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CBCS SCHEME

USN | | | | | | | | | | 15EC81

Eighth Semester B.E. Degree Examination, Dec.2019/Jan.2020
Wireless Cellular and LTE 4G Broadband

Time: 3 hrs. Max. Marks: 80

Note: *Answer 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. List the advantages of OFDM leading to its selection for LTE and explain. **(08 Marks)**
b. Discuss the delay spread and coherence bandwidth with relevant expressions. **(08 Marks)**

OR

2 a. Write the block diagram of end to end architecture of EPC supporting current and legacy Radio access networks and discuss the elements of EPC. **(08 Marks)**
b. Consider a user in downlink of a cellular system where the desired base station is at a distance 0.5 KM and the interfering base stations (i) B_1 and B_2 located at a distance of 1.0 KM, (ii) B3, B4 and B5 located at a distance of 2 KM (iii) B6 to B11 treated at a distance of 2.66 KM. Each of the stations transmitted power at the same level. Find the SIR when the path loss exponent $\alpha = 3$ and also when $\alpha = 5$ **(08 Marks)**

Module-2

3 a. With the help of neat diagrams explain how the timing and frequency synchronization is performed by the receiver to demodulate an OFDM signal. **(08 Marks)**
b. Write the block diagrams of receive diversity and explain the principle of operation. **(08 Marks)**

OR

4 a. Write the block diagram of OFDMA down link transmitter and explain the principle of operation. **(08 Marks)**
b. Explain the spatial multiplexing MIMO system and the key points of single user MIMO system model. **(08 Marks)**

Module-3

5 a. Discuss the radio interface protocol stock of LTE. **(08 Marks)**
b. Write the structure of downlink resource grid and explain the types of resource allocation. **(08 Marks)**

OR

6 a. Write the Frame structure Type 2 and explain the various fields applicable to TDD mode. **(08 Marks)**
b. Discuss the Broadcast channels and multicast channels. **(08 Marks)**

Module-4

7 a. With the help of a neat block diagram, explain the SC-FDMA base band signal generation **(08 Marks)**
b. Discuss the random access procedures in detail. **(08 Marks)**

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OR

8 a. Explain the seven different transmission modes, defined for data transmission on the PDSCH channel. (07 Marks)

b. Discuss the scheduling and resource allocation in LTE. (09 Marks)

Module-5

9 a. Explain the main services and functions of the PDCP. (08 Marks)

b. Describe the various phases of S1 mobility with a neat diagram. (08 Marks)

OR

10 a. Explain the data transfer modes and the main services and functions of the RLC sublayer. (08 Marks)

b. Discuss the intercell interference coordination in downlink and uplink. (08 Marks)

* * * * *

WC & LTE 4G Broadband - 17EC81/15EC81

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Scheme & Solution.

Q1 a List the advantages of OFDM leading to selection for LTE.

LTE use OFDM (orthogonal frequency division multiplexing) as the modulation techniques. OFDM has emerging choice for achiving high data rates.

The advantages of OFDM for LTE

1. Elagant Solution to multipath interference. In wireless channel. Intersymbol Interference caused b multipath. OFDM is multicarrier modulation technique, it devides high bit rate data stream into the several parallel lower bit streams and modulate each stream on seperate carrier. Guard time is introduced between OFDM symbols that are larger than expected delay. Hence ISI is completely eliminated

2. Reduced Computational Complexity: using IFFT/FFT the Bandwidth computational complexity is reduced to $O(B \log BT_m)$, which has complexity of $O(B^2T_m)$

3. Graceful degradation of performance under excess delay. The performance of OFDM is increased by coding and low constallation size, it provides fall back rate under the delay spread.

4. Exploitation of frequency diversity: OFDM facilitates coding & interleaving of subcarriers in the frequency domain, this is robustness against

burst error caused by deep fades the channel bandwidth is scalable to be scalable without changing the hardware design of the Base Station & mobile station.

5. Enables efficient multiaccess techniques: multiaccess schemes by partitioning different subcarriers among multiple users. The scheme is referred as OFDMA. achive significant capacity improvements

6. Robust against Narrow band Interference: Interference affects only a fraction of subcarriers

7. Suitable for Coherent demodulation: Pilot Based Channel estimation suitable for Coherent demodulation

8. Facilitates use of MIMO. multiple input and multiple output, that use multiple antennas at both the transmitter and receiver to improve the performance. MIMO techniques improves the capacity of OFDM, it is effective in Wi-Fi & Wi-Max

9. Efficient support of Broad cast services: Synchronizing base station to the timing error within the OFDM guard interval. OFDM network single frequency network (SFN). It allows broadcast signals

1X8 = 8M

1X10 = 10M

2

2

Q1

b. Delay spread is the very important prop of wireless channel. It specifies the duration of the channel impulse response $h(\tau, t)$. Delay spread is the amount of time that elap between first arriving path & last arrivi path. The delay spread is found $A(\Delta\tau, 0) \triangleq A_\tau(\Delta\tau)$ by setting $\Delta t = 0$ in the channel auto correlation function. $A_\tau(\Delta\tau)$ is multipath intensity profile or power delay profile. The maximum delay spread is τ_{max}

$V = \frac{\tau_{max}}{T_s}$ $V \rightarrow$ number of taps

$T_s \rightarrow$ sampling time.

The average and rms delay spread are τ_{max}

$$\mu_\tau = \frac{\int_0^\infty \Delta\tau A_\tau(\Delta\tau)\, d\Delta\tau}{\int_0^\infty A_\tau(\Delta\tau)\, d\Delta\tau}$$

$$\tau_{rms} = \sqrt{\frac{\int_0^\infty (\Delta\tau - \mu_\tau)^2 A_\tau(\Delta\tau).d(\Delta\tau)}{\int_0^\infty A_\tau(\Delta\tau).d(\Delta\tau)}}$$

3 $\tau_{rms} \rightarrow$ measure of width or spread

τ_{rms} → implies highly dispersive channel more and long channel impulse response (lar
Small τ_{rms} is channel is not very dispersive
The channel coherence bandwidth B_c is the -04
frequency domain dual of the channel delay spread. The channel bandwidth gives the seperation between f_1 and f_2 where the channel frequency response is correlated

$|f_1 - f_2| \leq B_c \Rightarrow H(f_1) \cong H(f_2)$

$|f_1 - f_2| > B_c \Rightarrow H(f_1)$ and $H(f_2)$ are uncorrelated

τ_{max} is ball park. B_c is the ball park value describing the range of frequencies over which the channel stays constant. The channel delay spread

$$B_c \simeq \frac{1}{5\tau_{max}} \simeq \frac{1}{\tau_{rms}}$$

Exact relation found between B_c & τ_{rms} defining the notation of the coherence.
B_c & τ are inversely related

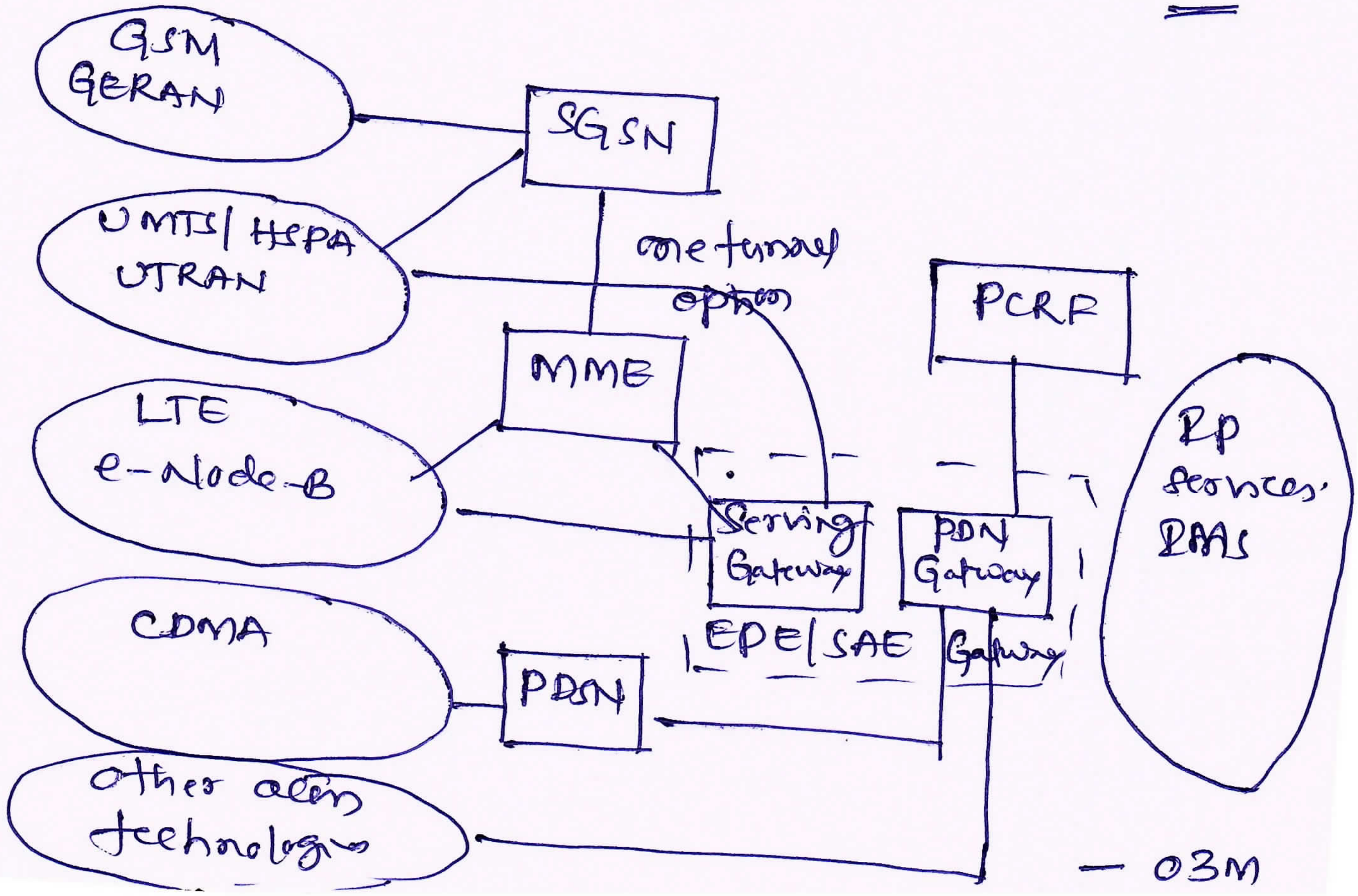
04M

or $1 \times 5M = 5$

4 $1 \times 5M = 5$

29 End to End Architecture of EPC. The brief view of network Architecture of the LTE is called Evolved packet Core (EPC). EPC is designed to provide a high capacity, All IP, reduced latency, flat architecture, supports advanced real time and media rich services with enhanced quality of experience. It provides interworking with 2G GERAN, & 3G UTRAN via SGSN. The functions of EPC includes service control, packet routing and transfer, mobility management, security, radio resource management and network management. The below figure shows end-to end architecture

— 02M



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— 03M

EPC includes four elements ① SGW ② PGW ③ M
4. PCRF

1. SGW – Serving gateway : It act as a demarcation point between RAN and core network and manage the user plane mobility. SGW does downlink packet buffering and initiation of network triggered service request procedure

2. PGW – Packet data network gateway : PGW act as termination point of EPC towards the PDN such as Internet (IP) or IM. PDN provides the services IP address allocation, policy enforcement, packet filtering and charging support

3. Mobility management entity – MME : MME peforms signaling and control functions to manage the access to the network connection as assignment of network resources, mobility management functions, Idle mode location tracking paging, roaming and handover.

4. Policy and charging rules functions (PCRF)
PCRF concatanation of PDF (policy decision function) and CRFC charging rules function
It supports service data flow detection, policy enforcement and flow based charging

6

03M

2b Given d = 500 meters (0.5 km). The 3 interfering base station distance 1 km, 3 at a distance of 3 km, 10 at a distance of 4 km,
SINR = ? when $\alpha = 3$ and $\alpha = 5$

For $\alpha = 3$ and d_0 in units kilometers, the desired received power

$$P_{r,d} = P_t P_0 d_0^3 (0.5)^{-3}$$

and the interference power is

$$P_{r,I} = P_t P_0 d_0^3 [3(1)^{-3} + 3(2)^{-3} + 10(4)^{-3}]$$ — 02M

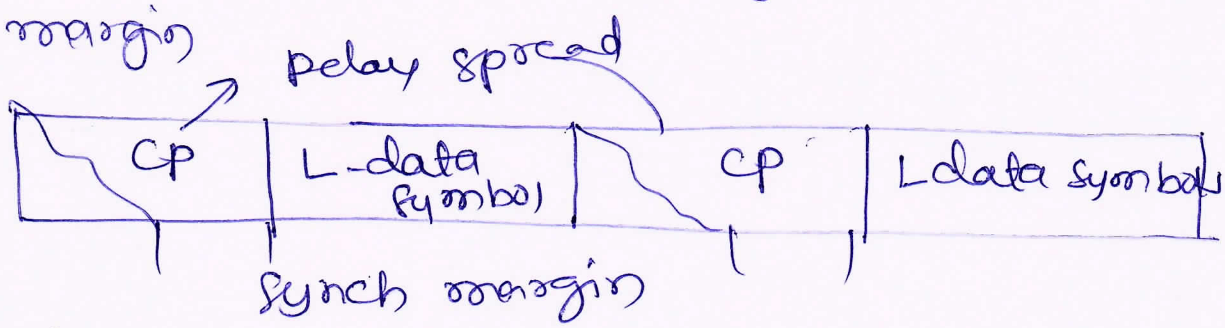
$$SIR(\alpha=3) = \frac{P_{r,d}}{P_{r,I}} = 2.27 \,(3.55\,dB)$$ 02 M

$$SIR(\alpha=5) = \frac{P_{r,d}}{P_{r,I}} = 10.32 \,(10.32\,dB)$$ — 02M

[Empirical path loss formula:
$$P_r = P_t P_0 \left(\frac{d_0}{d}\right)^{\alpha}$$] — 02 M

$\alpha \rightarrow$ Path loss exponent
$P_0 \rightarrow$ Path loss at reference distance d_0

3a The timing offset of the symbol is referred as the timing synchronization
Receiver must align to its carrier as closely as transmitted carrier frequency. This is referred as frequency synchronization.
The perfect synchronization is maintained to tolerate timing offset of τ seconds without any degradation $0 \leq \tau \leq T_g - T_m$. T_g is the guard time, $T_m \rightarrow$ maximum channel delay spread
$\tau < 0$ corresponds to sampling earlier than the ideal instant $\tau > 0$ greater than ideal instant
The acceptable τ, timing synchronization margin

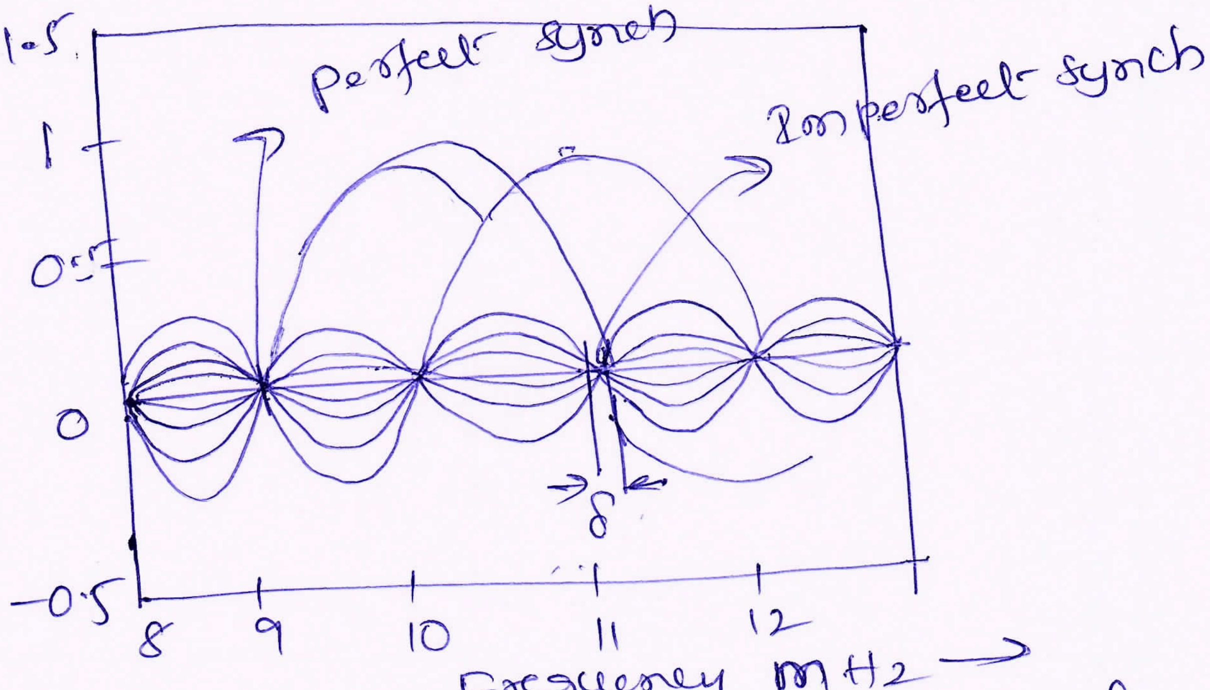


The timing offset is not within this window $0 \leq \tau \leq T_m - T_c$, Inter symbol interference
SNR loss can be approximated

$$\Delta SNR \simeq -2 \left(\frac{\tau}{LT_s} \right)^2$$

SNR $\rightarrow$ decreases quadratically 04M
8 Longer OFDM symbols are increasing minimum
$\tau \lll LT_s$, Timing synchronization errors

Frequency synchronization: OFDM achieves high degree of bandwidth efficiency. The sub carrier picking is extremely tight. The multicarrier signal is very sensitive to the frequency offset due to the subcarrier over lap is shown in fig below.



Zero crossing of (synch) frequency domain synch pulse, frequency offset δ=0 there is no interference

$f_{offset} = f_c (0.1ppm)$ ($f_c = 3GHz$)

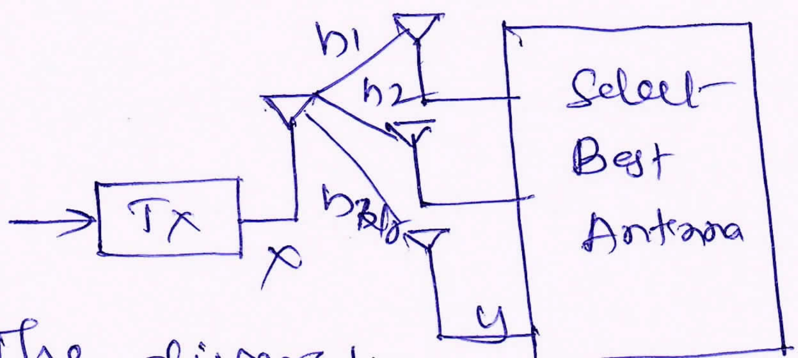
$= 300 + 100$ degrades the orthogonality of the subcarrier. Inter carrier Interference (ICI) corresponding to sub carrier

$$x_l(t) = X_l \cdot e^{j\frac{2\pi f t}{LTs}}$$

9 $$ASNR = \frac{Ex/No}{Ex/No + Co(LTs\delta)^2 \cdot Ex}$$ 04M

3b Receive diversity: The received diversity re[fers] as a receiver that processes the N_r receive streams and combines them in some fashion. Two widely used combining algorithms, Selection Combining and maximal ratio combining (MRC)

Selection Combining (SC): It is a simplest type of combiner and estimates the strength of each of N_r stream and selects the highest one. and SC ignores the other stream and it reduced hardware and power requirements



Selection Combing

The diversity gain confirmed quickly. The probability that received SNR drops below threshold $p_{out} = p(\gamma < \gamma_0) = p = p^{N_r}$

$\Rightarrow p = 1 - e^{-\gamma_0 / \bar{\gamma}}$, $\bar{\gamma} \rightarrow$ average received SNR

The average received SNR for N_r branch SC $\bar{\gamma}_{SC} = \bar{\gamma} \sum_{i=1}^{N} \frac{1}{i} = \bar{\gamma}(1 + \frac{1}{2} + \frac{1}{3} + \cdots \frac{1}{N_r})$

Antenna increases the average SNR

BEP performance improvement with increasing N_r. Target BEP of 10^{-4} about the 15 dB of improvement

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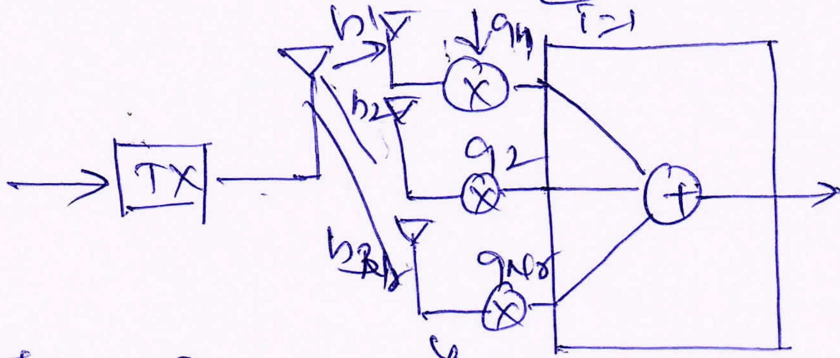
Maximal ratio combining (MRC) - Combines the information from all the received Branches. The received signal on each Bra as $x(t)\, h_i$, complex value $h_i = |h_i| e^{j\theta}$

The Combined signal can be written as

$$y(t) = x(t) \sum_{i=1}^{N_r} |g_i||h_i| \exp\{j(\varphi_i + \theta_i)\}$$

phase of the combining Coefficient $\varphi_i = -\theta_i$

$$\therefore \gamma_{mrc} = \frac{E_x \left(\sum_{i=1}^{N_r} |g_i||h_i|\right)^2}{\sigma^2 \sum_{i=1}^{N_r} |g_i|^2}$$



maximal ratio Combining (MRC)

The signal to Noise ratio can be found

$$\gamma_{mrc} = \frac{E_x \sum_{i=1}^{N_r} |h_i|^2}{\sigma^2} = \sum_{i=1}^{N_r} \gamma_i$$

The total SNR is achived by simply adding up the branch SNR

MRC → maximize the SNR performance

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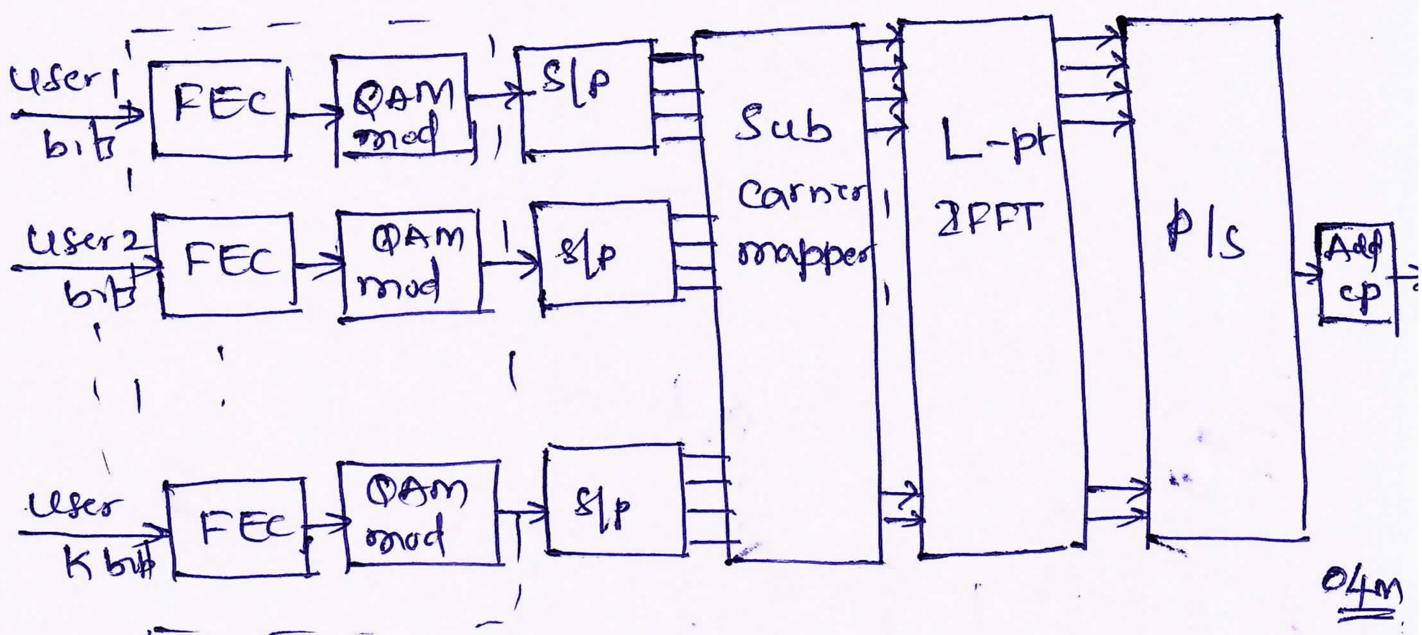
49. Block diagram of OFDMA down link transm

Orthogonal frequency Division multiple Access. It allocates subscriber time-frequency slices (resource grid). The M sub carrier either be ① spread out over the band called distributed or Comb or diversity ② bunched together. M contiguous sub carrier called a band AMC or grouped cluster. The block diagram for a downlink OFDMA shown in below fig



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The basic flow is very similar to OFDM except for now K users share the sub carriers, with each user allocated Mk sub carrier.

The user mapped to the sub carrier based on the general principles ie it is possible to have users sub carriers

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∴ $\sum_{k} M_k = L$ and each subcarrier only has one user assigned to it

At each receiver user cares about only m subcarriers but still has to apply an L point FFT to be received digital waveform in order extract the desired subset of subcarriers

For all the user bits in subcarrier uses suitable QAM modulation and then converted this into parallel data and is mapped to subcarrier mapper. This OFDM symbol applied to the L point IFFT to convert into the time domain of OFDM symbol and later is converted parallel to the serial and required CP is added at the end. This is how OFDMA down link transmitter works.

04M

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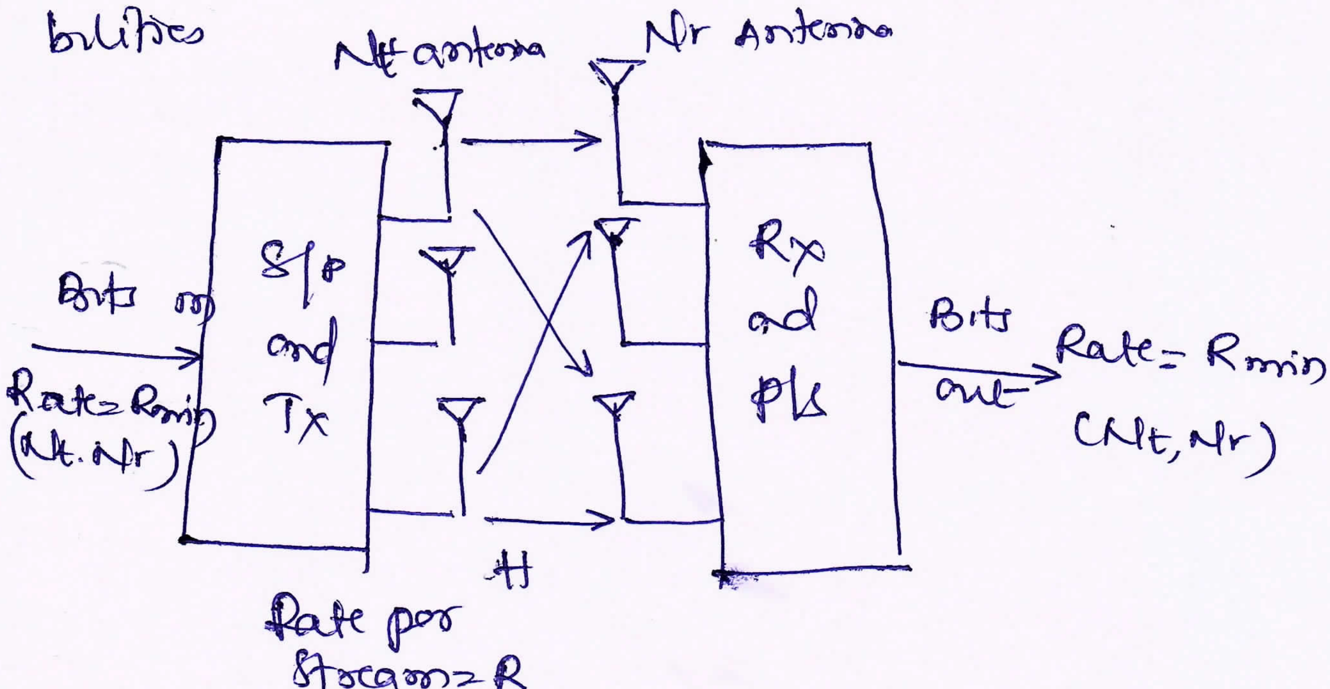
4b Spatial multiplexing

multiplexing refers to breaking incomin[g] high rate data stream into M parallel d[ata] streams shown in fig for $M = N_t$ and $N_t \leq$ Adding the antenna elements increase the data rate without increase in the band w[idth] , data rate increase comes at the expense of diversity and or interference suppression capabilities



The standard mathematical model for spatial multiplexing is very similar to linear precoding and interference suppression.

$$y = Ha + n$$

the size of the received vector y is $N_r \times 1$

the channel matrix is $H = N_r \times N_t$.

The transmit vector is normalized by N_t so

Each symbol in X has average energy Ex. The total transmit energy SISO case the channel matrix is in the form

$$H = \begin{bmatrix} h_{11} & h_{12} & h_{1Nt} \\ h_{21} & h_{22} & h_{2Nt} \\ \vdots & & \vdots \\ h_{Nr,1} & h_{Nr,2} & h_{Nr Nt} \end{bmatrix}$$

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The channel matrix and noise vector are complex gaussian and iid with zero mean and diagonal co-variance matrices.

Spatial channel experiences Rayleigh fading and gaussian noise.

The model enables rich MIMO based random matrix. The key points for the single user MIMO systems are.

1. Capacity, maximum data rate. When SNR high spatial multiplexing is optimal. When SNR low the capacity maximising strategy using diversity precoding
2. Both superior in terms of capacity to space time coding where the data rate grows logarithmically
3. The SNR of all stream maintained without increasing the total transmit power relative to SISO system transmitted stream received at $N_r \geq N_t$ antennas. eigen value channel matrix dominate the error performance

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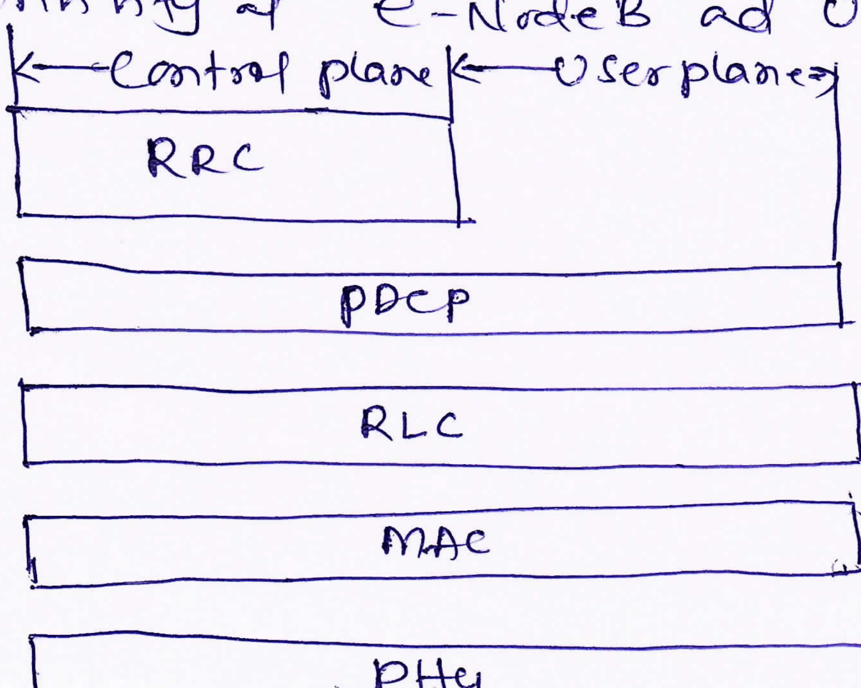
59 Radio interface protocol stack of LTE. LTE is designed based on the layered protocol stack which is divided into control plane and user plane protocol stack. This is shown in figure below.. This is composed of following layers

1. Radio Resource Control (RRC): The RRC layer performs the control plane functions including paging, maintainance & Release of RRC connection security handling, mobility management & QoS management

2. Packet data Convergence protocol (PDCP). PDCP includes IP packet header compression and de compression based Robust header compression (ROHC) protocol, ciphering of data & signaling and integrity protection for signaling and one PDCP entity at e-NodeB and UE per bearer



Radio interface protocol stack

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Radio link control (RLC): The main functions of RLC sublayer are segmentation and concatenation of data units, error correction through Automatic repeat request protocol (ARQ) and in sequence delivery of packets to the higher layers. It operates in 3 modes TM, UM & AM

TM - Transparent mode - without RLC header used for random access

UM - Unacknowledged mode: Allows the detection of packet lost, provides reordering & reassemble

AM - Acknowledged mode: Complex & configured for retransmission of the missing packet data units

Medium Access Control (MAC): MAC sublayer includes error correction through the H-ARQ mechanism, mapping between logical channel & transport channel, multiplexing / Demultiplexing of RLC PDU, priority handling, Dynamic scheduling, format selection, code rate, MIMO rank, power level, one MAC entity at e-Node-B & one at UE.

Physical layer (PHY): PHY is the actual transmission and Reception of data in forms of transport blocks. Responsible for various control mechanism

04M

5b physical resource block is described by time frequency resource grid, It makes initiative of radio resource allocation. Each column and each row of resource grid corresponds one OFDM symbol and one OFDM sub carrier. The smallest time frequency unit in a resource grid is denoted as a resource element.

The structure of each resource grid characterised by the three parameter

The number of downlink resource blocks (N_{RB}^{DL}) This is depends on the transmission bandwidth

$N_{RB}^{min,DL} \le N_{RB}^{DR} \le N_{RB}^{max,DL}$, $N_{RB}^{min,DL} = 6$, & $N_{RB}^{max,DL} = 110$, small for largest & Bandwidth.

Number of each subcarrier, N_{sc}^{RB} - It depends on the sub carrier spacing Δf, satisfying $N_{sc}^{RB} \Delta f = 180$ KHz. The value of N_{sc}^{RB} for different sub carrier spacing. The total sub carrier $N_{RB}^{DL} \times N_{sc}^{RB}$ sub carrier in each resource grid.

The number of OFDM symbol in each block (N_{symb}^{DL}) It depends on both cp length and the sub carrier spacing.

Therefore, each downlink resources grid has $N_{RB}^{DL} \times N_{RB}^{SC} \times N_{symb}^{DL}$ resource elements.

For example 10MHz Bandwidth, $\Delta f = 15$ KHz and normal cp, $N_{RB}^{DL} = 50$

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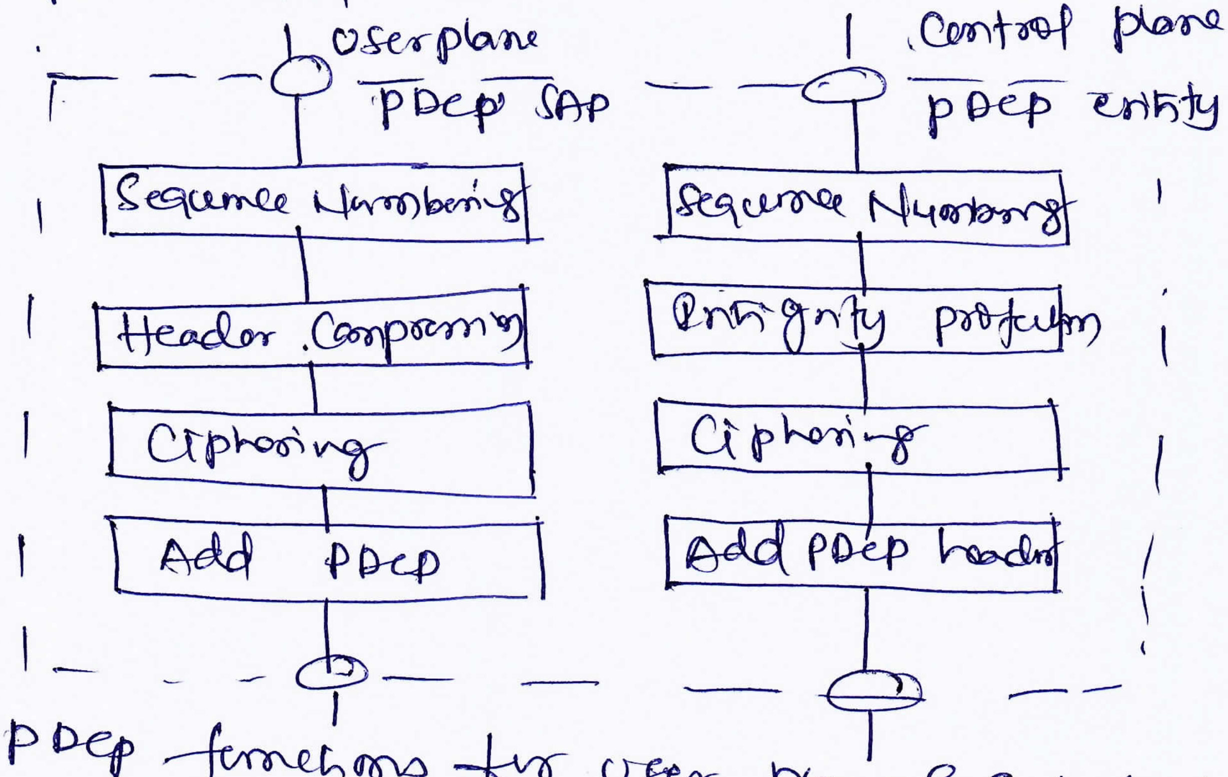
04M

Q99 The main Services and functions of the PDCP

The PDCP entity is associated either with Control plane or with user plane depending on which the radio bearer carries the da

Each radio bearer is associated with one PD & each PDCP associated with one or two RLC entities depending on the radio bearer characteristic. Radio bearer mapped on DCCH & DT types of logical Channel.

Services & functions of PDCP sublayer for user plane and Control plane



PDCP functions for user plane & Control plane

For user plane

① Header compression and decompression of IP data flows with Robust header compression (ROHC) protocol

② Ciphering and deciphering of user plane data

③ In sequence delivery and re ordering of upper layer PDU at handover

④ Buffering and forwarding of upper layer PDU from e-NodeB to target e-Node-B during handover

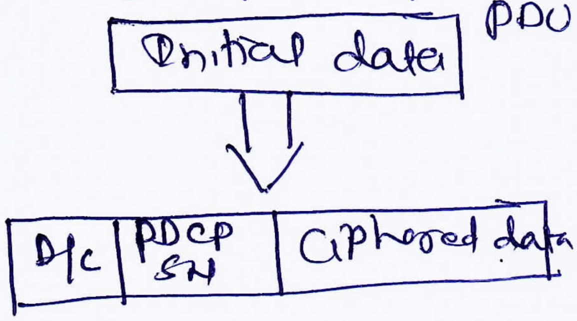
⑤ Timer based discarding of SDU in the uplink

For the control plane

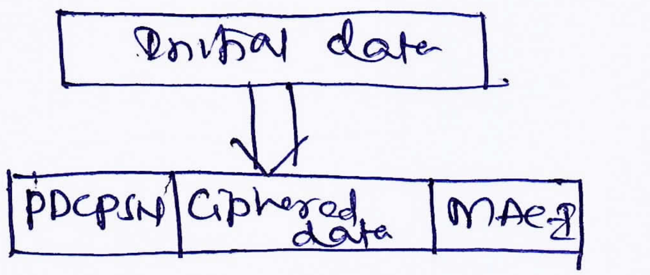
1. Ciphering and deciphering of control plane data
2. Integrity protection & Integrity verification of control plane data
3. Transfer of control plane data.

The PDCP PDU categorized as PDCP data PDU and PDCP control PDU

User plane PDCP data PDU



Control plane PDCP data PDU



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Q9b S1 - mobility : LTE mobility functions can be categorized as into two groups

(1) Intra - LTE mobility . (S1 mobility)
(X2 mobility)

(2) Inter - RAT - mobility

S1 mobility over serving radio network subsystem (SRNS) relocation procedure consists of the following steps

(1) preparation phase : once the decision is made for the handover and target MME and e-NodeB have been identified. The network needs to reallocates target side for impending handover. The MME sends the handover request to the target eNode-B requesting it to setup the appropriate resources for the UE. once the resources allocated at the target e-Node-B it sends handover request Ack to MME. once the message received by MME it sends the handover command to the UE via the source eNode B.

(2) Execution phase : UE receives the handover command. UE performs the handover, the source e-Node-B initiates the status transfer where the PDCP context of the UE a

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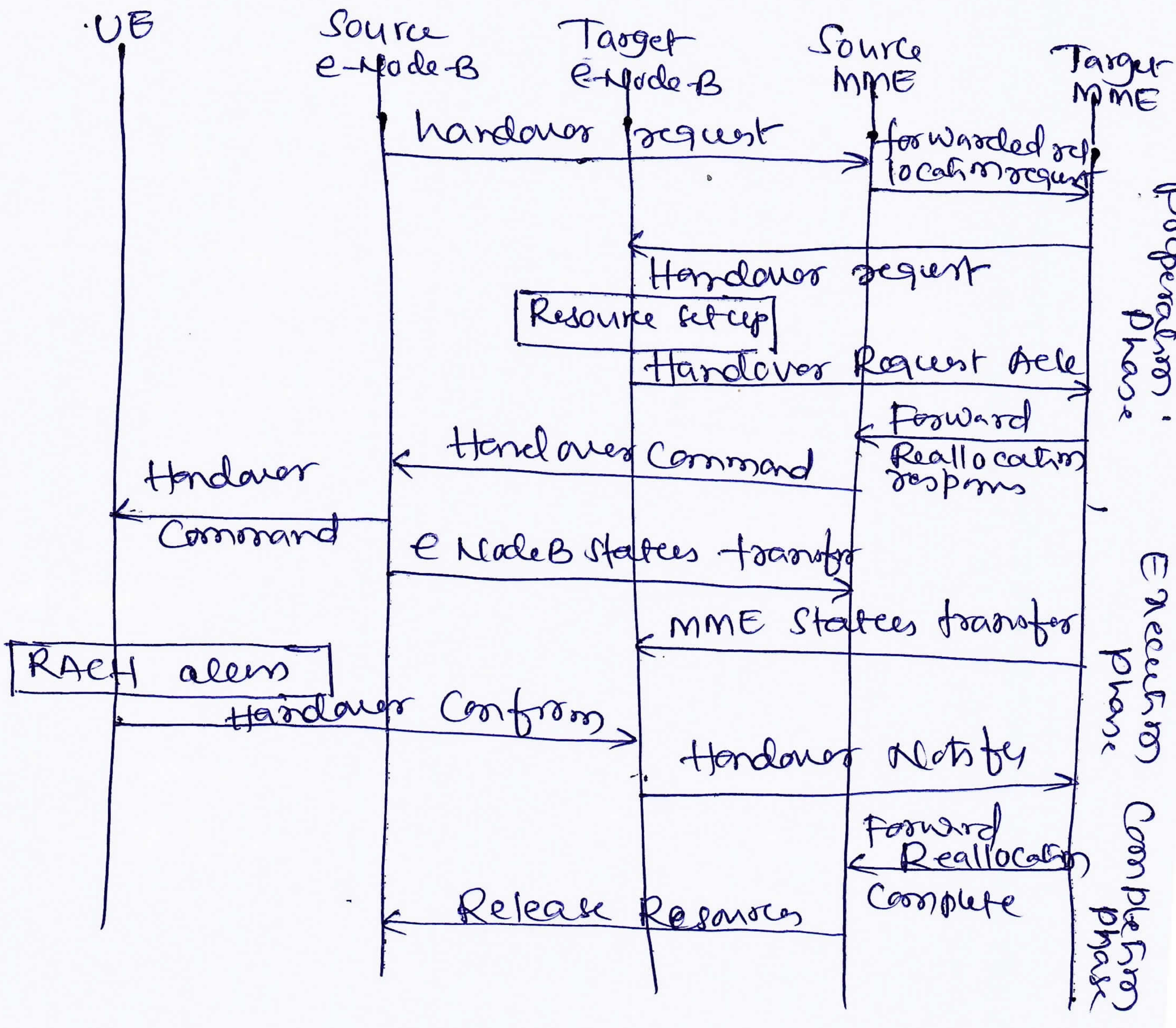
Transfered to the target eNode-B and estab-lishes the radio alem bearer (RAB) on the target e-Node-B. and it sends the handover Confirm message to the target e-Node-B

3. Completion phase:- The target eNode-B receives the hand over Confirm message, it sends handover notify message to the MME. The MME informs the source eNode-B to release the resources originally used by the UE.



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(8)

10a Data transfer modes and services & functions of RLC sublayer.

RLC operated in 3 different modes:- ① Transparent mode (TM) ② Unacknowledged mode (UM) and ③ Acknowledged mode

Transparent mode (TM): RLC entity does not add RLC header and no data segmentation or concatenation is performed. This is suitable for broadcast system information & paging. RLC data PDU by TM RLC called TMD (TMD)

② The unacknowledged mode (UM): It provides the sequence delivery. This is delay sensitive and error tolerant real time applications, VoIP. DTCH operated in the UM mode. UM RLC entity segments and concatenates the RLC SDU according to the total size of RLC PDU. The UM RLC entity performs the duplication, reordering and reassembly of UMD PDUs.

③ The Acknowledged mode (AM): It is complex mode which request retransmission of missing PDU. It is used by the error sensitive and delay tolerant application. AM RLC entity can be configured to deliver/receive RLC PDU through DCCH and DTCH. AM RLC entity

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delivers / receive AM data PDU and the Status PDU indicating ACK / NAK information of the RLC PDU. Retransmissiont portion of PDU results from the ARQ process and segmentation. The transmitted PDU is called AMD PDU segments.

— 04M

The function of RLC Sublayer.

1. Transfering / receiving the PDU from upper layers, i.e. CCCH logical channel
2. Error Correction through ARQ (in the AM)
3. Concatenation, segmentation, and Reassembles of RLC SDU (UM & AM mode)
4. Re segmentation of RLC data PDU (AM)
5. In sequence delivery of upper layer PDU (UM&A
6. Duplicate detection (UM & AM data)
7. Protocal error detection and recovery
8. RLC SDU discard (UM & AM data transfer
9. RLC - re - establishmen

— 04M

10b Inter cell - Interference Co-ordination in the 39
Cellular network is due to the frequency re-use
in other cell. ICI control must be applied
for the down link and uplink

Down link: Three basic approches for mitiga
① ICI randomization: Achived by scrambling
the Code word after channel coding with
pseudo random sequence, cell specific scra
mbling, ICI from the neighbouring cell is
randomized and then interference suppression
is achieved. ICI randomization is applied in
the system.
② ICI cancellation: This can be achived
with multi user detector at the UE. ICI can
ellation is performed on spacial domain by
number of antenna at UE
③ ICI coordination / Avoidance: This is achive
by the downlink resource management in co
rated way between the neighbouring cell. It
restriction on time frequency resources and
somt power at each e-Node-B communic
and UE measurement and reporting.
38 Static ICI Co-ordination / Avoidance
Semi Static ICI Co-ordination / Avoidance

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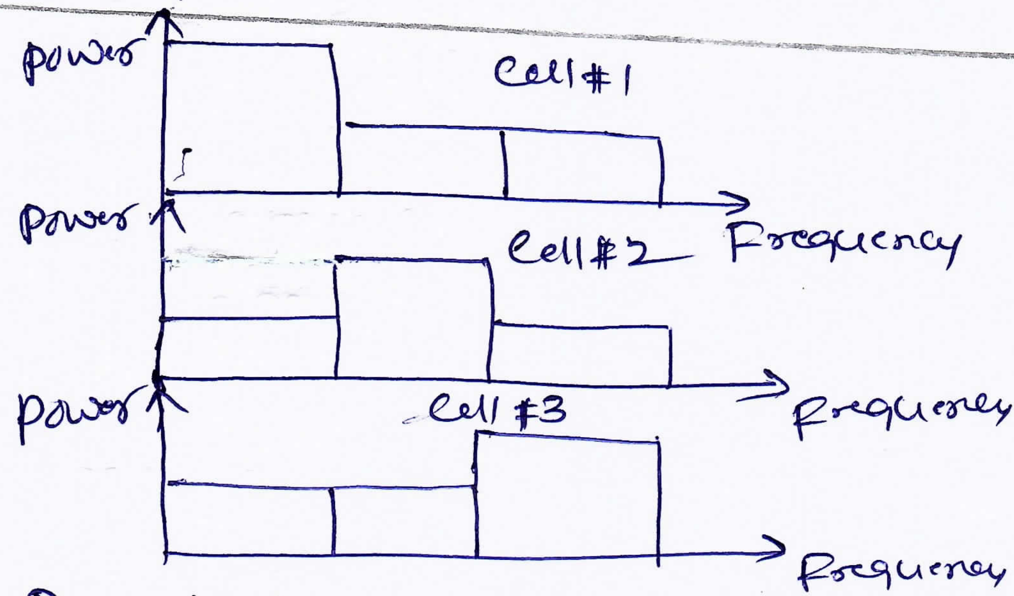

Down link power levels of three neighboring cells

uplink : approches for uplink ICI mitigation

① ICI randomization: This is achived by scrambling the encoded symbols prior to modulation. UE specific scrambling is used in the uplink as ICI comes from multiple UEs in the neighbouring cells

② ICI cancellation: ICI cancellation is in the uplink higher computational capacity & more antenna element

③ uplink power control: Power control is effective way to suppress ICI, Fractional power control (FPC) used in LTE

④ ICI Co-ordination/Avoidance: It is similar to the downlink.

Two messages are defined in LTE that can be exchanged over X2 interface

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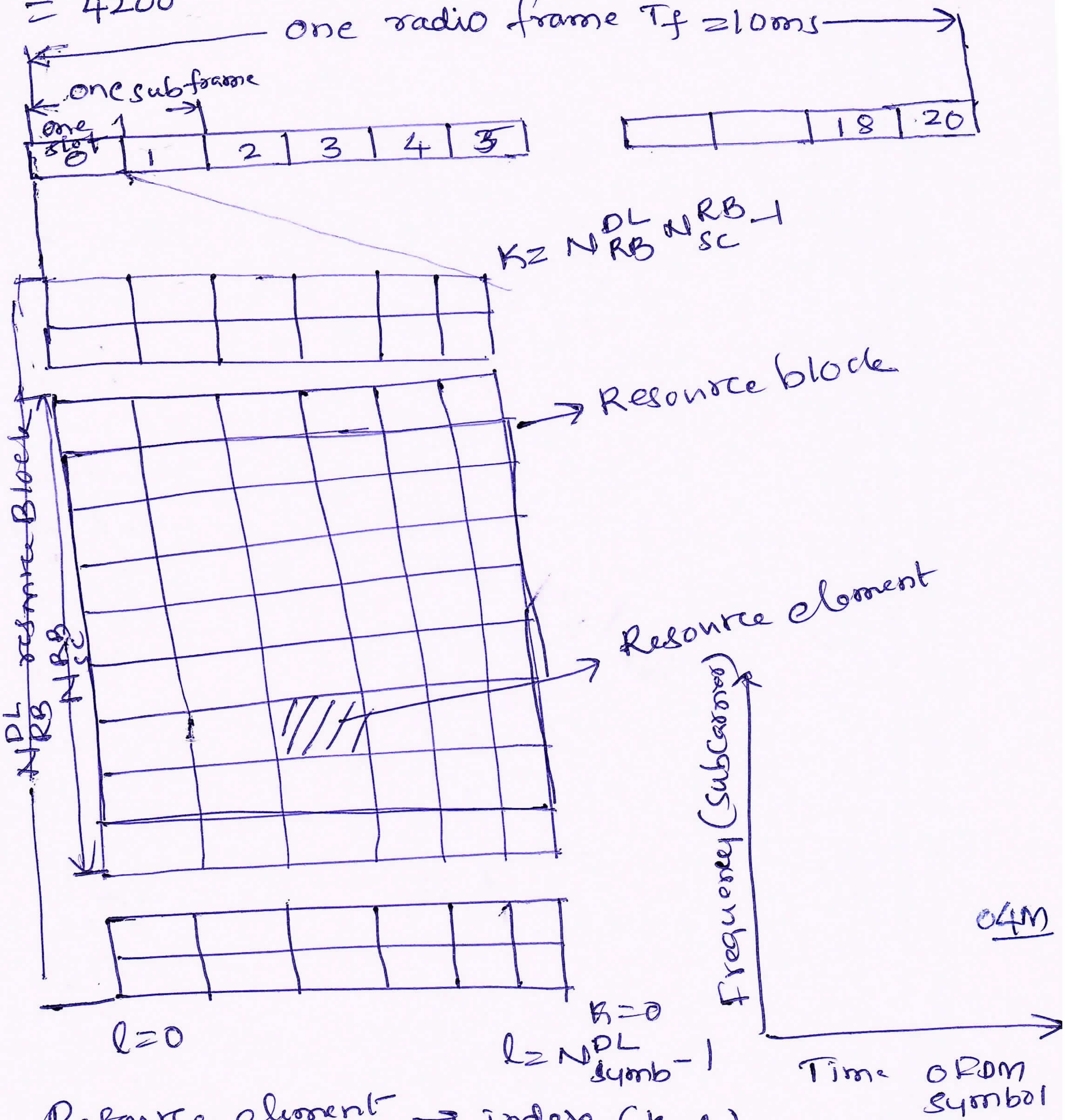
04M

$N^{SC}_{RB} = 12$ and $N^{DL}_{symb} = 7$, so there are $50 \times 12 \times 7$ 25

$= 4200$

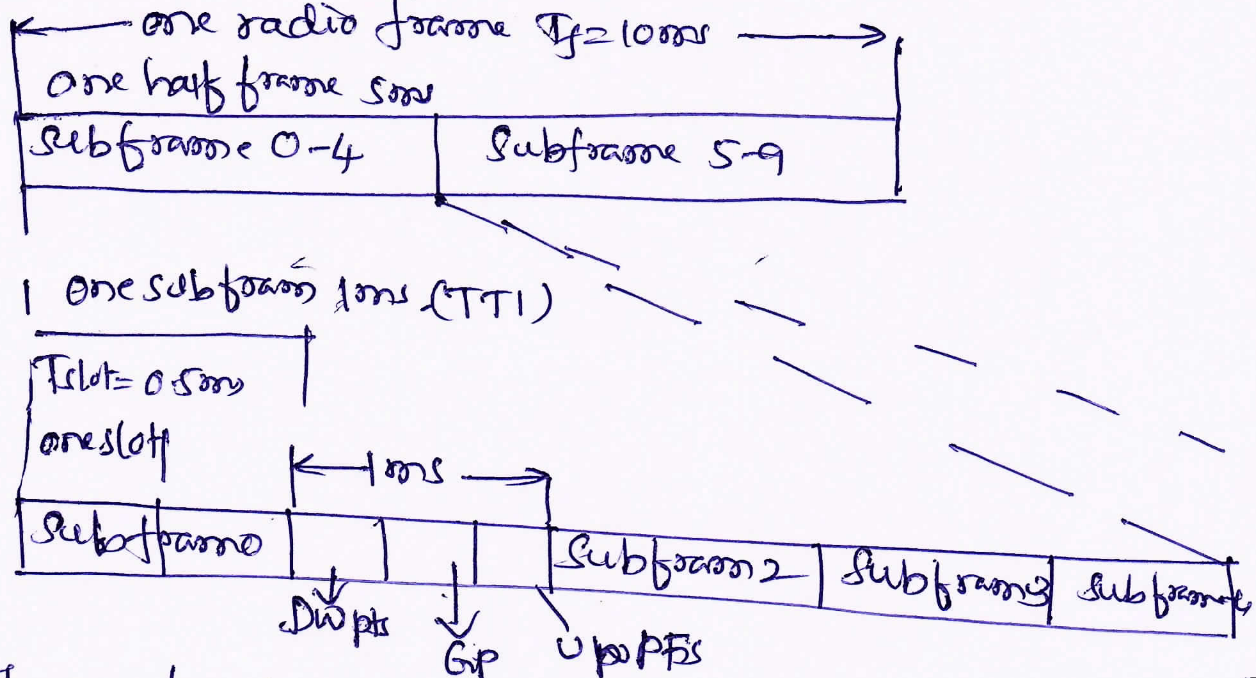


Resource element → index (k, l)

k → frequency domain index $k = 0, 1, \ldots N^{DL}_{RB} N^{RB}_{sc}$

19 l → Time domain index $l = 0, 1, \ldots N^{DL}_{symb} - 1$

6 g Frame structure type-2 is applicable to TDD mode.. Each radio frame of frame structure type is of length $T_f = 30720 \cdot T_s = 10ms$, which consists of two half frames of length 5ms each. each half frame is divided into 5 subframes with 1ms duration. The special subframe consists of Downlink pilot slot (DwPTS), Gaurd period (GP) & uplink pilot time slot (UpPTS) shown in below figure



— 04M

These fields are already defined in TD SCDMA. LTE TDD provides large gaurd period for switching between transmission and reception.

The DwPTS field: This is downlink part of spacial subframe. It is for Down link data transmission and length varied from three up to twelve OFDM symbols.

20 The UpPTS fields: This is uplink part of spatial

Subframe and has a short duration with one or two OFDM symbol and it can be used for transmission of uplink sounding reference signal and random access preambles.

The GP field. The remaining symbols in the special subframe are allocated to the GP field which is used to provide guard period for down to uplink and uplink to downlink switch.

The total length of 3 field is 1ms. LTE supports guard period ranging from two to ten OFDM symbols, sufficient for cell size upto and beyond 100 km. Subframes defined as two slots, each length Tslot = 0.5ms

Seven uplink - downlink configuration with 5ms or 10ms downlink to uplink switch are supported where D&U denote the downlink & uplink and S denotes the spatial subframe —04M

Uplink Downlink Configuration	Downlink to uplink switch point periodicity	Subframe number									
		0	1	2	3	4	5	6	7	8	9
0	5ms	D	S	U	U	U	D	S	U	U	U
1	5ms	D	S	U	U	D	D	S	U	U	D
2	5ms	D	S	U	D	D	D	S	U	D	D
3	10ms	D	S	U	U	U	D	D	D	D	D
4	10ms	D	S	U	U	D	D	D	D	D	D
5	10ms	D	S	U	D	D	D	D	D	D	D
6	5ms	D	S	U	U	U	D	S	U	U	D

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6b Broadcast channel and Multicast channel.

Broadcast channel carry the system information such as downlink system bandwidth & reference signal power. UE can get the necessary system information after the cell search procedure. Master information Block transmitted on PBCH. System information Block transmitted on PDSCH. PBCH contains the demodulation procedure of the PDSCH. PBCH is characterised by fixed pre-determined transport format and resource allocation.

CRC is provided to the e-Node-B transmit antenna. The modulation scheme is QPSK. PBCH supports single antenna transmission & OL transmit diversity. Dynamic adaptation modulation & coding due to the lack of channel quality feed back. The complex valued modulation symbols are mapped onto the 72 subcarriers centred around the DC subcarrier in slot 1 in subcarrier 0 during four consecutive radio frames. PBCH occupies the most narrow bandwidth (1.4MHz) by LTE. The resource mapping of PBCH is independent to the system bandwidth and duplex mode

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04M

multicast channels: multimedia Broadcast and multimedia services for UE (broadcast) or set of UE (multicast). MBMS receive the same data from multiple cells. LTE provides the enhanced support for the MBMS transmission is achieved through the single frequency operation (SFN). OFDM based multicast/Broadcast transmission from multiple base stations possible in LTE with an extended CP. The E-MBMS transmission in LTE on MCH transport channel along with 7.5kHz subcarrier spacing. There are two types of E-MBMS

① single cell transmission (Non MBMSFN operation) is transmitted on MCH and combining of MBMS transmission from multiple cell is not supported

② multi cell transmission (MBSFN operation) The MBMS service is transmitted synchronously on the MCH and combining is supported with SFN operation

The MCH is similar to the DL SCH. The MCH and DL SCH are multiplexed

MBSFN & DL SCH transmission can be multiplexed in TDM manner but cannot be transmitted within the subframe.

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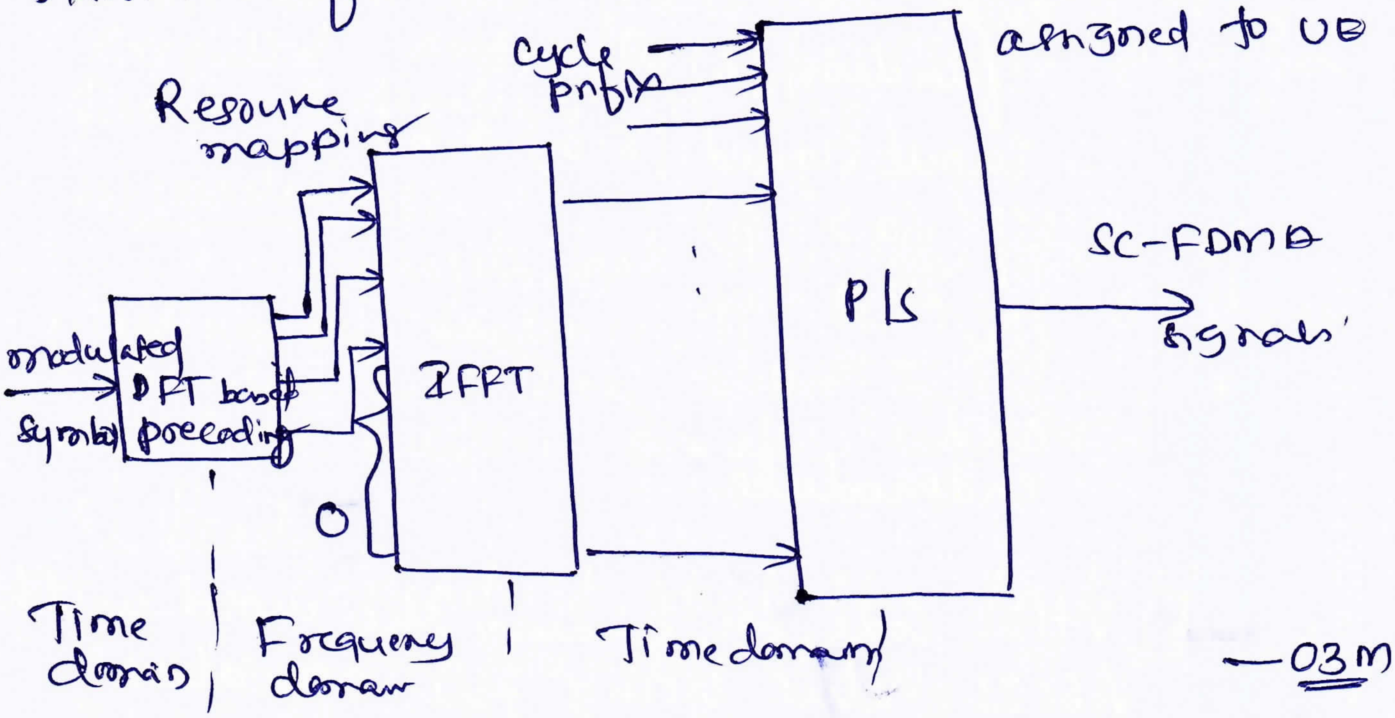
04M

7) SC-FDMA base band signal generation. 19

DFT based precoding is applied to the block of the complex valued modulation symbols which perform the time domain signal onto the frequency domain. There is a trade off between complexity of the implementation and the flexibility on the assigned bandwidth. DFT depends on the number of resource block shown in figure below assigned to UE



— 03M

The output of the DFT based precoder is mapped to the resource blocks that have been allocated for the transmission of the transport blocks. Localized resource allocation is supported in the uplink. Continuous resource block is assigned to the UE.

24

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3. The base band signal $s_l(t)$ in SC-FDMA symbol l in the uplink slot

$$s_l(t) = \sum_{k=\lfloor N^{UL}_{RB} N^{RB}_{sc}/2 \rfloor}^{\lceil N^{UL}_{RB} N^{RB}_{sc}/2 \rceil - 1} a_{(k^{-}+1), l} \cdot e^{j2\pi(k+l)/2 \Delta f (t - N_{cp,l} T_s)}$$

for $0 \leq t < (N_{cp,l} + N) \times T_s$ where $k^{-} = k + \lfloor N^{UL}_{RB} N^{RB}_{sc}/2 \rfloor$

N. is the FFT size, $\Delta f = 15kHz$

$a_{k,l}$ - is the content of resource element (k, l)

it is generated with IFFT operation afterwhich the cyclic prefix inserted. The SC-FDMA sub carriers are used on the uplink, in LTE all the subcarriers are shifted by sub carrier spacing to reduce this influence. The operation combining DFT based precoding IFFT applies to all the uplink physical signals

The generation of SC-FDMA signal shares the structure with additional DFT operation

-05m

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7b Random Access procedure.

Random access procedure during initial access or reestablishment of uplink synchronization. The random access preamble consists of a CP of length Tcp and sequence part of the length Tseq. Guard Time (GT) is also needed to account for the round trip propagation between e Node-B and UE. The values are depend on cell size and base station implimentation.

CP	Sequence	GT
Tcp	TSEQ	

Five different preamble format defined in LTE. Format 0 for normal cells, format 1 extended format for large cells, format 2 & 3 compensate for increased path loss, and used for small cell and large cell

Random Access Preamble Parameter

Preamble format	Tcp	TSEQ
0	3168.Ts	24576.Ts
1	21024 Ts	24576 Ts
2	6240.Ts	2.24576.Ts
3	21024.Ts	2.24576.Ts
4	448.Ts	4096.Ts

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— 04M

8

The parameter restricted to certain time & frequency resources. Physical random access channel (PRACH) resources are indicated by PRACH configuration index. Type 1 the format 0-3, one random access procedure & Type 2 format at 0-4 multiple random access resources in an uplink sub-frame. 25

The PRACH uses different subcarrier spacing (Δf_{RA}) than the other physical channels $\Delta f = 15KHz$. The base band PRACH is different from the physical channel.

The DFT zadoff-chu sequence is the continuous random access signal.

$$s(t) = \beta \sum_{k=0}^{N_{ZC}-1} \sum_{n=0}^{N_{ZC}-1} x_{u,v}(n) \cdot e^{-j\frac{2\pi nk}{N_{ZC}}} \cdot e^{j2\pi(k+\varphi+K(k_0+1/2))\Delta f_{RA}(t-T_{CP})}$$

where $0 \le t \le T_{SEQ} + T_{CP}$

$\beta \rightarrow$ amplitude scaling factor

$x_{u,v}(n)$ uth root Zadoff-chu sequence with cyclic shift

$\varphi \rightarrow$ fixed offset

$K = \Delta f / \Delta f_{RA}$, $k_0 = n^{RA}_{PRB} N^{RB}_{sc} - N^{UL}_{RB} \cdot N^{RB}_{sc}/2$

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— 04M

Q8a Seven different transmission modes: PDSCH supports all the MIMO modes. There are seven d erent transmission modes defined for data tra smission on the PDSCH channel

Single antenna port (port0): Transport block i transmitted from single physical antenna cor sponding to antenna port 0

Transmit diversity: transmit block is trans orted from more than one physical antenna port0, & port1, & port0,1,2,3 four antennas are used

open loop (OL) spatial multiplexing: one or two transport blocks are transmitted from two or four physical antenna. predifined precod matrices are used based on the Rand Indi cator feed back. Precoding matrix is fixed

closed loop (CL) spatial multiplexing: one or two code block is transmitted from two or foure physical antenna. The precoding matrix adapted based on the (PMI) feed back from the UE

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2

Multiuser MIMO: Two UE are multiplexed onto two or four physical antenna with one transport block with each UE. The rank-1 PMI feedback from each UE is used to create the overall precoding matrix

Closed loop rank-1 precoding: It is the special case of the CL spatial multiplexing with single layer transmission i.e. P X 1 precoder is applied.

Single antenna port (port 5): Transport block is transmitted from two or more physical antenna. The e-Node-B performs beamforming to single UE using all physical antenna. In this case reference signal is transmitted using the same beamforming vector that is used for the data symbols. The beamforming techniques at the e-Node-B is transparent to the UE. Beamforming is used to improve the received signal power and/or reduce the interference signal power. which is important for cell edge users

8b Scheduling and Resource allocation in LTE 31

The main purpose of scheduling and resource allocation is to efficiently allocate the available resources to the UE to optimize the certain performance metric with QoS requirement constraints.

Scheduling algorithms for LTE can be devided into two catagories.

Channel dependent scheduling: The allocation of resource blocks to a UE is based on the channel condition eg proportional fairness scheduler, max CI Scheduler

Channel Independent Scheduling: the allocation of resource blocks to UE is random and not based on the channel condition eg round robin scheduler — 03M

The channel dependent scheduling can be further devided into two catagories.

Frequency diverse scheduling: The UE selection is based on wide band CQI, The PRB allocation in the frequency domain is

30 random

It can exploit the time and frequency diversity of the channel.

Frequency selective scheduling: The UE selection is based on both wide band & Sub band CQI & PRB allocation is based on the subband CQI. This can exploit the time and frequency selectivity of the channel.

It focus on frequency selective scheduling. Dynamic channel dependent scheduling is one of the key feature to provide the high spectral efficiency in LTE. To better exploit the channel selectivity, the packet scheduler is allocated at e-Node-B

The objective of channel dependent scheduling is to exploit the multiuser diversity to improve the spectrum efficiency. Scheduling is tightly integration with link adaptation & H-ARQ process. The scheduling algorithm is not standardized and e-Node-B is vendor specific

O & M