July

MODULE - I

Silicon ...beyond teaching

Coming together is a beginning, keeping together is progress and working together is success.

4 Tuesday

Introduction To Cellular Systems

→ Most of the Commercial radio & TV systems uses tallest antennas which transmits Max. Power in order to achieve large area of coverage.

→ In this case the frequency used by one transmitter can't be reused again untill there is enough geographical separation in order to avoid the interference with another transmitter using the same frequency.

→ Cellular systems are designed to operate with groups of low power radios (The term NodeB was first introduced with the introduction of UMTS. The NodeB is a part of UTRAN).

5 Wednesday

→ The area served by each group of radios is called a cell and the radios are used to serve the mobile stations within the cell.

→ The cellular systems allows frequency reuse at much smaller distances.

→ A basic cellular system consists of three parts: a Mobile unit, a cell site and a mobile telephone switching office (MTSO), with connections to link the three subsystems.

AUG. 17

MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN
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21	22	23	24	25	26	27	28	29	30	31										

I am proud to be a Siliconite

6 Thursday

① Mobile Units :- A mobile telephone unit contains a control unit, a transceiver and an antenna system.

② Cell Site :- The cell site provides interface between the MTSO and the mobile units. It has a control unit, radio cabinets, antennas, a power plant, and data terminals.

③ MTSO :- The switching office, the central coordinating elements for all cell sites, contains the cellular processor and cellular switch. The MTSO is the heart of the cellular Mobile System.

→ To describe the cellular system in general,

7 Friday there are two basic cellular system;

① Circuit - switched system

② Packet - switched system.

- In circuit - switched system, each traffic channel is dedicated to a user until its call is terminated. The circuit-switched system can be further distinguished in two types,

① Analog cellular system

② Digital cellular system.

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8 Saturday 9 Sunday

① Analog cellular system :-

- The operating frequency is 824 MHz to 893 MHz. (824-849 MHz for Reverse channel (RC) & 869-893 MHz for FC)
- It provides basic calling and voice mail.

- The 1st generation cellular technology that were introduced in 1980 are considered as analog cellular systems.

- The 1G cellular employed various distinct and incompatible through the world e.g.

Nordic Mobile Telephone (NMT) used in Nordic countries, Switzerland, the Netherlands, Eastern Europe and Russia. Advanced Mobile phone system (AMPS) used in northen America and Australia. Total Accen Communication systems (TACS) in UK.

10 Monday

② Digital cellular system :-

- It operating frequency is same as analog cellular system.

- It provides advanced features, such as caller ID and telephones with built-in pagers and longer battery life.

- It provides high voice quality with low infrastructure cost.

- Ability to support new services.

11 - It has high radio frequency spectrum efficiency. Tuesday

- There are three main systems,
  (i) Global System for Mobile Communication (GSM)
  (ii) Japanese Digital Cellular (JDC)
  (iii) American Digital Cellular (ADC)
- Digital systems can use FDMA, TDMA, and CDMA technology.

12 → In a cellular system the power transmitted by the cell is chosen to be large enough to communicated with the Mobile stations located near the cell edge. Wednesday

→ Each base stations is allocated a portion of the total number of channels available to the entire system and near by base stations (BSs) are assigned different group of channels so that all the available channels are assigned to a relatively small no. of neighbouring BSs, so the interference is minimized.

→ With increase in the traffic the no. of cells and channels are also increased.

→ In practical, the coverage area

13 Thursday

of a cell is an irregularly shaped circle, because the exact coverage ~~of~~ depends on the physical features of land and other factors.

→ For design purposes it is assumed that the coverage areas are regular polygons (A first order approximation).

→ For an omnidirectional antennas having const. signal power, each cell sites coverage area would be circular.

→ To achieve full coverage ~~area~~ without dead spots, a series of regular polygons are required for cell sites.

14 Friday

→ Any regular polygon, such as an equilateral triangle, Square, or a hexagon can be used for cell design.

→ The hexagonal structure is more prefferable, because a hexagonal layout requires fewer cells and therefore fewer transmitter sites and a hexagonal cell layout is less expensive as compared to square and triangular cells.

→ The 'N' no. of cells which collectively use the complete set of available frequencies is called a "cluster".

→ In a hexagon geometry the no. of cells per cluster, 'N' can only have ~~values~~ values,

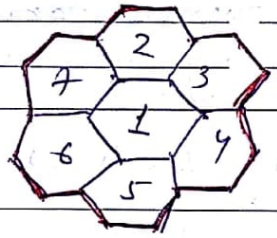
15 Saturday 16 Sunday

$$N = i^2 + ij + j^2 \quad \text{——— (1)}$$

where, i & j are non-negative integers.

Ex (1) let $i = 2$, $j = 1$

so $N = 4 + 2 + 1 = 7$



17 Monday

[A cluster of 7 no. of cells]

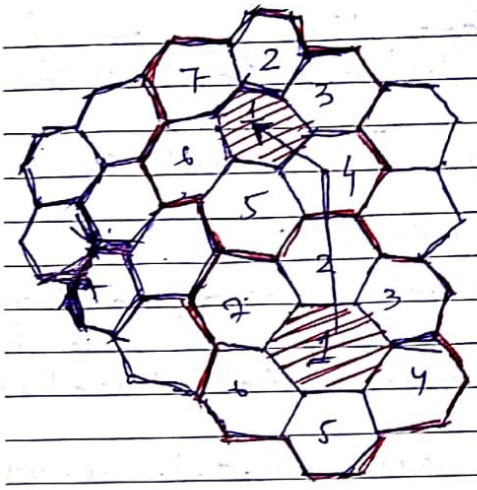
→ To find the nearest co-channel neighbor of a particular cell,

(i) Move 'i' cells along any chain of hexagon and then,

(ii) Turn 60° counter-clockwise and move 'j' cells.

Ex (2) - Considering Ex-1 i.e. $i = 2$, $j = 1$

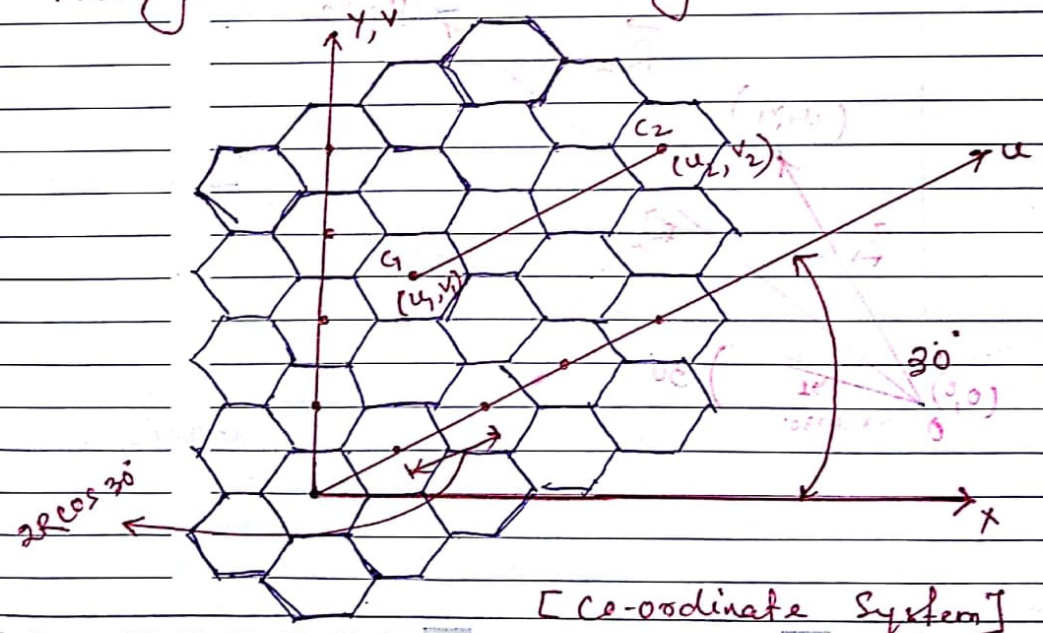
18 Tuesday



[Cell arrangement with reuse factor]

19 Wednesday

Hexagonal Cell Geometry.



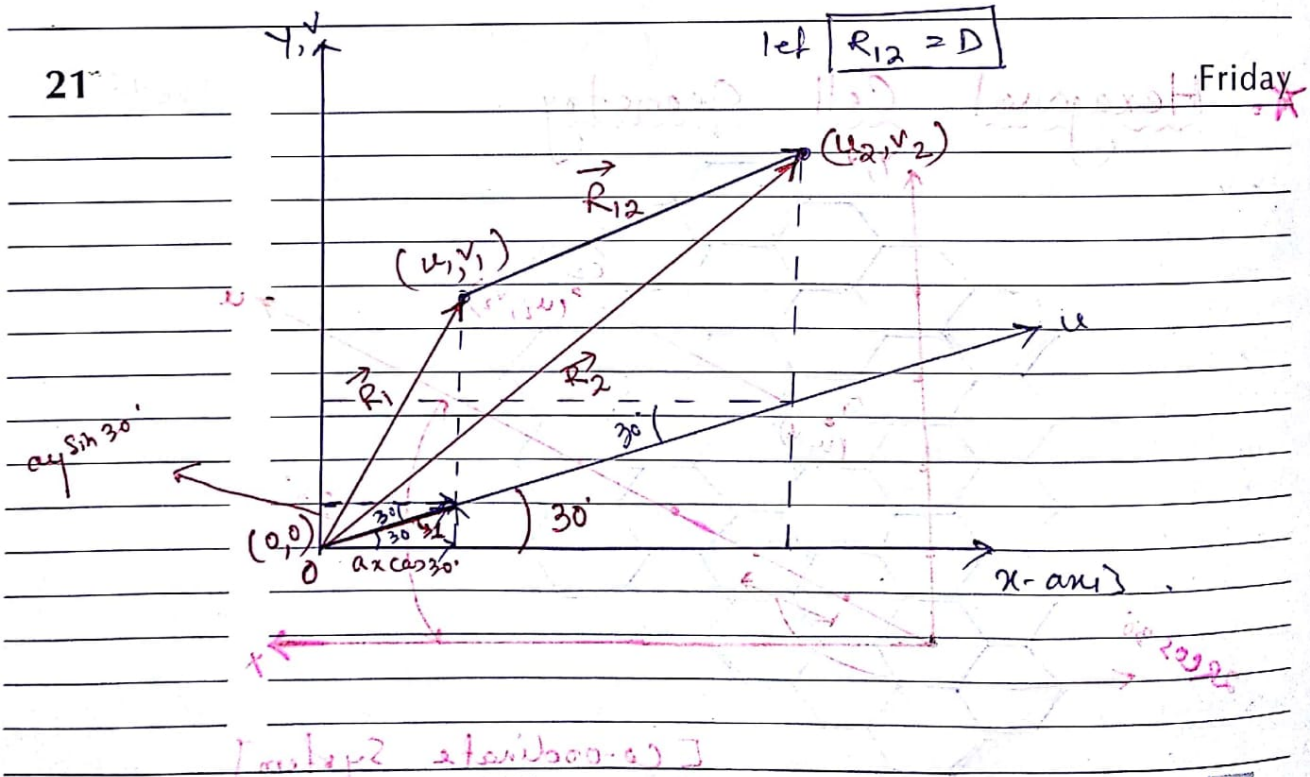
[Co-ordinate System]

20 Thursday

- let C_1 and C_2 are the center of two cells and the distance betⁿ them is D.
- The co-ordinates of C_1 and C_2 are (u_1, v_1) and (u_2, v_2)
- The u-v axes are chosen so that u-axis passes through the center of the hexagon and the v-axis is along the direction of y-axis.
- The angle of u-axis w.r.t. x-axis is 30°.
- In order to calculate D, the above co-ordinate system can be redrawn as,

21 Friday

let $R_{12} = D$



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22 Saturday

$\vec{R_1} = u_1 \hat{a}_u + v_1 \hat{a}_v$

$\hat{a}_u = \hat{a}_x \cos 30^\circ + \hat{a}_y \sin 30^\circ$

$\Rightarrow \vec{R_1} = u_1 [\hat{a}_x \cos 30^\circ + \hat{a}_y \sin 30^\circ] + v_1 \hat{a}_y$

u & v are in same direction

$\vec{R_2} = u_2 \hat{a}_u + v_2 \hat{a}_v$

$\hat{a}_u = \hat{a}_x \cos 30^\circ + \hat{a}_y \sin 30^\circ$

(1)

24 $\Rightarrow \vec{R_2} = u_2 [\hat{a}_x \cos 30^\circ + \hat{a}_y \sin 30^\circ] + v_2 \hat{a}_y$

According to the vector rule,

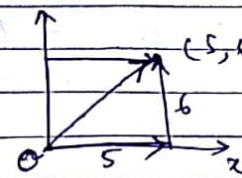
$\vec{R_1} + \vec{R_{12}} = \vec{R_2}$

$\Rightarrow \vec{R_{12}} = \vec{R_2} - \vec{R_1}$

$\Rightarrow \vec{R_{12}} = [u_2 \hat{a}_x \cos 30^\circ + u_2 \hat{a}_y \sin 30^\circ + v_2 \hat{a}_y] - [u_1 \hat{a}_x \cos 30^\circ + u_1 \hat{a}_y \sin 30^\circ + v_1 \hat{a}_y]$

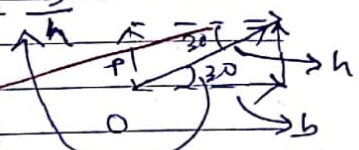
23 Sunday

Ex.



$R_{56} = 5a_x + 6a_y$

$\cos 30^\circ = \frac{b}{h}$



$h = 1$ (∵ position vector Magnitude = 1)

$\cos 30^\circ = \frac{b}{1} \Rightarrow b = \cos 30^\circ$

$\Rightarrow b = \cos 30^\circ \hat{a}_x$

∵ $\hat{a}_x$ vector shows the position in the x-axis direction

Monday

$\sin 30^\circ = \frac{P}{h}$

$P = \sin 30^\circ$

$\Rightarrow P = \sin 30^\circ \hat{a}_y$

∵ $\hat{a}_y$ = shows the position in y-axis direction

25 Tuesday

i) $\vec{R}_{12} = (u_2-u_1)\hat{a}_x \cos 30^\circ + (u_2-u_1)\hat{a}_y \sin 30^\circ + (v_2-v_1)\hat{a}_y$

$= (u_2-u_1)\hat{a}_x \cos 30^\circ + \{(u_2-u_1)\sin 30^\circ + (v_2-v_1)\}\hat{a}_y$

ii) $|\vec{R}_{12}| = \left[\{(u_2-u_1)\cos 30^\circ\}^2 + \{(u_2-u_1)\sin 30^\circ + (v_2-v_1)\}^2\right]^{1/2}$

$= \left[(u_2-u_1)^2 + (v_2-v_1)^2 + (u_2-u_1)(v_2-v_1)\right]^{1/2}$ ——— (1)

26 Wednesday

By assuming $(u_1, v_1) = (0,0)$ i.e. the origin of the co-ordinate system is the center of a hexagonal cell and considering (u_2, v_2) to be positive integer valued (i,j), then normalized distance D_{norm} of eqn (1) can be written as,

$$D_{norm} = \left[i^2 + j^2 + ij\right]^{1/2} \quad \text{——— (2)}$$

★ The normalized distance i.e. D_{norm} betn two adjacent cells is '1' for $(i=1, j=0$ or $i=0, j=1)$

★ The actual distance betn the centers of two adjacent hexagonal cell is $2R\cos 30^\circ$ or $\sqrt{3}R$.

where, R is the center-to-vertex distance.

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27 Thursday

→ By assuming that the 1st cell is centered at the origin (u=0, v=0), the distance betn any two cells will be,

$$D = (D_{norm})(\sqrt{3}R) \quad \text{---------- (3)}$$

→ As long as the cell size is fixed, and each cell transmits the same power, co-channel interference will be independent of the transmitted power of each cell.

→ The co-channel interference is a fun^n of q, where, $q = \frac{D}{R}$

28 But D is a fun^n of N_I and S/I. Friday

N_I = No. of co-channel-interferry cell in the first tier.

S/I = Received signal-to-interference ratio at the desired mobile receiver.

→ Normally the effects of co-channel-interferry cells in the 2nd, 3rd and higher tiers are neglected, because their contributions are much smaller as compared to the 1st tier cell.

→ Using eqn^n (3) and putting the value of eqn^n (2) in it,

29 Saturday 30 Sunday

$$D = (i^2 + j^2 + ij)^{1/2} \sqrt{3} R$$

$$\Rightarrow \boxed{D^2 = 3R^2(i^2 + j^2 + ij)} \quad \text{---------- (4)}$$

→ Since the area of a hexagon is proportional to the square of the distance bet^n center and vertex i.e.

$$A = K[3R^2(i^2 + j^2 + ij)]$$

where K = const.

31 Monday

⇒ from eqn' (4),

$$D^2 = 3R^2(i^2 + j^2 + ij)$$

$$\Rightarrow \frac{D^2}{R^2} = 3(i^2 + j^2 + ij)$$

$$\Rightarrow \frac{D^2}{R^2} = 3N \quad \left| \because N = i^2 + j^2 + ij \right.$$

$$\Rightarrow \frac{D}{R} = \sqrt{3N}$$

$$\Rightarrow \boxed{\frac{D}{R} = q = \sqrt{3N}} \quad \text{---------- (5)}$$

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Note

q = Reuse Ratio

N = cluster size or Reuse factor

→ The value of q is important because it affects the traffic-carrying capacity of a cellular system and the co-channel interference.

→ By reducing q, the no. of cells per cluster is reduced. But, co-channel interference is increased with small q and vice versa.

★. Cochannel Interference Ratio

The S/I ratio at the desired Mobile receiver is given as,

$$\frac{S}{I} = \frac{S}{\sum_{k=1}^{N_I} I_k} \quad \text{——— (1)}$$

Where,

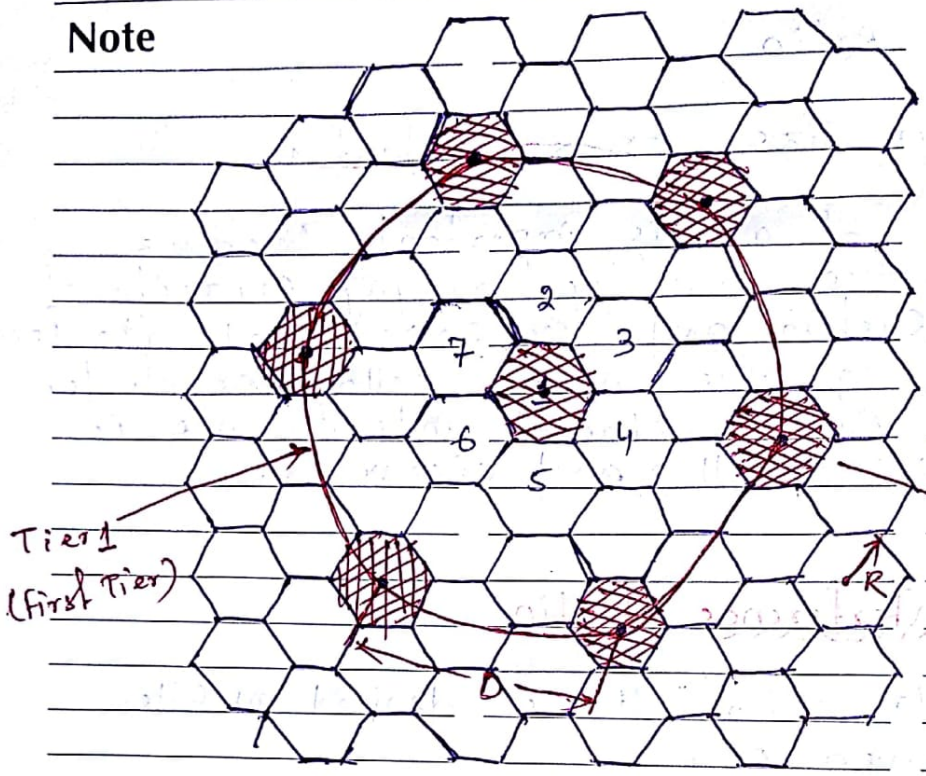
I_k = The interference due to the Kth interferer.

N_I = The no. of of interfering cells in the first tier.

→ In a fully equipped hexagonal-shaped cellular system, there are always six co-channel-interfering cells in the first tier i.e. $N_I = 6$.

→ Most of the cochannel interference results from the first tier.

Note



My consideration
$i = 2, j = 1$
$N = 7$

[Six Effective Interfering cells in tier 1 of cell 1]

→ Though the contribution from the 2nd and higher tiers are less than 1% of the total contribution, so they are neglected.

→ Cochannel interference can be experienced both at the cell site and the Mobile stations in the center cell.

→ In a small cell system, interference will be the dominating factor and thermal noise can be neglected.

→ Thus the S/I ratio can be given as,

$$\frac{S}{I} = \frac{1}{\sum_{k=1}^{6} \left(\frac{D_k}{R}\right)^{-\gamma}} \quad \text{---------- (2)}$$

1 Tuesday

Where,

$2 \le \gamma \le 5$ = the propagation path loss, and γ depends upon the terrain environment.

D_k = The distance betn Mobile and Kth interfering cell.

R = The cell radius.

- By assuming D_k is the same for the six interfering cell for simplification, or,

$$D_k = D$$

then Eqn (2) can be written as,

2 Wednesday

$$\frac{S}{I} = \frac{1}{6\left(\frac{D}{R}\right)^{-\gamma}}$$

$$\Rightarrow \boxed{\frac{S}{I} = \frac{1}{6(q)^{-\gamma}} = \frac{q^{\gamma}}{6}} \quad \text{---(3)}$$

where, $q = \frac{D}{R}$ = Reuse ratio.

$$\boxed{q = \left[6\left(\frac{S}{I}\right)\right]^{1/\gamma}} \quad \text{---(4)}$$

As we known that,

3 Thursday

$$q = \frac{D}{R} = \sqrt{3N} \quad \text{——— (5)}$$

Equating eqn (4) & (5)

$$N = \frac{1}{3}\left[6\left(\frac{S}{I}\right)\right]^{2/\gamma} \quad \text{——— (6)}$$

* Cellular System Design in Worst-case scenario with an omnidirectional Antenna.

→ In general the frequency reuse ratio can be find out as,

4 Friday

$$q = \frac{D}{R} = \sqrt{3N}$$

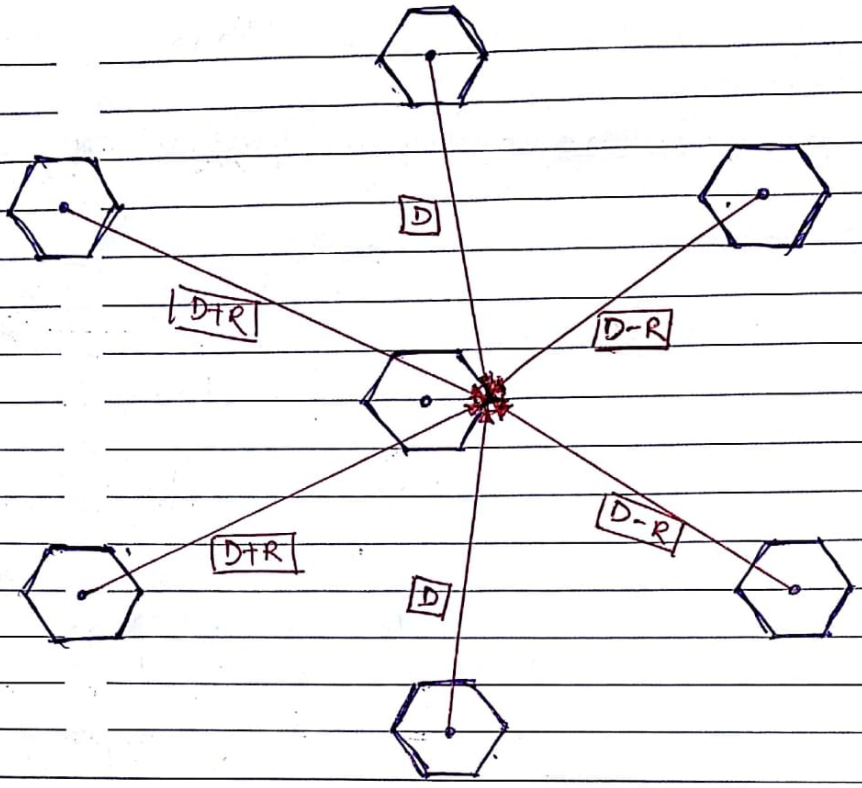
→ So for a $N = 7$ cluster

$$q = \sqrt{3 \times 7} = \sqrt{21} = 4.6$$

→ But in worst-case scenario, where the Mobile unit is located at the cell boundary, in this situation, the Mobile unit receives the weakest signal from its own cell and is subjected to strongest interference from all the interfering cells in the first tier.

→ The Distances from the six interfering cell are given in the fig.

10 Thursday



11 Friday

[Worst-case scenario for co-channel interference]

→ The S/I ratio can be given as,

$$\frac{S}{I} = \frac{1}{\sum_{k=1}^{6} \left(\frac{D_k}{R}\right)^{-\gamma}} \Rightarrow \frac{S}{I} = \frac{R^{-\gamma}}{2(D-R)^{-\gamma} + 2D^{-\gamma} + 2(D+R)^{-\gamma}} \quad \text{— (1)}$$

→ Using the path-loss exponent $\gamma = 4$ and $D/R = q$, eqn (1) can be written as,

$$\frac{S}{I} = \frac{1}{2(q-1)^{-4} + 2q^{-4} + 2(q+1)^{-4}} \quad \text{— (2)}$$

12 Saturday 13 Sunday

→ Substituting $q = 4.6$ (For $N = 7$), from eqn ②,

$$\boxed{\frac{S}{I} = 54.3 \text{ or } 17.3 \text{ dB}}$$

→ Considering only the shortest distance i.e. D-R,

$$\frac{S}{I} = \frac{1}{6\left(\frac{D-R}{R}\right)^{-\gamma}}$$

$$\Rightarrow \frac{S}{I} = \frac{1}{6\left(\frac{D-R}{R}\right)^{-4}} \Rightarrow \frac{S}{I} = \frac{1}{6\left(\frac{D}{R}-1\right)^{-4}}$$

14 $$\Rightarrow \frac{S}{I} = \frac{1}{6(q-1)^{-4}} \Rightarrow \frac{S}{I} = \frac{1}{6(4.6-1)^{-4}}$$ Monday

$$\Rightarrow \boxed{\frac{S}{I} = 28 \text{ or } 14.47 \text{ dB}}$$

→ Due to the rolling nature of terrain config and imperfect cell-site location, the S/I ratio is often less than 17.3 dB or could be less than 14 dB. Such condi may occur in heavy traffic.

→ So it is better to choose $N = 9$ [$q = 5.2$ and $\frac{S}{I} = 19.79$] or $N = 12$ [$q = 6.0$ and $\frac{S}{I} = 22.54$ dB] for designing cellular system in worst case scenario with an omnidirectional antenna.

SEPT. 17

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15. Co-channel Interference Reduction — Tuesday

→ The frequency reuse method is useful for increasing the efficiency of the spectrum usage to meet the increased traffic.

→ The frequency reuse method results in co-channel interference because the same frequency channel is used repeatedly in different co-channel cells.

→ As N increases the no. of frequency channels assigned to a cell is reduced which causes the decrease in cell capacity.

→ Instead of increasing N, the co-channel interference can be reduced by using,

16 — Wednesday

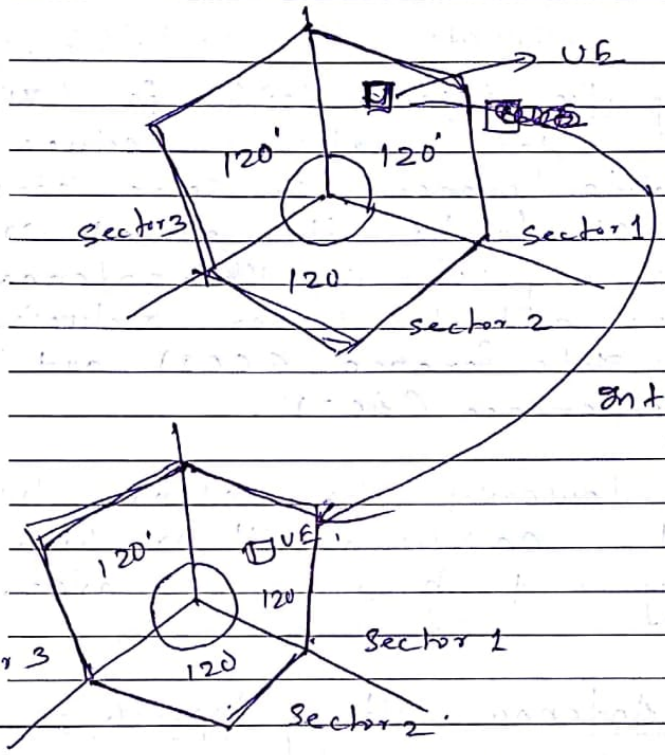
(1) Directional Antenna.

(2) Cell splitting :- where a congested cell is divided into smaller cells.

(3) Cell sectoring :- where each cell is divided into 3 or six no. of sectors where the directional antenna is used to serve each sector. Each sector is assigned a set of channels (either 1/3 or 1/6 of the frequency of the omni directional antenna.

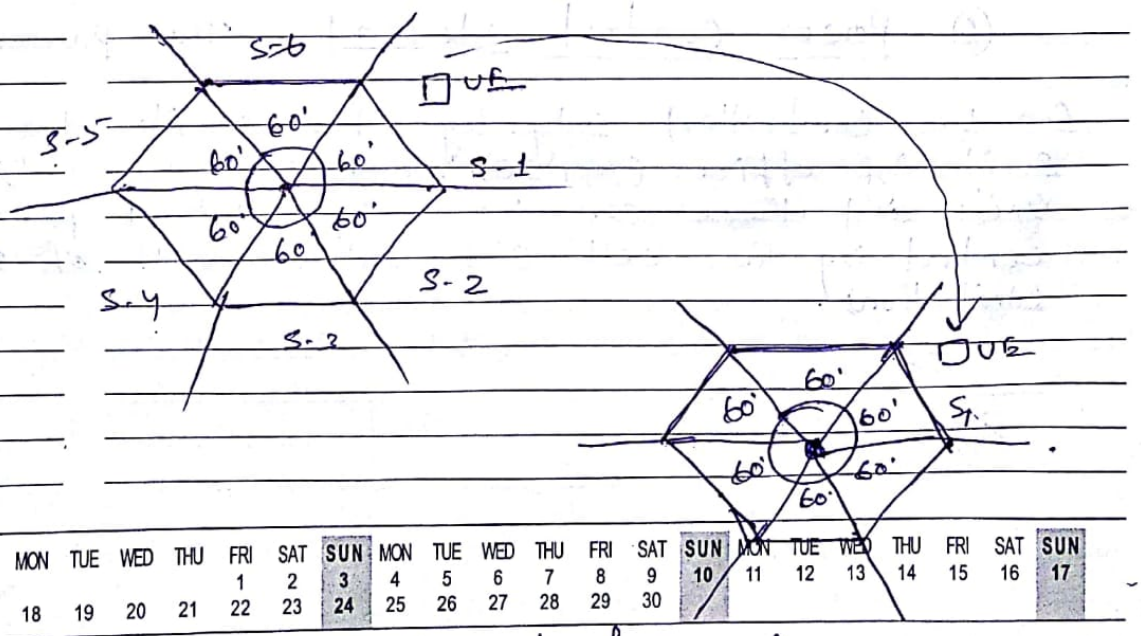
(4) Coverage

17 Thursday



18 Friday

[③ co-channel interference in 120° sectorized cell]



④ Lowering the Antenna Height :- Lowering the antenna height doesn't always reduce the co-channel interference. In some circumstances, such as on fairly flat ground or in a valley situation, lowering the antenna height will be very effective for reducing the co-channel interference (CCI) and adjacent channel interference (ACI).

- Lowering the antenna height is not helpful, on high hill or high spot, in a valley and in a forest area.

⑤ By Antenna tilting Approach :- where the mechanical and electrical tilting approach is used to optimize the coverage of the cell, thus reducing the CCI.

21 Monday

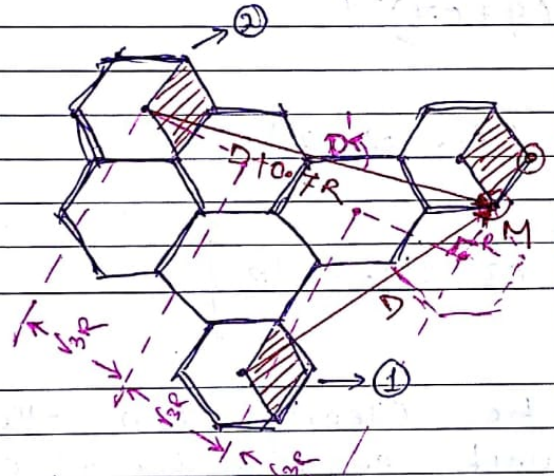
⑥ Power control Method :- The power level can be controlled only by the Mobile transmitting switching office (MTSO), not by the Mobile units and there can be only limited power control by the cell sites as a result of system limitations.

22 Tuesday

Directional Antenna in Seven-Cell Reuse Pattern

(1) Three-Sector Case :-

→ Considering the worst case scenario in which the Mobile unit is at position 'M'.



$D' = \sqrt{(\sqrt{3}+\sqrt{3}+\sqrt{3})^2 R^2 + R^2}$

$= \sqrt{(3\sqrt{3})^2 R^2 + R^2} = \sqrt{28}\, R$

$\boxed{D' = 5.29R}$

$q = 4.6 = \frac{D}{R}$

$\Rightarrow \frac{D}{R} = 4.6 \Rightarrow \boxed{D = 4.6R}$

$\Rightarrow D' = 5.29R = 4.6R + 0.7R$

$\Rightarrow \boxed{D' = D + 0.7R}$

[worst case scenario in a 120° directional antenna system (N = 7)]

23 Wednesday

→ In this situation, the mobile receives the weakest signal from its own cell and fairly strong interference from two interfering cells 1 & 2.

→ At the point 'M', the distance ~~bet~~ between the Mobile unit and the two interfering cells are D and (D+0.7R) respectively.

→ By considering the path loss exponent 'γ' in

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24 Thursday

the worst case scenario is '4', the signal to interference ratio is,

$$\frac{S}{I} = \frac{R^{-4}}{D^{-4} + (D+0.7R)^{-4}}$$

$$\Rightarrow \frac{S}{I} = \frac{1}{q^{-4} + (q+0.7)^{-4}}$$

using $q = 4.6$ (for $N = 7$)

$$\boxed{\frac{S}{I} = 285 \text{ or } 24.5 \text{ dB}}$$

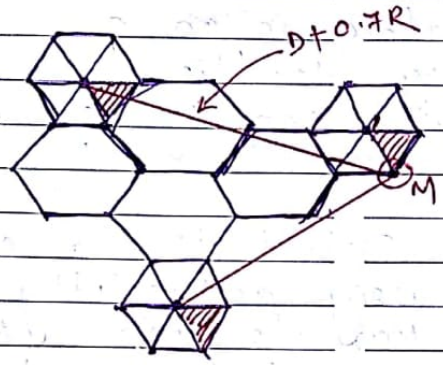
25 Friday

→ It can be clearly seen that the S/I for a Mobile unit served by a cell with 120° directional antenna exceeds 18 dB in the worst case scenario. So the use of directional antenna is helpful in reducing co-channel interference.

(2) Six-Sector case :-

→ In this case the cell is divided into six sectors by using a 60° beam width directional antenna, where the interfering cell reduces from 6 to 1.

26 Saturday 27 Sunday



[worst case scenario interference with 60° sectorized cells]

→ By considering the pathloss exponent $n = 4$

28 Monday

$$\frac{S}{I} = \frac{R^{-4}}{(D+0.7R)^{-4}} = \left(\frac{D+0.7R}{R}\right)^4$$

→ for $q = 4.6$ (for $N = 7$), $\frac{S}{I} = 789$ or 29 dB.

→ So it indicates that the S/I for a Mobile unit served by 60° sectorized directional antenna gives more S/I ratio as compared to 120° sectorized directional antenna, hence further decrease in co-channel interference.

→ But with with Six-sector configuration the cell capacity of the cell decreases.

29 Tuesday

★. Cell Splitting

→ When the cell traffic in an area increases, the cell with heavy traffic is splitted into smaller cells, so we can reuse frequency more often.

→ ~~Cell splitting~~ After subdividing a congested into smaller cells very cell splitting process, each smaller cell has its own base station and corresponding reduction in antenna height and transmitter power.

→ These smaller cells are known as Micro cell.

→ Cell splitting increases the capacity of a cellular system since it creates the no. of times that the channels are reused.

30 Wednesday

→ By defining new cells having radius smaller than the original cells almost half of the original cell and the distance betn co-channel cells also reduces to half.

→ As example shown in fig-2, the base stations are placed at the corner of the cell and the area covered served by BS (Base station) A is assumed to be saturated with traffic.

→ The cell splitting can be done in two ways

(1) Permanent Splitting

Seeing is believing, but feeling is truth.

31

Thursday

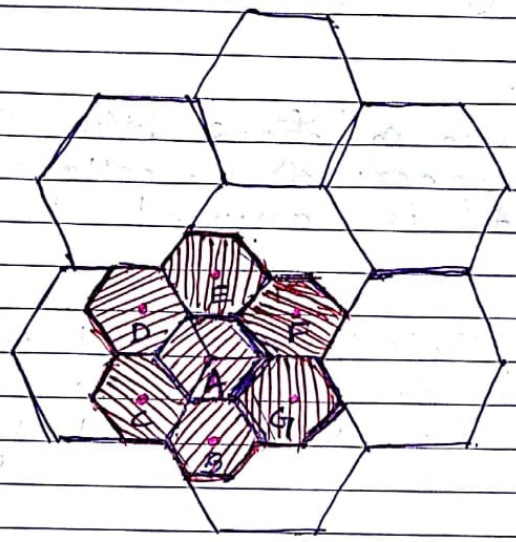
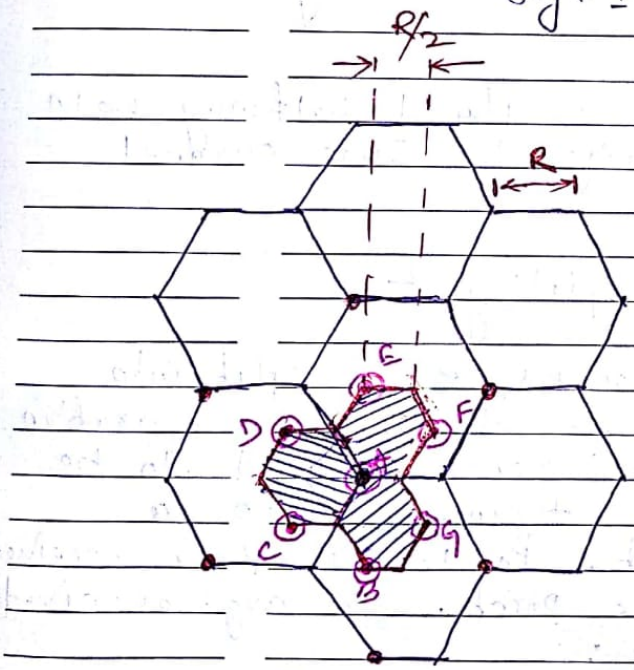
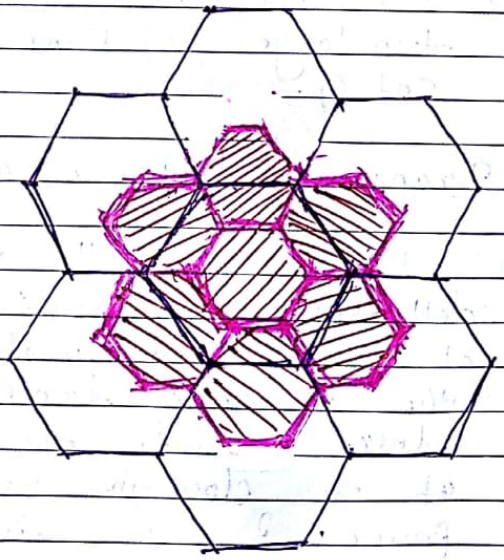


fig - 1.



[fig - 2]



[fig - 3].

Note

② Dynamic splitting (Real-time splitting)

→ As example shown in fig-2, the BS (Base station) are placed at corners of the cells and the area served by BS 'A' is assumed to be saturated with traffic.

→ New BS are therefore needed in the region to increase the no. of channels in the area and to reduce the area served by the single BS.

→ The original BS 'A' is surrounded by six new microcells.

→ The microcell BS 'G' is placed halfway between two larger stations utilizing the same channel set G.

Transmitted power after splitting :-

→ The large cell with radius R is split into cell with radius R/2. Let 'd' be the separation between the transmitter and receiver end d_0 be the distance from the transmitter to a close-in reference point. P_0 is the power received at the close-in reference point, the avg. received power, P_r, is given by;

$$P_r = P_0 \left(\frac{d}{d_0}\right)^{-\gamma} \quad \text{---(1)}$$

1 Friday

In dB :-

$$P_r(dBm) = P_0(dBm) - 10r \log\left(\frac{d}{d_0}\right)$$

→ P_{t_1} and P_{t_2} are the transmit power of the large cell (Radius R) BS and small cell (Radius R/2) BS respectively.

→ The received power, P_r at the large cell boundary is proportional to $P_{t_1} R^{-r}$ and P_r at the small cell boundary is proportional to $P_{t_2}(R/2)^{-r}$.

→ on the basis of equal power,

$$P_{t_1} R^{-r} = P_{t_2}\left(\frac{R}{2}\right)^{-r} \quad \text{——— (2)}$$

2 Saturday 3 Sunday

$$\frac{P_{t_1}}{P_{t_2}} = (2)^r \quad \text{——— (3)}$$

For $r = 4$, $P_{t_1}/P_{t_2} = 16\ (12dB)$. Thus, with cell splitting, where the radius of the new cell is one-half of the old cell, we achieve a 12dB reduction in the transmit power.

4 ★. Adjacent channel interference (ACI) :- Monday

→ Interference resulting from signals which are adjacent in frequency to the desired signal is called adjacent channel interference (ACI).

→ Adjacent channel interference results from imperfect receiver filters which allow nearby frequencies to leak into the passband.

→ The ACI is a serious if an adjacent channel user is transmitting in very close range to a subscriber's receiver, while the ~~subscribers~~ receiver attempts to receive a base station on the desired channel.

→ This is offered as the near-far effect, where
5 a near by transmitter captures the receiu Tuesday of the subscriber.

→ ACI can be minimized through careful filtering and channel assignments, like,

(1) Using modulation schemes which have low out-of-band radiation.

(2) Carefully designing the bandpass filter at the receiver front end.

(3) Assigning adjacent channels to different cells in order to keep the frequency separation between each channels ~~to different cells~~ in a given cell as large as possible.

6 Wednesday

★. Segmentation

→ With increase in traffic, sometimes it is necessary to add an additional cell at less than the reuse distance without following the cell splitting process.

→ This is done inorder to avoid the coverage hole/ coverage gap in the system. But these causes cochannel interference.

→ Segmentation divides a channel group into segments of mutually exclusive channel frequencies.

→ Then by assigning different segments to particular cell sites, CCI between these cell sites can be avoided.

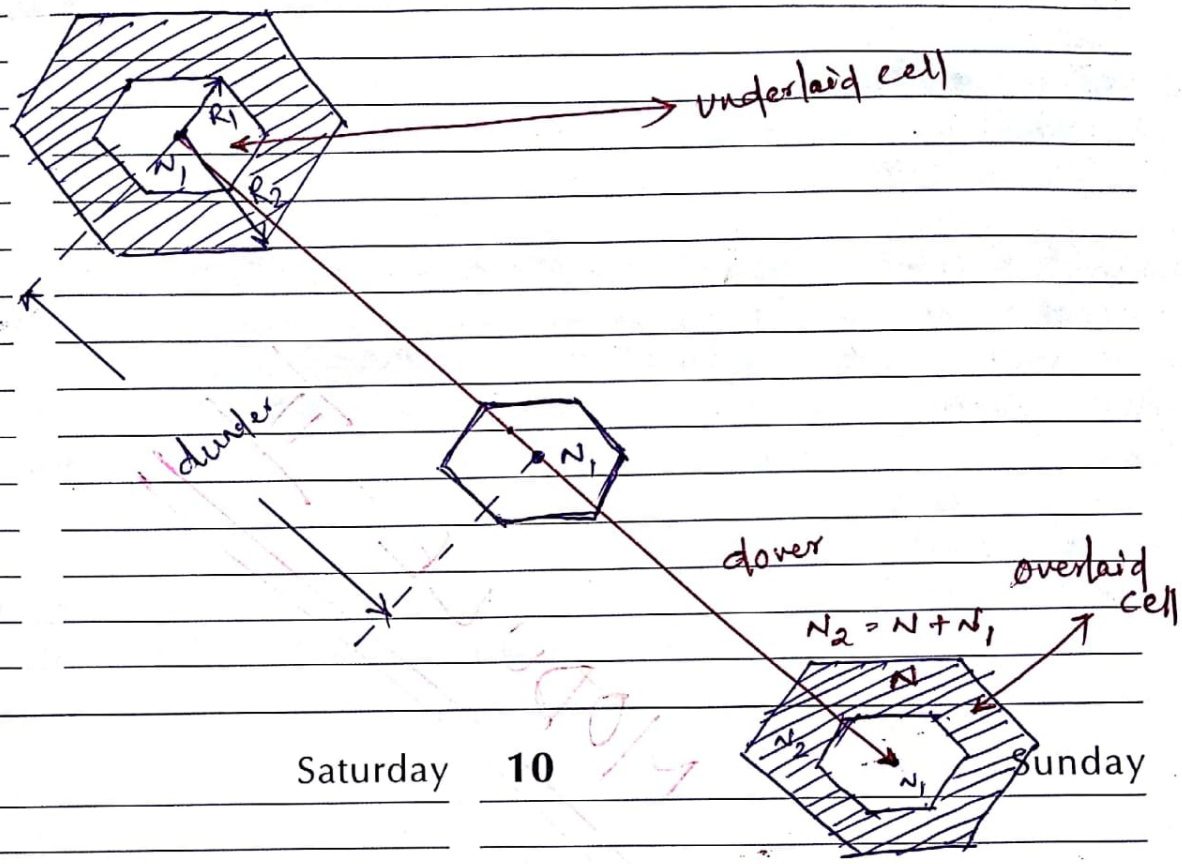
7 Thursday

→ The disadvantage of segmentation is that the capacity of segmented cell is lower than unsegmented cell.

→ When a cellular system is growing, there may be cells of different radii in the same region of coverage area.

→ By dividing the radii of the cell site into two separate serving groups, one for the larger (overlaid) cell and other for the smaller (underlaid) cell, the interference can be minimized.

8 Friday



9 Saturday 10 Sunday

[Two channels N are divided into two segments as N_1 & N_2]

→ The radii for the primary serving group serve the underlaid cell, and the radii of the secondary serving group are used to serve mobiles in the overlaid cell areas.

→ As the traffic in the smaller cells grows, more and more channels are removed from the secondary serving group and assigned to the primary group until the secondary group disappears.

Silicon
...beyond teaching

Miracles sometimes occur, but one has to work terribly hard for them.

September

11 Monday

MODULE - II

12 Tuesday

AUG. 17

MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN
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I am proud to be a Siliconite

13 ★. Introduction to wireless System — Wednesday

→ The design & operation of cellular system is quite differs from most commercial radio and television system.

→ The radio and TV system uses tallest antennas with max. operating power, where as in the cellular system the service area is divided into no. of cells and each is being served by low power transmitters.

→ In cellular system the available channels are efficiently used by following frequency reuse concept at much smaller distances.

14 — Thursday

→ Wireless communication system plays a vital role in the telecommunication industry.

→ Wireless system consists of,

- Wireless wide-area networks (WWAN)
- Wireless local area networks (WLAN)
- Wireless Personal area network (WPAN)

→ Due to the proliferation of mobile users and advancement in internet technology have increased network traffic considerably, resulting in a rapid growth of data rates.

15 → Friday

Some of the wireless networks are,

① WWAN :-

- Long Distance, High Power.
- 2G {GSM, PDC, GPRS (114 kbps), PHS (64 - 128 kbps)}.
- 3G {cdma2000, WCDMA} (384 - 2mbps)

② WPAN :-

- Short range, low power.

16 Saturday

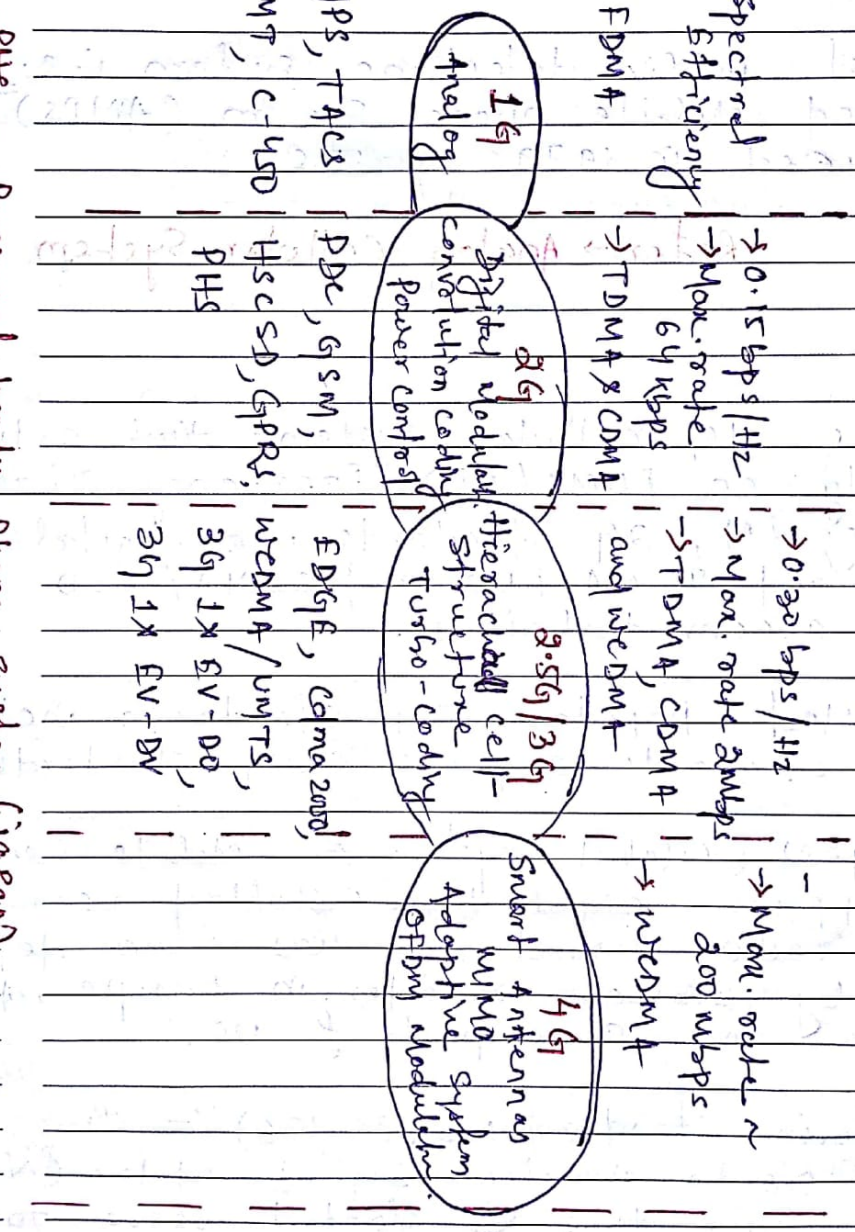
- Bluetooth (1 Mbps)
- ultra wide band (UWB) (< 100mbps)
- Sensor Networks
- IEEE 802.15.4, zigbee.

17 Sunday

③ WLAN :-

- Middle range, medium power.
- Home RF (10 Mbps)
- IEEE 802.11a, b, g (108 Mbps)

18 → Evolution of wireless Network from 1G to 4G. Monday



19 Tuesday

PHS - Personal handy phone system (Japan)
AMPS - Advanced mobile phone systems.

20 Wednesday

The first- and Second- Generation cellular system.

- The first and second-generation cellular systems are the WWAN.

- The 1st public telephone system i.e. 1G called Advanced Mobile phone system (AMPS) was introduced in 1979 by U.S.

Refer → Analog Cellular System

2G –

→ Unlike 1G cellular systems that relied exclusively on FDMA/FDD (Frequency Division Duplexing) and analog FM, 2G standards use digital modulation formats and TDMA/FDD and CDMA/FDD multiple access techniques.

21 Thursday

→ The most popular 2G standards include three TDMA standards and one CDMA standards:

(a) GSM (Global system for Mobile Communication):- which supports eight time slotted users for each 200 KHz radio channel and has been deployed widely by service provider in Europe, Asia, Australia and some parts of US.

(b) Interim standard 136 (IS-136) :- This is also known as North American Digital Cellular (NADC), which supports three time slotted users for each 30 KHz radio channel and is popular choice

22 Friday for carriers in North America, South America and Australia.

(c) Pacific Digital cellular (PDC) :- A japanese TDMA standard that is similar to IS-136.

(d) cdma one :- The popular 2G CDMA standard interim standard 95 code Division Multiple Access (IS-95), also known as cdma one, which supports upto 64 users that are orthogonally coded and simultaneously transmitted on each 1.25 MHz channel.

→ Another 2G system based on CDMA is a direct sequence spread spectrum (DSSS) system in which the entire bandwidth of the carrier channel

23 Saturday is made available to each user simultaneously. 24 Sunday In this case the bandwidth is many times larger than the bandwidth required to transmit the basic information.

→ CDMA systems limited by interference produced by signals of other users transmitting within the same bandwidth.

→ CDMA is the fastest growing digital wireless technology, increasing its world-wide subscriber base significantly, because it can offer 8 to eight times the capacity of analog technologies (AMPS) and upto four times the capacity of digital technologies such as TDMA.

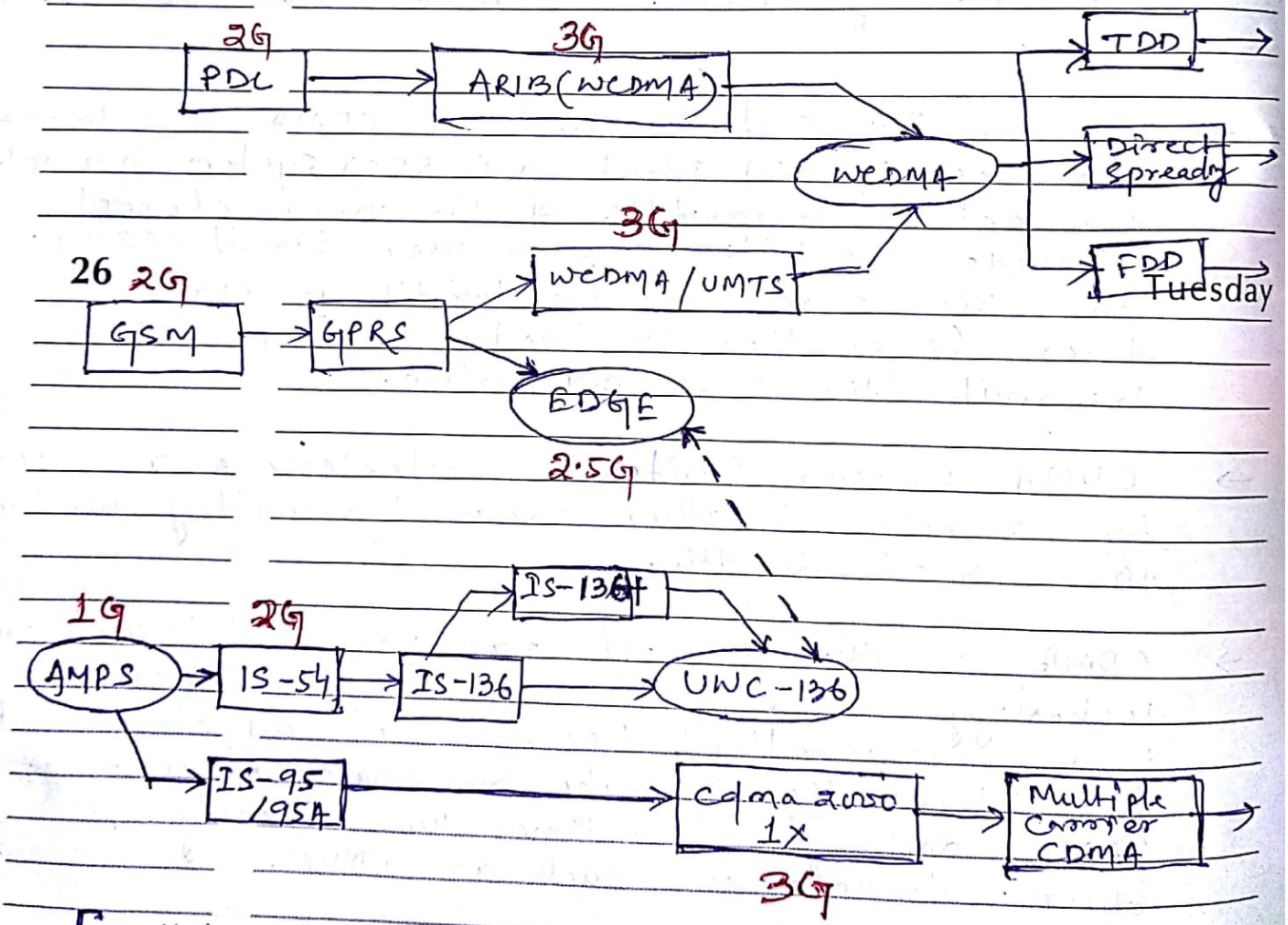
→ The Speech quality provided by CDMA systems

Monday

25 is far superior to any other digital cellular system particularly in difficult RF environments such as dense urban areas and mountainous regions.

→ The CDMA network offers, operators a smooth migration path to 3G mobile systems.

*. Cellular Communication from 1G to 3G



Tuesday

[Cellular Networks (WWAN) evolution from 1G to 3G]

AUG. 17

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27 Wednesday

→ The past few decade has shown a great advancement on the field of mobile communication.

→ with increase in the demand of communication and with increased no. of mobile subscribers telecommunication companies are working to bring new technologies into existence with better features so as to meet up the user requirements.

→ cellular technologies have come a long way and are mostly known as 1G, 2G, 3G and now 4G system is being introduced, where each new generation brings a new technology and more high data rates than the previous one.

28 (1) Thursday

The 1st Generation Mobile Comm^n (1G) :-

- The first generation mobile communication which was introduced in 1980 was based on the analog system.

- the most popular analog 1G systems were advanced mobile phone system (AMPS) which was launched in US.

- Nordic Mobile telephone (NMT), total acess comm^n system (TACS) and some other analog system were introduced in 1980's across the Europe.

- All the standards in 1G use frequency modulation

29 Friday

techniques for voice signals.

- The spectrum within cell was divided into no. of channels which was not efficient in terms of the available radio spectrum, and this placed a limitation on the no. of calls that could be made at any one time.

- Analog systems were based on ckt switching tech and offers only voice comm^n and no data comm^n.

Key features and facilities of 1G :-

(1) Based on analog system.
(2) It supports data speed of up to 2.4 kbps.
(3) Cordless telephone.

30 Saturday

Disadvantages of 1G :-

(1) only voice, no data comm^n.
(2) Low capacity.
(3) Poor handoff.
(4) Less secure.
(5) Poor voice link.

(2) The Second Generation Mobile Comm^n (2G) :-

Refer 2G

Note

Key features and facilities of 2G :-

- Enhanced spectrum efficiency.
- provides data rate of upto 64kbps.
- Improved system capacity and network coverage.
- Roaming facility.
- Voice and data services.
- Enhanced security.

Disadvantages of 2G :-

- It doesn't support high data rates.
- weaker digital signal.
- unable to handle complex data.

(2.5G) :-

- In an effort to retrofit the 2G standards for compatibility with increased throughput data rates that are required to support modern Internet application, new data-centric standards have been developed that can be overlaid upon existing 2G technologies.

- These new standards represent 2.5G technology and allow existing 2G equipment to be modified and supplemented with new base station add-ons and subscriber unit software upgrades to support higher data rate transmissions for web-browsing, email traffic, Mobile-commerce and location based Mobile services.

- The 2.5G technologies also support a popular new web browsing format language, called wireless

Full many a flower is born to blush unseen, and waste its sweetness on the desert air.

Note Application Protocol (WAP).

- A wide range of 2.5G standards have been developed to allow each of the major 2G technologies (GSM, CDMA and IS-136) to be upgraded incrementally for faster Internet data rates.

Evolution for 2.5G TDMA standards :-

1 Sunday

- Three upgrade paths have been developed for GSM.
- The three TDMA upgrade option include
  - (a) High-speed circuit switched Data (HSCSD)
  - (b) General packet Radio Service (GPRS)
  - (c) Enhanced Data Rates for GSM Evolution (EDGE)

(a) Hscsd for 2.5G GSM :-

- As the name implies, High speed circuit switched Data is a ckt switched tech. that allows a single Mobile subscriber to use consecutive user time slots in the GSM Monday
2 standards instead of limiting each user to only one specific time slot in the GSM TDMA standard.
- HSCSD relaxes the error control coding algorithm originally specified in the GSM standard for data transmission and increase the available application data rate to 14,400 bps. as compared to the original 9,600 bps in the GSM specification.

(b) GPRS for 2.5G GSM and IS-136 :-

- Unlike HSCSD, which dedicates ckt switched channels to specific user, GPRS can support many more users than HSCSD.

3 Tuesday

- The GPRS standard provides a packet network on dedicated GSM or IS-136 radio channels.

© EDGE for 2.5G GSM and IS-136 :-

- Enhanced Data rates for GSM (or Global) Evolution is more advanced upgrade to the GSM standard and requires the addition of new H/W and S/W at existing BTs.

- EDGE introduces a new digital modulation format, 8-PSK (Octal phase shifting keying), which is used in addition to GSM's standard GMSK Modulation.

- EDGE allows for nine different (autonomously and rapidly selectable) air interface formats, known as multiple modulation and coding schemes (MCS) with varying degrees of error control protection.

4 Wednesday

IS-95B for 2.5G CDMA :-

- Unlike the several GSM and IS-136 evolutionary paths to high speed data access, CDMA has a single upgrade path for eventual 3G operation.

- The interim data std^n for CDMA is called IS-95B.

- Like GPRS, IS-95B is already being deployed worldwide and provides high speed packet and ckt switched data access on a common CDMA radio channel by dedicating multiple orthogonal

5 user channels for specific purposes. Thursday

(3) The Third Generation wireless Networks (3G) :-

- The 3G brought a great transformation in Mobile Communication World.
- The fulfils the specification of International Mobile Telecommunications - 2000 (IMT-2000), the official International Telecommunication Union (ITU) which intended to provide wireless access to global telecommunication system.
- To meet the IMT-2000 standards, a system is required to provide peak data rates of at least 200 Kbps.

6 The most important IMT-2000 proposals are Friday the Universal Mobile Telecommunication System (UMTS) as the succesor to GSM.

- The UMTS uses W-CDMA, TD-CDMA, or TD-SCDMA air interfaces in which WCDMA is the most popular air-interface technology for the UMTS.
- The main components includes BS (or node B), RNC (Radio Network controller), apart from WMSC (Wideband CDMA Mobile Switching Center) and SGSN/GGSN.
- The WCDMA gives additional advantages of high transfer rate and increased system capacity and the communication quality by

7 Saturday

statistical multiplexing.

- The WCDMA uses the radio spectrum efficiently, because the CDMA tech enables all the Bs to use the same frequency.

- In the WCDMA system, the data is split into separate packets, which are then transmitted using packet switching technology, and the packets are re assembled in the correct sequence at the receiver end by using the code that is sent with each packet.

- The 3G basically focused on multimedia applications such as video calling, improved capacity, world roaming, low cost, better compatibility, high speed data.

8 Sunday

9 Monday

The key features and facilities of 3G :-

- Faster data rates.
- Supports multimedia applications
- Value added services like mobile television, GPS, video call and video conferencing.
- High speed mobile internet access.
- Increased capacity.

Disadvantages of 3G :-

- Requires 3G compatible handsets.
- The cost of upgrading to 3G devices is expensive.
- Power consumption is high.
- 3G requires closer Bs which is expensive.

10 Tuesday

★. Wireless 4G Systems

→ The 4G is an emerging technology in the field of Communication.

→ As the data requirements increased, efforts were made to improve the downlink and uplink throughput rates by employing higher modulation techniques.

→ The Third Generation Partnership Project (3GPP) launched the ~~System~~ Long Term Evolution (LTE) Project in Nov. 2004 inorder to ensure the continued ~~competiveness~~ competitiveness of UMTS in the future.

→ As LTE is considered as the evolution of

11 Wednesday

Universal Mobile Telephone System (UMTS), hence LTE's equivalent components are thus named evolved UMTS terrestrial radio access (E-UTRA) and evolved UMTS terrestrial radio access network (EUTRAN).

→ The ~~Syste~~ LTE is completely an all IP based system, where in the basic architecture of LTE contains a separate IP connectivity layer for all the IP based services and Evolved Packet System (EPS) which handles the overall comm? procedure.

→ By using OFDMA (Orthogonal frequency Division Multiple Access), LTE will be able to provide download rates about 100 mbps for multiple

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12 Thursday

antenna (2x2), multiple-input multiple output (MIMO) for the highest category terminals.

→ Recently several wireless broadband technologies have emerged to achieve high data rates and QoS.

→ "Navini Networks" developed a wireless broadband system based on TD-SCDMA (Time division Synchronous-CDMA).

→ The "Ripwave" uses beamforming to allow multiple subscribers in different part of sector to simultaneously use the Majority of the spectrum bandwidth.

→ The "Flarion Technologies" uses Flash-orthogonal
13 frequency-division multiplexing (OFDM) as Friday
a high-speed wireless broadband sol^n.

→ Flas-OFDM uses frequency hopping spread spectrum (FHSS) to limit interference and allows a reuse pattern.

→ ~~IP~~ IP wireless is the broadband technology based upon UMTS. It uses only QPSK modulation and no advanced antenna technologies. With the inclusion of advanced antenna technologies and the development of HSDPA (High-speed Downlink Packet Access), IP wireless has significant potential.

WiMAX - Worldwide Interoperability for Microwave Access.

14 Saturday 15 Sunday

Key features and facilities of 4G :-

→ High spectral efficiency.
- High voice quality.
- Easily access internet, video calls.
- very low latency.
- Simple protocol architecture.
- Efficient multicast and broadcast.

Disadvantages of 4G :-

- Higher data price for consumers.
- Complex H/w.
- It is very expensive and hard to implement.
- Power consumption is more.

16 Monday

A. Future Wireless Networks

→ As mobile networks evolve to offer both circuit and packet-switched services, users will be connected permanently via their personal terminal of choice to the network.

→ With the developement of intelligence in core network (CN), both voice and broadband multimedia traffic will be directed to their intended destination with reduced latency and delays.

→ As the no. of IP-based mobile application grows, 3G systems will offer the most flexible access technology ~~because of its~~.

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17 Tuesday

→ New developments will allow parameters like quality of service (QoS), data rate and bit error rate (BER) to be set by the operator.

→ Wireless systems beyond 3G (e.g. 4G) will consists of a layered combination of different access technologies.

① Cellular systems.

② WLANs for dedicated indoor applications (such as IEEE 802.11a, 802.11b, 802.11g)

③ World wide interoperability for microwave access (WiMAX) (IEEE 802.16) for metropolitan areas.

④ WPANs for short-range and low mobility applications around a room in the office or at home.

18 Wednesday

These access systems will be connected via a common IP-based core-network.

19 Thursday

RADIO PROPAGATION AND PROPAGATION PATH-LOSS MODELS.

★. Introduction.

→ Exponential growth of mobile communications has increased interest in many areas of radio wave propagation.

→ Radio wave propagation in urban areas is quite complex because it often consists of reflected and diffracted wave produced by multipath propagation.

→ In general radio wave propagation consists of three main attributes : reflection, diffraction and scattering.

20 Friday

→ Reflection occurs when radio wave propagating in one medium impinges (hits) upon another medium with different electromagnetic properties.

– The amplitude and phase of the reflected wave are strongly related to the medium's impedance, incident angle, electric field polarization

– Part of radio wave energy may be absorbed or propagated through reflecting medium, resulting in a reflected wave that is attenuated.

→ Diffraction is the phenomenon by which propagating radio waves bend or deviate in the neighbourhood of obstacles.

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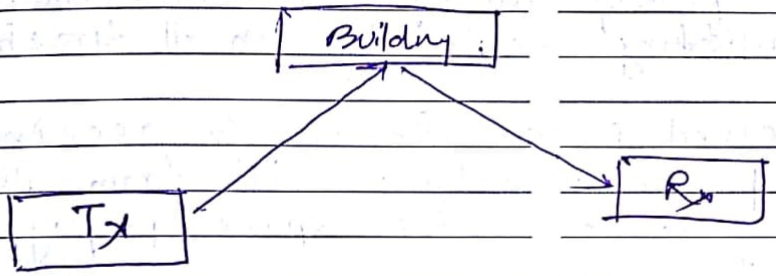
21 Saturday 22 Sunday

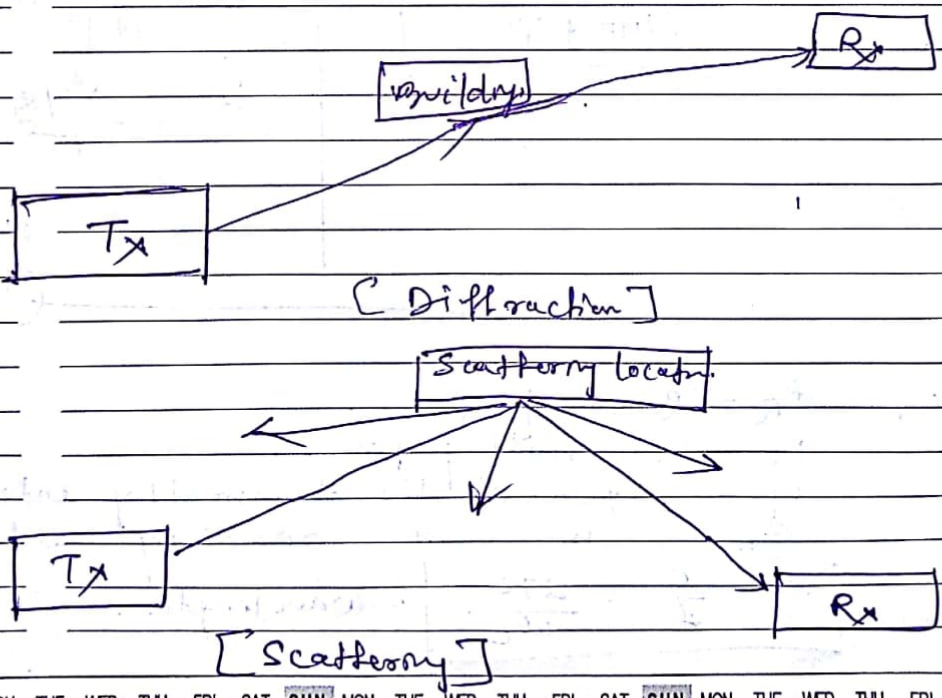
→ Scattering occurs when a radio signal hits a rough surface or an object having a size much smaller than or on the order of signal wavelength.

– This causes the signal energy to spread out in all directions.



[Reflection of the radio wave]

23 Monday



24 ★. Free Space Attenuation — Tuesday

→ The free space propagation is the most simple wave propagation where the received signal strength is predicted when the transmitting and receiver have clear, unobstructed line-of-sight path b/t them.

→ Considering a purely isotropic antenna (omnidirectional) radiating uniformly in all directions.

→ The received power, P_R at the receiving antenna located at a distance 'd' from the transmitter is given for free space propagation as,

25 Wednesday

$$P_R = \frac{P_T G_T G_R \lambda^2}{(4\pi d)^2}$$

At a dist of 'd',

$$P_R = \frac{P_T G_T}{4\pi d^2} \times A_e$$

$$A_e = \frac{\lambda^2 G_R}{4\pi}$$

(1)

Where, P_R = Received Power.
P_T = Transmitting power.
G_T = Gain of the transmitting antenna.
G_R = " " receiving antenna.
$\lambda = \frac{c}{f} = \frac{2\pi c}{\omega_c}$ = wavelength.

26 Thursday

f = Carrier frequency in Hz.
ω = " " in rad./sec.
c = Vel. of electromagnetic waves = 3×10^8 m/s

The values for P_T and P_R must be expressed in the same units and G_T and G_R are dimensionless quantities.

→ An isotropic radiator is an ideal antenna which radiates power with unit gain uniformly in all directions. The "Effective Isotropic Radiated Power" (EIRP) is defined as

$$\boxed{EIRP = P_T G_T}$$

27 Friday → In practice, effective radiated power (ERP) is used instead of EIRP to denote the max. radiated power as compared to a half-wave dipole antenna (instead of an isotropic antenna).

→ If other losses (not related to propagation) are also present, then eqn ① can be written as,

$$P_R = \frac{P_T G_T G_R}{L_0} \times \left(\frac{\lambda}{4\pi d}\right)^2$$

$$\boxed{P_R = \frac{P_T G_T G_R}{L_0 L_P}} \quad \text{——— ②}$$

Where,

L_o = other losses expressed as a relative attenuation factor.

$L_p = \left[\frac{4\pi d}{\lambda}\right]^2$ = free space path loss,

often expressed as an attenuation in decibels (dB).

$= 20 \log\left(\frac{4\pi d}{\lambda}\right)$ dB

L_p (dB) in free space can be expressed as,

30 Monday

$$L_{p(free)} = 32.44 + 20 \log f + 20 \log d \text{ (dB)}$$

→ The Friis free space model is only a valid predictor for P_R for values of d which are in the far field of the transmitting antenna.

– The far-field or Fraunhofer region of a transmitting antenna is defined as the region beyond the far field distance d_f, which is related to the largest linear dimension of the transmitter antenna aperature and the carrier wavelength. The fraunhofer distance is given by,

$$d_f = \frac{2D^2}{\lambda}$$

D = the largest physical linear dimension of the antenna.

where,

$d_f >> D$ and $d_f >> \lambda$

★. Attenuation over Reflecting Surface.

→ free space propagation is encountered only in rare cases such as satellite-to-satellite paths.

→ In terrestrial paths, the signal is partially blocked and attenuated due to urban clutter, trees and other obstacles.

→ Multipath propagation also occurs due to reflection from the ground.

→ For many wireless comm' in the range of 50-2000 MHz range, two components of the space wave are primary concern: energy received by means of direct wave, which travels a direct path from the transmitter to the receiver, and a ground reflected wave, which arrives at the receiver after being reflected from the surface of the earth.

→ This is commonly referred as two-ray model.

Note

→ By assuming that the antenna heights "h_b" and the mobile station "h_m" are much smaller compared to their separation, 'd' and the reflecting earth's surface is flat, the received power of the antenna located at a distance 'd' from the transmitter including other losses "L_0" is given as,

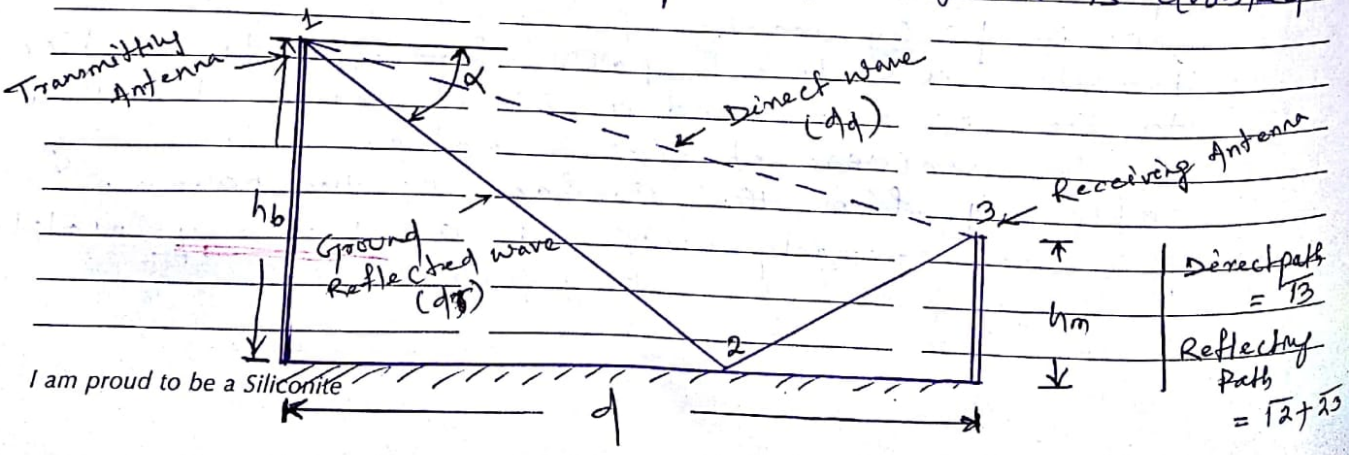
$$P_r = \left[\frac{h_b h_m}{d^2}\right]^2 \frac{G_b G_m}{L_0} P_t \quad \text{---} \textcircled{1}$$

where,

$$d >> \bar{d} \quad \text{and} \quad \bar{d} = \frac{4 h_m h_b}{\lambda}$$

→ So from the above equ^n it can be seen that the received signal level depends only on the transmitted power, antenna heights and the separation distance with there is no frequency dependence.

→ Furthermore, the total attenuation increases by 12dB when the separation distance is doubled.



Wednesday

1 → The expression for the effects of ground reflections from a flat earth provides results that are approximately correct for

$$\Delta\alpha = \frac{2\pi}{\lambda(d_d - d_r)} \leq \frac{\pi}{8}$$

→ This results are not valid for $\Delta\alpha > \pi/8$. When $\Delta\alpha > \pi/8$, the ~~apparent~~ attenuation factor will be,

$$A_{gr} = \sqrt{1 + f^2 - 2f\cos\Delta\alpha} \quad \text{——(2)}$$

where,

f = Reflection coefficient of ground (Assumed to be '-1')

2 Thursday

★. Radio Wave Propagation

→ Radio wave are electromagnetic wave that propagate through space.

→ The energy of the signals exists in the form of electrical and magnetic fields which varies sinusoidally with time.

→ These two fields always exists together because a change in the electrical field generates a magnetic field and a change in magnetic field developes an electrical field.

3 → So there is a continuous flow of energy from one field to the other. Friday

→ Radio waves arrive at a mobile receiver from different directions with different time delays.
→ They combine via vector addition at the receiver antenna to give resultant signal with a large or small amplitude depending upon whether the incoming waves combine to strengthen each other or cancel each other.
→ As the mobile receiver moves from one location to another, the phase relationship bet the various incoming waves also changes.
→ Thus there are substantial amplitude and phase fluctuations and the signal is subjected to

4 fading. Saturday 5 Sunday

→ When it is observed that for a distance of couple of kilometers, the power of the signal fluctuates around a mean value and the fluctuation have a longer period which is referred as long-term or slow fading.
→ If the signal power over a few hundred meters is found to be fluctuates more rapidly which are caused due to multipath, this phenomenon is referred as fast-fading or short-term fading.
→ A steady decrease in the received signal power at a separation distance 'd' of several Kms

6 is said to be attenuation.

→ The slow fading is caused by due to the travelling over long distance to produce gross variation in overall path betn the BS & MS. where as the fast fading occurs usually over distances of about half a wavelength.

→ The rapid fluctuation in the fast-fading is a result of small movements of transmitter, receiver and the surrounding objects.

→ For locations that are heavily shadowed by surrounding buildings, it is typically found that a "Rayleigh distribution" approximates the PDF. For location where there is one path having a dominant contribution to the received signal to the received signal, such as when the BS is visible to MS, the distribution, fun is typically found to be that of a Ricean distribution.

7 Tuesday

→ Because of shadowing by buildings and other objects, the avg. within small areas also varies from one small area to the next in an apparently random manner, referred to as the "shadow effect" shadow effect is often called lognormal fading.

→ ★ To separate the fast fading from slow fading, the magnitude of the received signal is averaged over a distance on the order of 10m and the result is referred to as the small-area avg. or Sector avg.

8 Wednesday

→ Using a reference distance, d_0 which is the signal attenuation at a standard distance from the antenna, the received power, P_r, at a dist. d is given as,

$$P_r = P_0 \left(\frac{d_0}{d}\right)^r \quad \text{——— (1)}$$

where, r = Path loss exponent $(2 \le r \le 5)$
P_0 = Power at reference dist. d_0.
P_r = Received power that is proportion to d^{-r}.

→ The received power under non-line-of-sight propagation cond^{n}s can be written as,

$$P_r(d) = 10 \lg [P_0(d_0)] + 10\,r \lg (d_0/d) \quad (d \ge d_0) \quad \text{——— (2)}$$

9 Thursday

→ The accuracy of P_r can be improved by accounting for a random shadow effect caused by obstructions such as buildings or mountains.

→ Shadow effect is described by a zero-mean Gaussian random variable, "X_σ" with standard deviation "σ" (dB).

→ Under ideal cond^n, it is possible to estimate path loss $L_p(d)$ from the transmitter (P_t) and receiver (P_r) as $L_p(d) = P_t - P_r$, but this approach ignores that fact that the signal undergoes lognormal fading, which could reduce the received power at any location.

Allowable path loss $L_p(d)$
= Path loss + Shadow effect X_σ — (3)

$$L_p(d) = \overline{L_p}(d_0) + 10n \log(d/d_0) + X_\sigma \text{ (dB)} \quad \text{— (4)}$$

$\overline{L_p}(d_0)$ = is known as the 1m or 1km loss or insertion loss that arises due to free-space path loss and antenna inefficiencies.

X_σ = is often based on measurement made over a wide range of locations and transmitter-receiver separation. An avg. value of

11 Saturday 12 Sunday

8dB for σ is often used giving X_σ as 10.5 dB.

→ It should be noted that whenever relative motion exists betn transmitter and receiver, there is a Doppler shift in the received signal. The max. Doppler shift f_m is given as,

$$f_m = v/\lambda = v/(c/f)$$

where,
c = velocity of the electromagnetic waves in free space.
v = velocity of the moving vehicle
f = frequency of the carrier.

13 → The received signal $S(t)$ can be expressed as the product of two components: the signal subjected to long-term fading, $m(t)$ and the signal subjected to short-term fading, $r(t)$ as: Monday

$$S(t) = m(t) \cdot r(t) \quad \text{——— (5)}$$

★. Characteristics of a wireless channel

→ The wireless channel is different and much more unpredictable than the wireline channel because of factors such as multipath fading, shadow fading, Doppler shift and time dispersion or delay spread.

→ These factors are all related to variability introduced by mobility of the user and the wide range of environmental cond's. Tuesday

14 → In multipath delays the reflected signals due to large buildings, trees, hills, or cars etc, arrives at the receiver with a random phase offset, since each reflected signal generally follows a different path to reach receiver, resulting in a random signal that fades as the reflections destructively or constructively.

→ A mobile radio channel exhibits both time dispersion and frequency dispersion.

→ "Time dispersion" is the distortion to the signal and is manifested by the spreading in time

15 Wednesday

of the modulation symbols. This is caused by "frequency-selective" fading.

→ A channel, which is said to be frequency selective, has many frequency components that take different times to arrive at the receiver and undergo different attenuation levels.

→ The frequency band over which the attenuation remains const. provides a frequency region where all frequency components behave identically. This frequency band is known as the "coherence bandwidth".

→ Time dispersion occurs when the channel is band limited or when the co-herence bandwidth of the channel is smaller than the modulation bandwidth. The time dispersion leads to "inter-symbol-interference" (ISI), where the energy from the symbol spills over into another symbol, thus by increasing the bit-error-rate (BER).

16 Thursday

→ Doppler shift is the random changes in a channel introduced as a result of a mobile user's mobility. Doppler spread has the effect of shifting or spreading the frequency components of a signal. This is described in terms of frequency dispersion.

→ Like the coherence bandwidth, Coherence time is defined as the time over which the channel can be assumed to be const. The co-herence time of the channel is inverse of Doppler Spread. It is the measure of the

OCT. 17

MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN
						1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31					

17 Friday

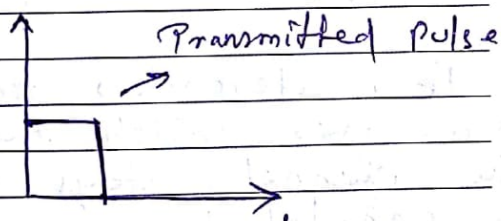
Speed at which channel char. changes. This determines the rate which fading occurs.

★ Multipath Delay Spread, Coherence Bandwidth and Coherence Time.

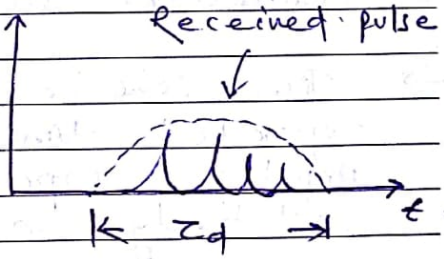
→ As discussed earlier, the multipath delay spread is the time time-dispersion char. of the channel.

→ The rms delay spread in multipath is denoted by "τ_d" and the max. spread in frequency due to Doppler shift, f_m.

18 Saturday



19 Sunday



→ The coherence-Bandwidth is defined as the range of frequencies ~~over~~ ~~which~~ over which two frequency components have a strong potential for amplitude correlation, to define whether the channel fading is flat or frequency selective. Mathematically the Coherence Bandwidth is given by,

Contd....

20 Monday

$$B_c = \frac{1}{2\pi \tau_d}$$

→ Frequency components of a signal separated by more than B_c will ~~fade~~ independently.

→ A channel is frequency selective if $B_c < B_w$, where B_w is the signal bandwidth.

→ In order to avoid channel-induced ISI distortion, the channel is required to be flat fading by ensuring that $B_c > B_w$.

→ Thus the channel coherence bandwidth sets an upper limit on the transmission rate that

21 Tuesday can be used without incorporating an equalizer in the receiver.

→ The coherence time, T_c, describes the expected time duration over which the impulse response of the channel stays relatively invariant or correlated.

The co-herence time can be given by,

$$T_c = \frac{1}{2\pi f_m}$$

$$\Rightarrow T_c \propto \frac{1}{f_m}$$

$f_m = \frac{v}{\lambda}$ = Max. Doppler spread

f = Carrier frequency.

v = vel. of moving vehicle.

22 Wednesday

→ If the signal symbol interval (T_s) >> T_c, the channel changes or fades rapidly compared to the symbol rate. This is called fast fading and frequency dispersion occurs.

→ If $T_s << T_c$, the channel doesn't change during the symbol interval. This is called as slow fading

⇒ Thus to avoid signal distortion caused by fast fading, the channel must be made to exhibit slow fading by ensuring that the signaling rate exceeds the channel fading rate i.e $T_s < T_c$.

Thursday

23 Signal fading statistics

Multipath is the propagation phenomenon that results in radio signals reaching the receiving antenna by two or more paths.

Fading refers to the distortion that a carrier-modulated telecommunication signal experiences over certain propagation media. In wireless systems, fading is due to multipath propagation and is sometimes referred as multipath induced fading.

The fading characteristics of a mobile radio signal can be described by 3 statistical distributions as follows,

24 Friday

① Rician Distribution.

② Rayleigh Distribution

③ Lognormal Distribution.

- The rapid variation (fast fading) in signal power caused by local multipaths are represented by Rayleigh distribution.
- The Rician distribution is often used for fast fading with LOS (line-of-sight) propagation path.
- The long-term variation (slow fading) in the mean level are denoted by Lognormal distribution.

① Rician Distribution :-

25 Saturday 26 Sunday

- In this distribution, one dominant signal component along with weaker multipath signals are present.
- The dominant signal obtained is due to such as LOS propagation path the small-scale fading envelope distribution is Rician.
- The probability density fun? (PDF) of Rician distribution is given by,

$$P(r) = \begin{cases} \frac{r}{\sigma^2} e^{-\left(\frac{r^2+A^2}{2\sigma^2}\right)} I_0\left(\frac{Ar}{\sigma^2}\right), & \text{for } A \geq 0, r \geq 0 \\ 0 & \text{otherwise } (r < 0) \end{cases}$$

27 Monday

where,

A = peak amplitude of the dominant signal

I_0 = Modified Bessel fun^n of first kind and zero order.

$r^2/2$ = Instantaneous power.

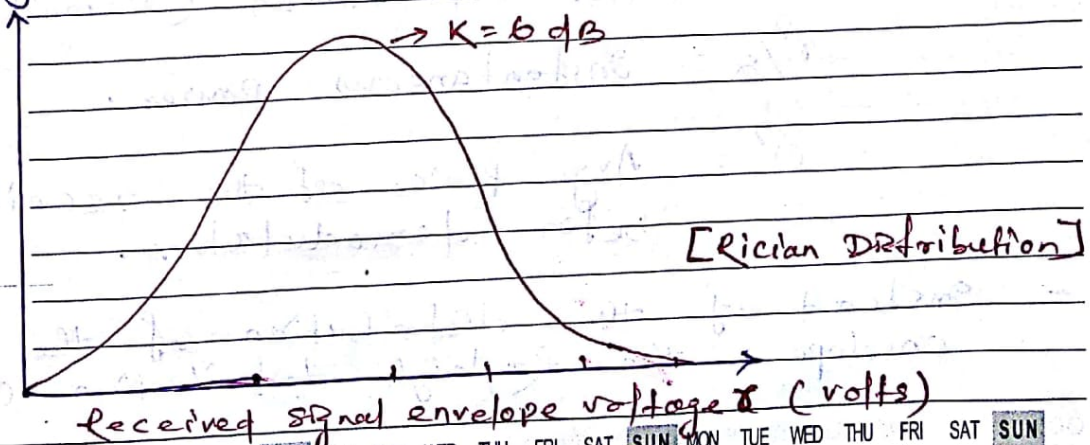
σ = standard deviation of the local power.

- The Rician distribution is often described in terms of a parameter K, commonly known as the Rician factor and is expressed as,

$$K = 10 \log \frac{A^2}{2\sigma^2} \text{ dB}$$

28 Tuesday

- As $A \to 0$ and $K \to \infty$ dB and the dominant path amplitude decreases in amplitude, the Rician distribution degenerates to a Rayleigh distribution.



29 Wednesday

(2) Rayleigh Distribution :-

- The Rayleigh distribution is used to describe the received envelope of a flat fading signal, or the envelope of an individual multipath component.

→ It is formed from the sum of two Gaussian noise signals.

→ The PDF of Rayleigh distribution is given by,

$$p(r) = \begin{cases} \frac{r}{\sigma^2} e^{-\left(\frac{r^2}{2\sigma^2}\right)} & \text{for } 0 \le r \le \infty \\ 0 & \text{for } r < 0 \end{cases}$$

30 Thursday

where,

σ = rms value of the received signal befor detection (Demodulation)

$r^2/2$ = Instantaneous power.

σ^2 = Avg. power of the received signal befor demodulation.

- Instead of the distribution of the received envelope, the Rayleigh distribution can be

Note described in terms of the distribution fun? of its received normalized power.

* Normalized Power (NP) is a power averaging method, measured in watts, used to compensate for changes in ride cond's for a more accurate depiction of power expenditure.

So, let $\phi = (r^2/2)/\sigma^2$

$= \frac{\text{Instantaneous power}}{\text{Mean received power}}$.

$\Rightarrow \frac{d\phi}{dr} = \frac{r}{\sigma^2}$

$\Rightarrow d\phi = \left(\frac{r}{\sigma^2}\right) dr$

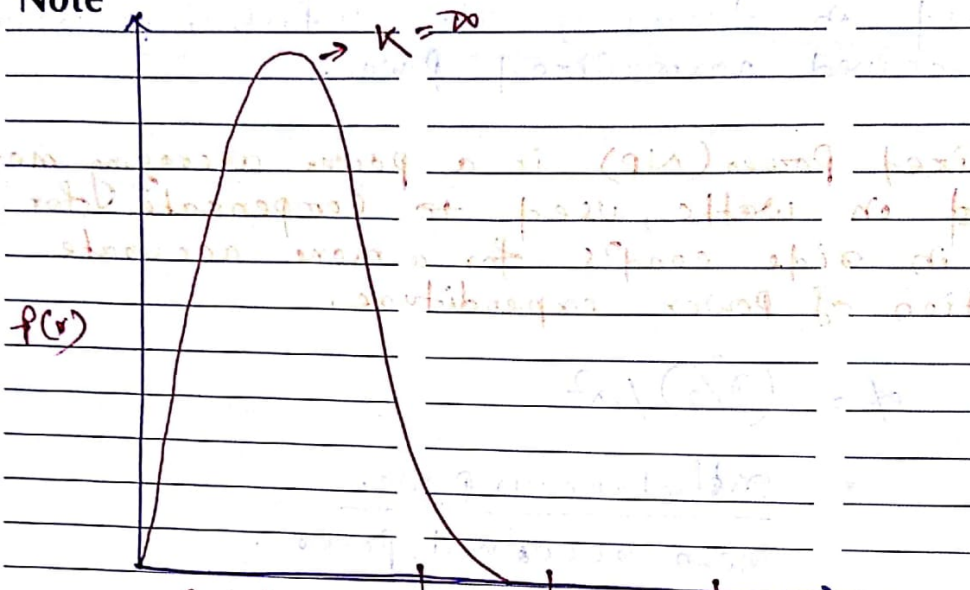
- Since $P(r)\,dr = P(\phi)\,d\phi$, then

$$P(\phi) = \frac{P(r)\,dr}{d\phi} = \frac{P(r)\,dr}{\left(\frac{r}{\sigma^2}\right) dr}$$

$$= \frac{P(r)}{\left(r/\sigma^2\right)} = \frac{\left(r/\sigma^2\right) e^{-\left(r^2/2\sigma^2\right)}}{\left(r/\sigma^2\right)}$$

$= e^{-\phi}$, for $0 \le \phi \le \infty$

Note



[Rayleigh Distribution]

③ Lognormal Distribution :-

- Lognormal distribution describes the random shadowing effects which occurs over a large no. of measurement location which have the same transmitter and receiver separation but have different levels of clutter on the propagation path.

→ The PDF of lognormal distribution is given by,

$$f(x) = \frac{1}{\sqrt{2\pi}\,\sigma_s}\, e^{-\left[\frac{(10\log x - \mu)^2}{2\sigma^2}\right]}$$

where,

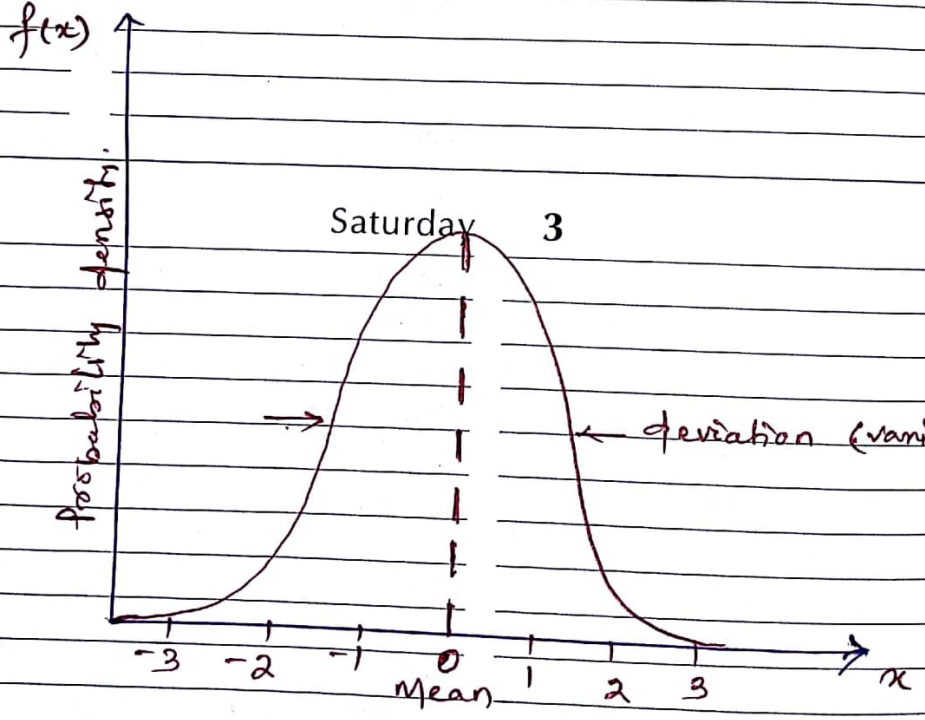
μ = Mean value of x in dBm

σ_s = standard deviation of x in dB

$10 \log x$ (in dBm)

x = Signal power in mW.

- Typically, the standard deviation, σ_s equals to 8 to 10 dB.



[Lognormal Distribution]

Monday

4. Propagation Path-Loss Models

- Propagation path-loss models play an important role in the design of cellular systems to specify key system parameters such as transmission power, frequency, antenna heights and so on.

- The propagation model is basically devided into 3 categories,

  1. Empirical Models
  2. Semi-deterministic models.
  3. Deterministic models.

1. Empirical Model :- Based on measurement data, Simple (few parameters), use statistical properties, not very accurate.

Tuesday

5

2. Semi-deterministic Model :- Based on empirical model + deterministic aspects.

3. Deterministic Models :- Site specific, require enormous no. of geometry information about the site, very important computational effort, accurate.

- Propagation models are used to determine the no. of cell sites required to provide coverage for the network. Initial network design typically is based on coverage. Latter growth is engineered for capacity.
- The propagation model is also used to optimize the handoff, power level adjustment and antenna placements.

6 Wednesday

Several Models have been proposed for cellular systems operating in different environment i.e. indoor, outdoor, urban, suburban, rural.

- Although no propagation model account for all variations experienced in real life, it is essential that one should use several models for determining the path losses in the network.

Models of Different Types of cells :-

① Macro-cell path loss Models

- Empirical Models
  - ⓐ Okumura-Hata Model
  - ⓑ COST 231-Hata Model (semi-deterministic)
- Semi-empirical Models
  - ⓐ COST 231-Walfisch-Ikegami
- Deterministic Model
  - ⓐ Plane earth model
  - ⓑ Ikegami Model.

7 Thursday

27 (2) Microcell Path Loss Model — Wednesday

- Empirical Model
  - (a) Dual slope empirical Model.
- Deterministic Model
  - (a) Two-Ray Model.

(3) Picocell Path Loss Models

- Empirical Model
  - (a) Wall and floor factor Models – ITU-R Models.
- Semiempirical Models.

28 (a) COST 231 LOS Model. — Thursday

- The OKUMURA-Hata Model has been used extensively both in Europe and North America for cellular system.
- The COST 231 Model has been recomended by the ETSI for use in personal Communication Network (PCN) or personal communication System (PCS)

COST 231 Model

- This Model is a combination of empirical and deterministic Models for estimating the path loss in urban area over the frequency

29 Friday

range of 800 MHz to 2000 MHz and $4 \le h_b \le 50m$.

- This Model is used primarily in Europe for the GSM 1800 system.

$$L_{50} = L_f + L_{rts} + L_{ms} \text{ dB} \quad \text{——— (1)}$$

where,

L_{50} = Median path loss (dB)

L_f = free space loss (dB)

L_{rts} = roof top to street diffraction and scatter loss (dB).

30 Saturday 31 Sunday

L_{ms} = Multiscreen (Multiscatter) Loss (dB)

- free space loss is given as,

$$L_f = 32.4 + 20\log d + 20\log f_c \text{ dB} \quad \text{——— (2)}$$

- The roof top to street diffraction and scatter loss is given as,

$$L_{rts} = -16.9 - 10\log W + 10\log f_c + 20\log \Delta h_m + L_o \text{ dB}$$

Note Where,

W = street width (m)

$\Delta h_m = h_r - h_m$ (m)

h_r = avg. building height (m)

$L_O = -10 + 0.354\phi$ $\quad 0 \le \phi \le 35^\circ$

$L_O = 2.5 + 0.075(\phi - 35)$ dB $\quad 35^\circ \le \phi \le 55^\circ$

$L_O = 4 - 0.114(\phi - 55)$ dB $\quad 55^\circ \le \phi \le 90^\circ$

ϕ = Incident angle relative to street.

f_c = Carrier frequency.

- The Multiscreen (Multiscatter) loss eq is given as,

$$L_{ms} = L_{bsh} + K_a + K_d \log d + K_f \log f_c - 9 \log b$$

where,

b = Distance bet^n building along radio path (m)

d = Distance bet^n transmitter and receiver (km)

$L_{bsh} = -18 \log(1 + \Delta h_b)$ $\quad h_b \ge h_r$

$L_{bsh} = 0$ $\quad h_b < h_r$

(h_b and h_m are base station and Mobile station heights respectively).

$\Delta h_b = h_b - h_r$

$K_a = 54$ $\quad h_b > h_r$

$K_a = 54 - 0.8 h_b$ $\quad d \ge 500m,\ h_b \le h_r$

Note $K_a = 54 - 0.8\Delta h_b (d/500)$ $d < 500m$, $h_b \leq h_r$

*. Both L_{bsh} & K_a increase path loss with lower base station antenna heights.

$K_d = 18$ $h_b < h_r$

$K_d = 18 - \frac{15\Delta h_b}{\Delta h_m}$ $h_b \geq h_r$

$K_f = 4 + 0.7 (f_c/925 - 1)$ for mid-size city and Suburban area with moderate tree density.

$K_f = 4 + 1.5 (f_c/925 - 1)$ for metropolitan area.

- COST 231 Model is valid within the following range

① $800 \leq f_c \leq 2000$ MHz.

② $4 \leq h_b \leq 50$ m

③ $1 \leq h_m \leq 3$ m.

④ $0.02 \leq d \leq 5$ km.

The following default values may be used in the model,

$b \geq 20 - 50$ m, $w = b/2$, $\phi = 90°$

$h_r = 3$ (no. of floors) + roof, Roof = 3m for pitched roof and 0m for flat roof.

Silicon
...beyond teaching

January

The whole world steps aside for the man who knows where he is going.

1 Monday

MODULE - III

2 Tuesday

DEC. 17

MON	TUE	WED	THU	FRI	SAT	SUN
				1	2	3
18	19	20	21	22	23	24

MON	TUE	WED	THU	FRI	SAT	SUN
4	5	6	7	8	9	10
25	26	27	28	29	30	31

MON	TUE	WED	THU	FRI	SAT	SUN
11	12	13	14	15	16	17

I am proud to be a Siliconite

3 ★. Fundamentals of WLAN Transmission Technology. Wednesday

→ Wireless Local-Area Network (WLAN) is a technology which uses radio frequency to transmit and receive data over the air, providing all the features and benefits of traditional LANs.

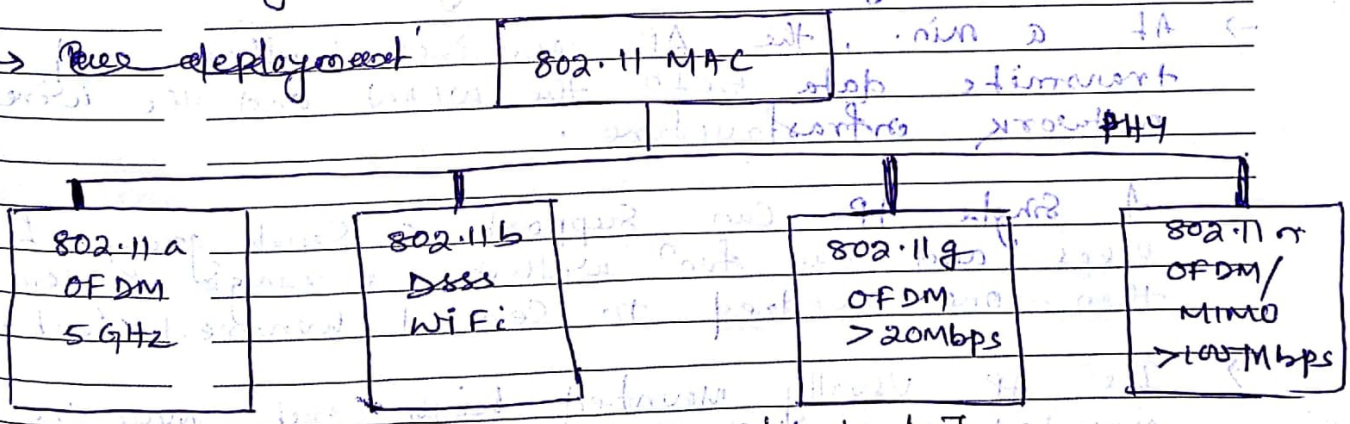
→ It is a data communication system providing wireless peer-to-peer (PC-to-PC, PC-to-hub, printer-to-hub) and point-to-point (LAN-to-LAN) connectivity within a building or campus.

→ WLANs transmit and receive data over electromagnetic waves. In a typical WLANs config, a transmitter/receiver (transreceiver) device called an access

4 → The IEEE 802.11 Committee is responsible for WLAN standards. Thursday Point.

→ WLANs include IEEE 802.11a (WiFi 5), IEEE 802.11b (WiFi), IEEE 802.11g and 802.11n

→ Peer deployment



IEEE WLAN Standards

FEB. 18

MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN
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19	20	21	22	23	24	25	26	27	28											

5 Friday

→ The deployment of WLANs can provide connectivity in homes, factories, and hot-spots.

→ WLANs perform traditional network communication fun? such as file transfer, peripheral sharing, email and data base accen.

→ WLAN technology standard 802.11b has the strongest momentum to becoming the main standard for corporate internal WLAN networks.

→ The bandwidth of 802.11b is 11 Mbps and operates at 2.4 GHz frequency.

→ The Succesor of this current 802.11b standard is 802.11a and it is deigned to be faster speed and operate at a different frequency with bandwidth is 54 Mbps.

6 Saturday 7 Sunday

→ In a WLAN config. an access point (AP) connects to the wired network from a fixed location using standard cabling.

→ At a min., the AP receives, buffers, and transmits data betn the WLAN and the wired network infrastructure.

→ A Single AP can Support a small group of users and can fun? within a range of less than - one hundred to Several hundred feet.

→ The AP Usually mounted high - but may be mounted essentially anywhere that is practical

DEC. 17

MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
18	19	20	21	22	23	24	25	26	27	28	29	30	31							

8 as long as the desired radio coverage is obtained. Monday

Advantages of WLAN :-

(1) Easy deployment
(2) LAN Extension.
(3) Easy Access.
(4) WLAN Mobility.
(5) Cost Effective.
(6) Smart Working.
(7) Increased Productivity.

Disadvantages of WLAN :-

(1) Limited Bandwidth.
9 Tuesday
(2) Incompatibility.
(3) Interference.
(4) Black or Dead spots (Regions where there is zero or very weak radio signal strength)
(5) Less Security.
(6) Need of Backbone Network

10 *. WLAN Application. Wednesday

→ Basically WLAN is best suitable for dynamic environment.

→ There are four important applications of wireless LAN, as follows.

(i) LAN Extension.

(ii) Nomadic Access.

(iii) Cross building Interconnection.

(iv) Ad-hoc Networks.

11 (i) LAN Extension :- Thursday

→ Wireless LANs save the cost of installation of LAN cabling, they can easily relocated and the network structures can be easily modified.

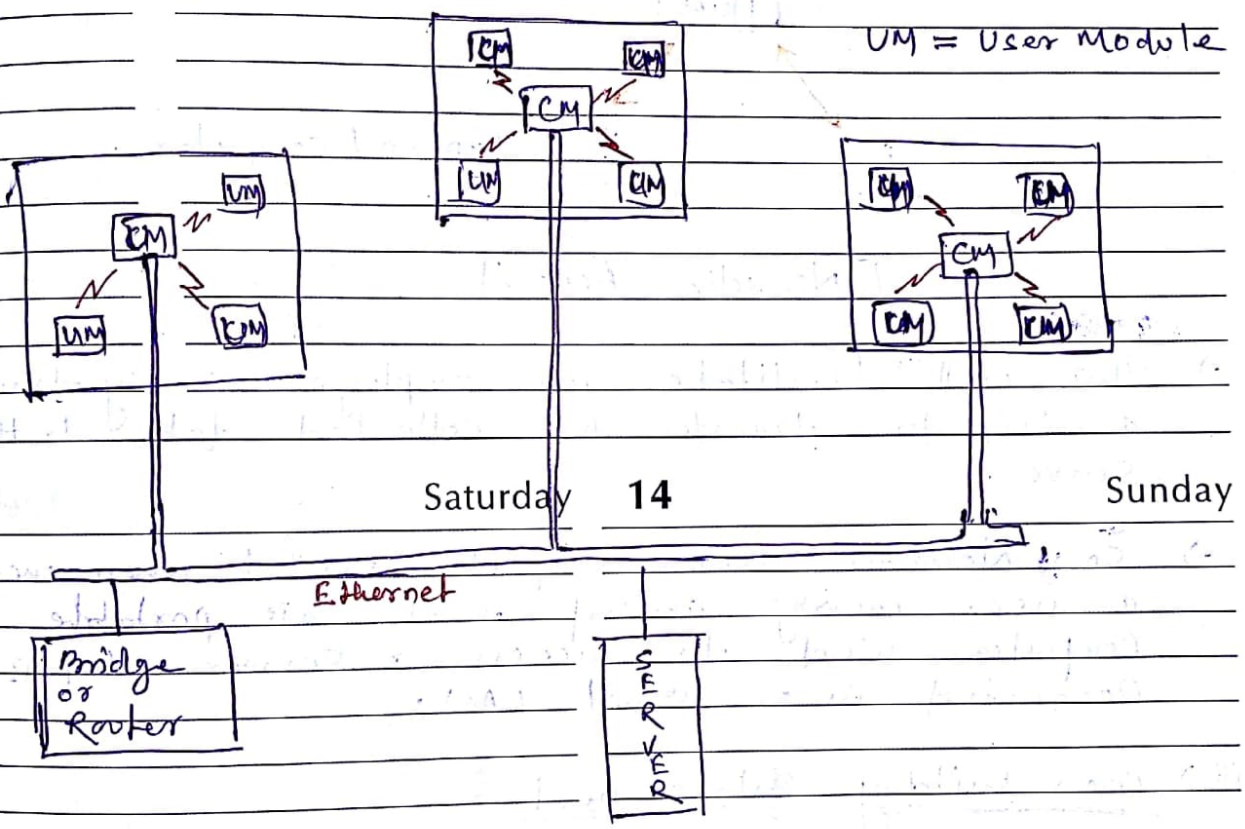
→ Many time WLAN is linked into a wired LAN on the same premises. Thus this application area is referred to as LAN extension.

→ There is a backbone wired LAN such as Ethernet which is used for supporting the servers, workstations and bridges or routers.

→ A control module (CM) acts as an interface to WLAN.

12 → The Control Module (CM), consists of some Friday kind of access control logic like polling or token passing scheme for regulating the access.

→ Every CM controls many wireless systems within its range.



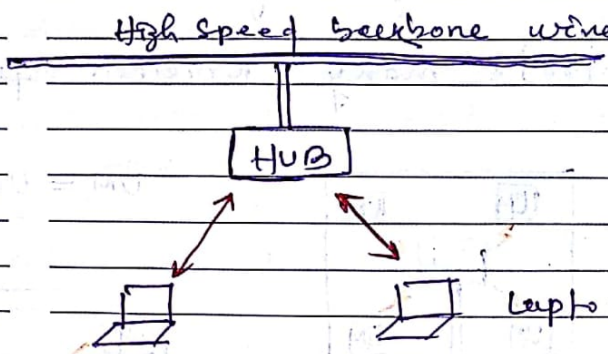
(ii) Nomadic Access :-

→ Nomadic access provides a wireless link between a LAN hub and a mobile data terminal equipment having an antenna.

→ The mobile data terminal equipment (DTE)

15 Monday

Can be a laptop computer or a notepad computer.



[Nomadic Access]

⇒ This will facilitate an employee coming from a trip to transfer his collected data to the server.

16 Tuesday

⇒ So Nomadic access is quite useful when ever a user moving around with his portable computer want to access a server that is connected in a wired LAN.

(iii) Cross building Interconnect :-

→ It is used for connecting LANs in nearby buildings.

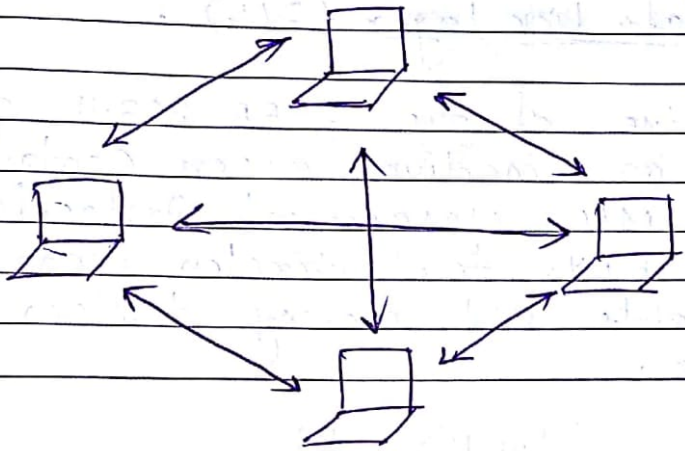
⇒ These LANs can be wired or wireless.

⇒ Here a point-to-point wireless link is used bet'n two buildings.

17 → The devices so connected are bridges or routers. Wednesday

(iv) Ad-Hoc Networking :-

→ It is a peer-to-peer networking without any centralized server.



18 Thursday

[Ad-Hoc Networking]

→ The Ad-Hoc LAN is set up temporarily to meet some immediate requirements.

→ Ex - Such as a group of people with laptops conferencing with each other in a room.

→ The Ad-Hoc LAN doesn't have any infrastructure it is just a collection of few stations within range of each other dynamically configuring themselves into a temporary network.

19 ★. IEEE 802.11 Friday

- In 1997 the IEEE developed an international standard for WLANs as IEEE 802.11. This standard was revised in 1999.

- This standard covers/focuses the bottom two layers of OSI Model i.e. the physical layer (PHY) and the data link layer (DLL).

- The objective of the IEEE 802.11 standard was to define an medium access control (MAC) sublayer, MAC management protocols and services, and three PHYs for wireless connectivity of fixed, portable and moving devices within a local area.

20 Saturday 21 Sunday

IEEE 802.11 Architecture :-

→ The architecture of the IEEE 802.11 WLAN is designed to support a network where most decision making is distributed to mobile stations.

→ This type of architecture has several advantages like,
- Tolerant to faults in all of the WLAN equipments.
- Flexible
- offers significant power savings and prolongs the battery life of mobile equipment without losing connectivity.

22 Monday

⇒ IEEE 802.11 defines two types of services.

① Basic Service Set (BSS)

② Extended Service Set (ESS)

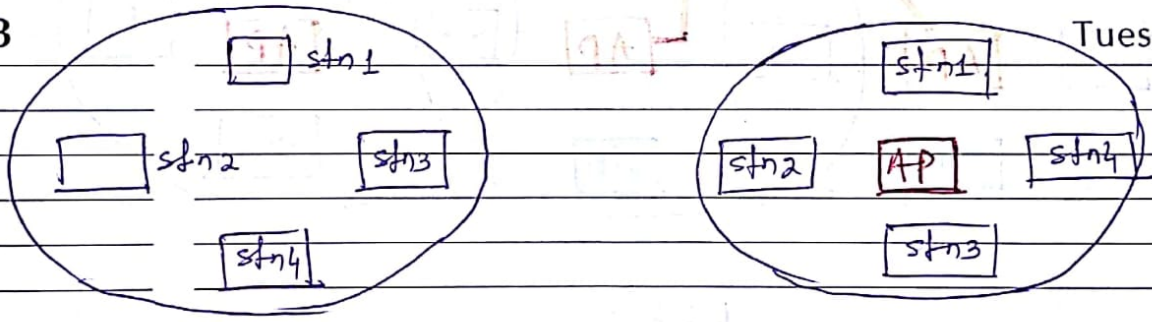
① Basic Service Set :-

- It is defined as the basic building block of WLAN.

- A BSS is made of stationary or moving wireless stations and a central BS (Base station) called as the access point (AP).

- A BSS can be either without AP or with AP

23 Tuesday



[BSS without AP] [BSS with AP]

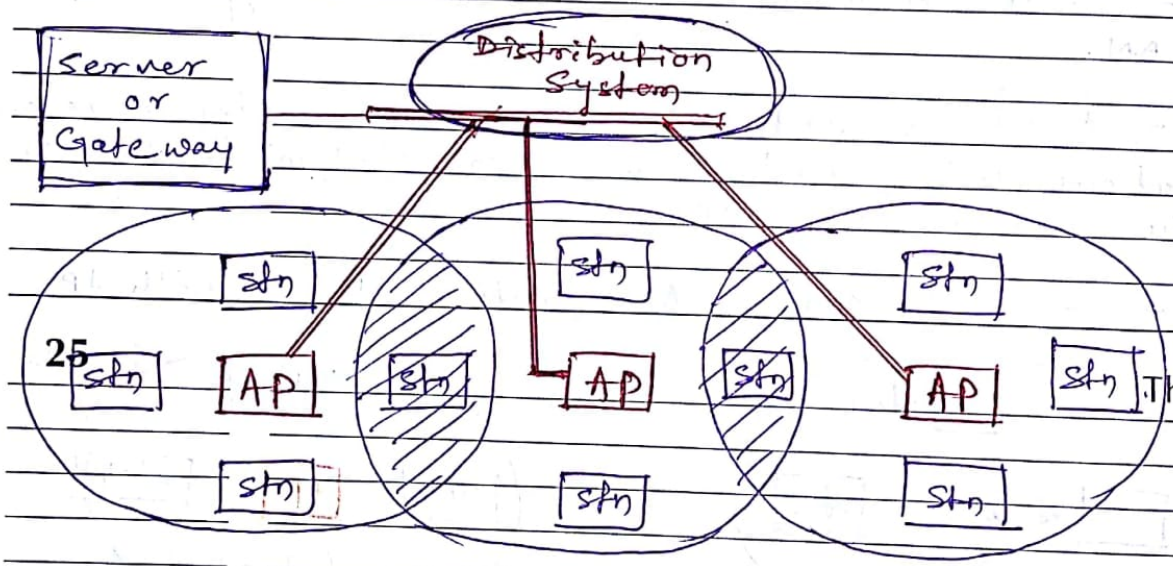
- The BSS without AP cannot send data to another BSS. Hence it is known as the ~~standalone~~ standalone network or ad-hoc architecture.

24 Wednesday

② Extended Service set (ESS) :-

- An ESS consists of two or more BSS with APs.

- The BSS, in this system are connected to each other via a distribution system which is generally a wired LAN.



[ESS]

25 Thursday

- The distribution system connects the APs to each other.

- The distribution system ~~connects~~ can be any type of LAN such as Ethernet.

26 Friday

There are two different network architectures defined in the IEEE 802.11 standard, as follows,

① Infrastructure Network :-

- An infrastructure network is the network architecture for providing communication betn wireless clients and wired network resources.
- The transition of data from the wireless to wired medium occurs via an AP.
- The Bss are connected with each other to form an infrastructure network.

② Ad-hoc (Point-to-Point) network :-

- An ad-hoc network is the architecture that is used to support mutual communication betn wireless clients.

27 Saturday 28 Sunday

- An ad-hoc network doesn't support access to wired networks.
- A stand alone network (A Bss without AP) is known as ad-hoc network.
- An ad-hoc network is also refferred as IBss (Independent Bss).
- An IBss config. is analogous to a peer-to-peer office network in which no single node is required to act as a Server.

802.11 Physical Layer (PHY).

- At the physical layer (PHY), IEEE 802.11 has defined the specification for converting bits to signal. one of them is the infra-red frequency spectrum / diffused infrared

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29 Monday

(baseband) and the other five specifications are (in RF range) listed below,

① FHSS – frequency Hopping spread spectrum (802.11)

② DSSS – Direct Sequence spread spectrum (802.11)

③ OFDM – Orthogonal frequency Division Multiplexing (802.11a)

④ HR-DSSS – High Rate DSSS (802.11b)

⑤ OFDM (802.11g)

30 Tuesday

22 Thursday

★. Zigbee Technology.

→ The Zigbee named for erratic, zig-zag patterns of bees between flowers which symbolizes communication betn nodes in a mesh network.

→ Zigbee is a technological standard designed for control and sensor networks.

→ The IEEE 802.15.4 WPAN standard is intended to serve a set of industrial, residential and medical applications with very low power consumption, low data rate, low cost requirements.

→ The Zigbee Alliance is an organization defining global standard for reliable, cost effective, low data rate, low power wireless applications.

23 Friday

→ The IEEE 802.15.4 comonitee and Zigbee Alliance worked together and developed the technology commercially known as zigbee.

→ The Zigbee technology is expected to provide low-cost and low-power connectivity for devices that need battery life as long as several months to several years but does not require data transfer rates as high as those enabled by Bluetooth.

→ The Zigbee operates in the unlicensed RF worldwide i.e. 2.4 GHz global, 915 MHz in America and 868 MHz in Europe with a data rate of 250 Kbps at 2.4 GHz, 40 Kbps at 915 MHz and 20 Kbps at 868 MHz.

24 Saturday 25 Sunday

Some General characteristics of Zigbee :-

① Low cost
② Low power consumption
③ Low data rate.
④ short range transmission.
⑤ Scalability.
⑥ Reliability.
⑦ CSMA-CA channel Access

26 Monday

⑧ Very long battery life.
⑨ Supports large no. of nodes.
⑩ Flexible protocol design suitable for many applications.

Zigbee Components and Network Topologies :-

→ A Zigbee consists of several components. The most basic is the device, which can be devided as,
① Full function device (FFD)
② Reduced function device (RFD).

→ A network includes atleast one FFD, operating

27 as the personal area network (PAN) co-ordinator. Tuesday

→ The FFD can operate in three modes, a PAN co-ordinator, a co-ordinator or a device.

28 Wednesday

WiMAX

→ WiMAX (World Interoperability for Microwave Access) is a family of wireless communication standards based on the IEEE 802.16 set of standards.

→ WiMAX is an advanced technology solution based on an open standard, designed to meet the need for very high speed wide area internet access, in a cost-effective and flexible way.

→ WiMAX is optimized for IP-based high speed wireless broadband which will provide for a better mobile wireless broadband internet experience.

→ With its large range and high transmission rate, WiMAX can serve as a backbone for 802.11 hotspots for connecting to the internet.

2 Friday

→ Alternatively, users can connect UE directly to WiMAX BS without using 802.11, which upto a range of 4 to 6 miles.

→ WiMAX can typically support data rates from 500 Kbps to 2 Mbps.

→ There are two main types of WiMAX i.e. fixed WiMAX (802.16d - 2004), and mobile WiMAX (802.16e - 2005).

→ fixed WiMAX is a point-to-multipoint technology, where as the mobile WiMAX is a Multipoint-to-Multipoint technology, similar to that of

3 Saturday

Cellular infrastructure.

→ Mobile WiMAX uses OFDMA technology which has the inherent advantages in latency, spectral efficiency, advanced antenna performance and improved multipath performance in an NLOS environment.

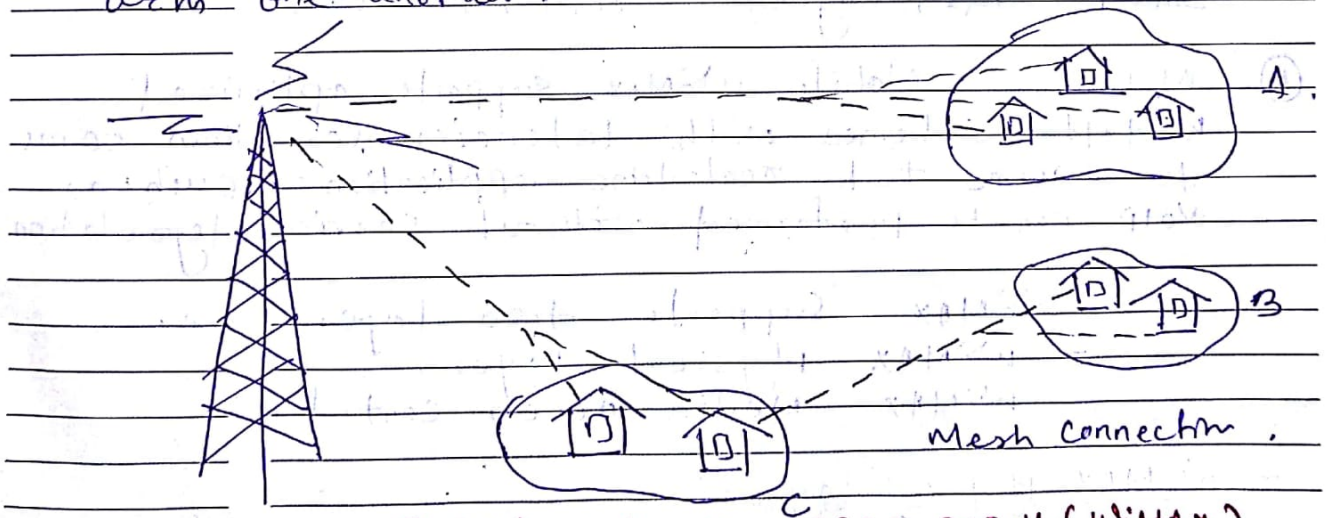
→ Release 1 of mobile WiMAX will cover 5, 7, 8.75 and 10MHz channel bandwidths for licensed worldwide spectrum allocations in 2.3 GHz, 2.5 GHz, 3.3 GHz and 3.5 GHz frequency bands.

→ The 802.16 standard was designed mainly for point-to-Multipoint topologies, in which a BS distributes traffic to many Subscribers stations (SS) that are mounted on rooftops.

4 Sunday

5 Monday

→ The 802.16 also supports a mesh mode, where subscriber stations can communicate directly with one another.



[Mesh Mode in IEEE 802.16 (WiMAX)

APR. 18

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6 Tuesday

Some Salient features supported by WiMAX are,

(1) High data rates :- The inclusion of ~~Multi-point~~ Multiple-input Multi-out (MIMO) antenna techniques along with flexible sub-channelization schemes, advanced coding and modulation all enables WiMAX technology to support peak downlink data rates of 63 Mbps per sector and uplink data rates upto 28 Mbps per Sector in a 10 MHz channel.

(2) Quality of Service (QoS) :-

(3) Scalability :- Mobile WiMAX is designed to be able to scale to work in different channelization from 1.25 to 20 MHz to comply with varied worldwide requirements.

7 Wednesday

(4) Security :- Support for a diverse set of user credentials exists including SIM/USIM cards, Smart cards, digital certificates etc.

(4) Mobility :- Mobile WiMAX supports optimized handoff schemes with latencies less than 50 ms to ensure that real-time applications such as VoIP can be performed without service degradation.

WiMAX supports two layers i.e.
- WiMAX physical layer.
- WiMAX Media Access control.

- WiMAX physical Layer :-
→ The 802.16 PHY supports TDD and full and

FEB. 18

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8 Thursday

Half duplex FDD operations. However the initial release of ~~WiMAX~~ Mobile WiMAX supports TDD.

→ Another advanced features include adaptive modulation and coding (AMC), hybrid automatic repeat request (HARQ) and fast channel feedback (CQICH) to enhance coverage and capacity of WiMAX in mobile application.

→ For the bands in the 10-66 GHz range, 802.16 defines one air interface called wireless MAN-SC.

→ The PHY design for the 2-11 GHz range (both licensed and unlicensed bands) is more complex because of interface.

→ There are three interfaces for the 2-11 GHz range as follows,

9 Friday

(i) Wireless MAN-SC uses Single carrier Modulation.

(ii) Wireless MAN-OFDM uses a 256-carrier OFDM. This air interface provides multiple access to different stations through TDMA.

(iii) Wireless MAN-OFDM uses a 2048-carrier OFDM scheme. The interface provides multiple access by assigning a subset of the carriers to an individual receiver.

→ For Mobile WiMAX it supports QPSK, 16-QAM and 64-QAM in down link; where in uplink the 64-QAM is optional.

→ Both conventional code and turbo code with variable code rate and repetition coding are supported.

10 Saturday 11 Sunday

→ WiMAX provides signalling to allow fully asynchronous operation. The asynchronous operation allows variable delay set retransmission which gives more flexible flexibility to the scheduler at the cost of additional overhead for each retransmission.

- WiMAX Media Access Control (MAC) :-

→ The MAC layer of 802.16 is designed to serve sparsely distributed stations with high data rates.

→ Subscriber stations are not required to listen to one another because this listening might be difficult to achieve in the WiMAX environment.

→ The 802.16 MAC is a scheduling MAC where the

12 Monday

subscriber only has to compete once for the initial entry to the network. After that it is allocated a time slot by the BS.

→ This scheduling algorithm is ~~suitable~~ stable under overload and oversubscription. It is also more bandwidth efficient.

→ ~~The~~

→ The scheduling algorithm allows the BS to control QoS by balancing the assignment among the needs of subscribers.

Spectrum Allocation for WiMAX

→ The IEEE 802.16 specification applies across a wide swath of RF spectrum.

FEB. 18

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13 → Tuesday

→ There is no uniform global licensed spectrum for WiMAX in the US.

→ The biggest segment available is around 2.5 GHz.

→ Mobile WiMAX based on the 802.16e standard will most likely be in 2.3 GHz and 2.5 GHz frequencies

X. Comparison of Wi-Fi and WiMAX.

Wi Fi	WiMAX
① 802.11a - OFDM, Max. rate = 54 Mbps 802.11b - DSSS, max. rate = 11 Mbps 802.11g - OFDM, max. rate = 54 Mbps	① 802.16 - OFDM, max. rate = 50 Mbps 802.16e - OFDM, max. rate ≈ 30 Mbps.
② Range < 100 m	② A few km's NLOS, more with LOS.
③ Indoor Environment	③ Outdoor Environment.
④ No admission control and no load balancing.	④ Admission control and load balancing.
⑤ No quality of service (QoS)	⑤ Five QoS classes enforced by BS.

14 → Wednesday

Silicon
...beyond teaching

March

Success depends more on common sense than on genius.

15 Thursday

Module IV

16 Friday

FEB. 18	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN
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I am proud to be a Siliconite

17 Saturday 18 Sunday

★. Spectral Efficiency.

-> Spectral efficiency, is the most desirable feature of a mobile communication.

→ The main of spectral efficiency is to use the available spectrum in a more efficient way.

→ There are different techniques such as, reducing the channel bandwidth, information compression variable bit rate codec, improved channel allocation algorithms etc are used to improve the spectral efficiency.

→ Spectral efficiency of a mobile communication system depends on the choice of a multiple access scheme.

19 Monday

→ The measure of spectral efficiency enables one to estimate the capacity of a mobile communication system.

★. Multiple Access Techniques.

→ Multiplexing deals with the division of resources to create multiple channels.

→ Multiplexing can create channels in frequency, time, etc.

→ Depending on the channel division multiplexing

20 Tuesday

It divided into two types as,

① Frequency - Division Multiplexing (FDM)

② Time - Division Multiplexing (TDM)

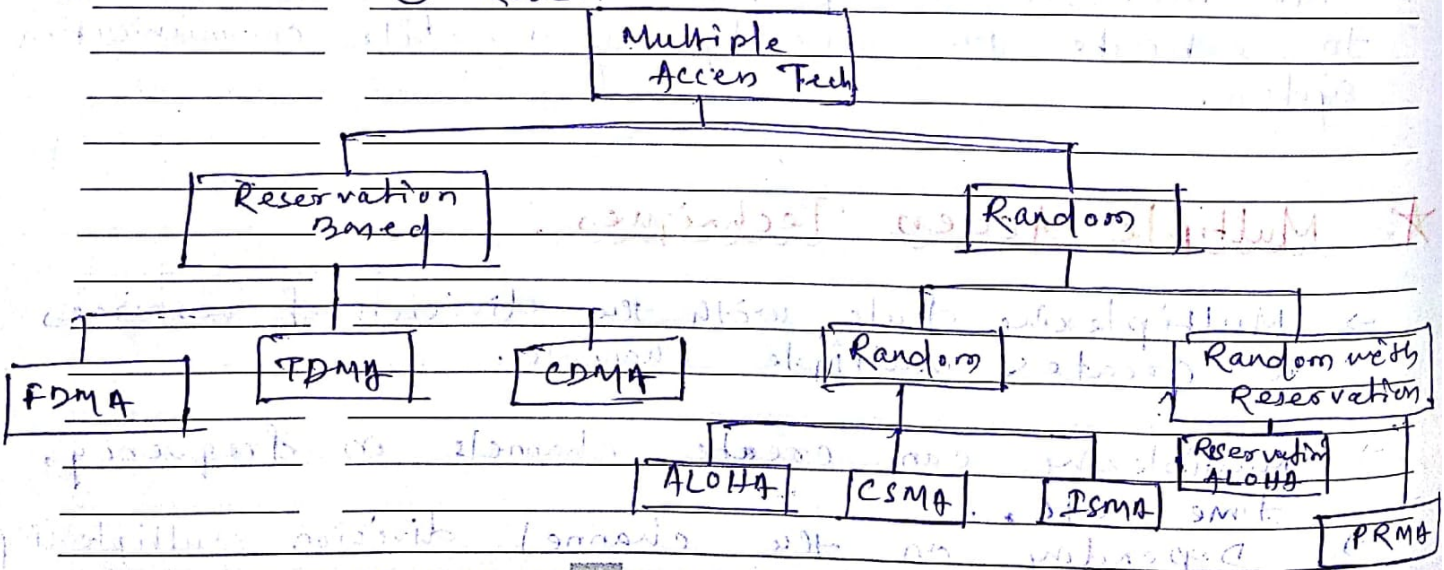
→ Since the amount of spectrum available is limited, it is necessary to find out the ways to allow multiple user to share the available spectrum simultaniously.

→ Shared accen is used to implement a multiple accen scheme when accen by many users to a channel is required.

→ Multiple accen schemes allow many users to share the radio spectrum efficiently.

21 Wednesday

→ Multiple accen schemes can be classified as,



22 Thursday

→ ISMA - Idle signal costly Multiple Access.
PRMA - Packet Reservation Multiple Access.
CSMA - Carrier sense Multiple Access.

⇒ If the data traffic is continuous and a small transmission delay is required, then reservation based multiple accen is required.

⇒ The reservation based multiple accen techniques has disadvantage in that once the channel is assigned, it remains idle if the user has nothg to transmit, while the other users may have data waiting to be transmitted.

⇒ This problem is critical when data generation is random and has a high-peak-rate to avg. rate ratio.

23 Friday

⇒ In this case, random multiple accen is more efficient, because a communication channel is shared by many users and users transmit their data in a random or partially co-ordinated fashion.

⇒ If the data arrives in a random manner and the data length is large, then random multiple accen combined with a reservation protocol will perform better than both random and reservation based schemes.

24 Saturday 25 Sunday

Narrow-band channelized Systems

→ Traditional architectures for analog and digital wireless systems are channelized.

→ In a channelized, the total spectrum is divided into a large no. of relatively narrow radio channels that are defined by carrier frequency.

→ Each radio channel consists of a pair of frequencies.

→ The frequency used for transmission from the BS to MS is called forward channel (downlink) and the frequency used for transmission from MS to BS is called reverse channel (uplink).

26 Monday

→ A user is assigned both frequencies for the duration of the call.

→ A narrow band channelized system demands precise control of ofp frequencies for an individual transmitter.

Frequency Division Duplex (FDD) and Time Division Duplex (TDD) System.

→ Many cellular systems (such as AMP, GSM, DAMP etc) uses FDD in which the transmitter and receiver operate simultaneously on different frequencies.

27 Tuesday

→ Separation is provided both the downlink and uplink channels to avoid the transmitter causing self interference to its receiver.

→ other precautions are also needed to prevent self interference, such as using two different antennas or alternatively one antenna with a duplexer

→ A cellular system can be designed to use one frequency band by using time division duplex (TDD)

→ In a TDD a bidirectional flow of information is achieved using the simplex-type scheme by automatically automatically alternating in time the direction of transmission on a single frequency.

28 Wednesday

→ The amount of spectrum required for both FDD and TDD is the same.

→ The difference lies in the use of two bands of spectrum separated by the required bandwidth for FDD, where as TDD requires only one band of frequencies but twice the bandwidth.

→ With TDD the transmitter slot and the receiver slot of the subscriber unit occurs at different times.

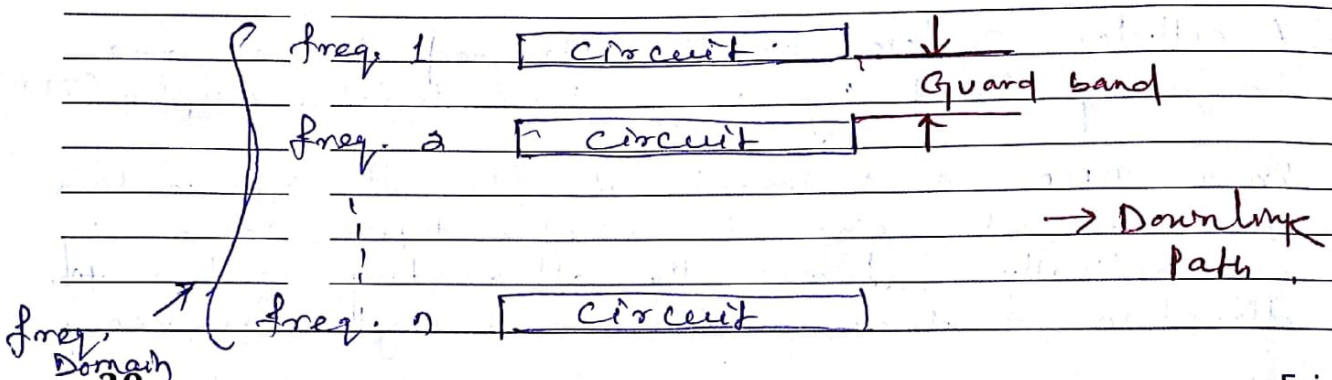
→ Since the bandwidth of TDD channel is twice that of a transmitter and receiver in an FDD system, RF filters in all the transmitters and receivers for TDD system must be

29 Thursday

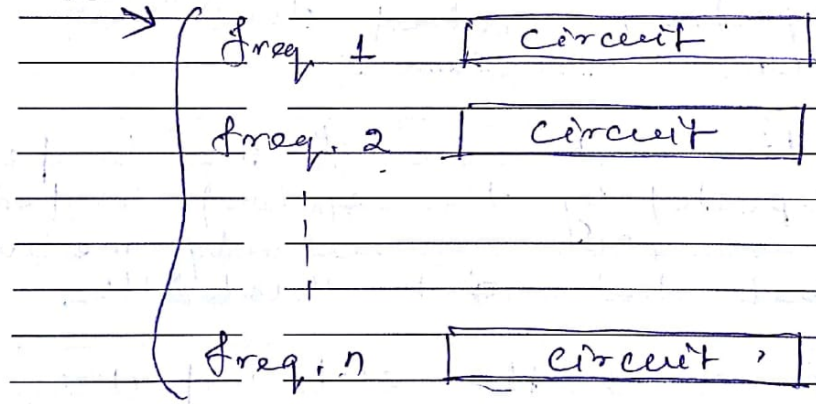
designed to cover twice the bandwidth of FDD systems filters.

FDMA

→ In FDMA scheme different users are assigned with different carrier frequency.



30 Friday



[FDMA / FDD Channel Architecture]

→ Multiple users are isolated users bandpass filters.

⇒ In FDMA, signals from various users are assigned different frequencies, just as in analog system.

⇒ Frequency guard bands are provided betn adjacent signal spectra to minimize crosstalk betn adjacent channels.

Advantages :-

① Capacity can be increased by reducing the information bit rate and using an efficient digital speech coding scheme.

② Technological advances required for implementation are simple.

③ Hardware simplicity, because multiple users are isolated by employing simple bandpass filter.

Disadvantages :-

① Crosstalk arising from adjacent channel interference is produced by non-linear effects.

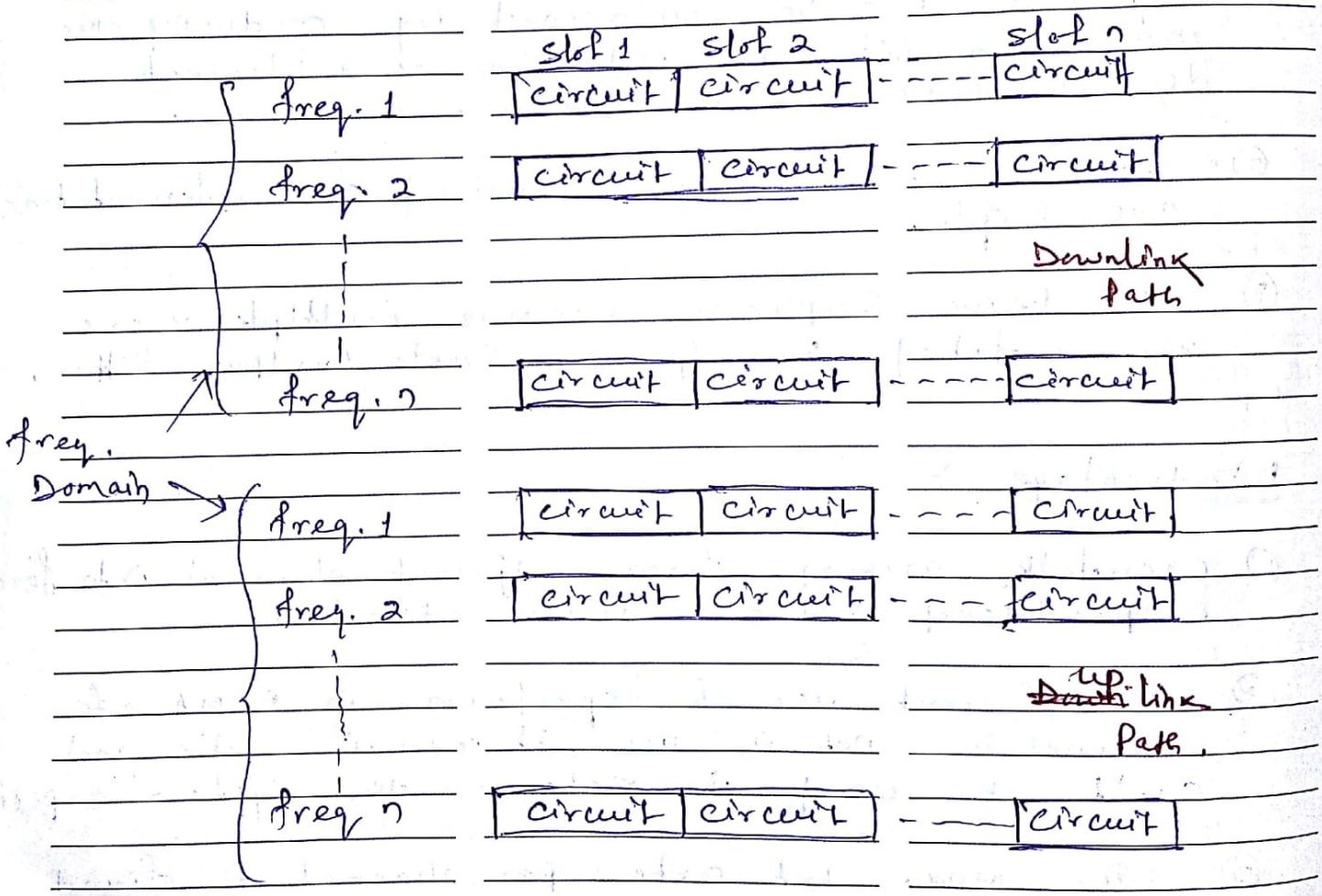
② Inefficient use of spectrum, in FDMA if channel is not in use, it remains idle and can't be used to enhance the system capacity.

③ The max. bit-rate per channel is fixed and small, inhibiting the flexibility in bit-rate

Note capability that may be a requirement for computer file transfer in some applications in future.

TDMA

→ In a TDMA system, each user uses the whole channel bandwidth for a fraction of time, compared to an FDMA system where a single user occupies the channel bandwidth for the entire duration.



[TDMA/TDD Channel Architecture.

1 → Sunday

→ In TDMA system, time is divided into equal time intervals, called slots.

→ User data is transmitted in slots. Several slots make up a frame.

→ Guard times are used betn each user's transmission to minimized crosstalk betn channel

→ Each user is assigned a frequency and a time slot to transmit data.

→ The data is transmitted via a radio-carrier from a BS to several active mobiles in the downlink.

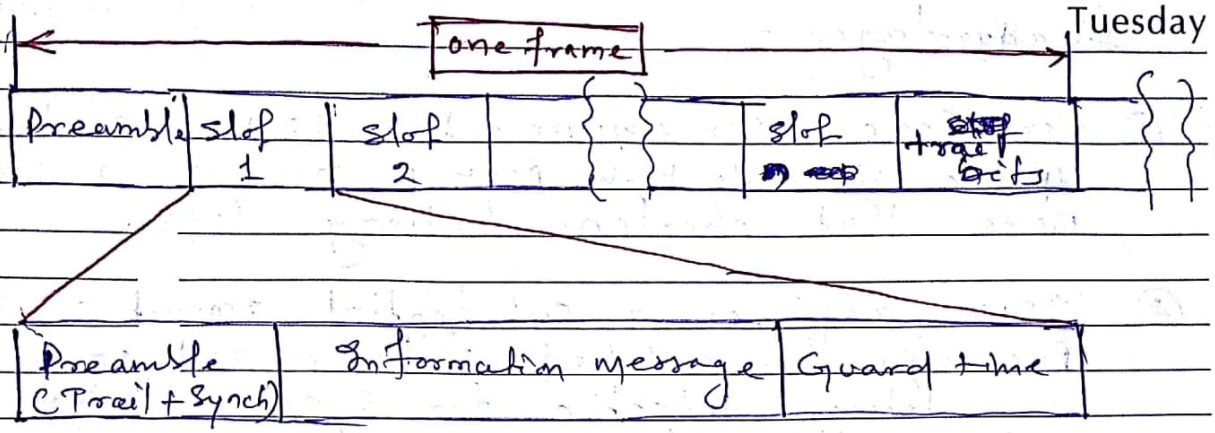
2 → In the uplink, transmission from mobile to BS is time-sequenced and synchronized Monday on a common frequency for TDMA.

→ In TDMA system, the user can use multiple slots to support a wide range of bit rates by selecting the lowest multiplexing rate.

→ This enables supporting a variety of voice codig tech. at different bit rates with different voice quality.

→ Free preamble

3 Tuesday



[TDMA frame]

→ The preamble carries the address and Synch. information that both the BS and MS use for identification.

4 Wednesday

Advantages:

(1) TDMA permits a flexible bit rate, not only for multiples of the basic single channel rate but also submultiples for low bit rate broadcast-type traffic.

(2) TDMA offers the opportunity for frame-by-frame monitoring of signal strengths / bit error rates to enable either Mobiles or BS to initiate and execute handoffs.

(3) TDMA, when used exclusively and not with FDMA, utilizes bandwidth more efficiently because no frequency guard band is required between channels.

5 Thursday

Disadvantages :-

① For some user equipments, TDMA on the uplink demands high peak power in transmit mode, that shortens battery life.

② TDMA requires a substantial amount of signal processing for matched filtering and ~~co-~~ correlation detection for synchronizing with a time slot.

③ TDMA requires synchronization. If the time slot synchronization is lost, the channels may collide with each other.

6 Friday