الجامعة التكنولوجية/ قسم علوم الحاسوب

# Wireless Techniques

## 4th class –Network Management Branch

د. اسيا علي سلمان

**Second course 2024-2025**

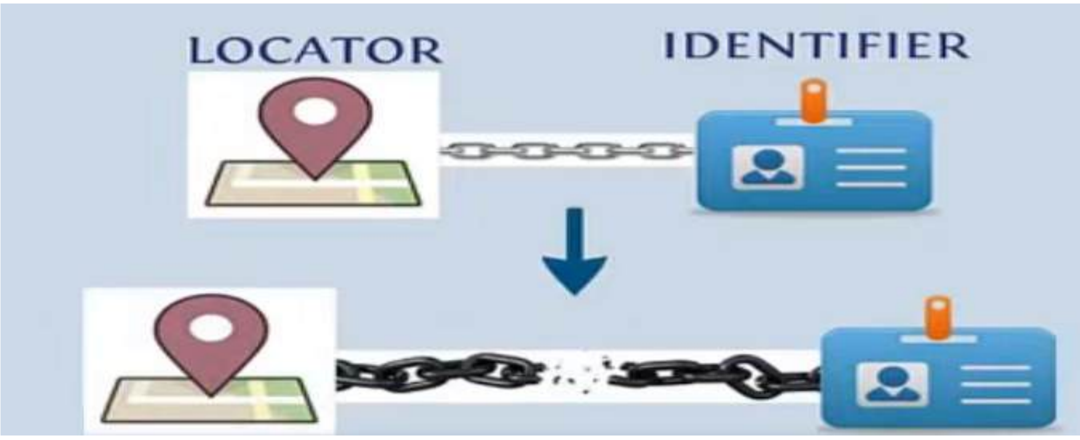
# Mobile Network layer

In previous lectures, we explain the physical and data link layer

| TCP/IP Protocol Stack | |
|---|---|
| 5 | Application |
| 4 | Transport |
| 3 | Internet |
| 2 | Data Link |
| 1 | Physical |

} WiFi

The network layer function is to support mobility. The most prominent example is Mobile IP.




The IP ( Internet protocol) designers have designed it to be the locator and the identifier of a node and combined them together.

Mobile IP is the standard that allows users using mobile devices whose IP is associated with one network to stay connected when moving to other networks.

In Mobile IP, this chain separated in to define several entities as follows

**Mobile Node (MN)**

- Laptop, PDA, etc.. that may move about.

**Home address:** is the address of the MN in its home network

**Home Agent (HA)**

- Router in home network of the MN, helps in forwarding messages to the mobile node when the MN outside the homenetwok.
- registers current MN location, tunnels IP datagrams to COA

**Foreign Agent (FA)** Router in current foreign network of MN

- forwards tunneled datagrams to the MN Care-of Address (COA)

- address of the current tunnel end-point for the MN (at FA or MN)
- can be chosen, e.g., via DHCP

NOTE: **Care-of address (COA): the new address of the MN in the outside network,**The COA defines the current location of the MN
from an IP point of view.

**Correspondent Node (CN)**

- Node that wants to communicate with MN, the CN can be a fixed or mobile node.

## Home Network

- No mobile IP support is needed within the home network

## Foreign network

- The foreign network is the current subnet the MN visits and which is not the home network.

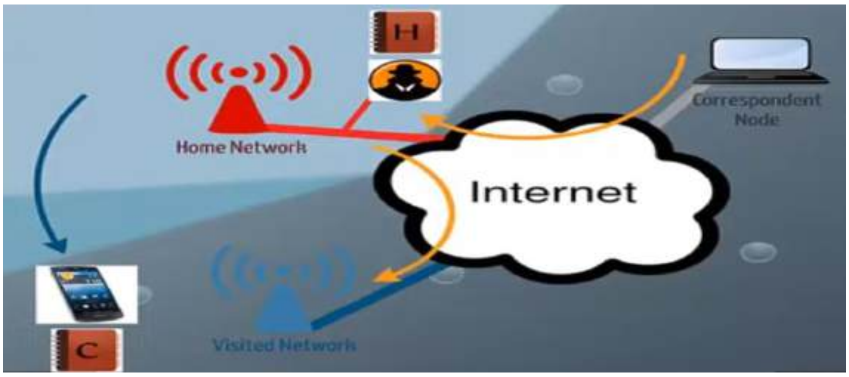

Session continuity from foreign network to local network. Reachability communication must be possible where the mobile node is (moving or stable in the same place)

Mobility not including mobile phone or a laptop. It can be any of the following (1) terminal (host) mobility where the host change his point of attachment when a node change the access point to another access point. (2) Network mobility change its point of attachment. A train with a Wi-Fi can be the network that in a train that is moving and keeps changing its association. For example, a network is the train and its keep on changing the access points as it is moving.

(3) Session mobility: communication session means transfer from one device to other one. For example, you are watching on your mobile some video and wanted to transfer it or continue it on the TV.

**How mobile IP works?**

Suppose a home network with a home agent connected to it and to the Internet. If the MN moves from its home network to a foreign network and in the foreign network, and there is a corresponding node that tries to send messages to the MN. The corresponding node will use the home address of MN that the corresponding node already knows. The message will be intercepted by the home agent, which will look up for the new address of the MN in the care of address or the new network. The home agent will encapsulate the message it just received and set the destination address to the MN care of address using **tunnelling protocol***. The message then tunnelled to the MN new address in the foreign network.




***t**unneling protocol is a communications protocol that allows for the movement of data from one network to another. It involves allowing private network communications to be sent across a public network (such as the Internet) through a process called encapsulation.

## Mobile ad-hoc network:

Mobility relies on the existence of at least some infrastructure. Mobile IP requires, e.g., a home agent, tunnels, and default routers.

DHCP requires servers and broadcast capabilities of the medium reaching all participants or relays to servers.

Cellular phone networks require base stations, infrastructure networks etc.

However, sometimes, users of a network cannot rely on an infrastructure, it is too expensive, or there is none at all. In these situations, mobile ad-hoc networks are the only choice.

## Mobile ad-hoc network provides several functions:

- **Instant infrastructure:**
- **Disaster relief**
- **Remote area**

Main topic: routing

- no default router available
- every node should be able to forward

## Mobile Transport Layer

Supporting mobility only on lower layers up to the network layer is not enough to provide mobility support for applications. Most applications rely on a transport layer, such as TCP (transmission control protocol) or UDP (user datagram protocol) in the case of the internet.

***Two functions of the transport layer in the internet:***

- *checksum over user data
- *Multiplexing/de-multiplexing of data from/to applications.

*The **TCP**/IP **checksum** is used to detect corruption of data over a **TCP** or IPv4 connection.IPv4 uses the **checksum** to detect corruption of packet headers. i.e. the source, destination, and other data. The **TCP** protocol includes an extra **checksum** that protects the packet "payload" as well as the header.

*****Transport layer gathers chunks of data it receives from different sockets and encapsulate them with transport headers. Passing these resulting segments to the network layer is called multiplexing. The reverse process which is delivering data to the correct socket by the transport layer is called de-multiplexing.

**While the network layer function**

- addresses a host, ports in UDP or TCP
- allow dedicated applications to be addressed.
- The connectionless UDP does not offer much more than this addressing

UDP is connectionless and does not give certain guarantees about reliable data delivery, TCP is much more complex and, needs special mechanisms to be useful in mobile environments. Mobility support in IP (such as mobile IP) is already enough for UDP to work. The main difference between UDP and TCP is that TCP offers connections between two applications. Within a connection TCP can give certain guarantees, such as in-order delivery or reliable data transmission using retransmission techniques. TCP has built-in mechanisms to behave in a ‘network friendly’.

One of the main reasons to stay with protocols like TCP is that when TCP encounters packet loss, it assumes network internal congestion and slows down the transmission rate. This is. One key requirement for new developments in the internet is ‘TCP friendliness’. UDP requires that applications handle reliability, in-order delivery etc. UDP does not behave in a network friendly manner, i.e., does not pull back in case of congestion and continues to send packets into an already congested network.

## Traditional TCP

Several mechanisms of the transmission control protocol (TCP) that influence the efficiency of TCP in a mobile environment. A transport layer protocol such as TCP has been designed for

- fixed networks
- fixed end-systems.

# Wireless Network

**2nd course lecture 2**

1. The transport layer in wireless network

**Lecturer: Dr. Asia Ali**

## ➢ TCP Congestion control in Fixed Network

The probable reason for a packet loss in a fixed network is ***a temporary overload some point in the transmission path, i.e., a state of congestion at a node***.

The packet buffers of a router are filled and the router cannot forward the packets fast enough because the sum of the input rates of packets destined for one output link is higher than the capacity of the output link.

- Timeouts/Packet loss typically due to (temporary) overload.
- Routers discard packets when buffers are full.
- TCP recognizes congestion only indirectly via missing ACKs, retransmissions unwise, since they increase congestion.
- slow-start algorithm as reaction.

## 1. TCP Slow start algorithm

The behaviour TCP to get rid of congestion quickly i.e. after the detection of the congestion is called **slow start.**

- The sender always calculates a **congestion window*** for a receiver.
- The start size of the congestion window is one segment (TCP packet).
- The sender sends one packet and waits for acknowledgement.
- If this acknowledgement arrives, the sender increases the congestion window by one, now sending two packets (congestion window = 2).
- After arrival of the two corresponding acknowledgements, the sender again adds 2 to the congestion window, one for each of the acknowledgements.
- This scheme doubles the congestion window every time the acknowledgements come back. This is called the exponential growth of the congestion window in the slow start mechanism. The exponential growth stops at the **congestion threshold**.
- Linear increase continues until a time-out at the sender occurs due to a missing acknowledgement, or until the sender detects a gap in transmitted data because of continuous acknowledgements for the same packet.
- Congestion window starts again with one segment (TCP packet).

*The **congestion window** (**CWND**) is a state variable maintained independently **at each host calculated** to estimate how much **congestion** there is on the link.

## 2- Fast retransmit/fast recovery

*Two things lead to a reduction of the congestion threshold.*

One is a sender receiving continuous acknowledgements for the same packet.

**This informs the sender of two things.**

One is that the receiver got all packets up to the acknowledged packet in sequence. In TCP, a receiver sends acknowledgements only if it receives any packets from the sender. Receiving acknowledgements from a receiver also shows that the receiver continuously receives something from the sender.

The gap in the packet stream **is not due to severe congestion**, but a simple packet loss due to a transmission error. The sender retransmit the missing packet(s) before the timer expires. This behaviour is called **fast retransmit**. No need to use **a slow start**. The sender can continue with the current congestion window. The sender performs a **fast recovery** from the packet loss.

## ➢ Influences of Wireless/mobility on TCP-mechanisms

slow start is one of the most useful mechanisms in fixed networks. However, in wireless network it not because of the use of slow start under the wrong assumptions. From a missing acknowledgement, TCP concludes a congestion situation. However, the main reason for packet loss in networks with mobile and wireless end-systems is transmission error.

Mobility itself can cause packet loss. For example, when using mobile IP, there could still be some packets in transit to the old foreign agent while the mobile node moves to the new foreign agent. The old foreign agent may not be able to forward those packets to the new foreign agent or even buffer the packets if disconnection of the mobile node takes too long. This packet loss has nothing to do with wireless access but is caused by the problems of rerouting traffic.

## ➢ The performance of an unchanged TCP degrades severely

- TCP cannot be changed fundamentally due to large installed base in the fixed network, TCP for mobility has to remain compatible
- the basic TCP mechanisms keep the whole Internet together

## ➢ Classical TCP improvements

***There are several mechanisms for the classical TCP improvements with the goal to increase tcp's perfromance in wireless and mobile environment***

*1- Indirect TCP 2- snooping TCP 3- mobile TCP 4- Fast retransmit/fast recovery*
*5 transmission/time-out freezing 6- selective retransmission 7- transaction oriented TCP*

# 1. Indirect TCP(I-TCP)

**Two reasons for creating this improvement**

1. TCP performs poorly together with wireless links; 2. TCP within the fixed network cannot be changed.

*I-TCP segments a TCP connection into a fixed part and a wireless part.*

Figure 1 shows an example with a mobile host connected via a wireless link and an access point to the 'wired' internet where the correspondent host resides. The correspondent node could also use wireless access.

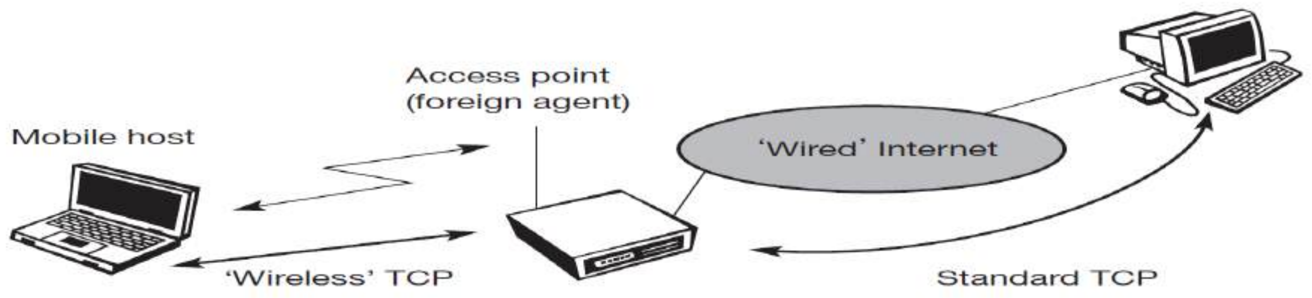



Figure 1- Indirect TCP segments a TCP connection into two parts

***The following would then also be applied to the access link of the correspondent host*.**

- Standard TCP is used between the fixed computer and the access point. No computer in the internet recognizes any changes to TCP.

- Instead of the mobile host, the access point now terminates the standard TCP connection, acting as a proxy. This means that the access point is now seen as the mobile host for the fixed host and as the fixed host for the mobile host.

- Between the access point and the mobile host, a special TCP, adapted to wireless links, is used.

- changing TCP for the wireless link is not a requirement. Even an unchanged TCP can benefit from the much shorter round trip time.

- A good place for segmenting the connection between mobile host and correspondent host is at the foreign agent of mobile IP

- foreign agent controls the mobility of the mobile host anyway and can also hand over the connection to the next foreign agent when the mobile host moves on.

I-TCP requires several actions as soon as a handover takes place.

As Figure 2 demonstrates, not only the packets have to be redirected using, e.g., mobile IP. In the example shown *the access point acts as a proxy buffering packets for retransmission*. After the handover, the old proxy must forward buffered data to the new proxy because it has already acknowledged the data. After registration with the new foreign agent, this new foreign agent can inform the old one about its location to enable packet forwarding. Besides buffer content, the sockets of the proxy, too, must migrate to the new foreign agent located in the access point. The socket reflects the current state of the TCP connection, i.e., sequence number, addresses, ports etc. No new connection may be established for the mobile host, and the correspondent host must not see any changes in connection state.

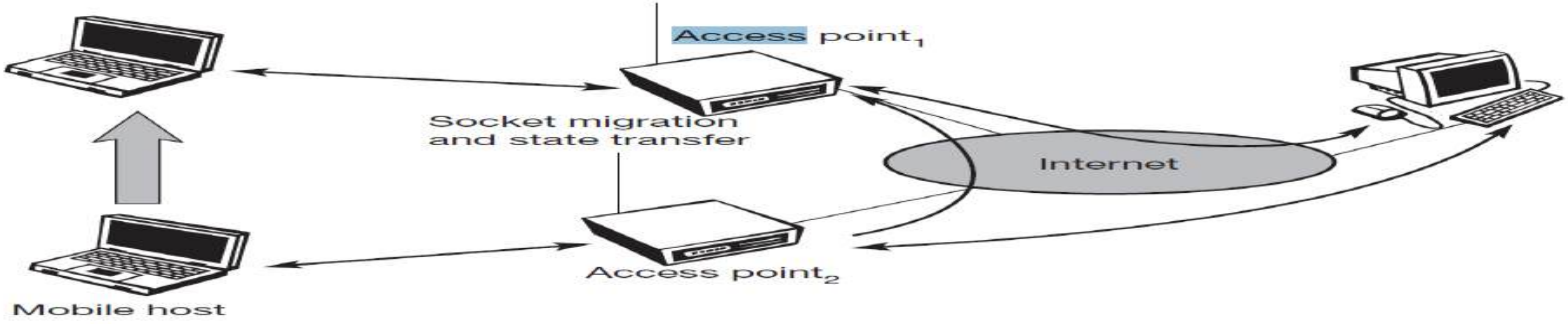



Figure 2- Socket and state migration after handover of a mobile host

## ➢ There are several advantages with I-TCP:

● I-TCP does not require any changes in the TCP protocol. All current optimizations for TCP still work between the foreign agent and the correspondent host.

● simple to control, mobile TCP is used only for one hop between, e.g., a foreign agent and mobile host

● Due to the strict partitioning into two connections, transmission errors on the wireless link, i.e., lost packets, cannot propagate into the fixed network.

● therefore, a very fast retransmission of packets is possible, the short delay on the mobile hop is known.

## ❖ But the idea of segmentation in I-TCP also comes with some disadvantages:

● The loss of the end-to-end semantics of TCP might cause problems if the foreign agent partitioning the TCP connection . An acknowledgement to a sender does now not any longer means that a receiver really got a packet. Foreign agent might crash.

● latency may be much more problematic. All packets sent by the correspondent host are buffered by the foreign agent besides forwarding them to the mobile host (if the TCP connection is split at the foreign agent). Latency also occur when moving from foreign agent to another foreign agent.

# 2-Snooping TCP

One of the drawbacks of I-TCP is the segmentation of the single TCP connection into two TCP connections. This loses the original end-to-end TCP semantic.

***The following TCP enhancement works completely transparently and leaves the TCP end-to-end connection intact.***

The main function of the enhancement is to buffer data close to the mobile host to perform fast local retransmission in case of packet loss.

A good place for the enhancement of TCP could be the foreign agent (see Figure 3).

***In this approach:***

-The foreign agent buffers all packets with **destination mobile host** and additionally 'snoops' the packet flow in both directions to recognize acknowledgements.

- The reason for buffering packets toward the mobile node is to enable the foreign agent to perform a local retransmission in case of packet loss (both direction) on the wireless link.
- The foreign agent buffers every packet until it receives an acknowledgement from the mobile host.
- If the foreign agent does not receive an acknowledgement from the mobile host within a certain amount of time, either the packet or the acknowledgement has been lost.
- Alternatively, the foreign agent could receive a duplicate ACK, which also shows the loss of a packet.
- The foreign agent retransmits the packet directly from the buffer, performing a much faster retransmission compared to the correspondent host.
- The time out for acknowledgements can be much shorter, because it reflects only the delay of one hop plus processing time.

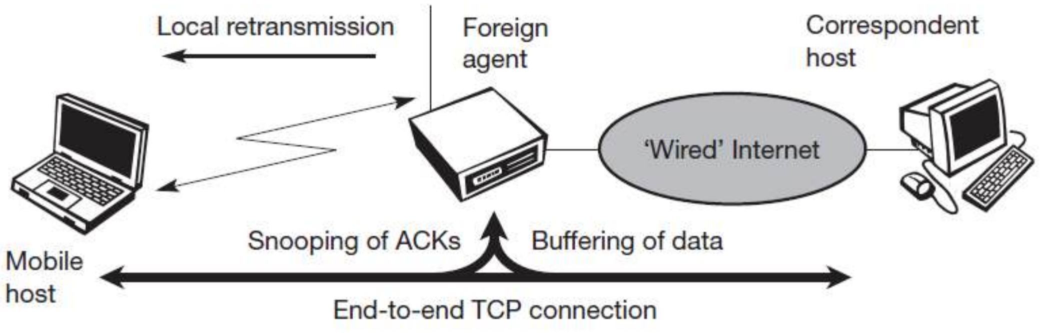



Figure 3- Snooping TCP as a transparent TCP extension

**To remain transparent TCP in Foreign agent:**

- The foreign agent must not acknowledge data to the correspondent host. This would make the correspondent host believe that the mobile host had received the data and would violate the end-to-end semantic in case of a foreign agent failure.
- However, the foreign agent can filter the duplicate acknowledgements to avoid unnecessary retransmissions of data from the correspondent host.
- If the foreign agent now crashes, the time-out of the correspondent host still works and triggers a retransmission.
- The foreign agent may discard duplicates of packets already retransmitted locally and acknowledged by the mobile host. This avoids unnecessary traffic on the wireless link.

**Data transfer from the mobile host with destination correspondent host works as follows.**

- The foreign agent snoops into the packet stream to detect gaps in the sequence numbers of TCP.
- As soon as the foreign agent detects a missing packet, it returns a negative acknowledgement (NACK) to the mobile host.
- The mobile host can now retransmit the missing packet immediately.
- Reordering of packets is done automatically at the correspondent host by TCP.

**Extending the functions of a foreign agent with a ‘snooping’ TCP has several advantages:**

- The end-to-end TCP semantic is preserved.
- The correspondent host does not need to be changed;
- It does not need a handover of state as soon as the mobile host moves to another foreign agent.
- It does not matter if the next foreign agent uses the enhancement or not. If not, the approach automatically falls back to the standard solution.

**The scheme also results in some disadvantages**

- snooping TCP does not isolate the wireless link as good as I-TCP
- snooping might be tough if packets are encrypted

# Wireless Network

## 2nd course lecture 3

- Continue with the transport layer in wireless network

**Lecturer: Dr. Asia Ali**

*Continue with the new approaches for TCP in lecture 2 we talk about snooping TCP. Here the other methods.*

## 3- Early approach: Mobile TCP

Mobile TCP has the same goals of I-TCP and snooping TCP. M-TCP wants to improve overall throughput, to lower the delay, to maintain end-to-end semantics of TCP, and to provide a more efficient handover. Additionally, M-TCP is especially adapted to the problems arising from lengthy or frequent disconnections.

***As *I-TCP does M-TCP splits the TCP connection into two parts.***

- An unmodified TCP is used on the standard host-**supervisory host (SH)** connection. (fixed networks)
- optimized TCP is used on the SH-MH connection (wireless nodes).

***The supervisory host***

- Is responsible for exchanging data between both parts similar to the proxy in I-TCP. The M-TCP approach assumes a relatively low bit error rate on the wireless link. Therefore, it does not perform caching/retransmission of data via the SH.
- If a packet is lost on the wireless link, it has to be retransmitted by the original sender.

*As we have explained before I-TCP splits the TCP into shared TCP and wireless TCP

***Advantages***

- This maintains the TCP end-to-end semantics.
- The SH monitors all packets sent to the MH and ACKs returned from the MH. If the SH does not receive an ACK for some time, it assumes that the MH is disconnected.
- SH then chokes the sender by setting the sender's window size to 0 (the sender automatically goes into persistent mode).
- Since it does not buffer data in the SH as I-TCP does, it is not necessary to forward buffers to a new SH. Lost packets will be automatically retransmitted to the new SH.

***The lack of buffers and changing TCP on the wireless part also has* some disadvantages:**

- As the SH does not act as proxy as in I-TCP, packet loss on the wireless link due to bit errors is propagated to the sender (fixed network).
- M-TCP assumes low bit error rates, which is not always a valid assumption.

# 4- Fast retransmit/fast recovery

Changing to a new foreign agent can cause packet loss or time out at mobile hosts or corresponding hosts. TCP concludes congestion and goes into slow start, although there is no congestion.

**Forced fast retransmit**

- As soon as the mobile host has registered with a new foreign agent, the MH sends duplicated acknowledgements on purpose
- This forces the fast retransmit mode at the communication partners.
- Additionally, the TCP on the MH is forced to continue sending with the actual window size and not to go into slow-start after registration.

**Advantage**

- ❑ simple changes result in significant higher performance
- ❑ No foreign agent or correspondent host has to be changed

***The main disadvantage of this scheme***

- ❑ Cooperation required between IP and TCP, making it harder to change one without influencing the other (no transparent approach).
- ❑ Forcing fast retransmission increases the efficiency, but retransmitted packets still have to cross the whole network between correspondent host and mobile host.

# 5- Transmission/time-out freezing

This method has been designed for mobile host when it goes on a longer interruption time because of losing the connection**.** Examples are the use of mobile hosts in a car driving into a tunnel, which loses its connection to, e.g., a satellite. The result will be ( No packet exchange possible and TCP disconnects after time out completely).

## TCP freezing

- the MAC layer has already noticed connection problems, before the connection is actually interrupted from a TCP point of view.
- the MAC layer knows the real reason for the interruption and does not assume congestion, as TCP would.
- The MAC layer can inform the TCP layer of an upcoming loss of connection or that the current interruption is not caused by congestion.
- TCP can now stop sending and ‘freezes’ the current state of its congestion window and further timers. If the MAC layer notices the upcoming interruption early enough, both the mobile and correspondent host can be informed.
- MAC layer signals again if reconnected.

**Advantage**

Scheme is independent of data

**Disadvantage**

TCP on mobile host has to be changed, mechanism depends on MAC layer

## 6- Selective retransmission

TCP acknowledgements are cumulative, i.e., they acknowledge in-order receipt of packets up to a certain packet.
If a single packet is lost, the sender has to retransmit everything starting from the lost packet (go-back-n retransmission).
This obviously wastes bandwidth, not just in the case of a mobile network, but also for any network (particularly those with a high path capacity, i.e., bandwidth delay-product).

Using RFC 2018 Technique, TCP can indirectly request a selective retransmission of packets. The receiver can acknowledge single packets, not only trains of in-sequence packets. The sender can now determine precisely which packet is needed and can retransmit it.

**The advantage of this approach is:**

- A sender retransmits only the lost packets. This lowers bandwidth requirements and is extremely helpful in slow wireless links, (much higher efficiency).
- Using selective retransmission is also beneficial in all other networks.

**There might be the minor disadvantage:**

- more complex software on the receiver side, because now more buffer is necessary to re-sequence data and to wait for gaps to be filled at the receiver side.

## 7- Transaction-oriented TCP

Assume an application running on the mobile host that sends a short request to a server from time to time, which responds with a short message. If the application requires reliable transport of the packets, **it may use TCP** (many applications of this kind use UDP and solve reliability on a higher, application-oriented layer).

*Using TCP now requires several packets over the wireless link.*

- TCP uses a three-way handshake to establish the connection.
- At least one additional packet is usually needed for transmission of the request
- Requires three more packets to close the connection via a three-way handshake.
- Assuming connections with a lot of traffic or with a long duration, this overhead is minimal. But in an example of only one data packet, TCP may need seven packets altogether.

**This led to the development of a transaction-oriented TCP (T/TCP, RFC 1644).**

- T/TCP can combine packets for connection establishment and connection release with user data packets.
- This can reduce the number of packets down to two or three instead of seven.

**The advantage**

- reduction in the overhead which standard TCP has for connection setup and connection release(efficiency).

**A major disadvantage**

- T/TCP is not the original TCP anymore, so it requires changes in the mobile host and all correspondent hosts.
- Mobility not longer transparent.
- Furthermore, T/TCP exhibits several security problems.

# Comparison of different approaches for a “mobile” TCP

| Approach | Mechanism | Advantages | Disadvantages |
| --- | --- | --- | --- |
| Indirect TCP | splits TCP connection into two connections | isolation of wireless link, simple | loss of TCP semantics, higher latency at handover |
| Snooping TCP | “snoops” data and acknowledgements, local retransmission | transparent for end-to-end connection, MAC integration possible | problematic with encryption, bad isolation of wireless link |
| M-TCP | splits TCP connection, chokes sender via window size | Maintains end-to-end semantics, handles long term and frequent disconnections | Bad isolation of wireless link, processing overhead due to bandwidth management |
| Fast retransmit/ fast recovery | avoids slow-start after roaming | simple and efficient | mixed layers, not transparent |
| Transmission/ time-out freezing | freezes TCP state at disconnect, resumes after reconnection | independent of content or encryption, works for longer interrupts | changes in TCP required, MAC dependant |
| Selective retransmission | retransmit only lost data | very efficient | slightly more complex receiver software, more buffer needed |
| Transaction oriented TCP | combine connection setup/release and data transmission | Efficient for certain applications | changes in TCP required, not transparent |

# Wireless Network

## 2nd course lecture 4

- Wide-Area Wireless Networks (WANs)
- GSM Evolution

Lecturer: Dr. Asia Ali

# Global System for Mobile communications (GSM Evolution)

- GSM second generation (2G) digital systems is widely used standard for mobile phones.
- GSM describes the protocols for second-generation (2G) digital cellular networks used by mobile devices such as mobile phones and tablets.
- In the 1G the wireless transmission is in analog format ( poor voice quality connection and security). Uses frequency division multiple access which uses the available spectrum in an inefficient way. 1$^{st}$ generation GSM used 400MHZ and 450MHZ.
- GSM is **a circuit-switched network**; ideal for the delivery of voice but with limitations for sending data.
- In 2000 the introduction of General Packet Radio Service (GPRS) added **packet-switched functionality to GSM network**, (starting the delivery of the Internet on mobiles).
- GSM systems provide data rates of up to 100 Kbps by aggregating all timeslots together for a single user.
- Text messaging and even low speed internet access. Multimedia messaging was added to its list of features allowing subscribers to send pictures, audio clips, and even short video clips to each other.
- GSM needs base transceiver station module to communicate with mobile device.
- Mobile device can change base transceiver station based on coverage and capacity.
- GSM operates in different frequency bands, 900MHZ and 1800 MHZ allocated for GSM communication.
- USA and Canada use 850MHZ and 1900MHZ for GSM.
- Europe and Asia GSM service is on 900 and 1800 MHZ bands.
- The GSM standard uses a combination of TDMA and slow frequency hopping with frequency-shift keying for the voice modulation.
- EDGE… almost 3G:The next advance in GSM radio access technology was EDGE (Enhanced Data rates for Global Evolution), or Enhanced GRPS.

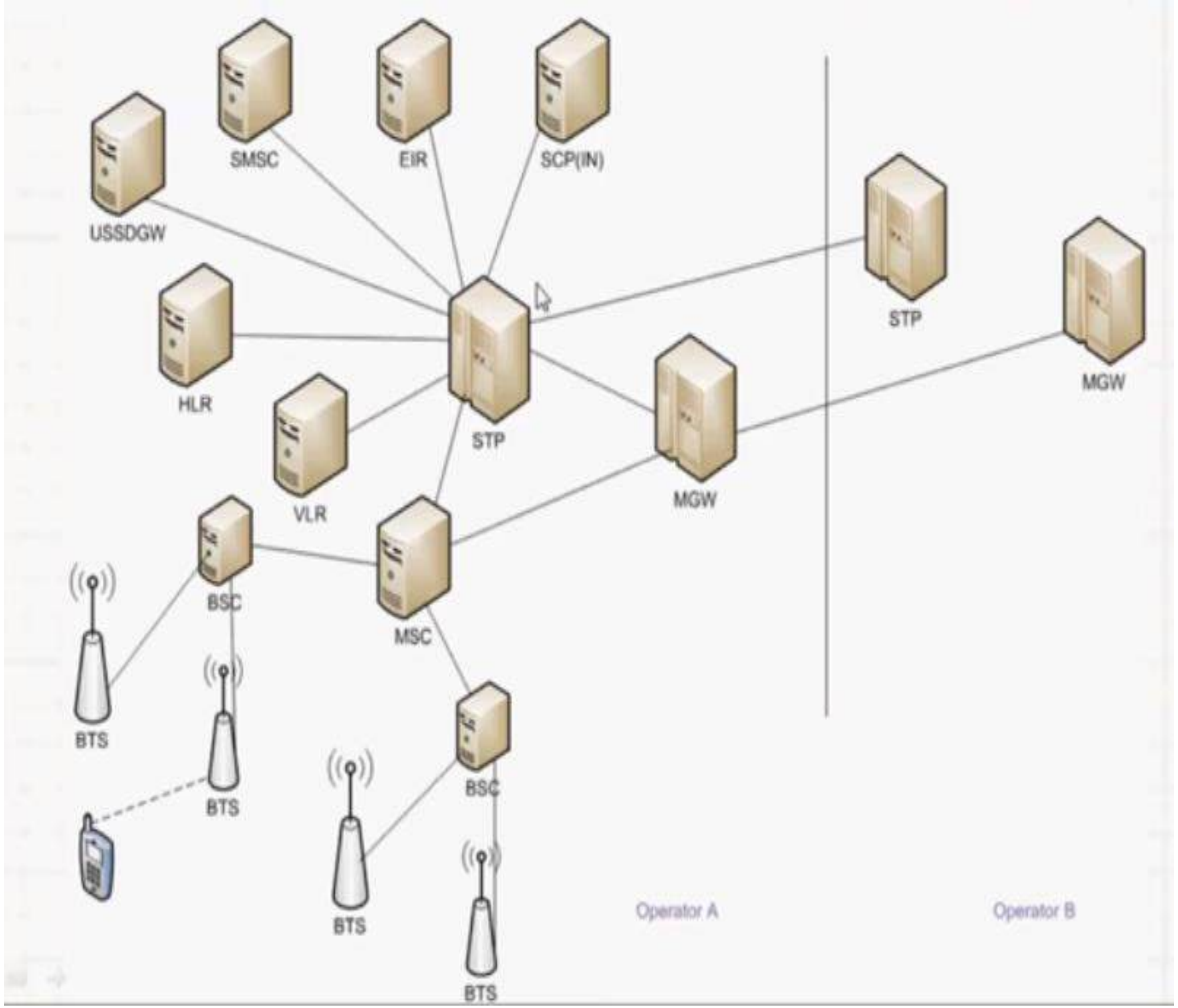



*Figure 1-GSM network architecture*

- BTS : Base transceiver station
- BSC : Base station controller
- MSC : Mobile switching center
- HLR : Home location register
- VLR : Visitor location Register
- STP : Signal Transfer Point
- MGW : Media Gateway
- EIR : Equipment identity Register
- SMSC : Short Message Service Center
- USSD : Unstructured Supplementary Service Data
- SIM : Subscriber identity module
- ICCID : Integrated Circuit Card Identifier
- IMSI : International Mobile Subscriber Identity
- MSISDN : Mobile Subscriber ISDN Number
- IMEI : International Mobile (Station) Equipment Identity
- GPRS : General Packet Radio Service
- GGSN : Gateway GPRS support node
- SGSN : Serving GPRS support node
- EDGE : Enhanced Data Rates for GSM evolution
- HSPA : High-Speed Packet Access
- LTE : Long Term Evolution
- 3GPP : 3rd Generation Partnership Project
- ETSI : European Telecommunications Standards Institute
- APN : Access point name
- PDP : Packet Data Protocol
- WAP : Wireless Application Protocol
- MMS : Multimedia Messaging Service
- MMSC : Multimedia Messaging Service Center

**Signal Transfer Point (STP)**: is the Signal Transfer Point, STP is message router used between GSM signal end points and other STPs. it is the centre for operator A (network A).
If there is no STP the MSC (Mobile Switching Center) is the centre for operator A (network A).
The nodes (USSDGW, SMSC, EIR, SCP(IN), HLR, VLR) are connected to the STP and they are for processing the signals only.

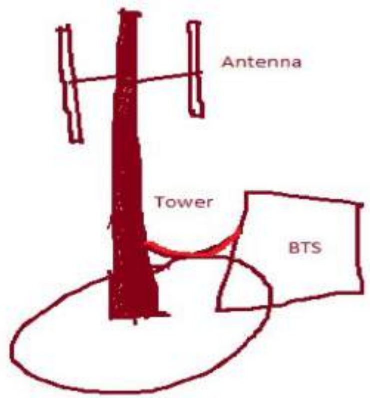
**Media Gateway (MGW ):** is the Media Gateway or voice getaway. A MGW is a circuit switch or IP gateway that converts voice packet/data from format A to Format B required by the destination or connected network/end points.

Both the STP and MGW are connected to each other and to the external network operator B.
The field level network is the BTS (Base transceiver station) all the mobiles are connected to BTS. Group of BTS connected with BSC (Base Station Controller). One MSC can cover number of BSC. We can have more than one MSC in one network.

## Base Transceiver Station

- BTS is a wireless transmission and receiving terminal.
- All mobile devices connected with a nearest BTS.
- A group of BTS connected with a BSC
- Each BTS has an ID number in the network, based on site and capacity it can be separated

to 3-6 cell. there is an antenna for each cell.




## Base Station Controller

- BSC is a GSm node that controls one or more BTS in the network. BTS can be connected using microwave or optical fiber.
- BSC connected with MSC for voice and signal communication. For data communication, it's connected with Serving GPRS support node (SGSN).
- Mobile devices handover intelligence between BTS which is called BTS handover and call setup controlled by BSC.
- Radio network management including radio frequency controlled by BSC.

## Mobile Switching Center

- MSC is the sub canter of large network or centre of small network(GSM core network)
- MSC is related with switching, call setup , release
- MSC control a group of BSC.
- In large GSM network MSC connected with STP for signal routing and MGW for voice switching.

## Home Register Locater (HRL)

HRL is a central database contain mobile subscribers details information which is used for core network. Every subscriber should be identified with IMSI/MSISDN pair and uniquely associated with one HRL.

## Visitor Location Register

•VLR is a subscriber database having subscribers details information. VLR response will be faster than HLR, VLR store some additional information for which HLR need to communicate with voice network or radio network.

## Mobile Subscriber ISDN number

MSISDN is a unique number for every mobile subscriber.

### *MSISDN format*

| Cc | NDC/NPA | SN |
|---|---|---|

Cc: country code
NDC: national Destination Code
NPA: Numbering Plan Area
SN: Subscriber Number
Example: 0088-014-12345678

## Subscriber Identity Module

•SIM is a physical module provided to subscriber.
•MSISDN is mapped with the SIM in reference with IMIS.
•SIM is electronic circuits that store some encrypted data written by service provider.
•3 type of SIM available (MINI-MICRO-Nano)

## Mobile Subscriber ISDN number

MSISDN is a unique number for every mobile subscriber.

## Integrated Circuit Card Identifier

ICCID is unique identification number for SIM.
It is 20 digit.

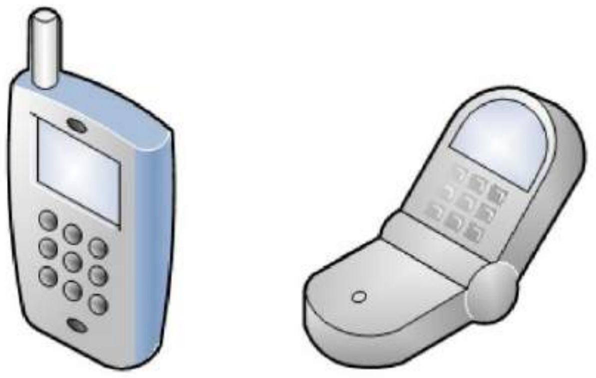
## Short Message Service Center

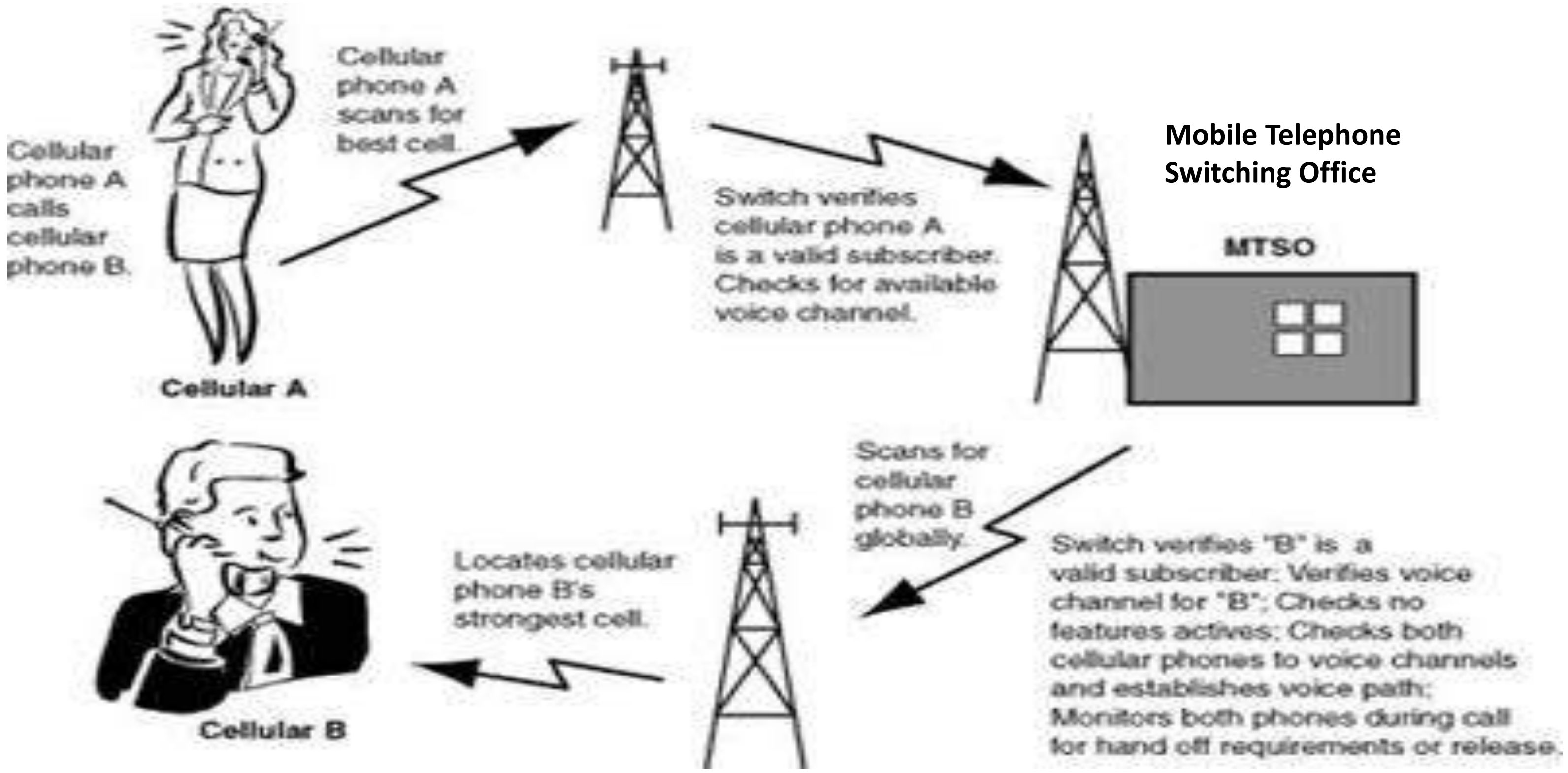
•SMSC is a node that deliver SMS to subscriber. Any SMS either from subscriber to subscriber or application to subscriber must be sent via a SMSC.

- Every subscriber SIM store a service center number where the subscriber initiated SMS send.
- SMSC communicate with HLR for subscriber location and VLR for delivering the SMS.

## Mobile device

- Wireless transceiver module that will communicate with Base Transceiver Station (BTS).
- Voice and data communication module where voice and data can be used simultaneously.
- Several types of mobile devices available now. Categories based on capability of 2G and 3G.





## International Mobile Equipment Identity

- IMEI is a universal unique number for mobile device.
- It's a 15 or 17 digit number where last digit is the checksum. Using the IMEI GSM network can lock the stolen device
- To check the IMEI user need to enter *#06#

## General Packet Radio Service

- GPRS is packet based data service for mobile users in GSM.
- GPRS charged based on volume instead of minutes in circuit switched network.
- Based on GPRS GSM provider offers MMS, Internet, push to talk service

## Gateway GPRS Support Node

- **GGSN** is the main component of the GPRS network and this is the gateway between the GPRS network and external packet data networks like Internet.
- From network point of view GGSN is a router to a sub network.
- GGSN convert address the data packet coming from SGSN to GSM address of the destination user.

## Serving GPRS Support Node

- SGSN handles all packet switched data within the network.
- Packet routing, packet transfer, mobility management .
- SGSN stores user location and user profiles. All data users must be registered in SGSN to get GPRS service.

## High-Speed Packet Access

- HSPA is a combination of two protocol HSDPA (High speed downlink packet access) and HSUPA (High speed uplink packet access)
- HSPA extends and improves the performance of existing 3G mobile telecommunication networks utilizing the *WCDMA protocol
- Evolved HSPA (HSPA+) is a improved 3GPP standard

## 3rd Generation Partnership Project

•3GPP is a collaboration between groups of telecommunication association who prepare globally applicable 3G mobile phone system speciation based on GSM speciation

## European Telecommunications Standards Institute

- ETSI is an independent non-profit standardization organization in Europe telecommunications industry, **Global System for Mobile Communications** (**GSM**) is a standard developed by them.

## Long Term Evolution

- LTE is incompatible with GSM 2G/3G network and it need a separate radio spectrum. It reduces signifcant transfer latency for IP based system.
- LTE together with WiMax and HSPA+ know as 4G

* *Wideband Code Division Multiple Access (**WCDMA**) is a third-generation (3G) standard that employs the direct-sequence code division multiple access (DS-CDMA) channel access method and the frequency-division duplexing (FDD) method to provide high-speed and high-capacity service.*

# Wireless Network

## 2nd course lecture 5

*Lecture outlines*

- Case study in GSM
- General Packet Radio Service (GPRS)
- The Universal Mobile Telecommunications System (UMTS)

Lecturer: Dr. Asia Ali

# Case study: How a mobile phone works in a simple explanation ?

When we speak using our mobile phones, the microphone in the mobile picks the voice and change it to digital signals the antenna inside the phone convert the 0 and 1 to electromagnetic signal.

In the case of freq., 0 and 1 sent as a waves. And in the case of having a long distance call as electromagnetic waves cannot travel long distance and the earth is carved is another problem. Cellular network created to have cell towers in a hexagon shape to create national and international connections.

At the base of a tower there is a base box in the ground for signal processing (BTS).to be sent by BTC to the destination tower (BTS) to be received by the user.

There is a big issue: the mobile communication is successful only when your tower sent to the destination tower of the destination user, but how they can know each other?

The use of the mobile switching center (MSC). The center point of the cell tower.

When we buy a sim card all the subscription information will be registered in a specified MSC which is your home MSC service plans your current location and your activities status. As we move from place to other you inter into a foreign MSC . as we get on a foreign MSC the foreign connect to your home MSC. Therefore, your home MSC knows in which MSC area you are entering. MSC uses number of technique:

1. Time based update the home MSC in predefined time.
2. Location area based ( from tower to tower until your home MSC now your location when the phone turned on.

If client (A) calls client (B) and A is in his home the home MSC the call will sent to his cell tower in his area.

If B is not in his home. The home MSC of B forward the call request to the foreign MSC. And the call request. then the same previously explained procedure works.

## General Packet Radio Service (GPRS)

Is a Mobile Data Service accessible to GSM and IS-136 mobile phones users. This service is packet-switched and several number of users can divide the same transmission channel for transmitting the data.

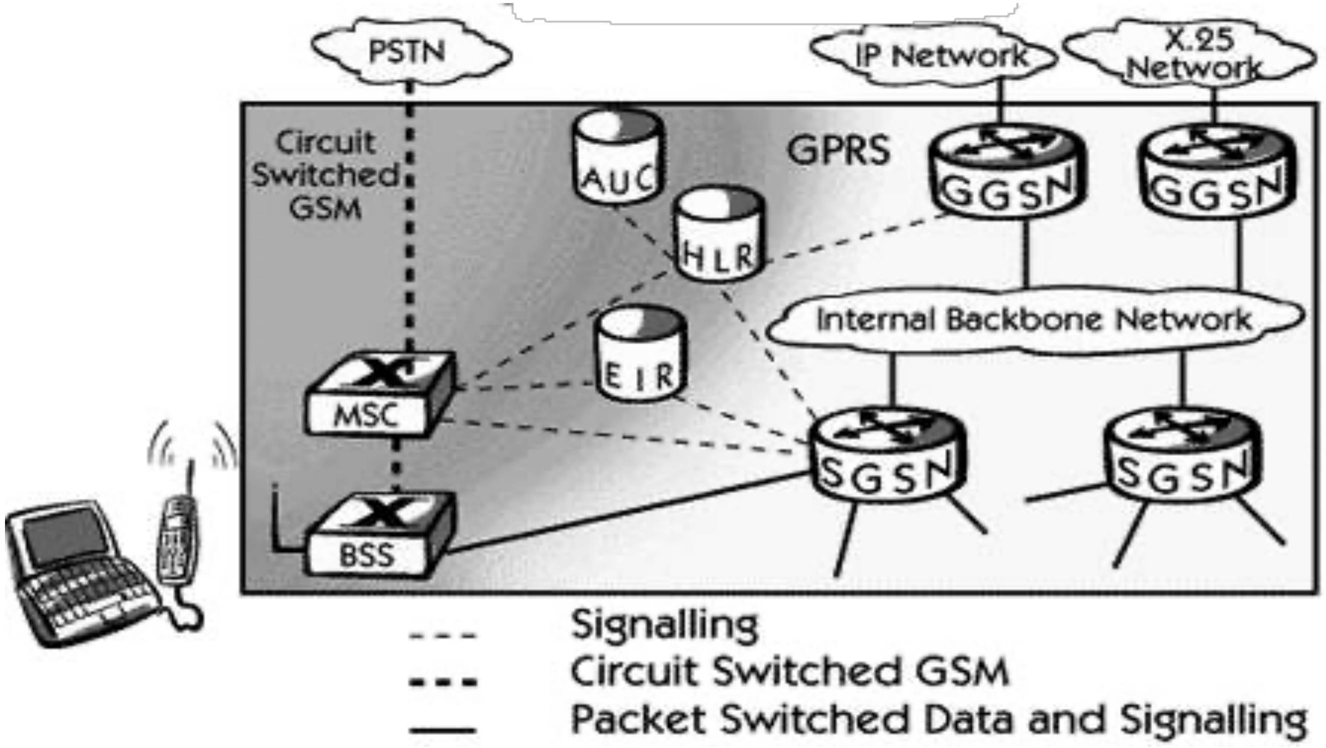
### Who owns GPRS ?

The GPRS specifications are written by the European Telecommunications Standard Institute (ETSI), the European counterpart of the American National Standard Institute (ANSI).

### Higher Data Rate

GPRS offer higher data rates in turn of shorter access times. In the typical GSM mobile, 9.6 kbit/s. GPRS data rates are up to many 10 kbit/s.

**GPRS architecture** works on the same procedure like GSM network, but, has additional entities that allow packet data transmission. This data network overlaps a second-generation GSM network providing packet data transport at the rates from 9.6 to 171 kbps. Along with the packet data transport the GSM network accommodates multiple users to share the same air interface resources concurrently. Following is the GPRS Architecture diagram:




GPRS reuse the existing GSM network elements, but to effectively build a packet-based mobile cellular network, some new network elements, interfaces, and protocols for handling packet traffic are required. Therefore, GPRS requires modifications to numerous GSM network elements as summarized below:

| GSM Network Element | Modification or Upgrade Required for GPRS. |
| --- | --- |
| **Mobile Station (MS)** | New Mobile Station is required to access GPRS services. These new terminals will be backward compatible with GSM for voice calls.to handle enhanced air interface or packet data. A variety of MS can exist, including a high-speed version of current phones to support high-speed data access, a new PDA device with an embedded GSM phone, and PC cards for laptop computers. |
| **BTS** | A software upgrade is required in the existing Base Transceiver Station(BTS). |
| **BSC** | The Base Station Controller (BSC) requires a software upgrade and the installation of new hardware called the packet control unit (PCU). The PCU directs the data traffic to the GPRS network and can be a separate hardware element associated with the BSC.<br><br>When either voice or data traffic is originated at the subscriber mobile, it is transported over the air interface to the BTS, and from the BTS to the BSC in the same way as a standard GSM call. However, at the output of the BSC, the traffic is separated; voice is sent to the Mobile Switching Center (MSC) per standard GSM, and data is sent to a new device called the SGSN via the PCU over a Frame Relay interface. |
| **GPRS Support Nodes (GSNs)** | The deployment of GPRS requires the installation of new core network elements called the serving GPRS support node (SGSN) and gateway GPRS support node (GGSN). |
| **Databases (HLR, VLR, etc.)** | All the databases involved in the network will require software upgrades to handle the new call models and functions introduced by GPRS. |

## Serving GPRS Support Node (SGSN)

The Serving GPRS Support Node is responsible for:

- Authentication of GPRS mobiles
- Registration of mobiles in the network
- Mobility management
- Collecting information on charging for the use of the air interface.

## Internal Backbone

The internal backbone is an IP based network used to carry packets between different GSMs. Tunnelling is used between SGSNs and GGSNs, so the internal backbone does not need any information about domains outside the GPRS network. Signalling from a GSN to a MSC, HLR or EIR is done using SS7.

## Routing Area

GPRS introduces the concept of a Routing Area. This concept is similar to Location Area in GSM, except that it generally contains fewer cells. Because routing areas are smaller than location areas, less radio resources are used While broadcasting a message.

# Overview of The Universal Mobile Telecommunications System (UMTS) Terrestrial Radio access network

- UMTS based on the GSM standards and it is developed by 3GPP (3 Generation Partnership Project) a joint venture of several organization. First mobile broadband utilizing IP protocols.
- 3G UMTS is a third-generation (3G): broadband, packet-based transmission of text, digitized voice, video, multimedia at data rates up to 2 Mbps. video calling, that allows people to see each other while talking.
- Also referred to as wideband code division multiple access (WCDMA) which can achieve speeds of up to 7.2mbps
- provide new services like alternative billing methods or calling plans.
- The higher bandwidth also enables video conferencing or IPTV.
- Once UMTS is fully available, computer and phone users can be constantly attached to the Internet wherever they travel and, as they roam, will have the same set of capabilities.
- A primary assumption for UMTS is that it is based on an evolved GSM core network. The core network supports both **GSM** and **UMTS/IMT-2000** services, including handoff and roaming between the two.
- UMTS retains voice and data domains, e.g. different gateways and servers for voice and data.
- The proposed WCDMA based UMTS terrestrial radio access network (UTRAN) is connected to the GSM-UMTS core network using a new multi-vendor interface (**Iu**). The transport protocol within the new radio network and the core network will be IP.  (see Figure 1).

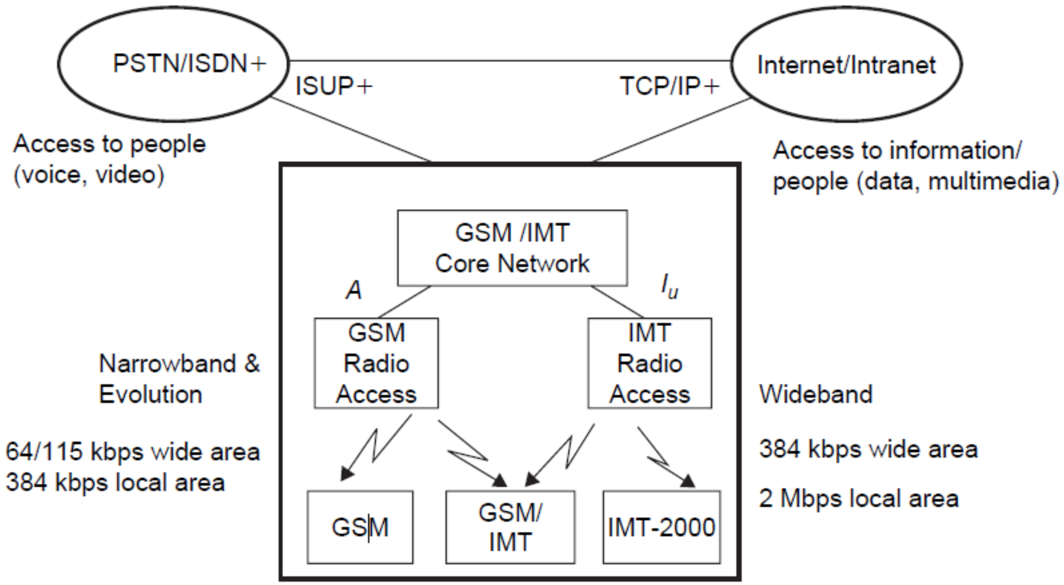



*Figure 1- **Evolution to UMTS/IMT-2000 in a GSM environment.***

*IMT-2000 stands for International Mobile Telecommunications-2000, is an initiative of the International Telecommunication Union (ITU) to create a global standard for wireless data networks.

**ISDN (Integrated Services Digital Network) User Part** or **ISUP** is part of Signaling System No. 7 (SS7)

## Purpose

• The Dream was that 2G and 2.5G systems are incompatible around the world.

- Worldwide devices need to have multiple technologies inside of them, i.e. *tri-band phones, dual-mode phones.

• To develop a single standard that would be accepted around the world.

-One device should be able to work anywhere.

• Increased data rate.

- Maximum 2048Kbps

*Most current TDMA **phones** in the U.S. are **tri-mode**, meaning they can use both analog and digital in the 800/850 **band**. **Dual-band** CDMA **phones** can be **dual-mode** or **tri-mode**. **Dual-mode phones** only support analog or digital on the 800/850 **band**, while **tri-mode phones** support both. The 1900 MHz **band** is always digital.

There is a clear separation between the services provided by UTRAN and the actual channels used to carry these services. All radio network functions (such as resource control) are handled within the radio access network and clearly separated from the service and subscription functions in the UMTS core network (UCN). The GSM-UMTS network, shown in Figure 2, consists of three main entities:

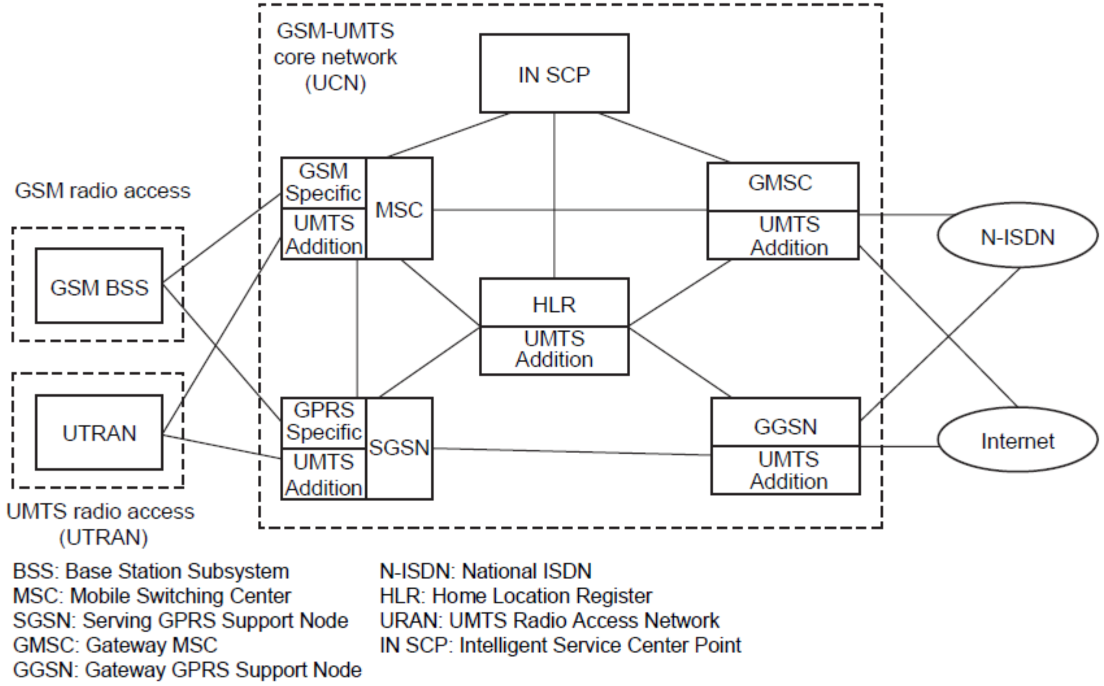



*Figure 2- **General GSM-UMTS network architecture.***

GSM-UMTS core network (UCN)

UMTS terrestrial radio access network (UTRAN)

GSM base station subsystem (BSS) Like the GSM-GPRS core network

The GSM-UMTS core network has two different parts: a circuit-switched MSC and a packet-switched GRPS support node (GSN).

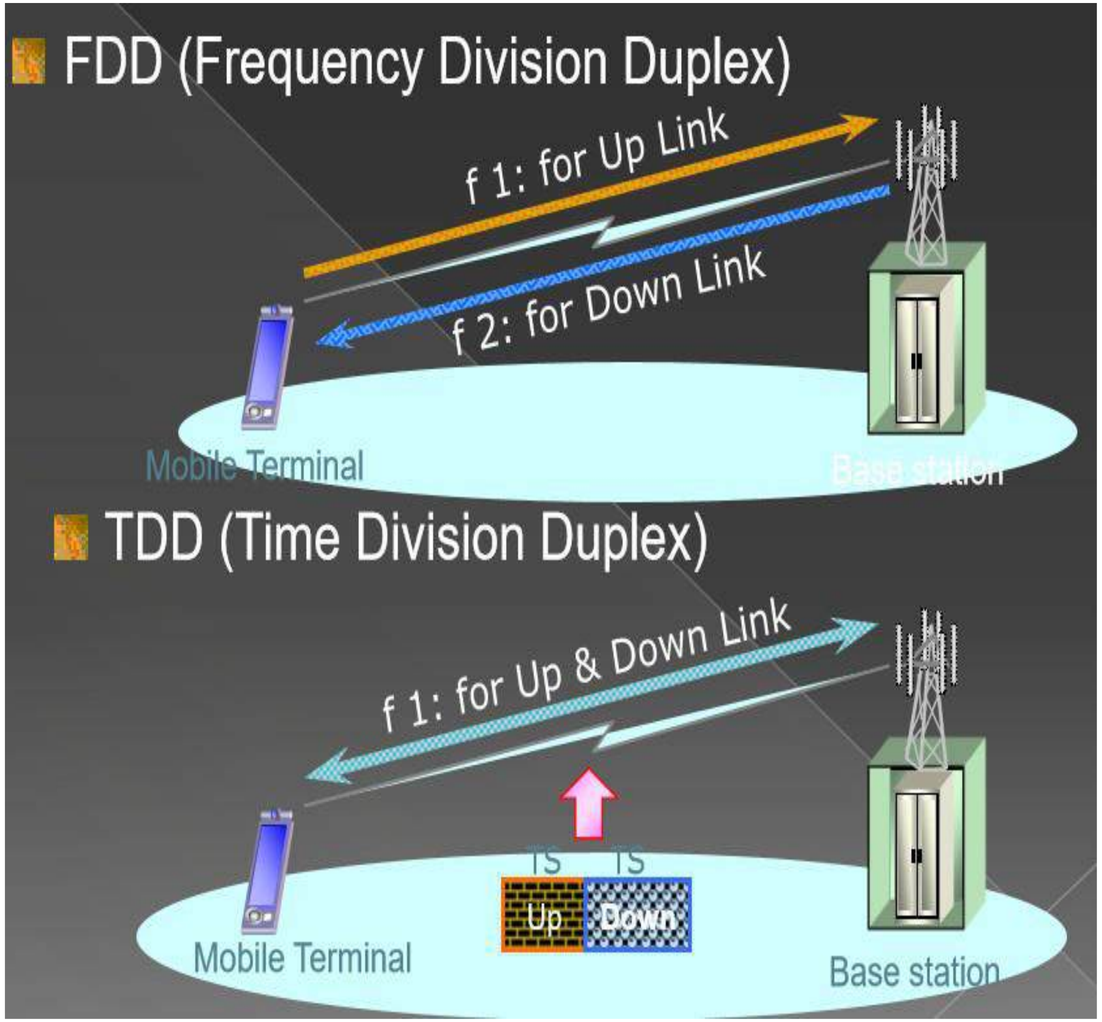
The core network access point for GSM circuit-switched connections is the GSM MSC, and for packet-switched connections it is the SGSN.

# UMTS Modes

It has two modes.
I) UMTS-FDD
ii) UMTS-TDD.

In **frequency division duplex** mode there are two frequencies used one for the uplink and the other for the downlink.

In **Time division duplex** mode only one frequency is used for both uplink and downlink, but the frequency is divided into time slots for uplink and downlink communication

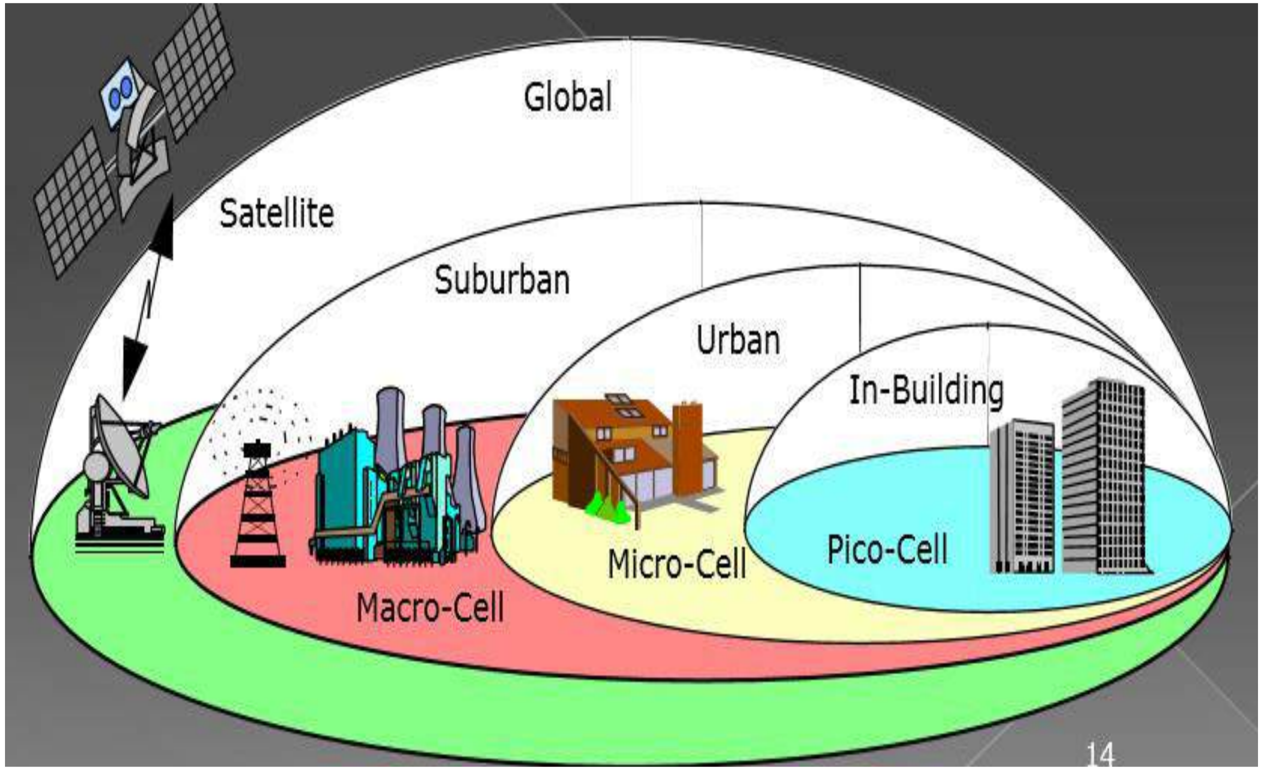


# Types of Cells and its Data Rates

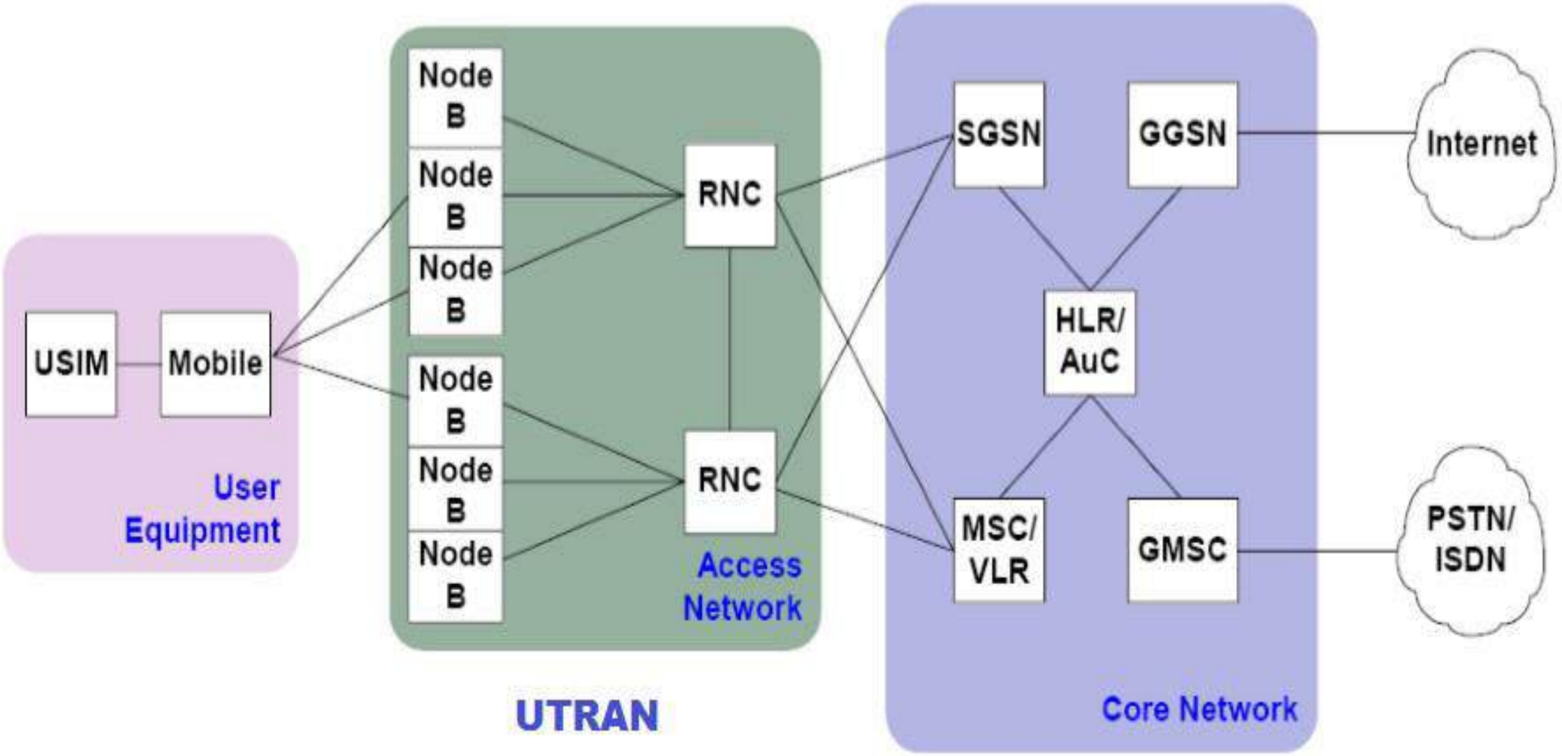
- › **Macro Cell**
- These cover a large area and will give slow access.
- 144 Kbps – max speed of 500 Km/h. Low data rate.

- › **Micro Cell**
- These should cover a medium area.
- 384 Kbps max speed 120 Km/h. Medium data rate.

- › **Pico Cell**
- Less than 100 metres.
- 2 Mbps – max speed of 10 Km/h. High data rat



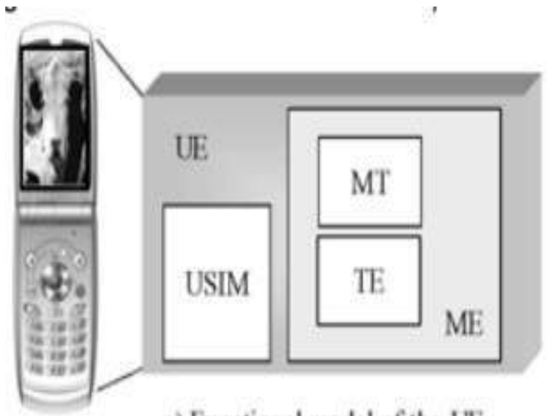
# Architecture of UMTS



## 1- User Equipment

- It is not a simple mobile phone but rather, a mobile multimedia terminal provides simultaneously voice, video and data services.

- UE is composed of two parts
- Mobile Equipment(ME)
- Universal subscriber identity module (USIM).



a) Functional model of the UE

### 1.1 Mobile Equipment

- It performs reliable data and signalling message transfer throughout the radio Interface.

- User data is generated in uplink and processed in the downlink, Application protocols such as WAP/IP are located in the TE.

### 1.2 USIM

Information located in USIM are:

- The personal identification Number(PIN). -
- The preferred languages
- The codes to enable emergency call
- One or several IMSI and MSISDN.
- The user's temporary identities allocated.
- Circuit and packet switched temporary location information.

## 2- UTRAN

- The UMTS(UMTS Terrestrial Radio Access network) has two elements:

- RNC
- Node B.

- UTRAN is subdivided into individual radio network (RNS), where each RNS is controlled by RNC.
- The RNC is connected to a set of Node B elements, each of which can serve one or several cells.

## 2.1 RNC

- The RNC enables autonomous radio resource management (RRM) by UTRAN.
- The RNC handles protocol exchanges between Iu, Iur and Iub interfaces
- The RNC uses the Iur interface for eliminating the burden from CN.
- Provide air interface between UE's and Core Network).

## 2.2 Node B

- Node B is the physical unit for radio TX/RX with cells.
- A single Node B can support both FDD and TDD modes.
- The Main task of Node B is the conversion of data to and from th Uu radio interface, including forward error correction (FEC)
- Node B also participates in power control.

## 3. Core Network

The UMTS core network may be split into two different areas:

**Circuit switched elements**

Carry data in a circuit switched manner, i.e. a permanent channel for the duration of the call.

**Packet switched elements**

Carry packet data. This enables much higher network usage as the capacity can be shared and data is carried as packets which are routed according to their destination.

### 3.1 Circuit switched elements

The circuit switched elements of the UMTS core network architecture include the following network entities:

**Mobile switching center (MSC)**

An exchange performing all the switching and signalling functions

**Functions**

–call management
–mobility management(handling attach and authentication)
–subscriber administration
–maintenance of charging data(for radio network usage)
–supplementary call services (call forwarding, etc.)

### 3.2 Packet switched elements

The packet switched elements of the 3G UMTS core network architecture include the following network entities:

**Serving GPRS Support Node (SGSN)**

The SGSN provides a number of functions within the UMTS network architecture.

- Mobility management
- Session management:
- Interaction with other areas of the network:
- Billing:

### 3.3 Shared Elements

The shared elements of the 3G UMTS core network architecture include the following network entities:

**Home location register (HLR)**

Contains all the administrative information about each subscriber along with their last known location

**Equipment identity register (EIR)**

The EIR is the entity that decides whether a given UE equipment may be allowed onto the network or not on the basis of IMEI.

**Authentication centre (AuC)**

The AuC is a protected database that contains the secret key also contained in the user's USIM card.

**Gateway MSC (GMSC)**

–Provides interconnection between the UMTS core network and external PSTN/ISDN networks.

**Gateway GPRS Support Node (GGSN):**

- Central element in UMTS.
- It handles inter-working between the UMTS packet switched network and external packet switched networks.

# Wireless Network

## $2^{nd}$ course lecture 6

***Lecture outlines***

- UMTS Core Network Architecture
- UMTS - WCDMA Technology
- UMTS – High-speed Packet Access (HSPA) Standardization And Deployment

Lecturer: Dr. Asia Ali

## UMTS Core Network Architecture

The figure-1 in the next slide shows the UMTS core network (UCN) in relation to all other entities within the UMTS network and all of the interfaces to the associated networks.

The **UCN** consists of a CS entity for providing voice and CS data services and a PS entity for providing packet-based services. The logical architecture offers a clear separation between the CS domain and PS domain.

**The CS domain contains the functional entities:**

- Mobile switching center (MSC)
- Gateway MSC (GMSC) .

**The PS domain comprises the functional entities:**

- Serving GPRS support node (SGSN)
- Gateway GPRS support node (GGSN)
- Domain name server (DNS).
- Dynamic host configuration protocol (DHCP) server
- Packet charging gateway, and firewalls

***The core network can be split into the following different functional areas:***

- Functional entities needed to support PS services (e.g. 3G-SGSN, 3G-GGSN)
- Functional entities needed to support CS services (e.g. 3G-MSC/VLR)
- Functional entities common to both types of services (e.g. 3G-HLR).
- Other areas that can be considered part of the core network include: Network management systems (billing and provisioning, service management, element management, etc.)

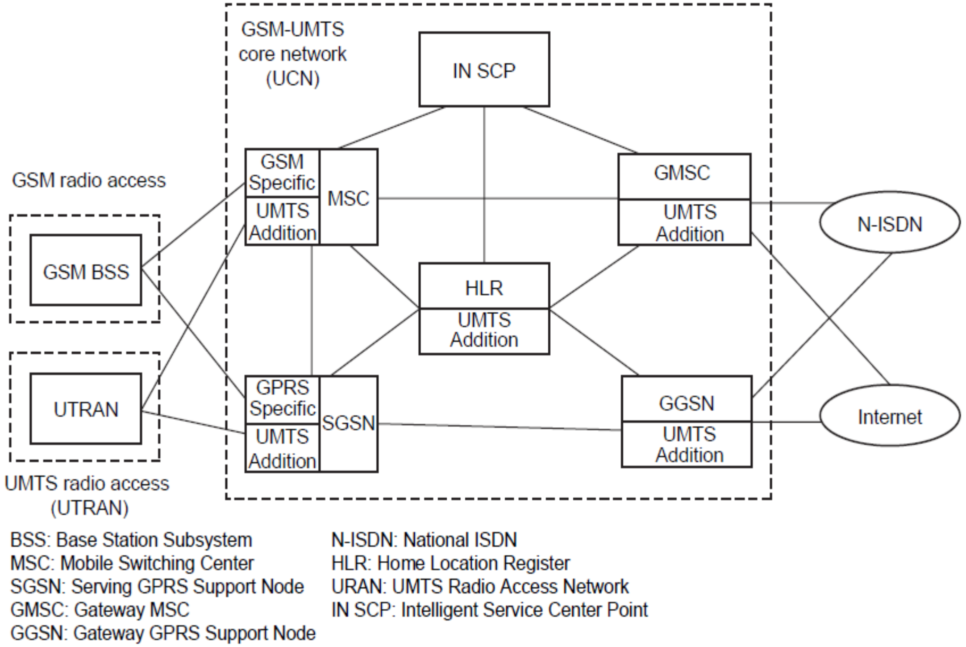



Figure-1- *General GSM-UMTS network architecture*

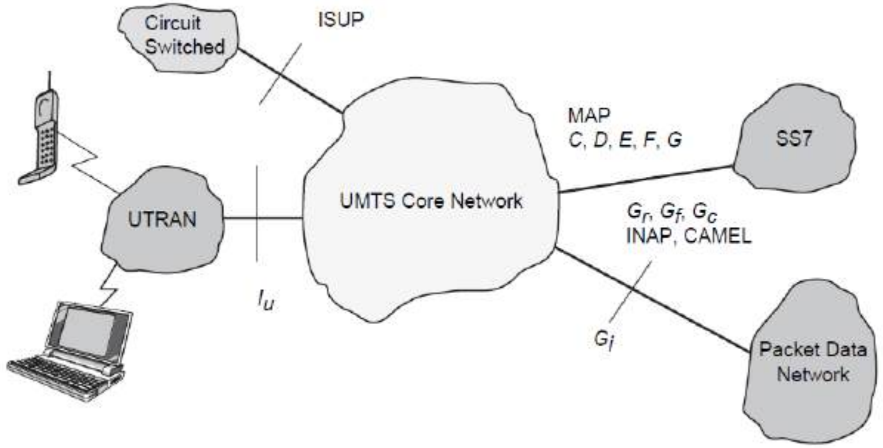



Figure-2- the entities that connect to the core network

Figure 2 - Shows all the entities that connect to the core network — UTRAN, PSTN, the Internet and the logical connections between terminal equipment Mobile Station(MS) and User Equipment(UE), and the PSTN/Internet.

**PSTN** (public switched telephone network) is the world's collection of interconnected voice-oriented public telephone networks. **PSTN** stands for public switched telephone network, or the traditional circuit-switched telephone network.

**UTRAN**: is a term for the network and equipment that connects mobile handsets to the public telephone network or the Internet.

**CAMEL**: Customized application for mobile network enhanced logic.

# UMTS - WCDMA Technology

- Wideband CDMA is a third-generation (3G) wireless standard which allows use of both voice and data and offers data speeds of up to 384 Kbps.
- WCDMA is also called UMTS and the two terms have become interchangeable.
- The first Multiple Access Third Generation Partnership Project (3GPP) Wideband Code Division networks (WCDMA) were launched in 2002.
- At the end of 2005, there were 100 WCDMA networks open and a total of more than 150 operators with licenses for frequencies WCDMA operation.

- WCDMA networks are deployed in UMTS band of around 2 GHz in Europe and Asia, including Japan and America.
- WCDMA is deployed in the 850 and 1900 of the existing frequency allocations.
- 3GPP has defined WCDMA operation for several additional bands-it allows WCDMA networks to carry a greater share of voice and data traffic.
- WCDMA can offer a lot more voice minutes to customers with better quality.
- WCDMA can also improve broadband voice service, which clearly provides better voice quality than fixed telephone landline.
- In addition to the high spectral efficiency, third-generation (3G) WCDMA provides even more changes in capacity of the base station and the efficiency of the equipment.

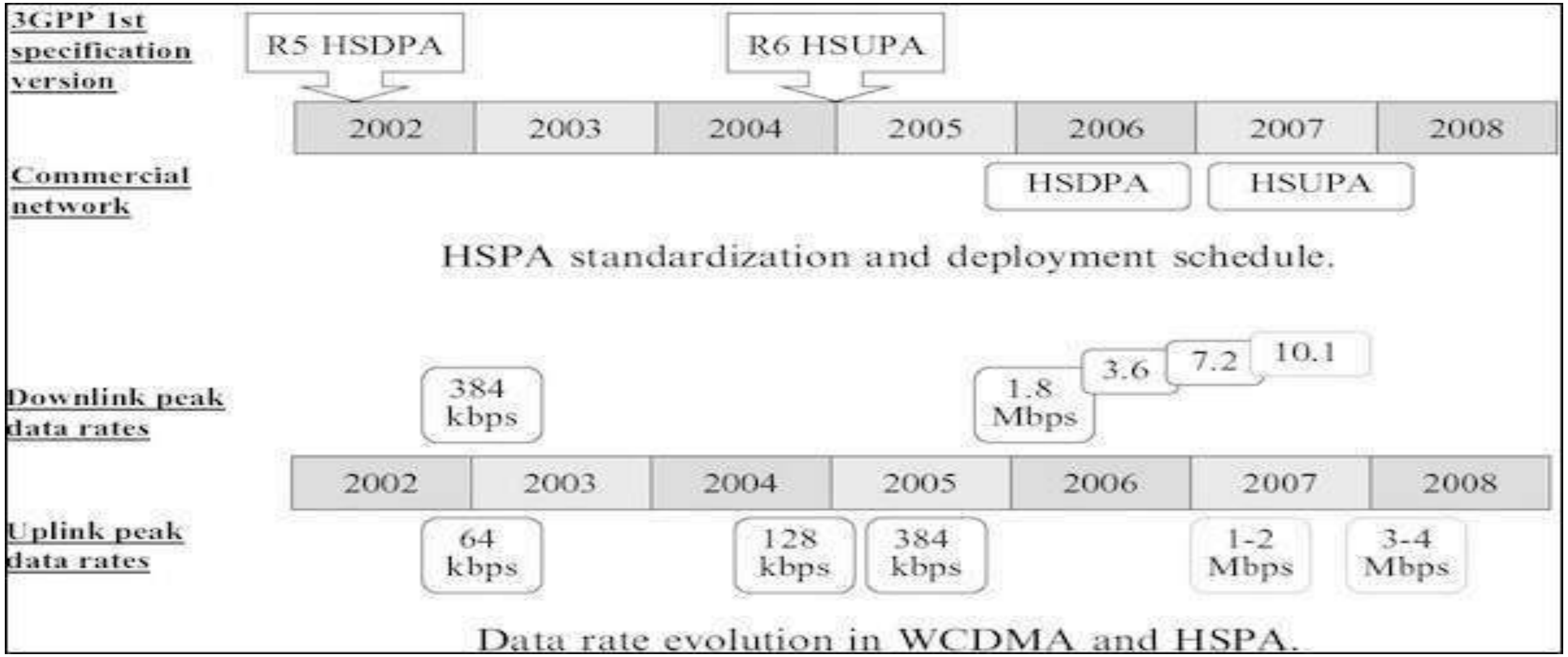
# UMTS – High-speed Packet Access (HSPA) Standardization And Deployment

## The standardization schedule of HSPA in brief –

- In third-generation partnership project (3GPP) standards, Release 4 specifications provide efficient IP support enabling provision of services through an all-IP core network.
- High-speed downlink packet access (HSDPA) was standardized as part of 3GPP Release 5 in March 2002.
- High-speed uplink packet access (HSUPA) was part of 3GPP Release 6 in December 2004.
- HSDPA and HSUPA together are called High-Speed Packet Access' (HSPA).
- The HSDPA peak data rate available in the terminals is initially 1.8Mbps and will increase to 3.6 and 7.2 Mbps during 2006 and 2007, and later on 10Mbps and beyond 10Mbps.
- The HSUPA peak data rate in the initial phase was 1–2 Mbps and the second phase was 3–4Mbps.
- HSPA is deployed over the WCDMA network on the same carrier or - for high capacity and high speed solution - using another carrier, see the figure in the next slide.
- WCDMA and HSPA can share all the network elements in the core network and the radio network comprising base stations, radio network controller (RNC), Serving GPRS Support Node (SGSN) and the Gateway GPRS Support Node (GGSN).
- WCDMA and HSPA also share the site base station antennas and antenna cables.

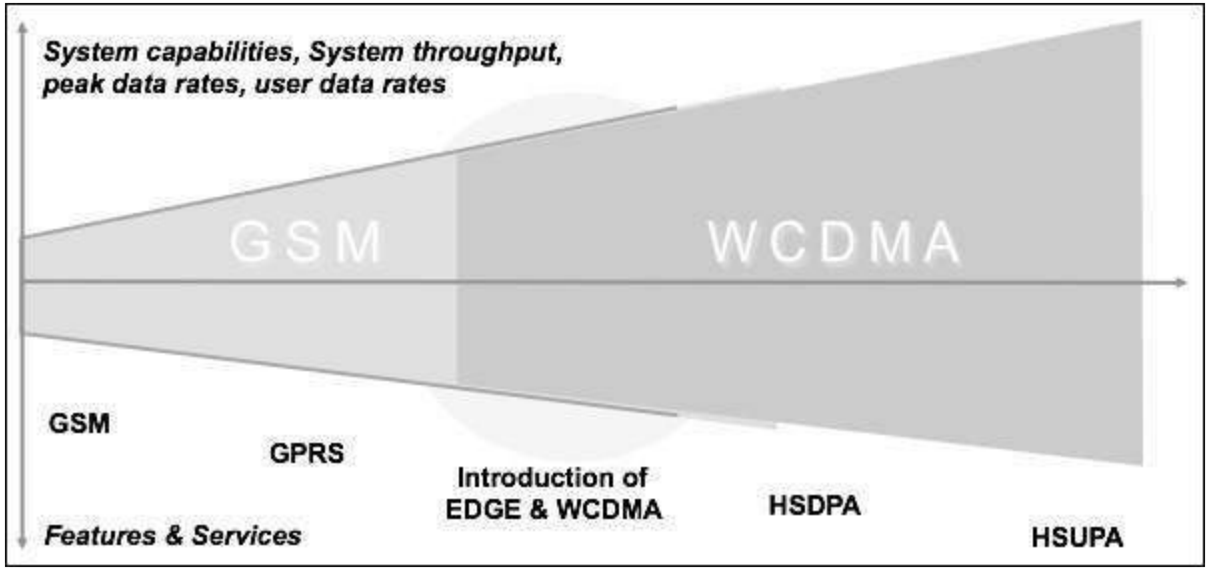
# High speed Downlink packet access (HSDPA)

- Release 5 specifications focus on HSDPA to provide data rates up to approximately 8–10 Mbps to support packet-based multimedia services.
- Multi input and multi output (MIMO) systems are the work item in Release 6 specifications, which will support even higher data transmission rates of up to 20 Mbps.
- HSDPA is evolved from and backward compatible with Release 99 WCDMA systems.



HSPA standardization and deployment schedule.

Data rate evolution in WCDMA and HSPA.

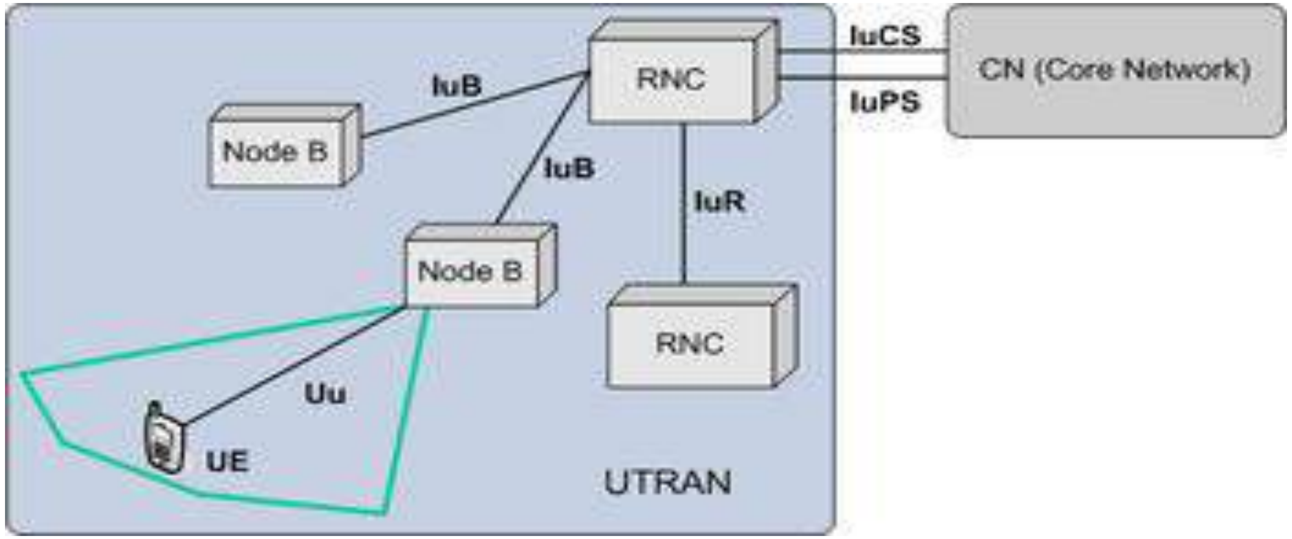



**HSUPA** – High Speed Uplink Packet Access
**HSDPA** – High speed downlink packet access

# Major Interface

There are four major new interfaces defined in UMTS:

- Iu The interface between UTRAN and the CN
- Iur The Interface between different RNCs
- Iub The interface between the Node B and the RNC
- Uu The air interface




User Equipment (UE).

**GSM is FTDMA (frequency and time division multiple access)**. The radio channel is shared by using different frequencies (per cell) and timeslots (per mobile). Since radio frequency is used to distinguish participants, great care must be taken that not two GSM participants use the same frequency at the same time at the same location.

The solution to this is cells, where geographic areas have different frequencies assigned. Network planning must ensure that no two neighbouring cells use the same frequencies as this may lead to interference since you cannot control exactly the size of a cell (e.g. due to absorption and reflection).

In GSM, a BTS has a fixed number of radio transmission channels, the number depends on the BTS hardware configuration. If all channels are in use, the cell is full, this is indpendent of the location of a mobile in the cell.

**UMTS is CDMA (code division multiple access)**. The radio channel is shared by encoding the payload in a way that allows to decode it later even if several senders use the same frequency range. That requires coding schemes which are collision free (all codes are different from each other to avoid senders using too similar codes) and a great deal of signal processing.

• The UMTS architecture takes advantage of the existing GSM and GPRS networks which serve as a core network in UMTS infrastructure.

• The main difference between the UMTS and GSM come with the new radio interface called as Uu.s.

The only drawback behind 3G technology is the fact that it is not backward compatible to the older GSM technology. This means that your 3G mobile phones cannot communicate with GSM towers and 2G phones cannot communicate with 3G towers.

To preserve backwards compatibility, most telecoms install newer 3G radios while still maintaining the older GSM radios. Mobile phone makers also include 3G support into their phones without removing 2G technologies.

Note that there is no concept of cells in WCDMA/UMTS. The cells only existed in GSM AND GPRS

Telcos have slowly rolled out 3G towers in areas where they feel that the demand is the greatest. So they have to operate two radios in certain areas; one for 3G and one for GSM. Mobile phone owners are also required to switch mobile phones in order to take advantage of the new features.

| Parameters | GPRS | GSM | UMTS |
| --- | --- | --- | --- |
| Data rates | 57.6 kbps | 14.4 kbps | 2 Mbps |
| Carrier size | 200 KHz | 200 KHz TDMA | 5 MHz CDMA |
| System generation | 2.5G | 2G | 3G |
| Base system | GSM | TDMA | GSM,GPRS |

Figure 1-comparission between GPRS, GSM, and UMTS

# Wireless Network

## $2^{nd}$ course lecture 7

***Lecture outlines***

- LTE network architecture and protocol.

Lecturer: Dr. Asia Ali

# LTE network architecture and protocol.

(LTE) has been designed to support ***only packet-switched services***.

**LTE** aims to provide seamless Internet Protocol (IP) connectivity between user equipment (UE) and the packet data network (PDN), without any disruption to the end users' applications during mobility.

While the term "LTE" encompasses the evolution of the Universal Mobile Telecommunications System (UMTS) radio access through the Evolved UTRAN (E-UTRAN), it is accompanied by an evolution of the non-radio aspects under the term "System Architecture Evolution" (SAE), which includes the Evolved Packet Core (EPC) network. Together LTE and SAE comprise the Evolved Packet System (EPS).

It is the last step toward the 4th generation (4G) of radio technologies designed to increase the capacity and speed of mobile telephone networks. While the former  generation of mobile telecommunication networks are collectively known as 2G or 3G, LTE is marketed as 4G.

## According to 3GPP, a set of advanced requirements was identified:

- **Reduced cost per bit**
- **Increased service provisioning – more services at lower cost with better user experience**
- **Flexibility of use of existing and new frequency bands**
- **Simplified architecture, Open interfaces**
- **Allow for reasonable terminal power consumption**

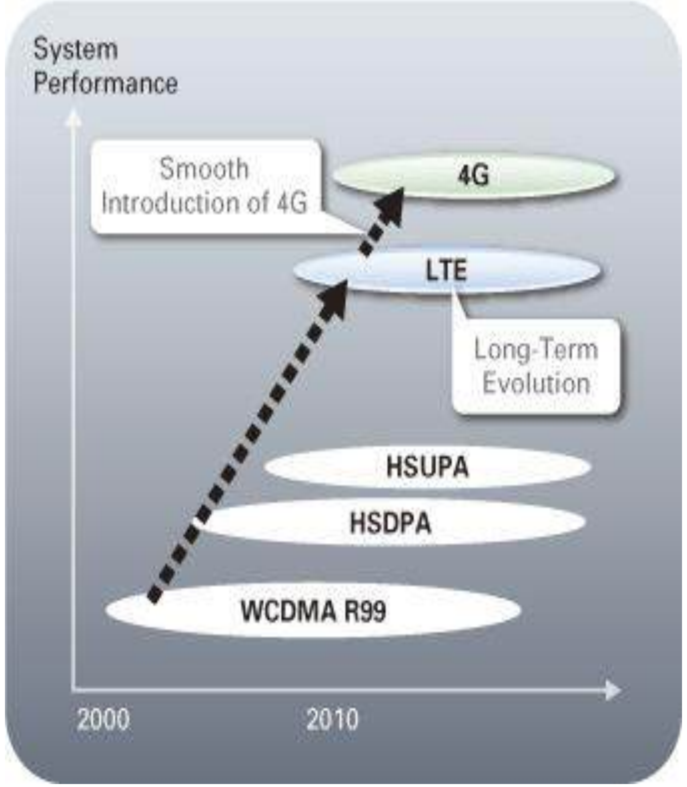



Figure 1-Roadmap to 4G.

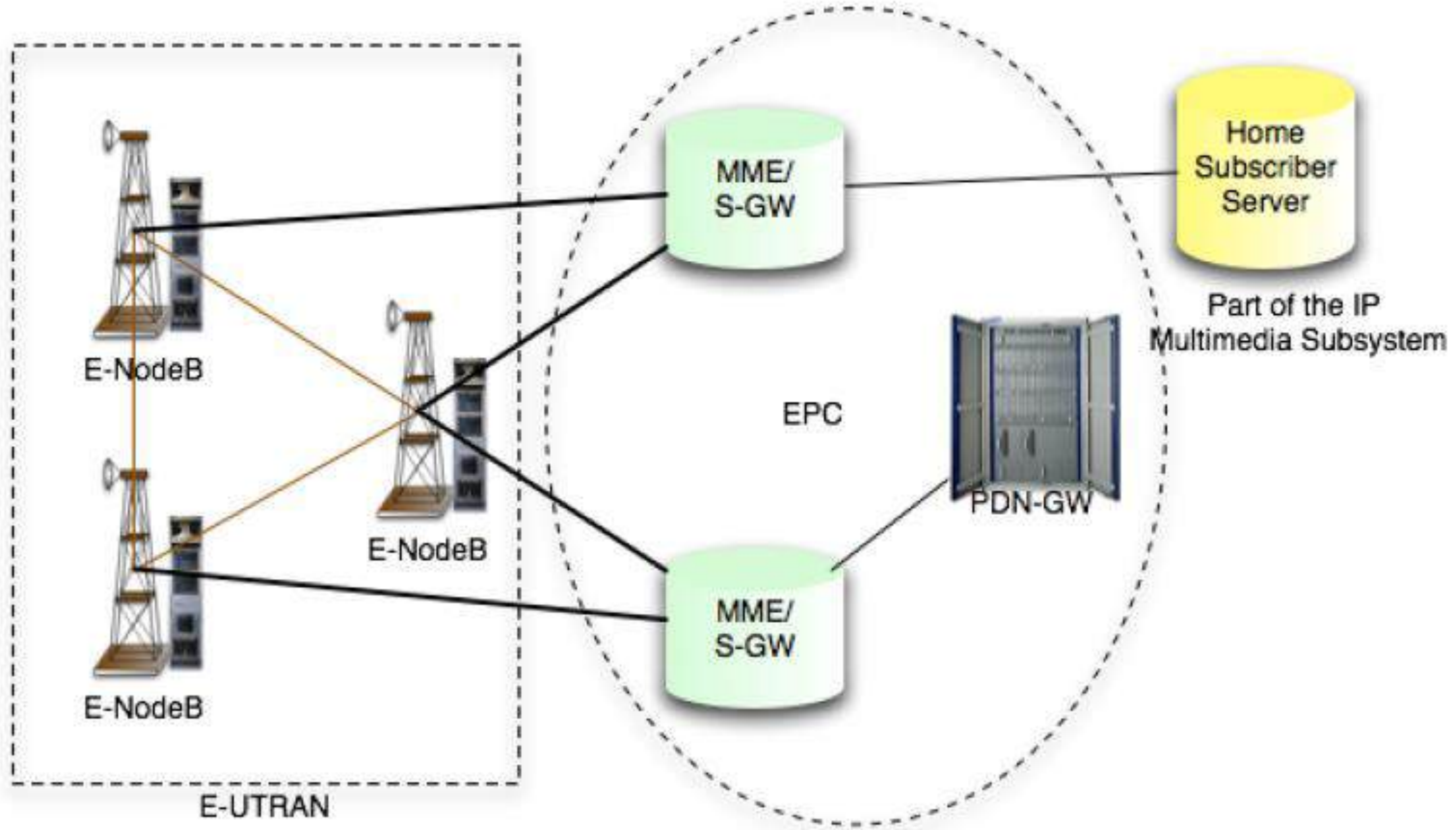
- LTE is a kind of 4G that provides fastest connection to mobile Internet experience-10 times faster than 3G.
- The terms 4G and 4G LTE are not the same.
- 4G is a great substitute for 3G, 4G provides a faster speed for users who view website and download data. Fast speed of 4G means reduction buffer, some might say that 4G opened a new era of mobile internet.
- 4G LTE is 10 times faster than older 3G technology, so when users switch from 3G to 4G LTE, the speed difference is obviously. Speed is determined by signal intensity and server load 4G is actually 3.9G but for commercial sake they named it 4G.
- Now LTE stands for long term evolution. which means all the 5G, 6G that will come will come under LTE. the generation means improved technique, speed, coverage etc. But the main technology remains the same.
- Although there are major changes between LTE and its 3G predecessors, it is looked upon as an evolution of the UMTS / 3GPP 3G standards.
- LTE uses a different form of radio interface (OFDMA / SC-FDMA instead of CDMA), but there are many similarities with the earlier forms of 3G architecture and opportunities for re-use of some elements of 3G network architecture.

- **OFDM (Orthogonal Frequency Division Multiplex)**
  - OFDM technology has been incorporated into LTE because it enables high data bandwidths to be transmitted efficiently while still providing a high degree of resilience to reflections and interference.
  - OFDM is the medium access/modulation scheme.
- **MIMO (Multiple Input Multiple Output)**
  - One of the main problems that previous telecommunications systems have encountered is that of multiple signals arising from the many reflections that are encountered in antenna deployments. By using MIMO, these additional signal paths can be used to advantage and are able to be used to increase the throughput.
- **SAE (System Architecture Evolution)**
  - With the very high data rate and low latency requirements for 3G LTE, the system architecture must evolve to achieve the performance improvement benchmarks.
  - One change is that a number of the functions previously handled by the core network have been transferred out to the periphery. Essentially this provides a much "flatter" form of network architecture. In this way latency times can be reduced and data can be routed more directly to its destination.

## LTE Network Architecture

- Evolved Packet System (EPS) consists of two parts
  - E-UTRAN – Evolved UMTS Terrestrial Radio Access Network
  - EPC – Evolved Packet Core
- E-UTRAN
  - Consists of only one kind of node: eNode-B
  - Compare with UMTS
- Evolved Packet Core (EPC)
  - Fully based on IP – consists of elements
    1. MME – Mobility Management Entity (like SGSN)
    2. S-GW & PDN-GW: Serving and Packet Data Network Gateways
    3. Home subscriber server (HSS)
  - Voice and real-time applications will make use of the IP Multimedia Subsystem (IMS)

# LTE Network Architecture



# Functional Changes

- E-NodeB
  - Does a lot more now! (no RNC or BSC)
  - Selection of MME, RRM functions, Handling Mobility
- MME
  - Sends pages to e-NodeBs
  - Security
  - Idle state mobility
- S-GW
  - Termination of user plane
  - Switching of user plane (mobility)

| Parameters | Description |
|---|---|
| Frequency range | UMTS FDD bands and TDD bands |
| Duplexing | FDD, TDD, half-duplex FDD |
| Mobility | 350 km/h |
| Modulation Schemes | UL: QPSK, 16QAM, 64QAM(optional)<br>DL: QPSK, 16QAM, 64QAM |
| Multiple Access Schemes | UL: SC-FDMA (Single Carrier Frequency Division Multiple Access) supports 50Mbps+ (20MHz spectrum)<br>DL: OFDM (Orthogonal Frequency Division Multiple Access) supports 100Mbps+ (20MHz spectrum) |
| Multi-Antenna Technology | UL: Multi-user collaborative MIMO<br>DL: TxAA, spatial multiplexing, CDD ,max 4x4 array |
| Peak data rate in LTE | UL: 75Mbps(20MHz bandwidth)<br>DL: 150Mbps(UE Category 4, 2x2 MIMO, 20MHz bandwidth)<br>DL: 300Mbps(UE category 5, 4x4 MIMO, 20MHz bandwidth) |
| MIMO<br>(Multiple Input Multiple Output) | UL: 1 x 2, 1 x 4<br>DL: 2 x 2, 4 x 2, 4 x 4 |
| Coverage | 5 - 100km with slight degradation after 30km |
| Latency | End-user latency < 10mS |

# Wireless Network

## 2nd course lecture 8

***Lecture outlines***

- **Wireless 4G Systems.**
- **Applications of 4G.**
- **4G Technologies.**

**Lecturer: Dr. Asia Ali**

# Wireless 4G Systems

4G networks can be defined as wireless ad hoc peer-to-peer networking with high usability and global roaming, distributed computing, personalization, and multimedia support.

4G mobile systems focus on seamless integration of existing wireless technologies including WWAN, WLAN, and Bluetooth. This is in contrast with 3G, which merely focuses on developing new standards and hardware. **The 4G networks will use**

- distributed architecture and end-to-end Internet Protocol (IP).
- Every device will be both a transceiver and a router for other devices in the network eliminating the spoke-and-hub architecture weakness of 3G cellular systems.
- Network coverage/capacity will dynamically change to accommodate changing user patterns.
- Users will automatically move away from congested routes to allow the network to dynamically and automatically self-balance.

# Applications of 4G

The following are some of the applications of the 4G system:

***Virtual presence*** — 4G will provide user services at all times, even if the user is off-site.

***Virtual navigation*** — 4G will provide users with virtual navigation through which a user can access a database of streets, buildings, etc., of a large city. This requires high speed transmission.

***Tele-medicine*** — 4G will support the remote health monitoring of patients via video conference assistance for a doctor at anytime and anywhere.

***Tele-geo-processing applications*** — 4G will combine geographical information systems (GIS) and global positioning systems (GPS) in which a user will get location querying.

***Education*** — 4G will provide a good opportunity to people anywhere in the world to continue their education on-line in a cost-effective manner.

# 4G Technologies

**1- Multicarrier Modulation.**

**2-Smart Antenna Techniques.**

**3- OFDM-MIMO Systems**

**4- Adaptive Modulation and Coding with Time-Slot Scheduler**

## 1- Multicarrier Modulation

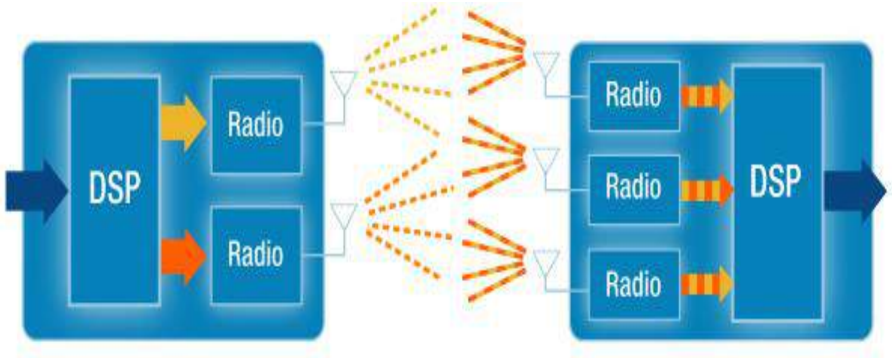
Multicarrier modulation (MCM) is a derivative of frequency-division multiplexing(FDM). It is not a new technology. Forms of multicarrier systems are currently used in DSL modems and digital audio/video broadcast (DAB/DVB). MCM is a baseband process that uses parallel equal bandwidth sub channels to transmit information.

## 2-Smart Antenna Techniques

- Multiple-input multiple-output (MIMO) systems, can extend the capabilities of the 3G and 4G systems to provide customers with increased data throughput for mobile high-speed data applications.
- MIMO systems use multiple antennas at both the transmitter and receiver to increase the capacity of the wireless channel.
- With MIMO systems, it may be possible to provide in excess of 1 Mbps for 2.5G wireless TDMA EDGE and as high as 20 Mbps for 4G systems.
- With MIMO, different signals are transmitted out of each antenna simultaneously in the same bandwidth and then separated at the receiver.
- With four antennas at the transmitter and receiver this has the potential to provide four times the data rate of a single antenna system without an increase in transmit power or bandwidth.
- MIMO techniques can support multiple independent channels in the same bandwidth, provided the multipath environment is rich enough.
- High capacities are theoretically possible, unless there is a direct line of- sight between the transmitter and receiver.
- The number of transmitting antennas is *M*, and the number of receiving *Antennas is N*, ***where***

***N _ M. We examine four cases:***

**Single-Input, Single-Output (SISO)**
**Single-Input, Multiple-Output (SIMO)**
**Multiple-Input, Single-Output (MISO)**
**Multiple-Input, Multiple-Output (MIMO)**




Multiple data streams transmitted in a single channel at the same time Multiple radios collect multipath signals delivers simultaneous speed, coverage, and reliability improvements.

## 3- OFDM-MIMO Systems

OFDM and MIMO techniques can be combined to achieve high spectral efficiency and increased throughput.
The OFDM-MIMO system transmits independent OFDM modulated data from multiple antennas simultaneously.
At the receiver, after OFDM demodulation, MIMO decodes each sub channel to extract data from all transmit antennas on all the sub channels.

## 4- Adaptive Modulation and Coding with Time-Slot Scheduler

*In general, TCP/IP is designed for a highly reliable transmission medium in wired networks where packet losses are seldom and are interpreted as congestion in the network*.

A wireless network uses a time varying channel where packet losses may be common due to severe fading. This is misinterpreted by TCP as congestion which leads to inefficient utilization of the available radio link capacity. This results in significant degradation of the wireless system performance.

***There is a need for a system with efficient packet data transmission using TCP in 4G.*** This can be achieved by using :

- A suitable automatic repeat request (ARQ) scheme + an adaptive modulation + coding system, and a time-slot scheduler that uses channel predictions. This way, the lower layers are adapted to channel conditions while still providing some robustness through retransmission.

The time-slot scheduler shares the spectrum efficiently between users while satisfying the QoS requirements.

## 5- Cognitive Radio(CR)

With the CR paradigm, **spectrum** can be efficiently shared in a more flexible fashion by a number of operators/users/systems.

**The CR can be viewed as an enabling technology**

- It will benefit several types of users by introducing new communications in wireless world.
- Creating better business opportunities for the *incumbent operators.
- New technical dimensions for smaller operators.

In 2003, the IEEE Committee on Communications and Information Policy (CCIP) recommended CR for consideration by the FCC as a means to conserve valuable spectrum utilization.

Most of the research work currently is focusing on spectrum sensing cognitive radio — particularly on the utilization of TV bands for communication.

The essential problem of spectrum sensing CR is the design of high quality sensing devices and algorithms for exchanging spectrum sensing data between nodes.

**The goal of CR** is to relieve radio spectrum overcrowding, which actually translates to a lack of access to full radio spectrum utilization.

***Incumbent Operator means** any person, who owns, controls, and/or operates a provider.