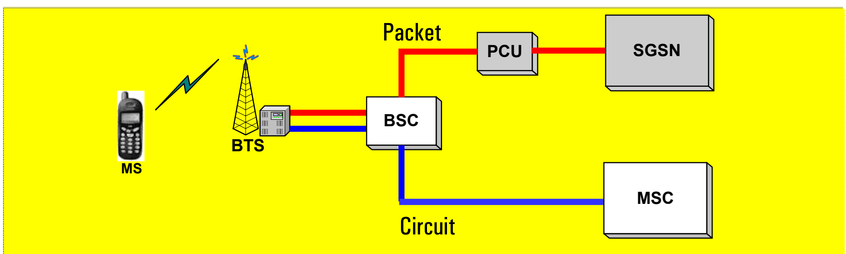


The GGSN is similar to a GMSC (in GSM) since it provides a gateway between the GPRS network and the public PDN (Packet Data Network) or other GPRS networks. It provides authentication and location management functions as well as firewall functions on the Gi interface to the PDN. (A border gateway function helps with this process.) It also connects to the HLR (Home Location Register) by means of the new Gc interface. In addition, it counts the number of packets it transmits to give accurate billing.

The main job of the GGSN is to route incoming PDU's to appropriate SGSN's. It is responsible for routing data packets entering and leaving the radio network, and it also serves as a router for packets within the network The GGSN converts GPRS packets from the SGSN into packet data protocol format (IP, X.25) for the external networks. It converts PDP addresses of incoming data packets to GSM address of destination user, and forwards to responsible SGSN. The GGSN stores the current SGSN address of the user and the user's profile in its location register.

GPRS Network Architecture - PCU

- **Packet Control Unit**
  - Manages and controls radio-related operations
  - Compresses and decompresses frames
  - PCU allows very few modifications to the BSS



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The PCU takes care of the radio resource functionality's like allocation of air interface channel blocks. It will also do packet segmentation due to limitation of bandwidth on the air interface. The PCU will also do some Quality of Service measurements to alter communication parameters on a real time basis.

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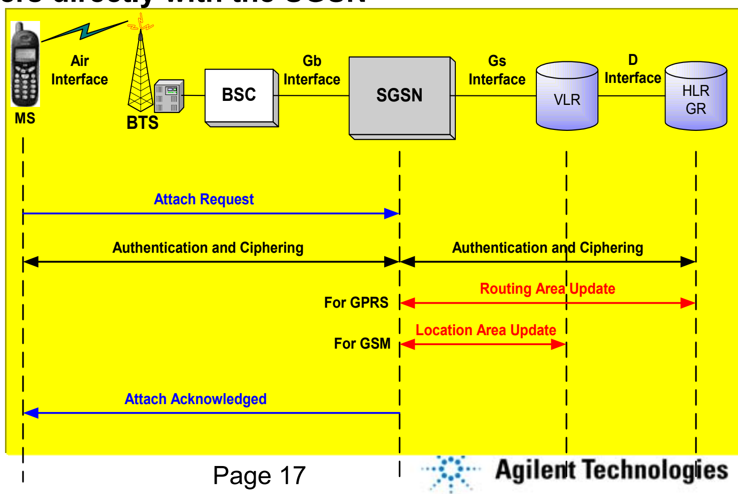
Now that we've introduced the GPRS architecture and some of the terminology, let's see how a data call gets set up. The GPRS attach and PDP context activation are required for this to happen.

GPRS Attach Process (Mobility Management)

- Process of registration of the mobile into the GPRS network
- Occurs when mobile is first powered on and can occur afterwards based on network settings
- Mobile registers directly with the SGSN

Information Exchanged:

- IMSI or P-TMSI
- TLLI
- RA, LA
- Power class mark
- Type of registration (GSM, GPRS)
- Authentication
- Ciphering



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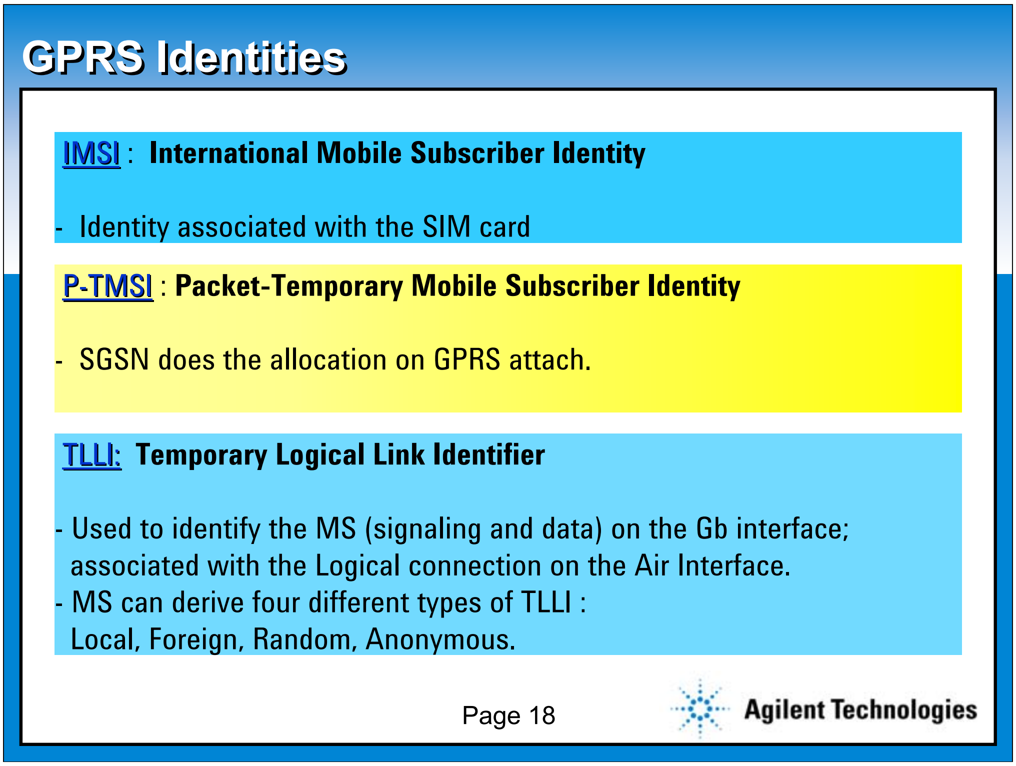
A GPRS Attach is a GMM (GPRS Mobility Management) process. It is always initiated by the mobile. The GPRS default mode does an attach on Power On, and it can also be forced. A GPRS Attach is made to the SGSN.

A GPRS attach is a transparent process to the BSS and is done with the SGSN. In a GPRS Attach the Mobile informs the SGSN about it's identity IMSI or P-TMSI (packet TMSI). It also informs its Old Routing Area Identification, Classmark, CKSN etc with Attach type which indicates the SGSN whether this Mobile wants to do a GPRS, GSM or both Attaches. The SGSN will attach the mobile and inform the HLR if there was a change in the RAI. If the Attach type is both then the SGSN will also do a Location Update with the VLR, provided the Gs interface exists.

Note: A GPRS attach does not mean that the mobile can transmit and receive data. To transmit and receive data, a Mobile has to active a PDP context.

In summary, before a mobile station can use GPRS services, it must register with an SGSN within the GPRS network. The network checks to see if the user is authorized. It copies the user profile from the HLR to the SGSN, and assigns a packet temporary mobile subscriber identity (P-TMSI) to the user. This procedure is called GPRS attach. For mobile stations with both circuit-switched and packet-switched services it is possible to perform combined GPRS/IMSI attach procedures.

Disconnection from the GPRS network is called GPRS detach, and it



Some of the terms used in the previous slide are described in more detail here.

IMSI **(International Mobile Subscriber Identity) for GPRS is the same as GSM. It is associated with the SIM and hence remains common for GSM and GPRS services. Even a GPRS-only subscription SIM will have an IMSI.**

P-TMSI, or Packet TMSI **(Packet-Temporary Mobile Subscriber Identity)**

TMSI in GSM is used for identity confidentiality of the IMSI. The TMSI was allocated to the GSM mobile by the VLR on a GSM Attach /Location Update. A Packet-TMSI is similar to the TMSI but is assigned by the SGSN. The SGSN does this assignment when the mobile performs a GPRS attach. The P-TMSI is also used by the mobile to derive another identity which is the TLLI.

TLLI **(Temporary Logical Link Identifier)**

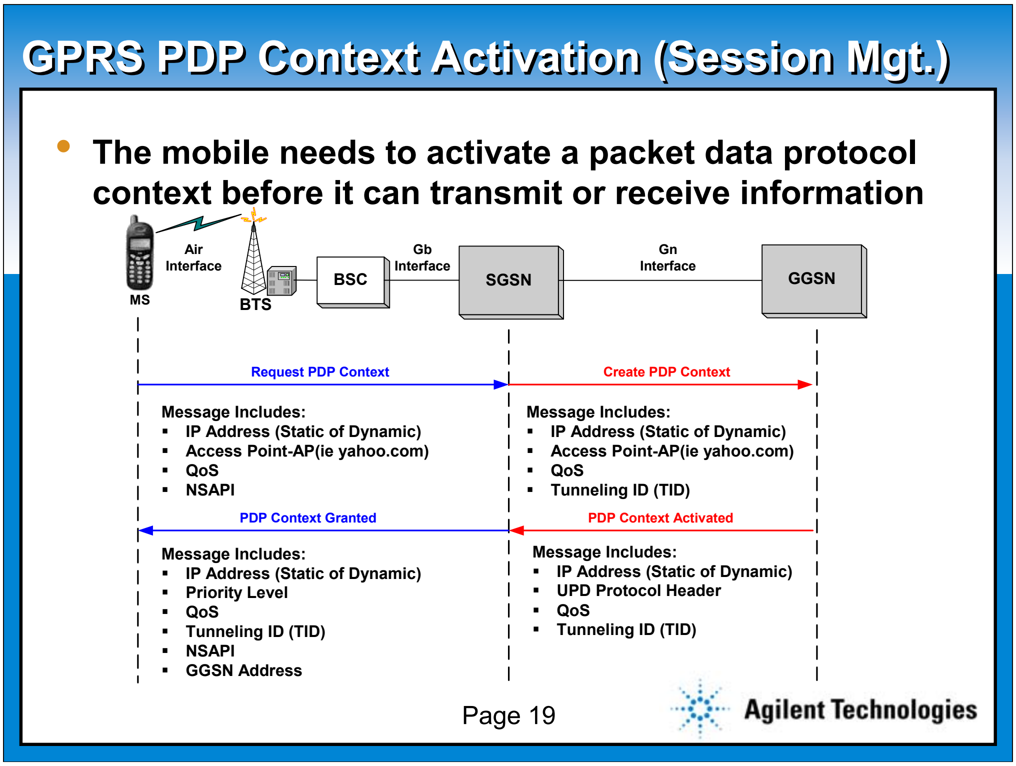
The TLLI is an identity used to identify the mobile during a PDP session on the Um and Gb interface. NSAPI is used at the SNDCP layer whereas TLLI is used at the RLC/MAC layer on the Um interface and in the BSSGP layer on the Gb interface. TLLI can be derived from one of the four sources.

Local TLLI: It is derived using the P-TMSI form the SGSN which is only valid in the routing area associated with the P-TMSI.

Foreign TLLI: It is derived from a P-TMSI allocated in a different routing area.

Random TLLI: It is selected randomly by the MS, and is used when the MS does not have a valid P-TMSI available or when the MS originated an anonymous access.

Auxiliary TLLI: It is selected by the SGSN and is used by the SGSN and MS to unambiguously identify an Anonymous Access MM and PDP context.



A PDP context activates a packet communication session with the SGSN. It provides information for mapping and routing information between the mobile and the GGSN. The mobile in PDP context activation procedure either specifies a static IP address or requests for an IP address. It also specifies the Access Point with which it wants to communicate like some intranet network (e.g., agilent.com) or some Internet Service Provider. It also requests for the desired Quality of Service and a Network Service Access Point Identifier (NSAPI). A mobile can establish multiple PDP context sessions for different applications (get connected to mail server and to a different ISP). In order to discriminate data packets between different applications, NSAPI is required. When the SGSN obtains the mobile information, it decides on the GGSN connected to the APN and forwards the request to the GGSN. The GGSN then connects the mobile to the desired Access Point if a static address existed; if not, then it gets an IP address form the APN. The GGSN also provides some transaction identifiers for communication of data to reference this mobile between the GGSN and SGSN. The SGSN in its request also provides a negotiated QOS based on subscription information of the user and availability of services. Once the communication and activation at GGSN is successful the appropriate information is forwarded to the mobile.

In summary, the mobile requests a PDP context from the SGSN. Security functions (authentication) will be performed. The SGSN will ask for a PDP context from the GGSN. The GGSN will create a new entry in its PDP context table. The GGSN sends confirmation to the SGSN including address, if dynamic. The SGSN updates its PDP context

GPRS Mobile Station Classes

Class Type	GSM and GPRS Simultaneously	GSM or GPRS Sequentially	GSM Only GPRS Only
Class A	Yes	Yes	Yes
Class B	No	Yes	Yes
Class C	No	No	Yes

- Class A supports simultaneous circuit and packet switched
- Class B supports packet and circuit switched sequentially
  - Currently only Class B mobiles being developed
- Class C does not support parallel operation
  - Operates in either packet or circuit mode only
  - Low cost unit available for mass market deployment

There are three different Mobile classes defined by ETSI:

Class A (GSM/GPRS): This class of mobile can simultaneously attach to the GPRS and GSM network. This means the mobile can receive a GSM voice/data/SMS call as well as a GPRS data call request. For this to happen, it is essential for the mobile to monitor both networks for an incoming call. This class of mobile can make and receive a GPRS call as well GSM calls simultaneously. This class operational requirements also enforces a design of an additional receiver in the phone for neighbor cell measurements.

Class B (GSM/GPRS): This class is similar to class A with an exception that this class of mobile phones will not be able to support simultaneous traffic. If a GPRS call is ON, the phone cannot receive GSM calls and vice versa.

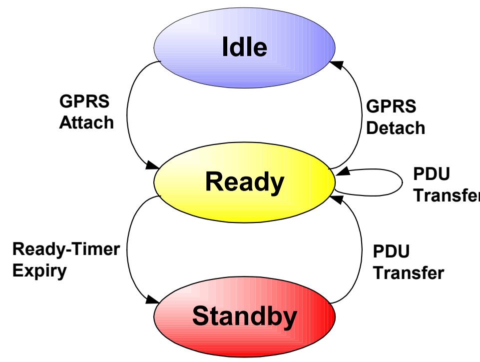
Class C (GSM or GPRS): This class of mobile phones will have both GSM and GPRS functionality but will use only one at a time. Class C phones can attach on only one network at a time. So if the phone is GPRS attached, it is GSM detached and hence will not receive GSM calls. Similarly if the Phone is GSM attached, in order to make to GPRS connection and call, it has to first detach from the GSM network.

Most of the manufacturers are focusing on Class B phones.

In summary, in a GSM/GPRS network, two classes of service can run concurrently: Circuit-Switched Services (speech, data, and SMS) and Packet-Switched Services (GPRS). Three Classes of Mobile Stations are defined: Class A mobiles support simultaneous operation of GPRS and conventional GSM services, but two separate radio chains are required. Class B mobiles are able to register with the network for both GPRS and conventional GSM services simultaneously, but can only use one of the two services at a given moment - voice can preempt data. Class C mobiles are able to attach for either conventional GSM or GPRS, but are manually switched. Simultaneous registration (and usage) is not possible, except for SMS messages

GPRS Mobility Management States

- Mobility management states apply for both the mobile and the SGSN
- Idle: Mobile is powered on but not attached to GPRS
- Standby: Mobile is powered on and attached to GPRS. No packet transfer is in progress. Routing area updates are sent as needed.
- Ready: The mobile is currently engaged in packet transfer or recently terminated a packet transfer. The Ready state is determined by a timer. No need to page a mobile in Ready state



GPRS Mobility Management States for MS

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A mobile can be in any of three states depending on its current traffic level. Location update frequency is dependent on the MS state.

In IDLE state, the mobile is not reachable.

Upon performing a GPRS attach, the mobile enters the READY state.

With a GPRS detach the mobile may disconnect from the network and fall back into the IDLE state. All PDP contexts will be deleted.

The STANDBY state is reached when a mobile does not send any packets for a long period of time. This causes the READY timer to expire.

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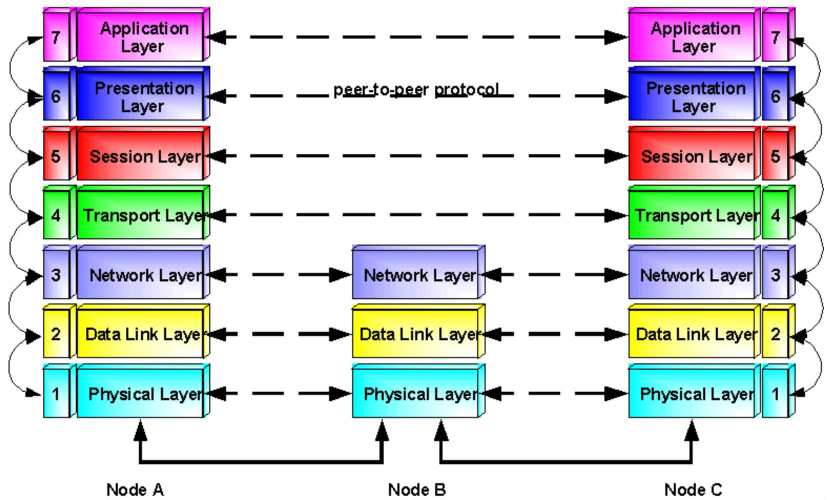
To understand how data is transported in a GPRS network, it is necessary to review the GPRS protocol stacks and coding schemes.

GPRS Protocol Stack - ISO/OSI Model

- Allows for compatibility between different equipment manufacturers



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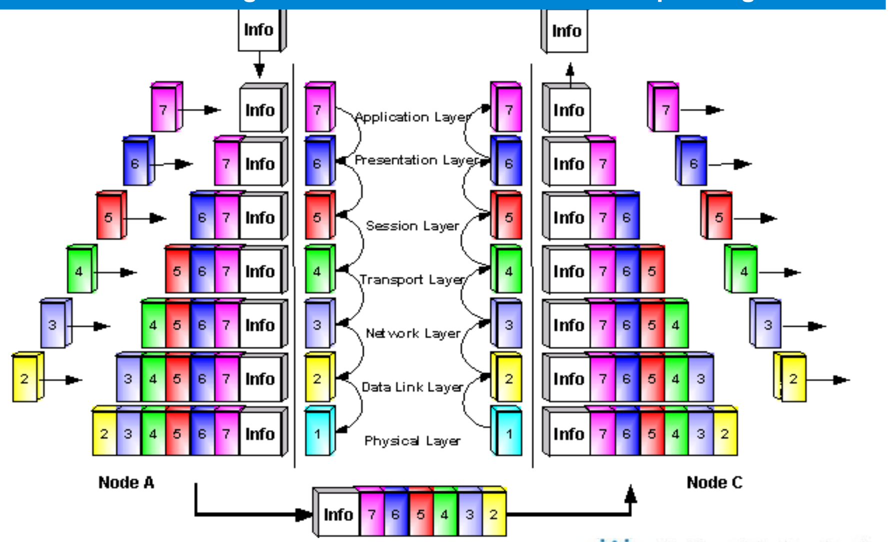
The International Telecommunications Union (ITU) and International Standardization Organization (ISO) developed the 7 level Open Systems Interconnect (OSI) model.

The lowest layer is the physical layer. The highest layer is the Application layer.

The generic diagram shows three different nodes and their respective protocol stack layers. For a GPRS network, Node A would represent the mobile, node B the SGSN, and Node C the GGSN, for example.

GPRS Protocol Stack - ISO/OSI Model

- Each layer adds its own header to the message
- Each layer at destination removes corresponding header



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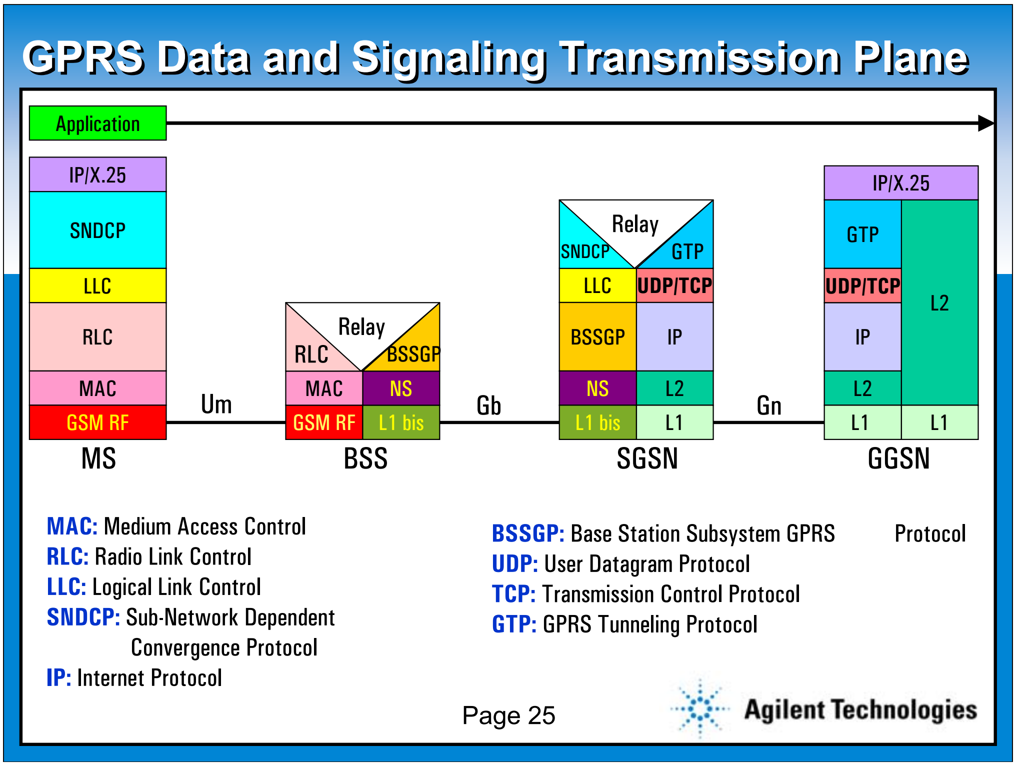
To understand how the protocol stacks provide transmission of data from one layer to the next, refer to the diagram. Let's start with some information ('info') at the top of the Node A stack. To transport that information (text, photo, etc.) over the air interface, the system must add a new header at each successive layer as it travels from top to bottom. For example, at the Application layer, it adds header message #7. By the time it reaches the physical layer, it has added headers 2 through 7.

Then the data is sent over the physical layer interface to the destination (Node C). In GSM or GPRS, layer 1 corresponds to the air interface. The GPRS layers fall between OSI layers 2 and 3.

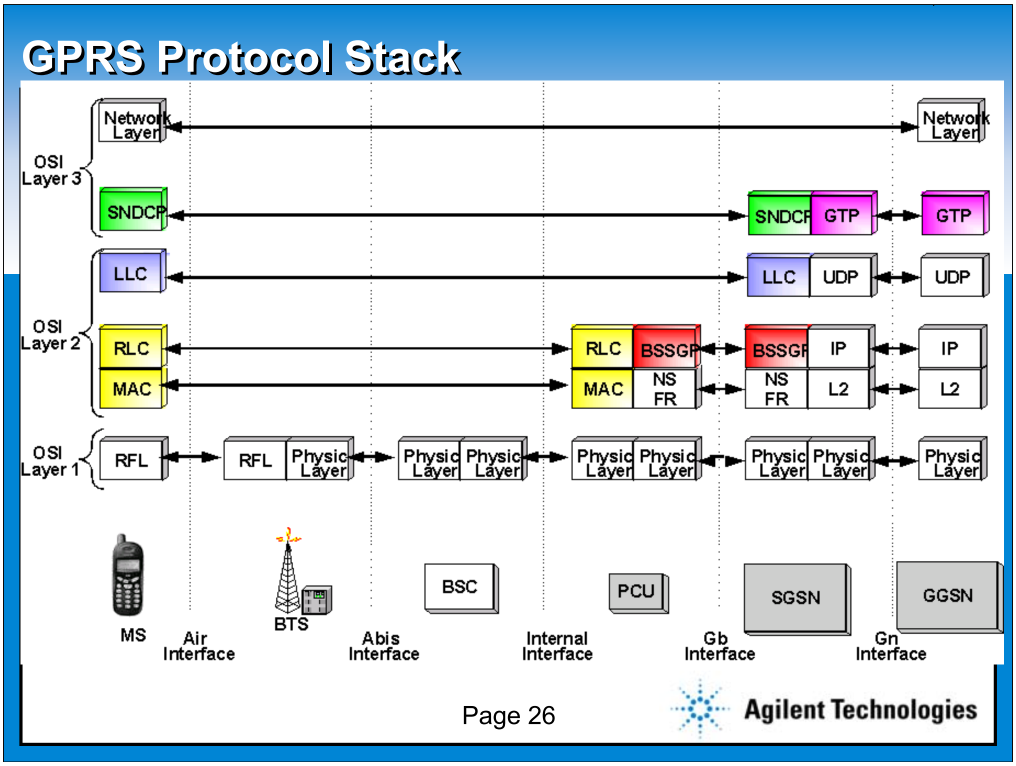
At the destination (Node C), the same layer removes its corresponding header. So layer 2 removes header #2, etc. By the time the data travels up the stack, the headers are completely removed leaving just the original information.



Now, let's specifically look at the GPRS protocol stacks for the mobile, BSS (PCU), SGSN, and GGSN. The physical layer (layer 1) provides the connectivity between the network elements.

A brief definition of the protocol stack layers is provided here for your reference. Any more detail beyond these simple definitions is outside the scope of this paper.

GTP (GPRS Tunneling Protocol) deals with IP datagrams coming from the external network and tunnels it across the GPRS service nodes (GGSN/SGSN). TCP (Transmission Control Protocol) is used to transfer packet data units (PDUs) across the Gn interface. User Datagram Protocol (UDP) carries PDUs across the Gn interface when reliability is not required. IP (Internet Protocol) is used to route user data and signaling information across the Gn interface. SNDCP (Sub Network Dependent Convergence Protocol) is used between the SGSN and MS and converts network layer PDUs into a suitable format for the underlying network architecture. LLC (Logical Link Control) is used to provide a highly reliable ciphered logical link between SGSN and MS. NS (Network Service) uses Frame Relay across the Gb interface and could be a point-to-point connection between the SGSN and the BSS or a Frame Relay Network. RLC (Radio Link Control) is responsible for transferring LLC-PDUs between the LLC layer and the MAC function, segmentation of LLC-PDUs into RLC data blocks and re-assembly of RLC data blocks. MAC (Medium Access Control) controls the access signaling across the air interface.



Let's see how the data is transported within the GPRS network. For simplicity, only OSI layers 1, 2, and 3 are shown.

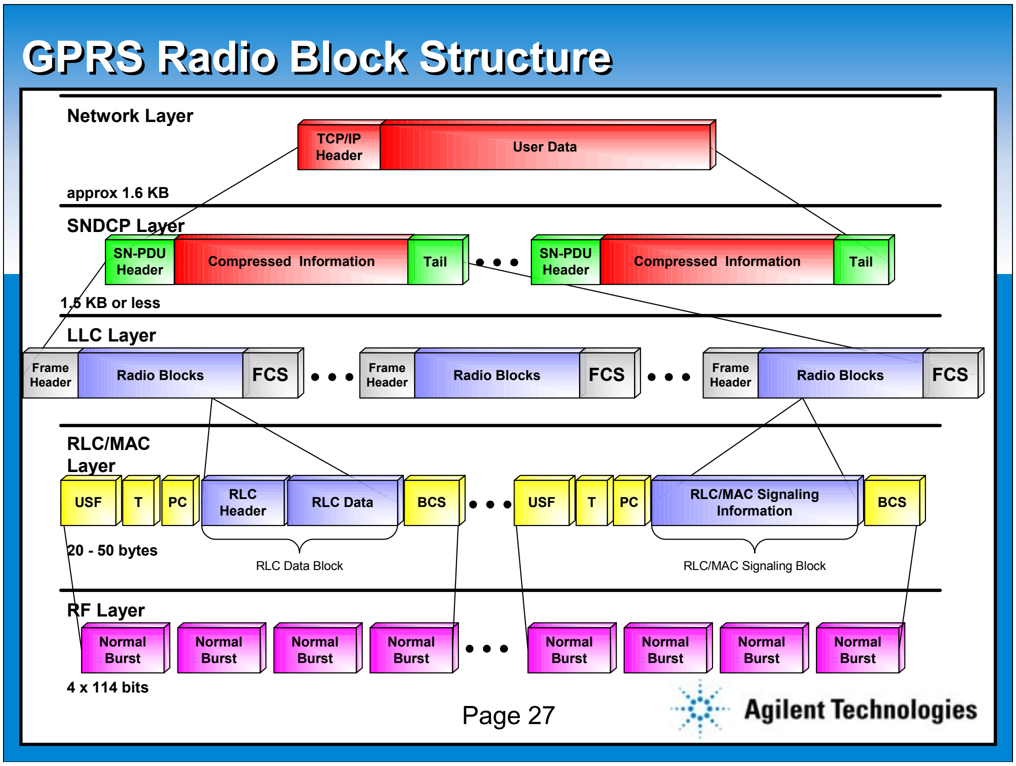
The arrows show the corresponding layers between the mobile (MS) and the PCU, SGSN, and GGSN. Recall that the information must travel down the stack of each device and add the appropriate headers prior to being sent over the physical layer to the next device.

The RLC/MAC layers in the mobile and the PCU are responsible for the segmentation of data blocks prior to transmission over the air interface. RLC is the Radio Link Protocol and MAC is the Medium Access Control.

The LLC layers in the mobile and SGSN are used to divide up the data into frames prior to being segmented into RLC blocks in the layer beneath.

The SNDCP (Sub-Network Dependent Convergence Protocol) layers in the mobile and SGSN are responsible for converting network layer PDUs (packet data units) into a suitable format for the underlying network architecture.

Note the interfaces between each network element. The Gb and Gn interfaces are new in the GPRS network.



A closer look at the protocol stacks reveals how the data transport occurs. The accompanying diagram illustrates how the headers are attached to the user data as it is transported down each successive layer. This diagram provides an overview of the process. Subsequent slides will provide details on each layer.

A temporary block flow (TBF) is first established. (Refer to the text in the following slide.) A TBF is a physical connection used by the two radio resource (RR) entities to support the unidirectional transfer of Logical Link Control (LLC) PDUs on packet data physical channels. The TBF is allocated some radio resources on one or more PDCHs and comprises a number of RLC/MAC blocks carrying one or more LLC PDUs. A radio block consists of a 1 byte MAC header, followed by RLC data or an RLC/MAC control block and terminated by a 16-bit block check sequence (BCS). It is carried by four normal bursts (i.e., 114 bits long).

A TBF is temporary and is maintained only for the duration of the data transfer. Each TBF is assigned a temporary flow identity (TFI) by the network. The TFI is unique in both directions. GPRS allows a maximum of eight slots per frame to be allocated to the PDTCH on the downlink and uplink on all radio blocks B0-B11.

On the downlink, an IP datagram of 1500 bytes to be transmitted as an LLC PDU must first be fragmented into 29 RLC blocks. These blocks can be transmitted using a total of 116 consecutive bursts. During one 52-multiframe with an 8 slots/frame dynamic allocation scheme, 3.3 such IP datagrams can be transmitted, yielding a maximum rate of 165.5 kb/s for the GPRS downlink

On the uplink, an IP datagram of 1500 bytes to be transmitted as an LLC PDU, is fragmented into 31 RLC blocks which can be transmitted in 124 slots. During one 52-multiframe with an 8 slots/frame dynamic allocation

Packet Data Transmissions

- A packet transmission is referred to as a temporary block flow (TBF)
- Each TBF is assigned a temporary flow identity (TFI)
- The TFI is located inside the LLC header information
- The TFI allows for multiplexing several users over the same timeslot
- The TFI also allows assignment of priority classes

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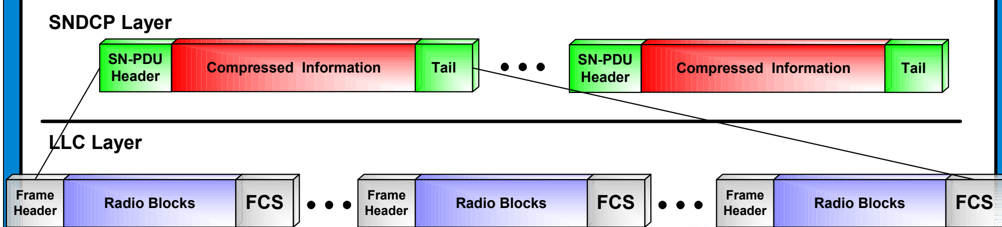
As discussed in the previous slide, a TBF is a physical connection used by the two radio resource (RR) entities to support the unidirectional transfer of Logical Link Control (LLC). A TBF is temporary and is maintained only for the duration of the data transfer. Each TBF is assigned a temporary flow identity (TFI) by the network. The TFI is unique in both directions. It allows for multiplexing several users over the same timeslot, and it can provide the assignment of priority classes.

GPRS Protocol Stack - LLC

- **Logical Link Control**
  - Provides a logical reliable link between MS and SGSN
  - Designed as independent as possible from the radio interface layers
  - Encapsulation of SNDCP packet data units
  - Ciphering procedures between MS and SGSN
  - Detection and recovery of lost LLC packet data units
  - Responsible for acknowledged/unacknowledged operation



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The LLC (Logical Link Control) layer provides the reliable link between MS and SGSN. LLC supports these layer-3 Protocols:

SNDCP Sub-Network Dependent Convergence Protocol

GMM/SM GPRS Mobility & Session Management

SMS Short Message Service

Protocols supported by the LLC provide:

Data ciphering for security

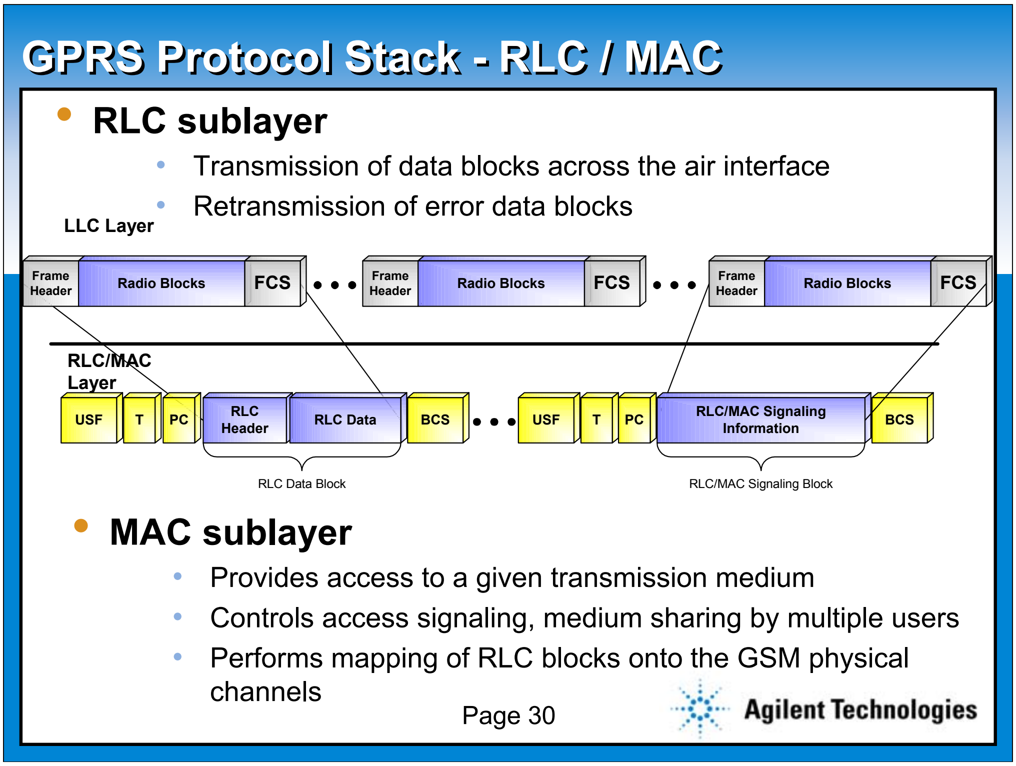
Flow control; sequential order of delivery; error detection/recovery

Acknowledged and Unacknowledged data transfer modes

The LLC provides transparency - the lower level radio link protocols are not involved and do not affect the GPRS applications running above.

Both acknowledged and unacknowledged modes are supported. The protocol is mainly an adapted version of LAPDm of GSM. The FCS bits in the diagram refer to the frame check sequence.

In summary, the LLC layer is used to provide a highly reliable ciphered logical link between SGSN and MS. It uses both Acknowledged and Unacknowledged mode of frame transmission depending of negotiated QOS for the end user. It manages the frame retransmission, buffering , information length based on User SAPIs (service access point identifiers) which is based on negotiated QOS delay class.



The RLC (Radio Link Control)/MAC (Medium Access Control) layer includes two functions. First, the RLC layer is a reliable link between the MS and BSS. It includes segmentation and reassembly of LLC frames into RLC data blocks.

The MAC layer controls the access attempts of the MS on the radio channel shared by several mobiles. It includes algorithms for contention resolution, multiuser multiplexing on a PDTCH, scheduling and prioritization based on the negotiated QoS. Both acknowledged and unacknowledged modes are supported.

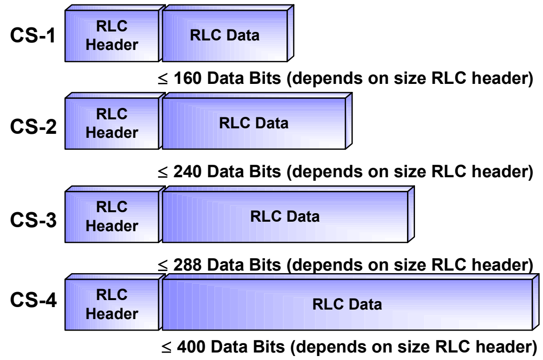
The RLC function is responsible for transferring LLC-PDUs between the LLC layer and the MAC function and segmentation of LLC-PDUs into RLC data blocks and re-assembly of RLC data blocks (to fit into TDMA Frame blocks). Segmentation is a process of taking one or more LLC-PDUs and chopping them into smaller RLC blocks. The LLC-PDUs are collectively known as a Temporary Block Flow (TBF) which is allocated resources one one or more Packet Data Channels (PDCH). The TBF is temporary and as thus is only maintained for the duration of the data transfer. Each TBF is assigned a Temporary Flow Identity (TFI) by the network and which is unique among concurrent TBF's. The same TFI value may be used concurrently for TBFs in opposite directions. The RLC data blocks consist of an RLC header, an RLC data unit and spare bits. The RLC data block along with a MAC header may be encoded using one of the four defined coding schemes. The coding scheme is critical in deciding the segmentation process.

The MAC layer controls the access signaling across the air interface. Access signaling includes management of the shared transmission resources (assignment of radio block to multiple users on the same timeslot). MAC achieves these functionality's by placing a header in front of the RLC header in both the RLC/MAC data and control blocks. The MAC header contains several elements, and certain elements are direction specific (downlink/uplink).

The BCS (Block Check Sequence) was defined earlier. The USF (Uplink Status Flag) is transmitted in the RLC/MAC header of the downlink RLC block. It informs the mobiles which uplink resources are to be used. With this concept, multiple users are allowed to be multiplexed on the same timeslot, and they only transmit when the USF flag indicates their turn. The MS's monitor the USFs on the allocated PDCHs and transmits radio blocks on those that currently bear the USF value reserved for the usage of the MS.

GPRS Coding Schemes

- GPRS defines four coding schemes
- Only CS-1 is mandatory for the BTS
- All coding schemes are mandatory for the MS
- The higher the coding scheme, the higher the throughput
- The higher the throughput, the lower protection against errors
- Encoded 456 bits interleaved over 4 TDMA bursts



	1 TS	2 TS	3 TS	4 TS	8 TS
CS-1	9.05 kbps	18.1 kbps	27.15 kbps	36.2 kbps	72.4 kbps
CS-2	13.4 kbps	26.8 kbps	40.2 kbps	53.6 kbps	107.2 kbps
CS-3	15.6 kbps	31.2 kbps	46.8 kbps	62.4 kbps	124.8 kbps
CS-4	21.4 kbps	42.8 kbps	64.2 kbps	85.6 kbps	171.2 kbps

After understanding the common RF processes and operations, let's now get back to the information being sent on the air interface. We have discussed earlier in brief about the coding on the radio interface. A radio interface has the maximum limitations on the data transfer rate. One TDMA burst can carry up to 114 bits of information and hence each radio block of 4 bursts can only carry 456 bits of information. What is this information? This information will contain the user data and coding. Coding is essential to compensate for the impairments on the air interface. Coding provides error detection and error correction.

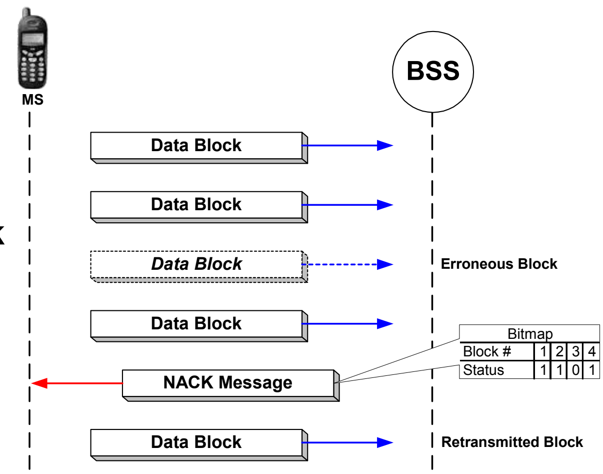
The common process used in GSM coding was inserting CRC bits and convolutional encoding and we will adhere to the same mechanisms for GPRS traffic also. But the major difference is that we have four options of coding the data in different ways. With each option we compromise the level of coding and hence increase the probability of errors. On the other hand, we increase the throughput. The above table illustrates the process. As we go higher on the coding scheme we reduce the CRC bits, which will reduce the probability of bad frame detection. We also do puncturing, by which we remove some of the protection bits and hence this leaves us with less than 100% protection on the bits. So if the radio interface is poor we will suffer from errors.

There are several ways of assigning the coding scheme. Coding schemes will assigned in the initial channel assignment process. But later the coding scheme can be toggled using the control bits on the burst.

Coding scheme will play a very important role in optimizing throughput on the air interface. Remember it's not the coding scheme but rather the air

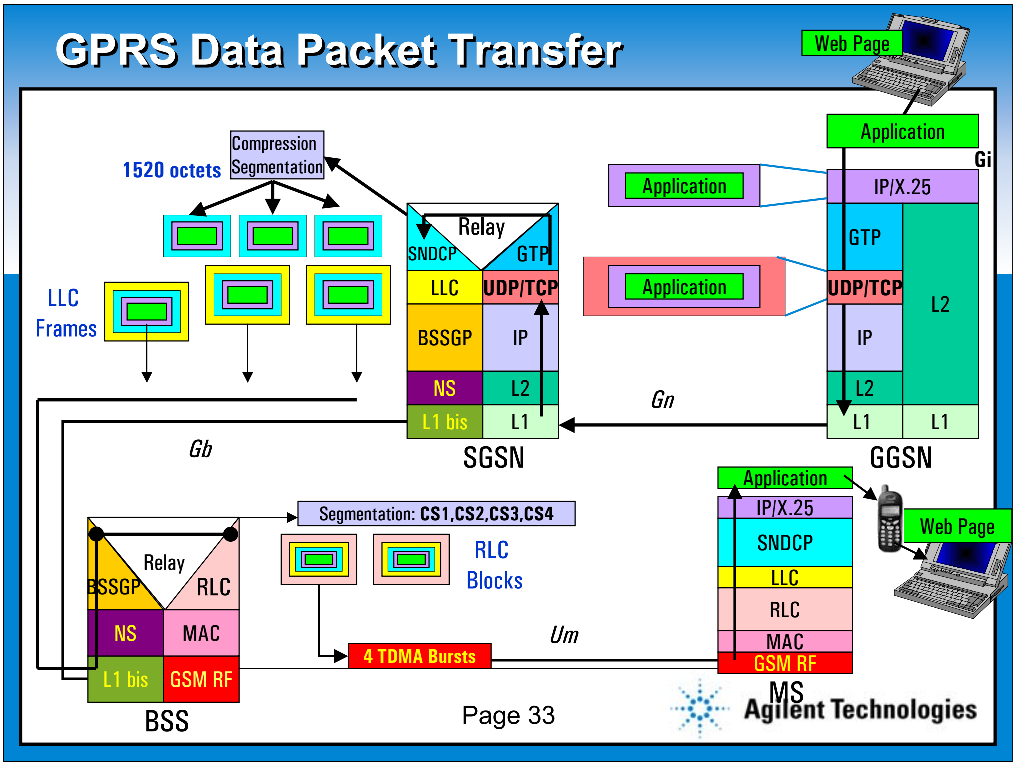
GPRS Acknowledged/Unacknowledged Mode

- RLC layer can be set to mode of operation
- Unacknowledged mode offers no means for error detection
- Acknowledged mode for error detection
- Message type ACK/NACK contains a bitmap of received blocks (UL/DL)
- Recipient sends ACK/NACK message after receiving a packet transfer
- Correct blocks are "1", incorrect blocks are "0"
- Erroneous blocks are retransmitted



GPRS Mobility Management States

The RLC layer can be set to either Acknowledged or Unacknowledged mode of operation. Unacknowledged mode offers no means of error detection. Acknowledged mode uses error detection. ACK/NACK messages contain a bitmap of received blocks whereby the recipient sends a 1 for correct blocks and a 0 for incorrect blocks. Bad blocks are retransmitted.



Now that we have a better understanding of the GPRS concepts, let's take an example of how a PDU (packet data unit) is sent from the landline network to a mobile. The user sends a text message from a PC through the Internet to the wireless operator's network and finally to the end user's GPRS wireless data device.

The diagram shows how headers are added to the 'Application' (successive layering of the rectangular boxes surrounding the word 'Application') as the data goes from the PC at the top right, through the network nodes and BSS, and over the air to the MS to the other PC on the lower right.

The diagram shows the formation of the LLC frames (blocks) at the LLC layer in the SGSN. Then, the data is segmented into RLC blocks in the BSS at the RLC layer. It also shows where the coding schemes (CS) originate. Finally, the data is transmitted in bursts at the GSM RF layer from the BSS and over the air to the mobile where the other PC receives the data.

Contents

- GPRS highlights
- GSM background
- GPRS network architecture
- GPRS attach and PDP context activation
- GPRS protocols and coding schemes
- GPRS logical channels

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The last section of this paper provides an overview of the logical channels used in the GPRS network. This will serve as background for understanding some of the layer 3 messages and GPRS messages that are decoded during drive testing.

GPRS Logical Channels

- Signaling and traffic channels are also required for GPRS
- A new family of packet data channels (PDCHs) has been defined
- Some existing GSM signaling channels can still be used for GPRS
- The GPRS mobile still requires to listen to the GSM broadcast channel for GPRS channel information

New GPRS Logical Channels

Group	Channel	Direction	Function
PBCH	PBCCH	DL	Broadcast
PCCCH	PPCH	DL	Paging
	PRACH	UL	Random Access
	PAGCH	DL	Access Grant
	PNCH	DL	Group Notification
PTCH	PDTCH	DL / UL	Traffic
	PACCH	DL / UL	Associated Control
	PTCCH	DL / UL	Timing Advance

GSM logical channels

Group	Channel
BCH:	BCCH, FCCH, SCH
CCCH:	PCH, AGCH, RACH
DCCH:	SDCCH, SAACH, FACCH
TCH:	TCH

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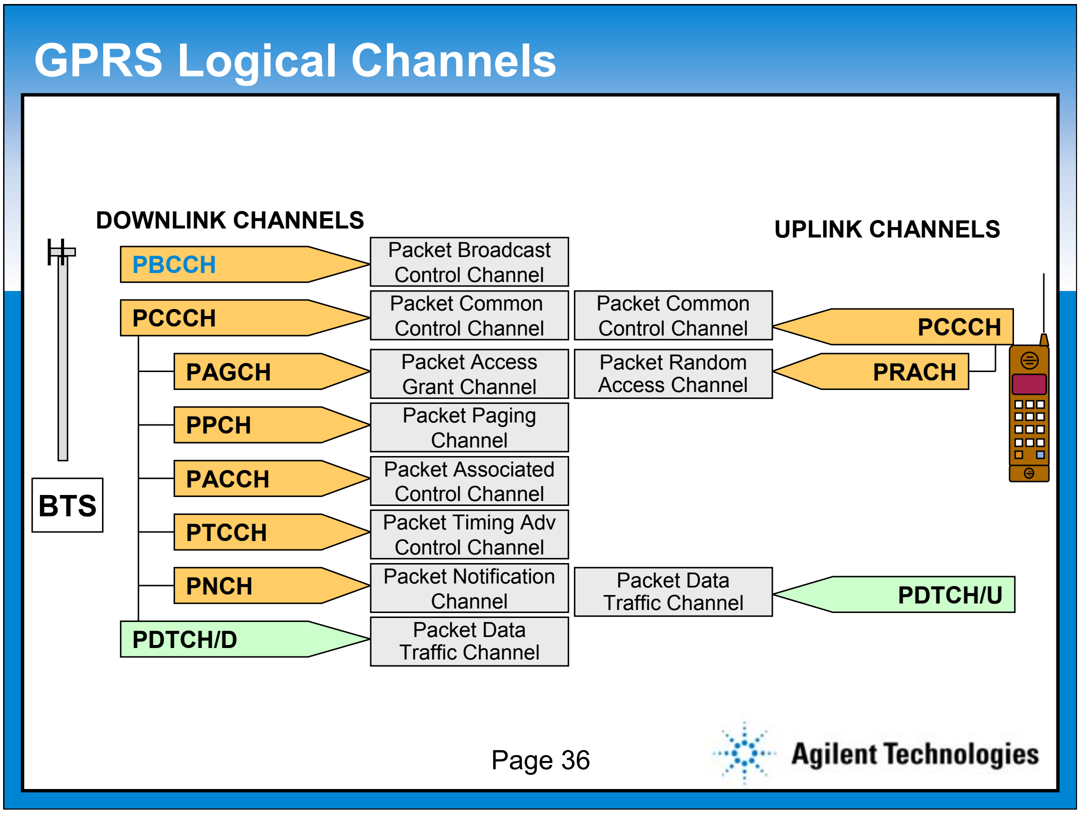
Logical channels are used for signaling and are carried on physical channels (timeslot 0, etc.). This allows the multiplexing of different types of information or services. GSM logical channels are optimized for voice services. GPRS requires signaling and traffic channels to send and receive data over the air interface. A new family of packet data channels has been defined and optimized for GPRS data. Refer to the list shown here. Having both GSM and GPRS channels optimizes the distribution of users between voice and data. Some of the existing GSM channels are still used in GPRS. Until the PBCCH is available, the GPRS mobile is required to listen to the GSM broadcast channel for channel information. Sharing the BCH between GSM and GPRS traffic can often lead to excessive cell reselections. This is covered in another paper.

The new GPRS logical channel acronyms are defined in the next slide.

(For reference, the GSM logical channels that are carried on the GSM physical channel are also included here. They can be divided into traffic and signaling categories. Signaling channels can be further categorized as broadcast, common control, and dedicated control. The TCH is the traffic channel. BCCH is the broadcast control channel. FCCH is the frequency correction channel. SCH is the synchronization channel. PCH is the paging channel. AGCH is the access grant channel. The RACH is the random access channel. SDCCH is the standalone dedicated control channel. SAACH is the slow associated control channel. FACCH is the fast associated control channel. The BCH group is for the downlink only. The PCH and AGCH are for the downlink only. The RACH is for the uplink only. The DCCH group and



This slide defines each of the logical channels mentioned in the previous slide.

The packet data traffic channel (PDTCH) is used to transfer user data

- Assigned to one mobile station (or multiple stations under certain conditions)
- One mobile can use several PDTCHs simultaneously

The packet broadcast control channel (PBCCH) is a unidirectional point-to-multipoint signaling channel from the BSS to mobile stations

- Used by the BSS to broadcast configuration data about the GPRS network to all GPRS mobile stations
- The PBCCH also broadcasts configuration data about the GSM cell so a GSM/GPRS mobile does not need to listen to the BCCH

The packet common control channel transports signaling information for network access management (allocation of radio resources & paging). It consists of four sub-channels:

- The packet random access channel (PRACH) is used by the mobile to request one or more PDTCH
- The packet access grant channel (PAGCH) is used to allocate one or more PDTCH to a mobile
- The packet paging channel (PPCH) is used by the BSS to find out the location of a mobile (paging) prior to downlink packet transmission
- The packet notification channel (PNCH) informs a mobile station of incoming PTM messages (multicast or group call)

Summary

- GPRS ‘always on’ operation and packet-based transmissions provide users with higher data rates
- GPRS builds on the success of the worldwide GSM installed base
- Existing GSM networks require minimal GPRS hardware and software upgrades when compared to UMTS
- New protocols and coding schemes developed to meet QoS needs
- Air interface can often be the bottleneck in GPRS data networks. Test tools are required to optimize performance.

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In summary, this paper provided a high-level overview GPRS concepts that should help you better understand some of the measurements that will be described in some of the other papers.

GPRS uses a packet-based transmission and provides higher data rates than GSM. The GPRS network is overlayed on the existing GSM network, thereby minimizing the amount of hardware upgrades required. The GGSN, SGSN, and PCU are new network elements required for the GPRS data network.

New protocols and coding schemes enable GPRS networks to deliver high-speed data over wireless links. Like any new network technologies, early GPRS networks have experienced some throughput and reliability issues. The air interface is often the bottleneck, but network issues can also affect the throughput. With better planning and design tools, network optimization drive test solutions, and other troubleshooting test equipment that is now available, the GPRS operator can improve the QoS to better meet their customers’ expectations.

Acknowledgements

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  - *Scott Baxter and Associates, Nashville, TN*

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