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1. a) What is wireless communication concept? Draw the block diagram of GSM network component. 4
   b) Write down the differences between walkie-talkies and cordless telephones. 3
   c) Why is FM, rather than AM, used in most mobile radio systems today? 3
   d) What is paging? Why do paging systems need to provide low data rates? How does a low data rate lead to better coverage? 4

2. a) How will 5g change the wire line architecture that currently supports 4g mobile backhaul? Will Fiber Deployment Patterns Change When 5g Is Deployed? 4
   b) Define OSI layers. Are there any alternative models to the OSI model? If yes, define it. 5
   c) Prove that, for a hexagonal geometry, the co-channel reuse ratio is given by, $Q = \sqrt{3N}$ where, $N = i^2 + ij + j^2$ 5

3. a) What is frequency reuse? Draw 3-cell, 4-cell and 7-cell reuse pattern. 4
   b) Show that the frequency reuse factor for a cellular system is given by k/S, where k is the average number of channels per cell and S is the total number of channels available to the cellular service provider. 5
   c) If a total of 33 MHz of bandwidth is allocated to a particular FDD cellular telephone system which uses two 25 kHz simplex channels to provide full duplex voice and control channels, compute the number of channels available per cell if a system uses (a) 4-cell reuse, (b) 7-cell reuse (c) 12-cell reuse. If 1 MHz of the allocated spectrum is dedicated to control channels, determine an equitable distribution of control channels and voice channels in each cell for each of the three systems. 5

4. a) What is sectoring? Draw 120° and 60° sectoring. 3
   b) What is Layered Network Architecture? Write short notes on Macro cell, Pico cell and Femto cell. 6
   c) A cellular service provider decides to use a digital TDMA scheme which can tolerate a signal-to-interference ratio of 15 dB in the worst case. Find the optimal value of N for (a) omni-directional antennas, (b) 120° sectoring, and c) 60° sectoring. Should sectoring be used? If so, which case (120° or 60°) should be used? (Assume a path loss exponent of n = 4 and consider trunking efficiency). 5

5. a) What is link budget? Why link budget is important? Explain. 4
   b) Analyze the link budget with transmitter and receiver components. 4
   c) Show that, the maximum allowable path loss(L_{max}) that the link can tolerate is, 6

$$L_{max(dB)} = \Omega_{t(dBm)} + G_{T(dB)} + G_{R(dB)} - \Omega_{th(dBm)}$$

where, Ω_t = transmit carrier power, G_T = transmit antenna gain, G_r = receiver antenna gain, Ω_{th} = receiver sensitivity

6. a) What is path loss and path loss model? 2

   b) Show that, Hata model is well suited for large cell mobile system , but not PCS(personal communications systems) 6

   c) If a transmitter produces 50 watts of power, express the transmit power in units of (a) dBm, and (b) dBW. If 50 watts is applied to a unity gain antenna with a 900 MHz carrier frequency, find the received power in dBm at a free space distance of 100 m from the antenna, What is P (10 km) 2 Assume unity gain for the receiver antenna. 6

7. a) What is cell splitting? How to increase capacity of a cellular network. 4

   b) Write short notes on 10

      i) dBm & dBi
      ii) ERP & EIRP
      iii) Mobile-Station Subsystem and Base-Station Subsystem
      iv) Hard-handoff and Soft-handoff
      v) Balanced link and unbalanced link

8. a) What is receiver sensitivity? What are the differences between large scale fading and small scale multipath fading. 4

   b) When we care about link budget? What we can change to achieve a balanced link budget within a given cell size. 4

   c) What is free space path loss? 2

   d) Suppose that a signal with 200kHz bandwidth at 290k temperature, where, noise factor for amplifier is 1.2dB, modulation scheme requires SNR of 15dB. Find out the sensitivity. 4

1. **a) What is wireless communication concept? Draw the block diagram of GSM network component.**

Ans:

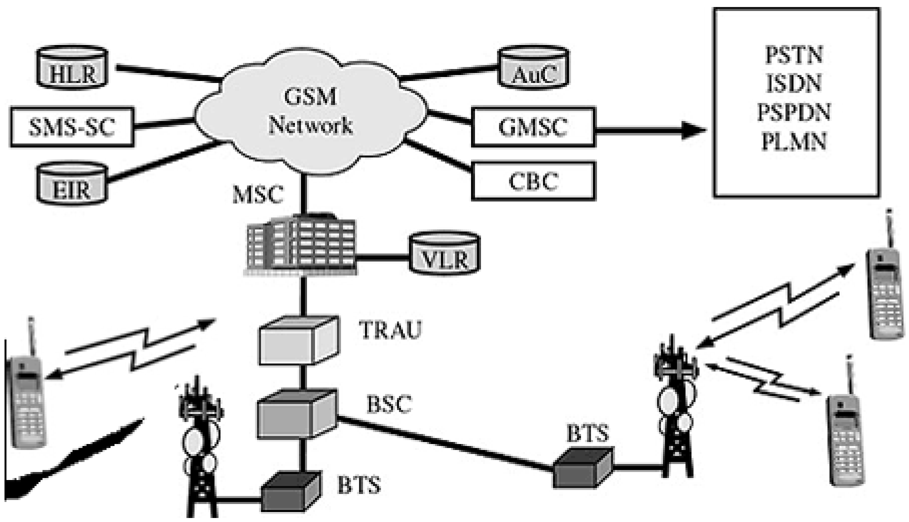
Wireless communication is the transfer of information between two or more points that are not connected by any physical medium. Wireless communications can be via

Radio communication.

Microwave communication.

Light, Visible and Infrared communication.

Block diagram of GSM network component:



b) Write down the differences between walkie-talkies and cordless telephones.

Ans:

Walkie-talkies	**Cordless telephones**
Communication not dependent on network availability	No calls can be made without network
Group Conversations happen in less than 10 seconds	30-60 seconds needed for group conferences
Very strong noise cancellation feature	Noise cancellation is not very effective
Can function well for even a decade or more	Typical shelf life is 1.5-2 years
Connects instantly for communication	Takes at least 30 seconds to connect

c) **Why is FM, rather than AM, used in most mobile radio systems today**?

Ans:

FM is clearer in transmission than AM. Its wave length is short whereas the frequency is high and vise-verse for AM. Hence the frequency is modulated and in Am amplitude is modulated. Natural or human activity like traffic etc. doesn't affect the FM transmission whereas AM transmission gets affected.

1. Lesser distortion. Frequency modulated wave is less susceptible to interferences from buildings, traffic etc. which provides improved signal to noise ratio (about 25dB) w.r.t. To man-made interference.
2. Waves at higher frequencies can carry more data than the waves at low frequency.
3. Smaller geographical interference between neighboring stations.
4. Less radiated power
5. Well defined service areas for given transmitted power.

d) **What is paging? Why do paging systems need to provide low data rates? How does a low data rate lead to better coverage?**

Ans:

Paging is a method of delivering a message, via a public or private communications system or radio signal, to a person whose exact whereabouts are unknown.

For paging system small RF bandwidths are used to maximize the signal-to-noise ratio at each paging receiver, so low data rates (6400 bps or less) are used.
Simulcasting is used in paging systems to achieve better coverage. Simulcast is a simultaneous broadcast of page by a number of transmitters on a single radio frequency. These simultaneous broadcasts from multiple transmitters can have overlapping areas. So lower the data rate better the coverage in overlapping areas.
Paging systems are designed to provide reliable communication to subscribers wherever they are; whether inside a building, driving on a highway, or flying in an airplane. This necessitates large transmitter powers (on the order of kilowatts) and low data rates (a couple of thousand bits per second) for maximum coverage from each base station.

2. a) How will 5g change the wire line architecture that currently supports 4g mobile backhaul?

Ans:

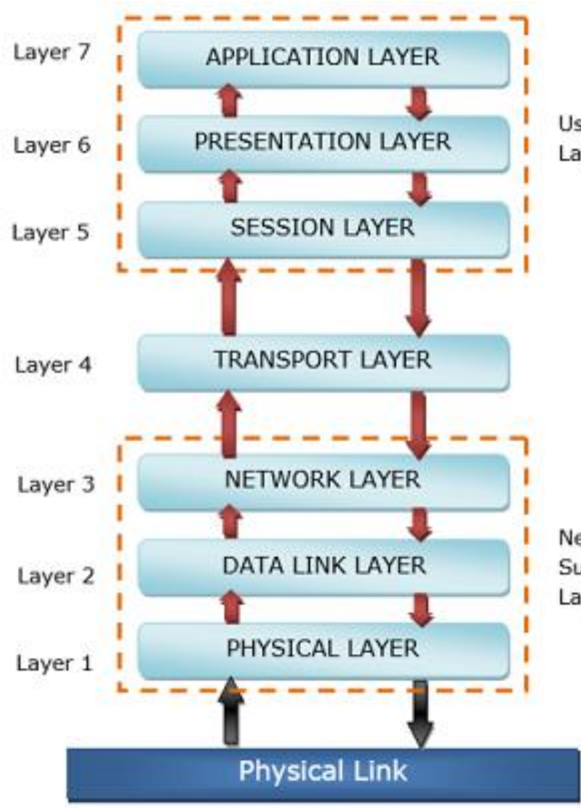
That will depend on MNO's rollout patterns, how many users are on the network, and what limits they'll set on speeds. Today MNOs typically feed a 1 GB/s Ethernet line to a 4G cell sites, of which an average of 200-300 Mb/s is being used. With 5G, that same macro tower may need 10's to 100's of gaps, which will require an enormous capacity upgrades to those towers.

Direct communication between cells is planned for 5G networks, skipping the connection to the packet core wherever possible, which would offload a lot of traffic. Those cells might be wired together directly in the shortest path, but I think traffic will mostly home back to a central location.

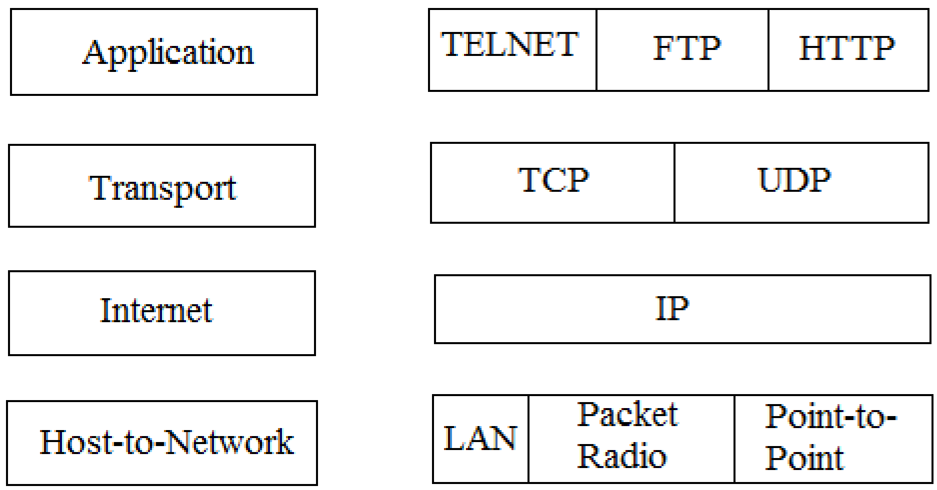
b) Define OSI layers. Are there any alternative models to the OSI model? If yes, define it.

Ans:

OSI stands Open System Interconnection. There are 7 layers in the OSI model. OSI model helps networking professionals in understanding information flow from one source to destination. Although, the OSI model not performing any function in the networking process.



TCP/IP is the alternate model that also explains the information flow in the network. It is a simpler representation in comparison to the OSI model but contains fewer details of protocols than the OSI model.



c) Prove that, for a hexagonal geometry, the co-channel reuse ratio is given by, $\boldsymbol{Q = \sqrt{3N}}$ where, $\boldsymbol{N = i^2 + ij + j^2}$

Ans:

When the size of each cell is approximately the same and the base stations transmit the same power, the co-channel interference ratio is independent of the transmitted power and becomes a function of the radius of the cell (R) and the distance between centers of the nearest co-channel cells (D). By increasing the ratio of D/R, the spatial separation between co-channel cells relative to the coverage distance of a cell is increased. Thus, interference is reduced from improved isolation of RF energy from the co-channel cell. The parameter Q, called the co-channel reuse ratio, is related to the cluster size For a hexagonal geometry $Q = D/R = \sqrt{3N}$

A small value of Q provides larger capacity since the cluster size N is small, whereas a large value of Q improves the transmission quality, due to a smaller level of co-channel interference. A trade-off must be made between these two objectives in actual cellular design.

Co-channel Reuse Ratio for Some Values of N

	Cluster Size (N)	Co-channel Reuse Ratio (Q)
$i = 1, j = 1$	3	3
$i = 1, j = 2$	7	4.58
$i = 2, j = 2$	12	6
$i = 1, j = 3$	13	6.24

3. a) What is frequency reuse? Draw 3-cell, 4-cell and 7-cell reuse pattern.

<u>Ans:</u>

Frequency Reuse is the scheme in which allocation and reuse of channels throughout a coverage region is done. Each cellular base station is allocated a group of radio channels or Frequency sub-bands to be used within a small geographic area known as a cell. The shape of the cell is Hexagonal. The process of selecting and allocating the frequency sub-bands for all of the cellular base station within a system is called Frequency reuse or Frequency Planning**.**

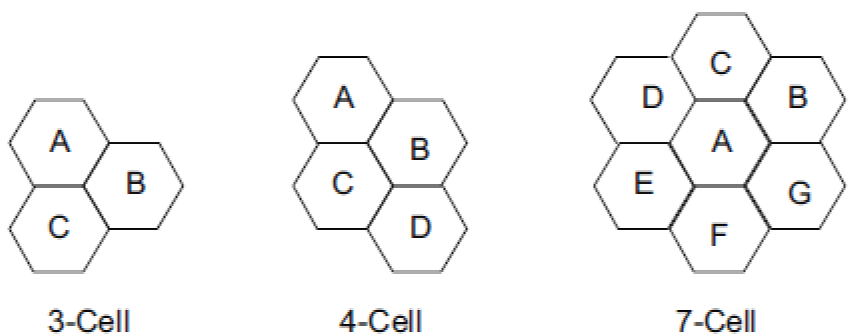


Fig**.** 3-cell, 4-cell and 7-cell reuse pattern

b) Show that the frequency reuse factor for a cellular system is given by k/S, where k is the average number of channels per cell and S is the total number of channels available to the cellular service provider.

<u>Ans:</u>

Let, a cellular system which has a total of S duplex channels available for use. If each cell is allocated a group of k channels (k < S), and if the S channels are divided among N cells into unique and disjoint channel groups which each have the same number of channels, the total number of available radio channels can be expressed as

$$S = kN$$

The N cells which collectively use the complete set of available frequencies is called a cluster. If a cluster is replicated M times within the system, the total number of duplex channels, C, can be used as a measure of capacity and is given by

$$C = MkN = MS$$

The frequency reuse factor of a cellular system is given by 1/N, since each cell within a cluster is only assigned 1/N of the total available channels in the system.

N, can only have values which satisfy $N = i^2 + ij + j^2$ where i and j are non-negative integers.

c) If a total of 33 MHz of bandwidth is allocated to a particular FDD cellular telephone system which uses two 25 kHz simplex channels to provide full duplex voice and control channels, compute the number of channels available per cell if a system uses (a) 4-cell reuse, (b) 7-cell reuse (c) 12-cell reuse. If 1 MHz of the allocated spectrum is dedicated to control channels, determine an equitable distribution of control channels and voice channels in each cell for each of the three systems.

Ans:

Given, Total bandwidth = 33 MHz

Channel bandwidth = 25 kHz × 2 simplex channels = 50 kHz/duplex channel

Total available channels = 33,000/50 = 660 channels

(a) For N = 4, total number of channels available per cell = 660/4 ≈ 165 channels.

(b) For N = 7, total number of channels available per cell = 660/7 ≈ 95 channels.

(c) For N = 12, total number of channels available per cell = 660/12 ≈ 55 channels.

A 1 MHz spectrum for control channels implies that there are 1000/50 = 20 control channels out of the 660 channels available. To evenly distribute the control and voice channels, simply allocate the same number of voice channels in each cell wherever possible. Here, the 660 channels must be evenly distributed to each cell within the cluster. In practice, only the 640 voice channels would be allocated, since the control channels are allocated separately as 1 per cell.

(a) For N = 4, we can have five control channels and 160 voice channels per cell. In practice, however, each cell only needs a single control channel (the control channels have a greater reuse distance than the voice channels). Thus, one control channel and 160 voice channels would be assigned to each cell.

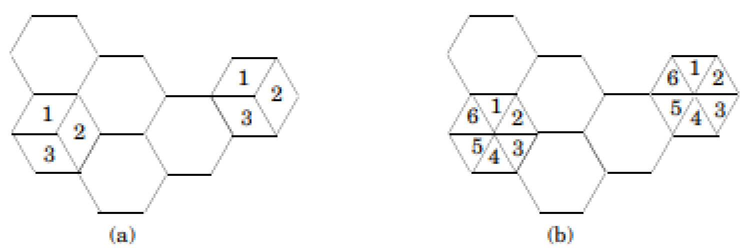
(b) For N = 7, four cells with three control channels and 92 voice channels, two cells with three control channels and 90 voice channels, and one cell with two control channels and 92 voice channels could be allocated. In practice, however, each cell would have one control channel, four cells would have 91 voice channels, and three cells would have 92 voice channels.

(c) For N = 12, we can have eight cells with two control channels and 53 voice channels, and four cells with one control channel and 54 voice channels each. In an actual system, each cell would have one control channel, eight cells would have 53 voice channels, and four cells would have 54 voice channels

4. a) What is sectoring? Draw 120° and 60° sectoring.

<u>Ans:</u>

The technique for decreasing co-channel interference and thus increasing system capacity by using directional antennas is called sectoring. The factor by which the co-channel interference is reduced depends on the amount of sectoring used. A cell is normally partitioned into three 1200 sectors or six 60° sectors.



(a) 120° sectoring; (b) 60° sectoring.

b) What is Layered Network Architecture? Write short notes on Micro cell, Macro cell, Pico cell and Femto cell.

<u>Ans:</u>

A layered network architecture is a composite architecture made of hierarchical stack of cells. Its main idea is that network capacity, especially large capacity in hotspot areas, cannot be solely carried by macro cells, but unloaded gradually at different layers through the layered stack of cells.

Macro cell: A macro cell provides the main coverage in a mobile network. Macro cell base stations have a typical power output of tens of watts. A macro cell tends to have a range from 3-35 km.

Micro cell: Micro cells provide infill radio coverage and additional capacity where there are high numbers of users within macro cells. Typically, micro cells provide radio coverage across smaller distances and are placed 300m -1000m apart. They have lower power than macro cells, usually a few watts

Pico cell: A pico cell provides even more localized coverage than a microcell→ hot spots. They are normally found inside buildings where coverage is poor or where there are a high number of users, such as in public places, e.g., airports, train stations, convention centers or shopping malls.

Femto cell: Femto cell is a small cellular base station, typically designed for use in a home or small business. It connects to the service provider’s network via broadband (such as DSL or cable). A femto cell allows service providers to extend service coverage indoors, especially where access would otherwise be limited or unavailable.

c) A cellular service provider decides to use a digital TDMA scheme which can tolerate a signal-to-interference ratio of 15 dB in the worst case. Find the optimal value of N for (a) omni-directional antennas, (b) 120° sectoring, and c) 60°sectoring.

Should sectoring be used? If so, which case (120° or 60°) should be used? (Assume a path loss exponent of n = 4 and consider trunking efficiency).

Ans:

Given, SIR= 14dB, n = 4, N =?

a) For omni-directional antennas,
The number of co-channel interfering cells, $i_{\circ} = 6$
We know,

$$SIR = \frac{(\sqrt{3N})^4}{i_{\circ}}$$

SIR = 15dB = $10^{1.5}$ = 31.623 (dB to ratio)
Then, N = 4.59 $\approx$ we choose N = 7

b) For 120° sectoring, $i_{\circ} = 2$
Then, N = 2.65 $\approx$ we choose N = 3

c) For 60°sectoring, $i_{\circ} = 1$

Then, N = 2.65 $\approx$ we choose N = 3

Sectoring can increase the capacity by 7/3 = 2.33 times for both 120° and 60° sectoring.

Although, 60° increases the capacity by the same factor as 120° sectoring, it will reduce the trunking efficiency.

Therefore, if sectoring is to be used, 120° sectoring would be better choice.

5. a) What is link budget? Why link budget is important? Explain.

Ans:

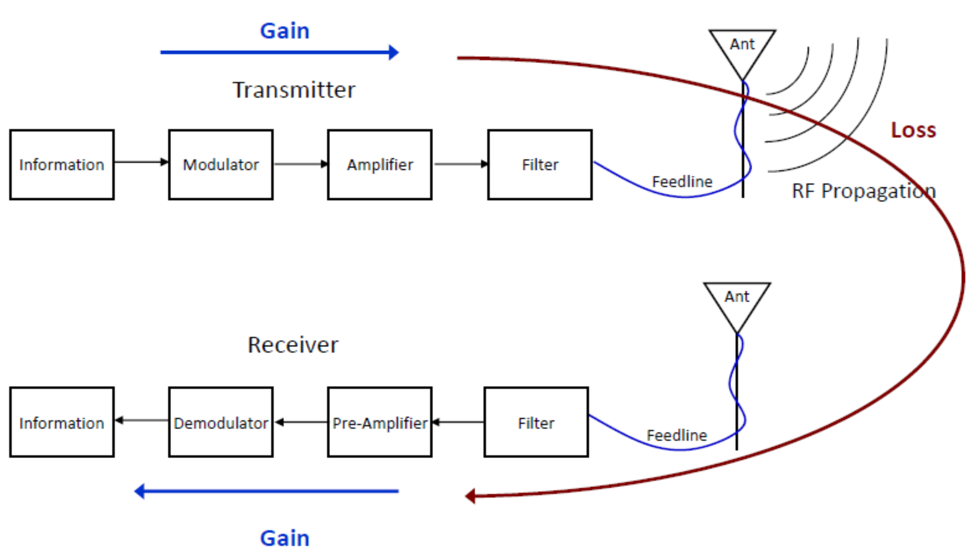
A link budget is an accounting of all the gains and losses in a (wireless) transmission system.

Link budget is important because:

1. Determines tower transmit ERP for sufficient signal strength at the cell boundary for a quality mobile call
2. Defines the cell coverage radius when used with a path loss model
3. Determine transmit ERP and cell radius
4. Ensure path balance
5. Balance the uplink and downlink power
6. Don’t transmit more base station power than the needed

b) Analyze the link budget with transmitter and receiver components.

The **link budget analysis** determines if there is enough power at the receiver to recover the transmitted information



Transmit Power Components:

•Begin with the power output of the transmit amplifier

–Subtract (in dB) losses due to passive components in the transmit chain after the amplifier

•Filter loss

•Feed line loss

•Jumpers loss

–Add antenna gain

•dBi

•Result is EIRP

Receiver System Components:

•The Receiver has several gains/losses

–Specific losses due to known environment around the receiver

•Vehicle/building penetration loss

–Receiver antenna gain

–Feedline loss

–Filter loss

•These gains/losses are added to the received signal strength

–The result must be greater than the receiver's sensitivity

c) Show that, the maximum allowable path loss (L_{max}) that the link can tolerate is,

$$L_{max(dB)} = \Omega_{t(dBm)} + G_{T(dB)} + G_{R(dB)} - \Omega_{th(dBm)}$$

where, Ω_t = transmit carrier power, G_T = transmit antenna gain, G_r = receiver antenna gain, Ω_{th} = receiver sensitivity

Ans:

The average received carrier power can be expressed as,

$$\Omega_p = \frac{\Omega_t\, G_T G_R}{L_p\, L_{R_x}}$$

Where, Ω_t = the transmitted power, G_T and G_R are the transmitter and receiver antenna gains.

The total input thermal noise power to the detector is

$$N = kT_{\circ} B_w F$$

The value of $kT_{\circ}$ at a room temperature of 17°C is 174 dBm/Hz.
The received carrier-to-noise ratio, Γ defines the link budget, where

$$\Gamma = \frac{\Omega_p}{N} = \frac{\Omega_t \, G_T G_R}{kT_{\circ} B_w F L_p \, L_{R_x}}$$

The carrier-to-noise ratio, Γ and modulated symbol energy-to-noise ratio, $\frac{E_s}{N_o}$ are related as follows

$$\frac{E_s}{N_o} = \Gamma \times \frac{B_w}{R_s}$$

Hence, the link budget can be written as

$$\frac{E_s}{N_o} = \frac{\Omega_t \, G_T G_R}{kT_{\circ} B_w F L_p \, L_{R_x}} \times \frac{B_w}{R_s}$$

Converting to decibel units gives

$$\frac{E_s}{N_o}(dB) = \Omega_{t\,(dBm)} + G_{T\,(dB)} + G_{R\,(dB)} - kT_{o\,(dBm)/Hz} - R_{s\,(dBHz)} - F_{(dB)} - L_{R_{x}\,(dB)} - L_{p\,(dB)}$$

The receiver sensitivity is defined as

$$\Omega_{th\,(dBm)} = L_{R_{x}\,(dB)} + kT_{o(dBm)/Hz} + F_{(dB)} + E_s/N_{o\,(dB)} + R_{s(dBHz)}$$

Then by substituting the resulting value for $\Omega_{th\,(dBm)}$ the maximum allowable path loss that the link can tolerate is obtained as

$$L_{\max(dB)} = \Omega_{t\,(dB)} + G_{T\,(dB)} + G_{R\,(dB)} - \Omega_{th\,(dBm)}$$

6. **a) What is path loss and path loss model?**

Ans:

Path loss is a reduction in the signal's power, which is a direct result of the distance between the transmitter and the receiver in the communication path.

There are many models used in the industry today to estimate the path loss and the most common are:

- Free Space
- Hata
- Lee

Each model has its own requirements that need to be met in order to be utilized correctly

b) Show that, Hata model is well suited for large cell mobile system , but not PCS(personal communications systems)

Ans:

The Hata model is an empirical formulation of the graphical path loss data provided by Okumura, and is valid from 150 MHz to 1500 MHz. Hata presented the urban area propagation loss as a standard formula and supplied correction equations for application to other situations. The standard formula for median path loss in urban areas is given by

$$L_{50}(urban)(dB) = 69.55 + 26.16\log f_c - 13.82\log h_{te} - a(h_{re}) + (44.9 - 6.55 log h_{te}) log d$$

Where, f_c is the frequency (in MHz) from 150 MHz to 1500 MHz,
h_{te} is the effective transmitter (base station) antenna height (in meters) ranging from 30 m to 200 m, h_{re} is the effective receiver (mobile) antenna height (in meters) ranging from 1m to 10 m, d is the T-R separation distance (in km), and $a(h_{re})$ is the correction factor for effective mobile antenna height which is a function of the size of the coverage area.
To obtain the path loss in a suburban area the standard Hata formula can be modified as

$$L_{50\,(dB)} = L_{50\,(urban)} - 2\left[\log\left(\frac{f_c}{28}\right)\right]^2 - 5.4$$

for path loss in open rural areas, the formula is modified as

$$L_{50}(dB) = L_{50}(urban) - 4.78(log f_c)^2 - 18.33 log log f_c - 40.98$$

Although Hata's model does not have any of the path-specific corrections which are available in Okumura's model, the above expressions have significant practical value. So, This model is well suited for large cell mobile systems, but not personal communications systems (PCS) which have cells on the order of 1km radius.

d) If a transmitter produces 50 watts of power, express the transmit power in units of (a) dBm, and (b) dBW. If 50 watts is applied to a unity gain antenna with a 900 MHz carrier frequency, find the received power in dBm at a free space distance of 100 m from the antenna, What is P (10 km) 2 Assume unity gain for the receiver antenna.

Ans:

Given:
Transmitter power, P_t = 50 W
Carrier frequency, f_c = 900 MHz
(a) Transmitter power,

$$P_t(dBm) = 10\log[\frac{P_t(mW)}{(1mW)}]$$
$$= 10\log[50 \times 10^3]$$
$$= 47.0\ dBm$$

(b) Transmitter power,

$$P_t(dBW) = 10\log\left[\frac{P_t(W)}{(1W)}\right] = 10\log[50] \quad = 17.0 \text{ dBW}$$

The received power can be determined as follows,

$$P_r = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2 L} = \frac{50\,(1)(1)\left(\frac{1}{3}\right)^2}{(4\pi)^2(100)^2(1)} = 3.5\times10^{-3}\,mW$$

$$P_r(dBm) = 10 log P_r(mW) = 10\log(3.5\times10^{-3}\,mW) = -24.5\,dBm$$

The received power at 10 km can be expressed in terms of dBm,
where d_o = 100 m and d = 10km

$$P_r(10km) = P_r(100) + 20\log\left[\frac{100}{1000}\right] = -24.5dBm - 40dB = -64.5\,dBm$$

7. a) What is cell splitting? How to increase capacity of a cellular network?

Ans:

Cell splitting is the process of dividing the radio coverage of a cell site in a wireless telephone system into two or more new cell sites.

Add new channels

- Not all channels used to start with
- Frequency borrowing
- Taken from adjacent cells by congested cells
- Or assign frequencies dynamically

Cell splitting

- Non-uniform distribution of topography and traffic
- Smaller cells in high use areas
- Original cells 6.5 –13 km
- 1.5 km limit in general
- More frequent handoff
- More base stations

b) Write short notes on

i) **dBm & dBi**
ii) **ERP & EIRP**
iii) **MSC & BSS**
iv) **Hard-handoff and Soft-handoff**
v) **Balanced link and unbalanced link**

i) **dBm:** dBm is an abbreviation for the power ratio in decibels (dB) of the measured power referenced to 1 mW. It is used in radio, microwave and fiber optic networks as a convenient measure of absolute power because of its capability to express both very large and very small values in a short form.

   dBi: dBi is a unit to measure antenna gain in reference to an isotropic antenna. An isotropic antenna has a power gain of unity; i.e., 0 dBi.

ii) **ERP:** ERP (Effective Radiated Power): is the radiated power (transmit powertimes antenna gain) with respect to a dipole antenna within a given geographic area.

   EIRP: In radio communication systems, the Equivalent isotropically radiated power (EIRP) or, alternatively, is Effective isotropically radiated power is the amount of power that a theoretical isotropic antenna (which evenly distributes power in all directions) would emit to produce the peak power density observed in the direction of maximum antenna gain.

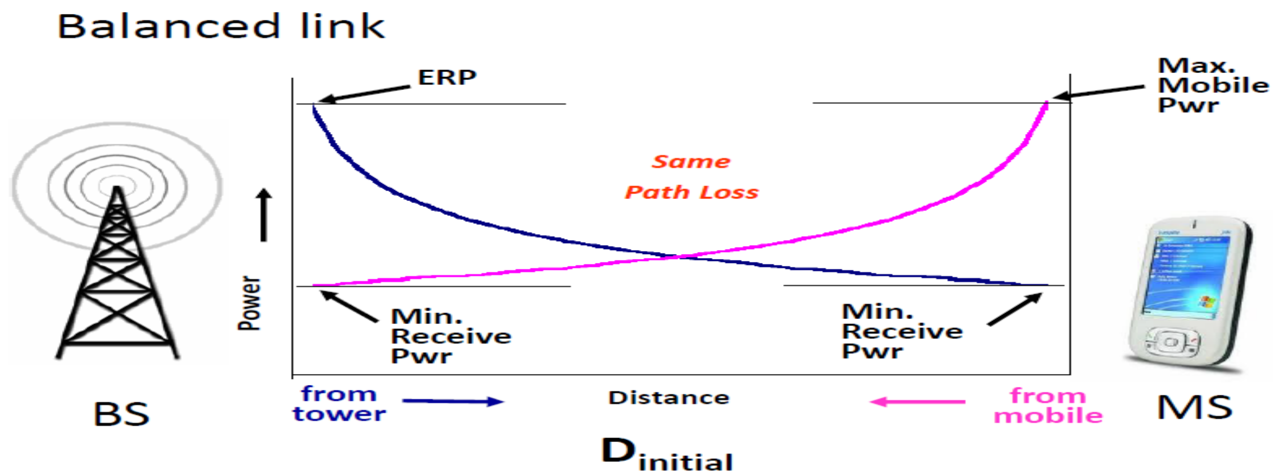
iii) **Mobile-Station Subsystem(MSC):** Mobile Switching Center (MSC) is the primary service delivery node for GSM/CDMA, responsible for routing voice calls and SMS as well as other services (such as conference calls, FAX and circuit switched data)

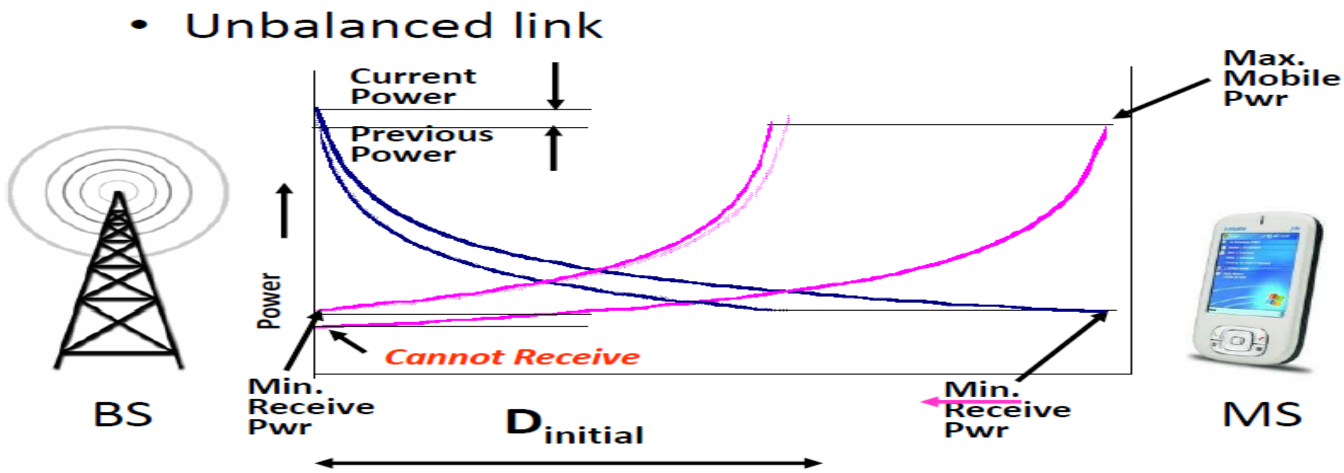
   Base-Station Subsystem(BSS): The base station subsystem (BSS) is the section of a traditional cellular telephone network which is responsible for handling traffic and signaling between a mobile phone and the network switching **s**ubsystem.

iv) **Hard handoff:** It means that all the old radio links in the MS are removed before the new radio links are established. In GSM, it is general. We can say Break before Make. So, in this case higher rates of call drops is found.

   Soft Handoff: It means the radio links are added and removed in a way that the MS always keeps at least one radio link to the UTRAN. In CDMA this technique is performed. In simple words we can say Make befor Break. To lower the rates of call drops, this technique is used.

v) Balanced link and unbalanced link:





8. **a) What is receiver sensitivity? What are the differences between large scale fading and small scale multipath fading.**

Ans:

Receiver sensitivity is defined as the signal optical power required at the **receiver** to achieve the targeted bit error rate.

Small scale fading

• Small scale fading is concerned with rapid fluctuations of received signal strength over very short distance and short time period.
• These multipath fading types depend on propagation environment.
• It is divided into two main categories viz. multipath delay spread and doppler spread.
• Based on multipath delay spread there are two types of small scale fading viz. flat fading and

frequency selective fading.
• Doppler spread is divided into fast fading and slow fading.

Large scale fading

• Large scale fading occurs when an obstacle comes in between transmitter and receiver. This interference type causes significant amount of signal strength reduction. This is because EM wave is shadowed or blocked by the obstacle. It is related to large fluctuations of the signal over distance.
• It includes path loss and shadowing effects.
• The free space path loss can be expressed as follows.

$$\frac{P_t}{P_r} = \frac{(4\pi d)^2}{\lambda^2}$$

• Shadowing is deviation of received power of EM signal from average value. It is result of obstacles over the path between transmitter and receiver. It depends on geographical position as well as radio frequency of EM (Electro Magnetic) waves.

b) **When we care about link budget? What we can change to achieve a balanced link budget within a given cell size**.

Ans:

•For cell-based systems, we have to:

–Provide continuous coverage over the entire region

–Ensure transmitters in one cell don’t interfere with those in the closest cell that uses the same frequency

–Consider reducing cell size in order to have more capacity through a larger number of cells

•To achieve a balanced link budget within a given cell size we can:

–Adjust transmit power

–Adjust transmit tower height

–Adjust transmit antenna gain

–Modify the receivers

•For planning a system we can use a link budget to:

–Determine the cell size

–Determine the frequency reuse ratio

c) **What is free space path loss?**

Ans:

The free-space path loss (FSPL) is the attenuation of radio energy between the feedpoints of two antennas that results from the combination of the receiving antenna's capture area plus the obstacle free, line-of-sight path through free space (usually air).

d) **Suppose that a signal with 200kHz bandwidth at 290k temperature, where, noise factor for amplifier is 1.2dB, modulation scheme requires SNR of 15dB. Find out the sensitivity**.

Ans:

Sensitivity = Thermal Noise + NF + Required SNR

Thermal Noise = $kTB = \left((1.3803 \times 10^{-23}) JK^{-1}\right)(290\text{K})(200\text{KHz})$

$= 8.006 \times 10^{-16}\ W$

= -151dBW or -121dBm

Sensitivity (W) = ($8.006 \times 10^{-16}\ W$) (1.318) (31.62) = 3.33×10^{-14} W

Sensitivity (dBm) = -121dBm + 1.2dB + 15dB = -104.8dBm