UMTS

universal mobile telecommunications system

tutorialspoint

SIMPLY EASY LEARNING

About the Tutorial

The Universal Mobile Telecommunications System (UMTS), based on the GSM standards, is a mobile cellular system of third generation that is maintained by 3GPP (3rd Generation Partnership Project). It specifies a complete network system and the technology described in it is popularly referred as Freedom of Mobile Multimedia Access (FOMA).

This tutorial starts off with a brief introduction to the history of mobile communication and cellular concepts and gradually moves on to explain the basics of GSM, GPRS, and EDGE, before getting into the concepts of UMTS.

Audience

This tutorial is prepared for beginners to help them understand the basic-to-advanced concepts related to UMTS.

Prerequisites

You need to have a basic understanding of various telecom terminologies to understand the topics covered in this tutorial.

Copyright & Disclaimer

Table of Contents

1. History of Mobile Communication

Wireless communication was a magic to our ancestors but Marconi could initiate it with his wireless telegraph in 1895. Wireless Communication can be classified into three eras.

- Pioneer Era (Till 1920)
- Pre Cellular Era(1920-1979)
- Cellular Era (beyond 1979)

The first commercial mobile telephone system was launched by BELL in St. Louis, USA, in 1946. Few lucky customers got the services. Early mobile systems used single high power transmitters with analog Frequency Modulation techniques to give coverage up to about 50 miles and hence only limited customers could get the service due to this severe constraints of bandwidth.

First Car-Mounted Telephone

Cellular Era

To overcome the constraints of bandwidth scarcity and to give coverage to larger sections, BELL lab introduced the principle of Cellular concept. By frequency reuse technique this method delivered better coverage, better utility of available frequency spectrum and reduced transmitter power. But the established calls are to be handed over between base stations while the phones are on move.

Even though the US based BELL lab introduced the cellular principle, the Nordic countries were the first to introduce cellular services for commercial use with the introduction of the Nordic Mobile Telephone (NMT) in 1981.

First Generation Systems

All these systems were analog systems, using FDMA technology. They are also known as First Generation (1G) systems. Different systems came into use based on the cellular principle. They are listed below.

Year	Mobile System
1981	Nordic Mobile Telephone(NMT)450
1982	American Mobile Phone System(AMPS)
1985	Total Access Communication System(TACS)
1986	Nordic Mobile Telephony(NMT)900

Disadvantages of 1G systems

- They were analog and hence are were not robust to interference.
- Different countries followed their own standards, which were incompatible.

To overcome the difficulties of 1G, digital technology was chosen by most of the countries and a new era, called 2G, started.

Advantages of 2G

- Improved Spectral Utilization achieved by using advanced modulation techniques.
- Lower bit rate voice coding enabled more users getting the services simultaneously.
- Reduction of overhead in signaling paved way for capacity enhancement.
- Good source and channel coding techniques make the signal more robust to Interference.
- New services like SMS were included.
- Improved efficiency of access and hand-off control were achieved.

Name of the systems	Country
DAMPS-Digital Advanced Mobile Phone System	North America
GSM-Global System for Mobile communication	European Countries and International applications
JDC - Japanese Digital Cellular	Japan
CT-2 Cordless Telephone–2	UK
DECT-Digital European Cordless Telephone	European countries

History of GSM

GSM standard is a European standard, which has addressed many problems related to compatibility, especially with the development of digital radio technology.

Milestones of GSM

- 1982- Confederation of European Post and Telegraph (CEPT) establishes Group Special Mobile.
- 1985- Adoption of list of recommendation was decided to be generated by the group.
- 1986- Different field tests were done for radio technique for the common air interface.
- 1987- TDMA was chosen as the Access Standard. MoU was signed between 12 operators.
- 1988- Validation of system was done.
- 1989- Responsibility was taken up by European Telecommunication Standards Institute (ETSI).
- 1990- First GSM specification was released.
- 1991- First commercial GSM system was launched.

Frequency Range of GSM

GSM works on four different frequency ranges with FDMA-TDMA and FDD. They are as follows:

System	P-GSM (Primary)	E-GSM (Extended)	GSM 1800	GSM 1900
Freq Uplink	890-915MHz	880-915MHz	1710-1785Mhz	1850-1910MHz
Freq Downlink	935-960MHz	925-960MHz	1805-1880Mhz	1930-1990MHz

2. Cellular Concepts – Introduction

The immense potential of conventional telephone cannot be exploited to its maximum due to the limitation imposed by the connecting wires. But this restriction has been removed with the advent of the cellular radio.

Frequency Scarcity Problem

If we use dedicated RF loop for every subscriber, we need larger bandwidth to serve even a limited number of subsc in a single city.

Example

A single RF loop requires 50 kHz B/W; then for one lakh subscribers we need 1,00,000 x 50 kHz = 5 GHz.

To overcome this B/W problem, subscribers have to share the RF channels on need basis, instead of dedicated RF loops. This can be achieved by using multiple access methods FDMA, TDMA, or CDMA. Even then the number of RF channels required to serve the subscribers, works out to be impracticable.

Example

Consider a subs density of 30Sq.Km., Grade of service as 1%, Traffic offered per mobile sub as 30m E. Then number of RF channels required are:

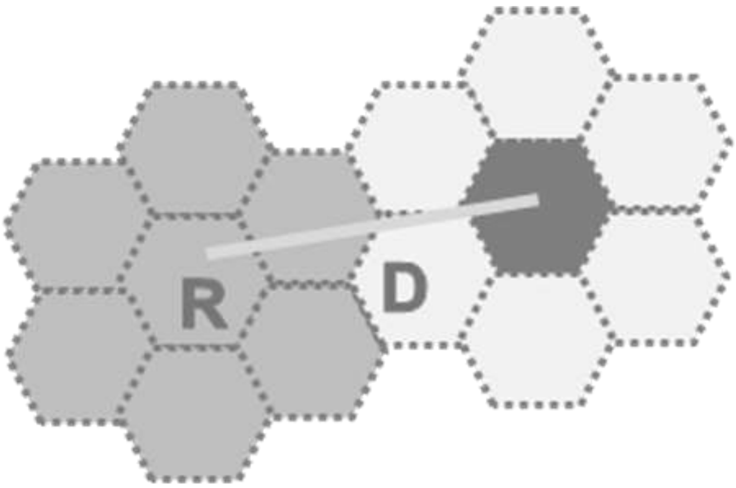
Radius (km)	Area in Sq. Km	Subs	RF Channels
1	3.14	100	8
3	28.03	900	38
10	314	10000	360

For 10,000 subs to allot 360 radio channels we need a B/Wof 360 x 50 KHz = 18 MHz. This is practically not feasible.

Cellular Approach

With limited frequency resource, cellular principle can serve thousands of subscribers at an affordable cost. In a cellular network, total area is subdivided into smaller areas called “cells”. Each cell can cover a limited number of mobile subscribers within its boundaries. Each cell can have a base station with a number of RF channels.

Frequencies used in a given cell area will be simultaneously reused at a different cell which is geographically separated. For example, a typical seven-cell pattern can be considered.



Total available frequency resources are divided into seven parts, each part consisting of a number of radio channels and allocated to a cell site. In a group of 7 cells, available frequency spectrum is consumed totally. The same seven sets of frequency can be used after certain distance.

The group of cells where the available frequency spectrum is totally consumed is called a cluster of cells.

Two cells having the same number in the adjacent cluster, use the same set of RF channels and hence are termed as "Co-channel cells". The distance between the cells using the same frequency should be sufficient to keep the co-channel (co-chl) interference to an acceptable level. Hence, the cellular systems are limited by Co-channel interference.

Hence a cellular principle enables the following.

- More efficient usage of available limited RF source.
- Manufacturing of every piece of subscribers' terminal within a region with the same set of channels so that any mobile can be used anywhere within the region.

Shape of Cells

For analytical purposes a "Hexagon" cell is preferred to other shapes on paper due to the following reasons.

- A hexagon layout requires fewer cells to cover a given area. Hence, it envisages fewer base stations and minimum capital investment.
- Other geometrical shapes cannot effectively do this. For example, if circular shaped cells are there, then there will be overlapping of cells.
- Also for a given area, among square, triangle and hexagon, radius of a hexagon will be the maximum which is needed for weaker mobiles.

In reality cells are not hexagonal but irregular in shape, determined by factors like propagation of radio waves over the terrain, obstacles, and other geographical constraints. Complex computer programs are required to divide an area into cells. One such program is "Tornado" from Siemens.

Operating Environment

Due to mobility, the radio signals between a base station and mobile terminals undergo a variety of alterations as they travel from transmitter to receiver, even within the same cell. These changes are due to:

- Physical separation of transmitter and receiver.
- Physical environment of the path i.e. terrain, buildings, and other obstacles.

Slow Fading

- In free space conditions (or) LOS, RF signal propagation constant is considered as two i.e. r = 2. This is applicable for static radio systems.
- In mobile environment, these variations are appreciable and normally 'r' is taken as 3 to 4.

Rayleigh Fading

The direct line of sight in mobile environment, between base station and the mobile is not ensured and the signal received at the receiver is the sum of a number of signals reaching through different paths (multipath). Multipath propagation of RF waves is due to the reflection of RF energy from a hill, building, truck, or aero plane etc.; the reflected energy undergoes a phase change also.

If there are 180 out-of phase with direct path signals, they tend to cancel out each other. So the multipath signals tend to reduce the signal strength. Depending upon the location of the transmitter and receiver and various reflecting obstacles along the path length, signal fluctuates. The fluctuations occur fast and it is known as "Rayleigh fading".

In addition, multipath propagation leads to "pulse widening" and "Inter symbol Interference".

Doppler Effect

Due to the mobility of the subscriber, a change occurs in the frequency of the received RF signals. Cellular mobile systems use following techniques to counter these problems.

- Channel coding
- Interleaving
- Equalization
- Rake receivers
- Slow frequency hopping
- Antennae diversity

Co-Channel Interference and Cell Separation

We assume a cellular system having a cell radius "R" and Co-channel distance "D" and the cluster size "N". Since the cell size is fixed, co-channel interference will be independent of power.

Co-chl interference is a function of "q" = D/R.

Q=Co-chl interference reduction factor.

Higher value of "q" means less interference.

Lower value of "q" means high interference.

"q" is also related to cluster size (N) as q= 3N

q=3N=D/R

For different values of N, q is:

N=	1	3	4	7	9	12
Q=	1.73	3	3.46	4.58	5.20	6.00

Higher values of "q"

- Reduces co-channel interference,
- Leads to higher value of "N" more cells/cluster,
- Less number of channels/cells,
- Less traffic handling capacity.

Lower values of "q"

- Increases co-channel interference,
- Leads to lower value of "n" fewer cells / cluster,
- More number of channels / cells,
- More traffic handling capacity.

Generally, N=4, 7, 12.

C/I Calculations and 'q'

The value of "q" also depends on C/I. "C" is the received carrier power from the desired transmitter and "I" is the co-channel interference received from all the interfering cells. For a seven-cell reuse pattern, the number of co-channel interfering cells shall be six in number.

$$I = \sum_{Mz1}^{m2b} I_m$$

Loss of signal is proportional to (distance) –r

R – Propagation constant.

C ∝ R –r

R = Radius of cell.

I ∝ 6 D-r

D= Co-channel separation distance

C/I = R – r / 6D –r = 1/6 x Dr / Rr = 1/6 (D/R) r

C/I = 1/6 q r since q = D/R and q r = 6 C/I

Q = [6 x C/I]1/r

Based upon the acceptable voice quality, the value of C/I has been found to be equal to 18 dB.

Assuming,

A seven-cell reuse pattern

Omni directional antennae

Value of 'q' can be typically around 4.6.

Value r is taken as 3.

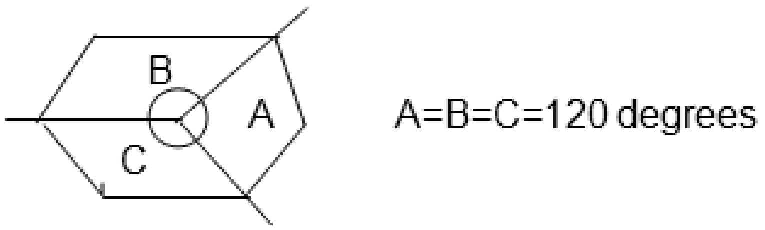
This is an ideal condition, considering the distance of the mobile units from the interfering cells to be uniformly equal to 'D' in all cases. But practically mobile moves and distance 'D' reduces to 'D-R' when it reaches the boundary of the cell, and C/I drops to 14.47 dB.

Hence 'freq' reuse pattern of 7 is not meeting C/I criteria with omni directional antennae.

	If N=9 (or) 12,	
N=9	q=5.2	C/I = 19.78 dB
N=12	q=6.0	C/I = 22.54 dB

Hence, either 9 or 12 cell pattern is to be with omni directional antennae, but traffic handling capacity is reduced. Hence they are not preferred.

In order to use N=7 (or lower), directional antennas are used in every cell site. A cell having 3 sectors is very popular and will be like the figure shown below.



Antenna's font – back coupling phenomenon reduces number of potential interferers.

For example if N=7.

With omni directional antennae, number of interfering cells shall be six. With directional antennae & 3 sectors the same is reduced to two. For N=7 and three sectors, the C/I improves from 14.47 dB to 24.5 dB even in worst conditions. Then C/I meets the requirement of 18dB. For N=7 and six sectors, the C/I improves to 29 dB.

For Urban applications, N=4 and a three sector cell is used so that more number of carriers per cell are obtained than N=7. Also the C/I becomes 20 dB in worst cases.

DAMPS Uses 7/21 cell pattern

GSM Uses 4/21 cell pattern

Advantages of sectoring

- Decrease co-channel interference
- Increase system capacity

Disadvantages of sectoring

- Large number of antennas at the base station.
- Increase in the number of sectors/cell reduces the trunking efficiency.
- Sectoring reduces the coverage area, for a particular group of channels.
- Number of 'Hand offs' increases.

Hand Off

When the mobile unit travels along a path it crosses different cells. Each time it enters into a different cell associated with f=different frequency, control of the mobile is taken over by the other base station. This is known as 'Hand off'.

Hand off is decided based on:

- Received signal strength information if it is below a threshold value.
- Carrier to interference ratio is less than 18 dB.

Adjacent Channel Interference

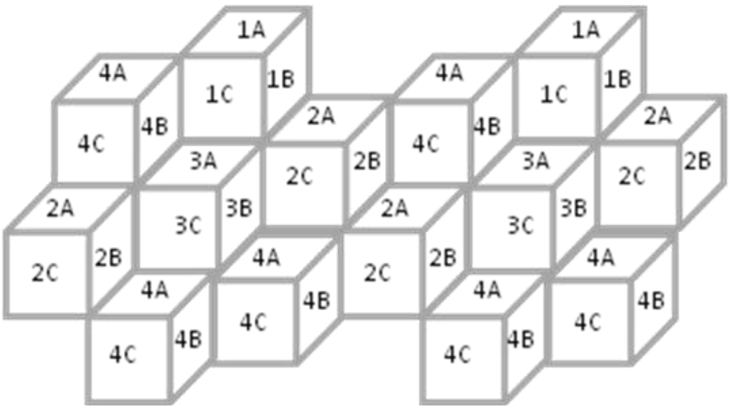
A given cell/sector uses a number of RF channels. Because of imperfect receiver filters, which allow nearby frequencies to leak into pass band, adjacent channel interference takes place.

It can be reduced by keeping the frequency separations between each RF channel in a given cell as large as possible. When the reuse factor is small, this separation may not be sufficient.

A channel separation, by selecting RF frequencies, which are more than 6 channels apart, is sufficient to keep adjacent channel interferences within limits.

For example, in GSM which follows 4/12 pattern, N=4

Sectors = 3/cell



IA will use RF Carr. 1, 13, 25,………..

IB will use RF Carr 5, 17, 29,…………

IC will use RF Carr. 9, 21, 33,……….. and so on.

Trunking

Cellular radios rely on trunking to accommodate a large number of users in a limited radio spectrum. Each user is allocated a channel on need/per call basis and on termination of the cell, the channel is returned to the common pool of RF channels.

Grade of Service (GOS)

Because of trunking, there is a likelihood that a call is blocked if all the RF channels are engaged. This is called 'Grade of Service' "GOS".

Cellular designer estimates the maximum required capacity and allocates the proper number of RF channels, in order to meet the GOS. For these calculations, 'ERLANG B' table is used.

Cell Splitting

When the number of users reaches a saturation in a start-up cell (initial design) and no more spare frequency is available, then the start-up cell is split, usually in four smaller cells and traffic increases by four and more number of subscribers can be served.

After 'n' splits, the traffic will be:

$$T2 = T0 \times 42$$

Power will be reduced:

$$P2 = P0 - n \times 12 \text{ db}$$

Hence cell splitting improves the capacity and lowers the transmission power.