UNIT–2 : Cellular Architecture and Multiple Access (PYQ Solution)

PART–A Answers (≈70 Words Each)

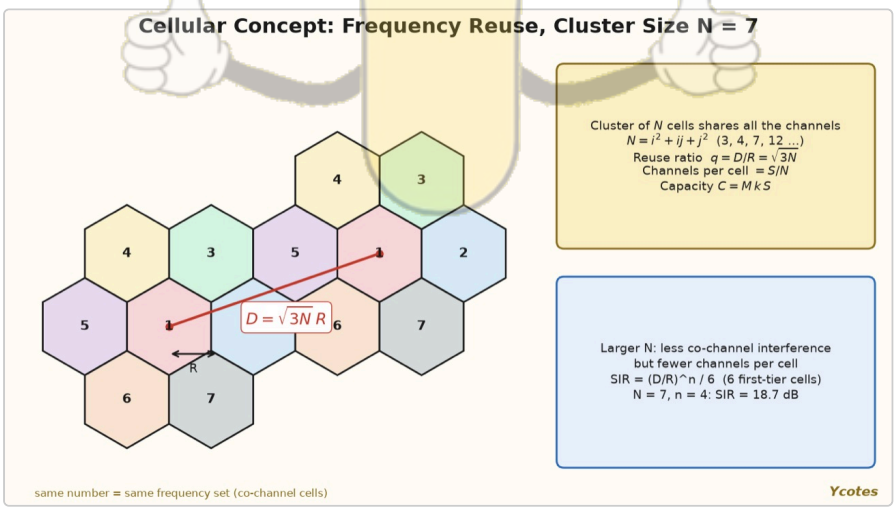
Q1. Explain the frequency reuse concept / frequency reuse ratio. (2019, 2025)

Frequency reuse means using the same set of channels in different cells that are separated by a sufficient distance, so that co-channel interference stays acceptable. The S channels are shared by a cluster of N cells, each cell getting S/N.

Frequency reuse ratio (co-channel reuse ratio):

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

where D is the distance between co-channel cells and R the cell radius. Larger q means less interference but less capacity.



Q2. Define the cellular concept. (Feb 2024)

The cellular concept replaces one powerful transmitter covering a large area by many low-power base stations, each serving a small area called a cell.

Neighbouring cells use different channel groups, while distant cells reuse the same channels.

It gives a large capacity from limited spectrum, and handoff lets a call continue as the mobile moves from cell to cell. Cells are drawn as hexagons to model the coverage without gaps or overlaps.

Q3. Define duplexing. (Feb 2024)

Duplexing is the method that allows two-way communication between the mobile and the base station.

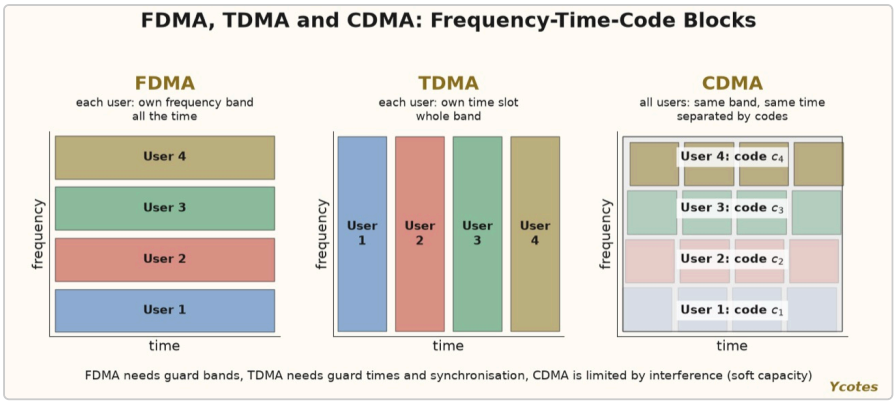
- **FDD (frequency division duplex): uplink and downlink use different carrier frequencies at the same time (e.g. GSM, LTE FDD).**
- **TDD (time division duplex): both directions use the same frequency but in different time slots (e.g. WiMAX, LTE TDD).**

FDD needs a duplexer and paired spectrum; TDD suits asymmetric traffic and allows channel reciprocity.

Q4. Write two differences between FDMA and TDMA. (2025)

FDMA	TDMA
Each user gets a separate frequency band for the whole call	Each user gets a time slot on the same wide band
Continuous transmission, narrowband, needs guard bands	Burst transmission, needs guard time and synchronisation

Other points: TDMA is digital only and allows slots to be used for handoff measurements, while FDMA has no frame overhead.


FDMA, TDMA and CDMA: Frequency-Time-Code Blocks
FDMA
each user: own frequency band
all the time
User 4
User 3
User 2
User 1
frequency
time
TDMA
each user: own time slot
whole band
User 1
User 2
User 3
User 4
frequency
time
CDMA
all users: same band, same time
separated by codes
User 4: code c_4
User 3: code c_3
User 2: code c_2
User 1: code c_1
frequency
time
FDMA needs guard bands, TDMA needs guard times and synchronisation, CDMA is limited by interference (soft capacity)
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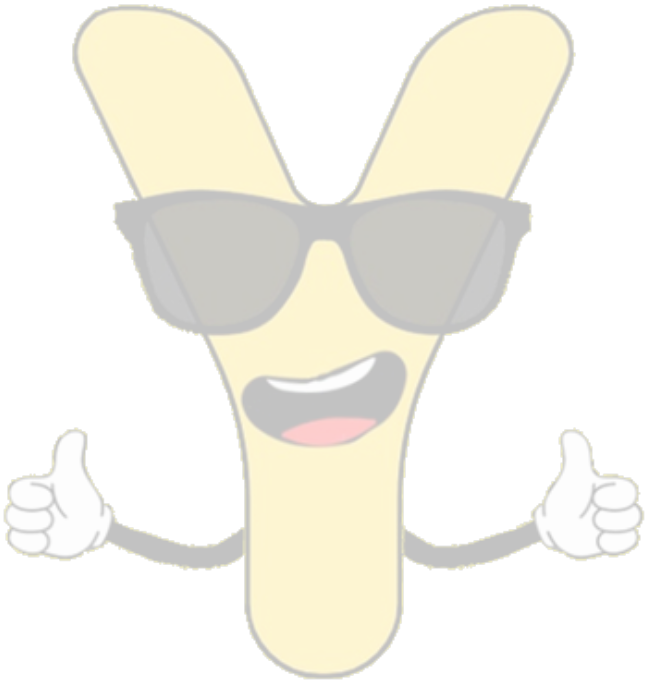


PART–B Answers (≈250 Words Each)

Q1. Describe the capacity of a cellular CDMA system. (2019)

In **CDMA** all users share the same band at the same time, separated by unique spreading codes, so capacity is **interference limited** (soft capacity).

Single cell: with processing gain $G_p = W/R$ and N users with perfect power control, each user's signal faces $N-1$ equal-power interferers:

$$\frac{E_b}{N_0} = \frac{W/R}{N-1} \;\Rightarrow\; N = 1 + \frac{W/R}{E_b/N_0}$$

Practical improvements:

- Voice activity factor $\nu \approx 0.4$ increases capacity by $1/\nu$
- Sectoring with 3 sectors gives a gain $G \approx 3$
- Interference from other cells (factor $f \approx 0.6$) reduces it by $1/(1+f)$

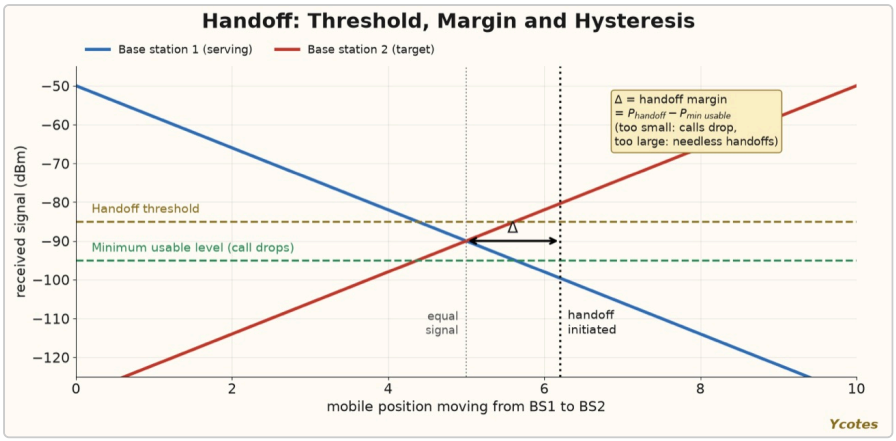
$$N \approx \frac{W/R}{E_b/N_0} \cdot \frac{G}{\nu(1+f)}$$

Example: $W = 1.25$ MHz, $R = 9.6$ kbps, $E_b/N_0 = 10$ dB $= 10$: $W/R = 130.2$. A single cell supports $1 + 13.02 \approx 14$ users, and with the improvements $N \approx 13.02 \times 3/(0.4 \times 1.6) \approx 61$ users per cell.

Points: accurate power control (near-far problem), soft handoff and a frequency reuse factor of one make CDMA capacity higher than FDMA or TDMA.

Q2. Explain handoff in detail and the situations that trigger a handoff. (Feb 2024)

Handoff (handover) transfers an ongoing call from one base station or channel to another without interrupting the call as the mobile moves.



Situations that trigger a handoff:

1. Received signal strength falls below the handoff threshold
2. Poor signal quality (high BER, low SIR)
3. The mobile reaches the cell boundary
4. Congestion in the serving cell (traffic or load balancing handoff)
5. A better cell is available (power budget handoff), or speed-based handoff to umbrella cells

Types: hard handoff (break before make; FDMA, TDMA), soft handoff (make before break; CDMA), softer handoff (between sectors of one base station) and inter-system handoff.

Process: measure signal, compare with threshold plus margin, request the target base station, allocate a channel, switch and release the old channel. In **MAHO** the mobile measures the neighbouring cells and reports to the network.

Margin: $\Delta = P_{handoff} - P_{min\ usable}$. A small Δ can drop calls before handoff is complete; a large Δ gives needless handoffs. Hysteresis avoids ping-pong.

Q3. Describe the handoff process. A mobile user is moving at a speed of 72 km/h in a cellular network where the cell radius is 1 km. If the user makes a call lasting 10 minutes, determine the expected number of handoffs during the call. (2025)

Handoff process: the serving base station monitors signal strength; when it falls below the threshold, the MSC asks neighbouring base stations to measure the mobile. The best candidate is selected, a channel is allocated, the mobile is told to retune, and the old channel is released.

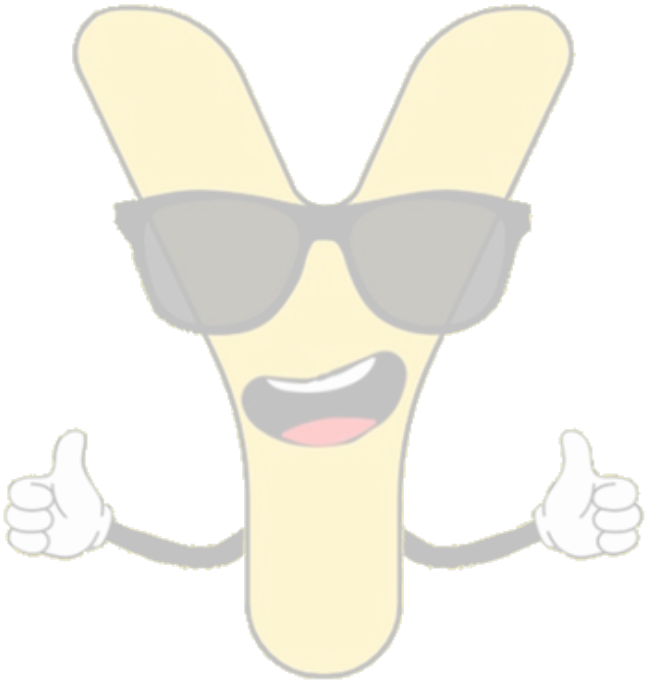
Numerical:

Speed: $v = 72\ \text{km/h} = 72/3.6 = 20$ m/s.
Distance in the call: $d = vt = 20 \times 600 = 12\,000$ m = 12 km.
Cell crossing length: assuming the user passes through the centres of the cells, each cell is crossed over its diameter $2R = 2$ km. Dwell time per cell $= 2000/20 = 100$ s.

Number of handoffs:

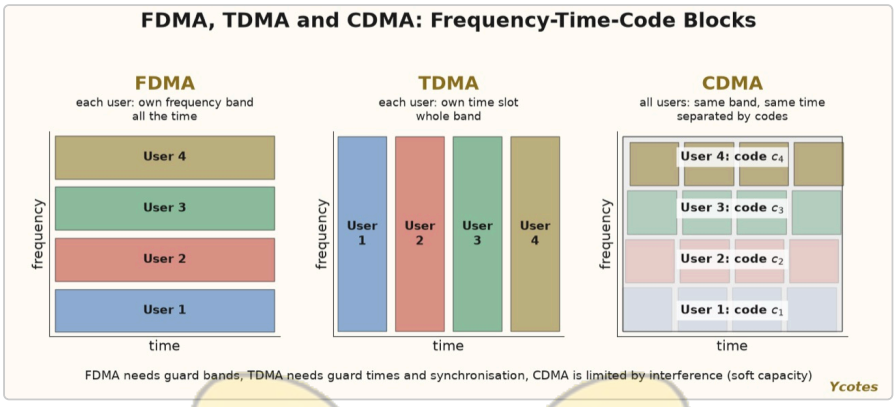
$$N_{ho} = \frac{d}{2R} = \frac{12}{2} = 6$$

Answer: about **6 handoffs** during the 10 minute call (assuming a straight path through cell centres; the first partial cell may make it 5 or 6).



PART–C Answers (≈500 Words Each)

Q1. Differentiate between FDMA, CDMA and TDMA. Also explain their working. (Feb 2024)



FDMA (frequency division multiple access): the available band is divided into narrow channels (e.g. 30 kHz in AMPS). Each user is assigned one channel for the whole call, with one channel per carrier. Guard bands separate the channels. Transmission is continuous and analogue or digital; no synchronisation is needed but the base station needs many transceivers.

TDMA (time division multiple access): a wide carrier (e.g. 200 kHz in GSM) is divided into frames and time slots (8 slots in GSM). Each user transmits only in its own slot, in bursts, so one transceiver serves several users. Guard times and accurate synchronisation are needed; the idle slots allow handoff measurements.

CDMA (code division multiple access): all users transmit over the whole wide band at the same time. Each user's data is multiplied by a unique, nearly orthogonal pseudo-random spreading code of much higher rate, so the signal is spread over W. The receiver correlates with the same code to recover the wanted user, and other users appear as noise. It offers soft capacity, soft handoff, RAKE reception and frequency reuse of one.

	FDMA	TDMA	CDMA
Resource divided	Frequency	Time	Code
Shared	Time	Frequency	Time and frequency
Guard needed	Guard bands	Guard times	None, but power control
Capacity	Fixed	Fixed	Soft, interference limited
Synchronisation	No	Yes	Yes (code)
Handoff	Hard	Hard	Soft
Interference	Adjacent channel	Slot overlap	Multiple access (near-far)
Example	AMPS	GSM	IS-95, WCDMA

Capacity examples: FDMA: $N = (B_t - 2B_g)/B_c = (12.5\ \text{MHz} - 20\ \text{kHz})/30\ \text{kHz} = 416$ channels. TDMA: $N = m(B_t - 2B_g)/B_c = 8 \times (25\ \text{MHz} - 0.2\ \text{MHz})/200\ \text{kHz} = 992$ channels.

Q2. A hexagonal cell within a four cell system has a radius of 1.387 km. A total of 60 channels are used within the entire system. If the load per user is 0.029 Erlangs and lambda = 1 call/hour. The system is designed with a 5% probability of delayed calls. Compute (a) how many users per square km this system can support (b) probability (waiting time of a delayed call > 10 s) (c) probability (call will be delayed > 10 s). (2025)

Assumptions: the paper's cell loads (15 Erlang for 15 channels and 10 Erlang for 10 channels) are garbled, so we design with the given data: $N = 4$, 60 channels, so $C = 60/4 = 15$ channels per cell; delayed calls are queued, so use **Erlang C** with $P(\text{delay} > 0) = 0.05$. The same method holds for $C = 10$.

Step 1: traffic per cell. Solving the Erlang C formula

$$P(\text{delay} > 0) = \frac{A^C/C! \cdot \frac{C}{C-A}}{\sum_{k=0}^{C-1} A^k/k! + A^C/C! \cdot \frac{C}{C-A}} = 0.05$$

with $C = 15$ gives $A \approx 9.04$ Erlang per cell (computed numerically).

Step 2: users per cell:

$$U = \frac{A}{A_u} = \frac{9.04}{0.029} = 312 \text{ users}$$

Step 3: cell area:

$$A_{cell} = \frac{3\sqrt{3}}{2} R^2 = 2.598 \times (1.387)^2 = 5.0 \text{ km}^2$$

(a) Users per km^2:

$$\frac{312}{5.0} \approx 62 \text{ users/km}^2$$

Holding time: $H = A_u/\lambda = 0.029 \text{ hr}/1 = 104.4 \text{ s}.$

(b) Delay of a delayed call exceeding t:

$$P(W > t \,|\, W > 0) = e^{-(C-A)t/H} = e^{-(15-9.04)\times 10/104.4} = e^{-0.571} = 0.565$$

(c) Probability a call is delayed more than 10 s:

$$P(W > 10) = P(W > 0) \times 0.565 = 0.05 \times 0.565 = 0.028$$

Answers: (a) about 62 users per km^2; (b) 0.565 (56.5%); (c) 0.028 (2.8%).

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