Beykent University Network Courses

Module 2 : Mobile Wireless Networks and Systems

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Course Outline

- Introduction to Wireless Networking
- Technical Challenges of Wireless Communication
- Evolution of Wireless Networks
- GSM and General Wireless Network Concepts
- GPRS
- UMTS
- EPC & LTE
- Q&A

Introduction to Wireless Networking

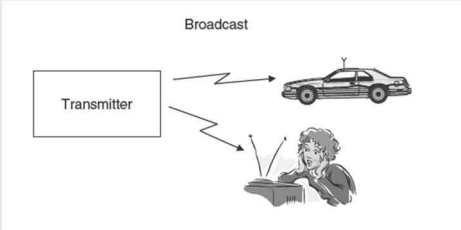
- Wireless networking is the basic obstacle to be solved for the mobile computing
- Basic architecture consists;
  - wireless mobile devices
  - wireless link
  - base station
- Wireless media has different characteristics than the current wired networks
- Different applications have different requirements QoS
- Data networking protocols are optimized for the current wired networks
  The protocols are not efficient in the wireless environments

Differences from Wireline Technologies

- **Latency**
  - 802.11 : round-trip time 2ms, TCP buffer size 8KB
  - GSM : 0.7s with one byte packet
  - TCP throughput is related to latency : High latency, low throughput
  - Interactive applications suffer from long latency times
- **Jitter**
- **Error rate**
  - GSM offers less than 10-8 bit error rate with highly variable transmission delays
- **Throughput**
  - Wireless Networks can be considered weak
- **Unexpected Disconnections**
  - Recovery support exists?

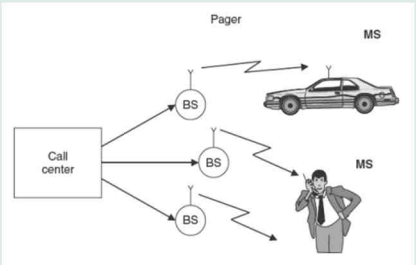
Classification of Wireless Networks

- **Broadcast Networks** - Radio Service
  - Information sent only one direction
  - Transmitted information is same for all users
  - The information is transmitted continuously
  - There may be multiple transmitters



Classification of Wireless Networks

- **Broadcast Networks**
- **Paging Networks** - Unidirectional Wireless Systems
  - Information can only be received
  - Transmitted information can only be received by a single user
  - The amount of transmitted information is very small
  - There may be multiple transmitters



Classification of Wireless Networks

- **Broadcast Networks**
- **Paging Networks**
- **Cellular Telephony Networks** - Wireless Telephony Systems
  - Information flow is bi-directional
  - Transmitted information can only be received by a single user
  - Analogue signaling is done by fairly big mobile phones
  - First-come-first-serve basis (FCFS)
  - Mobile-to-mobile or mobile-to-PSTN communication is possible
  - Continuously evaluating GSM, GPRS etc.

Classification of Wireless Networks

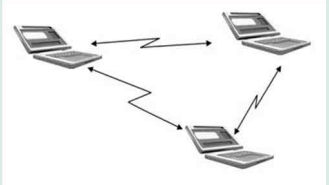
- **Broadcast Networks**
- **Paging Networks**
- **Cellular Telephony Networks**
- **Trunking Radio Networks** – Special Networks No PSTN connection.
  - Only for a closed user group.
  - Can be broadcast, uni- and bi-directional.
  - Group calls
  - Call priority
  - Relay Networks

Classification of Wireless Networks

- Broadcast Networks
- Paging Networks
- Cellular Telephony Networks
- Trunking Radio Networks
- Cordless Telephony Networks – Cordless Telephone systems
  - Wireless link between handset and box of the telephone. Digital.
  - Fixed low frequency
  - PSTN

Classification of Wireless Networks

- Broadcast Networks
- Paging Networks
- Cellular Telephony Networks
- Trunking Radio Networks
- Cordless Telephony Networks
- Ad-hoc Networks – Self-communicating device Networks (M2M Networks)
  - Controller OR master/slave functionality
  - Low cost
  - High flexibility
  - Smaller range
  - Restrictions on number of interconnected devices



Classification of Wireless Networks

- Broadcast Networks
- Paging Networks
- Cellular Telephony Networks
- Trunking Radio Networks
- Cordless Telephony Networks
- Ad-hoc Networks
- Wireless Local Area Networks – WLAN (IEEE 802.11)
  - Allowing mobility
  - Robust
  - Multi-channel roaming
  - Security Wired Equivalent Privacy (WEP)
  - Restrictions on number of interconnected devices

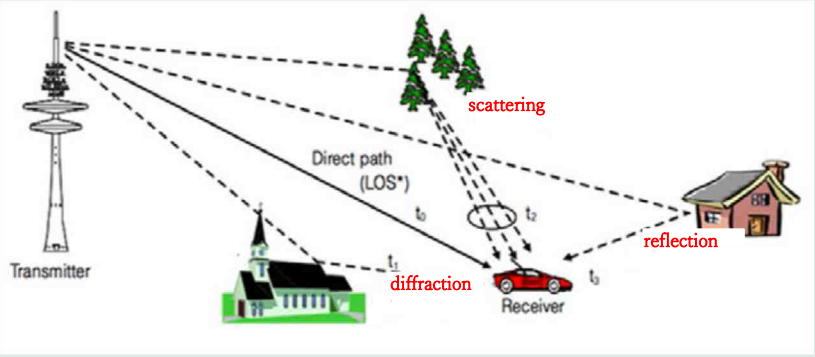
Speaking the same language / Dieselbe Sprache sprechen

buffer	temporary cache(memory) of a device/network.
throughput	The rate of successful message delivery over a channel
round-trip time (RTT)	Time required from source to destination and back.
BTS	Base tranceiver station
BSC	Base station controller
BSS	Base station subsystem
VLR	Visitor Location Register
HLR	Home Location Register
MSC	Mobile Switching Center
VPLMN	Visited Public Land Mobile Network
HPLMN	Home Public Land Mobile Network
roaming	Being attached to a VPLMN temporarily
Relay networks	Relaying info over intermediate devices at far distances

Technical Challenges of Wireless Communication

1 - Multipath Propagation

- The fact that a transmit signal can reach the receiver via different paths.
- Line of sight (LOS) + Scattering + reflection + diffraction = FADING



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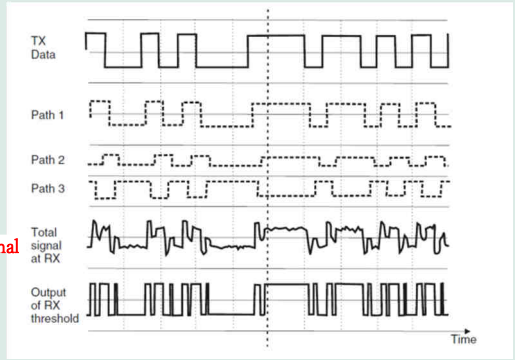
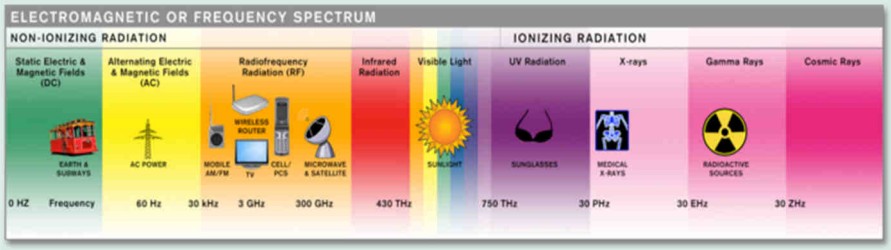


Faded signal

Technical Challenges of Wireless Communication

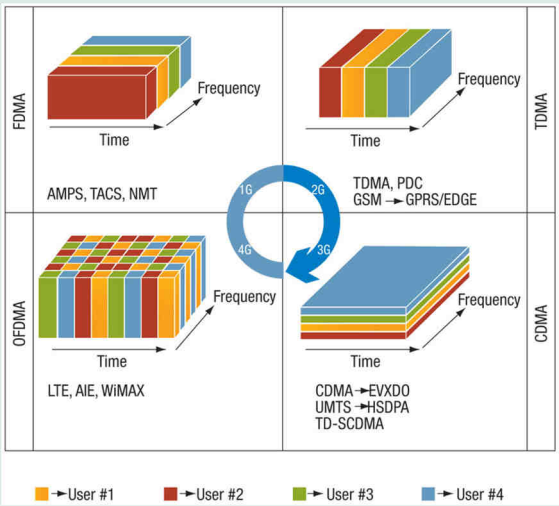
2 – Spectrum Limitations

- The spectrum available for Wireless communication services is limited by international agreements.
- Spectrum has to be used efficiently. How? Modulation!!! = Multiple Access



Technical Challenges of Wireless Communication

Modulation Scheme for a quick review



FDMA – Frequency Division Multiple Access
TDMA – Time Division Multiple Access
CDMA – Code Division Multiple Access
OFDMA – Orthogonal Frequency Division Multiple Access

Technical Challenges of Wireless Networks

3 – Limited Energy

- Power amplifiers in the transmitter have to be efficient.
- Signal processing should be done in energy-saving manner.
- The RX needs to be highly sensitive.
- Signal power should be adapted to channel state.
- For cell-phones a ‘standby‘ or ‘sleep‘ mode has to be defined.

Technical Challenges of Wireless Communication

4 – User Mobility

- For incoming call, the network has to know in which cell the user is located. For this;
  - UE should send signal at regular intervals informing BTS about it‘s location.
  - HLR or VLR registers it‘s location
- BTS handover should be smooth and non-interrupting.

Those actions need
VERY COMPLICATED
signaling !!!
Details on Module A4

Evolution of Wireless Networks

First Generation (AMPS)
Analog voice communication using frequency modulation.

Second Generation (GSM)
Digital techniques and time-division multiple access (TDMA) or code-division multiple access (CDMA)

Second-and-half Generation (GPRS)
GPRS Services - GSM Phase 2+

Third Generation
Evolving from second-generation wireless systems
Will integrate services into one set of standards. (UMTS)
3GPP.
Enhanced Data Rates for GSM Evolution (EDGE)
MSC Server and MGW (Media Gateway) advancements.

Fourth Generation
Successor of UMTS
OFDMA, Orthogonal Frequency Division Multiple Access.
IP Based Core Network = EPS

Evolution of Wireless Networks

Evolution at a glance

2004	Monolitic Architecture	❑ MSCs carry voice signaling and traffic in CS Core Network ❑ SGSN/GGSN carry data signaling and traffic in PS Core Network ❑ Transport Network is ATM based
	Layered CS Mobile Core Network	❑ MSCs are replaced by MSS and MGW
2008	Layered PS Core Network	❑ Node B is straightforward connected to GGSN for data traffic ❑ SGSN carry data signaling only
2010	Evolved Packet System	❑ UMTS, HSPA, HSPA+, LTE and VLAN, WiMAX technologies are started to be supported
	Long Term Evolution	❑ No CS support anymore ❑ Voice services are over IP (VoIP)

Evolution of Wireless Networks

Data Rates

GPRS	40 Kbps uplink/downlink
3G	384 Kbps uplink/downlink
HSDPA	384 Kbps uplink / 14.4 Mbps downlink
HSPA	5.76 Mbps uplink / 14.4 Mbps downlink
HSPA+	11.5 Mbps uplink / 28 Mbps downlink
LTE	75 Mbps uplink / 300 Mbps downlink

Global System for Mobile Communication (GSM)

GSM Architecture

GSM architecture consists of two main parts
- Radio Access Network (RAN)
- Core Network (CN)

The GSM network is also called a Public Land Mobile Network (PLMN).

Radio Access Network (RAN)

The Radio Access Network enables the radio access of the mobile subscribers to the GSM network. It is also the Base Station Subsystem (BSS).

Core Network (CN)

The RAN is attached to the Circuit Switched (CS) Core Network. The main functions of the Core Network are:

- Switching of calls
- Localization of mobile subscribers
- Roaming of mobile subscribers
- Administration of mobile subscriber data
- Charging
- Internetworking to other telephone networks (PSTN, ISDN)
- Network Management (Operation, Administration, Maintenance)

GSM Association

Based on the MoU also the GSM Association (GSMA, www.gsmworld.com) was founded. Today nearly 800 operators are member of the GSMA. The GSMA mainly deals with the following tasks

- Commercialization of GSM
- Roaming, roaming agreements
- Interoperability tests
- Framework for the exchange of billing data between operators
- Operation of an interconnection network

GSM Phase 1

In 1990 ETSI published the GSM phase 1 standards. GSM phase 1 only specified the following basic functionalities:
- Mobile originated calls
- Mobile terminated calls
- Roaming

GSM Phase 2
- SMS services

GSM Phase 2+
- GPRS Services

Global System for Mobile Communication (GSM)

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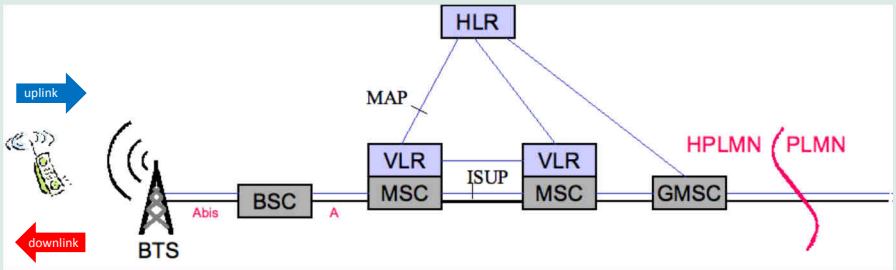


General Wireless Network Concepts

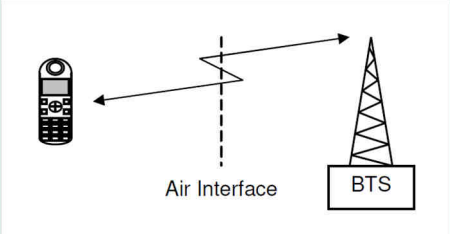
Architectural Components

User Equipment (UE)

Or the Mobile Station (MS) is the handset. It consists of the following components:
- Subscriber Identity Module (SIM)
- Mobile Termination (MS)
- Terminal Equipment (TE)

Base Transceiver Station (BTS)

The Base Transceiver Station (BTS) consists of the signal processors, the transmitter and the receiver of the electromagnetic waves, and the antennas. The MS communicates with the BTS over the air interface.

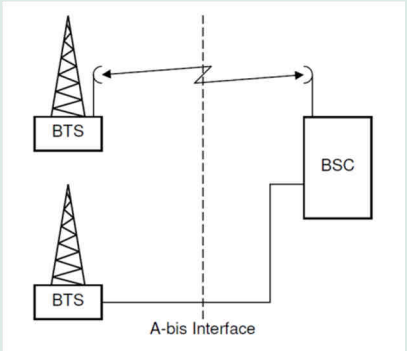


General Wireless Network Concepts

Architectural Components

Base Station Controller (BSC)

The BSC is responsible for
the encryption of the data stream which is sent to the UE
decryption of the data stream which is received from the UE
synchronization of BTSs



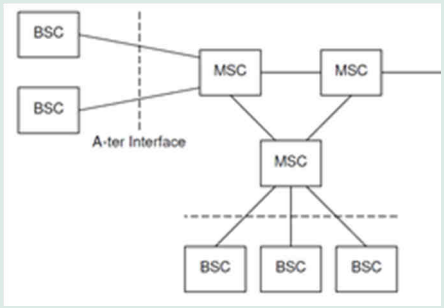
General Wireless Network Concepts

Architectural Components

Mobile Switching Center (MSC)

Is responsible for the following tasks:

•Call control (setup and release of voice calls)
•Bearer control (reservation of time slots for voice calls)
•Switching of the telephone connections
•Linking with different MSCs
•Mobility management for circuit switched services
•Control function for handover between different BSC areas
•Charging and logging
•Connectivity to different PSTNs and PLMNs
•Echo cancellation for connections between PSTNs and PLMNs
•Connectivity to intelligent network systems (application server)
•Connection points for legal interception equipment



General Wireless Network Concepts

Architectural Components

Home Location Register (HLR)

The Home Location Register (HLR) is the central database.
The HLR contains the following information:

- subscriber data (identity of the subscriber)
- service authorizations and administration for national and international roaming supplementary services(call forwarding)
- location area where the user is attached to

There are only signaling links to the HLR

Visitor Location Register (HLR)

- VLR is a mirror database which stores the subscriber data of the subscribers who are located within the location area which the VLR is responsible for.
- The VLR gets the subscriber data from the HLR during the location update procedure.
- Usually a VLR is co-located with an MSC.
- There are only signaling connections to the VLR.

General Wireless Network Concepts

Architectural Components

Transcoding and Rate Adaptation Unit (TRAU)

The data rate at the air interface is limited to a data rate of a maximum of 13 kbit/s to achieve this data rate special speech codecs are used.

The core network always uses the G.711 codec for speech transmission at a bit rate of 64 kbit/s. This is due to compatibility reasons with fixed line networks (ISDN and PSTN).

- **Location Area (LA)** is a grouping of several cells. The **Location Area Identity (LAI)** is the international unique identity of a LA.
- Format of the LAI
  - Mobile Country Code (MCC)
  - Mobile Network Code (MNC)
  - 2 bytes Location Area Code (LAC)

General Wireless Network Concepts

Cellular Structure and SDMA(Space Division Multiple Access)

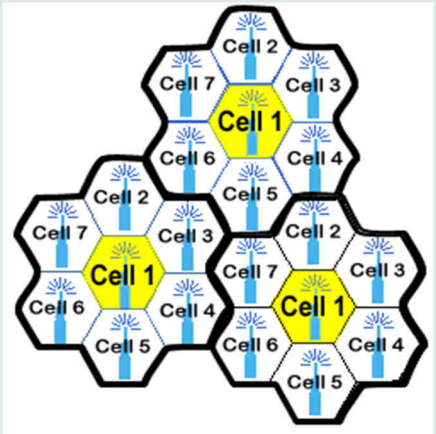
Each Base Transceiver Station (BTS) covers a cell with a diameter from some hundred meters to some kilometers.

A mobile station (MS) is always attached to one BTS only.

If a MS changes the cell then it will attach to another BTS.

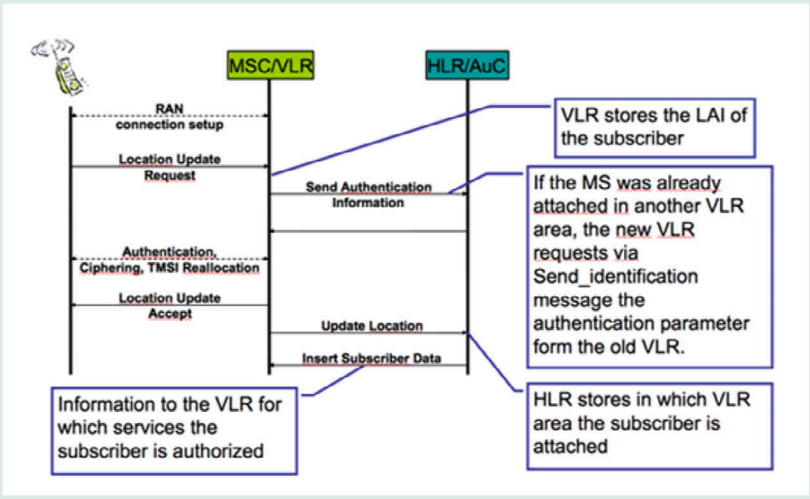
In neighbor cells different frequencies are used.

In a certain distance the same frequencies can be reused **(frequency reuse)**



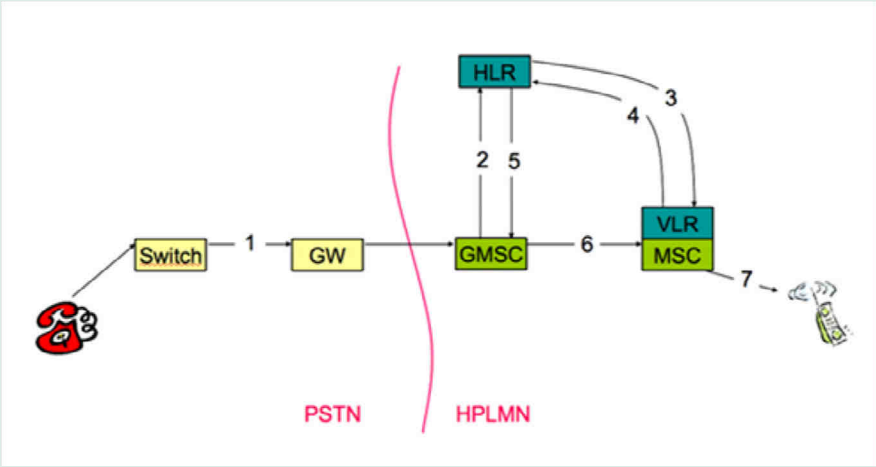
General Wireless Network Concepts

Location update procedure



General Wireless Network Concepts

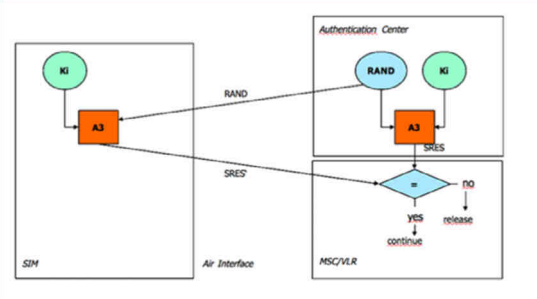
Incoming call setup procedure



General Wireless Network Concepts

SIM card authentication procedure

1. When the MS tries to attach to the network a random number (RAND) is created in the Authentication center (AuC)
2. The RAND is sent to the MS as a challenge. This challenge is passed from the MS to the SIM.
3. 3. The SIM calculates a response value using the authentication algorithm A3, the RAND and the individual key Ki as input parameter. The response value calculated by the SIM is called the Signed Response (SRES)
4. If the SRES of MS and value of AuC are the same. Then MS is allowed to enter the network.



General Packet Radio Service (GPRS)

Differences than GSM

Circuit Switched Core Network → **Packet Switched GPRS Core Network**
each BSC is enhanced with PCU
(packet control unit)

- Introduction of **High Speed Circuit Switched Data (HSCSD)**
  Allows allocating several time slots and thus several circuit-switched channels to one subscriber. By the bundling of circuit-switched channels higher data rates can be achieved.
- In order to support packet oriented data transfer with the introduction of GPRS the core network architecture was enhanced. Two new network nodes have been introduced:
  Serving GPRS Support Node (SGSN)
  Gateway GPRS Support Node (GGSN)
- **Idle** state has been established

General Packet Radio Service (GPRS)

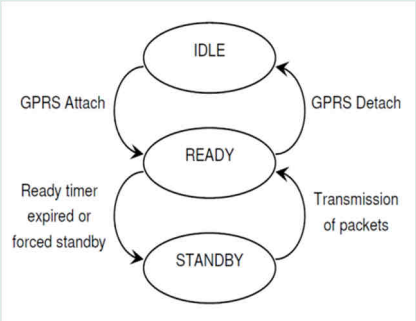
Differences than GSM

Therefore the following three states have been introduced in GPRS:
- Idle State
- Ready State
- Standby State

Idle state
After switching on the MS and activating the SIM card by entering the PIN the MS enters the Idle State. During the Idle State the MS is not attached to the GPRS network.

Transition from the Idle State to the Ready State
By performing the GPRS attach procedure the MS enters the Ready State. During the Ready State the MS informs the GPRS network about every cell change. Therefore incoming data packets can be delivered without any additional delay to the MS.

Transition from the Ready State to the Standby state
If the MS does not transmit or receive data packets for a longer time period the MS switches to the Standby State.



General Packet Radio Service (GPRS)

Serving GPRS support node (SGSN)

SGSN is responsible for:

- Transport of data packets from the PCU to the GGSN within the own service area
- Transport of data packets from the GGSN to the PCU within the own service area
- GPRS attach procedure of the MS
- GPRS detach procedure of the MS
- authentication of the MS

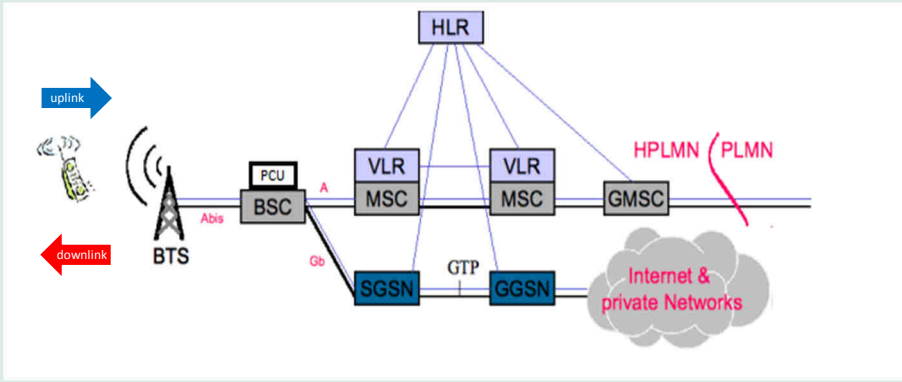
Gateway GPRS support node (GGSN)

- The Gateway GPRS Support Node (GGSN) is the gateway connecting the GPRS core network to external packet-oriented data networks such as the Internet.
- The GGSN stores the following information:
- Status of the MS of each GRPS subscriber
- SGSN to which each active GPRS subscriber is assigned to
- By using the GPRS Tunneling Protocol (GTP) the GGSN sets up a tunnel to the SGSN to send data packets from the external networks to the SGSN.

Several SGSNs can be connected to one GGSN.

General Packet Radio Service (GPRS)

Architecture



Universal Mobile Telecommunication System (UMTS)

Release 3

- It includes a GSM / GPRS core network combined with a Wideband Code Division Multiple Access (WCDMA) based radio access network.
- New RAN network. UMTS Terrestrial Radio Access Network (UTRAN) has been introduced. UTRAN consists of:
  - Node B
  - Radio Network Controller (RNC) – together Radio Network Subsystem (RNS)

Release 4

- Bearer Independent Core Network (BICN) mechanism is implemented.
- In Release 4 there have been some technical improvements also in the network architecture to deploy an All-IP core network by the introduction of the following new network elements:
  - MSC server
  - Media Gateway

Release 5

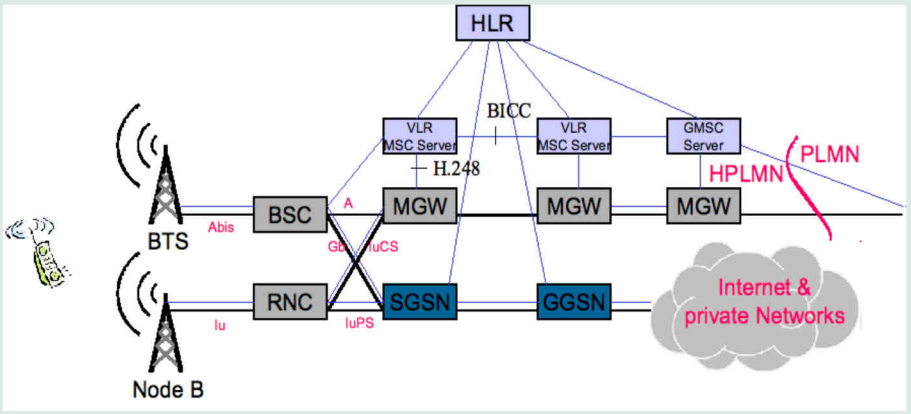
- The major upgrade of UMTS has been presented with Release 5 by the addition of:
  - High Speed Downlink Packet Access (HSDPA)
  - IP Multimedia Subsystem (IMS) = Module A4

Release 7

- Release 7 introduces
  - High Speed Packet Access Evolution (HSPA+)
  - Decreasing latency and Quality of Service (QoS) improvements
  - Integration of real-time applications like Voice over IP (VoIP)

Universal Mobile Telecommunication System (UMTS)

Architecture



Enhancements

Node B

The Node B is the UMTS counterpart of the GSM Base Transceiver Station (BTS) with developed antenna systems.

Radio Network Controller

The Radio Network Controller (RNC) owns and controls the radio resources of the connected.

- Administration of the radio resources for all connected cells
- Control of the usage of radio channels
- Transmitter power control
- Control of handover procedures
- The RNC is connected to the Circuit Switched (CS) domain and Packet Switched (PS) domain of the Core Network (CN), and it is also connected to the other RNCs.

MSC Server

- The MSC Server terminates and translates the user-network signaling over the Nc interface.
- It also terminates the signaling over the Mc interface with the multimedia gateway thus acting as a media gateway controller.
- The MSC Server is integrated with a VLR to hold the mobile subscribers' service data.

Media Gateway

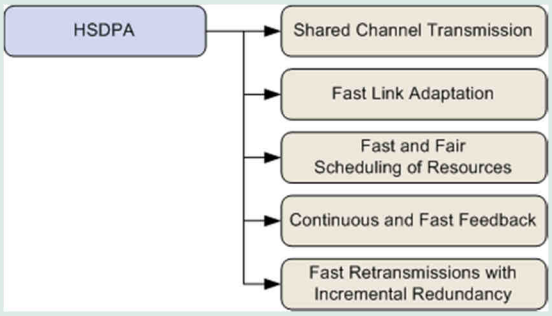
A media gateway is a translation device or service that converts digital media streams between disparate telecommunications networks

Because the media gateway connects different types of networks, one of its main functions is transcoding.

Enhancements

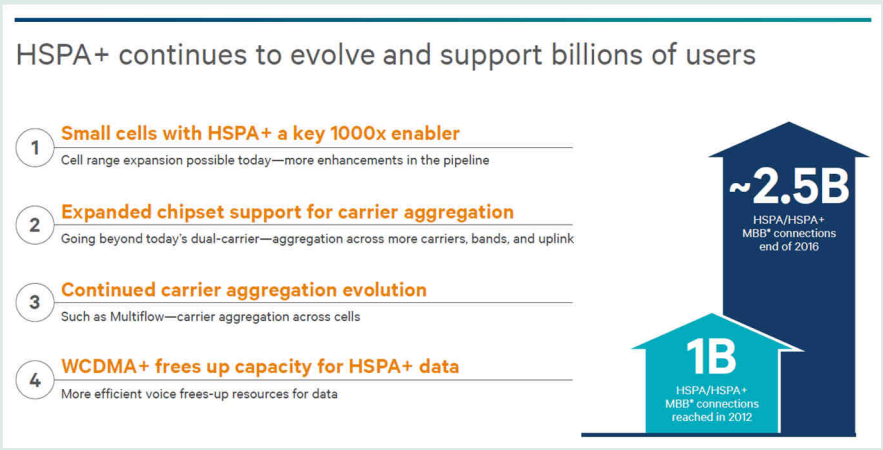
High Speed Downlink Packet Access (HSDPA)

- provide data rates up to approximately 8–10 Mbps to support packet-based multimedia services
- shared downlink packet data channel
- high peak data rates
- shortens the round-trip time reduces variance in downlink transmission delay
- Using a short frame length to further accelerate packet scheduling for transmission.
- Adapting the modulation and coding scheme according to the quality of the radio link



Enhancements

High Speed Downlink Packet Access (HSPA+)



Long Term Evolution (LTE)

- Long Term Evolution (LTE) is the name for a new mobile communication system after UMTS
- LTE is not a technical enhancement of UMTS but a completely new system which was intended to replace UMTS.
- LTE consists of a new network architecture which is called the Evolved Packet System (EPS).
- It uses Orthogonal Frequency Division Multiple Access (OFDMA) as new multiple access technology in the radio access network.
  - The EPS replaces the UMTS network architecture.
  - OFDMA replaces Code Division Multiple Access (CDMA) of UTRAN

Evolved Packet Core (EPC)

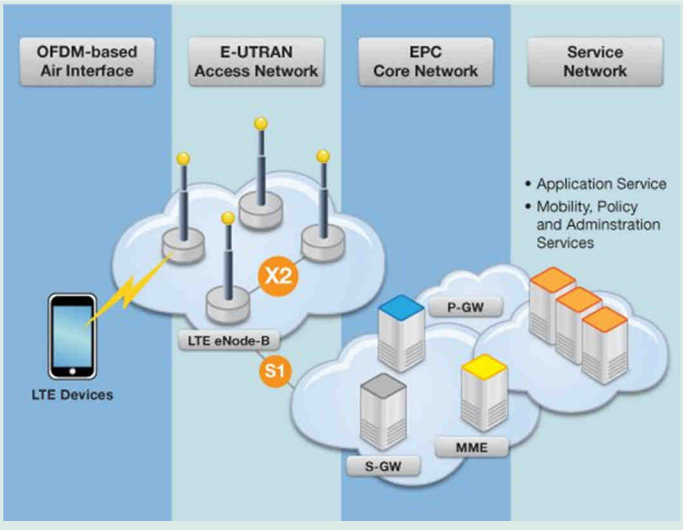
- Optimization of packet transfer providing lower latency
- Access to the EPC also from non-3GPP access networks
- Handover between 3GPP access networks and non-3GPP access networks (UMTS, HSPA, HSPA+, LTE) (VLAN, WiMAX)

- Clear separation of control plane and user plane
- Optimized handover to the following networks:

GSM EDGE Radio Access Network (GERAN)
UTRAN including High Speed Packet Access (HSPA)
3GPP2 High Rate Packet Data (HRPD) networks

Long Term Evolution (LTE)

Architecture



Long Term Evolution (LTE)

Architectural Components

Mobility Management Entity
The Mobility Management Entity (MME) is a control plane node.
- Authentication
- Authorization
- Location management
- Session management
- Roaming

Serving Gateway
The Serving Gateway (S-GW) is a user plane node. It is comparable with the SGSN
- Mobility support by switching the route to the eNB
- Termination of the RAN traffic
- Forwarding of user traffic
- Support of Quality of Service (QoS) management

Packet Data Network Gateway
The Packet Data Network Gateway (PDN-GW) provides connectivity to external networks. It is comparable with GGSN
- Forwarding of user traffic
- Provision of IP addresses to the handsets using the (DHCP)
- Support of QoS management
- Packet filtering

Thanks a world for participating

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