ANALYSIS OF RAN AND COMPARING WITH C-RAN FOR LTE-NETWORKS

CAPSTONE PROJECT REPORT

Masters of Science in Internetworking

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ABSTRACT

The demand for mobile data traffic is increasing at a rapid pace. Specifically, at highly dense areas where the population is high, it is really hard for carriers to provide uninterrupted service. The carriers are installing more base stations in small area order to keep a smooth flow of traffic. These base stations instead of satisfying the high demand creates interference with each other and causes loss of energy and increase in cost. They work at maximum capability even at non-peak hours causing wastage of power. The traditional Radio Access Network (RAN) has become more expensive in terms of cost as well as in terms of energy consumption. Thus, there is a need to implement Centralized RAN (CRAN). In CRAN, the Base station (BS) is divided into Remote Radio Head (RRH) and Base Band Unit (BBU). The BBUs are aggregated into a centralized BBU pool and are connected to the RRH through front haul. The BBUs in the BBU pool share energy and resources. It can lower cost of deployment of the network and its operation as well as improve energy efficiency, mobility and coverage performance. By using new technologies at various stages of C-RAN, it provides more flexible and efficient services. With the centralized processing of the C-RAN architecture, the number of base station sites can be reduced and it is much easier to implement algorithms to mitigate inter-cell interference.

Acknowledgements

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1. Introduction

The RAN conceptually resides between Evolved packet core (EPC) and the User Equipment (UE) and its functionality is provided by the chip residing in EPC and UE. The Traditional RAN has base station (BS) which compromises of Remote radio head (RRH) and Baseband unit. Today there is a strong competition in the wireless mobile environment. In order to meet the fast-increasing demand of the data services, there is a need to upgrade the network frequently. While the cost to build, operate and upgrade the Radio Access Network (RAN) is increasing, the growth of revenue is not at the same rate, which indirectly impacts the ability of the operator to build the networks in timely fashion and offer services.

Traditional RAN has several limitations. Firstly, they are costly to build and operate, consisting of power sources, backup battery, cooling, and monitoring system. Secondly, each Base Station only handles transmission/reception signals in small area as it has fixed number of sector antennas. Thirdly, interference increases when more base stations are added to improve its capacity as they use the same frequency. fourthly, as base stations are designed to handle maximum traffic and they cannot share the processing resources, the average utilization of individual base station is low, thus at idle times the processing resources and power are wasted.

In the population concentrated areas, the amount of data traffic on the network is increasing and will soon reach its limit. Simply increasing the base stations to provide smooth access of network for users is not acceptable anymore. The traditional RAN has become too expensive for the operators, it neither supports centralized interface management nor provide innovative applications through network flexibility, which can provide revenue for operators. Thus, the operators need to architect a radio network which can provide flexibility. Thus, Cloud RAN

(CRAN) has become the key architecture which overcomes the limitations of traditional RAN. All base stations controls are centralized as all the multiple Remote Radio Heads (RRH) are connected to a single master base station which provides versatility and improve utilization of resources.

2. Evolution of the network architecture

The 2G (Second Generation) Network was launched on GSM standards, where the caller and receiver were directly connected through the telecommunication network. It is based on circuit switched design and was voice centric with very low data rate. The core network is composed of the circuit-switched domain.

The 2.5G (Second and half) Network (GPRS) added Packet switched services in addition to the circuit switched circuits to offer more flexibility and efficiency. In the previous generation, a complete switch was used by a particular user which was inefficient when the channel had to carry data for a small period of time but by adding the packet switched approach the same circuit is being used by different users to transmit the data when the channel is not being used. The core network is composed of circuit-switched and packet-switched domains.

In 3G (UMTS), a few network elements were upgraded to the packet and circuit switched circuits and the same concept was continued along the core network.

In 4G LTE, IP was decided as a key protocol for the transportation of all services, thus circuit switched domain was discarded and packet switched architecture was evolved in 4G LTE.

3. Evolution of Radio Access Network

3.1 2G & 2.5G Radio Access Network

The RAN controls the radio interface to the mobile station [1]. Basic components in RAN are:

- Base Transceiver Station.
- Base Station controller.

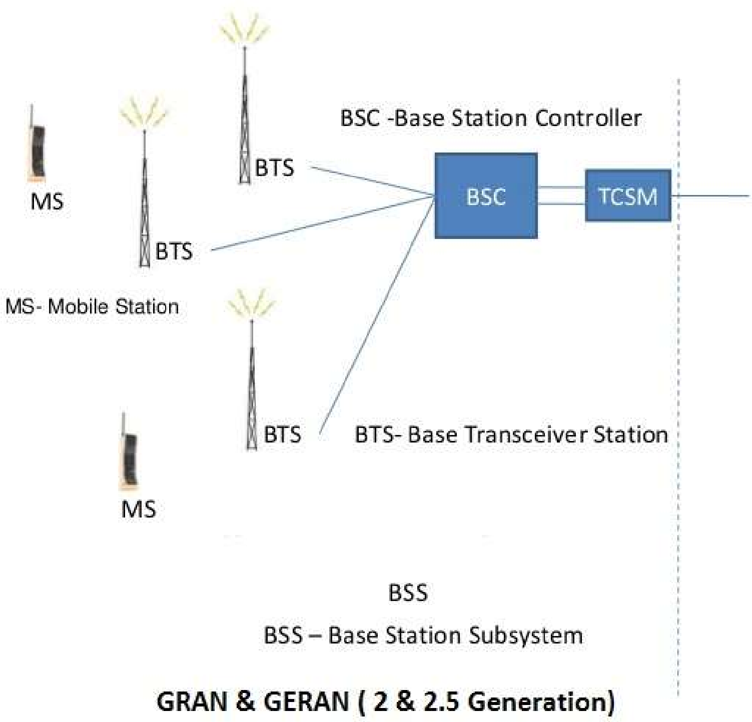


Figure 1. Radio Access Network Architecture[25] for 2 & 2.5 G

MS - Mobile Station

- The MS Converts speech to a digital layout and transmits this to the BTS through the air interface in the form of radio waves.
- Gets radio waves from the BTS and converts the digital signal to speech.
- Monitors the quality and state of the radio waves from the BTS, and reports those lower back, so the BSC can determine if the MS desires to receive from another BTS.
- Encrypts the radio indicators, so the decision cannot be listened to by human beings with scanners.

BTS -Base Transceiver Station

- Receives radio waves and converts them to digital type, to transmit to the BSC.
- Takes the digital format from the BSC and converts them to radio waves, which can be transmitted to the MS.
- Monitors quality and degrees of the radio waves and reports to the BSC, so the BSC can decide if the MS desires to obtain from any other BTS.
- Holds configuration and software program for itself. Reviews alarms returned to BSC that has an interface for team of workers to configure the BTS and reveal it.

BSC -Base Station Controller

- Sends and gets calls for all its BTS's returned to the rest of the Network, controls the decision capabilities.
- Tracks the tiers and quality of all the BTS and MS reviews, and controls the handovers of all the MS in its location.
- Holds configuration and software for itself, and all the BTS's attached to it. It additionally holds backups of those.

- Takes alarms for itself and all the BTS's attached to it and passes them to the tracking structures.
- Takes the performance statistics of itself and all the BTS's attached to it and passes this again to the tracking system.
- Presents an interface where workforce can change the configuration software program and functions of the BSC and the BTS's.

3.2 3G Radio Access Network

3rd Generation: RAN is UTRAN (Universal Terrestrial Radio Access Network)
Components:

- Node B.
- Radio Network Controller

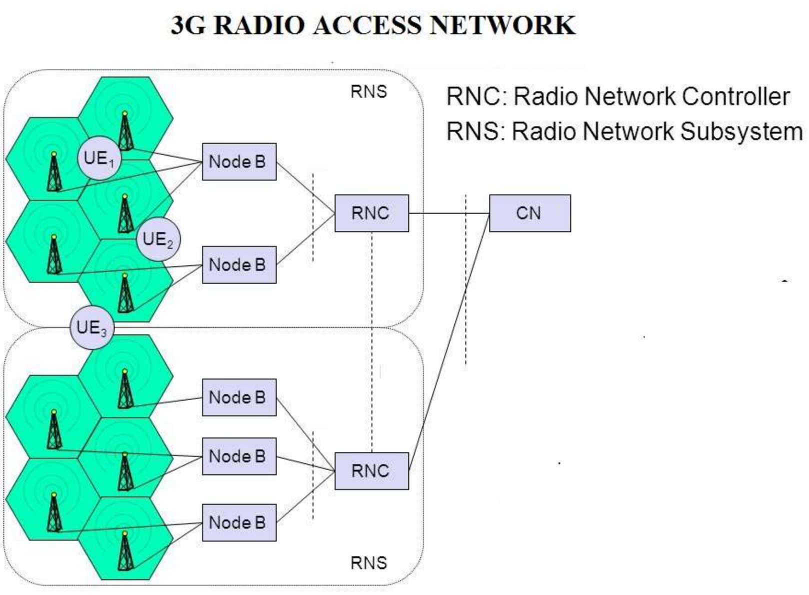


Figure 2. Radio Access Network Architecture for 3G

- **Radio Network Subsystem (RNS):** The RNS conjointly called the UMTS Radio Access network, UTRAN, is that the equivalent of the previous Base Station system or BSS in GSM. It offers and manages the air interface for the general network. A Radio network system (RNS) includes an RNC and one or additional NodeB.
- **Radio Network Controller, RNC:** This part of the UTRAN / radio network [2] controls the NodeB's that the area unit is connected to, i.e. the radio resources in its domain. The RNC undertakes the radio resource management and a few of the quality management functions, though not all. It's additionally the purpose at that encryption/decryption of data is performed to shield the user data from eavesdropping
- **Node B*:*** Node B is that the fundamental measure used within UMTS to denote the base station trans receiver [2]. This part of the UTRAN allows the transmitter and receiver to speak with the UEs inside the cell. It participates with the RNC within the resource management. NodeB is the 3GPP term for the base station, and infrequently the phrases are used interchangeably.

4. LTE Radio Access Network

4G LTE has a simplified architecture. It consists of three main components [3], they are (i) The User Equipment (UE) (ii) The Evolved UMTS Terrestrial Radio Access Network (E-UTRAN) and (iii) The Evolved Packet Core (EPC).

An entirely new packet-switched core network architecture was released in order to support the evolved universal terrestrial radio access network (E-UTRAN) by reducing the number of network elements, simpler functionality, and more importantly allowing connections and handover to other access technologies, giving the service network providers the ability to deliver a seamless mobility experience. Mobility management functions have been moved to the core network and have become part of mobility management entity (MME).

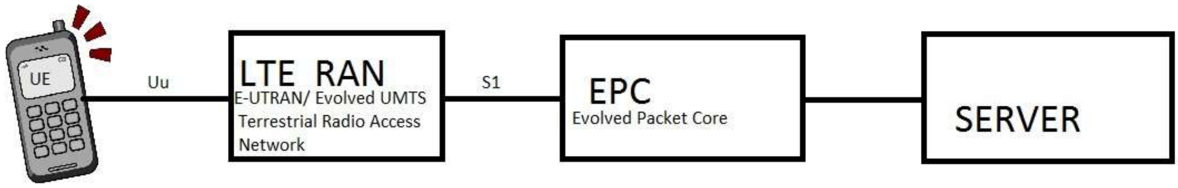


Figure 3. Architecture of 4G LTE

(i)The User Equipment (UE)

The UE is the equipment used by the end user. It connects to the eNodeB in E-UTRAN via air interface known as LTE Uu. The user equipment can be any device such as mobile, laptop or Router. UE handles Mobility management, Call control, Session management and Identity management towards the core network.

UE handles the following tasks towards the core network:

- The Mobility Management
- The Call control
- The Session Management
- The Identity Management

The corresponding protocols are transmitted transparently via a Node B, that is, Node B does no longer alternate, use or apprehend the facts. Those protocols also are called Non-Access Stratum protocols.

The UE is a tool which initiates all the calls at the terminal device in a network. The inner architecture of the consumer system for LTE is same to the one used by UMTS and GSM that's without a doubt a Mobile Equipment (ME). The mobile equipment comprised of the subsequent essential modules [3]:

- mobile Termination (MT): communication features are handled by MT
- Terminal Equipment (TE): This terminates the information streams.

- Universal Integrated Circuit Card (UICC): this is also referred to as the SIM card for LTE equipment's. It runs a utility called the Universal Subscriber Identity Module (USIM).

A USIM stores consumer-unique statistics very just like 3G SIM card. This maintains information approximately about the consumer's smartphone number, domestic network identification and security keys and many others.

(ii) LTE RAN (E-UTRAN)

The architecture of evolved UMTS Terrestrial Radio Access Network [3] (E-UTRAN) is shown below:

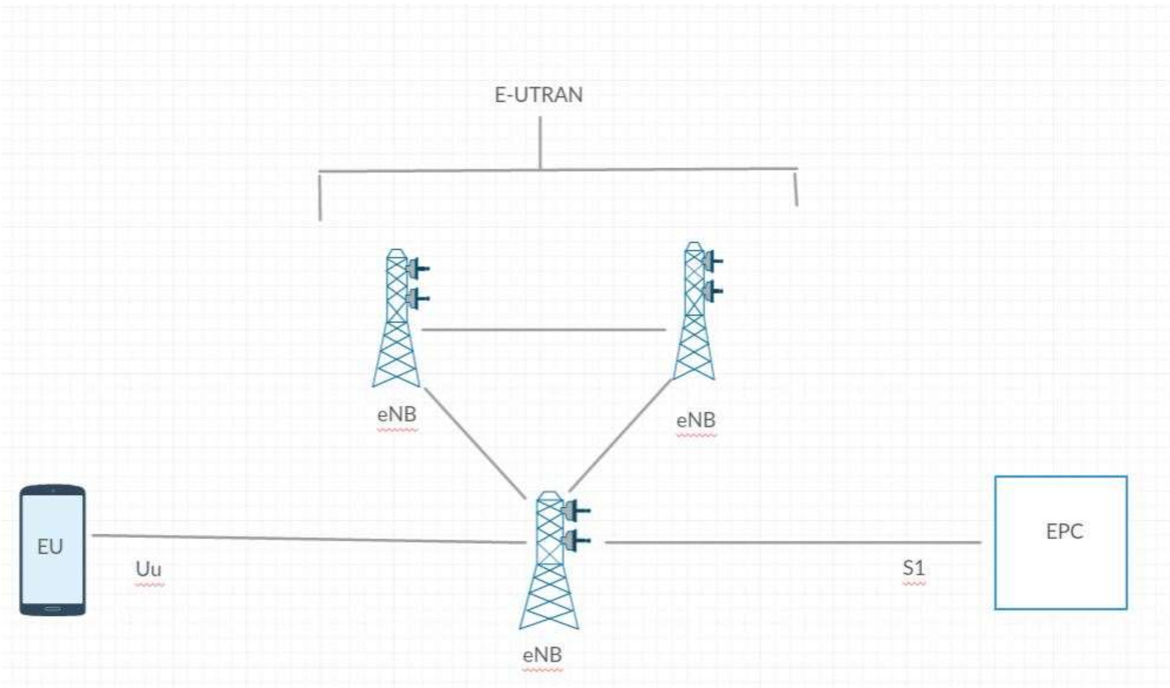


Figure 4. Radio Access Network Architecture for 4G

The E-UTRAN handles the radio communications between the mobile and EPC and simply has one component, the evolved base stations, referred to as eNodeB or eNB. Every eNB is a base station that controls the mobiles in one or greater cells. The base station this is interacting with a mobile is referred to as its serving eNB.

LTE Mobile communicates with just one base station and one mobile at a time and there are following major capabilities supported with the aid of eNB:

•The eNB sends and receives radio transmissions to all of the mobiles the use of the analogue and digital sign processing features of the LTE air interface.

•The eNB controls the low-degree operation of all its mobiles, by means of sending them signaling messages which include handover commands.

Each eNB connects with the EPC through the S1 interface and to the close by base stations via the X2 interface, that is specifically used for signaling and packet forwarding in the course of handover.

.

(iii) The Evolved Packet Core (EPC)

The EPC presents mobile core functionality that, in preceding cellular generations (2G, 3G), has been found out thru two separate sub-domains: circuit-switched for voice and packet-switched for data [3]. In LTE, those distinct cellular center sub-domains, used for separate processing and switching of cellular voice and information, are unified as a single domain.

The EPC has a packet-only structure. It's the first 3GPP machine without a circuit switch domain. The architecture of evolved Packet core (EPC) has been illustrated beneath. Those additives are just like the equipment identification register (EIR) and policy control and Charging rules function (PCRF).

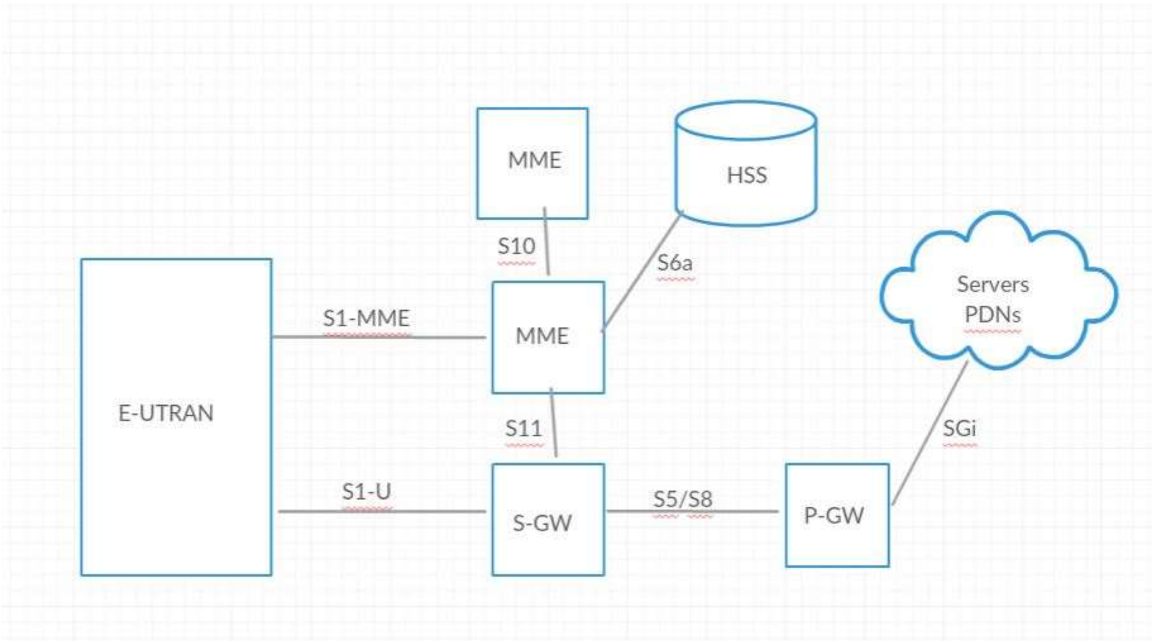


Figure 5. Evolved Packet Core

Underneath is a short description of every of the additives shown in the above architecture:

- The Home Subscriber Server (HSS) has been carried forward from UMTS and GSM and is a database that consists of statistics approximating all the N/W operator's subscribers.
- The Packet Data Network (PDN) - Gateway (P-GW) interconnects with the external by using SGi interface. Every packet data network is recognized by way of an Access point name (APN). The PDN gateway has the identical role like the GGSN and SGSN with the UMTS and GSM.
- S-GW performs like a router, and forwards the information among the base station and the PDN gateway.
- The mobility control entity (MME) controls the excessive-degree operation of the cellular by way of signaling the messages and HSS.
- PCRF is a part which is not shown inside the above diagram however it's answerable for policy control selection-making, in addition to for controlling the flow-based totally

charging functionalities within Policy Control Enforcement Function (PCEF), which resides inside the P-GW.

The interface between the serving and PDN gateways is referred to as S5/S8. This has barely extraordinary implementations, particularly S5 if the 2 devices are in the identical network, and S8 if they are in distinct networks.

5. EPC Architecture

The Evolved Packet core (EPC) is an all-IP mobile CN, offering a converged framework for IP-primarily based real-time/non-real-time programs and services [3][4]. The EPC presents the whole core functionality that, in preceding cell network generations was realized thru two separate domains: circuit-switched for voice and packet-switched for information.

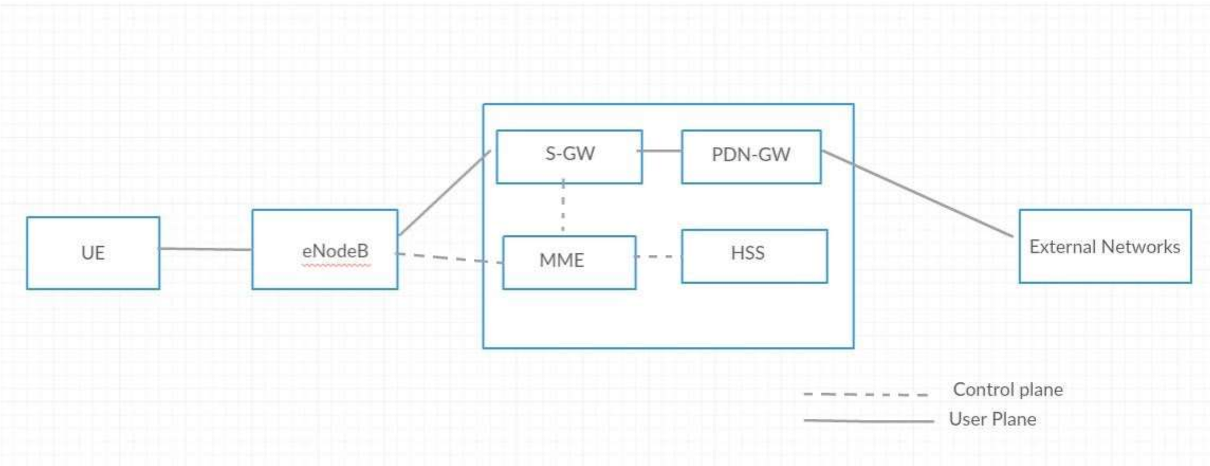


Figure 6. Architecture of Evolved Packet Core

The above figure shows the fundamental architecture of Evolved Packet System (EPS) such as UE, eNodeB and EPC. The UE interacts with EPC over E-UTRAN via eNodeB. The EPC includes 4 factors, they are Serving Gateway (S-GW), PDN Gateway, MME and HSS.

The EPC is designed to help non-3GPP access for cellular IP. Non-access stratum (NAS) is a further layer, which has been brought to defend security and safety internetworking among 3GPP and non-3GPP networks via ciphering and integrity safety. It also improves universal robustness. EPC handles user traffic plane and also has network manipulation entities for storing user subscription facts represented via HSS, determining the identification and privileges of a user and monitoring activities through authorization, authentication and accounting (AAA) server, and imposing charging and QoS policies through PCRF

.

5.1 Packet data network gateway (PDN-GW / P-GW)

The entity present inside the EPC which terminates the SGi interface towards packet data network is Packet data network gateway [4]. If there are more than one PDN connections for user equipment, then there are more than one P-GW concerned in the manner.

The functions of P-GW are as follows:

(i) IP address allocation
(ii) per-user packet filtering
(iii) gating control
(iv) rate enforcement
(v) lawful interception
(vi) uplink/downlink bearer binding
(vii) uplink bearer binding verification functions for the GTP-based network interfaces
(viii) uplink/downlink service level charging

It provides PDN connectivity to GERAN/UTRAN accomplished UEs in addition to E-UTRAN accomplished UEs using E-UTRAN or GERAN (or) UTRAN access networks. It provides PDN connectivity to E-UTRAN using E-UTRAN only over the S5/S8 interface.

5.2 Serving gateway(S-GW)

The entity present in the EPC which dismisses the interface toward E-UTRAN access network is S-GW [4]. There is only one S-GW assigned for each User Equipment.

The functions of S-GW are as follows:

(i) It routes and forwards the packets
(ii) It does event reporting to the PCRF
(iii) It provides uplink bearer binding verification along with the packet dropping of uncontrolled uplink traffic
(iv) It provides lawful interception
(v) It provides an anchor point for local mobility for inter-eNB handover
(vi) It provides transport-level packet marking in the uplink and downlink
(vii) It provides anchor point for mobility for inter-3GPP mobility
(viii) It provides uplink and downlink bearer binding toward 3GPP access

5.3 Mobility management entity

The (Non-Access Stratum) NAS signaling present among user equipment and CN which provides idle mode UE tracking and paging manner is managed via MME [4].

The 2 main functions of MME are:

(1) capabilities related to bearer control along with the status quo, protection, and launch of the bearers which might be handled by means of the session management function within the NAS protocol.

(2) Functions associated with connection control such as the established order of the connection and security association (SA) among the Network and UE which is treated via the connection or mobility control feature inside the NAS protocol.

Other functions include:

(i) It provides inter-node signaling for mobility between 3GPP access networks

(ii) In 2G/3G access networks, it provides SGSN selection for handovers
(iii) It provides authentication and roaming.
(iv) It helps in P-GW and S-GW selection by tracking area in list management
(v) It is a control-plane entity which performs mobility management functions including NAS signaling and security within EPS
(vi) Dedicated bearer establishment is one of the its bearer management functions

The MME creates a UE context whilst a UE is powered on and attaches to the network. It assigns a unique quick brief identity to the UE that identifies the UE context within the MME. This UE context holds person subscription records downloaded from the HSS. The nearby storage of subscription information inside the MME lets in faster execution of techniques, along with bearer establishment since it relaxes the need to frequently trade messages with the HSS. To reduce the overhead in the E-UTRAN and processing complexity within the UE, all UE-related records inside the network such as the radio bearers can be released at some point of lengthy durations of user state of being inactive, that's referred to as ECMIDLE state.

The MME keeps the UE context and the data approximately the set-up bearers at some point of these idle periods. To allow the network to interact an idle-mode UE, the UE provides the network with area replace every time it moves out of its modern-day monitoring area using a tracking vicinity replace technique. The MME is answerable for monitoring person location whilst the UE is in the ECM-IDLE. Upon availability of downlink information for an ECM-IDLE UE, the MME sends a paging message to all eNBs in the monitoring vicinity wherein the UE became currently located and the eNBs page the UE over the radio interface. Upon receipt of the paging message, the UE plays a service request system, which leads to transitioning to the ECM-CONNECTED state.

The UE-related statistics is thereby created within the E-UTRAN and the radio bearers are reestablished. The MME is accountable for the reestablishment of the radio bearers and updating the UE context inside the eNB. protection services are the obligation of the MME for each signaling and user records. whilst a UE attaches to the network, a mutual authentication of the UE and the network is carried out between the UE and the MME/HSS. This authentication procedure establishes the security keys that are used for encryption of the bearers.

5.4 Policy and Charging Rules Function

Policy and Charging Rules Function (PCRF) [4] a policy tool which plays a primary position in subsequent era networks. It's a part of evolved Packet core which determines policy policies inside the network. As opposed to implementing a policy on the prevailing network, a software aspect which operates on the network code is added. It charges the system in centralized way and can also get right of entry to the subscriber database. It has broader capacity role and strategic importance as it's far operated in real time.

The PCRF which is part of the architecture aggregates records to and from the network, operational assist systems, and different resources in real time, assisting the creation of regulations after which automatically making coverage choices for each subscriber lively on the network.

This sort of network would possibly provide multiple offerings, high quality of service (QoS) tiers, and charging policies. PCRF can offer a network agnostic solutions (cord line and wireless) and also can allow multi-dimensional technique which facilitates in developing a moneymaking and modern platform for operators. PCRF can also be included with unique structures like billing, rating, charging, and subscriber database or also can be deployed as a standalone entity.

5.5 Home subscriber server

The home subscriber server is the subscription data repository for all permanent consumer data. It keeps master copy of the subscriber profile, which incorporates data about the services that are relevant to the user [4]. It additionally saves the place of the user at the extent of visited network control node, inclusive of MME.

It's the entity containing the subscription-related records to support the network entities that take care of calls/sessions. A domestic N/W can also contain one or numerous HSSs depending on the quantity of mobile subscribers, the potential of the device, and the organization of the network. For instance, the HSS presents help to the call manipulate servers in order to complete the routing/roaming approaches through fixing authentication, authorization, naming/addressing resolution, region dependencies, and so forth.

The HSS is answerable for keeping statistics associated with user identity, numbering and addressing information, consumer security records, network access data for authentication and authorization.

The HSS supports the registration of the users and keeps inter-system location data as well as the user profile records. The HSS additionally generates user protection records for mutual authentication, communication integrity test, and ciphering. primarily based on this statistic, the HSS is likewise responsible for supporting the call decision manipulate and session management entities of the one-of-a-kind domains and subsystems.

6. E-UTRAN architecture

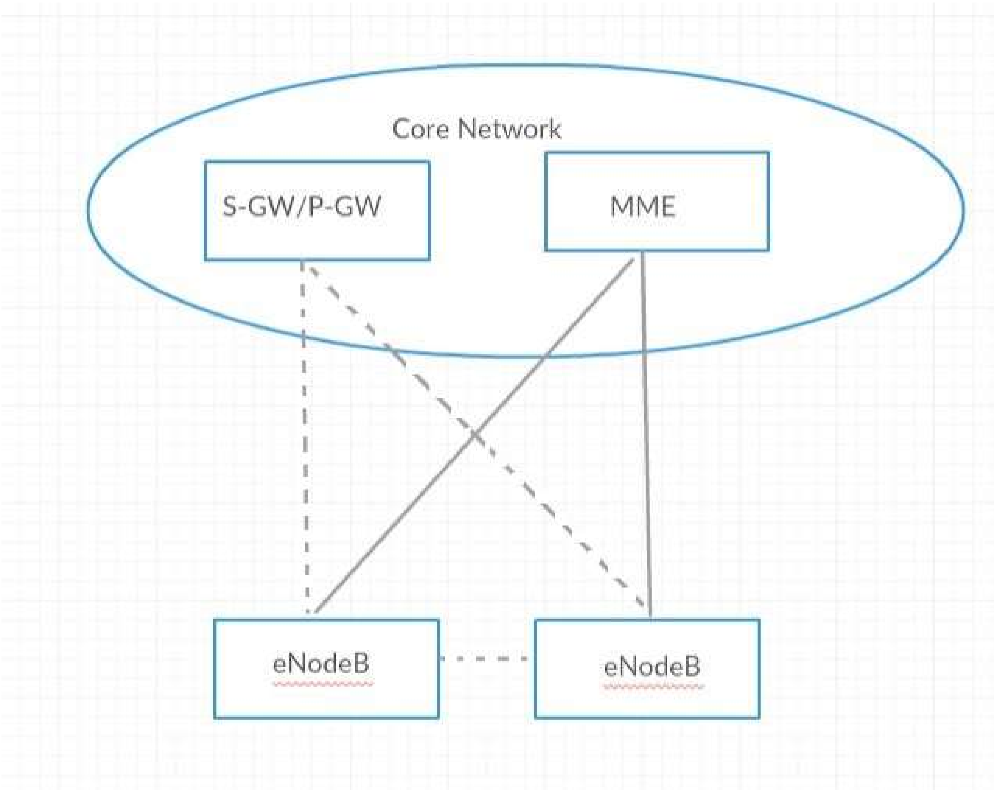


Figure 7. E-UTRAN Architecture

The E-UTRAN consists of a collection of eNBs linked in a network. Two eNBs are related with X2 interface and is linked to EPC by way of S1 interface [4]. The E-UTRAN consists of user plane and control plane terminations towards person equipment.

It is related to MME via S1-MME interface and to S-GW via S1-U interface. In LTE, the radio controller is included into the eNB which reduces latency and improves performance. It does not have a principal controller and is good in LTE because it does no longer help soft handovers hence decreasing fee, complexity and overhead. AS protocols are protocols between eNB and UE whereas NAS protocols are protocols between EPC and UE. The E-UTRAN is responsible for all radio-associated features that include RRM, the radio bearer control (RBC), the radio admission control (RAC), the radio mobility control, dynamic allocation and scheduling of the radio resources in each uplink and downlink, header compression and protection. As there may be no centralized controller available, the EPS have a provision available to keep away from data loss.

6.1 E-UTRAN Functions

The e-node B provides following functions and services [4]:

- It Encrypts the user data.
- It handles closed-subscriber group.
- It routes user-plane to S-GW.
- It provides IP header compression.
- It provides scheduling and transmission of broadcast information.
- It provides scheduling and transmission messages.
- It selects MME when UE attaches to network and no routing information provided by it.
- It provides dynamic allocation and scheduling of resources for the UE.
- It measures and reports configuration for mobility and scheduling.
- It handles emergency warning messages of transmission and scheduling.

6.2 E-UTRAN Interfaces

The two fundamental components of the E-UTRAN Network interface version are transport network layer and the radio network layer which can be further classified into User plane and control plane [4]. The user plane incorporates all user data in addition to application layer signaling whereas the control plane manages messages and techniques that are related to the radio interface. The protocols managed by user plane consist of session initiation protocol and real time protocol whereas control plane handles messages for handover.

The eNodeB's are interconnected by way of X2 interface and with Evolved packet (MME or S-GW) core over S1 interface. The S1 interface may be break up into control-plane (S1-MME) and user-plane (S1-U). The S1-MME is a signaling interface which supports functions and procedures between the eNB and the MME.

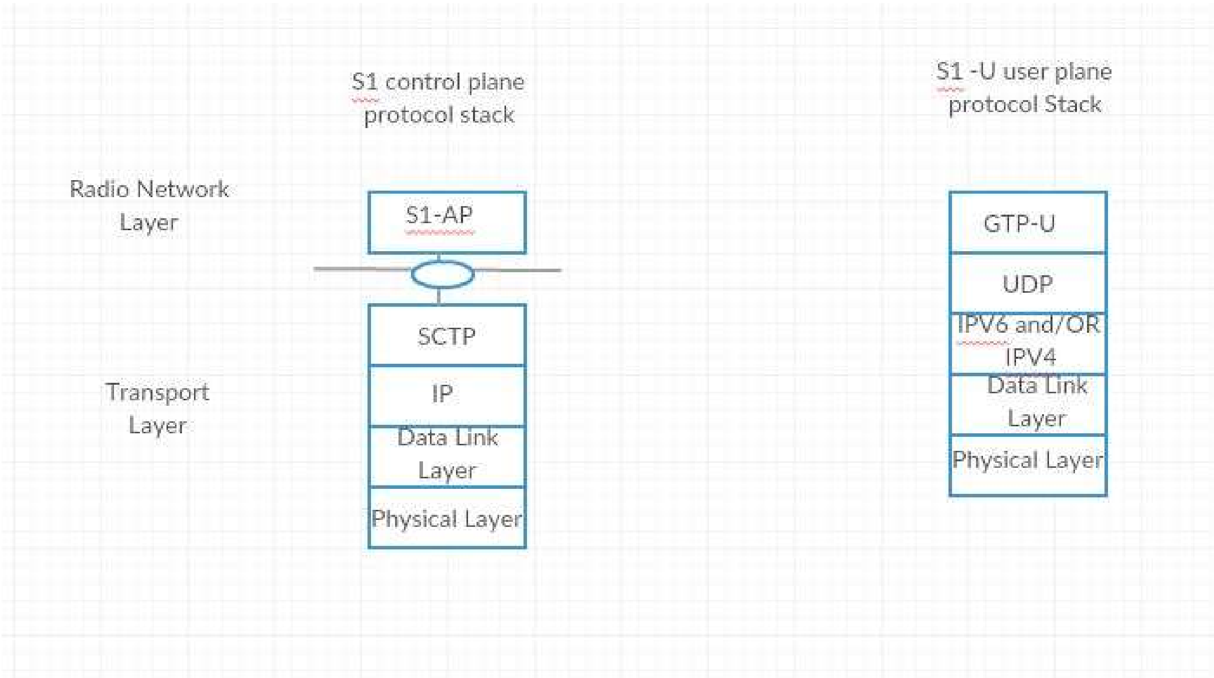


Figure 8. S1 Protocol Stack

All S1-MME signaling procedures belong to four main groups:

(1) bearer-level procedures

(2) handover procedures,

(3) NAS signaling transport

(4) paging procedure

In S1-MME interface stream control transmission protocol (SCTP) is used to avoid delays and message retransmissions whereas S1-U interface utilizes GPRS Tunneling Protocol (GTP) in order to transport user data between eNodeB and S-GW. It does not have any error control technique to check if data has been successfully been delivered. The control-plane signaling protocol which is between the eNB and the MME is known as S1 application part. It uses SCTP and supports the S1-MME interface, thus ensuring that the messages between the MME and the eNB are delivered.

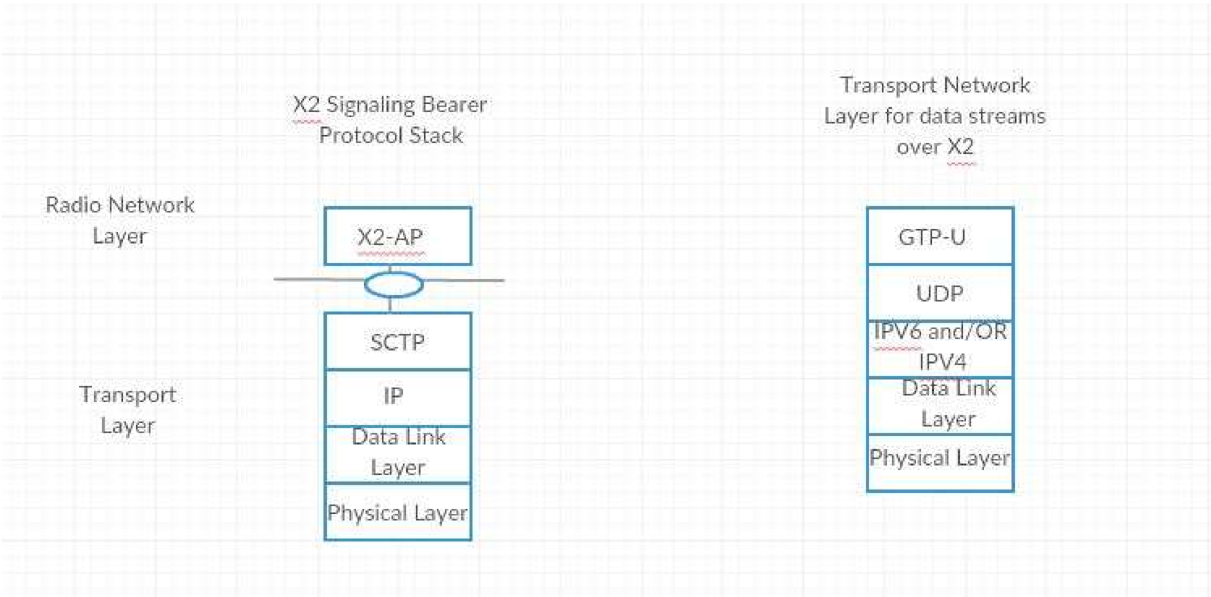


Figure 9. X2 Protocol Stack

Multiple eNBs are connected together by X2 interface. Data forwarding is simplified by LTE as it uses the same protocol structure for S1 and X2 interfaces. The X2 interface consists of User plane(X2-U) and control plane (X2-C). The User plane transports user data packets between eNodeB's. when the User equipment transfers from one eNodeB's cell area to another and provides forwarding of buffered packet data. Over the S1-U interface, the GTP tunneling is utilized by the X2-U interface.

The X2-C procedures are all related to user mobility between eNBs. The load management and handover coordination are managed by X2AP which is the control plane protocol. SCTP protocol is used for reliable transport of signaling between nodes for X2-C.

6.3 E-UTRAN Identifiers

The principle of handling of Application Protocol Identities when a new connection is created an Application Protocol Identity (AP ID) is allocated [13]. It uniquely identifies a connection within a node which can be either an eNB or MME . when the receiving node receives, the message containing the AP ID from sending node, it stores the AP ID for the duration of the connection and will include the previously received new AP ID to identify the connection to the UE. In all succeeding messages to and from sending node, AP IDs of both sending and the receiving node shall be included.

The definitions of AP IDs as used on S1 interface or X2 interface are shown below [5]

eNB UE S1AP ID:

An eNB UE S1AP ID might be assigned to particularly recognize the UE over the S1 interface inside an eNB. When a MME gets an eNB UE S1AP ID it should store it for the term of the UE-related sensible S1-association for this UE. When known to a MME, this IE is incorporated into all UE related S1-AP flagging. The eNB UE S1AP ID might be one of a kind inside the eNB logical node.

MME UE S1AP ID:

A MME UE S1AP ID might be assigned to particularly recognize the UE over the S1 interface inside the MME. When an eNB gets MME UE S1AP ID it should store it for the term of the UE-related sensible S1-association for this UE. When known to an eNB this IE is incorporated into all UE related S1-AP flagging. The MME UE S1AP ID might be one of a kind inside the MME logical node.

Old eNB UE X2AP ID:

An Old eNB UE X2AP ID might be assigned to particularly recognize the UE over the X2 interface inside a source eNB. At the point when an objective eNB gets an Old eNB UE X2AP ID it should store it for the term of the UE associated sensible X2-association for this UE. When known to an objective eNB this IE is incorporated into all UE related X2-AP flagging. The Old eNB UE X2AP ID might be one of a kind inside the eNB logical node.

New eNB UE X2AP ID:

A New eNB UE X2AP ID might be allotted in order to remarkably distinguish the UE over the X2 interface inside an objective eNB. At the point when a source eNB gets a New eNB UE X2AP ID it should store it for the term of the UE associated legitimate X2-association for this UE. When known to source eNB this IE is incorporated into all UE related X2-AP flagging. The New eNB UE X2AP ID should be one of a kind inside the eNB logical node.

eNB1 Measurement ID:

An eNB1 Measurement ID should be designated in order to remarkably distinguish the estimation arrangement over the X2 interface inside the eNB that demands the estimation. The eNB1 Measurement ID might be one of a kind inside the eNB logical node.

eNB2 Measurement ID:

An eNB2 Measurement ID should be assigned to particularly distinguish the measurement configuration over the X2 interface inside the eNB that plays out the estimation. The eNB2 Measurement ID might be one of a kind inside the eNB logical node.

There are unique identifiers for UE in E-UTRAN.

The E-UTRAN assigns unique identities to the UEs at the cell level. The UE resource allocations are temporarily identified by E-UTRAN identifiers. In the active state, they also help in UE specific control signaling. They [12] are

Identities	Description
C-RNTI	• Unique identification at cell level • Identifies RRC connection • Used for scheduling
Semi-Persistent Scheduling C-RNTI	• Unique identification used for semi-persistent scheduling
Temporary C-RNTI	• Identification used for the random access procedure
TPC-PUSCH-RNTI	• Identification used for the power control of PUSCH
TPC-PUCCH-RNTI	• Identification used for the power control of PUCCH
RA-RNTI	• Unambiguously identifies which time-frequency resource was utilized by the UE to transmit the Random Access preamble
MME-Id	• Identify the current MME for UE • S-TMSI contains MME-Id
ECGI	• E-UTRAN Cell Global Identifier • Identifies Cells globally using MCC, MNC, ECI
ECI	• Identifies cells within PLMN • Broadcasted in every cell
eNB-Id	• Identifies eNB within a PLMN • Contained within ECI
Global eNB Id	• Identifies eNB globally with MCC, MNC, eNB-Id
TAI	• Tracking Area Identity [MCC, MNC, TAC] • Broadcasted in every cell
EPS Bearer Id	• Identify EPS Bearer used at Uu interface
E-RAB Id	• Identify E-RAB allocated to UE used at S1 ® X2 • The value of E-RAB Id is same to EPS Bearer Id
eNB S1AP UE Id	• Temporary UE Id on S1-MME interface in eNB
PLMN Id	• Identifies PLMN of the cell providing access • Broadcasted in every cell

Table 1: E-UTRAN Identifiers [26]

7. Support for RRH in E-UTRAN

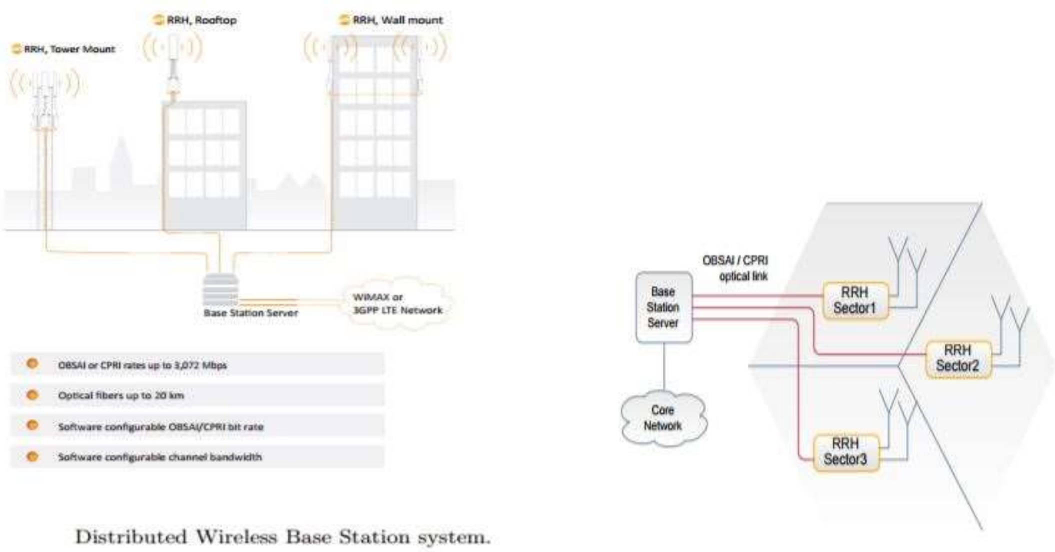


Figure 10. Remote Radio Head [27]

Cellular tower is a little structure at the tower's base [14]. These six-foot tall atmospheres controlled houses the base station (BS) hardware that empowers remote correspondence between the versatile client and cell. Long coaxial link associate the BS on the ground to reception apparatuses on the highest point of the tower. For quite a long time this design stayed unaltered. Be that as it may, as cost and productivity began turning out to be progressively critical to remote administrators, it was the ideal opportunity for an option.

An option arrangement is a dispersed base station, in which most of the base station apparatus is no longer situated in the sanctuary, however it is a fenced in area at the highest point of the tower close to the reception apparatuses. This different yet incorporated radio frequency (RF) unit is known as a remote radio unit or remote radio head. It is smaller in size; by and large no bigger than two feet by one foot by six inches.

The remote radio head is associated with the base station by means of a fiber optic connection. This lessens the coaxial sustain, increment framework proficiency, and give an abnormal state of adaptability in cell site development. While remote radio heads offer novel points of interest, they likewise accompany multifaceted nature because of the sheer number of segments that are required to fabricate the unit.

Given that remote radio heads are introduced at the highest point of the tower in extremely brutal ecological conditions, withstanding the climate is an essential test. Guaranteeing ideal execution is additionally basic, as access to the tower top is harder and all the more exorbitant if repair or substitution work should be finished.

One recent deployment trend, this is foreseen to be extensively carried out to LTE networks consists of splitting the base station functionalities into a baseband unit, which performs the scheduling and the baseband processing functions, and some of the RRHs answerable for all RF transmission/reception. The baseband processing unit is commonly positioned at the center of the cell and is connected through the optical fiber to the RRHs. Further to suppressing the feeder loss (since the energy amplifier is right now near the antenna), this method allows a baseband processing unit to control unique radio sites in a central manner. moreover, having geographically separated RRHs managed from the same location enables either centralized baseband processing devices mutually coping with the operation of numerous radio sites or the exchange of very low-latency coordination messages among individual baseband processing units.

Distributed base stations with RRHs can substantially help cellular operators to overcome price, overall performance, and efficiency problems while addressing the increasing call for better capacities in cell networks. Multimode radios operating in line with GSM, HSPA, LTE, and wi-fi standards and advanced software configurability are the key capabilities in the deployment of more flexible and energy-efficient radio networks. wireless and mobile network operators face the continuing project of upgrading their networks to effectively control high user traffic rates. Mobility and an expanded stage of multimedia content material for users require end-to-end network adaptations that support each new services and the multiplied demand for broadband and flat-rate internet access. Further, network operators need to recollect the most price-effective evolution of the networks closer to new generations. wireless and mobile generation standards are evolving towards better bandwidth requirements.

7.1 Architecture of Remote Radio Head

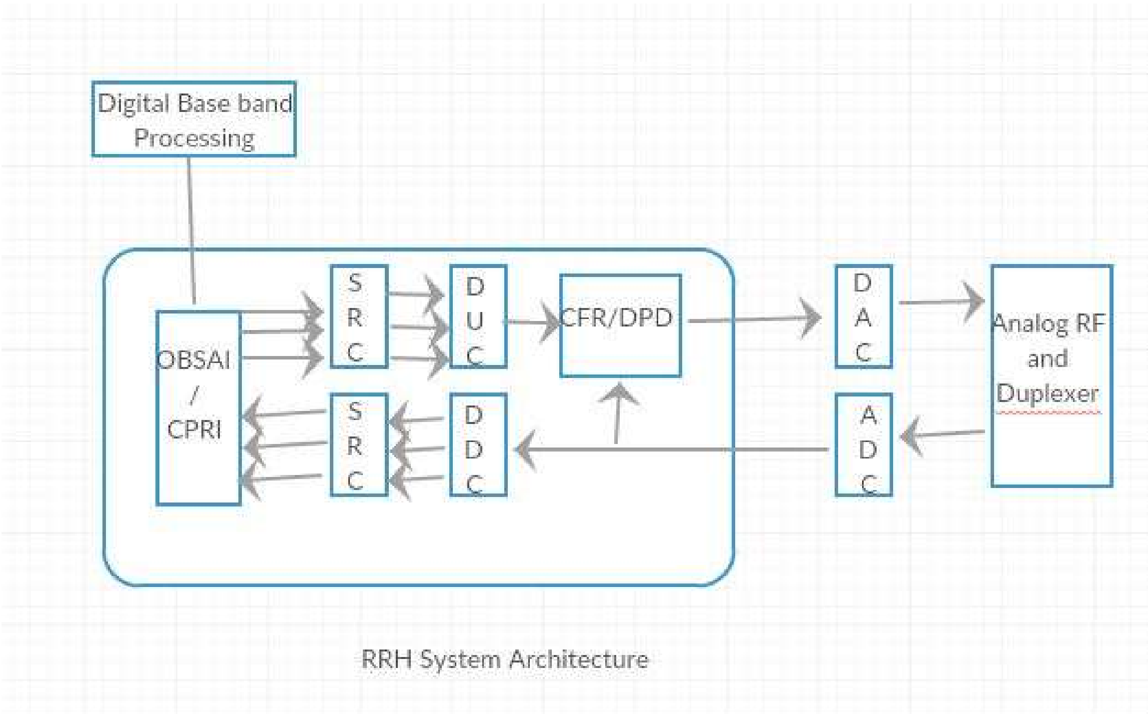


Figure 11. Architecture of Remote Radio Head

Typical advanced processing algorithms about RRHs include DUC or DDC, CFR, and DPD [14]. Where DUC or DDC stands for digital-up conversion or digital-down conversion, CFR stands for Crest factor reduction and DPD stands for digital pre-distortion**.** DUC interpolates baseband statistics in accordance with higher pattern quantity by means of a cascade of interpolation filters. It, in addition, mixes the complex information channels along IF service indicators so that much of RF modulation perform is simplified. CFR reduces the peak-to-average power ratio on the records hence that does not add the non-linear place concerning the RF rule amplifier [15]. DPD estimates the distortion triggered by the non-linear impact over the monitoring amplifier or pre-compensates the data. CFR or DPD defend the data, mitigate the impact on rule amplifier non-linear distortions, then extend the process range. However, CFR and DPD are computationally intensive and are necessary to help entirely high throughput flowing data. A FPGAs are the flawless platform for computationally-intensive RRH designs. Abundant hardened multipliers regarding an FPGA provide speed, area, and power reduction because notably arithmetic RRH implementations.

The today's requirements HSPA1, cell WiMAX, LTE/LTE-Advanced can fulfill today’s demand because high-performance cell capabilities and fast or dependable get access to the Internet anywhere or anytime. The network improvements required after deployment of networks have to be stable with the restricted presence on the latter spectrum, leverage present spectrum, then insure helpful process of the preferred wi-fi standards. Distributed open base station structure principles have developed in analogy stability together with the upward slope on the requirements after providing a flexible, low-cost, or scalable modular environment for managing the radio access. For example, OBSAI, CPRI requirements introduced measuring interfaces setting apart the bad status server or the RRH piece about a lousy station by using an optical fiber. The RRH notion constitutes an imperative part over a cutting-edge base station architecture. The RRH-based law implementation is pushed by way of the need in accordance with decrease each capital expense (CAPEX) and operational expenditure (OPEX) consistently, as approves an optimized then energy-efficient deployment. The structure where 2G/3G/4G bad stations are connected to RRHs upon optical fibers. Either CPRI then OBSAI can also stay used according to carry RF indicators in imitation of the RRH to cover a three-sector cell. The RRH accommodates a huge quantity on digital interfacing then technology functions. It also includes high-performance, efficient, and frequency-agile analog functions.

8.Mobility Management

The NAS is a set of protocols in the EPS [6][7]. The NAS is used to convey non-radio access- related signaling between the UE and the MME for an E-UTRAN access. The NAS procedures are grouped into two categories: EMM and ECM. The Mobility Management states that result from the mobility management procedure are described as EPS Mobility Management(EMM).

The two states are descried below:

- EMM-DEREGISTERED
- EMM-REGISTERED

The signaling connectivity between the UE and the EPC is described by EPS Connection Management (ECM)

There are two states described in ECM:

- The ECM IDLE
- The ECM CONNECTED

The ECM and EMM states are not dependent on each other. Transition of EPS Mobility Management from REGISTERED to DEREGISTERED can occur irrespective of the ECM state, e.g. by way of specific detach signaling in ECM-CONNECTED or by implicit detach in the MME in the course of ECM IDLE. However, the User Equipment must be in an ECM CONNECTED state for some relations such as from transition from EMM-DEREGISTERED to EMM-REGISTERED

8.1 EPS Mobility Management States

EMM DEREGISTERED

In this state, EMM conditions in MME doesn't hold a valid location or routing statistics for the UE [6][7]. The UE is not reachable by way of a MME, as the UE area is now not known. In the EMM-DEREGISTERED state, some UE context can still be saved in the UE and MME, e.g. to avoid jogging an AKA technique throughout all Attach process. All through the effective techniques of Inter-RAT RAU /TAU/handover and ISR activated is no longer indicated to the UE, the historic S4 SGSN/old MME modifications to the EMM state of the UE to GPRS-IDLE/EMM-DEREGISTERED/PMM-DETACHED.

EMM REGISTERED

The UE achieves the EMM-REGISTERED state by an effective enrollment with an Attach method to the E-UTRAN. The MME arrives in the state of EMM-REGISTERED by Tracking-Area-Update system for a UE choosing an E-UTRAN cell from GERAN/UTRAN or by an Attach method by means of E-UTRAN. In the EMM-REGISTERED express, the UE can get administrations that require enrollment in the EPS. The UE area is known in the MME to no less than a precision of the following territory list distributed to that UE.

In the EMM-REGISTERED state, the UE shall:

- have no less than one PDN connection which is active.
- Prepare the context of EPS security.

After executing the Detach process, the state is modified to EMM-DEREGISTERED in UE and MME. During reception of the TAU Reject and attach Reject messages the movements of the UE and MME rely upon the 'cause value' within the reject message, but, in many instances the state is modified to EMM-DEREGISTERED in the UE and within the MME. If all the bearers belonging to a UE are launched, the MME shall alternate the MM state of the UE to EMM-DEREGISTERED.

If the UE camps on E-UTRAN and the UE detects that every one of its bearers are released, the UE shall trade the MM state to EMM-DEREGISTERED. If all of the bearers belonging to a UE are launched, whilst the UE camps on UTRAN /GERAN, the UE shall deactivate ISR by way of setting its TIN to "P-TMSI". This ensures that the UE performs tracking area update whilst it re-selects E-UTRAN. If the UE switches off its E UTRAN interface while performing handover to non-3GPP access, the UE shall change its MM state to EMM-DEREGISTERED.

After the Implicit Detach timer expires, the MME can also perform an implicit detach any time. The state is changed to EMM-DEREGISTERED inside the MME after performing the implicit detach.

8.2 Main EPS Connection Management States

ECM-IDLE

when no NAS signaling connection among UE and network exists then the UE is in ECM-IDLE [6][7]. In ECM-IDLE state, a UE undergoes selection/reselection of cell.

In ECM-IDLE state there exists no UE context in E-UTRAN for the UE as well as there is no S1_MME and no S1_U connection for the UE.

Inside the EMM-REGISTERED and ECM-IDLE state, the UE shall:

- perform a monitoring area update if the present TA isn't always inside the list of TAs that the UE has acquired from the network so that it will keep the registration and allow the MME to page the UE.
- perform the periodic tracking place updating procedure to inform the EPC that the UE is available.
- carry out a monitoring location update if the RRC (Radio resource control) connection became launched with launch reason "load balancing TAU required".

- carry out a tracking area update when the UE reselects an E-UTRAN cell and the UE's TIN suggests "P-TMSI".
- perform a monitoring area replace for an alternate of the UE's core network functionality records or the UE particular DRX parameter.
- perform a tracking region update when the UE manually selects a CSG cell, and the CSG identification of that cell is not present from both E's Permitted CSG-list and UE's Operator CSG-list.
- solution to paging from the MME through acting a service request process.
- carry out the provider request process a good way to set up the radio bearers while uplink user data is to be sent.

The UE and the MME shall enter the ECM-linked state whilst the signaling connection is hooked up amid the UE and the MME. Early NAS messages initiate that change from ECM-IDLE to ECM-CONNECTED state are the attach Request, carrier Request or Detach Request, tracking location-update Request. The UE and the network can be unsynchronized in ECM IDLE state, i.e. the UE and the network might also have exclusive units of established EPS bearers. when the UE and the MME input the ECM connected state, the set of EPS Bearers is synchronized among the UE and network.

ECM-CONNECTED

The UE vicinity is known within the MME with an accuracy of a serving eNodeB identification. The mobility of UE is handled by way of the handover. The UE plays the tracking area update process whilst the TAI within the EMM device knowledge area is not inside the list of TA's that the UE registered with the network, or when the UE handovers to an E UTRAN cell and the UE's TIN shows "P-TMSI".

For a UE in the ECM-CONNECTED state, signaling connection exists between the UE and the MME . It is made of two elements: an RRC connection and an S1_MME connection. The UE shall arrive in the ECM-IDLE state when its signaling connection to the MME has been released or damaged. This release or failure is explicitly indicated by way of the eNodeB to the UE or detected by way of the UE. The S1 release technique modifies the state at each UE and MME from ECM- CONNECTED to ECM-IDLE.

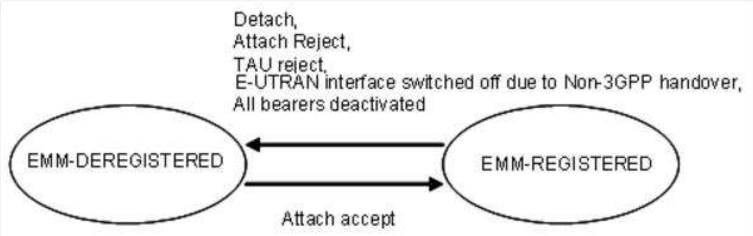


Fig. 1. EMM state model in UE

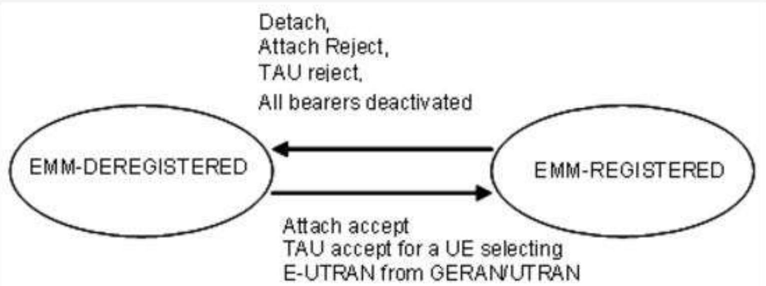


Fig. 2. EMM state model in MME

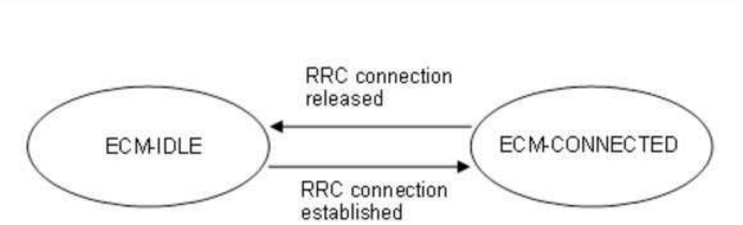


Fig. 3. ECM state model in UE

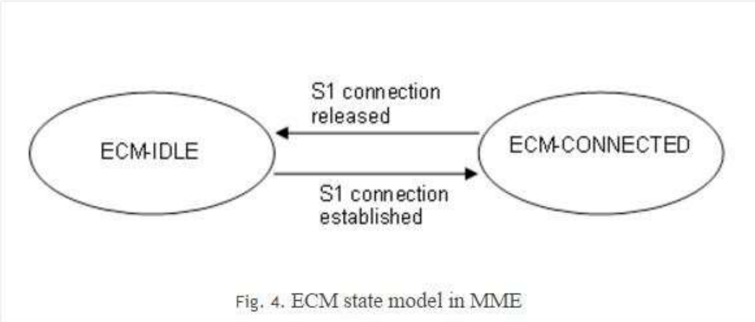


Figure 12. Mobility Management States [7]

9. Radio Resource Management

The reason for RRM capacity is to guarantee proficient utilization of the accessible system assets [4]. Specifically, RRM in E-UTRAN gives a way to oversee (e.g., allot, reassign, and discharge) radio assets in single and multi-cell situations. RRM might be dealt with as a focal application at the eNB in charge of interworking between various conventions (RRC, S1AP, and X2AP) so messages can be legitimately exchanged to various hubs crosswise over Uu, S1, and X2 interfaces. RRM may interface with operation and administration works keeping in mind the end goal to control, screen, review, or reset the status because of mistakes at a convention stack. The RRM comprises of the accompanying primary capacities.

• **Radio admission control**: The RAC practical module acknowledges or rejects demands for the foundation of new radio bearers. Confirmation control is performed by required QoS, current framework stack, and the required administration. The RAC work guarantees effective radio asset use by tolerating radio bearer for whatever length of time that radio assets are accessible, and legitimate QoS implementation for current sessions by dismissing radio carrier demands. It communicates with the RBC module to play out its capacities.

• **Radio bearer control:** The RBC useful module deals with the foundation, support, and arrival of radio bearers. It arranges the radio assets relying upon the present asset accessibility and utilization, and in addition QoS necessities of new and progressing sessions because of portability or different reasons. The RBC work discharges radio assets connected with radio bearers at session end, handover, or other comparable cases. The foundation, upkeep, or arrival of radio bearers is fixing to the design of radio assets connected with them.

• **Connection mobility control:** The CMC practical module oversees radio assets in the connected and idle modes. In idle mode, this module characterizes criteria and calculations for cell determination, reselection, and area enlistment that help the UE in selecting or outdoors on the best cell. Also, the eNB communicates parameters that arrange the UE estimation and reporting systems. In connected mode, this module deals with the portability of radio associations without disturbance of administrations. Handover choices might be founded on estimation reported by the UE, by the eNB, and different parameters arranged for every cell. Handover choices may consider extra data, for example, neighbor cell stack condition, movement circulation, transport and equipment assets, and administrator characterized strategies. Between RAT RRM can be one of the subsets of this capacity in charge of dealing with the assets in between RAT versatility and handovers. In the sit out of gear mode, the cell reselection calculations are controlled by setting of parameters (e.g., limits and hysteresis values) that characterize the best cell as well as decide when the UE ought to choose another cell. The E-UTRAN communicate parameters that arrange the UE estimation and reporting methods.

• **Dynamic Resource Allocation (DRA) or Packet Scheduling (PS):** The assignment of DRA or PS is to designate and de-apportion assets to client and control-plane bundles. The planning capacity ordinarily considers the QoS necessities connected with the radio bearers, the channel quality criticism from the UEs, support status, between cell/intra-cell impedance condition, and so forth. The DRA capacity may consider the limitations or inclinations on a portion of the accessible asset pieces or asset square sets because of inter cell interference coordination (ICIC) contemplations.

• **Inter-cell Interference Coordination:** ICIC work oversees radio assets with the end goal that intercell obstruction impacts are minimized. The ICIC is basically a multi-cell RRM work that considers asset use status and the activity stack conditions over numerous phones.

• **Load Balancing (LB):** LB has to take care of non-uniform conveyance of the activity stack over different cells. The reason for LB capacity is to control the heap dissemination in such a way, to the point that radio assets are productively used; to keep up the QoS of the present sessions however much as could reasonably be expected and to minimize the likelihood of call drops. The LB calculations may bring about handover or cell reselection choices with the motivation behind redistributing activity from over-burden cells to under-used cells.

• **Inter-RAT radio Resource Management:** Inter-RAT RRM is fundamentally worried with the administration of radio assets regarding Inter RAT versatility and RAT handover. Amid between RAT handover, the handover choice may consider the included RATs asset accessibility and additionally the UE abilities and the administrator arrangements. Between RAT RRM may likewise incorporate extra capacities for between RAT stack adjusting for the sit still mode and associated mode UEs.

• **Subscriber profile ID (SPID) for RAT/frequency priority**: The RRM work maps SPID parameters got by means of the S1 interface to a privately characterized setup keeping in mind the end goal to apply particular RRM systems (e.g., to characterize RRC_IDLE mode needs and control between RAT/between recurrence handover in RRC_CONNECTED mode). The SPID is a file alluding to client data, for example, versatility profile and administration utilization profile. The SPID data is UE-particular and applies to the majority of its radio bearers. The RRM methodology in E-UTRAN might be founded on client particular data.

10. Quality of Service

The end-to-end QOS experienced by an end client comes because of a blend of components all through the protocol stack and E-UTRAN/EPC parts [4]. In this way, the execution assessment of the administration requires a nitty gritty execution examination of the whole system, that is, from the UE up to the application server (AS) or remote UE. The QoE is a subjective estimation of the quality experienced by a client when he/she utilizes a correspondence benefit. At the end of the day, the QoE is characterized as the general adequacy of an application or an administration as saw subjectively by the end client. While assessing the QOS, the goal is to improve the operation of the system from a viewpoint which is absolutely in light of target parameters, or to decide the quality that the client is really encountering and its fulfillment level. The QoE considers the fulfillment of a client as far as both substance and application execution. In this sense, the presentation of cell phones has been a quantitative jump in client QoE Expectations.

The QoE has been customarily assessed through subjective tests did with the clients keeping in mind the end goal to evaluate their fulfillment with a mean sentiment score esteem. This approach can be very costly, tedious, and can't be utilized for constant basic leadership to enhance the QoE. New strategies have been risen as of late to appraise the QoE in light of certain execution markers connected with administrations. A conceivable answer for immediately assess the QoE is to coordinate the QoE examination devices in the portable terminal itself. On the off chance that portable terminals can report the estimations to a focal server, the QoE appraisal process is essentially improved. Different arrangements are centered around including new system components that are in charge of catching the movement from a specific administration and examining its execution. Now and again, the assessment of video-spilling quality in the portable terminals is tended to by observing target parameters. As said before, the E-UTRAN comprises of a system of eNBs which are commonly interconnected by method for a X2 interface and to the EPC by means of a S1 interface. The eNB substance assumes a basic part in keeping up the end-to-end QoS. The eNB performs QoS-related capacities which incorporate confirmation control and asset reservation; planning and circulation of radio assets among the set up bearers; and L1/L2 convention arrangement as per the QoS traits connected with the carrier. The LTE-empowered UEs may bolster numerous applications in the meantime, each having diverse QoS necessities. This is accomplished by setting up various EPS bearers for each QoS stream. The EPS bearers can be characterized into two classes in light of the attributes of the QoS they give: GBR bearers in which assets are for all time assigned and non-GBR bearers which don't ensure a specific piece rate. In the network, it is the eNB's duty to guarantee that the QoS necessities for a specific carrier over the radio interface are met. Every carrier has a related QCI, packet delay budget and admission packet loss rate; and an ARP utilized for call admission control. The IP bundles mapped to the same EPS carrier get a similar conveyor level parcel sending treatment. Subsequently, the UE is not just in charge of asking for the foundation of EPS bearers for each QoS stream, additionally to perform separating in the uplink into various bearers in view of TFTs, as P-GW accomplishes for the downlink . It was said before that one EPS Bearer/E-RAB is built up when the UE associates with a PDN, and that remaining parts set up all through the lifetime of the PDN association with give the UE dependably on IP availability to that PDN. That conveyor is alluded to as the default carrier. Any extra EPS bearer/E-RAB that is built up to the same PDN is alluded to as a devoted carrier. The default carrier QoS parameters are relegated by the system based upon membership information. The choice to set up or alter a devoted carrier must be taken by the EPC and the bearer level QoS parameter qualities are constantly doled out by the EPC.

11. Encapsulation

There are seven layers, marked 1 to 7, with layer 1 at the base of the convention stack [4] . Every layer is plainly known as a N layer. A N11 element (at layer N11) asks for administrations from a N element at layer N. At every level, two substances (N-element peers) communicate by method for the N convention by transmitting packet data units (PDU). An administration information unit (SDU) is a particular unit of information that has been passed down from an OSI layer to a lower layer, and which the lower layer has not yet epitomized into a PDU. A SDU is an arrangement of information that is sent by a client of the administrations of a given layer, and is transmitted semantically unaltered to a companion benefit client.

The PDU at a layer N is the SDU of layer N21. Indeed, the SDU is the payload of a given PDU. That is, the way toward changing a SDU to a PDU comprises of an exemplification procedure, performed by the lower layer. All information contained in the SDU gets to be epitomized inside the PDU. The layer N21 includes headers/sub-headers and cushioning bits (if important to modify the size) to the SDU, changing it into the PDU of layer N. The additional headers/sub-headers and cushioning bits are a piece of the procedure used to make it conceivable to get information from a source to a goal.

A PDU is a data trade between associate elements of a similar convention layer situated at the source and goal. On the descending course, the PDU is the information unit produced for the following lower layer. On the upward heading, it is the information unit got from the past lower layer. A SDU, then again, is an information unit traded between two neighboring convention layers. On the descending course, the SDU is the information unit got from the past higher layer. On the upward course, it is the information unit sent to the following higher layer

12. EUTRAN Protocol Stack

The following sub-layers are present in user plane protocol stack present between e-NodeB and UE [8]:

1.The Packet Data Convergence Protocol (PDCP)

2.Radio Link Control(RLC)

3. Medium Access Control (MAC)

Packets within the core network (EPC) are encapsulated in a specific EPC protocol and tunneled between the P-GW and the eNodeB in the user plane. Relying on the interface specific tunneling protocols are used. GPRS Tunneling Protocol (GTP) is used on the S1 interface among the eNodeB and S-GW and at the S5/S8 interface among the S-GW and P-GW.

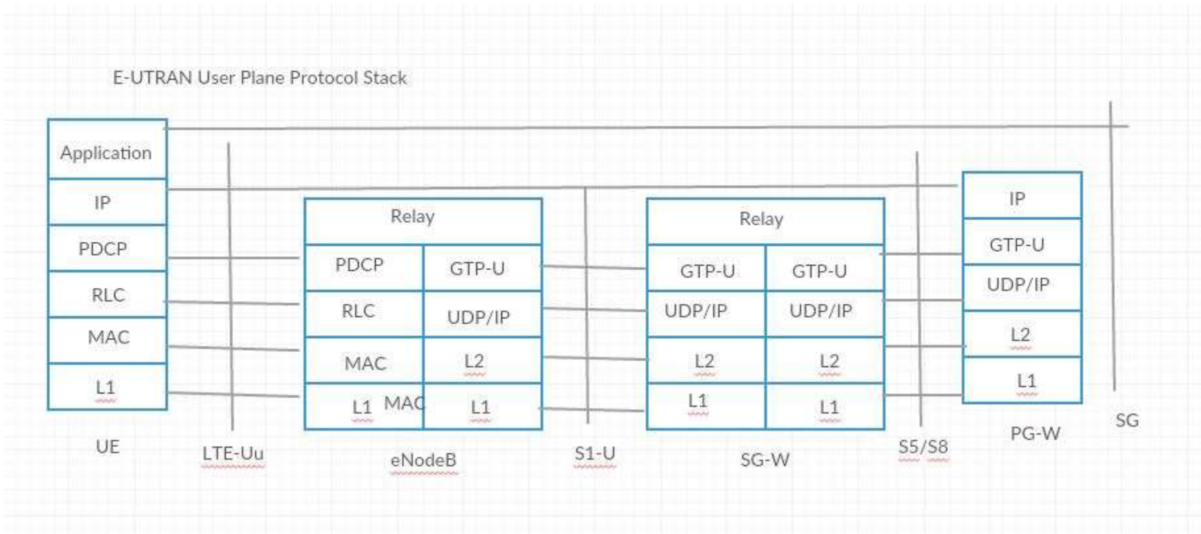


Figure 13. E-UTRAN User Plane Protocol Stack

The Radio Resource Control (RRC) protocol is referred to as “layer three” inside the AS protocol stack. it is the principle controlling function in the AS, being answerable for organizing the radio bearers and configuring all of the lower layers by means of RRC signaling between the eNodeB and the UE.

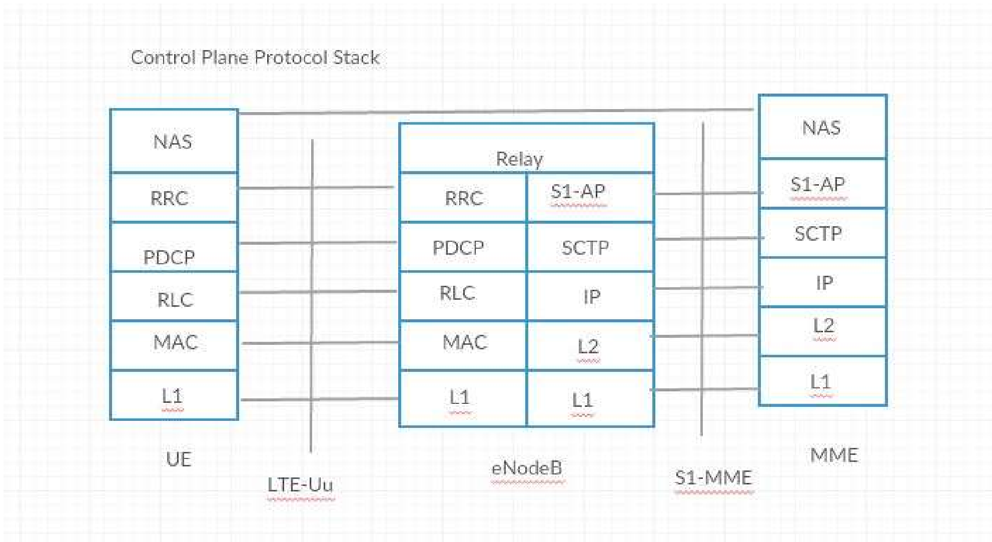


Figure 14. E-UTRAN Control Plane Protocol Stack

12.1 Protocol stack for S1 user-plane

The S1 user-plane interface (S1-U) is a well-known reference point between the eNB and the S-GW [4]. The S1-U interface offers non-guaranteed transport of user plane PDUs between the eNB and the S-GW. The transport network layer is constructed on IP transport and GTP-U is used on pinnacle of UDP/IP to lift the user-plane PDUs between the eNB and the S-GW.

12.2 Protocol stack for S1 control-plane

The standard reference point between the eNB and the MME is the S1 control-plane interface (S1-MME) [4]. The transport N/W layer is based on IP transport, like the client plane, yet for the dependable transport of flagging messages, SCTP is included on top of the IP layer. The application layer signaling protocol is alluded to as S1-AP. The SCTP layer ensures delivery of application layer messages. The IP layer indicate that direct transmission is utilized to convey the flagging PDUs. A solitary SCTP affiliation for every S1-MME interface occasion is utilized with one sets of stream identifiers for S1-MME regular techniques. Just a couple sets of stream identifiers ought to be utilized for S1-MME-committed methodology. MME correspondence setting identifiers that are doled out by the MME for S1-MME dedicated strategies and eNB correspondence setting identifiers that are allotted by the eNB for S1-MME-committed methods are utilized to recognize UE-particular S1-MME flagging transport bearers. The correspondence setting identifiers are passed on in the particular S1AP messages. On the off chance that the S1 flagging transport layer informs the S1AP layer that the flagging association is broken, the MME changes the condition of the UEs which utilized this flagging association with the ECM-IDLE state and the eNB discharges the RRC association with those UEs. On account of Relay Nodes (RNs), there is one S1 interface between the RN and the hand-off empowered eNB, and one S1 interface between the hand-off empowered eNB and each of the MMEs in the MME pool. The S1 interface conveys non-UE-related S1AP motioning between the RN and the hand-off empowered eNB and UE associated S1AP motioning for UEs associated with the RN. The S1 interface between the hand-off empowered eNB and a MME conveys non-UE-related S1AP flagging and UE-related S1AP motioning for UEs associated with the RN and for UEs associated with the hand-off empowered eNB

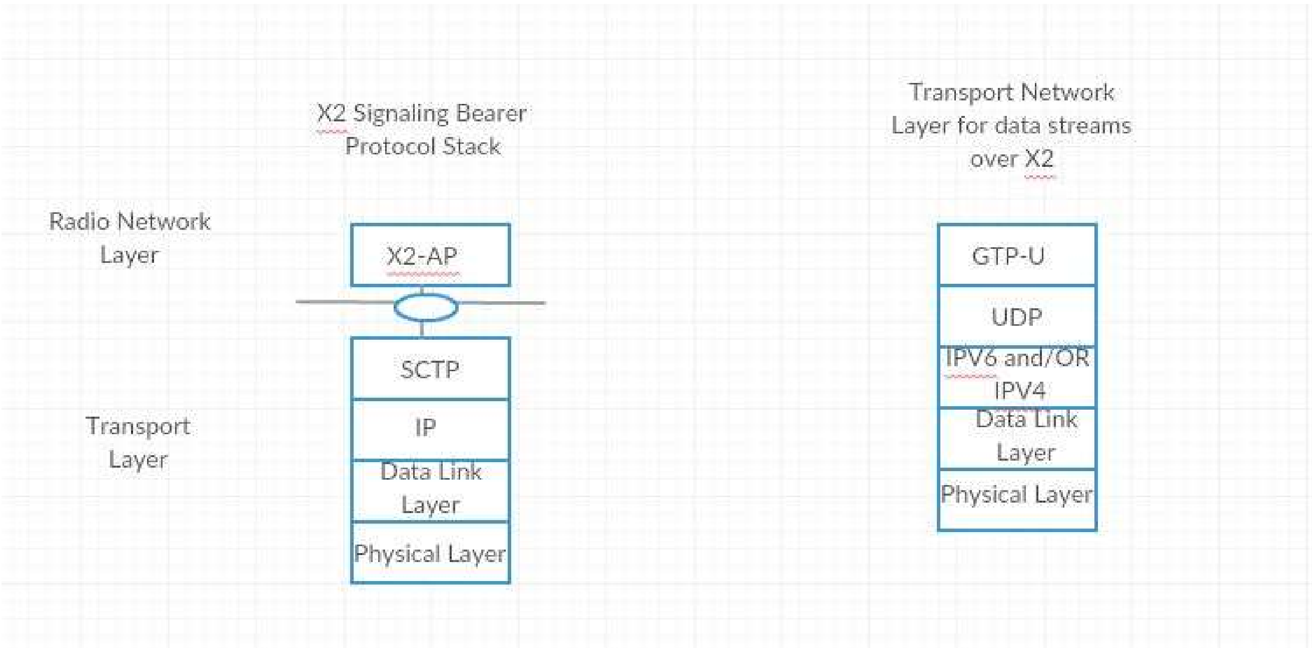


Figure 15. X2 Signaling Bearer Protocol Stack

12.3 Protocol stack for X2 user-plane

The X2 client plane interface characterizes information/control transport between eNBs [4]. TheX2-U interface gives non-ensured conveyance of client plane PDUs (because of utilization of UDP transport convention). The client plane convention stack on the X2 interface. The transport layer is based on top of the IP layer and GTP-U is utilized on top of UDP/IP to convey the client plane PDUs. The X2-U interface convention stack is indistinguishable to the S1-U convention stack

The X2 reference point is a sensible interface and despite the fact that it is ordinarily appeared as an immediate association between eNBs, it is generally directed by means of a similar transport association as the S1 interface to the site. The X2 interface control and user plane convention stacks . X2 is an open interface and is regularly utilized for control-plane data trade between neighboring eNBs. Notwithstanding, on account of consistent handover, it can be incidentally utilized for client information sending. The key contrast between the client plane and control-plane X2 interface convention stacks is the utilization of SCTP for control-plane data transmission between eNBs. The utilization of SCTP empowers dependable conveyance of control-plane data between eNBs, while for information sending, the UDP is viewed as adequate. The X2AP covers the radio-related flagging while the client plane GTP is utilized for client information transport.

The X2-AP functionalities are as per the following:

• Intra-LTE versatility administration where the handover messages between eNBs are transmitted on the X2 interface.

• Load administration to empower between cell impedance coordination by giving data on the asset status, over-burden, and movement condition between various eNBs.
• Setting up and resetting of the X2 interface.
• Handling Error for covering particular or general cases.

The X2 interface has a key part in the intra-LTE handover operation. The source-eNB utilizes the X2 interface to send the handover request for message to the target eNB. On the off chance that the X2 interface does not exist between the serving and the target eNBs, then methodology should be started to set up one preceding handover can be started. The handover ask for message advises the objective eNB to hold assets and to send the handover to ask for affirmation message expecting assets are accessible.

12.4 Protocol stack for X2 control-plane

The X2 control-plane interface characterizes control and flagging transport between two neighbor eNBs [4]. The SCTP is utilized for solid transport of control and flagging data. The application layer flagging convention is alluded to as X2-AP. A solitary SCTP affiliation for every X2-C interface example is utilized with one sets of stream identifiers for X2-C regular techniques. Just a couple sets of stream identifiers might be utilized for X2-C devoted techniques. Source-eNB correspondence setting identifiers that are appointed by the source-eNB for X2-C committed techniques, and target-eNB correspondence setting identifiers that are allotted by the objective eNB for X2-C devoted methodology, are utilized to recognize UE-particular X2-C flagging transport bearers. The correspondence setting identifiers are passed on in the separate X2-AP messages.

Inter cell interference coordination in E-UTRAN is performed through the X2 interface. At the point when the interference conditions change, the eNB signals the new condition to its neighbor eNBs, e.g., the neighbor eNBs for which a X2 interface is arranged because of portability prerequisites. At the point when a period space between cell obstruction coordination plot (e.g., eICIC) is utilized to moderate between cell impedance, the reference eNB signal Almost blank sub frame (ABS) examples to the neighboring eNBs, so that the accepting eNBs can misuse the ABS example of the reference eNB and adjust their exercises in like manner with a specific end goal to minimize the Inter cell obstruction. The Load indication procedure is utilized to exchange interference coordination data between neighboring eNBs overseeing intra-recurrence cells.

12.5 E-UTRAN and NAS protocols

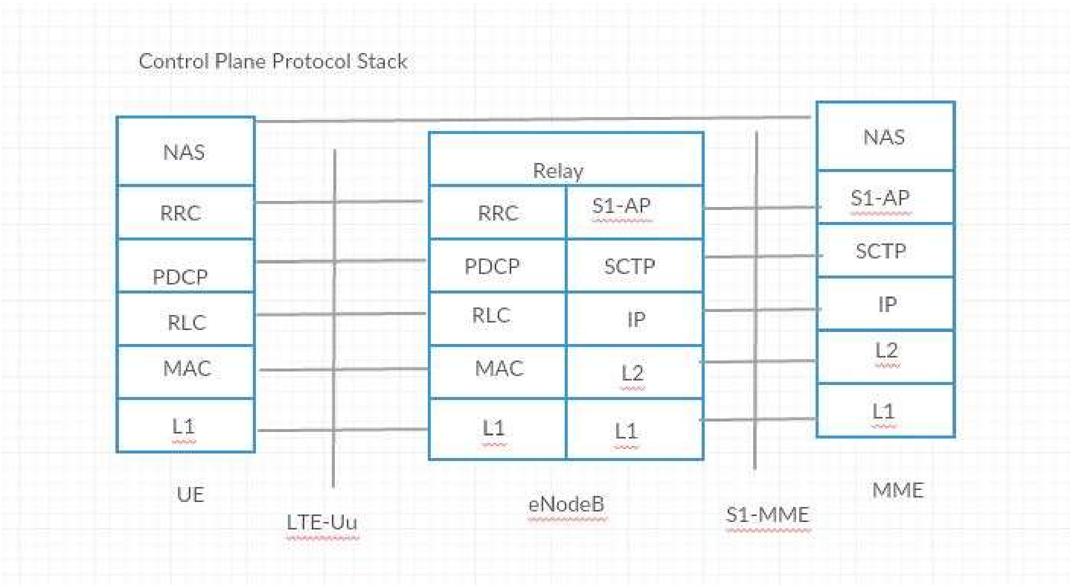


Figure 16. E-UTRAN and NAS Protocol Stack

Some broad standards thought about in the outline of E-UTRAN design [4], and additionally the E-UTRAN interfaces, are as per the following:

• Signaling and information transport systems are intelligently isolated.
• E-UTRAN and EPC N/W are isolated from transport N/W. The plans utilized as a part of E-UTRAN and EPC are not connected with the plans of transport N/W. Some E-UTRAN or EPC capacities dwell in a similar hardware.
• The portability for RRC association is controlled by the E-UTRAN.
• The interfaces depend on the sensible model of the substance which is controlled through this interface.
• One physical system component can actualize numerous coherent hubs.

The E-UTRA radio access network comprises of a system of eNBs. For unicast, there is no unified controller in E-UTRAN. The eNBs are interconnected through X2 interface and to the EPC by method for S1 interface. The protocols working between the eNBs and the UE are referred to as the AS protocols. The E-UTRAN is in charge of all radio-related capacities, which are given below:
• Radio Resource Management(RRM): It incorporates all capacities identified with the radio bearers, for example, admission control, radio bearer control.
• Header compression: It guarantees effective utilization of the radio interface by compacting the IP parcel headers that could somehow cause a huge overhead, particularly for little bundle applications, for example, VoIP.
• Security: It guarantees all information sent over the radio interface is encoded.
• Connectivity to the EPC: It comprises of the motioning toward MME and the conveyor way toward the S-GW.

All these functions exist inside the eNBs on the Network side, each of which can be in charge of dealing with different cells. Dissimilar to the past 3GPP discharges, LTE coordinates the radio controller work into the eNB. This permits tight connection between various protocol layers of the radio access network, in this way decreasing dormancy and enhancing effectiveness. Such disseminated control disposes of the requirement for an unpredictable focal controller with high handling power, which thus has the capability of lessening expenses. Besides, since LTE does not bolster delicate handovers like UMTS, there is no requirement for a concentrated information joining capacity in the system. One disadvantage for the absence of a central controller hub is that, as the UE moves, the system must exchange the UE setting, together with any supported information, starting with one eNB then onto the next. There are components and arrangements in E-UTRA to keep away from information loss amid handover. The general convention show for E-UTRAN interfaces is portrayed. The structure depends on the rule that the layers and planes are intelligently autonomous of each other. In this way, 3GPP can without much of a stretch adjust convention stacks and planes to fulfill future prerequisites.

The protocol stack comprises of two fundamental layers, the radio N/W layer and transport N/W layer. The E-UTRAN functions are acknowledged in the radio N/W layer, and the transport N/W layer represents the normal transport technology that is chosen to be utilized for E-UTRAN. The control-plane incorporates the application protocol, i.e., S1-AP and X2-AP. The application protocol is utilized for setting up bearers (i.e., E-RAB3) in the radio N/W layer.
The bearer limitations in the application protocol are not specifically fixing to the client plane innovation; rather, they are nonspecific bearer parameters. The client plane incorporates the data bearer(s) for the information stream(s). The information/data stream is portrayed in transport arrange layer by a tunneling protocol.

The eNBs are interconnected with each other through a X2 interface. The X2 interface permits eNBs to discuss specifically with each other and facilitate their exercises. The X2 interface is divided into independent control plane and user/client planes. The X2 control-plane conveys X2AP messages amongst eNBs and utilizes SCTP for dependable conveyance of messages. The X2AP is utilized to oversee between eNB portability and handovers, UE setting exchanges, Intercell Interference , and different error handling capacities. The X2 client plane uses GTP-U to passage client activity between eNBs. The primary administrations and elements of the NAS sublayer incorporate EPS bearer control, ECM-IDLE handling of mobility, paging start, and setup and control of security . The NAS systems, and specifically the association administration methods, are basically like those of UMTS. The principle change from UMTS is that EPS encourages mix of a few methodology to empower quicker foundation of associations and bearers. The MME makes a UE setting when a UE is turned on and appends to the system. It allots a one of a kind short transitory personality to the UE that distinguishes the UE setting in the MME. The UE setting contains client membership data got from the HSS. The nearby stockpiling of information in the MME permits quicker execution.

12.6 LTE-Uu interface protocols

The protocol over LTE-Uu and S1 interfaces are divided into two protocols namely user plane protocol and control plane protocol [4]. The user plane protocol that are the protocol actualizing the genuine E-RAB benefit, i.e., bringing client information through the AS, and control-plane protocol are in responsible of controlling the E-RABs and the association between the UE and the system from various angles including asking for the administration, controlling distinctive transmission assets, and handover. In the control-plane, the NAS functional block is utilized for system connection, verification, setting up bearers, and portability administration. All NAS messages are figured and trustworthiness ensured by the MME and the UE. There is additionally a component for straightforward exchange of NAS messages that is incorporated into the last gathering. The E-RAB administration is offered from service access point (SAP) to SAP by the AS. The layer 2 works in LTE is divided into MAC, PDCP and RLC functions. The SAP for between two nearby convention layers is set apart with a hover at the interface between sublayers. The SAP between physical and MAC sublayer provides the transport channels. The SAP between the MAC sublayer and the RLC sublayer gives the logical channels.

The multiplexing of a few coherent channels on a similar transport channel is performed by the MAC sublayer. Each sensible channel is characterized by the kind of data that is exchanged. The consistent channels are arranged into two gatherings: (1) control channels (for the exchange of control-plane data); and (2) traffic channels (for the exchange of client plane data). The RRC sublayer in the eNB, settles on handover choices in view of neighbor cell estimations reported by the UE, performs paging of the clients over the air-interface, communicates framework data, controls UE estimation and reporting capacities. It likewise executes exchange of UE setting from the serving eNB to the target eNB amid handover and performs security of RRC messages. The RRC sublayer is in charge of setting up and support of radio bearers.

The administrations and capacities gave by the PDCP sublayer in the client plane incorporate header compression and decompression of IP parcels, exchange of client information amongst NAS and RLC sublayer, successive conveyance of upper layer PDUs and copy recognition of lower layer SDUs taking after a handover for RLC recognized mode, retransmission of PDCP SDUs taking after a handover for RLC recognized mode. The administrations and capacities gave by the PDCP to the control-plane incorporate ciphering and the integrity protection and exchange of control-plane information where PDCP gets PDCP SDUs from RRC and advances it to the RLC sublayer. The RLC sublayer is utilized to format and transport the traffic between the UE and the eNB. The RLC sublayer gives three distinctive unwavering quality modes to information transport, i.e., the acknowledged mode (AM), the unacknowledged mode (UM), and the transparent mode (TM). The UM is reasonable for transport of constant administrations since such administrations are postpone delicate and can't endure delay because of ARQ retransmissions. The recognized mode is suitable for non-constant administrations, for example, document exchanges. The transparent mode is utilized when the extent of SDUs are referred to ahead of time, for example, for broadcasting framework data.

The RLC sublayer additionally gives successive delivery of SDUs to the upper layers and disposes of copy packets from being conveyed to the upper layers. It might likewise fragment the SDUs. The MAC sublayer is in charge of information exchange and sensible channel multiplexing, HARQ retransmissions and uplink/downlink booking, the random-access procedure and preservation of uplink timing. It is additionally in charge of multiplexing/de-multiplexing of information over different part bearers when carrier aggregation is utilized.

LTE-Advanced amplifies the abilities of LTE with support of bearer collection, where at least two segment transporters are accumulated so as to bolster more extensive transmission data transfer capacities up to 100 MHz. A client terminal may at the same time get or transmit one or various part bearers relying upon its abilities. From the UE point of view, the layer 2 parts of HARQ are like those of LTE. There is one transport block and one independent HARQ substance for every booked part transporter. Every transport block is mapped to a solitary part transporter on which all HARQ retransmissions may occur.

A UE might be planned over numerous part bearers at the same time, however at most one irregular method is performed. At whatever point a UE is designed with just a single segment carrier, LTE DRX is the pattern. In different cases, the same DRX operation will be connected to all arranged part bearers. Subsequently, the layer 2 structure of the LTE-Advanced is like that of LTE, aside from the expansion of the bearer collection usefulness; be that as it may, the multi-transporter nature of the physical layer is just presented to the MAC sublayer through transport channels, where one HARQ substance is required per segment transporter.

The logical and transport channel is characterized by the sort of data that is exchanged. The coherent channels are by and large ordered into two gatherings: (1) control channels (for the exchange of control-plane data); and (2) traffic channels (for the exchange of user plane data). The control channels are only utilized for exchange of control-plane data.

12.6.1 The control channels bolstered by MAC

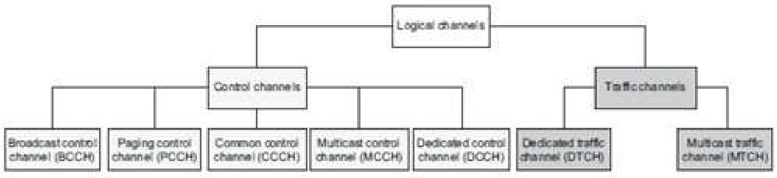


Figure 17. E-UTRAN Logical Channel Structure [4]

• **Broadcast control channel (BCCH):** A downlink channel for broadcasting framework data [4].

• **Paging control channel (PCCH):** A downlink channel that exchanges paging data and framework data change warnings. This channel is utilized for paging when the system does not know the area of the UE.

• **Common control channel (CCCH):** A channel for transmitting control data amongst UEs and eNBs. This channel is utilized for UEs that have no RRC association with the system.

• **Multicast control channel (MCCH):** An indicate multipoint downlink channel utilized for transmitting MBMS control data from the system to the UE for one or a few MTCHs. This channel is just utilized by UEs that are subscribed to MBMS.

• **Dedicated control channel (DCCH):** An indicate point bidirectional channel that transmits devoted control data between a UE and the system. It is utilized by UEs that have RRC association. The activity channels are solely utilized for the exchange of client plane data.

• **Dedicated movement channel (DTCH):** An indicate point bi-directional channel devoted to a solitary UE for the exchange of client data.

• **Multicast movement channel (MTCH):** An indicate multipoint downlink channel for transmitting communication/multicast information from the system to the UE. This channel is just utilized by UEs that get MBMS.

The physical layer gives data exchange administrations to the MAC and higher layers. The physical layer transport administrations are depicted by how and with what qualities information is exchanged over the radio interface. This ought to be plainly recognized from the order of what is transported which identifies with the idea of intelligent channels at the MAC sublayer.

12.6.2 The downlink transport channels

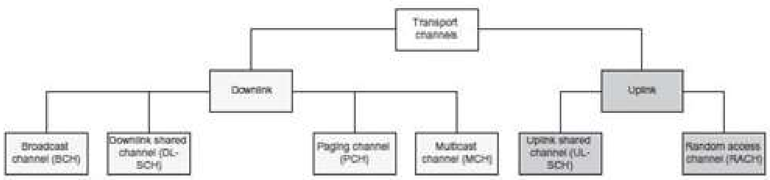


Figure 18. Downlink Transport Channels [4]

• **Broadcast channel (BCH)** is described by static, predefined transport setup, and is required to communicate in the whole scope region of the cell [4].

• **Downlink shared channel (DL-SCH)** is described by support for HARQ protocol, dynamic connection adjustment by shifting balance, coding, and transmit control, plausibility for communicating in the whole cell, probability to utilize beamforming, element and semi-static asset distribution, UE DRX to empower control sparing, and MBMS transmission.

• **Paging channel (PCH)** is portrayed by support for UE DRX keeping in mind the end goal to empower control sparing, prerequisite for communicate in the whole scope zone of the phone and is mapped to physical assets which can likewise be utilized progressively for movement or other control channels.

• **Multicast channel (MCH)** is described by prerequisite to be communicate in the whole scope zone of the cell, bolster for full scale assorted qualities consolidating of MBMS transmission on numerous cells, and support for semi-static asset distribution. The uplink transport channels are delegated takes after (see Figure 3.20):

• **Uplink shared channel (UL-SCH)** is described by plausibility to utilize shaft framing, bolster for element interface adjustment by differing the transmit power and regulation and coding plans, bolster for HARQ, bolster for both element and semi-static asset designation.

• **Random access channel (RACH)** is portrayed by restricted control data and crash chance.

13. Handovers

13.1 S1-based handover procedure

The S1-based handover process is used whilst the X2-based handover totally can't be used. The source eNodeB starts a handover by sending Handover Required signal over the S1-MME. This process may additionally relocate the MME and/or the Serving GW[9]. The target MME is selected by the source MME. The MME should not be relocated throughout inter-eNodeB handover except the UE leaves the MME Pool area in which the UE is served. The target MME determines if the Serving GW wishes to be relocated. If the Serving GW requests to be repositioned MME chooses the target-Serving GW. The source eNodeB chooses EPS bearers which are concern for forwarding of downlink and optionally additionally uplink packets from the serving eNodeB to the target eNodeB. The EPC does not change the choices taken through the RAN node. Packet forwarding can happen either at once from the serving eNodeB to the target eNodeB, or in a roundabout way from the serving eNodeB to the target eNodeB via the source and target Serving GWs.

The supply of an instantaneous forwarding path is determined inside the serving eNodeB and indicated to the serving MME. If X2 connectivity is available among the source and target eNodeB's, an immediate forwarding path is available. If a direct forwarding route is unavailable, indirect forwarding might be used. The serving MME uses the indication from the serving eNodeB to determine whether to apply indirect forwarding. The serving MME suggests to the target MME whether or not oblique forwarding needs to apply. Target MME checks if it applies indirect forwarding. If the MME gets a rejection to an S1 interface from the eNodeB with a demonstration that an S1 handover is in advancement, the MME shall reattempt the identical S1 interface process while both the handover is finished or is deemed to have failed if the MME remains the serving MME, besides in case of Serving GW relocation.

To minimize the number of procedures rejected, the MME needs to pause non-handover related S1 interface processes even as a handover is ongoing (i.e. from the time that a

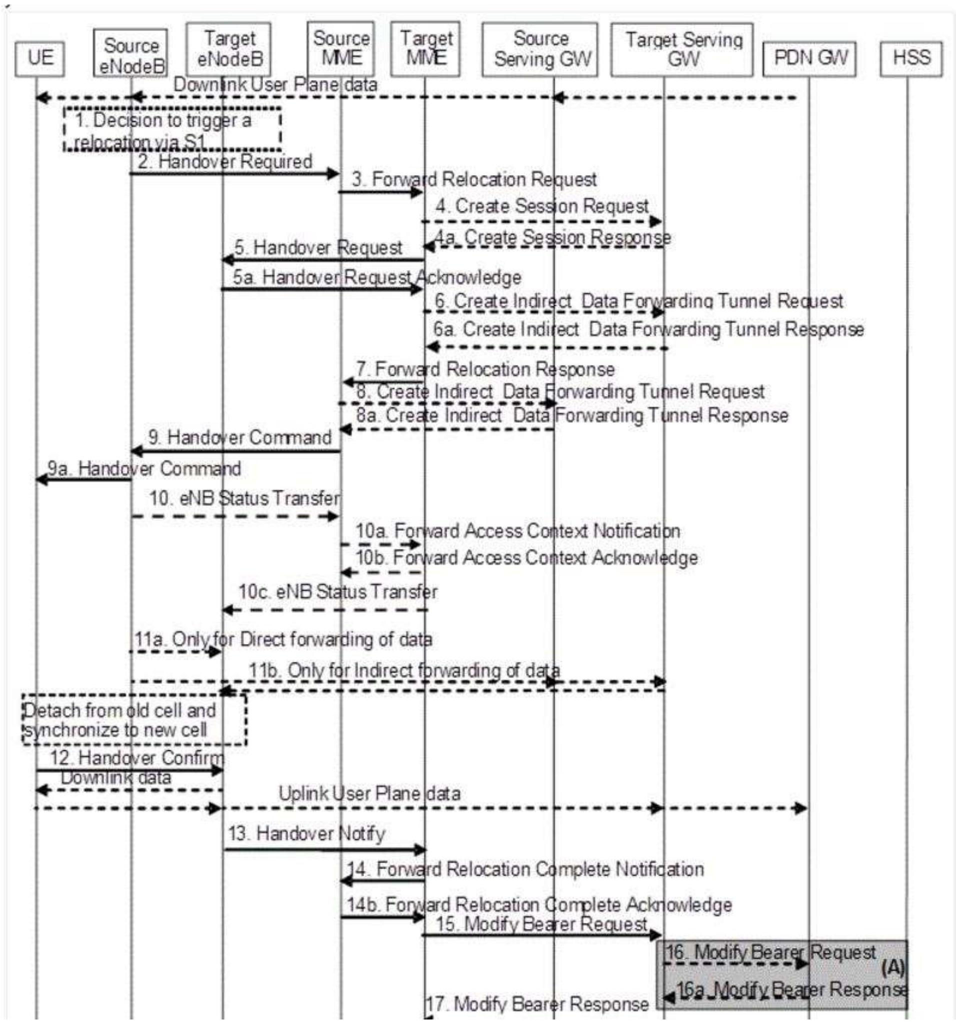
Handover Required has been acquired till both the Handover system has succeeded (Handover Notify) or failed (Handover Failure)) and preserve them till the Handover system has completed if the MME is still the serving MME, besides in case of Serving GW relocation.

If at some point of the handover system, the MME detects that the Serving GW or/and the MME needs be relocated, MME shall deny any PDN GW originated EPS bearer(s) request acquired given that handover started out and shall consist of a demonstration that the request has been temporarily rejected because of handover procedure in progress. The rejection is forwarded by way of the Serving GW to the PDN GW, with the equal indication. Upon receipt of a rejection for an EPS bearer(s) PDN GW initiated manner with a demonstration that the request has been briefly rejected due to handover technique in progress, the PDN GW shall begin a regionally configured timer. The PDN GW shall re-try the procedure, up to a pre-configured number of times, Using the message reception or guard timer expiry, it detects if the handover has been completed or failed

Handover to the target eNodeB is done independent of the restriction list when emergency bearer offerings are being executed for the UE. The MME checks, as a part of the monitoring region update in the execution segment, if the handover is to a confined vicinity and if so MME releases the non-emergency bearers. If the MME gets a denial to a UE Context message with a CS Fallback indication from the eNodeB with an illustration that an S1 handover is in progress, the MME shall resend a UE-Context-Modification-Request message with CS Fallback pointer to the target eNodeB when both the handover is whole or to the source eNodeB while the handover is deemed to have failed if the MME remains the serving MME.

13.1.1 S1-Based Handover Scenario

This procedure describes the S1-based handover in the general case [9], this scenario describes when the procedure is rejected by the target eNodeB or the target MME and describe when it is canceled by the source eNodeB.



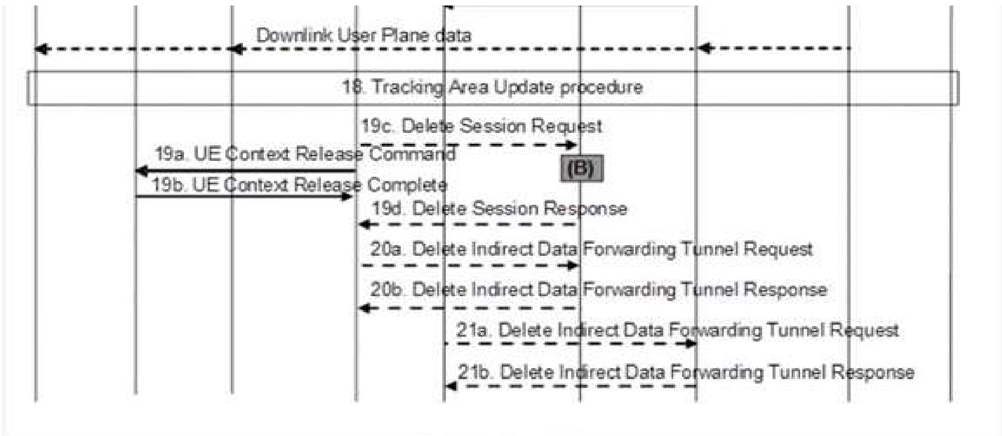


Figure 19. S1 Based Handover [9]

Step 1. The source eNodeB comes to a decision to initiate an S1-based handover to the target eNodeB. This could be induced e.g. by way of no X2 connectivity to the target eNodeB, or with the aid of information learned through the serving eNodeB or by an errors-indication from the target eNodeB after an unsuccessful X2-based handover.

Step 2. The serving eNodeB sends Handover Required (Direct Forwarding path Availability, target eNodeB identity, CSG identification, CSG access mode, target TAI, S1AP motive) to the source MME. The serving eNodeB indicates which bearers are subject to information forwarding. Direct Forwarding path Availability shows whether or not direct forwarding is available from the serving eNodeB to the target eNodeB. This indication from serving eNodeB may be based on e.g. the presence of X2. The target TAI is dispatched to MME to facilitate the selection of a suitable target MME. whilst the target cell is a CSG cell or a hybrid cellular, the serving eNodeB encompasses the CSG identification of the target cellular. If the target mobile is a hybrid cellular, the CSG mode will be indicated.

Step 3. The serving MME selects target-MME and if it has determined to relocate the MME, it sends a Forward Relocation message to the target MME. The target TAI is sent to the target MME to assist it to decide whether or not S GW relocation is needed.

Step 4. If the MME has been relocated, the target MME verifies whether or not the Serving GW can hold to serve the UE. If no longer, it selects a new Serving GW. If the MME has not been relocated, the source MME comes to a decision in this Serving GW re-selection. If the Serving GW keeps to serve the UE, no message is sent on this step. In this scenario, the target GW is same to the Serving GW. The target MME sends a Create-Session-Request message to the target GW in line with Packet Data Network connection, If a new Serving GW is selected. The target GW allocates the S GW addresses and TEIDs for the uplink visitors on S1_U reference factor . The target Serving GW sends a Create session response (Serving GW addresses and uplink TEID(s) for consumer plane) message back to the target MME.

Step 5. The Target MME sends Handover Request message to the target eNodeB. This message creates the UE context in the target eNodeB, such as records approximately regarding the bearers, and the security context. For every EPS Bearer, the Setup comprises of uplink TEID for user plane, Serving GW address and QoS of EPS Bearer. If there is a direct forwarding flag which shows inconvenience of the direct forwarding and therefore the target MME is conscious of that there is also no oblique records forwarding connectivity between source and target, the Bearers to Setup shall embody " The Data-forwarding is not possible" indication for every EPS bearer. The restrict list of Handover is sent if to be had among the target MME. S1AP cause shows the RAN cause as acquired from serving MME. The target MME shall encompass the CSG id and CSG membership while provided by using the source MME inside the forward Relocation Request message.

A Handover Request acknowledge message is sent by the target eNodeB sends to the target MME. The EPS Bearer Setup listing includes a list of addresses and TEIDs allotted on the target eNodeB for downlink traffic on S1 U reference point and addresses and TEIDs for receiving forwarded records if important. If the UE AMBR is modified, e.g. all the EPS bearers which might be associated to the identical APN are rejected inside the target eNodeB, the MME shall recalculate the brand-new UE-AMBR and signal the changed UE AMBR value to the target eNodeB. If target eNodeB doesn't accept any of the default EPS bearers, the handover is rejected by the target MME.

The target eNodeB shall verify the CSG identification furnished through the target MME, and reject the handover with the right cause if it does not fit the CSG identity for the target cell, if the target cell is a CSG mobile.x If the target eNodeB is in hybrid mode, it can use the CSG Indication to carry out differentiated treatment for CSG and non-CSG contributors.

Step 6. If Serving GW is relocated while the indirect-forwarding is in effect, then the target-MME arrange the forwarding parameters by way of sending Create indirect data Forwarding Tunnel Request to the Serving GW. The S-GW sends a Create-indirect-data -Forwarding-Tunnel response to the target MME. If the Serving GW isn't relocated, indirect forwarding can be used.

Step 7. If the MME has been relocated, the target MME sends an ahead Relocation reaction message to the source MME. For indirect forwarding, this message consists of Serving GW address and TEIDs for oblique forwarding. Serving GW alternate indication shows a new Serving GW has been decided.

Step 8. If indirect forwarding applies, the serving MME sends Create indirect data Forwarding Tunnel Request to the Serving GW. If the Serving GW is relocated it consists of the tunnel identifier to the goal serving GW.

The S-GW responds with a Create Indirect-data-Forwarding-Tunnel response message to the serving MME. Indirect forwarding can be executed through a S-GW which is not the same from the S-GW used as an anchor-point for the UE.

Step 9. The source MME contacts the source eNodeB and delivers the Handover message. It includes listing of TEIDs and addresses allotted for forwarding.

Step 9a. The Handover Command is constructed with the use of the target to source transparent container and is dispatched to the UE. Upon reception of this message the UE will put off any EPS bearers for which it did now not acquire the corresponding EPS radio bearers within the target cell.

Step 10. The serving eNodeB s ends the eNodeB Status Transfer message to the target eNodeB via the MME(s) to deliver the PDCP and HFN status of the E-RABs for which PDCP status maintenance applies. The serving eNodeB might also miss sending this message if none of the E-RABs of the UE will be treated with PDCP-status-preservation. The source MME sends this statistic to the target MME thru the Forward-Access-Context-Notification message when there is a MME relocation. The serving MME or, if the MME is relocated, the MME, sends the information to the target eNodeB via the eNodeB-Status-Transfer message

Step 11. The supply eNodeB need to start forwarding of downlink statistics from the serving eNodeB towards the target eNodeB for bearers due to data forwarding. This can be either direct or indirect forwarding.

Step 12. The UE sends a Handover-confirm-message to the target eNodeB when it has synchronized with target cell. It receives downlink packets from the supply eNodeB. Additionally, uplink packets can be dispatched from the UE, which are forwarded to the target Serving GW and directly to the PDN GW.

Step 13. The goal eNodeB sends a Handover Notify message to the target MME.

Step 14. If the MME is relocated, the target MME sends a Forward-Relocation-Complete-Notification message to the serving MME. The source MME in reaction Forward-Relocation-Complete-Acknowledge message to the target MME. Irrespective if the MME has been relocated, a timer in serving MME is commenced to supervise while resources in serving eNodeB and if the Serving GW is relocated, additionally assets in Serving GW shall be unconstrained. Upon receipt of the Forward Relocation Complete Acknowledge message the goal MME begins a timer if the goal MME allocated S GW resources for indirect forwarding.

Step 15. The MME sends a alter Bearer Request message to the target Serving GW for every PDN connection, such as the PDN connections that need to be launched. If the PDN GW requested UE's location and/or user CSG statistics, the MME additionally consists of the user location information IE and/or user CSG records IE on this message. If the UE Time zone has modified, UE Time-zone IE is included in the message by the MME. If neither MME nor Serving GW changed and if ISR changed into activated before this then MME needs to hold ISR. The UE is informed about the ISR status in the Tracking-Area-Update procedure. The MME issues the non-general committed bearers by means of triggering the bearer release technique. If the Serving GW gets a DL packet for a non-frequent bearer, the Serving GW drops the DL packet and does no longer send a Downlink Data Notification to the MME.

Step 16. If the source GW is transferred, the target Serving GW assigns addresses and TEIDs for downlink traffic from the PDN GW. It sends a alter Bearer Request message in line with PDN connection to the PDN GW(s). Even for non-accepted bearers on S5/S8, the S-GW allocates DL TEIDs. The PDN-GW updates its context and returns a modify-Bearer-response message to the target Serving GW. If the PDN-GW has MSISDN stored in UE, then it is included. With the use of newly obtained location and TEIDs, the downlink packets are sent from the PDN GW to the target GW. Those downlink packets will use the brand-new downlink direction through the target Serving GW to the target eNodeB. If the Serving GW is not relocated, however has obtained the user discourse statistics IE and/or UE Time region IE and/or consumer CSG records, the Serving GW shall tell the PDN GW(s) approximately those statistics that e.g. can be used for charging, with the aid of sending the message adjust Bearer Request to the PDN GW(s) worried. A modify Bearer reaction message is sent again to the Serving GW. If the Serving GW isn't relocated and it has not received user place records IE nor UE Time region IE nor consumer CSG records

IE , no message is dispatched in this step and downlink packets from the Serving GW are immediately dispatched directly to the target eNodeB.

Step 17. The target GW sends an alter Bearer response message to the target MME. If the Serving GW doesn’t exchange, the Serving GW will send one or extra "stop marker" packets at the old route without delay after switching the direction with a view to help the reordering function inside the target eNodeB.

Step 18. The UE initiates a Tracking Area update process while one of the conditions indexed in clause "Triggers for tracking vicinity update" applies. The target MME knows that it's miles a Handover procedure that has been finished for this UE as it acquired the bearer context(s) with the aid of handover messages and therefore the target MME performs only a subset of the TA replace system, specifically it excludes the context switch strategies among source MME and target MME.

Step 19. when timer which began in step 14 expires, a UE-Context-release-Command message is sent from the source MME to source eNB. The serving eNodeB releases its resources associated with the UE and responds with a UE Context release message. while the timer commenced in step 14 expires and if the source MME received the Serving GW exchange indication inside the forward Relocation response message, it deletes the EPS bearer resources by means of sending Delete session Request messages to the Serving GW. The Serving GW adjustments and the source Serving GW shall now not initiate a delete manner toward the PDN GW. The Serving GW recognizes with Delete session response messages. If ISR has been activated earlier than this technique, the reason additionally shows to the source S GW that the supply S GW shall delete the bearer sources on the other old CN node with the aid of sending Delete Bearer Request message to that CN node.

Step 20. If oblique forwarding was used then the expiry of the timer at supply MME started out at step 14 triggers the source MME to send a Delete oblique data Forwarding Tunnel Request message to the S GW to launch the temporary sources used for oblique forwarding that had been allocated at step 8.

Step 21. If indirect forwarding changed into used and the Serving GW is relocated, then the expiry of the timer at target MME commenced at step 14 triggers the goal MME to send a Delete oblique records Forwarding Tunnel Request message to the goal S GW to launch brief sources used for indirect forwarding that have been allotted at step 6.

13.1.2 S1-Based Handover Reject Scenario

The target eNodeB rejects the usage of the Handover process if none of the asked bearers inside the Handover Request message could be hooked up [9]. In this case, no UE context is hooked up in the target MME/eNodeB and no resources are allotted. In addition, the target MME rejects the handover request and clears all aid in target eNodeB and MME if the target eNodeB accepts the handover request but not any of the default EPS bearers gets resources allotted. In each instances, the UE remains within the source eNodeB/MME.

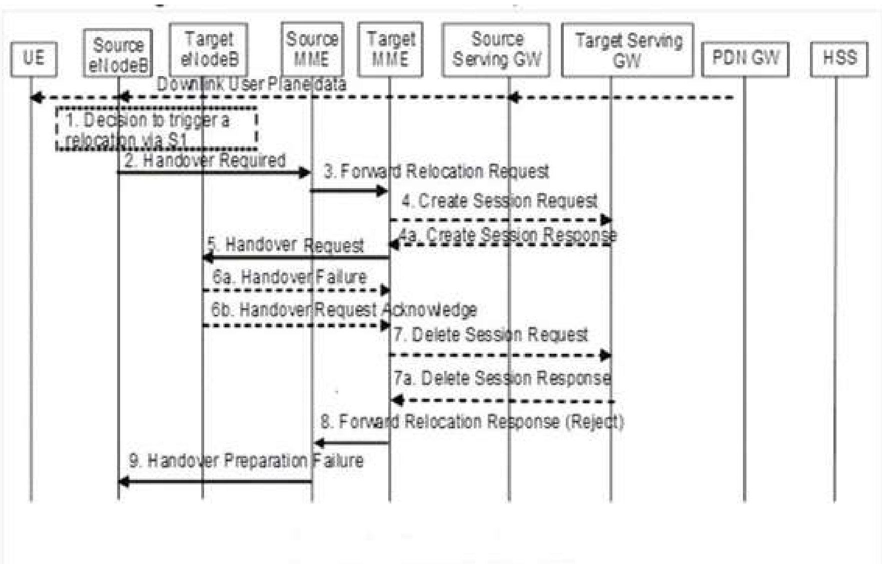


Figure 20. S1-based handover reject scenario [9].

Step 1-5. Steps 1 to 5 are same as steps 1-5 stated in above situation.

Step 6a. a Handover-Failure message is sent from target eNB to target MME if it fails to assign sources for EPS bearers. Any reserved resources inside the Target MME for UE are released.

Step 6b. If the target MME gets a Handover Request renowned message from the target eNodeB but not one of the default EPS bearers are within the EPS-Bearer-Setup-list IE, any reserved resources in target MME and eNB for UE are released

Step 7. This step is best achieved for Serving GW relocation, i.e. if steps 4/4a had been finished. The target MME deletes the EPS bearer resources through sending Delete session Request messages to the Target Serving GW. The target Serving GW acknowledges with Delete session response messages.

Step 8. The Forward-Relocation-Response-message is sent from target MME to the source MME.

Step 9. when the serving MME receives the forward Relocation response message, it sends a Handover Failure message to the serving eNodeB.

13.1.3 S1-Based Handover Cancel Scenario

Instead of finishing the handover procedure, the serving eNodeB at any time for the duration of the handover system, up to the time while a handover command message is dispatched to the UE cancel the relinquishment [9]. The MME shall cancel the handover resources for case the supply RAN is eNodeB

13.2 X2-based handover without S-GW change

This process is used to hand over a UE from a source eNodeB to a target eNodeB with the usage of X2 when the MME is unchanged and comes to a decision that the Serving GW is also unchanged [16]. The presence of IP connectivity among the Serving GW and the serving eNodeB, in addition to between the source GW and the target eNodeB is believed.

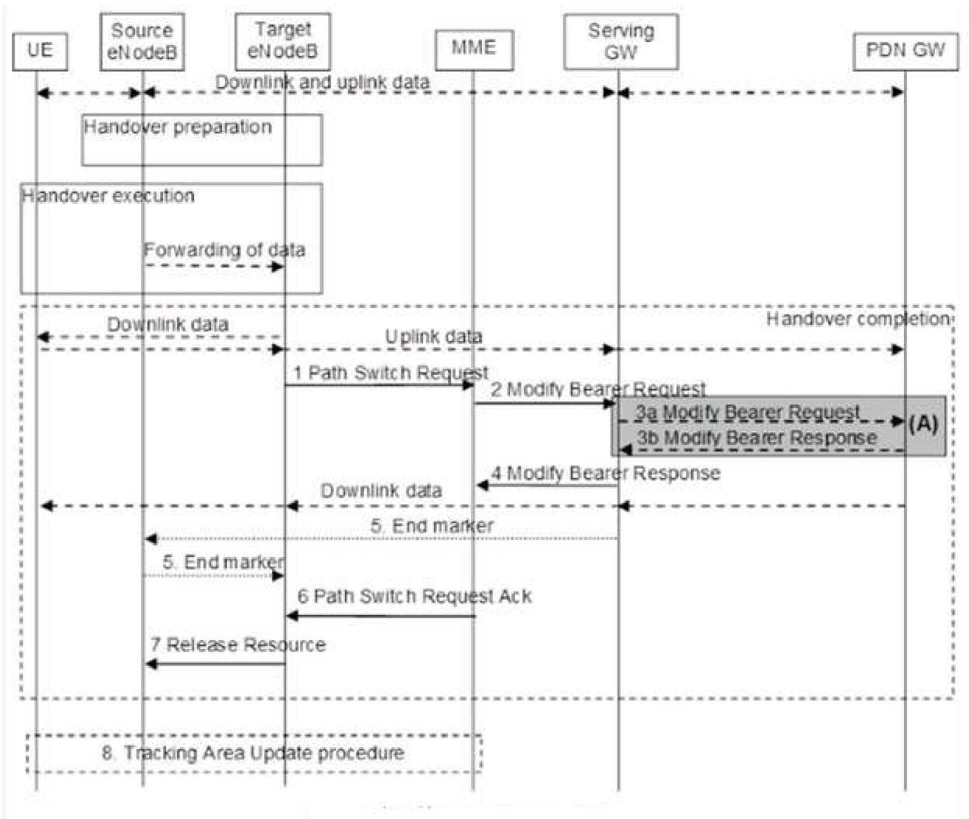


Figure 21. X2-based handover without SGW relocation [16].

Step 1. The target eNodeB sends a path switch Request message to MME to tell that the UE has modified cell , comprehensive of the TAI+ECGI of the target cell and also the listing of EPS bearers to be switched. The MME determines that the Serving GW will hold to serve the UE

Step 2. The MME sends a modify Bearer Request message in keeping with PDN connection to the Serving GW for every PDN connection wherein the default bearer has been established via the target eNodeB. If the PDN GW requested UE's location data, the MME also consists of the consumer area information IE in this message.

If the UE Time zone has modified, the MME includes the UE Time zone IE on this message. If ISR became activated before this method, MME must preserve ISR. The UE is knowledgeable about the ISR popularity inside the monitoring area update technique. The MME uses the list of EPS bearers to be switched, acquired in step 1, to determine whether any committed EPS bearers within the UE context have now not been regular with the aid of the target eNodeB. The MME releases the non-widely wide-spread dedicated bearers through triggering the bearer launch procedure. If the Serving GW gets a DL packet for a non-familiar bearer, the Serving GW drops the DL packet and does no longer send a Downlink-Data-Notification to MME. There are multiple PDN connections active if the default bearer of a PDN connection is not usual through the target eNodeB, the MME recalls all bearers of that PDN connection as failed and launch that PDN connection by using triggering the MME requested PDN disconnection manner.

Step 3. If the Serving GW has acquired the user position Information IE and/or the UE Time sector IE from the MME , the Serving GW informs the PDN GW about this records that e.g. may be used for charging, via sending the message regulate Bearer Request per PDN connection to the PDN GW concerned. A modify Bearer response message is dispatched again to the Serving GW.

Step 4. The Serving GW starts causing downlink of packets to the target eNodeB with the new nonheritable address and TEIDs. A modify Bearer response message is dispatched back to the MME.

Step 5. With a view to assist the reordering characteristic in the target eNodeB, the Serving GW shall deliver one or more "stop marker" packets on the old route without delay after switching the direction.

Step 6. The MME confirms the route switch Request message with the path switch Request Ack message. If the UE AMBR is changed, e.g. all of the EPS bearers that are associated to the same APN are rejected within the target eNodeB, the MME shall provide the updated cost of UE AMBR to the target eNodeB inside the path switch Request Ack message.

If a few EPS bearers have not been switched successfully within the core network, the MME shall suggest within the route switch Request Ack message which bearers were not established and for dedicated bearers initiate the bearer release manner to launch the core network resources of the failed committed EPS bearers. The target eNodeB shall delete the corresponding bearer contexts whilst it's miles informed that bearers have not been installed within the CN .

If none of the default EPS bearers had been switched successfully within the network or if they have no longer been typical by using the target eNodeB, the MME shall send a path switch appeal Failure message to the target eNodeB. The MME performs the explicit detach of the UE as described inside the MME initiated detach manner.

Step 7. By sending release resource the target eNodeB informs fulfillment of the handover to supply eNodeB and triggers the discharge of assets.

Step 8. The UE initiates a tracking area update method whilst one of the situations indexed in clause "Triggers for tracking region update" applies. If ISR is activated for the UE while the MME gets the tracking area update Request, the MME need to hold ISR with the aid of indicating ISR Activated within the tracking location update takes delivery of message.

13.3 X2-Based Handover With S-GW Relocation

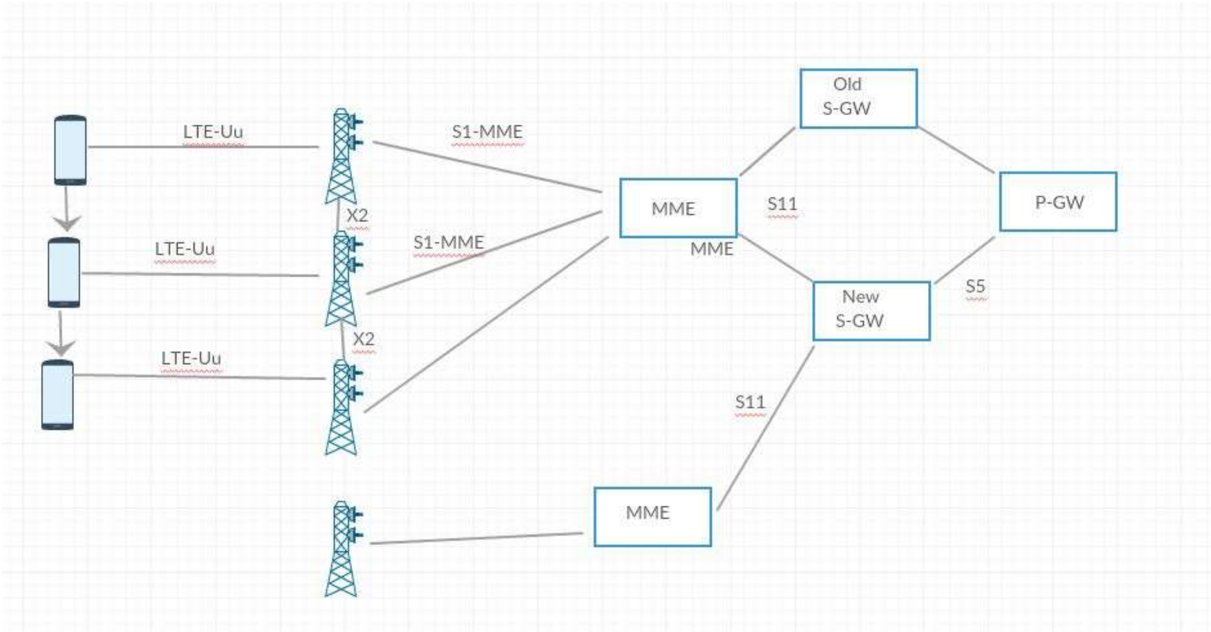


Figure 22. UE moving from old to new RAN Coverage

This technique is used to handover a UE from a source eNodeB to a target eNodeB with the use of X2 whilst the MME is unchanged and the MME makes a decision that the Serving GW is to be relocated [17]. The presence of IP connectivity among the source Serving GW and the source eNodeB, between the Serving GW and the target eNodeB, and among the target Serving GW and eNodeB is believed.

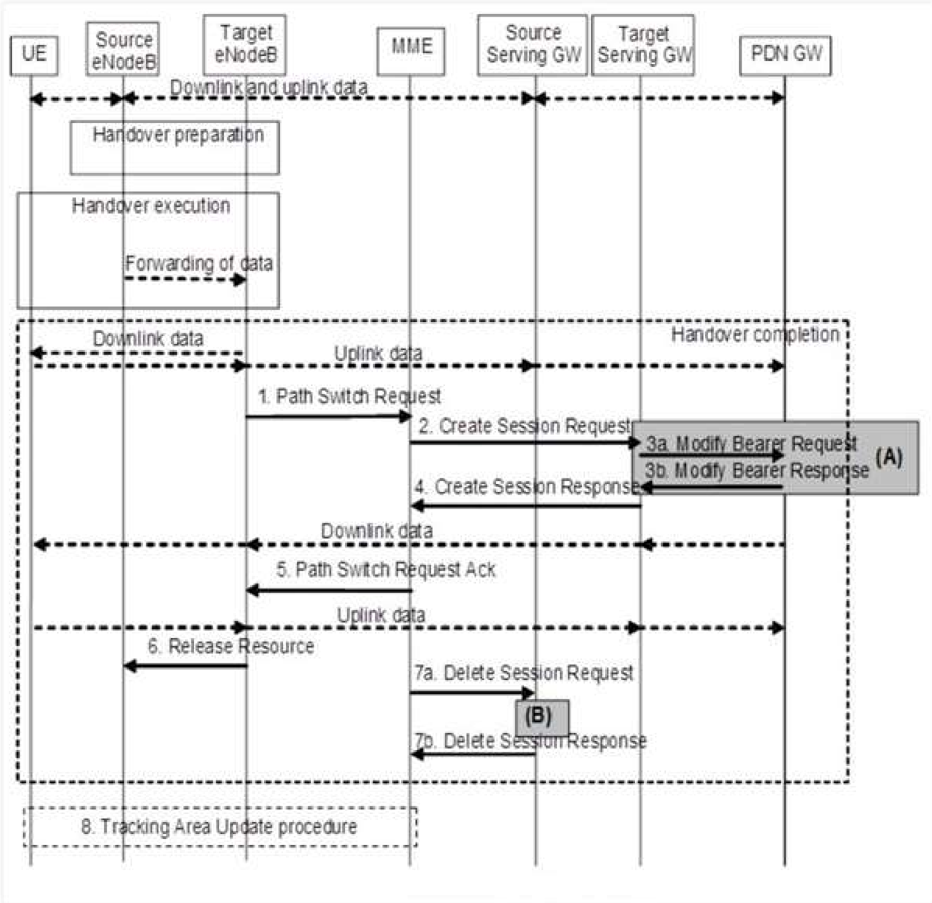


Figure 23. X2-based handover with SGW relocation [17].

Step 1. The target eNodeB directs a Path Switch Request message to the MME to inform that the UE has changed cell, including the ECGI of the target cell and the list of EPS bearers to be swapped . The MME regulates the Serving GW and is relocated and selects a new Serving GW.

Step 2. The MME sends a Create Session Request message in step with PDN connection to the target SGW for each PDN connection where the default bearer has been general by means of the target eNodeB. The target Serving GW allocates the SGW addresses and TEIDs for the uplink visitors on S1-U interface . The Protocol type over S5/S8 is provided to SGW which protocol need to be used over S5/S8 interface. If the PGW asked UE's location data, the MME also includes the user location Info IE on this message. The MME makes use of the list of EPS bearers to be switched, to decide whether or not any dedicated

EPS bearers inside the UE context have now not been frequent by means of the target eNodeB. The MME releases the non-standard dedicated bearers via triggering the bearer launch process via target SGW. If the SGW gets a DL packet for a non-usual bearer, the SGW drops the DL packet and does no longer send a Downlink information Notification to the MME**.**

If the default bearer of a PDN connection has now not been popular by using the target eNodeB and there are a couple of PDN connections lively, the MME shall consider all bearers of that PDN connection as failed and release that PDN connection by using triggering the MME requested PDN disconnection technique via source SGW. If the eNodeB does not accept any of the default EPS bearers by means of the target eNodeB, the MME shall act as specified in step 5.

Step 3. The target Serving GW assigns addresses and TEIDs for downlink traffic from the PDN GW. The Serving GW allocates DL TEIDs on S5/S8 even for non-widespread bearers. It sends a modify Bearer Request message per PDN connection to the PDN GW(s). The SGW additionally consists of user location information. IE and/or UE Time zone IE if it is found in step 2. The PDN GW updates its context field and returns a Modify Bearer message to the Serving GW. The MSISDN is covered if the PDN GW has it saved in its UE context. The PDN GW begins sending downlink packets to the target GW using the newly obtained location and TEIDs. These downlink packets will use the brand new downlink direction through the target Serving GW to the eNodeB. The Serving GW allocates the TEIDs for the bearers which have failed and inform to the MME.

Step 4. The target GW sends a Create session response message lower back to the goal MME. The MME

Step 5. The path switch Request message is confirmed by MME with the help of path switch Request Ack message. when the UE AMBR is modified, e.g. when all of the EPS bearers which are associated to the identical APN are rejected within the target eNodeB, the MME shall provide the updated UE AMBR to the target eNodeB inside the direction switch Request Ack message. The goal eNodeB begins the use of the new Serving GW deal with and TEID(s) for forwarding next uplink packets.

If a few EPS bearers have not been switched efficiently within the middle network, the MME shall indicate within the path switch Request Ack message which bearers did not be set up and for committed bearers provoke the bearer release technique to release the center network assets of the failed dedicated EPS bearers. The target eNodeB shall delete the corresponding bearer contexts whilst it's far knowledgeable that bearers have no longer been hooked up inside the center N/W. If none of the default EPS bearers were switched efficaciously inside the core network or in the event that they have not been customary by way of the goal eNodeB, the MME shall send a course transfer Request Failure message to the target eNodeB. The MME performs specific detach of the UE as defined in the MME initiated detach system.

Step 6. Through sending release resource the target eNodeB informs achievement of the handover to source eNodeB and triggers the release of assets.

Step 7. while the timer has expired after step 4, the serving MME releases the bearer(s) in the source Serving GW by means of sending a Delete session Request message . It is suggested to the source Serving GW that the source Serving GW shall no longer provoke a delete process closer to the PDN GW. The source Serving GW recognizes with Delete session response messages. If ISR has been activated earlier than this procedure, the purpose additionally suggests to the source SGW that the source SGW shall delete the bearer sources on the alternative unique CN node through sending Delete Bearer Request message(s) to that CN node.

Step 8. The UE initiates a tracking area update process when there is such need.

14. Remote Radio Head

Remote Radio head (RRH) became very essential subsystems for Base station architecture [18]. Base station's RF circuitry along with analog-to-digital or Digital -to-analog converters plus up/down converters are present in the RRH.

RRH has operation and control functions. It has optical interface, which connects RRH with the base station. RRH Base station machine consists of REC and RE, where in REC includes baseband processing chain viz. scrambling, channel coding and modulation. RE consists of ADC/DAC, PA, LNA and RF/IF filters. Distance between REC and RE can be normally approximately 10Km and interface can be an optical sign which normally brings control/mgmt, Sync and IQ indicators. RRH is used to extend the exposure of a base station sub-systems in the far off rural regions.

The principle functions of development of Remote Radio Head are as follows:

1. Offload IF and RF processing from base station.

2. Increase in distance among RF antenna and Base Station hardware.

3. Use of reasonably-priced optical fiber to hold records among RRH and Base Station Controller.

RRH contains following complicated functionalities, in order to have complex functionalities FPGAs are +used inside the design of RRH.

- Digital Up Conversion(DUC)
- Digital Down Conversion(DDC)
- Crest Factor Reduction(CFR)
- Digital Pre-distortion(DPD)

Remote Radio Head helps a couple of wi-fi standards/technologies. UMTS, WiMAX and E-UTRA standards are defined in the CPRI specification within the RRH layout.

14.1 RRH Interfaces

- Control and Management - Used for call processing and for operation and protection signals [18].
- Sync- Used for synchronization purpose, will convey timing facts.
- IQ- statistics with a view to be carried between radio base station to the mobile station and vice versa.

The interfaces are connected with Layer 2. Which is in turn connected with layer 1

15.Front Haul

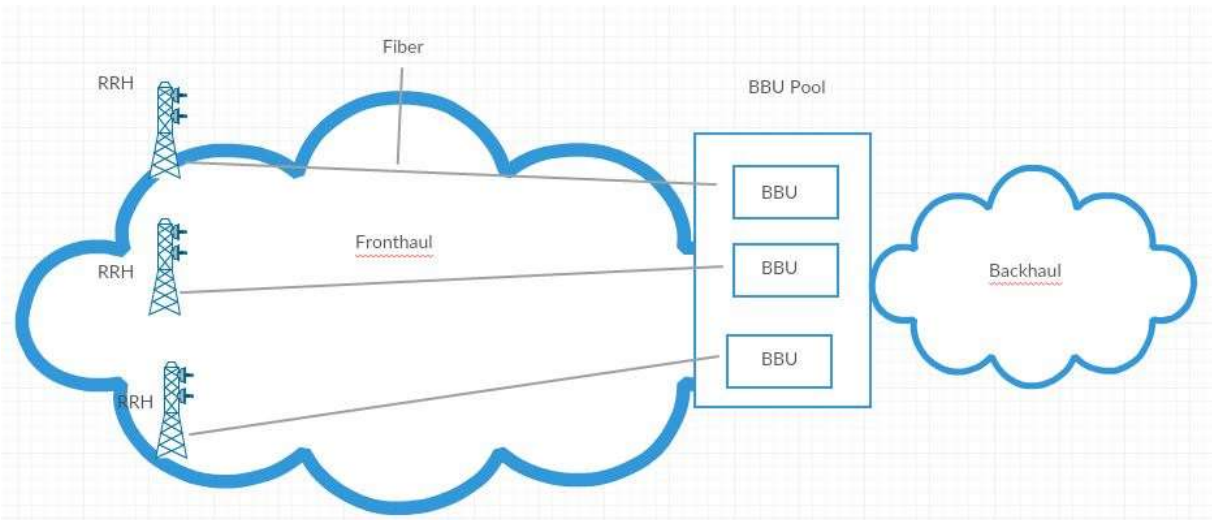


Figure 24. Front haul

Front haul is associated with a brand new and exclusive form of Radio Access Network (RAN) structure together with centralized baseband controllers and standalone radio heads installed at remote cellular sites positioned kilometers to tens of kilometers away [19]. Those BBU and RU purposeful blocks, as well as the device that plays those functions, are positioned similarly far from every apart from inside the cell backhaul version. Inside the front haul version, the RU system is now called a Remote Radio Head (RRH) however is still placed at the cell site. The BBU is now relocated to centralized and protected location where it serves a couple of RRHs. The optical links that interconnect the newly centralized BBU and the more than one RRHs is referred to as front haul.

A cooperative consortium of wi-fi carriers standardized the common Public Radio Interface (CPRI) protocol that runs over those front haul hyperlinks lower back in June of 2003. CPRI may be carried over tens of kilometers, is well suited with low-value and ubiquitous SFP/SFP+ pluggable, and leverages fee-powerful modulation schemes, inclusive of Quadrature Amplitude Modulation (QAM). CPRI also facilitates keeping network expenses down while facilitating optical link engineering.

The high overall performance requirements of CPRI -- as they relate to potential, reach, and in particular latency -- mandate fiber connectivity between centralized BBUs and the multiple RRHs. The usage of CWDM, and/or DWDM optics satisfies those desires, relying upon software specifics such as availability of fiber to the cell and at the tower feeding the RRHs set up on its pinnacle. Supported CPRI cost of 2.458Gbps, 3.072Gbps, 4.915Gbps, 6.144Gbps, 9.830Gbps, and potentially past, are extraordinarily high when in comparison to the plenty lower 1Gbps macro backhaul hyperlinks normally deployed nowadays. This higher CPRI bandwidth at once correlates to complicated and uncompressed baseband records samples

16.CPRI

The common Public Radio Interface (CPRI) is an industry cooperation meant to define a publicly available specification for the key inner interface of radio base stations among the Radio equipment control (REC) and the Radio equipment (RE)

16.1 Scope of Speculation

The important objects for delivery, connectivity and control are included in the specification [20]. This consists of user plane statistics, Control and Management Plane transport mechanisms and way for synchronization. A focus is being put on hardware structured layers. This ensures unbiased technology evolution , with a restrained need for hardware variation.

In addition, product differentiation in phrases of capability, control, and traits isn't always restrained. With a clean attention on layer 1 and layer 2 the scope of the CPRI specification is restricted to the hyperlink interface is most effective, which is largely a point to factor interface. Any such hyperlink shall have all the features necessary to enable a simple and sturdy utilization of any given REC/RE network topology, consisting of an immediate interconnection of multiport REs. Redundancy mechanisms aren't described within the CPRI specification, but all of the necessary functions to guide redundancy, in particular in system architectures presenting redundant physical interconnections (e.g. earrings) are defined

Radio base stations have to offer deployment flexibility for the cell network operators, i.e., in addition to a concentrated radio base station, greater flexible radio base station machine architectures concerning remote radio device shall be supported. This could be executed by using a decomposition of the radio base station into primary building blocks, the so-called radio system control (REC) and the radio equipment (RE) itself. both elements can be physically separated or both can be co-positioned as in a conventional radio base station layout.

The REC includes the radio features of the digital baseband area, while the RE consists of the analogue radio frequency functions. The functional split between both elements is done in this kind of way that a normal interface based totally on In-phase and Quadrature (IQ) statistics can be described. For the UMTS radio access network, the REC gives get admission to the Radio Network Controller through the Iub interface, while the RE serves as the air interface, referred to as the Uu interface, to the end device. For E-UTRA, the REC provides access to the EPC for the delivery of user and control plane site traffic thru S1 interface, while the RE serves as the air interface to the UE. For GSM, the REC provides access to the base Station Controller through the interface, whereas the RE serves because the air interface, known as the Um interface, to the cellular station.

A greater targeted description of the purposeful split between each components of a radio base station machine is provided. Similarly, to the user plane statistics (IQ records), control and management in addition to synchronization indicators ought to be exchanged between the REC and the RE. All information flows are multiplexed onto a digital serial exchange line using suitable layer 1 and layer 2 protocols. The distinct data flows have get entry to the layer 2 thru appropriate provider get entry to points. This defines the common public radio interface. The common public radio interface may also be used as a hyperlink among two nodes in machine architectures helping networking.

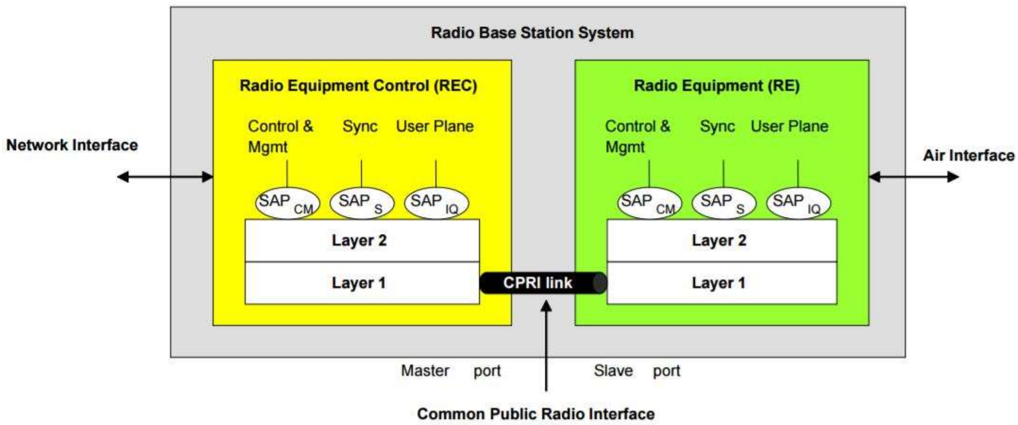


Figure 25. Common Public Radio Interface [28]

16.2 Basic Configuration

The primary configuration is composed of 1 REC and 1 RE related by a single CPRI hyperlink [20]. The basic configuration can be prolonged in several ways:

• First, numerous CPRI links can be used to increase the system capacity as required for large device configurations regarding many antennas and carriers. It's required that an IQ records flow of a positive antenna and a certain antenna-carrier is carried absolutely by means of one CPRI link. consequently, the range of bodily links isn't restricted with the aid of this specification.

• 2nd, several REs may be served by one REC for the so-called big star topology.

• 3rd, one RE can be served through a couple of RECs. The requirements for this configuration are not fully blanketed inside the CPRI specification.

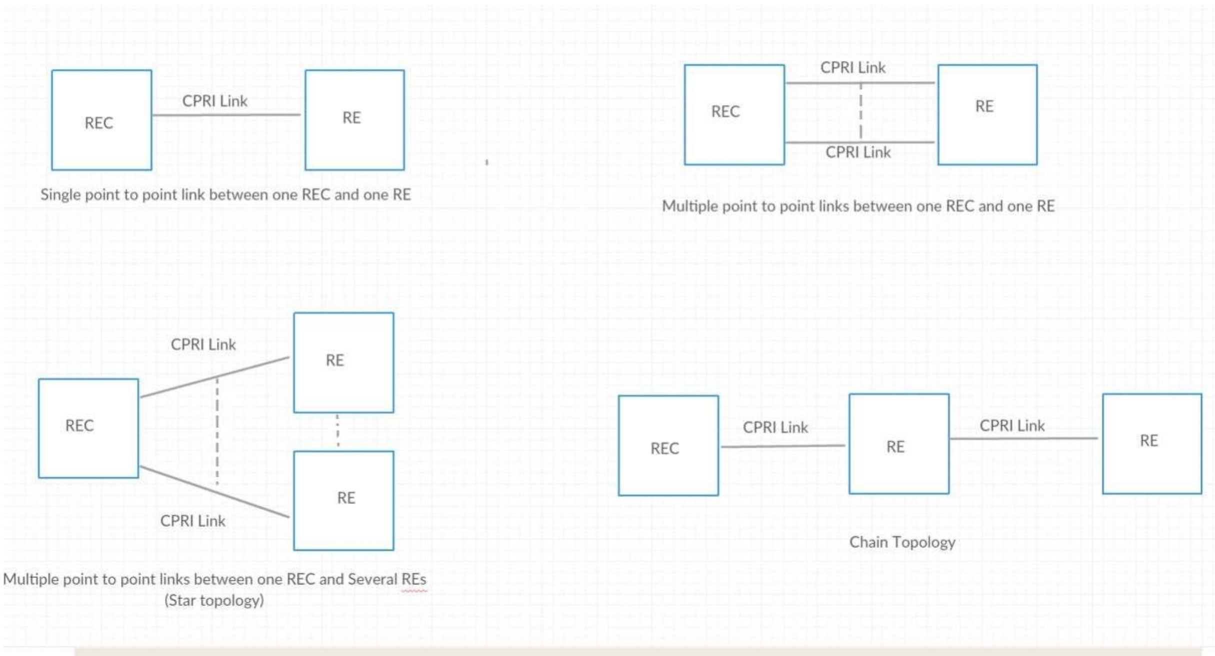
• furthermore, 3 simple networking topologies may be used for the interconnection of REs:

o Chain topology

o Tree topology

o Ring topology

o If a radio base station has more than one RECs, e.g. of various radio get admission to technology, the CPRI interface may be used for the interface among two RECs.



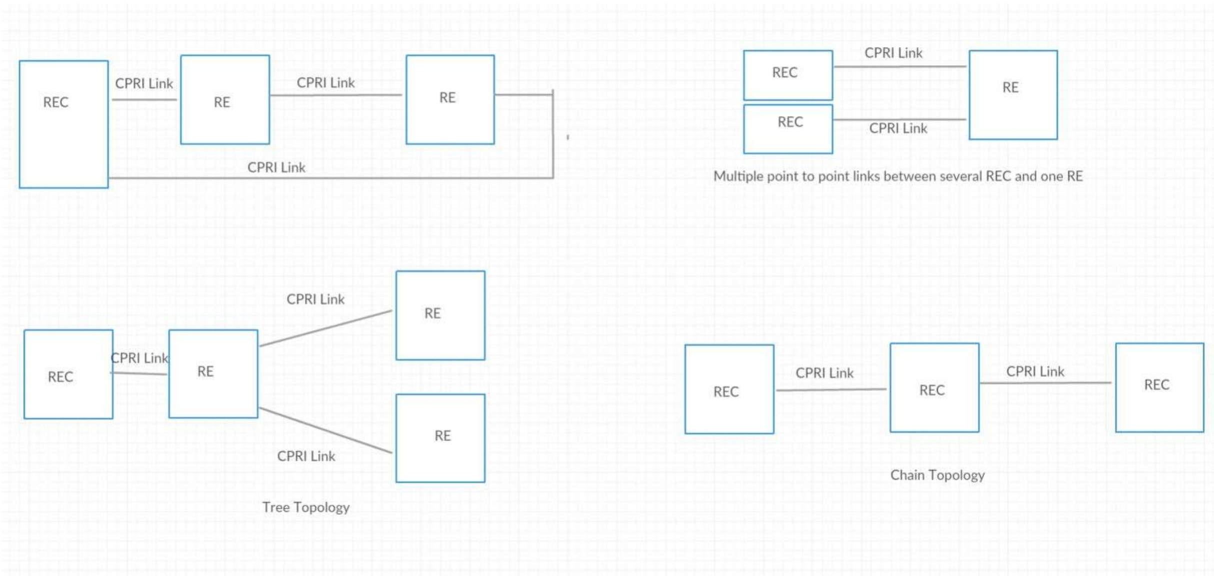


Figure 26. Basic CPRI Configurations

16.3 Designing CPRI

When designing a RRH with a CPRI link [21], there are a few system level decisions that must be made regardless of the actual hardware implementation of the CPRI interface:

1.Determine the wireless standard being supported and thus what CPRI mapping method required

2.What the number of antenna-carrier interface will be required per CPRI link

3.The CPRI line rate

4.The CPRI output data format

16.4 CPRI Frame Structure

A simple CPRI frame has length Tc=1/fc=1/3.84MHz = 260.41667ns. The basic body structure is shown below [21], wherein T is the phrase length given by means of (Line charge in Mbps)/76.8, so it varies with the line rate.

A primary frame consists of 16 phrases, wherein the first phrase of each simple frame is a control phrase. the opposite 15 words are used to hold user plane information.

The user plane information is presented within the form of in-phase and quadrature base band information, or IQ data. The frame structure illustrates the quantity of user plane information a particular line price can assist. The subsequent subsection is the way to pick line price based totally on a user application.

16.5 Choosing the CPRI Line Rate

The primary frame illustrates the amount of user plane statistics a selected line rate can bring [21]. the following equation calculates what number of statistics bits are to be had in a CPRI primary body to carry IQ information:

$$\text{Total number of information bits in a basic frame} = \frac{\text{Line Rate}}{\text{Sample Rate}} * \frac{15}{16} * \frac{8}{10} \quad (1)$$

The factor 15/16 accounts for the reality that out of the 16 words in a primary frame, 15 are information phrases. The component 8/10 accounts for the 8B10B encoding that the CPRI specification requires inside the Tx path. Based on 8B10B, most effective 80% of the CPRI line capability is used to transmit non-encoded statistics, with the other 20% getting used on encoding redundancy.

Line Rate (Mbps)	614.4	1228.8	245.76	3072	4915.2	6144
IQ Bits	120	240	480	600	960	1200

Table 2. No of IQ bits per frame as function of CPRI.

The minimum CPRI line rate ought to be able to guide a wi-fi system's general bandwidth. That is, the quantity of IQ information that comes throughout the CPRI link between the base station and the RRH all through a 260.67ns length, should no longer exceed the variety of IQ bits listed in Table 1for a given line charge.

The following instance considers a single zone, mixed bandwidth LTE FDD with two transmitting and receiving antennas. Across a 20MHz allocated bandwidth in line with antenna, a 10MHz LTE provider runs simultaneously with 5MHz LTE providers.

In this example, a complete of (1 + 2) x 2 = 6 antenna-service pairs, where the thing 2 is to account for 2 antennas on both the transmitting or the receiving aspect. assume both I and Q information are 16-bit wide. The range of bits the 6 antenna-carrier pairs deliver at some point of a 260.67ns primary body can be calculated as [Sample Rate (in MHz)/3.84] x 16 x 2 x [Number of AxCs]. In this situation, general number of IQ bits from the application is:

30.72/3.84x32x2 + 7.68/3.84x32x4 = 768.

Compare 768 with the total no of IQ bits that a line rate supports, in which 4.9Gbps is the minimal line rate required for this application. Instead, multiple parallel CPRI hyperlinks can be used to support excessive throughput excessive bandwidth programs. In maximum instances, however, having multiple parallel CPRI links complicates records path synchronization responsibilities within the actual implementation. It also requires a couple of optical cables between REC and RE, which provides to the gadget setup and renovation cost.

17. Centralized Radio Access Network

C-RAN is a Network structure in which baseband sources are pooled, so that they may be shared between base stations [11]. The place in which a mobile network covers is divided into cells, consequently the networks are known as cell networks. Traditionally, in cellular networks, users speak with a base station that serves the cell under coverage of which they are placed. The principle capabilities of a base station may be divided into baseband processing and radio functionalities. The main sub-features of the baseband processing module are coding, modulation and so on. The radio module is liable for digital processing, frequency filtering and energy amplification.

In CRAN, as BBUs from many sites are co-placed in one pool, they are able to have interaction with decrease delays – consequently mechanisms brought to boom spectral efficiency and throughput, together with more suitable ICIC (eICIC) and CoMP are significantly facilitated. Methods for implementing load balancing among the cells also are facilitated. Furthermore, overall performance is improved, e.g., by means of decreasing delay for the duration of intra-BBU Pool handover. C-RAN is visible as standard cognizance of cellular network assisting gentle and inexperienced technology in the fifth era (5G) mobile N/W in 12 months 2020 horizon. However, C-RAN is not the best candidate structure which can answer the demanding situations faced by way of cellular network operators. Different answers include small cells, being a part of HetSNets and big MIMO. Small cells deployments are the main competitors for outside hot spot in addition to indoor coverage situations. All-in-one small footprint solutions like Alcatel-Lucent's Light Radio can host all base station functionalities in some liters field. They may be positioned outdoors lowering the price of operation associated to cooling and cell website online rental. However, they may be underutilized in the course of low-hobby durations and can't hire collaborative functionalities in addition to C-RAN can do. Furthermore, they may be greater difficult to improve and restore than C-RAN. The brief contrast among C-RAN, large MIMO and HetSNets prove that power efficiency of big scale Small cellular Networks is higher compared with huge MIMO. Moreover, price assessment on exclusive options wishes to be executed in the order for a mobile network operator to pick the most appropriate answer. Comparison of TCO including CAPEX and OPEX over eight years, LTE C-RAN and small mobile indicates that the entire transport cost consistent with Mbps is maximum for macro cellular deployment - 2200$, medium for C-RAN - 1800$ and three instances smaller for small mobile - 600$. Therefore, it concludes that C-RAN desires to obtain widespread benefits to triumph over this type of high transportation value. Collaborative strategies which include CoMP and eICIC may be applied in small cells giving better blessings in HetNet configuration in place of C-RAN. C-RAN is attractive for operators that have free/reasonably-priced fiber assets available.

17.1 What is C-RAN

With disbursed BSs because the fundamental factor, a C-RAN device centralizes one-of-a-kind baseband processing sources together to form a pool so that sources may be managed and dynamically allocated on demand on a pool stage [11].

It includes three components.

• **Base-band Unit (BBU) pool:** A BBU pool is located at a centralized website and consists of time-various sets of BBU nodes. A soft BBU is a BBU instance in a conventional N/W where processing resources and abilities are dynamically allotted and reconfigured based on actual-time conditions (e.g. visitors popularity).

• **Remote Radio Unit (RRU) networks:** RRUs will be the same as in traditional systems to offer basic wireless signal.

• **Transport networks:** A transport network presents a connection between a BBU in a pool and the RRU. It may be of various paperwork depending on the situation. A few examples encompass direct fiber connection through dark fiber, microwave transmission and fiber delivery network

A. Traditional architecture

Within the traditional architecture, radio and baseband processing capability is incorporated in the interior of a base station. The antenna module is normally placed within the proximity (few meters) of the radio as coaxial cables hired to attach them show off excessive losses. X2 interface is described between base stations, S1 interface connects a base station with EPC. This architecture changed into famous for 1G and 2G mobile networks deployment.

B. Base station with RRH

In a base station, the bottom station is separated into a radio unit and a signal processing unit. The radio unit is named a RRH. RRH is responsible amplification and filtering of signals, conversions from analog to digital and digital to analog and also provides an interface for the fiber. The baseband signal process half is named a BBU. This structure was introduced while 3G networks are being deployed and correct currently most of the people of base stations use it.

The gap among a RRH and a BBU may be extended the maximum amount as forty kilometers, whereby the downside is returning from process and propagation delay. Glass fiber and microwave connections may be used. On this architecture, the BBU device can be placed in extra handy, effortlessly reachable place, permitting cost financial savings on site apartment and maintenance compared to the traditional RAN structure, wherein a BBU desires to be placed close to the antenna.

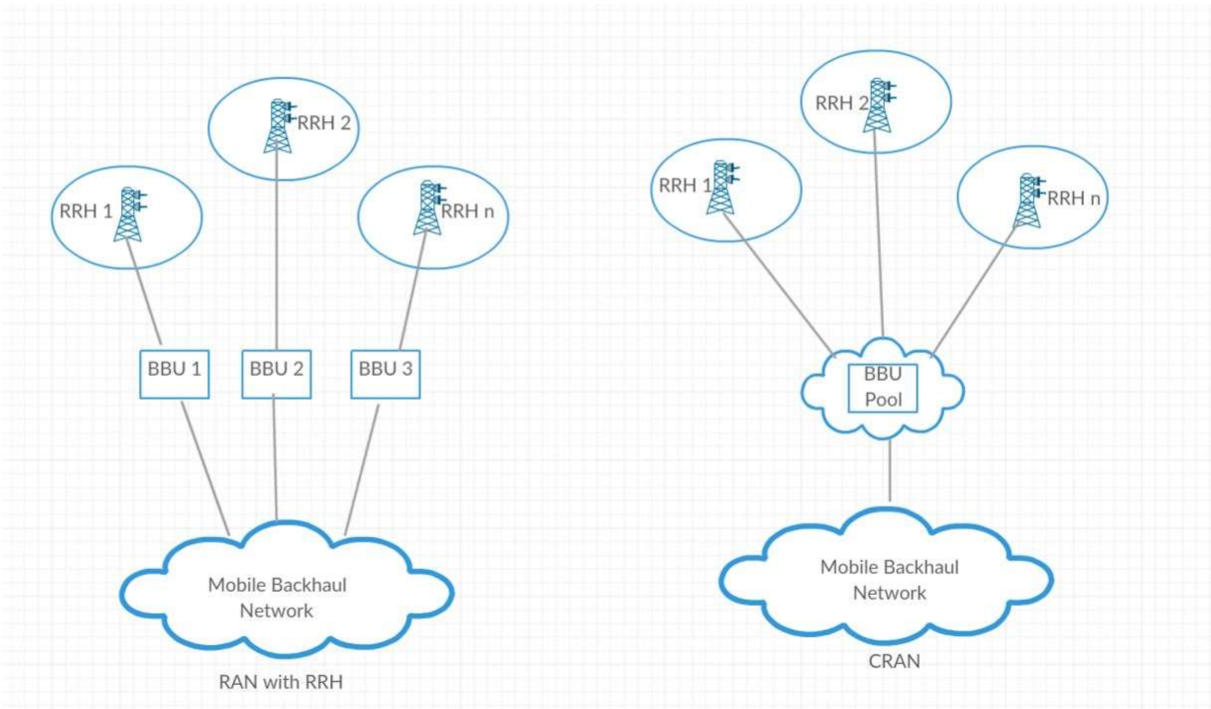


Figure 27. Architectures of RAN & CRAN

RRHs may be positioned upon poles or rooftops, leveraging green cooling and saving on air conditioning in BBU housing. RRHs are statically assigned to BBUs equally to the normal RAN. One BBU will serve several RRHs. Associate in Nursing Ir interface is represented, that connects RRH and BBU.

CPRI is the radio interface protocol widely used for IQ facts transmission between RRHs and BBUs - on Ir interface. It is a constant bit price, the bidirectional protocol requires precise synchronization and control of strict latency.

17.2 Centralized Base Station Architecture

In order to optimize BBU usage among heavily and gently loaded base stations, the BBUs are centralized into one entity this is called a BBU [11]. A BBU Pool is shared among mobile sites and virtualized. A BBU Pool is a virtualized cluster that could encompass popular purpose processors to perform baseband (PHY/MAC) processing. X2 interface in a brand-new form, often called X2+ organizes inter-cluster communication. The idea of C-RAN was first delivered via IBM beneath the name wireless network Cloud (WNC) and builds at the idea of allotted wireless communication machine.

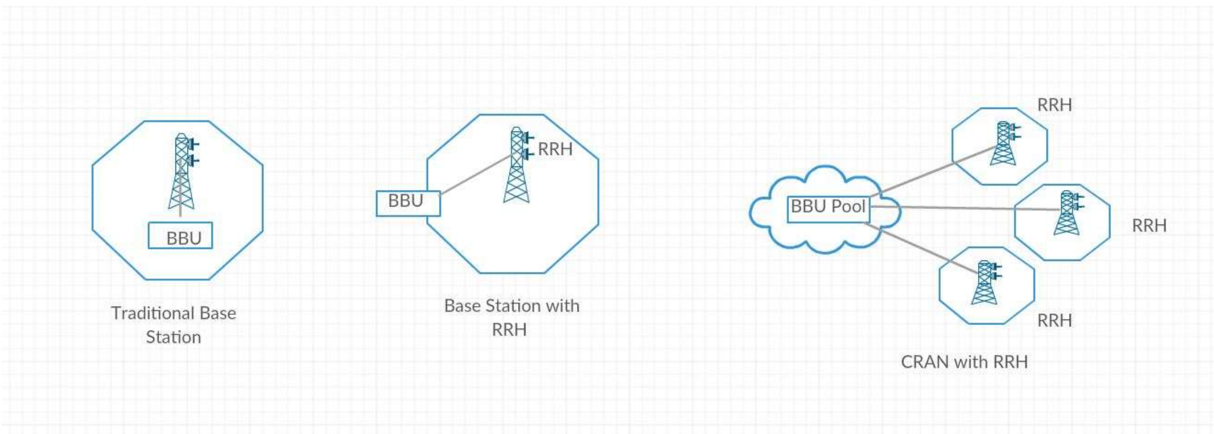


Figure 28. Base Station Architecture Evolution

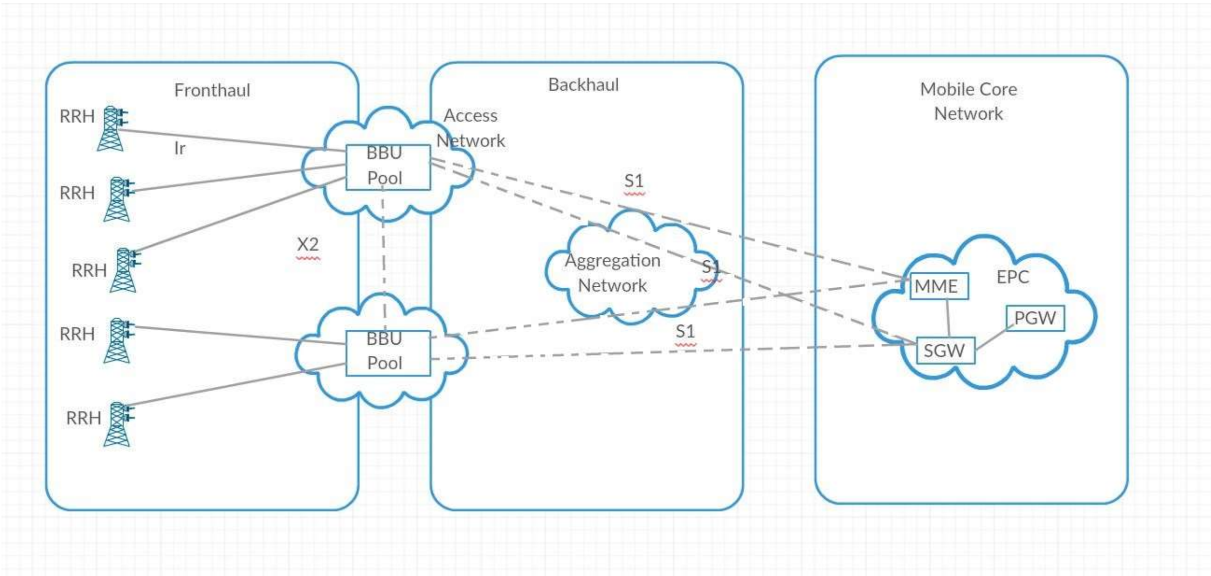


Figure 29. CRAN LTE Mobile Network

C-RAN is the term utilized now to depict this engineering, where the letter C can be translated as Cloud, Centralized processing, Cooperative radio, Collaborative or Clean. The above figure is a case of a C-RAN mobile LTE network. The front haul part of the system ranges from the RRHs locales to the BBU Pool. The backhaul interfaces the BBU Pool with the mobile core network. At a remote site, RRHs are co-situated with the receiving wires. RRHs are associated with the superior processors in the BBU Pool through low idleness, high transmission capacity optical transport links. digital baseband, i.e., IQ tests, are sent between a RRH and a BBU.

Architecture	Radio and baseband functionalities	Problem it addresses	Problems it causes
Traditional base station	Co-located in one unit	-	High power consumption Resources are underutilized
Base station with RRH	Spitted between RRH and BBU. RRH is placed together with antenna at the remote site. BBU located within 20-40 km away. Generally deployed nowadays	Lower power consumption. More convenient placement of BBU	Resources are underutilized
C-RAN	Spitted into RRH and BBU. RRH is placed together with antenna at the remote site. BBUs from many sites are co-located in the pool within 20-40 km away. Possibly deployed in the future	Even lower power consumption. Lower number of BBUs needed - cost reduction	Considerable transport resources between RRH and BBU

Table 3: Comparison Between Traditional BS, BS With RRH & C-RAN [11]

17.3 Advantages of C-RAN

In C-RAN architecture [11], a centralized BBU Pool allows an effective usage of BBUs and decreases the price of base stations deployment and operation. It additionally reduces energy consumption and presents extended flexibility in network upgrades and adaptableness to non-uniform visitors.

Furthermore, superior capabilities of LTE-A, which include CoMP can be successfully supported by way of C-RAN, that is crucial especially for small cells deployments. Ultimate but now not least, having high computational processing electricity shared by way of many customers placed towards them, cellular operators can provide users extra appealing Service Level Agreements (SLAs), because the reaction time of software servers is pretty shorter if statistics is cached in BBU Pool. Network operators can accomplice with third party provider developers to host servers for packages, finding them within the cloud - within the BBU Pool.

17.3.1 Adaptability to Non-Uniform Traffic & Scalability

Typically, for the duration of a day, customers are transferring from one area to another, e.g., residential and workplace [11]. Base stations are frequently dimensioned for busy hours, which means that once users pass from office to residential regions, the huge quantity of processing electricity is wasted inside the regions from which the customers have moved. The traffic load during peak can be ten times higher than off-peak hours.

In each mobile, daily traffic distribution varies, and the peaks of visitors occur at extraordinary hours. on the grounds that in C-RAN baseband processing of multiple cells is done within the centralized BBU pool, the overall utilization can be progressed. The specified baseband processing of the pool is anticipated to be lesser than sum of all the single base stations. The ratio of sum of the single base stations to the potential required inside the pool is called statistical multiplexing gain. In an evaluation on statistical multiplexing gain is finished as a characteristic of cellular format. The evaluation suggests that in a metropolitan place, the variety of BBUs can be reduced by using 75% as compared to the conventional RAN structure.

The multiplexing benefit of consolidating WiMAX base stations is in unique site visitor's situations. The benefit will increase linearly and it's far higher when base stations are experiencing better site visitor's intensity. The centralized structure can probably bring about savings of as a minimum 22% in compute sources by exploiting the variations in the processing load throughout base stations. The records traffic influences the variance of the compute resource usage, which in outcome results in giant multiplexing profits if a couple of sectors are combined into a single cloud BS. Combination of fifty-seven sectors into one single BBU Pool saves higher than twenty five percent of the compute assets. Furthermore, the consumer distribution has a robust impact on at the utilization of the compute resources. Coverage upgrades certainly require the connection of latest RRHs to the already present BBU Pool. To enhance Network capability, present cells can then be split, or additional

RRHs may be brought to the BBU Pool, which will increase network flexibility. Deployment of latest cells is in standard more effortlessly widely wide-spread via neighborhood communities, as simplest a small tool needs to be established on site (RRH) and now not a cumbersome base station. If the overall N/W capacity shall be improved, this could be without difficulty performed through upgrading the BBU Pool, both through adding greater hardware or replacing existing BBUs with greater effective ones.

As BBUs from a large region could be co-placed within the same BBU Pool, load balancing features may be enabled with advanced algorithms on both the BBU side and the cells facet. On the BBU facet, BBUs already form one entity, therefore load balancing is an issue of assigning proper BBU assets within a pool. on the cells side, users may be switched between cells without constraints if the BBU Pool has capacity to guide them, as capability may be assigned dynamically from the pool.

17.3.2. Savings of Cost & Energy

Eighty percent of the CAPEX is spent on RAN, therefore it's essential to work towards decreasing it [11]. Energy in cell network is spent on power amplifiers, supplying RRH and BBU with electricity and air conditioning. 41% of OPEX on a mobile website is spent on power. Using C-RAN gives reduction of power price, as the number of BBUs in a C-RAN is decreased in comparison to a traditional RAN. Furthermore, inside the lower visitor's period, e.g. at some stage in the night time, some BBUs within the pool can be switched off not affecting standard network insurance. Another essential element is the decrease of cooling resources, which takes 46% of cellular website energy consumption. Due to using RRHs aircon of radio module can be decreased as RRHs are obviously cooled by way of air hanging on masts or constructing partitions. ZTE estimates that C-RAN allows 67%-80% power financial savings as compared with traditional RAN structure, depending on how many cells one BBU Pool covers, which remains consistent with China mobile research claiming 71% energy savings [10]. In general, 15% CAPEX and 50%

OPEX financial savings are envisioned comparing to RAN with RRH or traditional RAN structure. But the cost of leasing the fiber connection to the web site may also boom CAPEX. IQ sign transported among RRHs and BBUs brings up an enormous overhead. consequently, the installation and operation of delivery network causes sizeable costs for operators.

17.3.3. Increase of Throughput, Decrease of Delays

The subsequent technology mobile network envisioned to eventually update the 3G networks are referred to as LTE and have been standardized with the aid of Third Generation Partnership project [11]. As LTE is being currently deployed globally, LTE and LTE-A are the maximum prominent requirements to be deployed as C-RANs. This section introduces LTE RAN and mechanisms. Due to pooling of BBU sources in a C-RAN, the features are significantly facilitated, as signal process from several cells is done over one BBU Pool, easing the implementation and reducing process and sending delays. Right data of eICIC and CoMP permits to end some chances that C-RAN provides. LTE operates with shared resources most effectively. There may be a scheduler in the base station (called evolved Node B (eNB) in LTE) that looks after all aid allocation/assignments. A key function in LTE is the radio access scheme based on OFDMA. The prime concept in OFDMA is to apply a massive wide variety of densely spaced, orthogonal providers. Assets may be dynamically allocated each in the frequency and time domain. This gives a very flexible usage of the to be had sources. LTE systems usually use a frequency reuse component, which means that each one cell perform on the same frequency. As a result, inter-cell interference is in particular high in such systems. This is observed as a totally excessive ratio among peak throughput and mobile area throughput. Essentially, there are methods to deal with the interference difficulty: minimizing interference and exploiting interference paths constructively

1) **MINIMIZING INTER CELL INTERFERENCE**

Inter cell interference may be prevented either statically or dynamically in time, frequency and power domain [11]. An apparent, static solution isn't always to use co-channel deployment, i.e., honestly by using the usage of one of a kind frequencies in adjoining cells. that is called hard frequency reuse and has the gain that it avoids X2 signaling nearly completely. Fractional frequency reuse can also be used but because the frequency sources on lower bands are scarce it's far higher to use other solutions instead of those related to frequency reuse. Therefore, this segment specializes in the case in which the equal frequency resources are being used in all cells and thus Inter-cell Interference Coordination (ICIC) was released. In this scheme, UEs will report back to the eNB just in case they expertise robust interference on bound sub-carriers. The eNB can then (by the use of the X2 interface) coordinate with the neighboring cell in order that these sub-carriers are not used for that particular cell. It's far vital to word here, that that is implemented to cell-edge mobiles only. close to the center of the cellular there may be no interference and the overall useful resource set may be utilized.

The scheme works in uplink (UL) in addition to downlink (DL). In DL the eNBs can change the so called RNTPs which is a bitmap comprising data on the transmit strength on each RB. In the UL they are reactive, using OI (Overload indicators) and proactive, with the use of HII strategies. It requires no synchronization of eNBs, simplest load and scheduling statistics need to be exchanged. The downside is that the scheduler running in each eNB could make less choicest scheduling decisions if it has to take neighbor mobile interference into consideration. Furthermore, the manipulate channels still intervene, as they're sent on constant resources. This scheme is slow enough to operate seamlessly on networks with a dispensed base station structure.

eICIC exploits the time domain via introducing ABS (Almost Blank Sub-frames) which means that precise sub-frames are muted. (In reality they're no longer muted absolutely. To lead them to backward compatible, a few signals, e.g., CRS is still being transmitted, consequently the name almost blank). In the event that one transmission is quieted, there will be no impedance and this obstruction loosened time interim can now be utilized to ship basic records, e.g., signaling and reference indicators. The actual muting sample to apply is being coordinated between the eNBs through the use of the X2 interface. The eICIC idea is standardized, however the actual muting styles and the algorithms to choose them are not. The energy domain can also be exploited to alleviate interference problems. These strategies are relevant basically in the UL path in HetNet eventualities. The concept is clearly to dynamically manage the transmit energy of the cellular station and in this way manage interference between the p.c. and macro layer.

2) **UTILIZING INTERFERENCE PATHS CONSTRUCTIVELY**

The most advanced manner of dealing with inter-cellular interference is known as CoMP, which is predicated on the essential idea to turn interference into a beneficial signal[11]. This will increase the signal to Interference plus Noise Ratio (SINR) at the cell, which again will become higher plausible bit quotes. With CoMP several cells, grouped in a so-referred to as CoMP set, cooperate on serving one consumer or a collection of users, based totally on feedback from the cellular(s). specially in DL this requires tight synchronization and coordination of a few of the base stations in a CoMP set.

The only CoMP implementation can be visible as an extension of ICIC. Here one mobile simplest gets transmission from one eNB , while the last eNBs within the CoMP set aid in warding off interference. They do this by means of no longer the usage of precise sub-providers (CS - Coordinated Scheduling) and/or making use of unique, e.g., beamforming, antennas (CB - Coordinated Beamforming). Hence, the gain here is that everyone cells in the CoMP set mutually decide on how to do scheduling and beamforming for you to decrease interference for all customers. CS/CB calls for base station synchronization much like ordinary LTE machine operation, as most effective one base station is actively transmitting to one consumer at a time.

A variety of CS/CB is known as Dynamic cell selection (DCS). In this example, the information to be transmitted to a specific cellular is made to be had to all cells in a CoMP set. At a given factor of time nonetheless handiest one eNB transmits to a mobile, however the cells coordinate which must do the real transmission. That's very good as transmission will currently be completed from the eNB that has most favorable transmission course to the mobile. This scheme requires base station synchronization at the equal stage as CS/CB. Joint Transmission (JT) is the most superior CoMP scenario. In JT the statistics to be transmitted is also to be had to all cells inside the CoMP set, but in this case, numerous cells at the same time and coherently transmit to at least one consumer. It is based on very well timed and accurate feedback from the terminal at the assets of the mixed channel from several base stations. so that you can acquire this, a new set of CSI (Channel State Information) reference sign became evolved and integrated into the standards. In single consumer JT, numerous cells simply ship the identical information to 1 consumer. Consequently, in preference to muting sources (as in ICIC), the identical facts is transmitted with specific timing to allow the signals to be mixed coherently on the receiver and as a result reaching a SINR gain. The downside is of route is that this takes up resources in several cells and for this reason efficiently creates a reuse issue 1/3 factor. which means that it's far most appropriate for gently loaded systems. Single consumer JT can be blended with DCS, meaning that the CoMP set is dynamically changing. For heavily loaded structures JT can be increased to multiuser JT, wherein groups of customers are sharing (time-frequency) assets. This is, in essence, a mixture of multi user MIMO and JT. This scheme calls for tight base station and it's miles accordingly beneficial to use in centralized (i.e., C-RAN) based N/W architectures

From an overall performance point of view, it turns out that DCS is brilliant scheme in 2x2 MIMO operation. Four transmit antennas are needed with a view to take gain of more complex schemes inclusive of JT. If all of the cells inside a CoMP set are served with the aid of one BBU Pool, then a single entity doing signal processing permits tighter interplay among base stations. Therefore, interference may be kept to a lower degree and therefore the throughput may be elevated. It's been proven that combining clustering of cells with CoMP makes greater green use of the radio bandwidth . Moreover, ICIC may be carried out over a primary unit - BBU Pool - optimizing transmission from several cells to multiple BBUs.

The factors affecting the performance of CoMP with LTE in C-RAN UL, are receiver set of rules, reference alerts orthogonality and channel estimation, density and length of the network. In present simulation consequences which evaluate spectrum performance of intracell and inter-cell JT to non-cooperative transmission. 13% and 20% increase in spectrum performance is found, respectively. For a cellular part consumer, spectrum efficiency can increase by means of 75% and 119%, respectively. Throughput benefit is 30-50% when there's no interference and might attain 150% while interference is present. MRC (Maximum Ratio Combining) and complete IRC (Interference Rejection Combining) are compared here. Due to the deduction of X2 usage in C-RAN, real time CoMP can supply 10-15% of joint processing gain, whilst real time ICIC permits 10-30% of multi cell Radio Resource Management (RRM) lead. The overall performance of more than one-point JT and multiple-person joint scheduling has been analyzed for a non-perfect channel with the service frequency offset. When the carrier frequency doesn't exceed 3~5ppb, C-RAN achieves outstanding overall performance benefit on both capacity and coverage even in non-ideal channel, i.e., 20%/52% for cellular average/mobile side. With the advent of the BBU Pool cooperative techniques, as Multi-cellular MIMO can be enhanced. This will be carried out due to tighter cooperation among base station within a pool. The downlink Antenna Selection Optimization scheme for MIMO based totally on C-RAN that confirmed benefits over traditional antenna choice schemes.

3) **DECREASE OF THE DELAYS**

The time needed to perform handovers is shriveled as a result of it should be distributed inside the BBU Pool rather than among eNBs [11]. In GSM, the whole common relinquishing interrupt time is decreased and so the sign is reduced thanks to higher synchronization of BBUs. In regular cellular Telecommunications system (UMTS) signal, Iub delivery bearer setup and shipping metric wants region unit reduced, but, the overall performance improvement might not be detected with the help of the person. For LTE X2-primarily based inter-eNB relinquishing the shelve and failure rate locality unit slashed. Moreover, the ultimate quantity of sign data dispatched to core cellular network is reduced, whereas being aggregated inside the pool.

17.3.4. Network Upgrades & Maintenance Ease

C-RAN architecture with numerous co-placed BBUs eases network renovation [11]. Now simplest C-RAN capacity peaks and failure might be absorbed by way of BBU Pool automated reconfiguration, therefore restricting the need for human intervention. However, on every occasion hardware screw ups and enhancements are simply required, human intervention is to be achieved best in a totally few BBU pool places. At the contrary for classic RAN, the servicing can be required at as many cell sites as there are within the network. C-RAN with a virtualized BBU Pool offers an easy way for introducing new standards, as hardware desires to be placed in few centralized places. Consequently deploying it may be taken into consideration through operators as part of their migration strategy. Co-locating BBUs in BBU Pool allows extra common CPU updates than in case while BBUs are located in far flung sites. It is therefore viable to enjoy the IT technology enhancements in CPU generation, be it frequency clock (Moore's law) or energy efficiency.

software Defined Radio (SDR) is a widely known skill that helps implementation in software program of such radio functions like modulation/demodulation, sign technology, coding and hyperlink-layer protocols. The radio gadget may be designed to guide a couple of requirements. A possible framework for implementing software program base stations which are remotely programmable, upgradable and optimizable. With such technology, C-RAN BBU Pool can assist multi-trendy multi-gadget radio communications configured in software. upgrades to new frequencies and new requirements may be accomplished through software program updates in place of hardware enhancements as it's far regularly achieved these days on non-well matched vertical answers. Multi-mode base station is consequently predicted to alleviate the price of N/W improvement and Operations, administration and maintenance (OAM).

17.4 Challenges of C-RAN

Earlier than the commercial deployment of C-RAN architectures some of the challenges that needs to be addressed are given below.

A. HIGH BANDWIDTH, STRICT-LATENCY AND JITTER & LOW COST TRANSPORT NETWORK

C-RAN architecture brings a large overhead at the optical hyperlinks between RRH and BBU Pool [11]. Comparing with backhaul requirements, the one on front haul are expected to be 50 instances higher. IQ data is sent among BBU and RRH, the primary individuals to the size of IQ statistics are: turbo coding, chosen radio interface (e.g., CPRI), IQ sample width and oversampling of LTE sign. As an example, 30.72 MHz sampling frequency is standardized for 20 MHz LTE, that's extra than 20 MHz wished in step with Nyquist - Shannon sampling theorem. Total bandwidth relies upon also on the wide variety of sectors and MIMO configuration. Equation 1 summarizes factors that have an effect on IQ bandwidth. The situation of 20 MHz LTE, 15+1 CPRI IQ pattern width, 10/eight line coding, 2x2 MIMO Tx leading to 2.5 Gbps bit rate in front haul link is often dealt with as a baseline.

Therefore, for 20 MHz 4x4 MIMO, 3 quarter base station, the predicted IQ throughput exceeds 10 Gbps. The centralized BBU Pool have to assist 10 - 1000 base station sites, consequently a substantial quantity of statistics needs to be carried in the direction of it.

IQ Bandwidth = sampling Frequency. sampleWidth.2. line Coding. MIMO . no Of Sectors

The transport network no longer wishes to assist high bandwidth and be cost green, but additionally wishes to guide strict latency and jitter requirements. underneath one-of-a-kind constraints on postpone and jitter are summarized:

1) The most advanced CoMP scheme, JT calls for 0.5s timing accuracy in collaboration among base stations, that's the tightest constraint. but, it is simpler to deal with synchronization demanding situations in C-RAN as compared to standard RAN due to the truth that BBUs are co-placed inside the BBU Pool.

2) No matter the put off due to the cable period, round trip delay of consumer records won't exceed 5s, measured with the accuracy of 16.276ns on every link or hop.

3) The sub-frame processing delay on a link between RRHs and BBU need to be saved under 1 ms, on the way to meet HARQ necessities. due to the put off necessities of HARQ mechanism, typically maximum distance between RRH and BBU should not exceed 20-40 km.

B. CLUSTERING, COOPERATION AND INTERCONNECTION OF BBU

Cooperation between base stations is needed to assist CoMP in terms of sharing the user records, scheduling at the base station and managing channel comments facts to deal with interference [11]. Co-place of many BBUs requires unique security and resilience mechanisms. solutions permitting connection of BBUs shall be dependable, assist high bandwidth and occasional latency, low cost with a flexible topology interconnecting RRHs. Consequently, RAN ought to offer a consistency which is better or comparable to the old-style optical networks like SDH, which finished excessive reliability because of their ring topology. Mechanisms like fiber ring N/W protection may be used. Cells must be optimally clustered to be assigned to at least one BBU Pool, which will achieve statistical multiplexing benefit, facilitating CoMP, nevertheless to stop the BBU Pool and transport network from overloading. One BBU Pool ought to guide cells from one-of-a-kind areas such as office, residential or industrial. After studying interferences a beneficial mission of cells to at least one BBU Pool may be chosen. To achieve finest energy savings of the C-RAN, base stations need to be selected in a manner that will optimize the number of energetic RRHs/BBU units within the BBU Pool. Right RRH aggregation and task to 1 BBU Pool can also facilitate CoMP . To obtain superior throughput at the cellular edges cooperative transmission/reception schemes are needed to cope with massive Inter cell Interference (ICI), enhancing spectrum performance. The aid sharing algorithms had been developed by the research network. They want to be mixed with a set of rules clustering the cells to lessen scheduling complexity. Therefore, the nicely-designed scheduler in C-RAN additionally has an impact on the spectrum efficiency. The recommend structure of CRAN that could dynamically alternate the connections of BBUs and RRHs in recognizing to the traffic call for. Semi-static and adaptive BBU-RRH switching schemes for C-RAN are offered and evaluated , in which it changed into proved that the quantity of BBUs may be decreased via 26% and 47% for semi-static and adaptive schemes, respectively, as compared with the static task.

C. VIRTUALIZATION TECHNIQUE

A virtualization method desires to be proposed to distribute or institution processing between virtual base station entities and sharing of assets among more than one operators [11]. Any processing set of rules have to be predicted to work real time - dynamic processing capability allocation is important to cope with a dynamically changing cellular load. various virtualization strategies are evaluated. Virtualization and cloud computing techniques for IT packages are properly described and evolved. But, C-RAN utility poses one-of-a-kind requirements on cloud infrastructure than cloud computing.

18. Transport Network Techniques

A C-RAN imposes a widespread overhead on the transport network. Let's deal with some of the transport N/W potential problems, evaluating the inner architecture of C-RAN and the physical medium [11], in addition to transport layer solutions that might support C-RAN. An essential attention is to apply IQ compression/decompression between RRH and BBU. The primary cognizance is on the front haul delivery network, as this is the feature for C-RAN. Considerations on backhaul N/W can be found also, the selection of the answer for the unique cellular network operator depends on whether or not C-RAN is deployed from scratch as inexperienced subject deployment or brought on the pinnacle of present infrastructure.

18.1 PHY Layer Architecture

1) PHY-layer architecture: There are two methods on how to break up base station capabilities between RRH and BBU within C-RAN that allows you to lessen transport network overhead. Within the completely centralized solution, L1, L2 and L3 functionalities reside within the BBU Pool [11]. This solution intrinsically generates excessive bandwidth IQ facts transmission between RRH and BBU. In partly centralized solution, L1 processing is co-located with the RRH, thus decreasing the weight in terms of bandwidth at the optical delivery links, because the demodulated sign occupies twenty to fifty times less bandwidth [10] than the modulated one. This solution is however less superior because useful resource sharing is extensively reduced and advanced functions including COMP cannot be effectively supported. CoMP benefits from processing the

signal on L1, L2 and L3 in a single BBU Pool in place of in numerous base stations [10]. consequently, a fully centralized answer is greater most excellent. Different answers, in among the 2 mentioned above, have additionally been proposed, in which only a few specific functions of L1 processing are co-located with the RRH, e.g., L1 pre-processing of cellular/sector specific features, and most of L1 is left in the BBU.

2) Physical medium: Handiest 35% of base stations may be linked via fiber, and 55% by way of wi-fi technologies, the ultimate 10% with the aid of copper on an international scale in 2014. But, the worldwide share of fiber connections is developing. In North, the united states the very best percentage of backhaul connections will be achieved over fiber - 62.5% in 2014. Fiber links allow huge transport potential, assisting up to tens of Gbps consistent with the channel. 40 Gbps consistent with the channel is now commercially available, even as future structures will be using one hundred Gbps modules and higher, whilst their charge and maturity will become greater attractive. Normal microwave answers provide from 10 Mbps-100 Mbps up to 1 Gbps variety.

For small cells deployment, wi-fi is visible as a probable solution for wireless backhauling. Consequently, the usage of the same solution, wi-fi can probably be used for hauling. The state-of-the-art wi-fi preferred, IEEE 802.11ad, can achieve the most theoretical throughput of 7 Gbps. however, the answer is not to be had on the market yet. The answer based totally on copper links isn't taken under consideration for C-RAN, as Digital Subscriber Line (DSL) can offer most effective up to10-100 Mbps. To finish, complete C-RAN deployment is currently handiest possible with fiber links among RRH and BBU Pool. In case C-RAN is installed in partially centralized architecture, the microwave can be used as a medium between RRHs and BBU Pool.

18.2. Transport Network

As fiber is that the most outstanding resolution for the physical medium, its handiness for the network operator has to be taken under consideration selecting the optimum transport network resolution. Moreover, operators might want to recycle their existing deployments. numerous transport network solutions area unit mentioned below.

18.2.1 Dark Fiber

Dark fiber is a favored solution for a BBU Pool with less than 10 macro base stations, because of ability requirements. Dark fiber may be deployed rapidly and with low fee, because no additional optical transport network equipment is necessary [10] [11]. Alternatively, this solution consumes giant fiber assets, therefore network extensibility is a tough task. New safety mechanisms are required in case of failure, in addition to additional mechanisms to put into effect O&M are needed. But, those demanding situations may be responded. It is fairly inexpensive to upgrade/upload new fibers. CPRI products are supplying 1+1 backup/ring topology protection features. If dark fiber is deployed with bodily ring topology it gives resiliency similar to SDH. O&M abilities may be added in CPRI.

18.2.2 WDM/OTN (Wavelength Division Multiplexing/ Optical-Transport Network)

WDM/OTN solutions are suitable for macro cell base station systems with constrained fiber resources, in particular inside the access ring [11]. The solution improves the bandwidth on BBU-RRH hyperlink, as 40-80 optical wavelength can be transmitted through a single optical fiber, consequently with 10 Gbps huge quantity of cascading RRH can be supported, reducing the demand on dark fiber. However, excessive value of improve to WDM/OTN need to be included. But, because the span on front haul N/W does now not exceed tens of kilometers, gadget can be inexpensive than in long distance spine networks.

Usage of undeniable WDM CPRI transceivers changed into mentioned and their performance became evaluated.

In nonhierarchical WDM, the WDM technology can extra efficaciously assist clustered base station deployments providing advanced flexibility in time period of network transparency and charges. The use of that concept already deployed fibers, including PONs (Passive-Optical-Networks) or metro rings, can be reused to carry any form of visitors, inclusive of CPRI, on a common fiber infrastructure. By way of organizing digital P2P WDM hyperlinks up to forty-eight bidirectional CPRI hyperlinks per fiber can be supported.

Coarse WDM is appropriate to be used for TD-SCDMA, even as Dense WDM for LTE, because of capacity requirements. OTN is fashionably proposed to provide a manner of supervising patron's indicators, assure reliability in comparison with Synchronous Optical Networking (SONET)/SDH network. It effectively helps SONET/SDH as well as Ethernet and CPRI. CPRI may be transported over OTN over low degree Optical Channel statistics Unit.

18.2.3 Unified Fixed and Mobile Access

Unified fixed and mobile access based on Coarse WDM, combines fixed broadband and cellular access network . UniPON gives both PON offerings and CPRI transmission[11]. It's far appropriate for indoor insurance deployment, offers 14 special wavelengths consistent with optical cable, decreasing common value due to sharing. However, it needs to be designed to be competitive in value.

A delivery N/W solution developed primarily based on Dense WDM(-PON) colorless optics helps in load balancing, auto configuration and route redundancy, while minimizing the network complexity. A way to reuse the deployed PON infrastructure for RAN with

RRHs is considered. Connections between RRHs and BBUs are separated using very dense WDM, coherent optical OFDM enables to cope with slim channel spacing's.

18.2.4 Carrier Ethernet

Carrier local area network transport can also be promptly applied from RRH nearer to BBU Pool. CPRI2Ethernet entry is required between RRH and BBU Pool [11]. CPRI2Ethernet entry has to be clear in terms of put over. It needs to provide multiplexing competencies to forward one in every of a form CPRI streams to be carried by means that of local area network to totally different locations. The period carrier local area network refers to 2 matters. The first is that the set of offerings that let to maneuver local area network frames over distinct delivery technology. The opposite one may be an answer thanks to delivering these services, named Carrier Ethernet Transport (CET). e.g., Provider Backbone Bridge - Traffic Engineering (PBB-TE) is meant to supply carrier- grade transport answer and leverage the economies of scale of standard local area network. To achieve Quality of Service (QoS) of local area network Transport carrier, traffic engineering is enabled in carrier local area network. PBBTE makes use of the set of VLAN IDs to get distinctive methods to given raincoat address. Consequently, a connection-oriented forwarding mode could also be introduced. Forwarding knowledge is provided through management craft and thus sure conduct on predefined methods could also be assured. Carrier local area network guarantees 99.999% carrier availableness, up to sixteen million customers may be supported that eliminates measurability trouble of PBB-TE forerunner.

The main mission within the usage of packet packed local area network inside the front haul is to fulfill the strict requirements to synchronization and syntonization. Synchronization refers to part and syntonization to the frequency alignment. Base stations wish to be section and frequency aligned for you to, e.g., switch between transmission and downlink within the proper moment and to measure within their allotted spectrum. For

LTE-A frequency accuracy wishes to remain inside 50ppb as phase accuracy of one:5s is required for cellular with radius 3km .

18.3 Network Equipment

The subsequent network equipment has been advanced for usage in C-RAN architecture [11].

18.3.1 Cpri2Ethernet Gateway

If Ethernet is selected as a transport network fashionable, CPRI2Ethernet gateway is needed to map CPRI statistics to Ethernet packets, close to or at the interface of RRH in the direction of BBU Pool.

18.3.2 IQ-Data-Routing Switch

It's built on a fat-Tree architecture of the DCN. In fat-Tree topology, several root nodes are related to distinct trees which ensures excessive reliability and a smooth solution to put into effect load balancing among BBUs. China cellular has done real time processing and link load balancing. further, useful resource management platform has been applied.

18.3.3 CPRI MUX

It's a tool that aggregates traffic from various radios and encapsulates the data for transporting it over a least variety of optical interfaces. It is able to also enforce IQ compression/decompression and will be having optical interfaces. By using CPRI mux , the BBU pool will be demultiplexing the indicators multiplexed by the way of BBU pool for coarse WDM.

18.3.4 x2OTN Gateway

If OTN is selected as a transport N/W solution, then CPRI/OBSAI to OTN gateway needs to map from two standard requirements. Altera has a soft Silicon OTN processor that may map any user into ODU container.

18.4 IQ Compression Schemes and Solutions

The rate of the data on the front haul hyperlink in C RAN is expected to be twelve to fifty-five times better in comparison to information rate on the radio interface, depending on CPRI IQ pattern width and modulation [11]. RRHs transmit raw IQ samples closer to BBU cloud, therefore, green compression schemes are to be optimized one for these large bandwidth transmissions over capability restricted hyperlinks. Solutions might be to reduce signal sampling charge, use of non-linear quantization, compression of frequency subcarrier or IQ records. Strategies may be combined and a designated scheme is a change-off between attainable compression ratio, algorithm and design complexity, computational postpone and the signal distortion it introduces in addition to electricity intake. The following strategies may be used to obtain IQ compression. Lowering signal sampling price is a low complex solution having minimum effect on protocols, improves compression up to sixty six percent with some performance degradation. By using non-linear quantization, greater quantization degrees are specific for the place in magnitude in which greater values are in all likelihood to be gift. This solution improves Quantization SNR (QSNR). To specify step size log encoding algorithms like -Law or A-law are available.

Digital Automatic Gain Control (DAGC)can be used for IQ data compression. This method is based on reducing the sign's dynamic variety through normalizing the power of each image to the average strength reference therefore reducing the signal dynamic choice. This technique impacts sign-to-noise ratio (SNR) and errors Vector magnitude (EVM) deteriorates in DL. capability high compression price may be achieved, but the approach has an excessive complexity and no mature algorithms are to be had. One instance of a frequency domain scheme is to performing the sub carrier compression. Employing the

FFT/Inverse FFT (IFFT) in the RRH allows forty percent reduction in Ir interface load. It is able to be easily completed in DL, however RACH processing is a massive challenge. This frequency domain compression will increase IQ mapping and complexity. It additionally calls for expensive devices, greater garage and larger FPGA processing capacity. On pinnacle of that, it limits the blessings of sharing the equipment in C-RAN, as L1 processing desires to be assigned to 1 RRH. numerous patents had been filed for this type of compression schemes. The layout standards for frequency domain compression algorithms for LTE-A structures which had been then evaluated in big scale city filed trials. Performance of JD underneath confined backhaul fees turned into located. It proved that a Gaussian compression codebook achieves exact performance for the compression of OFDM signals. The performance can be stepped forward using Frequency area AGC (FDAGC) or decorrelation of antenna signals.

For downlink path, the algorithm eliminates redundancies in the frequency area. Secondly, the quantity of manipulating information is reduced to minimal sending simplest the necessary information to reconstruct manipulate signals at RRH. Furthermore, a unique constellation coding is used to lessen variety of bits had to represent constellation symbols for QPSK, 16QAM and 64QAM modulations. For uplink course detection is used to transmit only occupied providers. The compression ratio of 33% is accomplished at full mobile load. Compression ratio up to 6.6% is achieved for 20% cellular load. The Compression technique applicable for UL transmission, which when combined with an efficient base station selection algorithm. Their contemporary work specializes in enforcing layered compression method in addition to joint decompression and interpreting. results in phrases of compression ratio and EVM are not available. To conclude, in order now not to lose the value advantage of BBU Pooling for renting a transport network, cellular network operator wishes to either very own big amount of fiber or use an IQ compression scheme. furthermore, the price of the optical excessive speed module should live similar to standard SDH shipping gadget so that you can make C-RAN economically attractive.

19. Real world example to model RAN and C-RAN in Cologne

Global Mobile Data Traffic in 2017

NGMN alliance has given recommendations on how to evaluate network performance, specifying among the traffic mix and defining particular applications. The global mobile data traffic has been provided by cisco [22].

Global Mobile Data Traffic in 2017

Application	TB per month	%
Web/Data	2,778,386	24.91 %
File sharing	395,342	3.54 %
Video	7,418,322	66.50 %
M2M	563,481	5.05 %

Table 4. Global Mobile Data Traffic in 2017 [22].

Let us consider city of Cologne which is located in Germany, we know that there are close to 2000 Base Stations in cologne. The data for the city cologne is provided by MTI Radio comp which provided inputs on C-RAN and also provided company view on the deployment scenarios. The mobile subscribers in 2017 will rise to 10 Billion, using this data we can make an assumption on projected mobile subscribers in the city of cologne. By having the data on Base stations and by assumption of having average traffic and the number of base stat ions being the same, the volume of daily traffic for each base station is calculated. The average usage per day of a mobile user is 75.8 MB which includes both transmitting and receiving of data which comes down to 2.3 GB.

Let us assume that the amount of traffic in uplink direction is 40% and uplink volume for daily traffic aimed at each application for ten Base stations is calculated. We get a ratio which is an exemplary value and it was inspired by means of unique structures of LTE Time division Duplex (TDD) frames-one out of 7 possible configurations and it assigns four out of 10 sub-frames for UL.

The traffic characteristics of Web, video and file sharing applications will considerably influence the characteristics of aggregated traffic. The below table will summarize the traffic parameters and their statistical characterization that are used in simulation

Traffic Parameters	Statistical Characterization
Web/Data [5]	
Web Page Size	Lognormal Distribution Mean = 321979 b, Variance = 10.91 Gb, corresponding to Standard Deviation = 413 kB
Aggregated Interpage Request Time	Exponential Distribution Mean = 1.1471s
File sharing – FTP [4]	
File Size	Lognormal Distribution Mean = 2MB, Standard Deviation = 0.722 MB
Reading Time	Exponential Distribution Mean = 180 s
Mobile Video [4]	
Inter-Arrival time between the beginning of each frame	Deterministic 100 ms (based on 10 frames per second)
Number of packets (slices) in a frame	Deterministic, 8 packets per frame
Packet (slice) size	Truncated Pareto Distribution Mean = 100 B, Maximum = 250 B, Minimum = 20 B, Shape α = 1.2, and a location x_m = 133 calculated based on above
Inter-arrival time between packets (slices) in a frame	Truncated Pareto Distribution Mean = 6 s, Maximum = 12.5 s, Minimum = 2.5 ms, Shape α = 1.2, and a location x_m = 1 calculated based on above

Table 5. Traffic Models [22].

A figure [23] is shown below which depicts the daily load base station in residential, office area. As we can see the commercial area, the base station load is smaller than other ones because small cells are expected to be used. In the lunch time and the evenings, the base station load in commercial area is high. The load is non-zero load during night up to four o'clock. Considerations were made that the city comprises of 20% commercial BS, 50% residential BS and 30% office BS. The load has been calculated in bits every hour daily and then is mapped for each application in traffic volume using cisco forecast and distribution of traffic load observed daily.

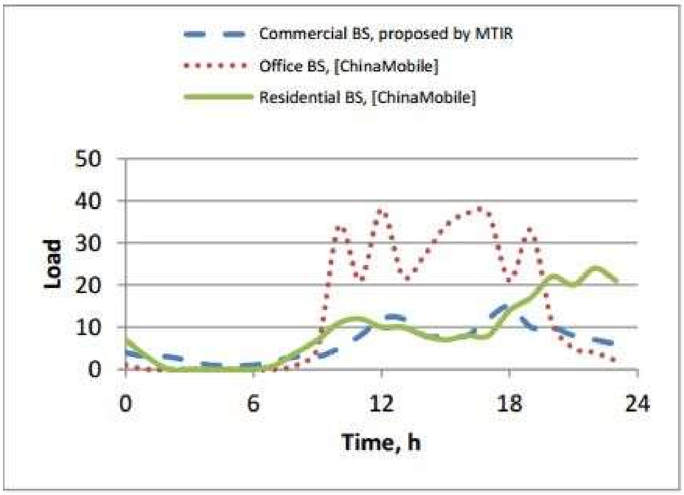


Figure 30. Daily Load On Different BSs [22].

RAN and CRAN Model

Two scenarios of C RAN and D-RAN architectures are made to examine the energy and cost saving. For each BBU in D-RAN, throughput peak values were added and used as reference for C-RAN. For each BBU in C-RAN scenario, throughput peak values were added and compared with the result gained from D-RAN scenario. By comparing both the results, relative savings in power consumption and number of BBU required can be assessed.

Simulation

Simulations were carried out for 24 hours to study the impact on varying traffic load throughout the day. The random number generator of OPNET modeler was used 24 times a with different values and least influenced values were obtained. The traffic is shown in figure 31 which was observed at commercial, office and residential BS. Fig 32 shows sum of the throughput sample which represents the trend that the BS feels highest throughput during office hours i.e., 10 am to 6 pm and the residential place felt it during evenings.

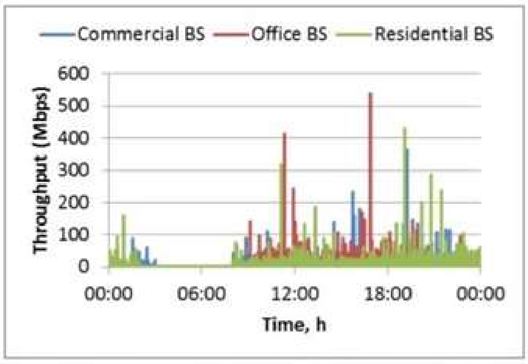


Figure 31. Daily Throughput on Different BSs [22]

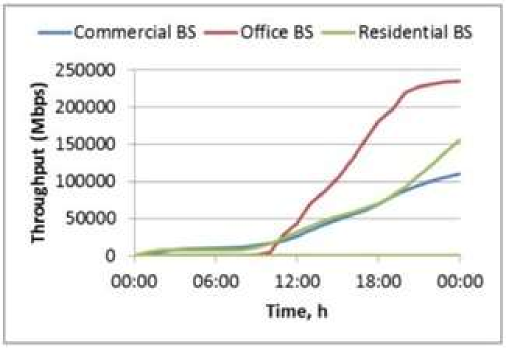


Figure 32. Sample Sum of Daily Throughput for different BSS [22]

Aggregated throughput for C-RAN is shown in Figure z. It is observed that peak throughput is observed at noon and evenings, low throughput at night and a stable throughput in morning around 10'0 clock.

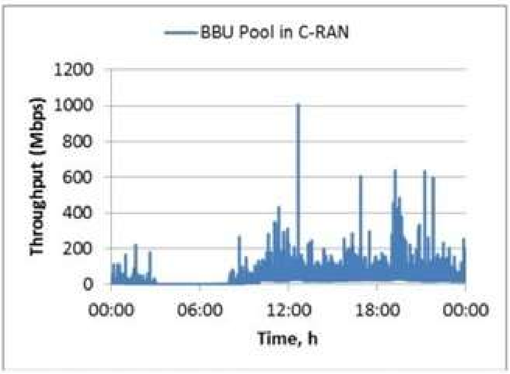


Figure 33. Aggregated traffic in BBU Pool in CRAN for different BSs [22]

The statistics of max throughput for every base station in D RAN vs max throughput for BBU pool in CRAN are given below in the table

D-RAN			C-RAN	
BS Type	BS	Peak throughput, Mbps	BS Type	Peak throughput, Mbps
Office	1	538.56	BBU Pool	**1005.46**
Office	2	253.96		
Office	3	350.25		
Commercial	4	363.69		
Commercial	5	267.57		
Residential	6	429.64		
Residential	7	157.74		
Residential	8	977.72		
Residential	9	608.97		
Residential	10	604.36		
Sum		4552.44		**1005.46**
Ratio		**4.53**	**Mean = 4.34, σ = 1.42**	

Table 6. Evaluation of Statistical Multiplexing Gain in CRAN [22]

After analyzing the 24 different seeds, mean value was calculated as 4.34 and the standard deviation was calculated to be 1.42. Thus, the simulations fall in the interval 1.50 -7.17 with a probability of 95%

To conclude, the aggregated traffic of data during peak in the BBU pool is four times lesser than sum of the peak throughput in the BBUs which are assigned to each cell. But the signals which are needed to carry on connections will be same in both scenarios. Thus, if the operator is setting up networks for average or peak traffic, the operator can make a reasonable assumption of setting up 4 times lesser BBUs for data processed in the pool rather than using the distributed setup. Thus, resulting in less CAPEX for deployment of network and less OPEX because of less energy consumption.

If the existing BBUS are aggregated in the pool, they can be operated at lower processing power saving energy consumed by BBUs. The reduction of resources is expected to be above 50% based on assumption that people move from home to work using 2 base stations in 2 places.

As we can see from the variance of the simulation result, it is sensitive to peak traffic. It might come through a particular traffic which might have significantly different packet sizes. It is assumed in model that the user gets all the requested resources, doesn’t have any delay which may not be true in congested networks. In order to shape the traffic, protocols of the different layers are introduced by mobile standard. The real value is lesser as resources needed are taken in account.

The problems related to cost of maintaining the growing network traffic are addressed by C-RAN. Anyhow, more evaluation is needed for resources which are needed in the BBU. The overhead associated with L1 to application data is v high in C-RAN and the cost of fiber needs to be taken into account. These results are vital for operators and equipment vendors as they would like to assess its benefits.

20. Model RAN and CRAN

Moose Jaw is a small city in the province of Saskatchewan. It has a population of 33,274 and let us assume that there 6 eNodeB's covering the city. Let's assume that 40% of the population in city use 4G LTE i.e., we have 13,309 4G mobile users. Thus, we can say that each base station on average covers 2218 mobile users.

<u>Radio Access Network:</u>

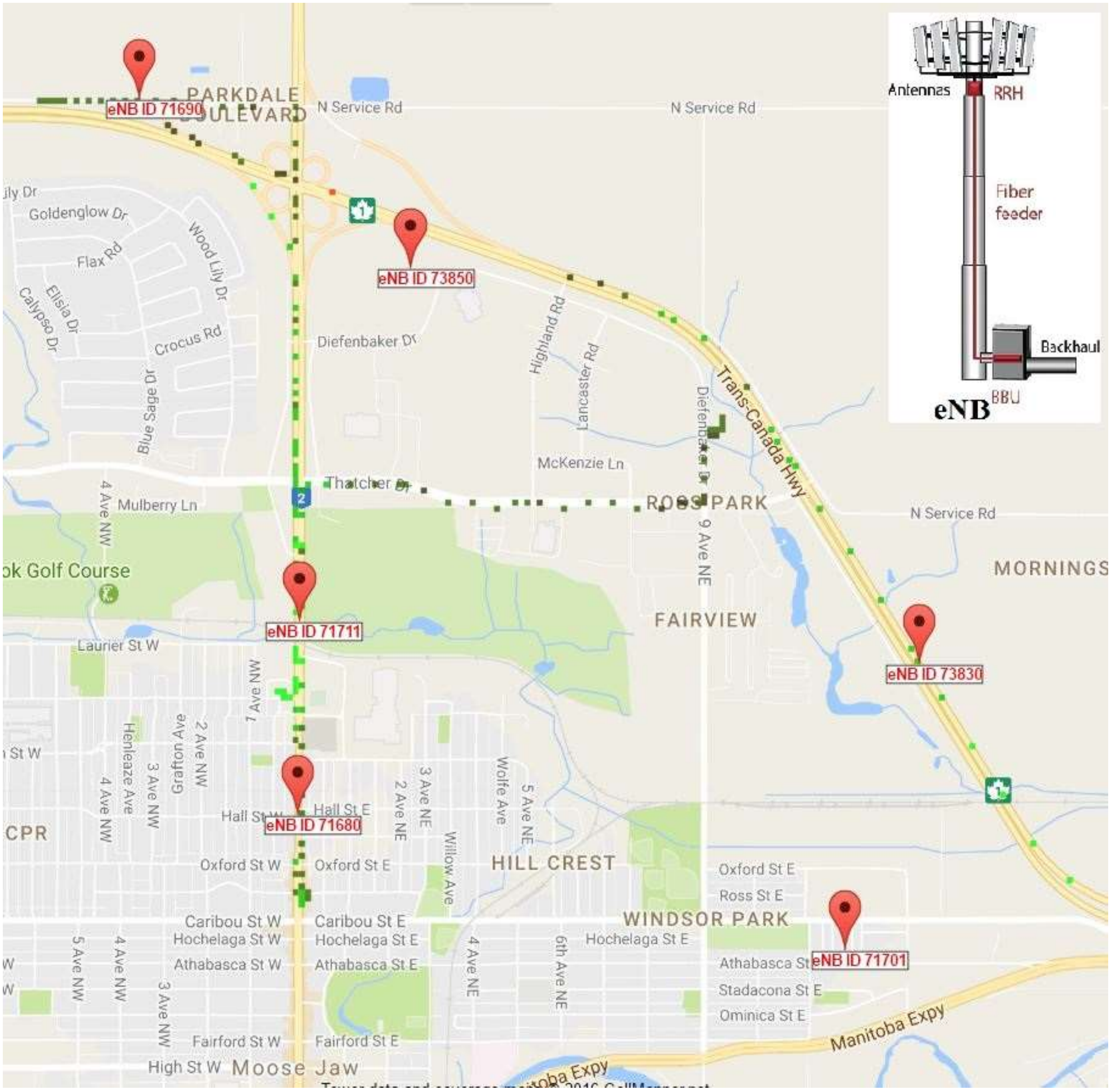


Figure 34. Model Radio Access Network

Note: The eNB are interconnected by X2 and are connected to the EPC by S1 interface

In traditional Radio Access Network, the eNB compromises of RRH and BBU, which are inter connected by a fiber. The power sources, backup battery, cooling, and monitoring system are added thus increasing the cost of traditional base station. Each eNB handles transmission/reception of signals in a small area. Each eNB is designed for handling the maximum traffic, thus they can't share processing resources. The average utilization of every eNB is low, thus at the idle times power and processing resources are wasted.

<u>**Centralized Radio Access Network:**</u>

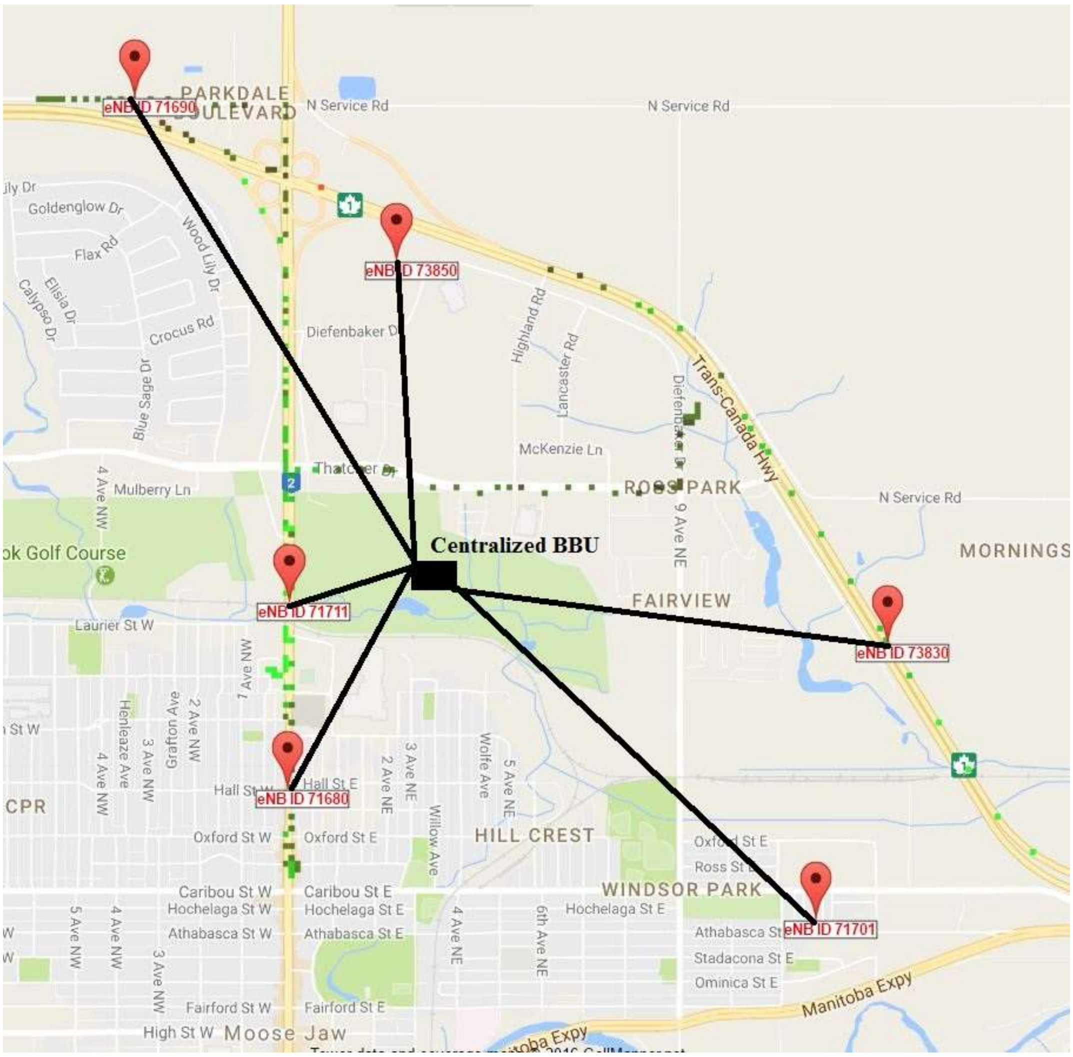


Figure 35. Model Cloud Radio Access Network

The above picture (taken from cellmapper.com) shows a hypothetical situation of CRAN implementation where the BBUs from all the eNodeBs are stacked together to form a centralized BBU pool. The BBU pool is connected to all the Remote Radio Head via fiber using the CPRI front haul. Fiber is being used in CPRI front haul because it can carry data with minimum loss. To maintain a lossless medium, the distance between the RRH and centralized BBU should be less than 20kms.

The distance of eNB ID 71690 to BBU pool is approximately 2.31 km

The distance of eNB ID 73850 to BBU pool is approximately 1.64 km

The distance of eNB ID 71711 to BBU pool is approximately 0.7 km

The distance of eNB ID 71680 to BBU pool is approximately 3.46 km

The distance of eNB ID 73830 to BBU pool is approximately 3.34 km

The total sum of distances from the centralized BBU pool is 11.45 Kms. Thus, optical fiber of 11.45 Km needs to be implemented from the centralized BBU pool to the different Remote radio heads across the city. The cost of fiber per meter according to [24]is around 0.92-1.68$. For the telecom operators in Moose Jaw, this calculation shows that it is economical to deploy. Using CPRI front haul, they can take advantage of CRAN which helps in implementation of advanced radio features such as Coordinated multipoint transmission and reception (COMP). It improves the capacity of network by executing load balancing and cooperative processing of signals initiating from different BS and adapt to nonuniform traffic and utilizes the base stations more efficiently. It reduces delay during intra BBU pool handover and improve the network performance leading to energy efficient network operation and cost savings on the baseband resources. Thus saving cost as well as energy and preparing the network for the sudden rise in load in near future and helping preparing in implementation of next generation 5G network to provide high Giga Byte Speed to the customers.

21. Conclusion

In an era where the world is moving towards the 5G technology, the traditional RAN is facing a lot of challenges, such as bottleneck of spectrum efficiency, absence of multi standard flexibility, tidal effect and increasing demand for providing internet service. There is a need for mobile operators to adapt to a low cost and high efficiency architecture. C-RAN has the potential to benefit both the users as well as the Network operators by reducing the consumption of energy and increasing spectral efficiency. The BBU's are combined in a physical BBU pool where they can share CSI for active users in the system. With the centralized processing of the C-RAN architecture, the number of base station sites can be reduced. It can lower the cost of deployment of the network and its operation as well as improve energy efficiency, mobility and coverage performance. It is adaptable to non-uniform traffic because of the load-balancing capability in the distributed BBU pool. It provides a central port for traffic offload and content management which provides reduced backhaul traffic, reduced core network traffic, and reduced latency, all leading to a better quality of user experience. It easier to upgrade and expand as C-RAN supports multi standard operations and multicell collaborative signal processing. Its architecture inherently facilitates flexible network topology designs. With C-RAN, it is much easier to implement algorithms to mitigate inter-cell interference. By using new technologies at various stages of C-RAN, we can provide more flexible and efficient services. Thus, C-RAN can provide mobile operators with an efficient, competitive, and profitable infrastructure in the dynamic market.

22. Acronyms

1G	-	First generation of wireless telephone technology
2G	-	Second-generation wireless telephone technology
3G	-	Third-generation wireless telephone technology
4G	-	Fourth-generation wireless telephone technology
3GPP	-	3rd Generation Partnership Project
AAA	-	Authorization, authentication and accounting
ABS	-	Almost blank sub frame
AM	-	Acknowledged mode
AMBR	-	Aggregate Maximum Bit Rate
AP ID	-	Application Protocol Identity
APN	-	Access point name
ARQ	-	Automatic repeat request
AS	-	Access Stratum
BBU	-	Base-band Unit
BCCH	-	Broadcast control channel
BCH	-	Broadcast channel
BS	-	Base Station
BSC	-	Base Station Controller
BTS	-	Base Transceiver Station
CAPEX	-	Capital expense
CB	-	Coordinated Beamforming
CCCH	-	Common control channel
CET	-	Carrier Ethernet Transport

CFR	-	Crest factor reduction
CMC	-	Connection mobility control
CN	-	Core network
CoMP	-	Coordinated Multi-point
CPRI	-	Common Public Radio Interface
CS	-	Coordinated Scheduling
CSI	-	Channel State Information
CSG	-	Closed subscriber group
CWDM	-	Coarse wavelength division multiplexing
DAGC	-	Digital Automatic Gain Control
DCCH	-	Dedicated control channel
DCN	-	Dynamic Circuit network
DCS	-	Dynamic cell selection
DDC	-	Digital down-conversion
DL	-	Downlink
DL-SCH	-	Downlink shared channel
DPD	-	Digital pre-distortion
DRA	-	Dynamic Resource Allocation
DRX	-	Discontinois Receotion
DSL	-	Digital Subscriber Line
DTCH	-	Dedicated movement channel
DUC	-	Digital up-conversion
DWDM	-	Dense Wavelength Division Multiplexing
ECGI	-	E-UTRAN Cell Global Identifier

ECM	-	EPS Connection Management
EIR	-	Equipment identification register
EMM	-	EPS mobility management
eNB	-	Evolved eNodeB
EPC	-	Evolved Packet Core
EPS	-	Evolved Packet System
E-RAB	-	E-UTRAN radio access bearer
E-UTRAN	-	Evolved UMTS Terrestrial Radio Access Network
EVM	-	Errors Vector magnitude
FDAGC	-	Frequency area AGC
FDD	-	Frequency division duplex
FPGA	-	Field-programmable gate array
GBR	-	Guaranteed bit rate
GERAN	-	GSM EDGE Radio Access Network
GGSN	-	GPRS support node
GPRS	-	General Packet Radio Service
GSM	-	Global System for Mobile communication
GTP	-	GPRS Tunneling Protocol
HARQ	-	Hybrid ARQ
HII	-	High Interference Indicator
HSS	-	Home Subscriber Server
ICI	-	Inter cell Interference
ICIC	-	Inter cell interference coordination
IE	-	Information Element

IP	-	Internet Protocol
IQ	-	In-phase and Quadrature
IRC	-	Interference Rejection Combining
ISR	-	Idle mode Signaling reduction
JT	-	Joint Transmission
LB	-	Load Balancing
LTE	-	Long-Term Evolution
MAC	-	Medium Access Control
MCCH	-	Multicast control channel
MCH	-	Multicast channel
ME	-	Mobile Equipment
MIMO	-	Multiple-Input Multiple-Output.
MME	-	Mobility management entity
MRC	-	Maximum Ratio Combining
MS	-	Mobile Station
MSISDN	-	Mobile Subscriber ISDN Number
MT	-	Mobile Terminal
MTCH	-	Multicast movement channel
NAS	-	Non-access stratum
N/W	-	Network
OAM	-	Operations, administration and maintenance
OBSAI	-	Open Base Station Architecture Initiative
OFDMA	-	Orthogonal Frequency-Division Multiple Access
OI	-	Overload indicators

OPEX	-	Operational expenditure
ORI	-	Open Radio equipment Interface
OTN	-	Optical Transport Network
PBB-TE	-	Provider Backbone Bridge - Traffic Engineering
PCCH	-	Paging control channel
PCEF	-	Policy Control Enforcement Function
PCH	-	Paging channel
PCRF	-	Policy control and Charging rules function
PDCP	-	Packet Data Convergence Protocol
PDN	-	Packet Data Network
PDU	-	Protocol data unit
P-GW	-	Packet Data Network Gateway
PHY	-	Physical
PON	-	Passive Optical Networks
PS	-	Packet Scheduling
QAM	-	Quadrature Amplitude Modulation
QOE	-	Quality of experience
QCI	-	QoS class identifier
QSNR	-	Quantization SNR
QOS	-	Quality of service
RAC	-	Radio admission control
RACH	-	Random access channel
RAT	-	Radio access technology
RBC	-	Radio bearer control

RE	-	Radio equipment
REC	-	Radio equipment control
RF	-	Radio frequency
RLC	-	Radio Link Control
RMC	-	Radio mobility control
RN	-	Relay Nodes
RNC	-	Radio Network Controller
RNS	-	Radio Network Subsystem
RNTP	-	Relative Narrowband Transmit power
RRC	-	Radio resource control
RRH	-	Remote Radio Head
RRM	-	Radio Resource Management
RRU	-	Remote Radio Unit
RU	-	Radio Unit
SA	-	Security association
SAP	-	Service access point
SCTP	-	Stream control transmission protocol
SDH	-	Synchronous Digital Hierarchy
SDR	-	Software Defined Radio
SDU	-	Service data unit
SGSN	-	Serving GPRS support node
S-GW	-	Serving Gateway
SINR	-	Signal to Interference plus Noise Ratio
SLA	-	Service Level Agreements

SPID	-	Subscriber profile ID
TA	-	Tracking area
TAI	-	Tracking area identity
TAU	-	Tracking area update
TDD	-	Time division Duplex
TE	-	Terminal Equipment
TEID	-	Tunnel endpoint ID
TFT	-	Traffic flow template
TIN	-	Temporary identification utilized in next update
TM	-	Transparent mode
Tx	-	Transmission
UE	-	User Equipment
UICC	-	Universal Integrated Circuit Card
UL	-	Uplink
UL-SCH	-	Uplink shared channel
UM	-	Unacknowledged mode
UMTS	-	Universal Mobile Telecommunications Service
USIM	-	Universal Subscriber Identity Module
UTRAN	-	Universal Terrestrial Radio Access Network
WDM	-	Wavelength-division multiplexing
WNC	-	Wireless network Cloud
X2-C	-	X2-control plane
X2-U	-	X2-user plane

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