Karnatak Law Society's
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DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

Semester	:	8th
Subject with code	:	Wireless & Cellular Communication – 18EC81
Scheme & Solution prepared by	:	Dr. Arun Kakhandki

19.09.2022

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CBCS SCHEME

USN | | | | | | | | | | |

18EC81

Eighth Semester B.E. Degree Examination, July/August 2022
Wireless and Cellular Communication

Time: 3 hrs. Max. Marks: 100

Note: ***Answer any FIVE full questions, choosing ONE full question from each module.***

Important Note : 1. On completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages.
2. Any revealing of identification, appeal to evaluator and /or equations written eg, 42+8 = 50, will be treated as malpractice.

Module-1

1 a. Explain in brief the basic three propagation mechanisms. **(06 Marks)**

b. Define :
   i) Delay spread
   ii) Coherence bandwidth
   iii) Doppler spread
   iv) Coherence time. **(08 Marks)**

c. Assume a receiver is located 10km from a 50W transmitter. The carrier frequency is 900MHz, free space propagation is assumed, $G_t = 1$, $G_r = 2$, find :
   i) The power at the receiver
   ii) The magnitude of E-field at the receiver antenna
   iii) The rms voltage applied to the receiver input assuming that the receiver antenna has real impedance of 50Ω and is matched to the receivers. **(06 Marks)**

OR

2 a. Explain cell splitting and cell sectoring. **(06 Marks)**

b. Explain the three statistical channel model of a broadband fading channel. **(09 Marks)**

c. If a transmitter produces 50Watts of power, express the transmit power in units of
   i) dBm and dBw
   ii) if 50Watts is applied to a unity gain antenna with a 900MHz frequency of carrier, find the received power in dBm at a free space distance of 100m from the antenna. **(05 Marks)**

Module-2

3 a. Explain with neat block diagram GSM network architecture. **(10 Marks)**

b. Explain GSM Hyper frame with neat sketch. **(10 Marks)**

OR

4 a. Explain GSM identities. **(10 Marks)**

b. Explain the types of GSM location updating. **(10 Marks)**

Module-3

5 a. Explain the CDMA basic spectrum spreading operation with necessary sketches. **(10 Marks)**

b. Explain forward logical channels of CDMA. **(10 Marks)**

OR

6 a. Explain CDMA mobile station initialization and call processing states. **(12 Marks)**

b. Explain the types of handoff used in CDMA. **(08 Marks)**

Module-4

7 a. Explain OFDM advantages and disadvantages. **(10 Marks)**
b. Explain with neat block diagram flat LTE SAE architecture. **(10 Marks)**

OR

8 a. Explain the differences between OFDM and SCFDE with neat block diagrams. **(10 Marks)**
b. Write a note on :
i) Frequency synchronization
ii) The Peak to Average Ratio (PAR) **(10 Marks)**

Module-5

9 a. Explain with neat block diagram OFDMA downlink transmitter. **(10 Marks)**
b. Mention SC-FDMA advantages and disadvantages. **(05 Marks)**
c. Mention OFDMA advantages and disadvantages. **(05 Marks)**

OR

10 a. Explain LTE end to end network architecture with neat block diagram. **(10 Marks)**
b. Explain LTE frame structures. **(10 Marks)**

* * * * *

Module - 1

Q.1> a) Explain in brief the basic three propagation mechanisms. (6m)

Soln.

The three basic propagation mechanisms are: Reflection, diffraction and scattering.

Reflection:

Reflection occurs when a propagating EM wave impinges upon an object which has very large dimensions when compared to the wavelength of the propagating wave. Reflections occur from the surface of the earth and from buildings and walls.

— 2m

Diffraction:

Diffraction occurs when the radio path between the tx and rx is obstructed by a surface that has sharp irregularities (edges). The secondary waves resulting from the obstructing surface are present throughout the space and even behind the obstacle, giving rise to a bending of waves around the obstacle, even when a LOS path does not exist between tx & rx. At high frequencies, diffraction, like reflection,

— 2m

depends on the geometry of the object, as well as the amplitude, phase and polarization of the incident wave at the point of diffraction.

Scattering:

Scattering occurs when the medium thro' which the wave travels consists of objects with dimensions that are small compared to the wavelength, and where the number of obstacles per unit volume is large. Scattered waves are produced by rough surfaces, small objects or by other irregularities in the channel. In practice, foliage, street signs, and lamp posts induce scattering in a mobile commn system.

— 2m

Q. 1) b) Define:
i) Delay spread (ii) coherence bandwidth
iii) Doppler spread (iv) coherence time

2 marks each

Soln. i) Delay spread : (τ) :
The delay spread is a very important property of a wireless channel, since it specifies the duration of the channel impulse response $h(\tau, t)$. Delay spread is the amount of time that elapses between the first arriving path and the last arriving path.
If $\tau \gg T$ then freq. is selective
If $\tau \ll T$ then freq. is flat.
The larger the delay spread relative to the symbol time, the more severe the ISI.

ii) Coherence bandwidth (B_c) :
It is the freq. domain dual of the channel delay spread. It gives a rough measure for the max. separation between a freq. f_1 and a freq. f_2 where the channel freq. response is correlated. i.e.,
If $1/B_c \ll T$, then freq. is flat
If $1/B_c \gg T$, then freq. is selective.

coherence bandwidth provides a guideline to subcarrier width $B_{sc} \approx B_c/10$, and hence number of subcarriers needed in OFDM: $L \geq 10B/B_c$.

iii) Doppler spread (f_D):

Unlike the power delay profile, the Doppler power spectrum is non-zero strictly for $\Delta f \in (-f_D, f_D)$, where f_D is called the maximum Doppler or Doppler spread. That is $S_t(\Delta f)$ is strictly "band-limited".

The Doppler spread is, $f_D = v \cdot \frac{f_c}{c}$.

where 'v' is the max speed between the tx & rx, 'f_c' is the carrier freq. and 'c' is the speed of light.

If $f_c \cdot v \gg c$, then fast fading
If $f_c \cdot v \leq c$, then slow fading.

If f_D/B_{sc} becomes non-negligible, subcarrier orthogonality is compromised.

iv) Coherence time (T_c):

Coherence time, T_c, is similar to coherence bandwidth, gives the period of time over which the channel is significantly correlated.

The coherence time & Doppler spread are inversly related

$$T_c \simeq \frac{1}{f_D}.$$

This makes intutive sense: if the tx & rx are moving fast relative to each other, and hence the Doppler is large, the channel will change much more quickly than if the tx & rx are stationary.

If $T_c >> T$, then slow fading
If $T_c \leq T$, then fast fading.

T_c small necessitates frequent channel esti-mation and limits the OFDM symbol duration but provides greater time diversity.

Q.1) c) Given:

Transmitter Power, $P_t = 50$ W
Carrier frequency, $f_c = 900$ MHz
Tx antenna gain, $G_t = 1$
Rx antenna gain, $G_r = 2$
Rx antenna resistance $= 50\,\Omega$

i) Power received at distance $d = 10$ km B

$$P_r(d) = 10 \log \left[\frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2} \right]$$

$$= 10 \log \left[\frac{50 \times 1 \times 2 \times (1/3)^2}{(4\pi)^2 \times (10000)^2} \right]$$

$$= -91.5 \text{ dBW} = -61.5 \text{ dBm}$$ — 2m

ii) Magnitude of received E-field B

$$|E| = \sqrt{\frac{P_r(d)\, 120\pi}{A_e}}$$

$$= \sqrt{\frac{P_r(d)\, 120\pi}{G_r \lambda^2 / 4\pi}} = \sqrt{\frac{7 \times 10^{-10} \times 120\pi}{2 \times 0.33^2 / (4\pi)}}$$

$$= 0.0039 \text{ V/m}$$ — 2m

WCPM

iii) The applied rms vg. at the Rx input is

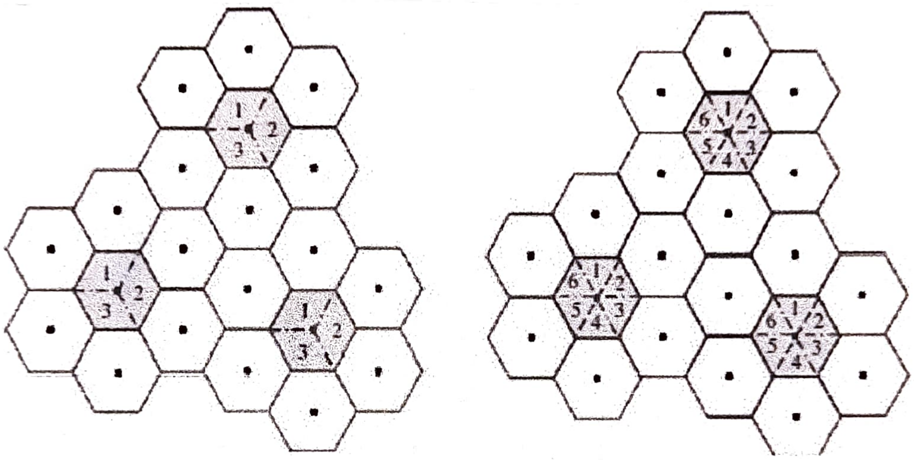
$$V_{ant} = \sqrt{P_r(d) \times R_{ant}} = \sqrt{7 \times 10^{-10} \times 50}$$

$$= 0.187 \text{ mV}$$

—2m

Q.2) a) Explain cell splitting and cell sectoring.

Soln. Cell sectoring is the popular technique to improve the band SIR (signal to interference) without sacrificing bandwidth as frequency reuse does. Cell sectoring is effective if frequencies are reused. By using directional antenna instead of an omni directional antenna at the base station, the co-channel interference can be significantly reduced.



(a) 3-sector cells (b) 6-sector cells

3-sector (120-degree) and 6-sector (60-degree) cells.

Q2)a)

— 2m

Assuming for 3-sector cells, although the absolute amount of bandwidth used is 3X before, the capacity increase is in fact more than 3X. No capacity is lost from sectoring because each sector can reuse time and code slots, so each sector has the same nominal capacity as an entire cell.

Furthermore, the capacity in each sector is actually higher than that in a non-sectored cellular system because the interference is reduced by sectoring, since users only experience interference from the sectors at their freq.

An alternative way to use sectors ~~that~~ is to reuse frequencies in each sector. In this case, all of the time/code/freq. slots can be reused in each sector, but there is no reduction in the experienced interference.

Although sectoring is an effective and practical approach to the OCI problem, it is not without cost. Sectoring increases the number of antennas at each base station and reduces trunking efficiency due to channel sectoring at the base station. Even though intersector handoff is simpler compared to intercell handoff, sectoring also increases the overhead due to the increased number of intersector handoffs — 6m

Q.2) b) Explain the three statistical channel model of a broadband fading channel.

Soln. The three statistical channel model of a broadband fading channel are :

i) Rayleigh fading
ii) Line-of-sight channel - The Ricean distribution
iii) Nakagami-m fading

— 3 marks each

(i) Rayleigh fading :

If the no of scatters is large and the angles of arrival between them are uncorrelated, from the central limit theorem it can be shown that the in-phase (cosine) and quadrature (sine) components of $r(t)$ denoted as $r_I(t)$ & $r_Q(t)$ follow two independent time-correlated Gaussian random processes.

Consider a snapshot value of $r(t)$ at time $t=0$ and note that $r(0) = r_I(0) + r_Q(0)$.

Since the values $r_I(0)$ & $r_Q(0)$ are Gaussian random variables, it can be shown that the distribution of the envelope amplitude $|r| = \sqrt{r_I^2 + r_Q^2}$ is Rayleigh, and the received power $|r|^2 = r_I^2 + r_Q^2$ is exponentially distributed. Formally

$$f_{|r|}(x) = \frac{2x}{P_r} e^{-x^2/P_r}, \quad x \geq 0 \quad —(1)$$

and

$$f_{|r|^2}(x) = \frac{1}{P_r} e^{-x/P_r}, \quad x \geq 0 \quad —(2)$$

where P_r is the average received power due to shadowing and path loss, as described for example in eqn. The path loss and shadowing determine the mean received power, and the total received power fluctuates around this mean due to the fading.

The Gaussian random variables r_I & r_Q each have zero mean & variance $\sigma^2 = P_r/2$. The phase of $r(t)$ is defined as

$$\theta_r = \tan^{-1}\left(\frac{r_Q}{r_I}\right)$$

which is uniformally distributed from 0 to 2π or equivalently from $(-\pi, \pi)$ any other contiguous full period of the carrier signal.

(ii) Line-of-Sight Channel - The Ricean distribution

An important suggestion in the Rayleigh fading model is that all the arriving reflections have a mean zero. This will not be the case if there is a dominant path, a LOS path between the tx and rx. For a LOS signal the received envelope distribution is more accurately modelled by a Ricean distribution which is given by

$$f_{|r|}(x) = \frac{x}{\sigma^2} e^{-(x^2+\mu^2)/2\sigma^2} I_0\left(\frac{x\mu}{\sigma^2}\right), \quad x \geq 0$$

where μ^2 is the power of the LOS component and I_0 is the 0^{th} order modified Bessel fn of the first kind. Although this expression is more complicated than a Rayleigh distribution it is really a generalization of the Rayleigh distribution. This can be confired by observing that $\mu = 0 \Rightarrow I_0\left(\frac{x\mu}{\sigma^2}\right) = 1$, so the Ricean distribution reduces to the Rayleigh distribution in the absence of a LOS component. Since the Ricean distribution depends on the LOS components power μ^2, a common way to characterize the channel is by the relative strengths of the LOS and scattered paths. This factor 'k' is quantified as

$$k = \frac{\mu^2}{2\sigma^2}$$

The avg. received power under Ricean fading is just the combination of the scattering power and the LOS power ie, $P_r = 2\sigma^2 + \mu^2$

(iii) <u>Nakagami-m fading</u>:-

The PDF of Nakagami fading is parameterized by 'm' and given as.

$$f_{|r|}(x) = \frac{2m^m x^{2m-1}}{\Gamma(m) P_r^m} e^{-mx^2/P_r}, \quad m \geq 0.5$$

The dependence on 'x' is simple and hence the Nakagami distribution can ~~be~~ in many cases be used in tractable analysis of fading channel performance.

Additionally $m = \frac{(k+1)^2}{(2k+1)}$ gives an appropriate Ricean distribution, and $m=1$ gives a Rayleigh. As $m \to \infty$, the received power tends to be a constant, P_r. The power distribution of Nakagami fading is

$$f_{|r|^2}(x) = \left(\frac{m}{P_r}\right)^m \cdot \frac{x^{m-1}}{\Gamma(m)} e^{-mx/P_r}, \quad m \geq 0.5$$

Similarly, the power distribution is also amenable to integration.

Q. 2) c) Given:

Transmitter power = 50 W

Carrier frequency, f_c = 900 MHz

∴ Tx power in dBm ⇒

$$P_t(dBm) = 10 \log\left[\frac{P_t(mW)}{1\,mW}\right]$$

$$= 10 \log\left[50 \times 10^{3}\right] = 47.0\,dBm$$

& Tx. power in dBW ⇒

$$P_t(dBW) = 10 \log\left[\frac{P_t(W)}{(1\,W)}\right]$$

$$= 10 \log[50] = 17\,dBW$$ — 2m

The received power can be determined by

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

$$= \frac{50 \times 1 \times 1 \times (1/3)^2}{(4\pi)^2 (100)^2 \times 1} = (3.5 \times 10^{-6})\,W = 3.5 \times 10^{-3}\,mW$$

∴ $P_r(dBm) = 10 \log P_r(mW)$

$= 10 \log(3.5 \times 10^{-3}\,mW)$

$= -24.5\,dBm$ — 3m

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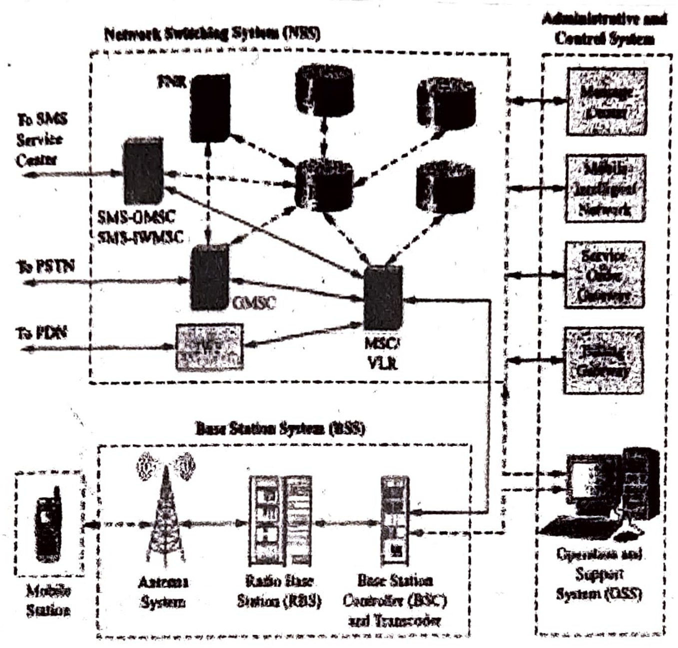
Module - 2

Q.3) a) Explain with neat diagram GSM network architecture

Soln. MS, BSS, NSS, Oprn and SS & other nodes.



GSM network architecture.

Q3)a)

— 3m

Mobile station : (MS)

MS is the device that provides the radio link b/w the GSM subscribe and the wireless mobile n/w. In GSM, the MS provides subscribers the means to control their systems access to the PSTN and PDN and also to facilitate their mobility once connected to the n/w. MS is a multifunctional s/m that continuously monitoring messages being broadcast from the base transceiver s/m (BTS) to support the setup and clearing of radio channels used for the transmission of various forms of subscriber traffic. MS also performs BER measurements.

The GSM s/m also makes use of a SIM card that when inserted in to the MS makes it functional.

In GSM standard, the MS consists of two elements : Mobile equipment (ME) and SIM card.

Base station System : (BSS)

BSS is the link between MS and the GSM mobile services switching centre (MSC). BSS consists of two elements : a Base transceiver System (BTS) and Base Station controller (BSC). Both the elements may be physically implemented by either two or three hardware systems depending upon the GSM hardware vendor.

The BTS is the BSS air interface device that corresponds to the subscriber's MS. It provides the radio link to the MS over the air interface. BTS is physically located near the antenna for the cell site.

The functional elements needed by a BSC to implement its operations may be all located in a single physical unit or split out into several seperate units. The basic BSC components are input & output interfacing ~~multiplexers~~ devices

Network Switching System (NSS):

The wireless NSS provides the necessary interface for the connection of the wireless n/w to other networks. Additionally it supports for the mobility of the GSM subscriber within the GSM n/w. The switching s/m maintains databases that are used to store information about the system's subscribers and facilitate the connection of a mobile to the system as long it has connection privilages. The GSM switching s/m was designed to communicate with the PSTN thro' ISDN protocols.

The basic components of NSS are: MSC, a gateway MSC, the visitors and home location registers.

Administrative and control system :—

Operation and Support System and other nodes -

The entire GSM wireless n/w is monitored and controlled by an Operation and Support System (OSS). This centralized S/m can be used to provide surveillance of the complete n/w and thus provide the operator a means to support operation and maintenance of the entire n/w. The OSS software usually provides the system operator with the ability to perform configuration, performance evaluation, and security management of each portion of the wireless n/w along with the traditional display of alarms or fault indicators for specific system elements.

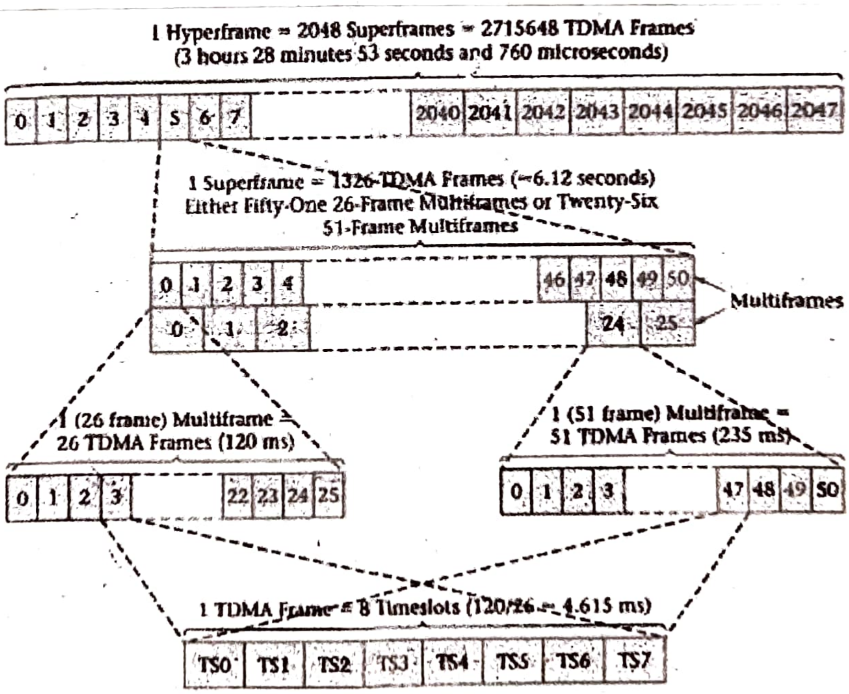
— 7m

Q.3) b) Explain GSM Hyper frame with neat sketch.

Soln. : GSM Hyper frame -

In GSM s/m, eight time slots constitute a TDMA frame. The system assigns numbers to the frames sequentially from 0 to 27,15,648 and then the process repeats itself. The description of GSM timing will start with the largest s/m time period.

The grouping of successive TDMA frames is known as a hyper frame.



A GSM hyperframe

Q3)b)

— 3m

As shown in the figure, The hyper frame consists of 2048 superframes (27,15,648 frames) and takes 3 hrs 28 mins 53 secs and 760 msecs to complete. Each superframe consists of 1,326 TDMA frames that take approximately 6.12 secs to complete These superframes may take on one of two possible formats. One form of a superframe consists of 51 (26 frame) multiframes. The other superframe format consists of 26 (51 frame) multiframes. Finally within a TDMA frame there are eight time slots that take approxim-ately 4.615 ms to complete.

— 7m

Q.4) a) Explain GSM identities

Soln: The GSM identities are as described below:

i) Mobile Station Associated Numbers -

The MS has a mobile station ISDN number (MSISDN) that uniquely identifies a mobile telephone subscription in the PSTN numbering plan. It is therefore a dialable number and is linked to one HLR. The IMSI is a unique identity allocated to each subscriber by the wireless service operator and stored in the subscriber's SIM. All network-related subscriber information is linked to the IMSI. Besides being stored in the subscribers SIM, the IMSI number is also stored in the HLR and VLR databases. The TMSI number is used by the GSM n/w to protect the subscriber's privacy over the air interface. The wireless n/w assigns a TMSI to the MS and the TMSI number only has local significance within the particular MSC/VLR coverage area during MS attachment. The IMEI number and IMEISV number are used by the GSM n/w for equipment identification and to uniquely identify an MS as a piece of equipment.

ii) Network Numbering Plans -

The GSM system uses both LAI numbers and CGI numbers. The LAI is used for MS paging and location updating. The CGI is used for cell identification within a location area. Within a wireless n/w itself, the n/w elements will have identity numbers or addresses that are necessary to facilitate the correct operation of the system.

iii) Mobile Station Roaming Number - (MSRN)

The MSRN is used by the GSM system during the call setup operation. Several operations must be performed before the call set up operation can be completed which are mentioned below:

Step #1: The GMSC receives a signaling message, "initial address message", from the PSTN about the incoming call for a particular MSISDN no.

Step #2: GMSC sends a signaling message "send routing information" to the HLR where the subscriber data for the particular MSISDN is stored.

Step #3: The HLR uses MSISDN to find the subscriber data in the data base.

step # 4 : The HLR sends a "provide roaming number" message to the MSC / VLR using the VLR address as the destination and the IMSI to identify the mobile subscriber.

Step # 5 : The VLR asks MSC to seize an idle MSRN from its available pool of numbers and to also associate it with the IMSI number received from the HLR.

Step # 6 : The MSC / VLR sends the MSRN back to the HLR.

Step # 7 : The HLR sends the MSRN back to the GMSC.

Step # 8 : The GMSC uses the MSRN to route the call to the correct MSC.

— 10 m

Q. 4 b) Explain the types of GSM location updating

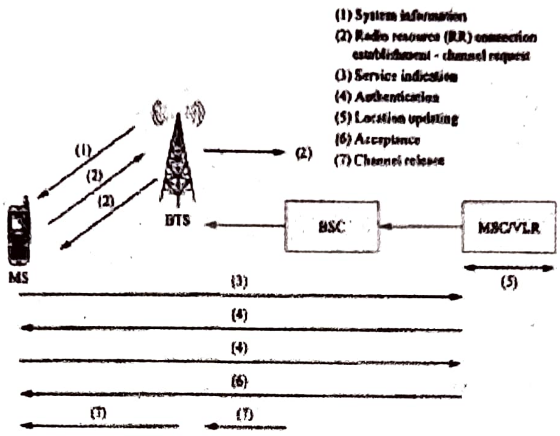
Soln: The operation used to support the subscriber's identity of mobile within the GSM n/w is known as location updating. At any given time, the subscriber may receive or initiate a call since the cellular system knows where the MS is located. within the n/w.

There are three different types of GSM location updating used in the GSM system viz; (i) normal or forced registration
(ii) periodic
(iii) ISMI attach.

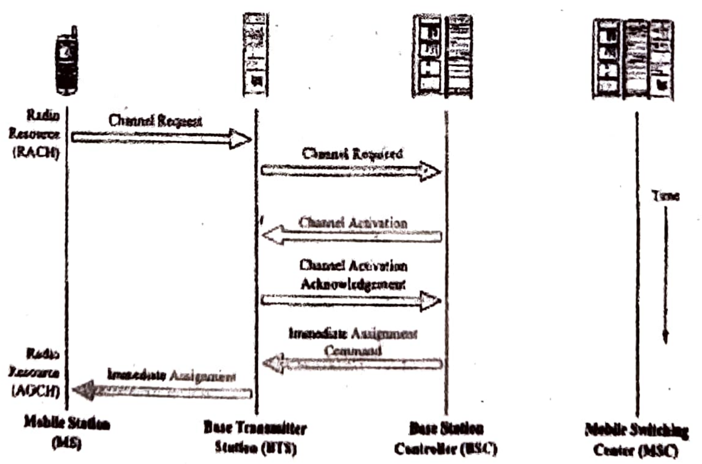
(i) Normal Location Updating (idle mode):

The basic steps involved with location updating look very similar to those used for call setup. The steps are radio resource connection establishment, service request, authentication, cipher mode setting, location updating, and then radio resource connection release.

Location area is identified as a group of cells that is controlled by one or more BSC's but only one MSC. When an MS in the idle mode, it listens to system information sent over the BCCH. This information includes LAI of the serving cell. If the MS detects an LAI different from that stored in the SIM card the MS must perform a normal location update.

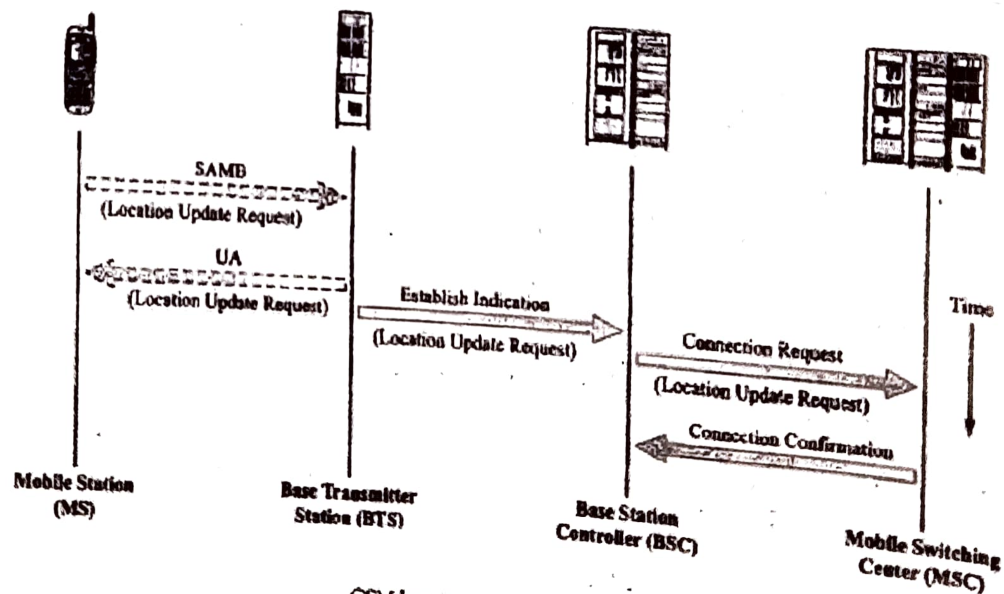


GSM location updating



GSM location updating.

As shown in the figure, the first step of the process is to perform a radio resource connection establishment operation. The MS sends a channel request message over the RACH. The BTS, in turn, sends a channel required message to the BSC. If a free SDCCH is available, the BSC sends a channel activation ~~channel~~ message to the BSC. Once the channel has been activated, the BSC sends an immediate assignment message to the MS and starts a system timer.



GSM location updating service request.

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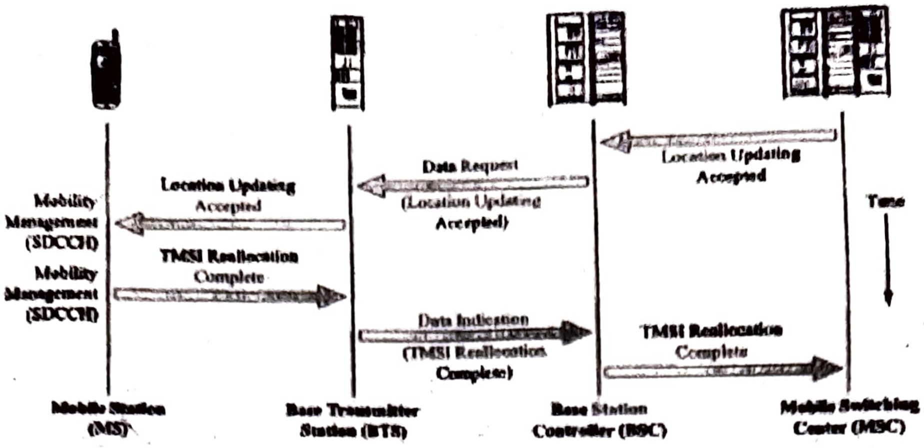
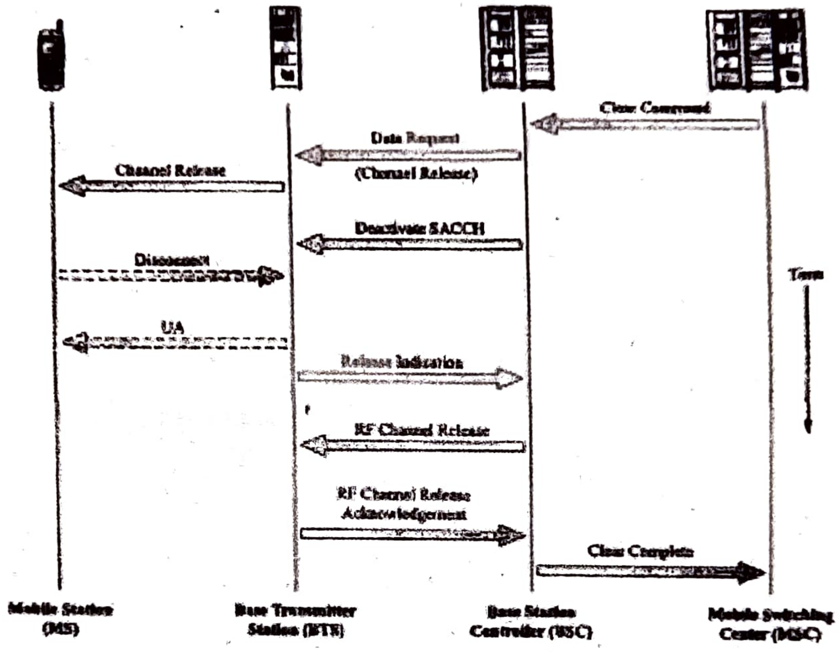
When the MS receives the immediate assignment message, it switches to the ordered channel and sends a service request via an SABM message that contains a location updating request message to the BTS. The message is looped back to the MS via a UA message for reasons mentioned previously and also forwarded to the BSC within an establish indication message. When this message arrives at the BSC the timer is disabled and the message is forwarded to the MSC within a connection request message. The location updating request message will include the old MS location and the new cell location.

The next step in the location update process is shown in the figure. If the MSC/VLR accepts the location updating, the MSC/VLR sends the location updating accepted message transparently thro' the BSC and BTS to the MS over a SDCCH. The message sent by the MSC/VLR may contain a new TMSI number.



GSM location updating accepted.



GSM connection release.

· The last step in this process occurs when the radio resource connection is released. This process is identical to the call release opr^n.

— 5m

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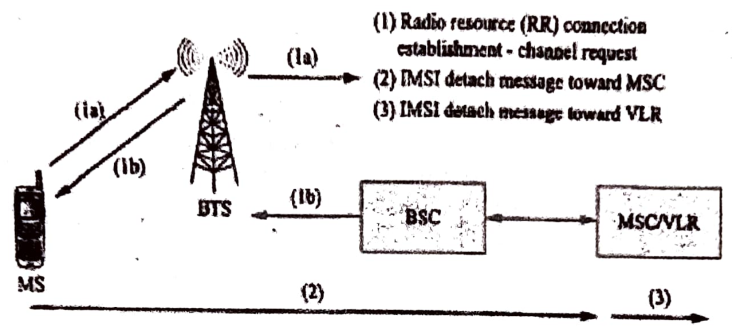
(ii) IMSI detach/attach location updating -

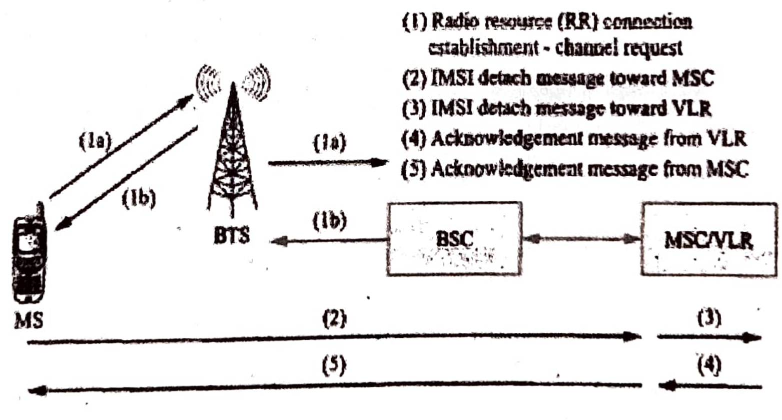
Depending upon the GSM S/m, the MS may use the IMSI detach procedure when powering off. and is as shown in the below figure.



GSM IMSI detach

When the MS power being turned off, the mobile requests an SDCCH. Over the SDCCH, the MS sends a message to the network that it is about to enter the detached state. The MSC denotes the MS status in the VLR. The VLR will reject incoming calls for the MS sending a voice message back to the caller that the subscriber is unavailable. Additionally, the VLR can send a message to the HLR indicating the detached condition of the subscriber.

The IMSI attach procedure is the complementary opr to the IMSI detach. If the MS is powered on the same location area where it performed an IMSI detach, then the operations shown in below figure will take place.



GSM IMSI attach

— 5m

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The MS requests a SDCCH, the s/m receives the IMSI attach message from the MS, The MSC passes the attach message on to the VLR. The VLR returns the MS to active status and resumes normal call handling for the MS. The MSC/VLR returns an IMSI attach acknowledgement message to the MS. If the IMSI detach process caused the HLR to be updated with the MS's detached status, the normal location updating will have to be performed by the mobile.

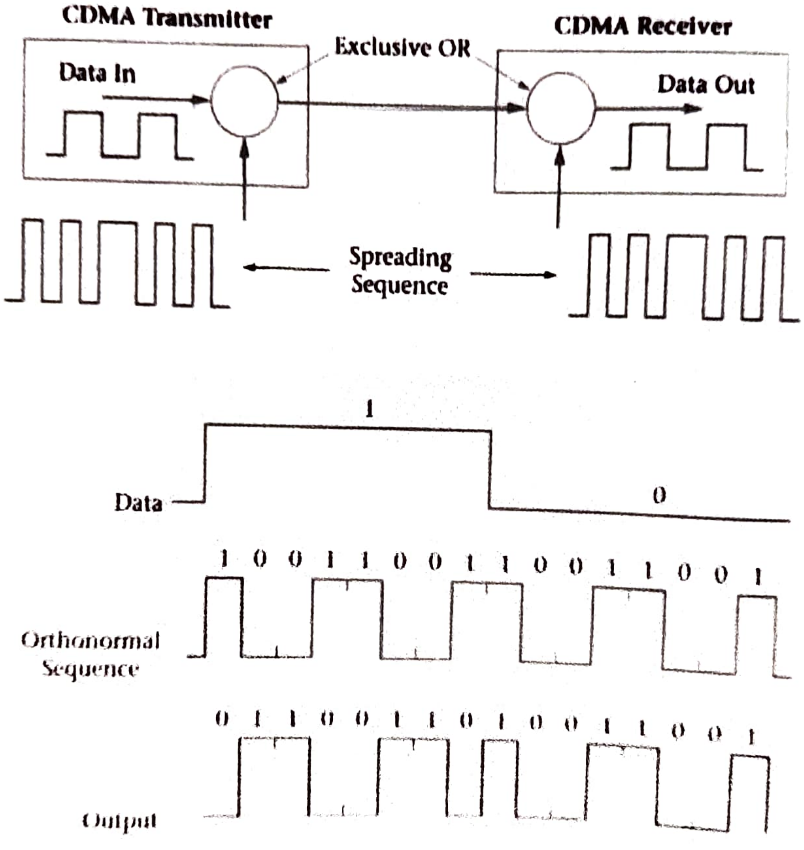
(iii) Periodic Location Updating -

Periodic location updating is used to prevent unnecessary use of n/w resources such as a paging of a detached MS. If the s/m uses periodic registration, the mobile is informed how often it must register. Timers in both the MS & MSC control this opr. When the MS timer expires the MS performs a location updating that does not require all of the steps involving authentication and ciphering mode setting oprns. If the timer in the MSC expires before the MS ~~program~~ performs a location updating, the MSC denotes the MS as attached. If the updating opr is performed on time, the MSC sends an ack. to the MS.

Module - 3

Q.5) a) Explain the CDMA basic spectrum spreading operation with necessary sketches.

Soln: CDMA basic spectrum spreading operation:



5(a)

— 4m

The forward channels in a CDMA S/m are encoded differently than the reverse channels. Additionally, two types of PN codes are used by the IS-95 CDMA S/m, which are known as Short & Long PN codes. The Short PN code is time shifted both to identify the particular CDMA base station and to provide time synchronization signals to the subscriber device so that it can become time synchronized with the radio base station. The Long PN code is used to provide data scram-bling on the forward traffic channels and for providing a means by which reverse link channels may be distinguished.

For an IS-95 CDMA cellular S/m, a single radio base station may consist of up to sixty-four seperate channel elements that all use the same carrier freq. or portion of the radio freq. spectrum. Each of the base station's modulated signals effectively becomes a seperate channel when the digital signal to be transmitted is encoded with a distinct Walsh code.

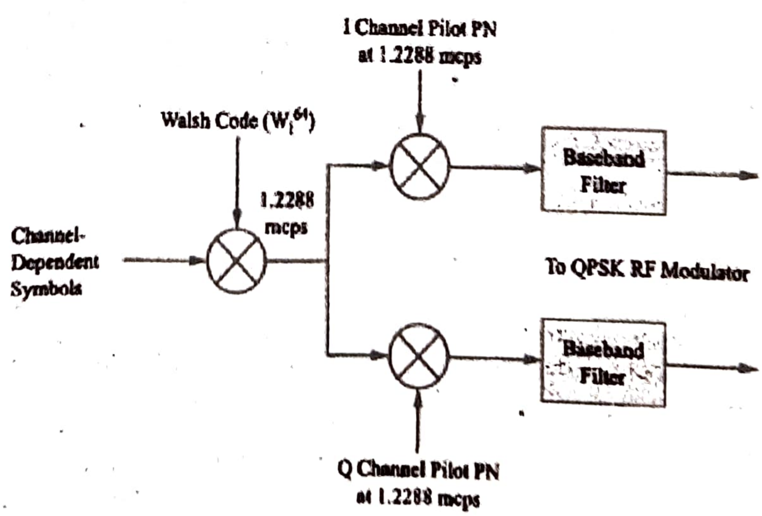
— 6m

Q.5) b) Explain forward logical channels of CDMA

Soln: The IS-95 CDMA forward channels exist between the CDMA base station and the subscriber devices. The first CDMA systems used the same freq. spectrum as the AMPS & NA-TDMA systems. However, the IS·95 signals occupies a bandwidth of approximately 1·25 MHz whereas the AMPS and NA-TDMA system standards each specify a signal bandwidth of 30 kHz.

Therefore an IS-95 signal will occupy approximately the same bandwidth as forty-two AMPS or NA-TDMA channels.

The basic spreading procedure used on the forward CDMA channels is illustrated by figure shown below



Basic spreading procedure used on CDMA forward channels.

5(b)

— 3M

As shown in the figure, the digital signal to be transmitted over a particular forward channel is spread by first exclusive OR-ing it with a particular ~~forward channel is spread by first~~ Walsh code (W_i^{64}). Then the signal is further scrambled in the in-phase (I) and quadrature phase (Q) lines by two different short PN spreading codes. These short PN spreading codes are not orthogonal codes; however they have excellent cross-correlation and auto correlation properties that make them useful for this application. The use of the short PN spreading codes assures that each channel is spread sufficiently over the entire bandwidth of 1.25 MHz channel. The short in-phase and quadrature PN spreading codes are generated by two linear feedback shift-registers of length 15 with a set polynomial value used to configure the feedback paths of each of the LFSR's. The outputs of the in-phase and quadrature phase signals are passed thro' baseband ~~signals~~ filters and then applied to an RF quadrature modulator IC that upconverts the final output signal to the UHF freq. bands. This channel

WCPM

element signal is linearly combined with other forward channel element signals, amplified, and the composite passband signal is transmitted over the air interface.

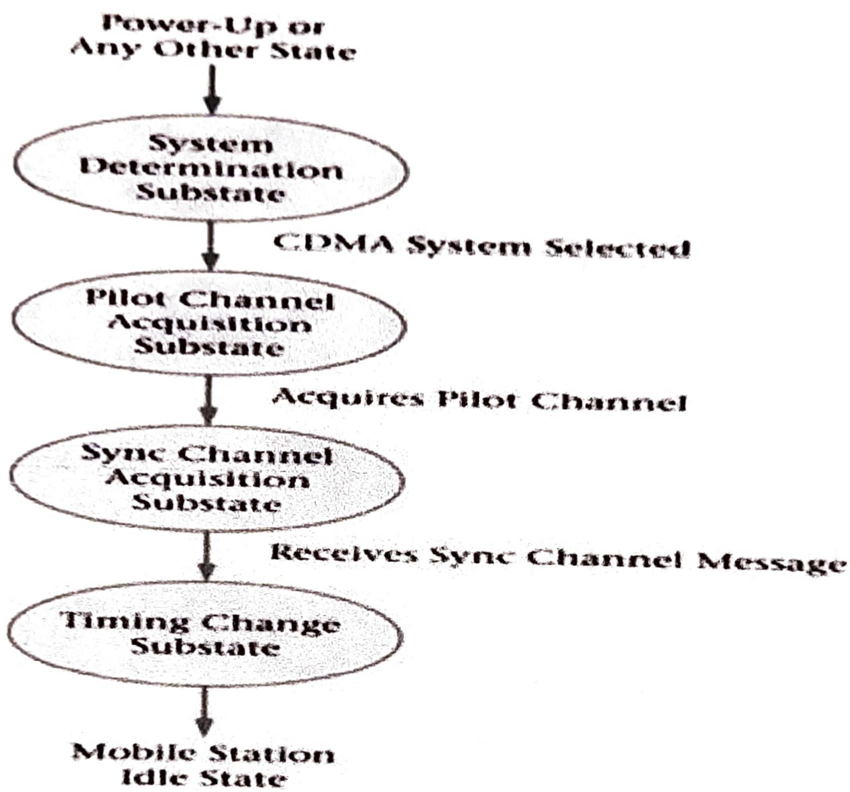
The short PN spreading codes provide the CDMA s/m with the ability to differentiate between different base stations transmitting on the same frequency. The same short PN code sequence is used by all CDMA base stations.; however for each base station the PN sequence is offset from the sequences used by other area base stations. The offset is in 64-bit increments, hence there are 512 possible offsets.

The initial IS-95 CDMA system imp-lementation uses four different types of logical channels in the forward direction. Viz; pilot channel, synchronization channel, paging channels, and traffic/power control channels.

— 7m

Q.6) a) Explain CDMA mobile station initialization and call processing states.

Soln: CDMA mobile station initialization/registration state :



6(a)(i)

— 2m

CDMA system registration procedures are dependent upon the status of the mobile station. The mobile may be either in detached or in an attached condition. When first turned-on, the mobile goes thro' a power-up state as shown in the fig. during which it selects a CDMA s/m and then acquires the pilot and synch channels, which allows it to synchronize its timing to the CDMA s/m.

When attached, the mobile may be in one of three states: the mobile station idle state, the system access state, or the mobile station control on the traffic channel state.

While in the idle state, the mobile monitors the paging channel. In the s/m access state the mobile station communicates with CDMA base station, sending & receiving messages, while performing various operations dictated by the different s/m access substates.

In the mobile station control on the traffic channel state the mobile communicates with the base station using the forward & reverse traffic channels.

Registration is the process by which the CDMA mobile station, thro' messages to the base station, informs the cellular s/m of its identification, location, status, slot cycle, and other pertinent information necessary for proper and efficient s/m opn. For slotted mode opn the mobile provides the base station with the

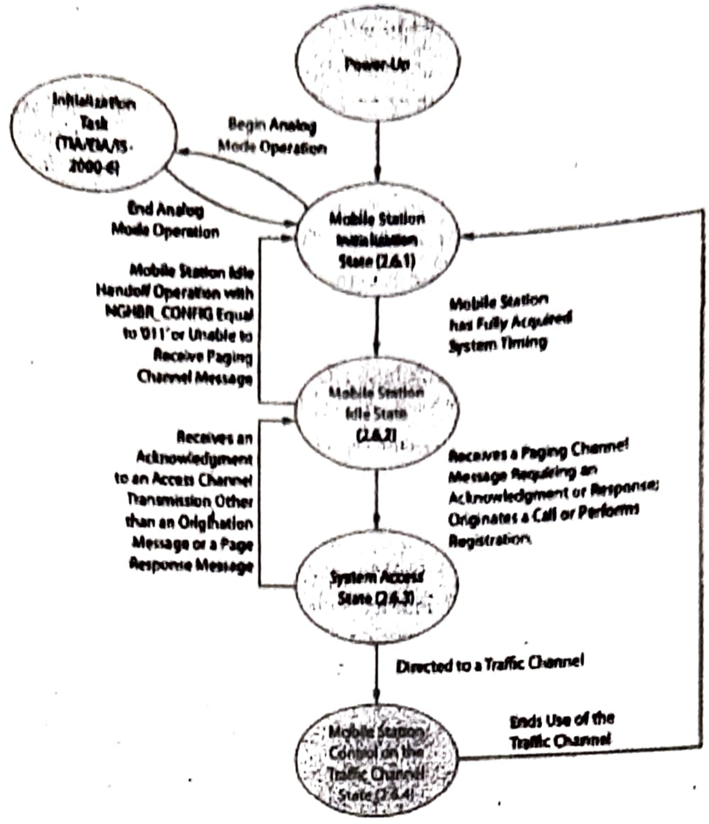
SLOT_CYCLE_INDEX value so that the base station may determine which slots the mobile is monitoring. Classmark values & protocol revision numbers allow the base station to know the capabilities of the mobile station.

CDMA mobile station call processing state:

CDMA s/m call set up requires various system tasks including mobile initialization, idle, system access, traffic channel communication, and call termination.

Initialization State:

When the mobile is first turned on it enters the mobile station initialization state. During this process the mobile searches for a pilot channel, by aligning its short PN code with a received short PN code. Once a valid pilot channel is acquired the mobile synchronizes with it. The mobile has 15 secs to locate and acquire a pilot signal. If the mobile can not perform this operation, it may decide to search for an AMPS control channel and enter an analog operational mode.



CDMA mobile station call processing states

6(a)(ii)

— 2m

When the mobile locates a CDMA pilot signal, it switches to Walsh code 32, W_{32}^{64}, and looks for the start of the synch channel messages. The synch channel message contains information about system time and the PN codes needed to synchronize its PN codes. After decoding the synch channel, the mobile aligns its timing to that of the serving base station.

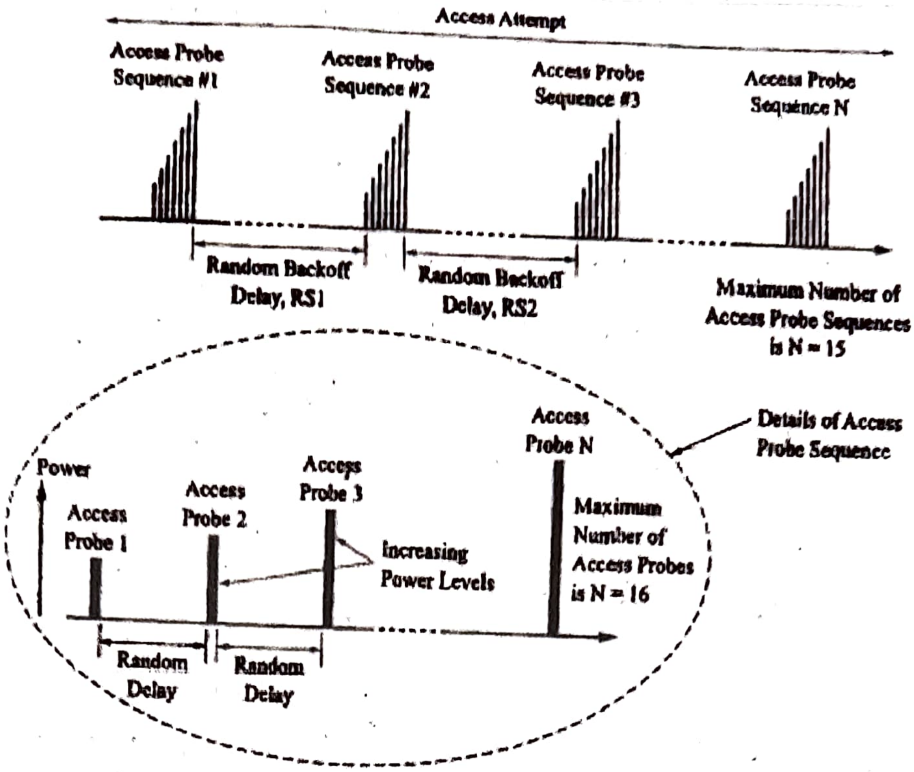
Idle State:

Once the mobile has achieved initialization it moves in to the idle state. When in the idle state, the mobile is waiting to receive calls or data messages or is ready to originate a call or some form of data transfer. To support subscriber connectivity and mobility the mobile is constantly monitoring radio channel quality, decoding paging channel messages to obtain s/m parameters, access parameters, and a list of neighboring cell sites to monitor. After acquiring sufficient s/m information, the mobile may be allowed to enter a sleep mode to conserve mobile battery power. This will be facilitated thro' the use of slotted mode opr by the mobile when monitoring the paging channel. Also to ensure optimal s/m opr, the mobile will monitor several other neighboring cells to see if a stronger pilot channel is available for a possible idle state handoff.

— 2m

Access State :

The CDMA mobile will enter the acess state when it receives a mobile directed message requiring an acknowledgement, originates a call, or is required to perform registration. When in the access state, the mobile will randomly attempt to access the s/m. Access to the S/m is obtained when the mobile station receives a response from the base station on the paging channel. Since multiple mobiles may be associated with a particular paging channel, they may simultaneously attempt to use the same access channel. The resulting signaling collisions at the base station will most likely result in few if any of the requesting mobiles being granted access to the s/m. Therefore to alleviate this problem, so form of collision avoidance scheme is necessary to increase the probability of a successful s/m access by a mobile. For the CDMA S/m, this access protocol is implemented thro' the use of access class groups with assigned priorities, a gradual increase in access request power level, random time ~~analysis~~ delays for access requests, and a max. no. of automatic access attempts.



CDMA access channel probing (Courtesy of 3GPP2).

6(a)(iii)

— 2m

The above figure shows what is known as access channel probing. The transmission of a series of access probe sequence is known as an access attempt.

Each access probe consists of an access channel preamble and an access channel message capsule of three to ten frames. The mobile station will randomly determine the start of each access probe transmission within a sequence and the backoff delay for the start of the next access probe sequence and the start of any additional access attempts if needed.

Traffic State:

The mobile enters a traffic state when it begins to transfer user information between the mobile & the base station. This information can be voice or data that originates from the PSTN or PDN or another mobile in the same or another n/w. While in the traffic state the mobile transmits voice and signaling information on the RTC and receives voice & signaling information on the FTC. Signaling over the traffic channel can be performed by either a blank-and-burst or dim-and-burst process. Various mode and flag bits are used to alert the receiver to the signaling method and the structure of the mixed voice & signaling frames.

Depending upon the message, the number of frames needed to send the signaling information will vary. Although the dim-and-burst method will not affect speech quality, it requires more time to transmit the signaling.

— 2m

Call termination :

Call termination occurs at the end of a call and can be initiated by either the mobile or the base station. If the mobile initiate the call termination, it sends a call termination message to the base station, stops transmitting on the RTC and returns to the mobile station initialization state. If the n/w initiates the call termination the base station sends a call termination message to the mobile. The mobile stops transmitting on the RTC and returns to the initialization state.

— 2m

Q.6) b) Explain the types of handoff used in CDMA.

Soln. : The different types of handoff used in CDMA are:
i) Idle / Access handoff
ii) Soft handoff : softer, soft & soft softer
iii) Hard handoff

i) Idle / Access handoff :

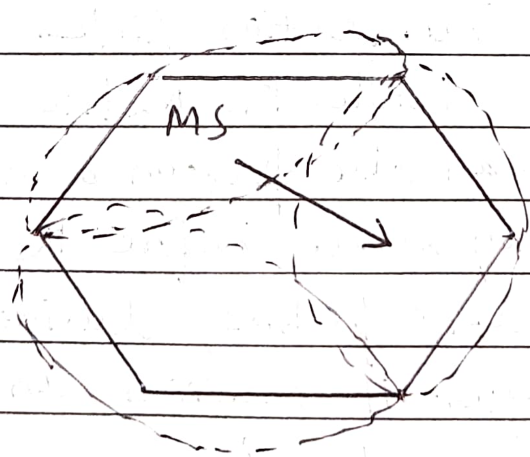
If the mobile is in the idle state and moves from the coverage area of one sector / cell in to another sector / cell, an idle handoff can occur. When the received signal strength of a different PC is determined to be twice as strong (> 3dB) than the current PC, the mobile will start listening to the paging channel associated with the stronger PC. This type of handoff is considered a form of hard handoff since there is a brief interruption of the communication link.

While the mobile is in the access state, it can also perform a handoff. The access handoff may occur before the mobile begins sending access probes, during access probes, and even after it receives an access probe acknowledgement. An access entry handoff allows the mobile to perform a hard idle handoff from one paging channel to another in the best signal-strength sector/cell just after the mobile enters the access state. After the mobile has started to send access probes, it can perform an access probe handoff if it detects a stronger ~~handoff~~ pilot signal that may provide it a better chance of receiving service. Even after the mobile has received an access probe acknowledgement, a handoff to a stronger pilot may be possible and necessary to prevent an access failure due to the rapid motion of the mobile away from the current pilot and its base station.

— 2m

ji) Soft handoff :

A distinct advantge of the CDMA system is that it supports soft handoffs.



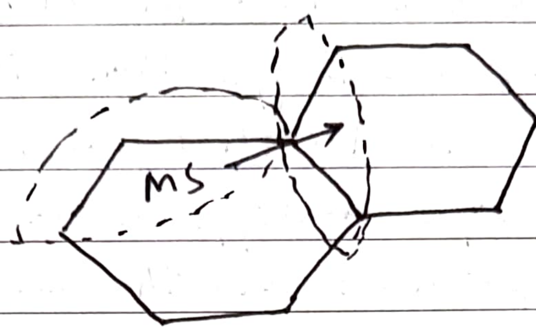
A soft handoff occurs when the mobile is able to communicate simultaneously with several new cells or new sector of the current cell over a FTC while still maintaining communications over the FTC of the current cell or sector. The mobile station can perform only a soft handoffs while in the traffic state to a new cell or sector that has the same freq. carrier. The use of soft handoffs is associated with the near-far problem and the associated power control mechanism used in CDMA s/m's. If a mobile moves away from the base station and continually increases its output power to compensate for the signal attenuation encountered at the greater distance it will cause a great deal of interference to mobiles in neighboring cells and raise the level of background noise in its own cell. To alleviate this problem and to make sure that the mobile is connected to the base station with the greatest RSS, a strategy employing soft handoffs has been designed in to CDMA wireless mobile systems.

There are three types of soft handoffs defined in IS-95 CDMA standard; viz

(a) Softer handoff :

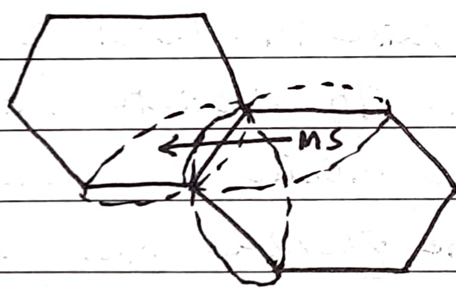
Here the handoff is between two sectors of the same cell.

(b) Soft handoff :



A soft handoff occurs between two different cells.

(c) Soft-softer handoff :



A soft-softer handoff can occur when the motion of the mobile gives it a handoff choice between two sectors of the same cell and a sector from an adjacent cell.

In all CDMA handoff procedures a number of base stations and their pilot channels are involved. The procedures for soft & softer handoffs control the manner in which a call is maintained as a mobile crosses boundaries b/w cells.

WCPM

— 2m

iii) **Hard handoff :**

In the traffic state, a hard handoff will occur for the case of an intercarrier handoff. Intercarrier handoff causes the radio link to be abruptly interrupted for a short period while the base & mobile station switch from one carrier freq. to another.

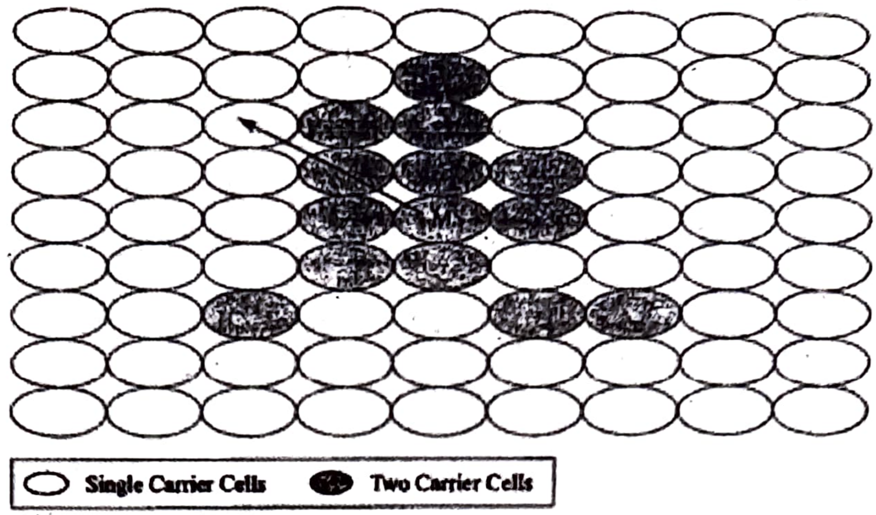
There are two basic types of intercarrier handoffs :

a hand-down : is a hard handover between two different carriers within the same cell

a hand-over : is a hard handoff between two different carriers in two different cells.

The circumstances necessary to cause a hard handoff can be due to the particular coverage area implementation of a service provider or the less frequent case of the existence of two service providers in adjacent areas.

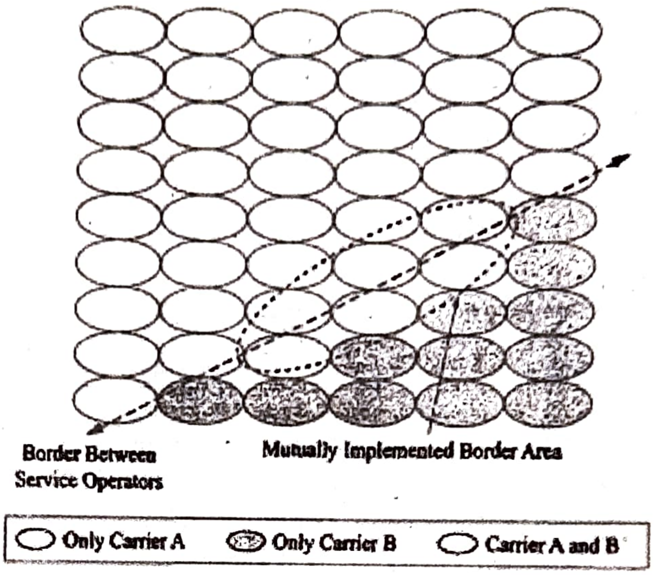
In a pocketed implementation case, a service providee might use a second CDMA carrier in individual or non-contiguous cells to provide additional capacity during s/m growth or for local high-traffic hot spots. Figure below shows a possible scenario of this situation.



Hard CDMA handoffs due to intercarrier handoff.
6(b)-1

A mobile that is using the second carrier and exiting the pocket of second-carrier cells must be handed off to the common carrier to continue the call. The best way to perform this handoff is to first hand down the call to the common carrier before the mobile leaves the pocketed area. Then a soft handoff can be performed as the mobile moves across the border from the pocketed area into the surrounding service area. Typically this process of hand-down occurs, if possible, at the border cells or sectors of the pocketed area.

It is possible to have disjoint systems where distinct CDMA carriers exist in different regions due to issues such as the availability of appropriate spectrum. The below figure depicts this situation.



Hard CDMA handoffs due to disjointed regions.

Q6)b-2

The most common methods used to provide handoff between the two regions is to implement a border area that supports the use of both carrier frequencies and is configured to provide hand-down to simply execute a hard handoff from one carrier to the other as the mobile crosses the border b/w the two regions.

— 4m

Module-4

Q.7.) a) Explain OFDM advantages and disadvantages.

Soln: Advantages of OFDM are:

(1) Elegant solution to multipath interference:

The critical challenge to high bit-rate transmissions in a wireless channel is intersymbol interference caused by multipath. In a multipath environment, when the time delay between the various signal paths is a significant fraction of the transmitted signal's symbol period, a transmitted may arrive at the receiver during the next symbol and cause ISI. At high data rates, the symbol time is shorter; hence it only takes a small delay to cause ISI, making it a bigger challenge for broadband wireless. OFDM is a multicarrier modulation technique that overcomes this challenge in an elegant manner. The basic idea behind multicarrier modulation is to divide a given high-bit-rate data stream into several parallel lower bit-rate streams and modulate each stream into many parallel streams increases the symbol duration of each stream such that the multipath delay spread is only a small fraction of the symbol duration. OFDM is a spectrally efficient version of the multicarrier modulation, where the subscribers are selected such that they are all orthogonal to one another over the symbol duration, thereby avoiding the need to have non-overlapping subcarrier channels to eliminate inter-carrier interference. In OFDM, any residual intersymbol interference can also be eliminated by using guard intervals between OFDM symbols that are larger than the expected multipath delay. By making the guard interval, however, implies power wastage and a decrease in bandwidth efficiency.

(2) Reduced computational complexity:

OFDM can be easily implemented using FFT/IFFT, and the computational requirements grow only slightly faster than linearly with the data rate or bandwidth. The computational complexity of OFDM can be shown to be $O(B \log BT_m)$ where B is the bandwidth and T_m is the delay spread. This complexity is much lower than that of a time-domain equalizer-based system - the traditional means for combating multipath interference - which has a complexity of $O(B^2 T_m)$. Reduced complexity is particularly attractive in the downlink as it simplifies receiver processing and thus reduces mobile device cost and power consumption.

(3) Graceful degradation of performance under excess delay :

The performance of an OFDM s/m degrades gracefullly as the delay spread exceeds the value designed for. Greater coding and low constellation sizes can be used to provide fallback rates that are significantly more robust against delay spread. In other words, OFDM is well suited for adaptive modulation & coding, which allows the system to make the best of available channel conditions. This contrasts with the abrupt degradation owing to error propagation that single-carrier systems experience as the delay spread exceeds the value for which the equalizer is designed.

(4) Exploitation of frequency diversity :

OFDM facilitates coding and interleaving across subcarriers in the freq. domain, which can provide robustness against burst errors caused by portions of the transmitted spectrum undergoing deep fades. OFDM also allow for the channel bandwidth to be scalable without impacting the hardware design of the BS & MS. This allows LTE to be deployed in a variety of spectrum allocations and different channel BW's.

(5) **Enables efficient multi-access scheme:**
OFDM can be used as a multi-access scheme by partitioning different subcarriers among multiple users. This scheme is referred to as OFDMA and is exploited in LTE. OFDMA offers the ability to provide fine granularity in channel allocation, which can be exploited to achieve significant capacity improvements, particularly in slow-time varying channels.

(6) **Robust against narrowband interference:**
OFDM is relatively robust against narrowband interference, since such interference affects only a fraction of the subcarriers.

(7) **Suitable for coherent demodulation:**
It is relatively easy to do pilot-based channel estimation in OFDM s/m's, which renders them suitable for coherent demodulation schemes that are more power efficient

(8) **Facilitates use of MIMO:**
MIMO refers to a collection of signal processing techniques that use multiple antennas at both tx & rx to improve s/m performance.

OFDM, however, converts a freq. selective broad band channel in to several narrowband flat fading channels where the MIMO models & techniques work well. The ability to effectively use MIMO techniques to improve s/m capacity gives OFDM a significant advantage over other techniques and is one of the key reasons for its choice.

(9) Efficient support of broadcast services:

By synchronizing base stations to timing errors well within the OFDM guard interval, it is possible to operate an OFDM n/w as a SFN. This allows broadcast signals from different cells to combine over the air to significantly enhance the received signal power, thereby enabling higher data rate broadcast transmissions for a given transmit power. LTE design leverages this OFDM capability to improve efficient broadcast services.

— 9m

Disadvantages of OFDM are:

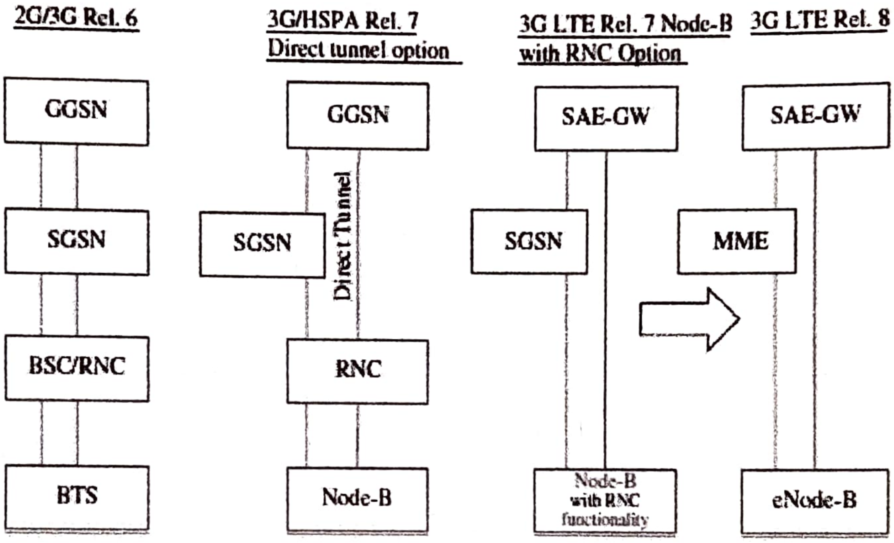
Problem associated with OFDM signals having high peak-to-average ratio (PAR) which causes non-linearities and clipping distortion when passed thro' an RF amplifier. Mitigating this problem requires the use of expensive and inefficient power amplifiers with high requirements on linearity, which increases the cost of the tx and is wasteful of power.

While the increased amplifier costs and power inefficiency of OFDM is tolerated in the downlink as part of the design, for the uplink LTE selected a variation of OFDM that has a lower-peak-to-average ratio.

— lm

Q.7 b) Explain with neat block diagram flat LTE SAE architecture.

Soln : Flat LTE SAE architecture :



BTS: Base Station Transceiver System
BSC: Base Station Controller
Node-B: 3G Base Station
SAE-GW: SAE Gateway
MME: Mobility Management Entity
RNC: Radio Network Controller
SGSN: Serving GPRS Service Node
GGSN: Gateway GPRS Service Node
eNode-B: Enhanced Node-B

3GPP evolution toward a flat LTE SAE architecture.

Q7)b)

— 4m

Besides the air interface, the other radical aspect of LTE is the flat radio and core network architecture. "Flat" here implies fewer nodes and a less hierarchical structure for the network.

The lower cost and lower latency requirements drove the design toward a flat architecture since fewer nodes obviously implies a lower infrastructure cost. It also means fewer interfaces and protocol-related processing, and reduced inter-operability testing, which lowers the development and deployment cost. Fewer nodes also allow better optimization of radio interface, merging of some control plane protocols, and short session start-up time.

A flat LTE SAE architecture has four network elements in the data path: the BS-B, RNC, SGSN, and GGSN. LTE on the other hand, will have only two network elements in the data path: the enhanced Node-B or eNode-B, and a system architecture evolution gateway (SAE-GW). Unlike all previous cellular systems, LTE merges the path includes a functional entity called the MME, which provides control plane functions related to subscriber, mobility, and session management. The MME and SAE-GW could be ~~collected~~ collocated in a single entity called the access gateway (a-GW).

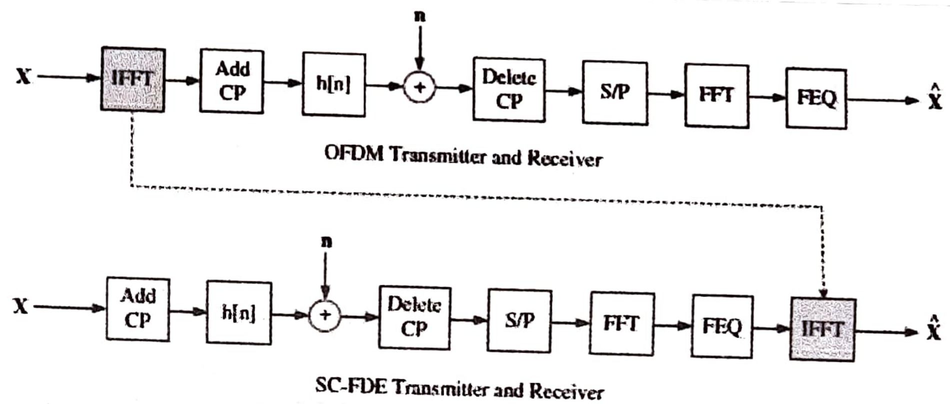
A key aspect of the LTE flat architecture is that all services, including voice,

are supported on the IP packet n/w using IP proto-
-cols. Unlike previous systems, which had a
seperate circuit-switched subnetwork for supporting
Voice with their own MSC and transport n/w's,
LTE envisions only a single evolved packet-switc-
hed core, the EPC, over which all services are
supported, which could provide huge operational
and infrastructure cost savings. It should be
noted, however, that although LTE has been
designed for IP services with a flat architecture,
due to backwards compatability reasons certain
legacy, non-IP aspects of the 3GPP architecture
such as the GPRS tunneling protocol and PDCP
still exists within the LTE n/w architecture.

— 6m

Q.8)a) Explain the differences between OFDM and SCFDE with neat block diagrams.

Soln: The block diagrams of both OFDM & SC-FDE are compared in below figure shown.



Comparison between an OFDM system and an SC-FDE system.

Q8)a)

— 4m

Frequency domain equalization is used in both OFDM & SC-FDE systems primarily in order to reduce the complexity inherent to time-domain equalization. The only apparent difference between the two systems is that the IFFT is moved to the end of the receive chain rather than operating at the tx to create a multicarrier waveform as in OFDM.

An SC-FDE s/m still utilizes a cyclic prefix at least as long as the channel delay spread, but now the transmitted signal is simply a sequence of QAM symbols, which have low PAR, on the order of 4-5 dB depending on the constellation size.

The action, in an SC-FDE s/m, is at the rx. As in an OFDM s/m, an FFT is applied, but in an SC-FDE s/m this operation moves the received signal appears to be circularly convolved.

Performance differences:

The primary difference in terms of performance between SC-FDE and OFDM comes from the way they treat noise. In both OFDM and SC-FDE receivers, the FEQ typically inverts each freq. bin, that is, the FEQ consists of L complex taps each of value $1/H_l$. In SC-FDE however, the FEQ does not operate on data symbols themselves but rather on the freq. domain dual of the data symbols. Therefore, just as in OFDM's FEQ, low SNR parts of the spectrum have their increased by a factor of $[1/H_l]^2$ while the noise power is increased by a factor of $[1/H_l]^2$.

Other considerations like desig is also more important in determining which is the appropriate method to use for a given applicat

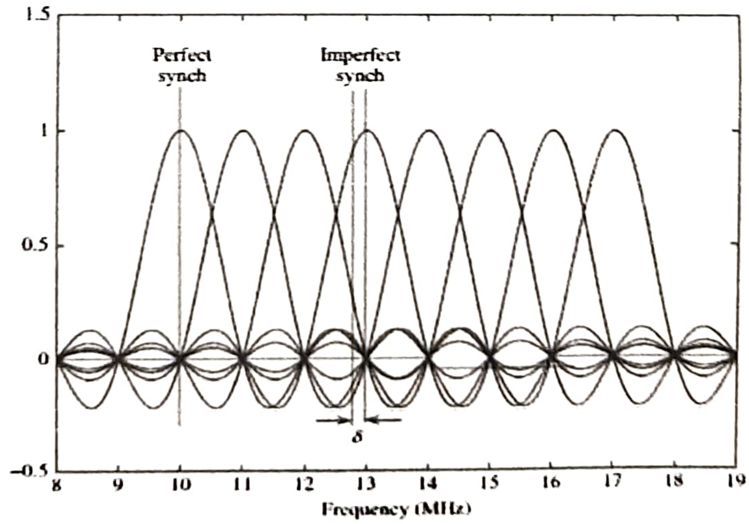
An obvious difference is that SC-FDE has a lower complexity tx but a higher complexity rx compared to OFDM. Since the rx was already considerably more complex than the tx in a typical OFDM system due to channel estimation, synchronization, and the error correction decoder, this further skews the asymmetry.

← 6 M

Q.8) b) Write a note on : (i) Frequency Synchronization
(ii) Peak to Average Ratio (PAR)

Soln: (i) Frequency Synchronization :

OFDM achives high degree of BW efficiency compared to other wideband systems. The subcarrier packing is extremely tight compared to conventional modulation techniques, which require a guard band on the order of 50% or more, in addition to special tx architectures such as the Weaver architecture or single sideband modulation that suppress the redundant negative-freq. portion of the passband signal. The price to be paid for this bandwidth efficiency is that the multicarrier signal shown in below figure is very sensitive to freq. offsets due to the fact that subcarriers overlap, rather than having each subcarrier truly spectrally isolated.



Q8)b)i)

Since the zero crossings of the freq. domain sinc pulses all line up as shown in figure, as long as the freq. offset $\delta=0$, there is no interference between the subcarriers. One intuitive interpretation for this is that since the FFT is essentially a very freq. sampling opn, if the freq. offset is negligible the receiver simply samples 'y' at the peak points of the sinc fns, where the ICI is zero from all the neighboring sub carriers.

In practice, of course, the freq. offset is not always zero. The major causes for this are mismatched oscillators at the tx & rx and Doppler freq. shifts due to mobility. Since precise crystal oscillators are expensive, tolerating some degree of freq. offset is essential in a consumer OFDM s/m like LTE.

If ICI to be analyzed in order to better understand its effect on OFDM performance, the matched filter rx corresponding to subcarrier l can be simply expressed for the case of rectangular windows as

$$x_l(t) = X_l e^{j\frac{2\pi l t}{LT_s}}$$

where $1/LT_s = \Delta f$ and again LT_s is the duration of the data portion of the OFDM symbol, that is

$$T = T_g + LT_s$$

An interfering subcarrier 'm' can be written as

$$x_{l+m}(t) = X_m e^{\frac{j2\pi(l+m)t}{LT_s}}$$

If the signal is demodulated with a fractional offset of δ, $|\delta| \leq 1/2$

$$\hat{x}_{l+m}(t) = X_m e^{\frac{j(2\pi(l+m+\delta)t)}{LT_s}}$$

The ICI between subcarriers l and $l+m$ using a matched filter is simply the inner product between them:

$$I_m = \int_0^{LT_s} x_l(t)\,\hat{x}_{l+m}(t)\,dt = LT_s X_m \frac{\left(1-e^{-j2\pi(\delta+m)}\right)}{j2\pi(m+\delta)}$$

It can be seen that in the above expression, $\delta=0 \Rightarrow I_m=0$, and $m=0 \Rightarrow I_m=0$, as expected.

The total avg. ICI energy per symbol on subcarrier l is then $ICI_l = E\left[\sum_{m\neq l} |I_m|^2\right] \approx C_0(LT_s\delta)^2 \mathcal{E}_x$

where C_0 is a constant that depends on various assumptions and $\mathcal{E}_x$ is the avg. symbol energy.

The SNR loss induced by freq. offset is given by

$$\Delta SNR = \frac{\mathcal{E}_x/N_0}{\mathcal{E}_x/\left(N_0 + C_0(LT_s\delta)^2\mathcal{E}_x\right)} = 1 + C_0(LT_s\delta)^2 SNR$$

— 5m

(ii) Peak to average Ratio (PAR) :

OFDM signals have a higher PAR – often called a peak-to-average power ratio (PAPR) – than do single-carrier signals. The reason for this is that in the time domain, a multicarrier signal is the sum of many narrowband signals. At some times, this sum is large; at other times it is small, which means that the peak value of the signal is substantially larger than the avg. value. This high PAR is one of the most imp. implementation challenges that face OFDM because it reduces the efficiency and hence increases the cost of RF power amplifier. Alternatively the same power amplifier can be used but the input power to the PA must be reduced; this is known as input backoff (IBO) and results in a lower avg. SNR at the receiver, and hence a reduced transmit range.

The PAR problem :

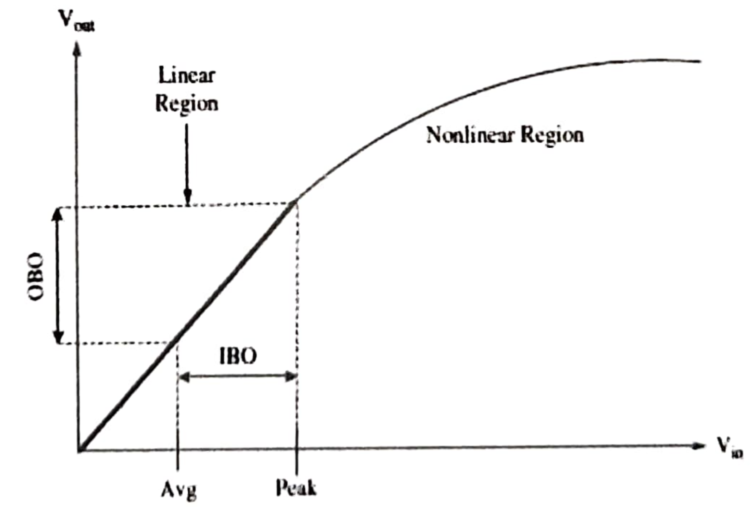
When a high peak signal is transmitted thro' a non-linear device such as a high power amplifier or DAC, it generates out-of-band energy and in-band distortion. These degradations may affect the s/m performance severely. The non-linear behaviour of HPA can be characterized by AM/AM and AM/PM responses. The below fig. shows a typical AM/AM response for an HPA, with the associated i/p & o/p backoff regions: IBO & OBO, resp^ly.

To avoid the undesirable nonlinear affects just mentioned, a waveform with high-peak power must be transmitted in the linear region of the HPA by decreasing the avg. power of i/p signal. This is called input backoff (IBO) and results in a proportional output backoff (OBO).

The input backoff is defined as

$$IBO = 10 \log_{10} \frac{P_{insat}}{\bar{P}_{in}}$$

where P_{insat} is the saturation power & $\bar{P}_{in}$ is the avg. input power. The amount of backoff is usually greater than or equal to the PAR of the signal.



Quantifying the PAR :

Since multicarrier s/m's transmit data over a no of parallel freq. channels, the resulting waveform is the superposition of 'L' narrowband signals. In particular, each of the 'L' o/p samples from an 'L' point IFFT opr^n involves the sum of 'L' complex nos. Due to the central limit theorem, the resulting o/p values can be accurately modeled as complex Gaussian random variables with zero mean & variance

Clipping and other PAR reduction techniques :

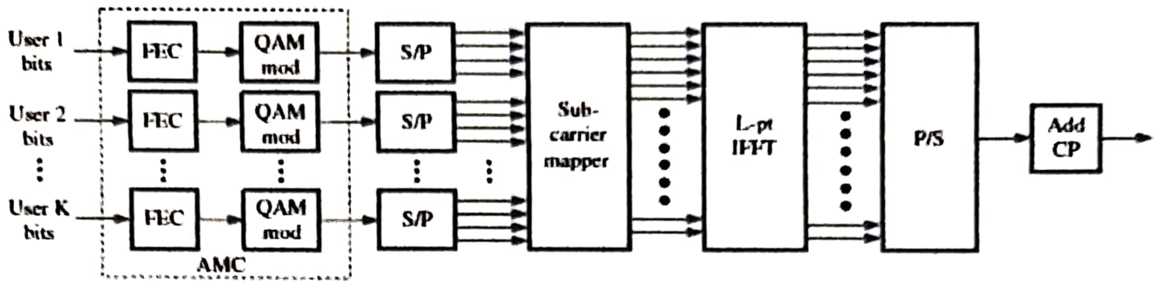
In order to avoid operating the PA in the non linear region, the i/p power can be reduced up to an amount about equal to the PAR. This, of course, is very inefficient and will reduce the range and/or SINR of the s/m by the same amount. However two imp. facts related to this IBO amount can be observed. First, since the highest PAR values are uncommon, it might be simply possible to "clip" off the highest peaks, at the cost of the some hopefully minimal distortion of the signal. Second and conversly, it can be seen that even for a conservative choice of IBO, there is still a distinct possibility that a given OFDM symbol will have a PAR that exceeds the IBO and causes clipping.

— 5m

Module-5

Q.9.) a) Explain with neat block diagram OFDMA downlink transmitter

Soln: OFDMA downlink transmitter :



OFDMA downlink transmitter.

Q9)a

The basic flow is very similar to an OFDM s/m except for now 'k' users share the 'L' sub carriers with each user being allocated M_k subcarriers. The method or rules for how users are mapped to subcarriers is not specified by the LTE standard but some general principles on how this should be performed.

— 10m

Q.9) b) Mention SC-FDMA advantages and disadvantages.

Soln. **Advantages of SC-FDMA :**

The advantages of SC-FDMA are like, the rationale for SC-FDMA is twofold. First the key advantage of OFDMA is preserved : Only part of the freq. Spectrum is used by any one user. at a time. This allows the band used to be chosen adaptively for higher throughput, and perhaps more crucially allows for much lower total transmit power than if the entire spectrum had to be used as in SC-FDE or OFDM-TDMA.

The second rationale is that the PAR of SC-FDMA is significantly lower than OFDMA. B'cause the transmitted SC-FDMA signal for each user is simply an over sampled single-carrier signal, the PAR is about the same as for the corresponding single carrier signal.

— 3m

Disadvantages of SC-FDMA :

Particularly. SC-FDMA can experience more spectral leakage than OFDMA, and achieve frequency diversity differently leading to slight difference in performance. SC-FDMA has a complexity disadvantage v/s OFDMA in both tx & rx.

— 2m

Q.9) c) Mention OFDMA advantages & disadvantages.

Soln: Advantages:

The advantages of OFDMA start with the advantages of single-user OFDM in terms of robust multipath suppression, relatively low complexity, and the creation of frequency diversity.

In addion, OFDMA is a flexible multiple access technique that can accommodate many users with widely varying applns, data rates, and QoS requirements. Because the multiple access is performed in digital domain, dynamic, flexible, and efficient bandwidth allocation is possible. This allows sophisticated time & freq. domain scheduling algorithms to be integrated in order to best serve the user population. — 3m

Disadvantages:

- The permutation and depermutation rules of subcarriers for allocation and deallocation to subchannels are complex. This makes tx and rx algorithms complex for data processing / extraction unlike OFDM
- OFDMA has higher PAPR. Hence large amplitude variations ~~used~~ lead to increase of in-band noise. Moreover it increases BER when OFDMA signal

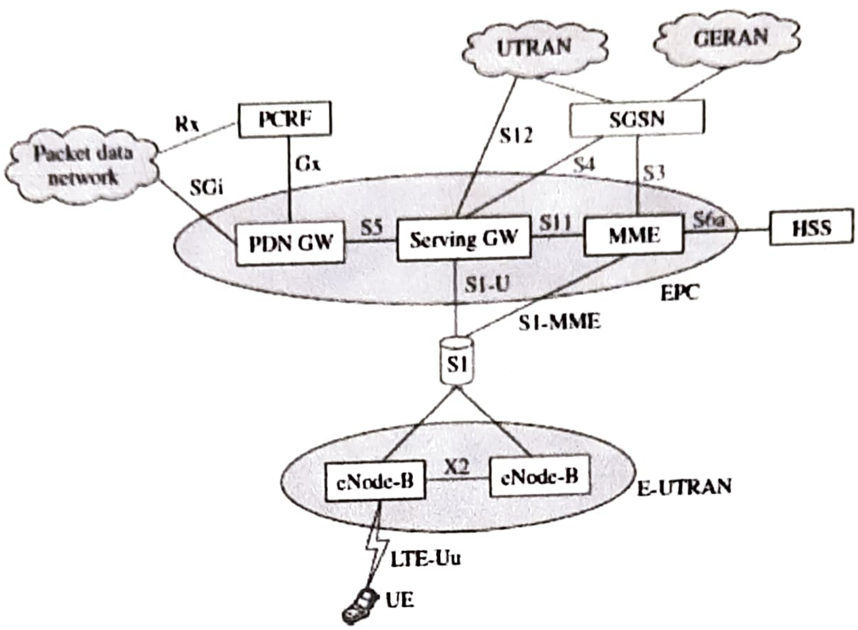
passes thro' the RF amplifier having non-lineа-
-rities

- OFDMA requires very tight time/freq./channel equalizations between users.
- Co-channel interference is more complex compared to CDMA technique.

— 2m

Q.10) a) Explain LTE end-to-end network architecture with neat block diagram

Soln: **LTE end-to-end network architecture:**



LTE end-to-end network architecture.

Q10)a

— 4m

The end-to-end n/w architecture of LTE is composed of the radio access network (E-UTRAN) and the core network (EPC).

The main components of E-UTRAN and EPC are

- UE : The mobile terminal

- eNode-B : The eNode-B terminates the air interface protocol and is the first point of contact for the UE. It's the only logical node in the E-UTRAN, so it includes some functions previously defined in the RNC of the UTRAN, such as radio bearer management, uplink & downlink dynamic radio resource management and data packet scheduling, and mobility management.

- Mobility Management Entity (MME) : MME is similar in fn to the control plane of legacy serving GPRS support node (SGSN). It manages mobility aspects in 3GPP access such as gateway selection and tracking area list management.

- Serving Gateway (Serving GW) : The Serving GW terminates the interface toward U-TRAN, ~~the~~ and routes data packets between U-TRAN & EPC. In addition it is the local mobility anchor point for inter-eNode-B handovers and also provides an anchor for inter-3GPP mobility. Other responsibilities include lawful intercept, charging, & some policy enforcement.

WCPM

- **Packet Data Network Gateway (PDN GW):**

The PDN GW terminates the SGi interface toward the PDN. It routes data packet between the EPC & external PDN, and is the key node for policy enforcement and charging data allocation. It also provides the anchor point for mobility with non-3GPP accesses. The external PDN can be any kind of IP n/w as well as the IMS domain. The PDN GW and the serving GW may be implemented in one physical node or seperated physical nodes.

- **S1 interface:** The S1 interface is the interface that separates the E-UTRAN and the CPC. It is split in to two parts: the S1-U, which carries traffic data between the eNode-B and the serving GW, and the S1-MME, which is signaling-only interface between the eNode-B and the MME

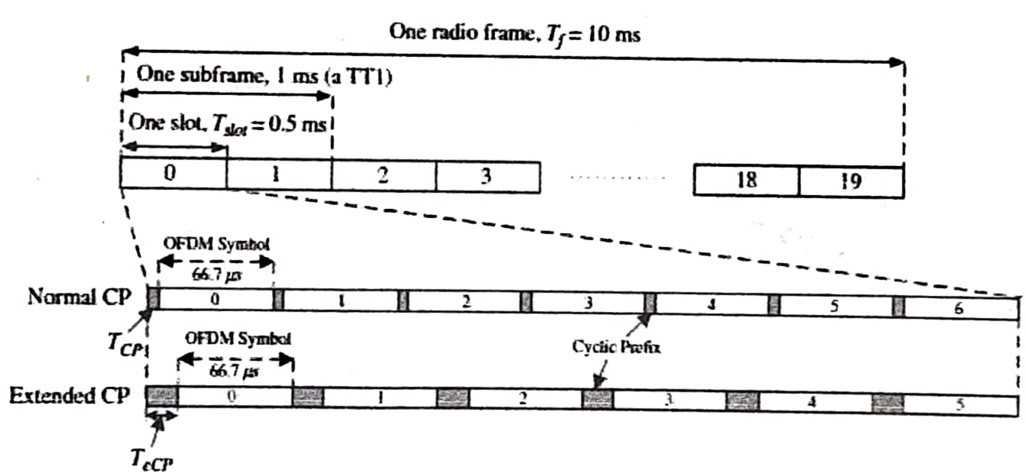
- **X2 interface:** It's the interface between eNode-B's consisting of two parts: the X2-C is the control plane interface between eNode-B's, while the X2-U is the user plane interface between eNode-B's. It's assumed that there is always exists an X2-interface between eNode-B's that need to communicate with each other, for ex- for support of handover. WCPM

6m

Q.10) b) Explain LTE frame structures

Soln: LTE supports two kinds of frame structures:
i) Frame structure type 1 for the FDD mode
ii) Frame Structure type 2 for the TDD mode

i) **Frame structure Type 1:**
This is applicable to both full duplex and half duplex FDD. There are three different kinds of units specified for this frame structure as shown in below fig.



Frame structure type 1.

Q10)b-i

— 3m

The smallest one is called a slot, which is of length $T_{slot} = 15360 \cdot T_s$
$= 0.5$ ms.

Two consecutive slots are defined as a subframe of length 1 ms, and 20 slots, numbered from 0 to 19, constitute a radio frame of 10 ms. Channel-dependent scheduling and link adaptation operate on a subframe level. Therefore the subframe duration corresponds to the minimum downlink TTI, which is of 1 ms duration, compared to a 2 ms TTI for the HSPA and a min. 10 ms TTI for the UMTS.

Each slot consists of a no of OFDM symbols including CP's. CP is a kind of guard interval to combat inter-OFDM-symbol interference, which should be larger than the channel delay spread. Therefore, the length of CP depends on the environment where the network operates, and it should not be too large, as it brings a BW and power penalty. As shown in the fig., LTE defines two different CP lengths: a normal CP and an extended CP, corresponding to seven and six OFDM symbols per slot resply. The extended CP is for multicell multicast / broadcast and very-large-cell scenarios with large delay spread at a price of BW efficiency. The normal CP is suitable for urban ~~development~~ environment and high data rate applications.

For FDD, uplink and downlink transmiare seperated in the freq. domain each with 10 subframes. In half-duplex FDD ~~subframe~~ oprn, the UE cannot transmit & receive at the same time while there are no such restrictions in full duplex FDD. However full-duplex FDD terminals need high quality and expensive RF duplex-filters to seperate to uplink and downlink channels, while half-duplex FDD allows hardware sharing between the uplink & downlink, which offers a cost of saving at the expense of reducing data rates by half. Half-duplex FDD UE's are also considered a good solution if the duplex seperation between the uplink & downlink transmissions is relatively small. In such cases, the half-duplex FDD is the preferable approach to mitigate the cross-interference between the transmit and receive chains.

ii) <u>Frame Structure Type 2</u>:

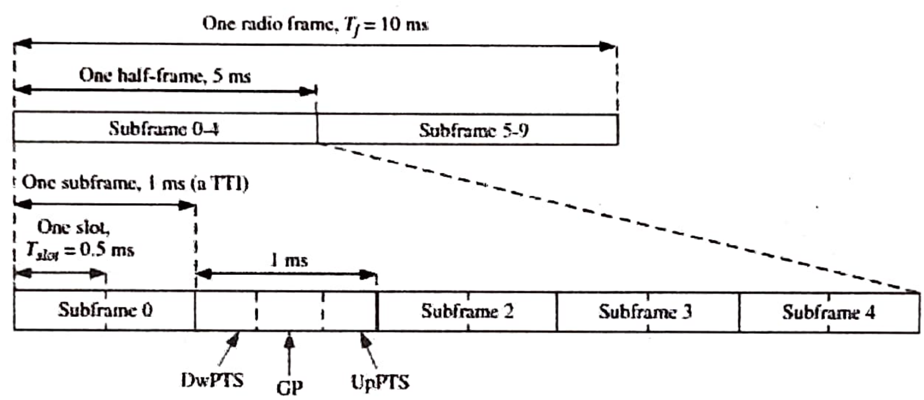
This is applicable to the TDD mode. It is designed for coexistence with legacy systems such as the 3GPP TD-SCDMA-based standard.

As shown in the figure below, each radio frame of frame structure type 2 is of length $T_f = 30720 \cdot T_s$

$= 10\ ms$,

Which consists of two half-frames of length 5 ms each. Each half-frame is divided in to five subframes with 1 ms duration. There are special subframes, which consists of three fields:

Downlink Pilot Timeslot (DwPTS),
Guard Period (GP), and
Uplink Pilot Timeslot (UpPTS).



Frame structure type 2.

Q10)b-ii

— 2m

- The DwPTS field: This is the downlink part of the special subframe, and can be regarded as an ordinary but shorter downlink ~~frame~~ subframe for downlink data transmission. Its length can be varied from three up to twelve OFDM symbols.

- <u>The UpPTS field</u>: This is the uplink part of the special subframe, and has a short duration with one or two OFDM symbols. It can be used for transmission of uplink sounding reference signals and random access preambles.

- <u>The GP field</u>: The remaining symbols in the special subframe that have not been allocated to DwPTS or UpPTS are allocated to the GP field, which is used to provide the guard period for the downlink-to-uplink and the uplink-to-downlink switch.

The total length of these three special fields has a constraint of 1ms. With the DwPTS and UpTPS durations mentioned above, LTE supports a guard period ranging from two to ten OFDM symbols, sufficient for cell size up to and beyond ~~100 km~~ 100 km. All other subframes are defined as two slots, each with length $T_{slot} = 0.5$ ms.

— 6m