

2G Cellular Systems Comparison and 2G Evolution

David Tipper
Associate Professor
**Graduate Telecommunications and Networking
Program**
University of Pittsburgh
Slides 10

Second Generation Cellular Systems



- Motivation for 2G Digital Cellular:
 - Increase System Capacity
 - Add additional services/features (SMS, caller ID, etc..)
 - Reduce Cost
 - Improve Security
 - Interoperability among components/systems (GSM only)
- Main 2G Systems
 - Global System for Mobile (GSM)
 - IS-95 (cdmaone)



1/2G Systems Comparison



	AMPS	GSM	IS-95
Physical Channel	30 kHz	200kHz	1.23 MHz
Modulation	FM/FSK	GMSK	OQPSK
Channel rate	10kbs	270.833kbs	1,228.8kbs
Modulation Efficiency (b/s/Hz)	.33	1.4	1.0

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2G Systems Comparison



	AMPS	GSM	IS-95
Speech Coding	Analog	REL P 13.3Kbps	QCELP 14.4 Kbps or variable 9.6, 4.8, 2.4, 1.2 Kbps
Traffic Channels per Carrier	1	8	Variable < 56
Security	None	SIM + encryption A3,A5, A8	Spread spectrum + CAVE encryption
Multiple Access	FDD/FD MA	FDD/FDMA/ TDMA	FDD/FDMA/ CDMA

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2G Systems Comparison



	AMPS	GSM	IS-95
Cellular Efficiency (traffic channels/cell/MHz)	$395/(7 \times 25) = 2.26$	$991/(3 \times 50) = 6.6067$	Variable (best case) $55 \times 10/25 = 22$, typical $= 32 \times 10/25 = 12.8$
Features	-	FHSS, SIM –card, Comfort noise, MAHO	Soft handoff, Dim and Burst signaling
System Cost	-	Cheapest	Most Expensive

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Comparison of 2G Systems



- Other metrics for comparison:
 - Geographical efficiency \rightarrow channels/MHz/km²
 - Communication efficiency \rightarrow Erlangs/MHz/ km²

Example: for B side cellular license (25 MHz of spectrum)
 Consider metro service area 40km x 182 km = 7280 km²
 assume identical hexagonal cells of 5 km radius = 65 km² \Rightarrow 112 Cells

AMPS: if cluster size = 7, 3 sectors per cell 416 radio channels – 21 for control \Rightarrow 395 per cluster

Geo efficiency = $395/(25 \times 7 \times 65) = .0347$

For communication efficiency at 2% call blocking, within a cluster of 7 cells 4 have 56 channels and 3 have 57 \Rightarrow 56 channels support 47.7 Erlangs, 57 channels support 48.7 Erlangs. Over cluster of 7 cells get $4 \times 47.7 + 3 \times 48.7 = 336.9$ Erlangs

Communication efficiency = $336.9/(25 \times 7 \times 65) = .0296$

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Comparison of 2G Systems



- Similar calculations for GSM and IS-95 shown below
 - GSM frequency reuse cluster size of 4
 - IS-95 frequency reuse cluster size 1

Note if sectoring is used then need to incorporate that into Erlangs supported – which will reduce the numbers below for all systems but IS-95

	AMPS	GSM	IS-95 (15)	IS-95 Max (55)
Geo. Eff.	.0347	.09990	.09231	.3385
Com. Eff.	.0296	.09286	.0848	.3303

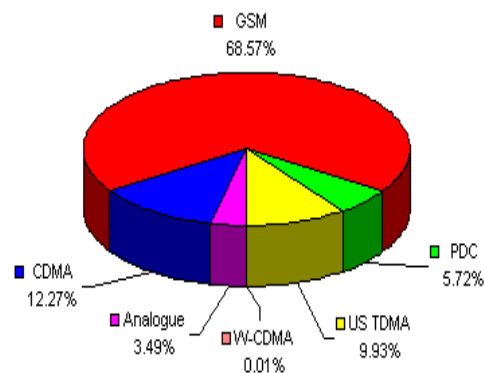
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Market Share by Standard



World cellular subscribers - by technology - June 2002



GSM has more users than **all other digital systems combined!**

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Comparison of 2G Systems



- Given clear technical superiority of IS-95 why is it not dominant standard??
 - GSM first 2G standard to market!
 - IS-95 held up in standard fight – delayed deployment
 - GSM **cheaper** to deploy in a green field design
 - Emphasis on standards and interoperability
 - At start of 2G market Qualcomm still a start up company
 - From user perspective no difference in services!
 - GSM has some attractive marketing features (SIM)
 - Larger number of countries where one can roam etc.

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2.5G Systems



- 2G Systems provide slow speed circuit switched data service (charged by minute)
 - 9.6 Kbps – 14.4 Kbps
- 2.5G
 - Attempt to improve data services from 2G and build customer base for wireless data service
 - GPRS, *cdma 2000 1x-RTT (cdmatwo)*
 - *Mislabeled as 3G when rolled out in the US*
 - Basically overlay network of data service on 2G networks (voice still circuit switched)
 - Max data rate 57 Kbps – 171 Kbps
 - Typical data rates ~50 Kbps – similar to dialup modem service
 - EDGE – 2.75 G: higher data rates on GPRS networks



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What is GPRS?



- GPRS stands for General Packet Radio Service
- Standard developed by ETSI and 3GPP
- An intermediate step (2+ or 2.5G) in the evolution from 2G to 3G
- Overlay on top of GSM physical layer and network entities
- Provides packet-switched capability to GSM networks
- Connects GSM networks to IP networks
- Theoretical maximum data rate of 171.2 Kbps
- “Always connected” access
- Spectrum efficiency– radio resources used only when actually sending or receiving data



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GPRS



- Overlay on top of GSM physical layer and network entities
- Extends data capabilities of GSM (2.5 G solution)
 - provides connection to external packet data networks through the GSM infrastructure
 - packet switching
 - Uses free TDMA slots only if data packets ready to send (e.g., 171 kbps using 8 slots temporarily)
 - standardization started 1998,
 - no hardware changes to the BTS/BSC!
- The physical layer is the same as GSM (uses GMSK)
 - Forward error correction and indication of uncorrectable code words using GSM convolutional coder
- Architecture includes new components in wired part of network
 - **GGSN – Gateway GPRS support Node**
 - **SGSN – Serving GPRS support Node**
 - **Packet Control Unit**

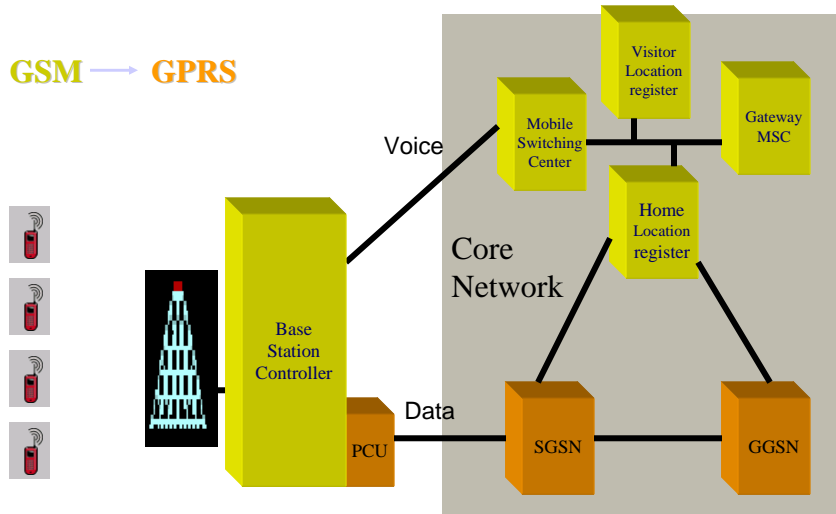
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GSM Evolution



GSM → GPRS



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GPRS Network Entities



- GPRS Support Node (GSN) Responsible for delivery and routing of data packets between the mobile station and external packet network
 1. Serving GPRS Support Node (SGSN)
 - supports the MS packet delivery (location, billing, security) for a group of BTS attached to BSCs (routing or service area of SGSN)
 - Like MSC/VLR in GSM
 2. Gateway GPRS Support Node (GGSN)
 - interworking unit between GPRS and PDN (Packet Data Network) : like HLR or Home Agent in Mobile IP



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GPRS Network Entities

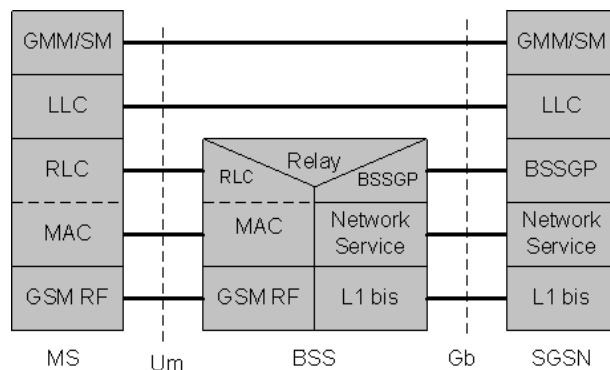


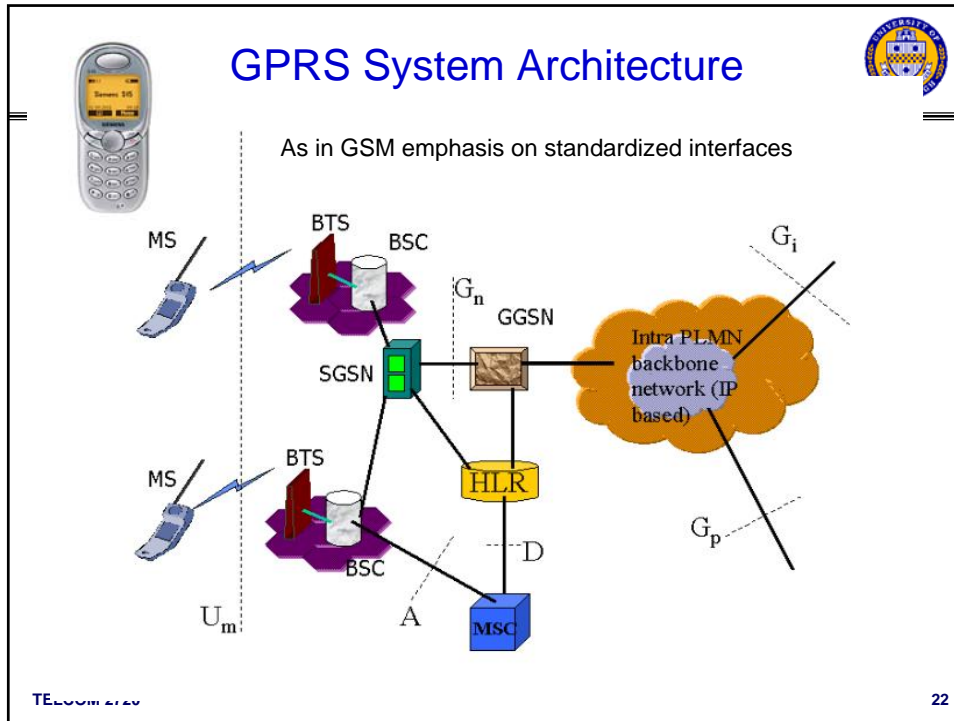
- GPRS Register (GR) co-located with the HLR
 - Stores routing information and maps IMSI to a packet data user address (IP address for example)
 - Signaling between SGSN, HLR, VLR, EIR is similar to GSM and extends only the GPRS related functionality
 - Based on Signaling System 7
 - Between the MS and SGSN signaling uses
 - GPRS mobility management protocol (GMM)
 - GPRS session management (SM) protocol

GPRS Architecture and Protocol Stack



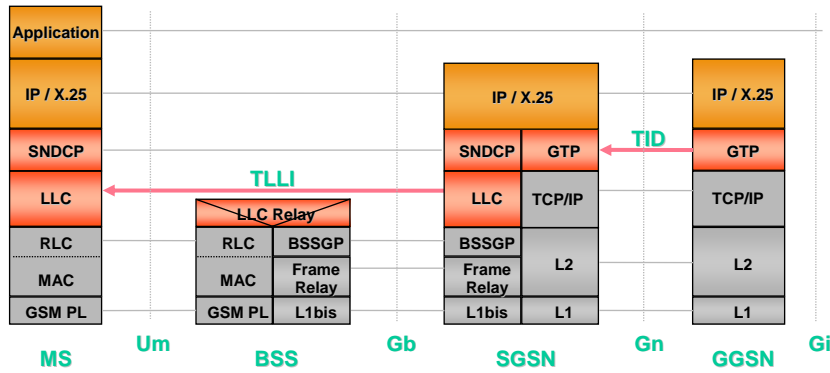
- Logical Link Control between MS and SGSN
- Radio Link Control between MS and BSS
- Frame Relay between SGSN and GGSN
- Standardized interfaces





- ## GPRS Vs GSM
- GPRS allows a MS to transmit on multiple time slots of the same TDMA frame unlike GSM
 - A very flexible channel allocation is possible since 1-8 time slots can be allocated per TDMA frame to a single MS
 - Uplink and downlink slots can be allocated differently – asymmetric data traffic
 - Some radio channels may be dedicated for GPRS. These are called Packet Data Channels (PDCH) or can just use idle slots
 - Point to Multipoint service possible
 - Multicast service to all subscribers in a given area: PTM-M
 - Multicast service to predetermined group that may be dispersed over a geographical area: PTM-G
 - Point to Point service supports two types
 - Connectionless based on IP
 - Connection oriented based on X.25:
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GPRS Transport Plane

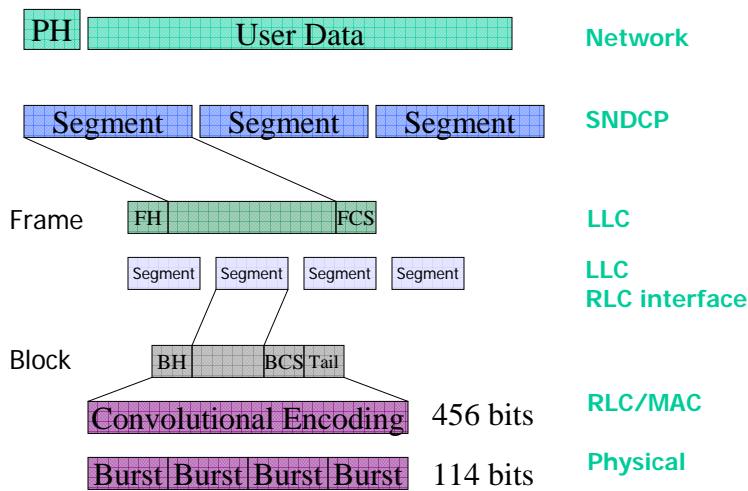


SNDCP: Subnetwork Dependent Convergence Protocol
 BSSGP: BSS Gateway Protocol
 GTP: GPRS Tunneling Protocol

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Packet Transformation Data Flow



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Allocation of Radio Resources

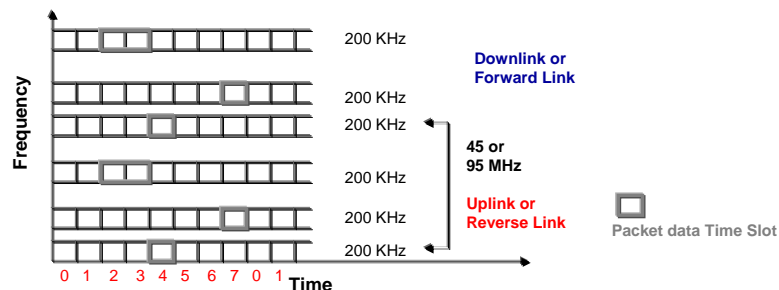


- Radio resources can be dynamically allocated between GSM and GPRS services or a certain portion of GSM bandwidth (ARFCN) dedicated to GPRS
- Most operators dedicate some portion of GSM bandwidth to GPRS or have deployed GPRS on new spectrum (3G licensed)
- GPRS information is broadcast on the CCHs
- PDCHs may be dynamically allocated or de-allocated by the network (usually the BSC)
- Logical channels in GPRS in a fashion similar to GSM

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GPRS in GSM Network: Radio Channels



- Operators can allocate individual time slots within a radio carrier to the packet data service - on an as needed basis.
- When there are no packet data users in a cell, all of the time slots in that cell can be allocated to voice service.
- When a user in that cell request packet data service, one of the idle time slots in that cell can be allocated to packet data service. As more users request packet data service, they can share the same time slot or more slots added for data.

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Logical GPRS Channels



Analogous to GSM, GPRS has traffic and control channels

- | GSM | GPRS |
|---|---|
| <ul style="list-style-type: none"> TCH: Traffic Channel - fixed data rate – symmetric BCCH: Broadcast Control Channel RACH: Random Access Channel AGCH: Access Grant Channel PCH: Paging Channel SACCH: Slow Associated Control Channel FACCH: Fast Associated Control Channel | <ul style="list-style-type: none"> PDTCH: Packet Data Traffic Channel variable data rate and asymmetric PBCCH: Packet BCCH – system information about GPRS and GSM PRACH: Packet Random Access Channel PAGCH: Packet Access Grant Channel PPCH: Packet Paging Channel PNCH: Packet Notification Channel PACCH: Packet Associated Control Ch. <ul style="list-style-type: none"> Use to send ACKs for received packets PTCCH: Packet Timing-advance Control Channel is used for adaptive frame synchronization |

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Logical GPRS Channels



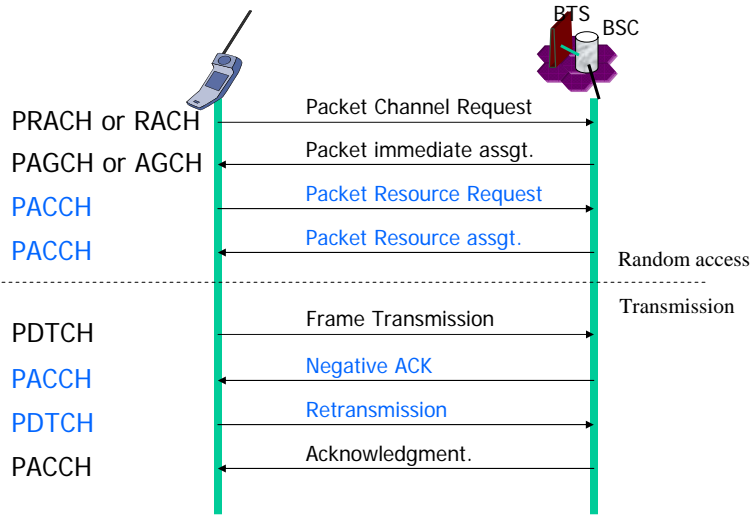
Analogous to GSM, GPRS has certain traffic and control channels

Group	Channel	Function	Direction
Packet data traffic channel	PDTCH	Data traffic	MS ↔ BSS
Packet broadcast control channel	PBCCH	Broadcast control	MS ← BSS
Packet common control channel (PCCCH)	PRACH PAGCH PPCH PNCH	Random access Access grant Paging Notification	MS → BSS MS ← BSS MS ← BSS MS ← BSS
Packet dedicated control channels	PACCH PTCCH	Associated control Timing advance control	MS ↔ BSS MS ↔ BSS

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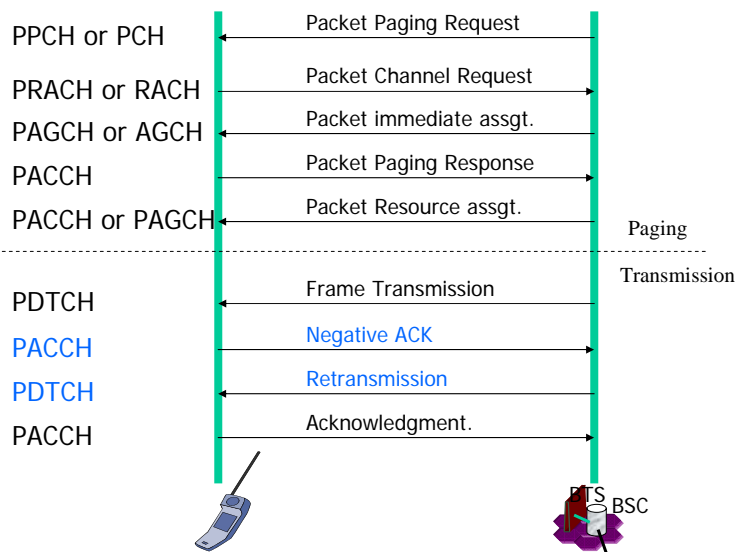
Uplink Data Transfer



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Downlink Data Transfer



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Attachment Procedure



- Before accessing GPRS services, the MS must register with the GPRS network and become “known” to the PDN
- The MS performs an **attachment procedure** with an SGSN
 - Authentication
 - Check with GR etc.
- It is allocated a temporary logical link identity (TLLI) by the SGSN
- **A PDP** (packet data protocol) **Context** is created for the MS
- For each session, a PDP context is created
 - PDP Type: (e.g. IPv4)
 - The PDP address assigned to the MS
 - The requested QoS
 - The GGSN address that serves the point of access to the PDN
- PDP context is stored in the MS, the SGSN, and the GGSN
- A user may have several PDP contexts enabled at a time
- The PDP address may be statically or dynamically assigned (static address is the common situation)

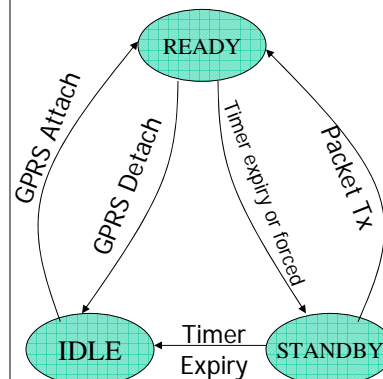
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Location Management



- Network defines Routing Areas (similar to GSM Location Areas)
- MS can be in three states
- IDLE state the MS is not reachable
 - All PDP contexts are deleted
- STANDBY state, movement across routing areas are updated to the SGSN but not across cells
 - Chance of packets reaching are medium
- READY state, every movement of the MS is indicated to the SGSN
 - Chances of packets reaching are high



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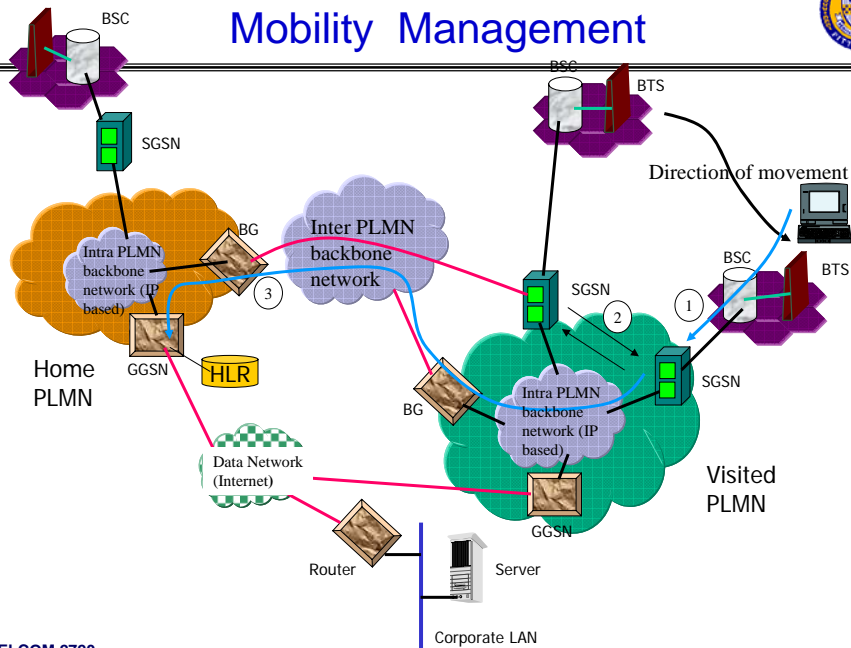
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Mobility Management



- Intra-SGSN RA Update
 - The SGSN already has the user profile
 - A new temporary mobile subscriber identity is issued as part of routing area update “accept”
 - The Home GGSN and GR(HLR) need not be updated
 - Similar to Intra –VLR update in GSM and IS-41
- Inter-SGSN RA Update
 - The new RA is serviced by a new SGSN
 - The new SGSN requests the old SGSN to send the PDP contexts of the MS
 - The new SGSN informs the home GGSN, the GR, and other GGSNs about the user’s new routing context
 - Similar to Inter –VLR update in GSM and IS-41
- Handoff Initiation
 - The MS listens to the BCCH and decides which cell it has to select
 - Proprietary algorithms are employed that use RSS, Cell ranking, Path loss, Power Budget, etc.
 - Network can ask the MS to report measurements (as in GSM)
- Handoff Procedure
 - Very similar to Mobile IP

Mobility Management



Steps in Mobility Management



- Inter-SGSN Handoff (similar to Handoff Forward in GSM/IS-41)
- 1. Update to new SGSN
- 2. Communication between new and old SGSN
- 3. Communication between new SGSN and Home-GGSN/HLR
- The Home GGSN “tunnels” packets to the new SGSN
- The HLR deletes old SGSN information and includes the new SGSN information in the database
- The new SGSN decapsulates packets and forwards them to the MS
- Notice session is not anchored at original SGSN as in GSM!

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Classes of GPRS MSs



- Class A
 - Operate GPRS and other GSM services simultaneously
- Class B
 - Monitor all services, but operate either GPRS or another service one at a time
- Class C
 - Operate GPRS service only



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GPRS Quality of Service (QoS) Parameters



- Service precedence
 - Priority of a service in relation to another service
 - High, normal and low
- Reliability
 - Transmission characteristics required
 - Three reliability cases are defined
- Delay
 - Defined as the end-to-end delay between two MSs or between a MS and the G_i interface
- Throughput
 - Maximum and mean bit rates

Reliability Classes



Class	Probability for			
	Lost Packet	Duplicated Packet	Out of Sequence Packet	Corrupted Packet
1	10^{-9}	10^{-9}	10^{-9}	10^{-9}
2	10^{-4}	10^{-5}	10^{-5}	10^{-6}
3	10^{-2}	10^{-5}	10^{-5}	10^{-2}



Delay Classes

Class	128 byte packet		1024 byte packet	
	Mean Delay	95% Delay	Mean Delay	95% Delay
1	< 0.5s	< 1.5s	< 2s	< 7s
2	< 5s	< 25s	< 15s	< 75s
3	< 50s	< 250s	< 75s	< 375s
4	Best effort	Best effort	Best effort	Best effort

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Limitations of GPRS

- Limited cell capacity for all users
- Speeds much lower than advertised, in reality 30 –40 kbps common - similar to dial up modem service
- Not widely deployed in some areas (US!) – some operators waiting on EDGE or 3G.
- Sub-optimal modulation/error control coding
- Transit delays
- Not store and forward.
- Service being replaced/phased out with EDGE or evolution to 3G UMTS



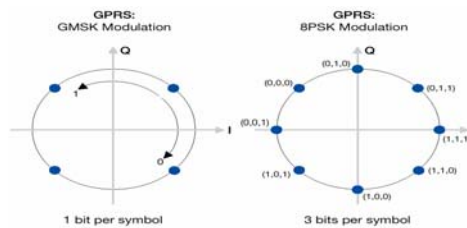
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Enhanced Data GSM Evolution



- Enhanced Data GSM Evolution (EDGE) is a step to get higher data rates out of a GPRS network
- Same TDMA frame and 200 KHz carrier bandwidth as GSM/GPRS
- Enhanced modulation and coding techniques yield higher data rates
 - Data throughput: 64Kbps - 384 Kbps
 - The network architecture used is the same as that of GPRS
 - Uses GSM MAP signaling in wired network
 - Requires changing hardware at BTS to support modulation/coding



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Expected Data Rates for GPRS and EDGE



	Per Time Slot	Per Carrier
GPRS	21.4 kbps	171.2 kbps
EDGE	59.2 kbps	473.6 kbps

- Table summarizes the maximum data rates achievable with EDGE and GPRS radio systems. Two values are given for each radio technology, one for a single time slot and one for the sum of all eight time slots.
- Actual data rates which end users will achieve will be lower than these values.
 - Operator may not allocate all eight time slots to packet data service.
 - The interference level in the area may cause high BER
 - GPRS and EDGE use shared data channels, data rate experienced by a user will depend on how many other users are accessing the system at the time and how much data they are transferring.

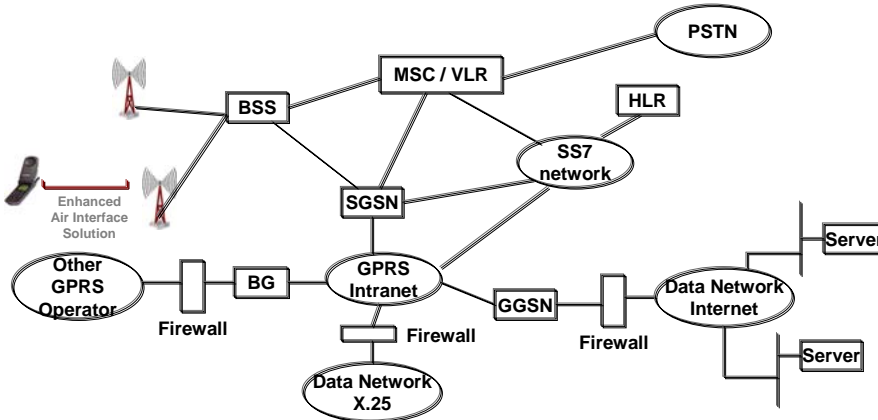
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GPRS/EDGE Network



- EDGE is operated on GPRS network components
- EDGE is an enhancement to the radio transmission technology only



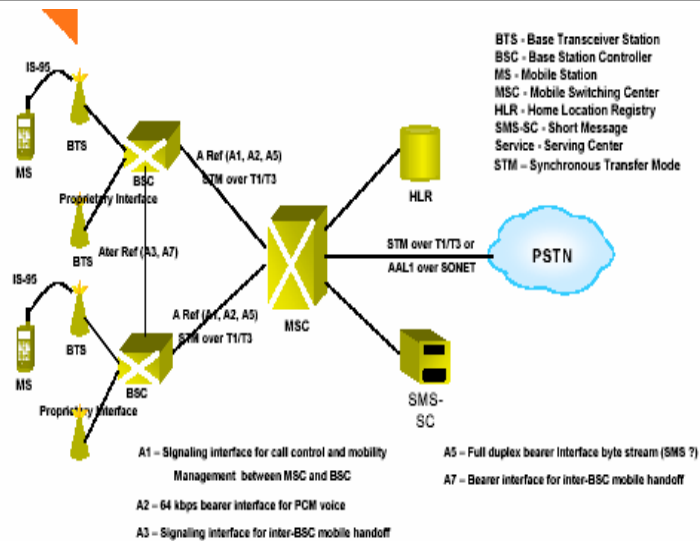
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2G System IS-95 (cdmaone)



- Cdmaone
- 2G system
- Voice
14.4 Kbps or variable rate
9.6 Kbps
- Data 14.4 Kbps
- 1.25 MHz carrier
- 64 Walsh codes per carrier



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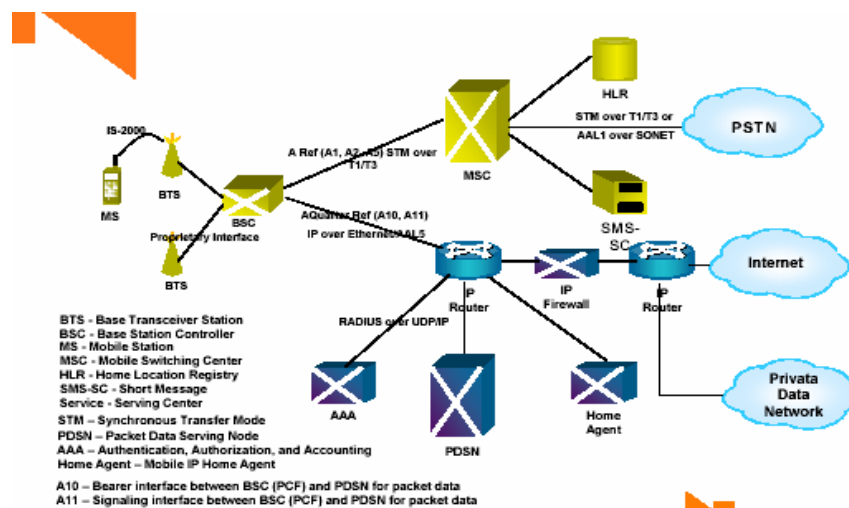
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cdma2000



- cdma2000
 - Goal: provide 2.5G services over TIA/EIA-41 systems which include IS-95a, b, cdmaone systems
 - Similar to GPRS provide a packet overlay on top of cellular network
 - Evolutionary path
 - cdma2000-1xRTT
 - User gets multiple Walsh codes on same 1.25 MHz carrier
 - Slight change to the modulation to provide 2.5G to support packet data – up to 144 Kbps
 - IS-41 signalling in core
 - Error control treats every bit the same

Cdma2000 – 1X RTT



cdma2000



- cdma2000 - 1x RTT
 - Packet Data Serving Node (PDSN) (similar to MSC for data sessions)
 - Establish, maintain, terminate PPP sessions
 - Support IP services
 - Route packets between mobiles and packet data networks
 - Authentication, Authorization and Accounting (AAA) server
 - Security key distribution and management, service profiles, usage data for billing
 - Home Agent (Mobile IP)
 - Track location of mobile IP subscribers when they move from one network to another
 - forward packets to mobiles current point of attachment

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2.5 G Systems



- 2.5G
 - Attempt to improve data services from 2G and build customer base for wireless data service
 - GPRS, EDGE, *cdma 2000 1x*
 - Basically overlay network of data service on 2G networks (voice still circuit switched)
 - Max data rate 57 Kbps – 384 Kbps
 - Typical data rates 30-70 Kbps – similar to dialup modem service
 - Cost
 - GPRS cheapest,
 - EDGE medium
 - *cdma 2000 1x* most expensive
 - For GSM operator EDGE is the cost effective solution until upgrade to 3G



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