Visvesvaraya Technological University, Belagavi.

PROJECT REPORT

on

"PERFORMANCE ANALYSIS OF CELL THROUGHPUT IN MULTIPLE USER ENVIRONMENT FOR NEAR CELL, CELL EDGE CONDITION."

Project Report submitted in partial fulfillment of the requirement for the award of the degree of

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CERTIFICATE

This is to Certify that the dissertation work **“Performance Analysis of Cell Throughput in Multiple User Environment for Near Cell, Cell Edge Condition.”** carried out by Pooja P Patel , Ritika Gupta , having USN 1CR16EC109 , 1CR16EC134, respectively are bonafide students of **CMRIT** in partial fulfillment for the award of **Bachelor of Engineering** in **Electronics and Communication Engineering** of the **Visvesvaraya Technological University, Belagavi,** during the academic year **2019-20**. It is certified that all corrections/suggestions indicated for internal assessment have been incorporated in the report deposited in the departmental library. The project report has been approved as it satisfies the academic requirements in respect of Project work prescribed for the said degree.

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ABSTRACT

The scheduling algorithm of Long Term Evolution (LTE) is responsible for allocating the resource blocks (RB) efficiently to the end users. Different algorithms have different impact to the network in terms of throughputs, spectral efficiency, and fairness. However, previous algorithms are unable to enhance the cell-edge user performance due to the unawareness of the location of user and user congestion in the cell area. We propose a downlink scheduling algorithm based on Deficit-Drop Fairness algorithm to improve the performance of the cell-edge user and all other users in the cell. The cell is divided into two regions namely outer and inner to differentiate the user in this proposed algorithm. It considers Received Signal Strength (RSS), a threshold value based on user congestion in the regions and the distance between eNodeB (eNB) and user. The obtained system-level simulation results show that the proposed algorithm significantly improves the cell-edge user throughput along with average user throughput, cell throughput, spectral efficiency and fairness index compared with the other existing algorithms.

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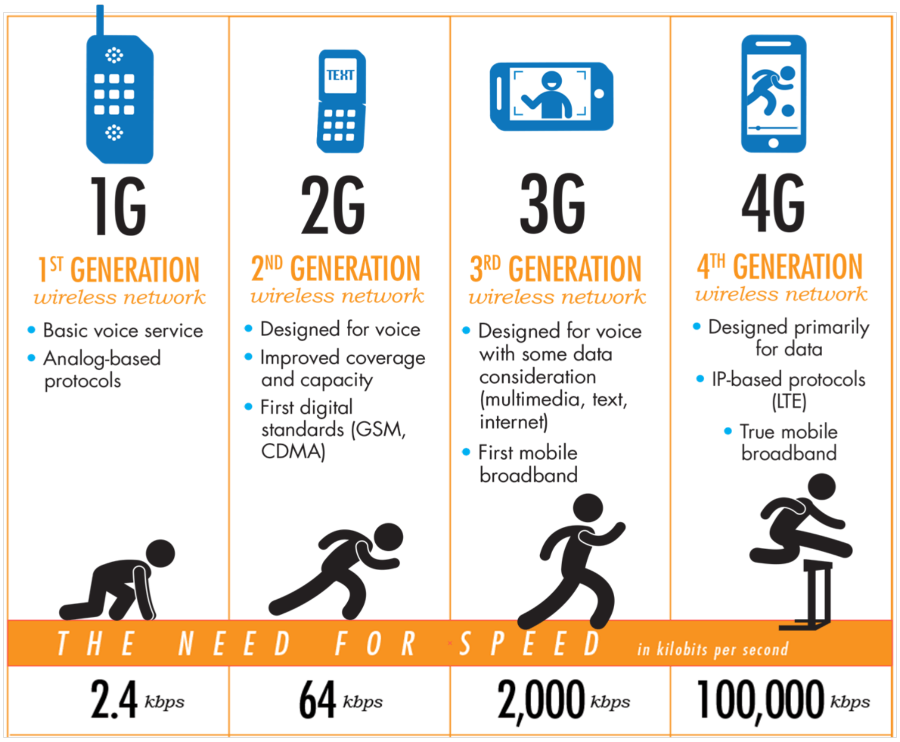
Chapter 1

INTRODUCTION

A smart phone without Internet is obsolete in today's world. With multitude of applications hosted in the personal handheld devices, the need of high speed Internet access has increased manifold. On one hand, in order to meet these demands, LTE-A 4G started a new era of improved network capacity as well as higher bandwidth availability to each user, while on the other hand the resource allocation for users has emerged as an active research area. Parameters such as number of users, channel conditions, type of traffic class and so on play an important role while designing a scheduling algorithm.

A smart phone without internet pack or Wi-Fi doesn't have much significance, the launch of 3G has proved that internet access to every common person can change and update the lives of many, in this way the demand for fast browsing internet has increased.



The much advanced and the present technology is the 4G technology. The data rates are from 100 Mbps- 1 Gbps, which is the highest data rates provided compared to all the other technologies. It provides a very good QoS support and the security levels are also improved. GSM/EDGE (Enhanced Data Rates for GSM Evolution) and Universal Mobile

Telecommunication System (UMTS)/ High Speed Packet Access (HSPA), all these network technologies form the base of 4G which will improve the network technology and reduces the radio interfacing issues from other networks. The bandwidth for this technology is around 100 MHz This

technology is mainly improved for the increased internet facilities. The browsing and streaming speed has increased a lot when compared to 3G browsing and streaming speed.

IP based protocols play a major role in the fourth generation technology. As everything is going with internet nowadays, for example, messages and calls to the person in the other country can be made with the help of internet in our smart phones, without going for the cellular networks calls, as it would be expensive to use cellular network calls option for ISD and STD. This is how the Voice Over Internet Protocol (VoIP) has gained its importance in the recent days. Across the globe there are 20 cellular operators for LTE.

Long Term Evolution (LTE) aims to meet the ever growing network demands such as improved network coverage, multimedia services and the "spectral efficiency". The inherent need of allocating best resources to the deserved users, LTE makes use of Advance Radio Resource Management procedures which takes care of physical functions such as Adaptive Modulation and Coding (AMC), Channel Quality Index (CQI) and Hybrid Automatic Retransmission Request (HARQ).

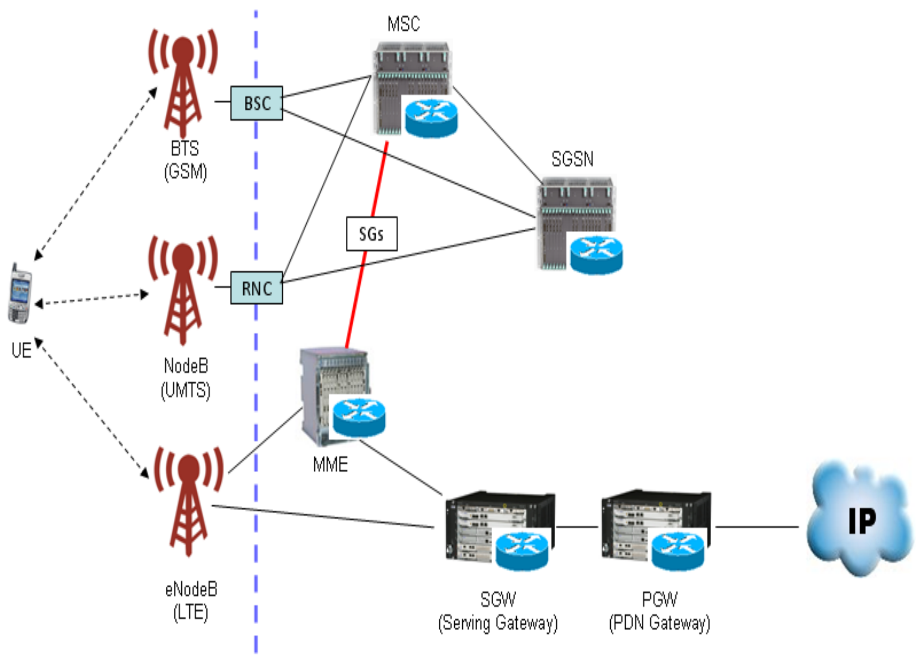
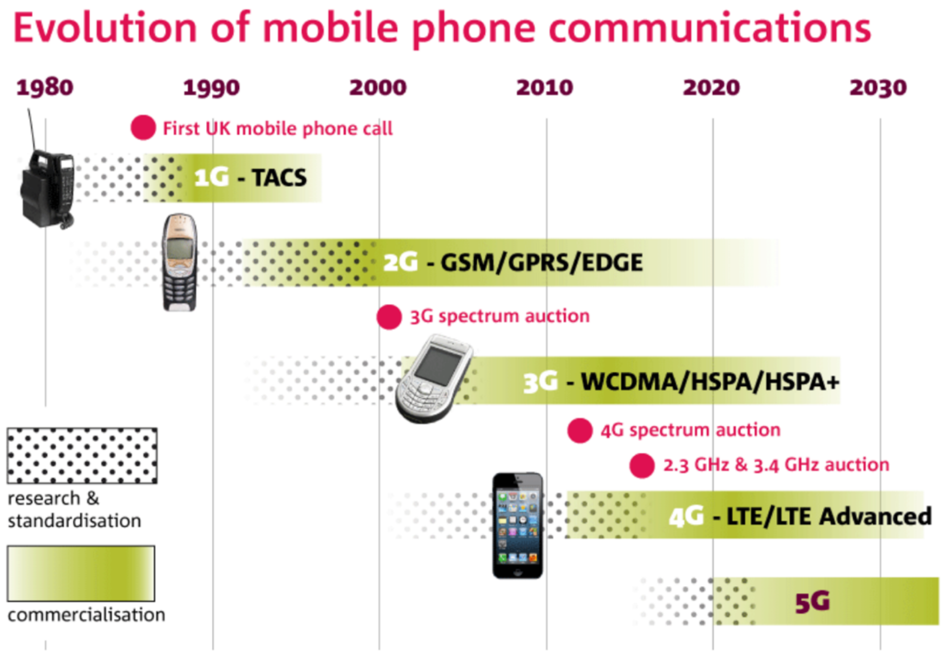


Figure 1.1 : LTE Architecture evolution

1.1 Evolution of Wireless Technologies in Mobile Communication

Mobile wireless communication system has gone through several evolution stages in the past few decades after the introduction of the first generation mobile network in early 1980s. Due to huge demand for more connections worldwide, mobile communication standards advanced rapidly to support more users. Let's take a look on the evolution stages of wireless technologies for mobile communication.



1.1.1 1G – First generation mobile communication system

The main technological development that distinguished the First Generation mobile phones from the previous generation was the use of multiple cell sites, and the ability to transfer calls from one site to the next as the user travelled between cells during a conversation. The first commercially automated cellular network (the 1G generations) was launched in Japan by Nippon Telephone and Telegraph company NTT in 1979. In 1984, Bell Labs developed modern commercial cellular technology, which employed multiple, centrally controlled base stations (cell sites), each providing service to a small area (a cell). The cell sites would be set up such that cells partially overlapped. In a cellular system, a signal between a base station (cell site) and a terminal (phone) only need be strong enough to reach between the two, so the same channel can be used simultaneously for separate conversations in different cells.

As the system expanded and neared capacity, the ability to reduce transmission power allowed new cells to be added, resulting in more, smaller cells and thus more capacity.

In the beginning of 1980s, it gained popularity in the US, Finland, UK and Europe. This system used analogue signals and it had many disadvantages due to technology limitations.

Most popular 1G system during 1980s

- Advanced Mobile Phone System (AMPS)
- Nordic Mobile Phone System (NMTS)
- Total Access Communication System (TACS)
- European Total Access Communication System (ETACS)

Key features (technology) of 1G system

- Frequency 800 MHz and 900 MHz
- Bandwidth: 10 MHz (666 duplex channels with bandwidth of 30 KHz)
- Technology: Analogue switching
- Modulation: Frequency Modulation (FM)
- Mode of service: voice only
- Access technique: Frequency Division Multiple Access (FDMA)

Disadvantages of 1G system

- Poor voice quality due to interference
- Poor battery life
- Large sized mobile phones (not convenient to carry)
- Less security (calls could be decoded using an FM demodulator)
- Limited number of users and cell coverage
- Roaming was not possible between similar systems

1.1.2 2G – Second generation communication system GSM

In the 1990s, the 'second generation' (2G) mobile phone systems emerged, primarily using the GSM(Global System for Mobile communication) standard. GSM technology became the base standard for further development in wireless standards later. This standard was capable of supporting up to 14.4 to 64kbps (maximum) data rate which is sufficient for SMS and email services.

These 2G phone systems differed from the previous generation in their use of digital transmission instead of analog transmission, and also by the introduction of advanced and fast phone-to-network signaling. The rise in mobile phone usage as a result of 2G was explosive and this era also saw the advent of prepaid mobile phones.

The second generation introduced a new variant to communication, as SMS text messaging became possible, initially on GSM networks and eventually on all digital networks. Soon SMS became the communication method of preference for the youth. Today in many advanced markets the general public prefers sending text messages to placing voice calls.

Some benefits of 2G were Digital signals require consume less battery power, so it helps mobile batteries to last long. Digital coding improves the voice clarity and reduces noise in the line. Digital signals are considered environment friendly. Digital encryption has provided secrecy and safety to the data and voice calls. The use of 2G technology requires strong digital signals to help mobile phones work properly.

Code Division Multiple Access (CDMA) system developed by Qualcomm also introduced and implemented in the mid 1990s. CDMA has more features than GSM in terms of spectral efficiency, number of users and data rate.

2.5G and 2.75G system

"2.5G" using GPRS (General Packet Radio Service) technology is a cellular wireless technology developed in between its predecessor, 2G, and its successor, 3G. GPRS could provide data rates from 56 Kbit/s up to 115 Kbit/s. It can be used for services such as Wireless Application Protocol (WAP) access, Multimedia Messaging Service (MMS), and for Internet communication services such as email and World Wide Web access.

2.75 – EDGE is an abbreviation for Enhanced Data rates for GSM Evolution. EDGE technology is an extended version of GSM. It allows the clear and fast transmission of data and information up to 384kbit/s speed.

In order to support higher data rate, General Packet Radio Service (GPRS) was introduced and successfully deployed. GPRS was capable of data rate up to 171kbps (maximum).
EDGE – Enhanced Data GSM Evolution also developed to improve data rate for GSM networks. EDGE was capable to support up to 473.6kbps (maximum).

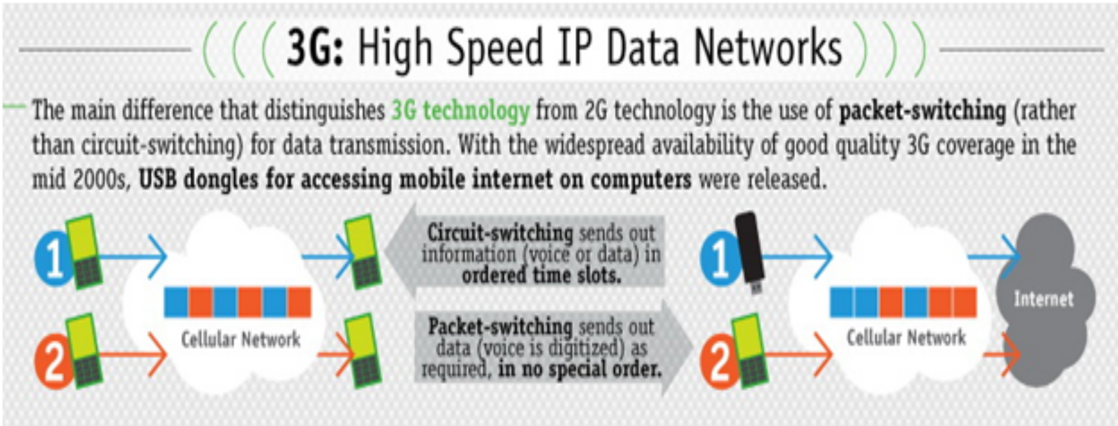
Another popular technology CDMA2000 was also introduced to support higher data rate for CDMA networks. This technology has the ability to provide up to 384 kbps data rate (maximum).

Key features of 2G system

- Digital system (switching)
- SMS services is possible
- Roaming is possible
- Enhanced security
- Encrypted voice transmission
- First internet at lower data rate
- Disadvantages of 2G system
- Low data rate
- Limited mobility
- Less features on mobile devices
- Limited number of users and hardware capability

1.1.3 3G – Third generation communication system (3G : High speed IP data networks)

As the use of 2G phones became more widespread and people began to use mobile phones in their daily lives, it became clear that demand for data services (such as access to the internet) was growing. Furthermore, if the experience from fixed broadband services was anything to go by, there would also be a demand for ever greater data speeds. The 2G technology was nowhere near up to the job, so the industry began to work on the next generation of technology known as 3G. The main technological difference that distinguishes 3G technology from 2G technology is the use of packet switching rather than circuit switching for data transmission.



The high connection speeds of 3G technology enabled a transformation in the industry: for the first time, media streaming of radio and even television content to 3G handsets became possible.

In the mid 2000s an evolution of 3G technology begun to be implemented, namely High-Speed Downlink Packet Access (HSDPA). It is an enhanced 3Gmobile telephony communications protocol in the High-Speed Packet Access (HSPA) family, also coined 3.5G, 3G+ or turbo 3G, which allows networks based on Universal Mobile Telecommunications System (UMTS) to have higher data transfer speeds and capacity. Current HSDPA deployments support down-link speeds of 1.8, 3.6, 7.2 and 14.0 Mbit/s. Further speed increases are available with HSPA+, which provides speeds of up to 42 Mbit/s downlink and 84 Mbit/s with Release 9 of the 3GPP standards.

Third generation mobile communication started with the introduction of UMTS – Universal Mobile Terrestrial / Telecommunication Systems. UMTS has the data rate of 384kbps and it support video calling for the first time on mobile devices.

After the introduction of 3G mobile communication system, smart phones became popular across the globe. Specific applications were developed for smartphones which handles multimedia chat, email, video calling, games, social media and healthcare.

3.5G to 3.75 Systems

In order to enhance data rate in existing 3G networks, another two technology improvements are introduced to network. HSDPA – High Speed Downlink Packet access and HSUPA – High Speed Uplink Packet Access, developed and deployed to the 3G networks. 3.5G network can support up to 2mbps data rate. 3.75 system is an improved version of 3G network with HSPA+ High Speed Packet Access plus. Later this system will evolve into more powerful 3.9G system known as LTE (Long Term Evolution).

Disadvantages of 3G systems

- Expensive spectrum licenses
- Costly infrastructure, equipment's and implementation
- Higher bandwidth requirements to support higher data rate
- Costly mobile devices
- Compatibility with older generation 2G system and frequency bands

Key features of 3G system

- Higher data rate
- Video calling
- Enhanced security, a greater number of users and coverage
- Mobile app support
- Multimedia message support
- Location tracking and maps
- Better web browsing
- TV streaming
- High quality 3D games

1.1.4 4G – Fourth generation communication system (Growth of mobile broadband)

Consequently, the industry began looking to data-optimized 4th-generation technologies, with the promise of speed improvements up to 10-fold over existing 3G technologies. It is basically the extension in the 3G technology with more bandwidth and services offers in the 3G. The expectation for the 4G technology is basically the high quality audio/video streaming over end to end Internet Protocol. The first two commercially available technologies billed as 4G were the WiMAX standard and the LTE standard, first offered in Scandinavia by TeliaSonera.

One of the main ways in which 4G differed technologically from 3G was in its elimination of circuit switching, instead employing an all-IP network. Thus, 4G ushered in a treatment of voice calls just like any other type of streaming audio media, utilizing packet switching over internet, LAN or WAN networks via VoIP.

4G LTE data transfer speed can reach peak download 100 Mbit/s, peak upload 50 Mbit/s, WiMAX offers peak data rates of 128 Mbit/s downlink and 56 Mbit/s uplink.4G systems are enhanced version of 3G networks developed by IEEE, offers higher data rate and capable to handle more advanced multimedia services. LTE and LTE advanced wireless technology used in 4th generation systems. Furthermore, it has compatibility with previous version thus easier deployment and upgrade of LTE and LTE advanced networks are possible.

Simultaneous transmission of voice and data is possible with LTE system which significantly improve data rate. All services including voice services can be transmitted over IP packets. Complex modulation schemes and carrier aggregation is used to multiply uplink / downlink capacity.

Wireless transmission technologies like WiMAX are introduced in 4G system to enhance data rate and network performance.

Key features of 4G system

- Much higher data rate up to 1Gbps
- Enhanced security and mobility
- Reduced latency for mission critical applications
- High definition video streaming and gaming

- Voice over LTE network VoLTE (use IP packets for voice)
- Disadvantages of 4G system
- Expensive hardware and infrastructure
- Costly spectrum (most countries, frequency bands are is too expensive)
- High end mobile devices compatible with 4G technology required, which is costly
- Wide deployment and upgrade are time consuming

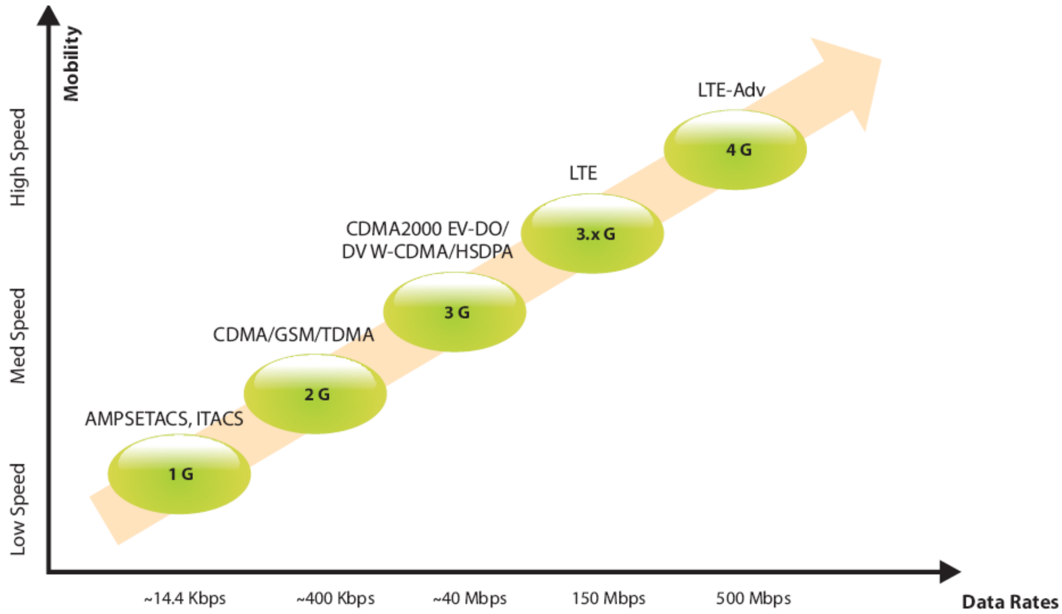


Figure1.2 : Evolution of Radio Access Technologies.

1.1.5 5G – Fifth generation communication system

5G will be using advanced technologies to deliver ultra-fast internet and multimedia experience for customers. Current LTE advanced networks will transform into supercharged 5G networks in future. In order to achieve higher data rate, 5G technology will use millimeter waves and unlicensed spectrum for data transmission.

Complex modulation technique has been developed to support massive data rate for Internet of Things. Cloud based network architecture will extend the functionalities and analytical capabilities for industries, autonomous driving, healthcare and security applications.

Key features of 5G technology

- Ultra-fast mobile internet up to 10Gbps
- Low latency in milliseconds (significant for mission critical applications)
- Total cost deduction for data

- Higher security and reliable network
- Uses technologies like small cells, beam forming to improve efficiency
- Forward compatibility network offers further enhancements in future
- Cloud based infrastructure offers power efficiency, easy maintenance and upgrade of hardware.

1.1.6 Comparison of 1G to 5G technology

Generation	Speed	Technology	Key Features
1G (1970 –1980s)	14.4 Kbps	AMPS,NMT, TACS	Voice only services
2G (1990 to 2000)	9.6/ 14.4 Kbps	TDMA,CDMA	Voice and Data services
2.5G to 2.75G (2001-2004)	171.2 Kbps 20-40 Kbps	GPRS	Voice, Data and web mobile internet, low speed streaming services and email services.
3G (2004-2005)	3.1 Mbps 500- 700 Kbps	CDMA2000 (1xRTT, EVDO) UMTS and EDGE	Voice, Data, Multimedia, support for smart phone applications, faster web browsing, video calling and TV streaming.
3.5G (2006-2010)	14.4 Mbps 1-3 Mbps	HSPA	All the services from 3G network with enhanced speed and more mobility.
4G (2010 onwards)	100-300 Mbps. 3-5 Mbps 100 Mbps (Wi-Fi)	WiMax, LTE and Wi-Fi	High speed, high quality voice over IP, HD multimedia streaming, 3D gamming, HD video conferencing and worldwide roaming.
5G (Expecting at the end of 2019)	1 to 10 Gbps	LTE advanced schemes, OMA and NOMA	Super fast mobile internet, low latency network for mission critical applications, Internet of Things, security and surveillance, HD multimedia streaming, autonomous driving, smart healthcare applications.

1.2 Introduction to LTE.

1.2.1 Key Requirements of LTE design.

Performance on par with wireless broadband

The two key network performance parameters are high throughput and low latency. For higher throughputs ,3GPP set peak data rate target of 100Mbps for downlink and 50Mbps for uplink. Which may be only experienced by fraction of users who happen to be in close radio proximity to the base stations.

To enable support for delay sensitive application like voice & interactive gaming, it is required that the network latency is kept very low. The target round trip latency for

LTE radio network is set to be lea than 10ms. This is better than the 20-40ms delay observed in many of DSL systems.

Enhancing QoS capabilities to support variety of applications is another goal of LTE. LTE system is required to support optimized high quality handoffs and connections up to speed of 15kmph with only minor degradations allowed for connections up to speeds of 120kmph .a lower quality support is envisioned for up to 350 kmph.

Flexible spectrum usage

The frequency band and amount of spread spectrum owned by different mobile operators Around the World Very significantly. since many LTE deployments are likely to be in reframe spectrum that is currently used for 3G and for 2G services, the amount of spectrum that could be made available for LTE will also depend on how aggressively individual operators wish to migrate to LTE . in order to truly Global stand and to make it attractive for deployment by a wider range of operators, 3GPP mandate a high degree of spectrum flexibility.

Operators can deploy LTE in 900 MHz, 1800 MHz, 700 MHz, and 2.6 GHz band. LTE support a variety of channel bandwidth; 1.43 3, 5, 10, 15 and 20 MHz .it is also Mandate that end-user divisor able to operate at all channel bandwidth slower than their maximum capability ; for example, 10MHz, a mobile device will support all bandwidth up to 10 MHz, the smaller 1.4 MHz, and 5 MHz, channels are optimized for GSM and CDMA reframing to support deployment where operators are unable to free larger amount of spectrum also supports both Frequency division duplexing (FTD) and time division duplexing (TDD) to accommodate paired as well as unpaired spectrum allocations. Commonly used is FDD.

Co-existence and Interworking with 3G systems as well as Non-3GPPsystems

Given the large base of existing mobile subcarriers, it is a critical requirement that LTE network interworks seamlessly with existing 2G and 3G systems. most existing cell operators are likely to face in LTE over a period of time with initial deployments being made in areas of high demand such as urban cores. service continuity and mobility-handoff in roaming-between LTE and existing 2G/3G systems are critical to obtain a seamless User experience. as LTE aims to be truly a global standard attracted to a variety of operators, internetworking requirements have been extended to a non-3GPP system such as the 3GPP2 CDMA and WiMAX networks for the, to facilitate fixed-mobile convergence, interworking requirement apply to all IP Network including wired IP networks .

Reducing cost per Megabyte

There is a growing gap between wireless data consumption and revenue. To bridge this gap, it is essential that substantial reductions be achieved in the total network cost to deliver data to end-users. 3GPP recognizes this issue and has made reducing the cost per megabyte of data key design criteria for LTE. A number of design criteria are tied directly to cost efficiency. These include:

- High capacity, high spectral efficiency air interface
- Ability to deploy in the existing spectrum and reuse cell size and transmission equipment
- into working with non-3GPP systems to drive towards one Global standard to achieve higher economies of scale.
- A flat architecture with fewer network components and protocols.
- A single IP packet code for voice and data.
- Architecture to leverage large development community and gain Economies of scale through convergence with wider communication systems.
- Support for lower-cost Ethernet-based backhaul network.
- Base station with low power and space requirements; could in many cases be put inside existing base station cabinet or mounted beside them.
- Support for self-configuration and self-Optimization optimizing Network and technologies to reduce installation and management cost.

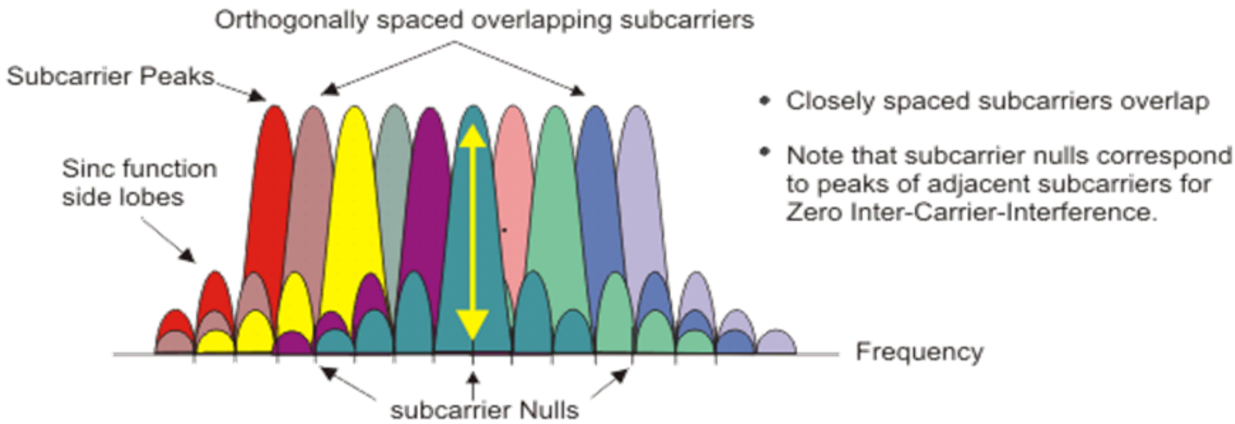
Feature	Capability					
Channel Bandwidth	1.4 MHz	3 Mz	5Mz	10 Mz	15 Mz	20 Mz
Transmission Scheme	Downlink : OFDMA (Orthogonal Frequency Division Multiple Access)					
	Uplink : SC-FDMA (Single Carrier Frequency Division Multiple Access)					
Modulation Formats	QPSK , 16 QAM, 64 QAM					
MIMO Technology	Downlink : TX Diversity, Rx diversity, Single-User MIMO, Beam Forming					
	Uplink: Multi-User MIMO					
Peak Data Rates	Downlink: 300 Mbps (4*4 MIMO, 20 MHz, 64 QAM)					
	Uplink: 75 Mbps (20MHz BW, 64 QAM)					
Bearer Services	Packet only - No Circuit Switched voice or data services are supported , Voice must use VoIP					
Transmission Time Interval (TTI)	1ms					

Table 1.1: Major features of LTE.

1.2.2 Key Enabling Technologies and Features of LTE

Orthogonal frequency division multiplexing (OFDM)

One of the key differences between existing 3G systems and LTE is the use of orthogonal frequency division multiplexing (OFDM) as the underlying modulation Technology. Widely deployed 3G system such as UMTS and CDMA2000 have based on code division multiple access (CDMA) Technology. CDMA Works by spitting on narrowband signal over the bandwidth to achieve interference resistance and performs remarkably. Well for low data rate communication such as voice where a large number of users can be multiplied to achieve high system capacity. However, for higher speed applications, CDMA becomes Untenable due to large bandwidth needed to achieve useful amounts of spreading.

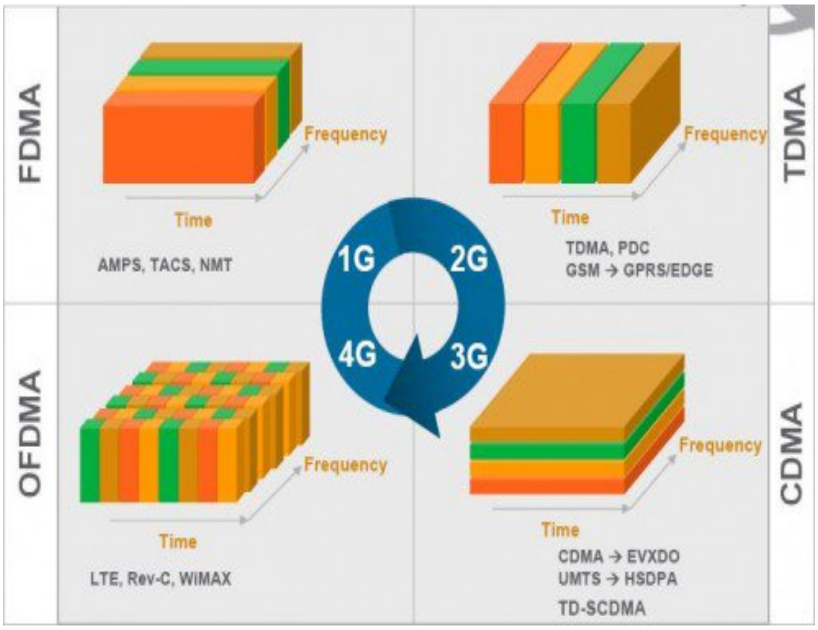


OFDM has emerged as a technology of choice for achieving high data rate it is the core technology used by a variety of systems including Wi-Fi and WiMAX the following advantages of OFDM lead to its selection of LTE.

Advantages of OFDM:

- Elegant solution to multipath interference
- Reduce computational complexity
- Graceful degradation of performance under excess delay
- Exploitation of frequency diversity
- Enables efficient multi access schemes
- Robust against narrowband interference
- Suitable for coherent demodulation
- Facilitates use of MIMO

- Efficient support of broadcast services
- Broadband services are improved by enabling higher data rate



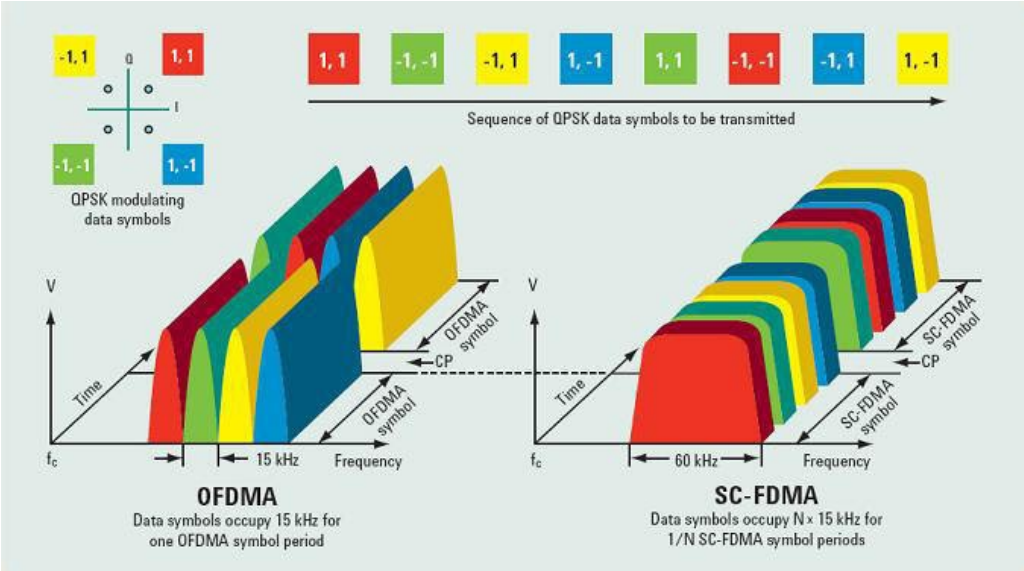
SC-FDE and SC-FDMA

LTE employs Orthogonal Frequency Division Multiple Access (OFDMA) for downlink data transmission and Single Carrier FDMA (SC-FDMA) for uplink transmission. SC-FDMA is a new single carrier multiple access technique which has similar structure and performance to OFDMA. A salient advantage of SC-FDMA over OFDM is the low Peak to Average Power (PAP) ratio : Increasing battery life.

To keep the cost down and the battery life up, LTE incorporated a power efficient trans mission scheme for the uplink. Single Carrier Frequency Domain Equalization (SC-FDE) is conceptually similar to OFDM but instead of transmitting the Inverse Fast Fourier Transform (IFFT) of the actual data symbols, the data symbols ne as a sequence of QAM symbols with a cyclic prefix added; the IFFT is added at the end of the receiver. SC-FDE retains all the advantages of OFDM such as multipath resistance and low complexity, while having a low peak-to-large ratio of 4-5 db.

The uplink of LTE implements a multi-user version of SC-FDE, called SC-FDMA, which allows multiple users to use parts of the frequency spectrum. SC-FDMA closely resembles OFDMA and can in fact be thought of is “DFT preceded OFDMA." SC-

FDMA also preserves the PAR properties of SC-FDE but increases the complexity of the transmitter and the receiver.



Channel dependent multiuser resource scheduling

The OFDMA scheme used in LTE provides enormous flexibility in how channel resources are allocated. OFDMA allows for allocation in both time and frequency and it is possible to design algorithms to allocate resources in flexible and dynamic manger to meet arbitrary throughput, delay, and other requirements. The standard supports dynamic, channel-dependent scheduling to enhance overall system. Capacity.

Given that each user will be experiencing uni-correlated funding channels, it is possible to allocate subcarriers among users in such a way that the overall is increased. This technique, called frequency selective multiuser scheduling, calls for focusing transmission power in each user's best channel portion, thereby increasing the overall capacity. Frequency selective scheduling requires good channel tracking and is generally only able in slow varying channels. For fast varying channels, the overhead involved in doing this regenerates the potential capacity gains.

In OFDMA, frequency selective scheduling calm be combined with multi-user time domain scheduling, which calls for scheduling users during the crests of their individual fading channels. Capacity gains are also obtained by adapting the modulation and coding to the instantaneous signal-to-noise ratio conditions for each user .

For high-mobility users, OFDMA can be used to achieve frequency diversity. By coding and interleaving across subcarriers in the frequency domain using a uniform random distribution of sub carriers over the whole spectrum, the signal can be made more robust 1gainst frequency selective fading or burst errors.

Multiantenna techniques

The LTE standard provides extensive support for implementing advanced multi-antenna solutions to improve link robust, system capacity, and spectral efficiency. Depending of the deployment scenario, one or more of the techniques can be used. Multi antenna techniques supported in LTE include:

Transmit diversity: This is a technique to combat multipath fading in the wireless channel. The idea here is to send copies of the same signal, coded differently, over multiple transmit antennas, LTE transmit diversity is based on space-frequency block coding (SFBC) techniques complemented with frequency shift time diversity (FSTD) when four transmit antenna are used. Transmit diversity is primarily intended for common downlink channels that cannot make use of channel-dependent scheduling. It can also be applied to user transmissions such as low data rate VoIP, where the additional overhead of channel-dependent scheduling may not be justified. Transmit diversity increases System capacity and cell manage.

Beam forming: Multiple antennas in LTE may also be used to transmit the same signal appropriately weighted for each antenna element such that the effect is to focus the transmitted beam in the direction of the receiver and away from interference, thereby improving the received signal-to-interference ratio. Beam forming an provide significant improvements in coverage range, capacity, reliability, and battery life. It can also be useful in providing angular information for user tracking. LTE supports beam forming in the downlink.

Spatial multiplexing: The idea behind spatial multiplexing is that multiple in dependent streams can be transmitted in parallel over multiple internals and can be separated at the receiver using multiple receive chains through appropriate sig mal processing. This can be done as long as the multipath channels as seen by the different antennas are sufficiently de-correlated us would be the case in a scattering.

IP-Based Flat Network Architecture.

Besides the air-interface, the other radical aspect of LTE is the flat radio and core network architecture. "Flat" here implies fewer nodes and a la hierarchical structure for the network. The lower cost and lower latency requirements drove the design toward a flat architecture since fewer modes obviously implies a lower infrastructure cost. It also means fewer interfaces and protocol-related processing, and reduced interoperability testing, which lowers the development and deployment cost. Fewer nodes also allow better optimization of radio interface, merging of some control plane protocols, and short start-up time. Figure shows how the 3GPP network architecture evolved over a few releases 3GPP Release 6 architecture, which is conceptually very similar to its predecessor, has four network elements in the data path: the base station or Node-B, radio network controller (RNC), serving GPRS service node (SGSN), and gateway GRPS service node (GGSN). Release 7 introduced a direct tunnel option from the RNC to GGSN, which eliminated SGSN from the data path. LTE on the other hand, will have only two network elements in the data path: the enhanced Node-B or e Node-B, and a System Architecture Evolution Gateway (SAE-GW). Unlike all previous cellular systems, LTE merges the base station and radio network controller functionality into a single unit. The control path includes a functional entity called the Mobility Management Entity (MME), which provides control plane functions related to subscriber, mobility, and session management. The MME and SAE-GW could be collocated in a single entity called the gateway (1-GW). More details about the network architecture are provided in the next section.

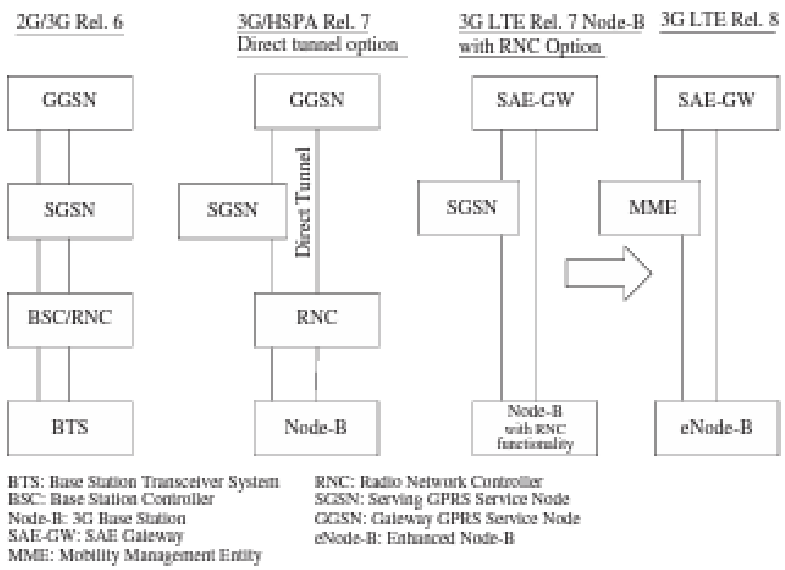
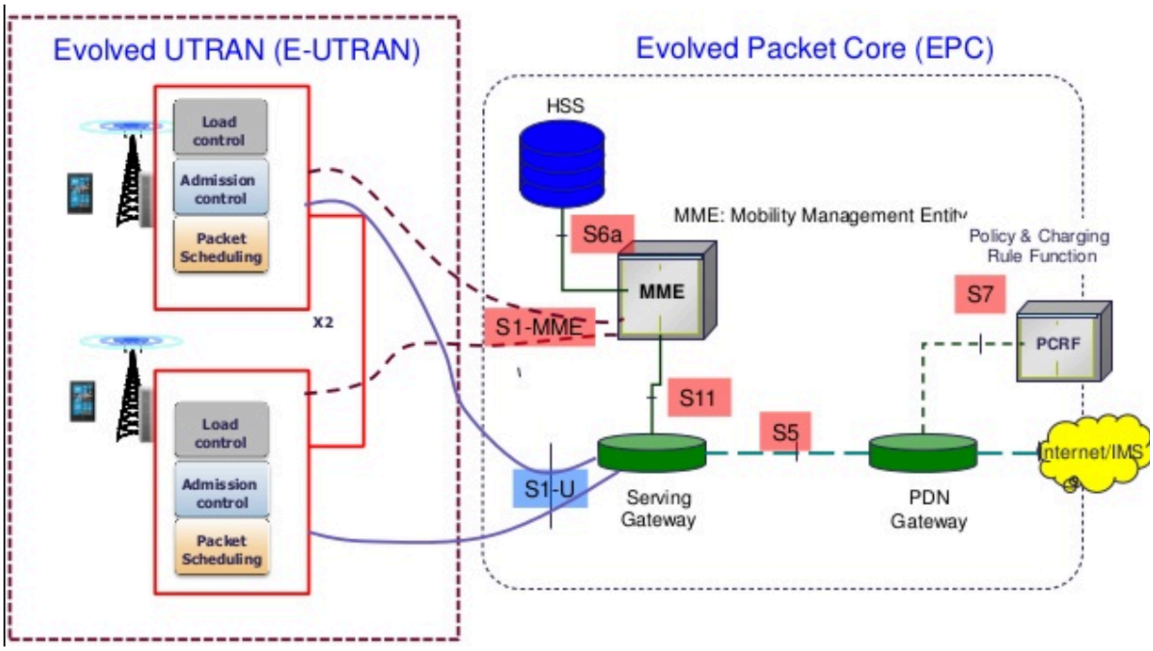


Figure 1.3 : 3GPP evolution toward a flat LTE SAE architecture.

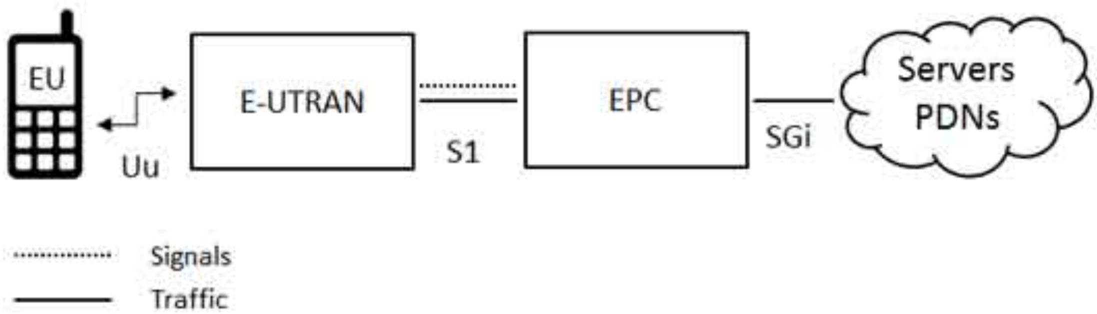
1.2.3 LTE NETWORK ARCHITECTURE



The high-level network architecture of LTE is comprised of following three main components:

- The User Equipment (UE).
- The Evolved UMTS Terrestrial Radio Access Network (E-UTRAN).
- The Evolved Packet Core (EPC).

The evolved packet core communicates with packet data networks in the outside world such as the internet, private corporate networks or the IP multimedia subsystem. The interfaces between the different parts of the system are denoted Uu, S1 and SGi as shown below:



The User Equipment (UE)

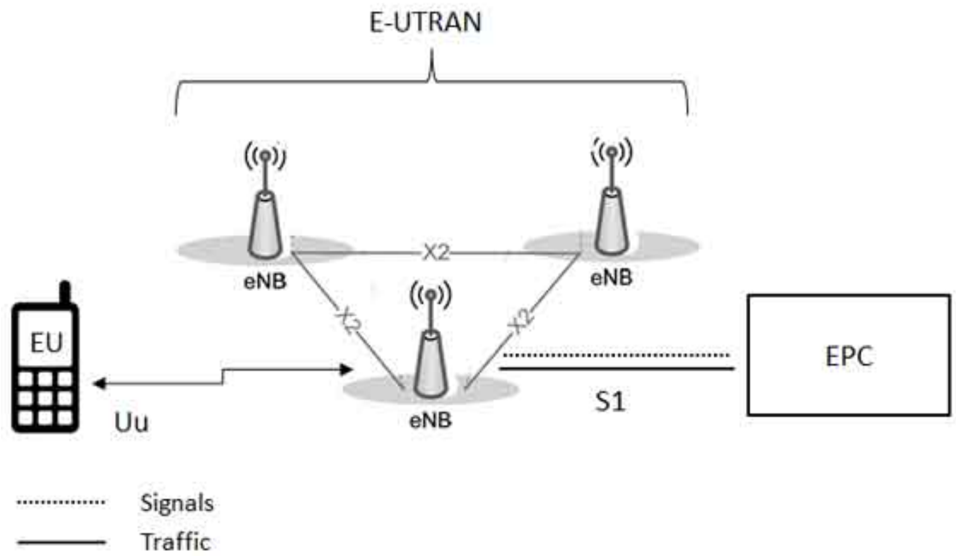
The internal architecture of the user equipment for LTE is identical to the one used by UMTS and GSM which is actually a Mobile Equipment (ME). The mobile equipment comprised of the following important modules:

- Mobile Termination (MT) : This handles all the communication functions.
- Terminal Equipment (TE) : This terminates the data streams.
- Universal Integrated Circuit Card (UICC) : This is also known as the SIM card for LTE equipment's. It runs an application known as the Universal Subscriber Identity Module (USIM).

A USIM stores user-specific data very similar to 3G SIM card. This keeps information about the user's phone number, home network identity and security keys etc.

The E-UTRAN (The access network)

The architecture of evolved UMTS Terrestrial Radio Access Network (E-UTRAN) has been illustrated below.



The E-UTRAN handles the radio communications between the mobile and the evolved packet core and just has one component, the evolved base stations, called eNodeB or eNB. Each eNB is a base station that controls the mobiles in one or more cells. The base station that is communicating with a mobile is known as its serving eNB..

LTE Mobile communicates with just one base station and one cell at a time and there are following two main functions supported by eNB:

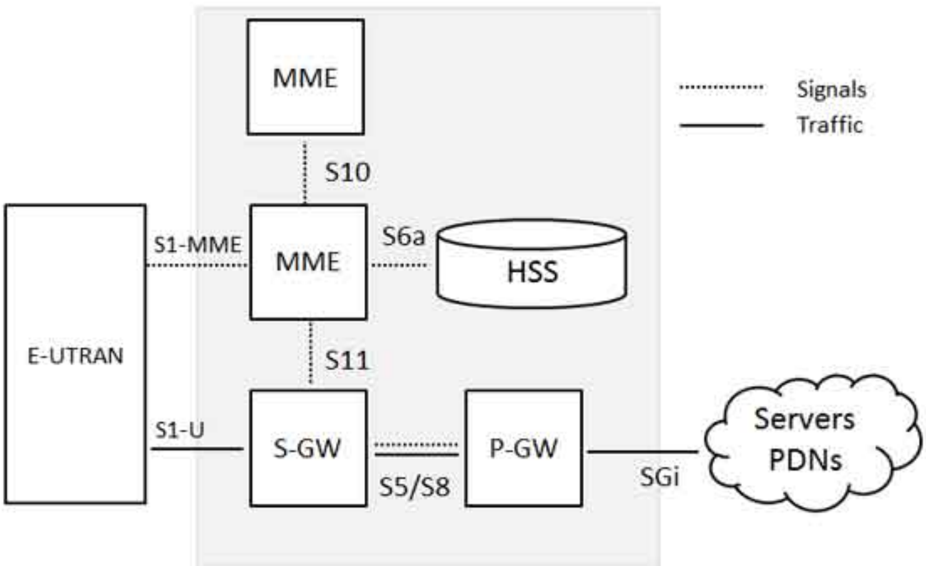
- The eBN sends and receives radio transmissions to all the mobiles using the analogue and digital signal processing functions of the LTE air interface.
- The eNB controls the low-level operation of all its mobiles, by sending them signalling messages such as handover commands.

Each eBN connects with the EPC by means of the S1 interface and it can also be connected to nearby base stations by the X2 interface, which is mainly used for signalling and packet forwarding during handover.

A home eNB (HeNB) is a base station that has been purchased by a user to provide femtocell coverage within the home. A home eNB belongs to a closed subscriber group (CSG) and can only be accessed by mobiles with a USIM that also belongs to the closed subscriber group.

The Evolved Packet Core (EPC) (The core network)

The architecture of Evolved Packet Core (EPC) has been illustrated below. There are few more components which have not been shown in the diagram to keep it simple. These components are like the Earthquake and Tsunami Warning System (ETWS), the Equipment Identity Register (EIR) and Policy Control and Charging Rules Function (PCRF).



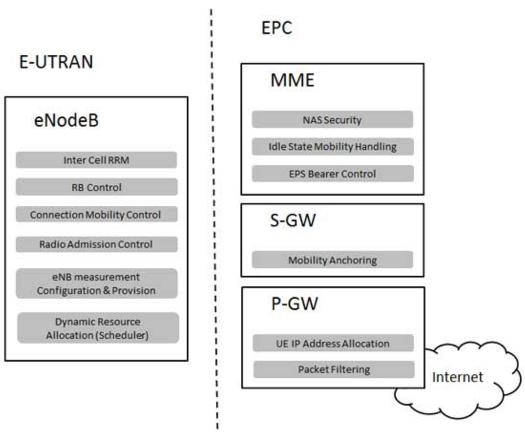
Below is a brief description of each of the components shown in the above architecture:

- The Home Subscriber Server (HSS) component has been carried forward from UMTS and GSM and is a central database that contains information about all the network operator's subscribers.
- The Packet Data Network (PDN) Gateway (P-GW) communicates with the outside world . packet data networks PDN, using SGi interface. Each packet data network is identified by an access point name (APN). The PDN gateway has the same role as the GPRS support node (GGSN) and the serving GPRS support node (SGSN) with UMTS and GSM.
- The serving gateway (S-GW) acts as a router, and forwards data between the base station and the PDN gateway.
- The mobility management entity (MME) controls the high-level operation of the mobile by means of signalling messages and Home Subscriber Server (HSS).
- The Policy Control and Charging Rules Function (PCRF) is a component which is not shown in the above diagram but it is responsible for policy control decision-making, as well as for controlling the flow-based charging functionalities in the Policy Control Enforcement Function (PCEF), which resides in the P-GW.

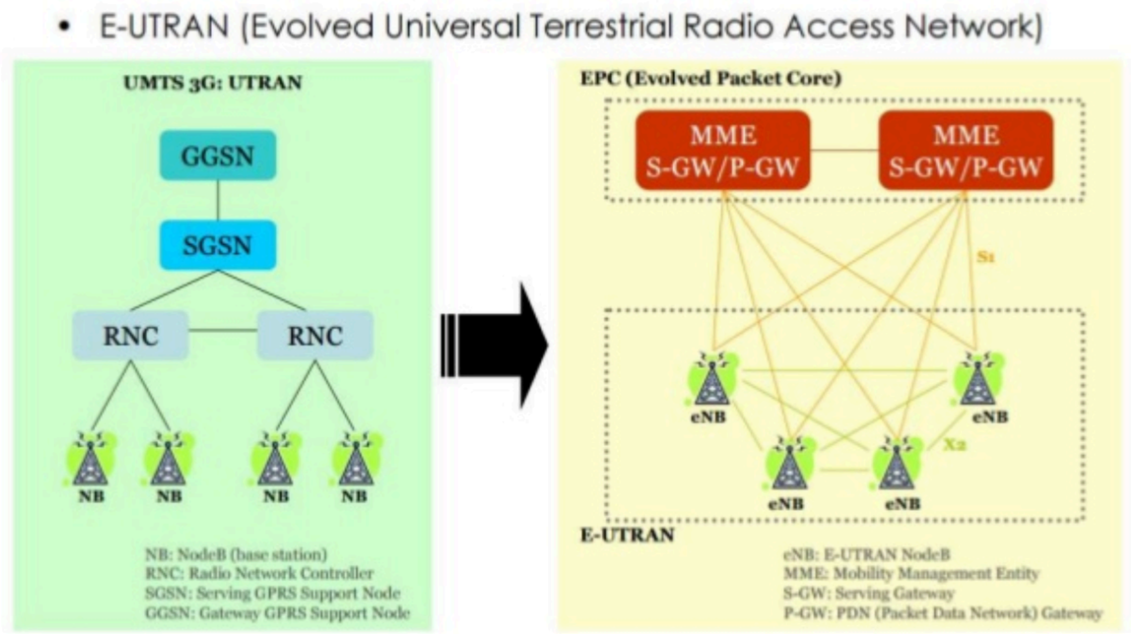
The interface between the serving and PDN gateways is known as S5/S8. This has two slightly different implementations, namely S5 if the two devices are in the same network, and S8 if they are in different **networks.**

Functional split between the E-UTRAN and the EPC

Following diagram shows the functional split between the E-UTRAN and the EPC for an LTE network:



Evolution to LTE Network Architecture.



1.2.4 Channels in LTE

The information flows between the different protocols layers are known as channels. These are used to segregate the different types of data and allow them to be transported across different layers. These channels provide interfaces to each layers within the LTE protocol stack and enable an orderly and defined segregation of the data.

Actually, LTE uses several different types of logical, transport and physical channel, which can be distinguished by the kind of information they carry and by the way in which the information is processed.

Classification of Channels in LTE:

Broadly in LTE Channel are divided into three categories named as below:

- Logical channels
- Transport channels
- Physical Channels

These all three types of channel are present in Downlink as well as Uplink direction. Mapping of these channels is shown in below pictures.

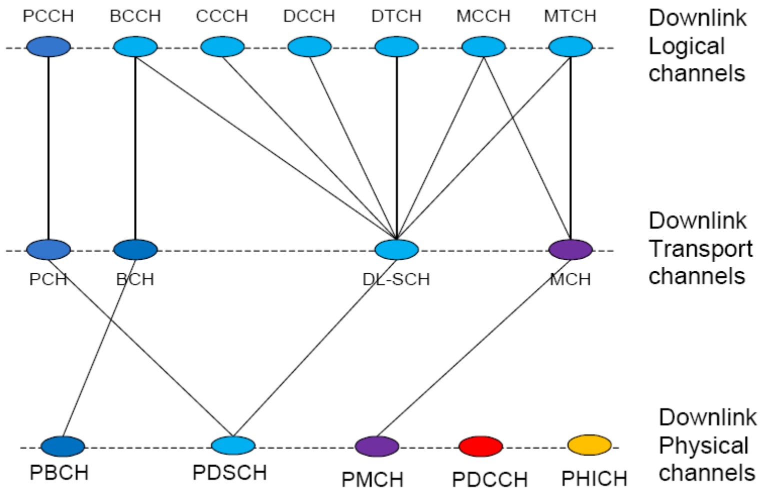


Figure 1.4 : LTE downlink channels

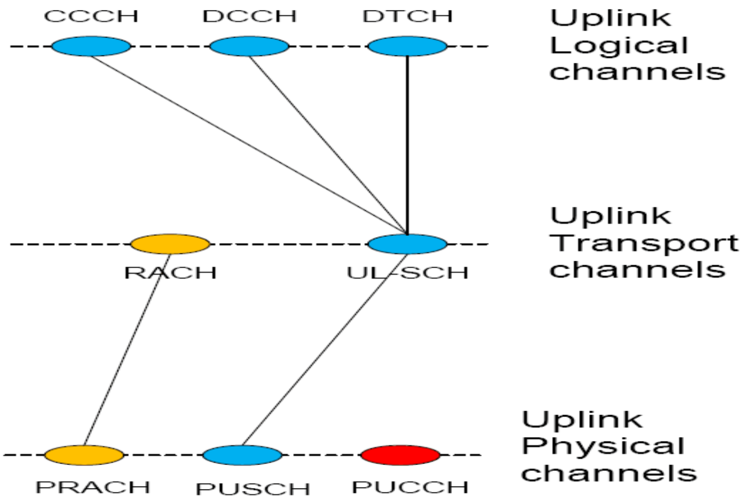


Figure 1.5 : LTE uplink channels

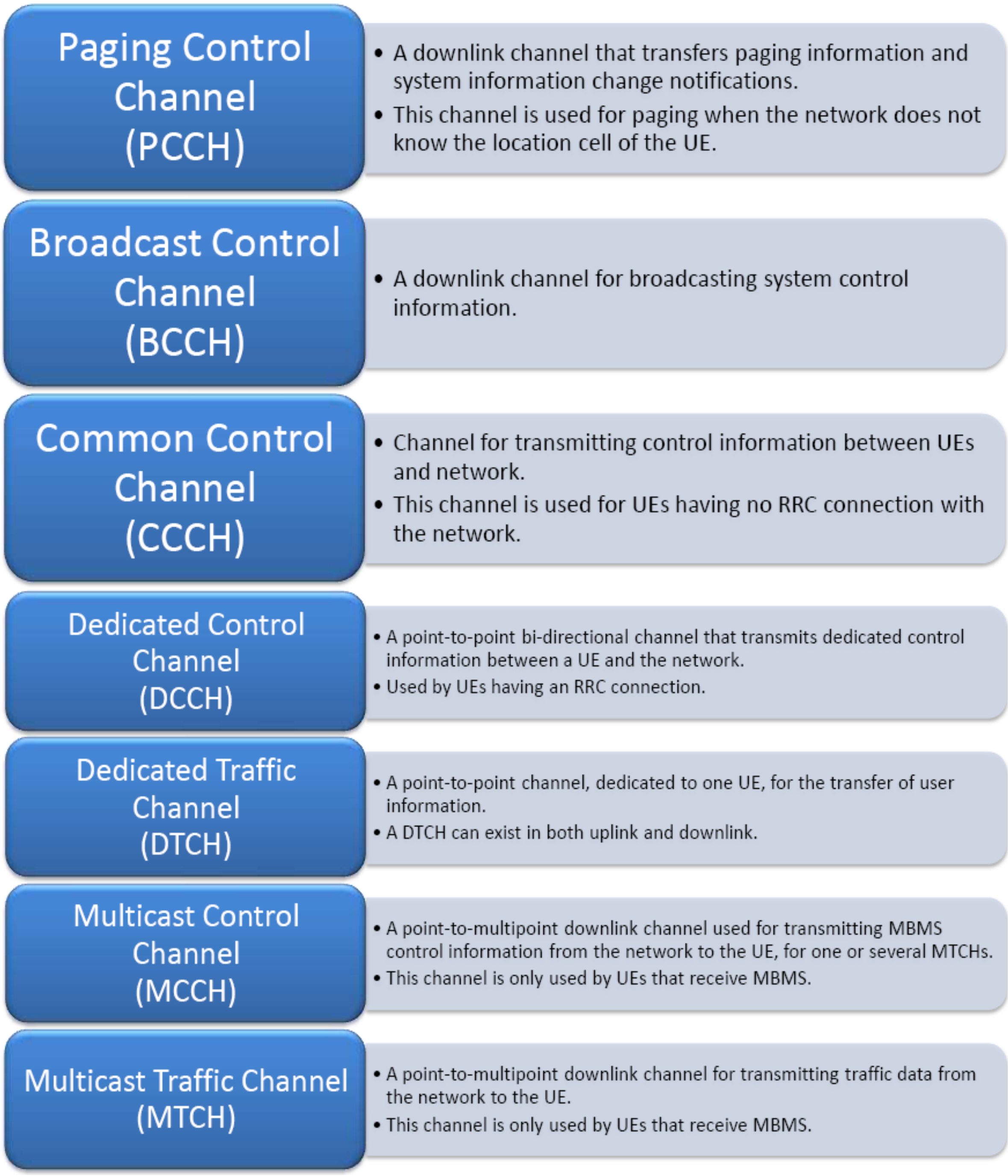
Logical Channels

Logical channels define what type of information is transferred. These channels define the data-transfer services offered by the MAC layer. Data and signalling messages are carried on logical channels between the RLC and MAC layers.

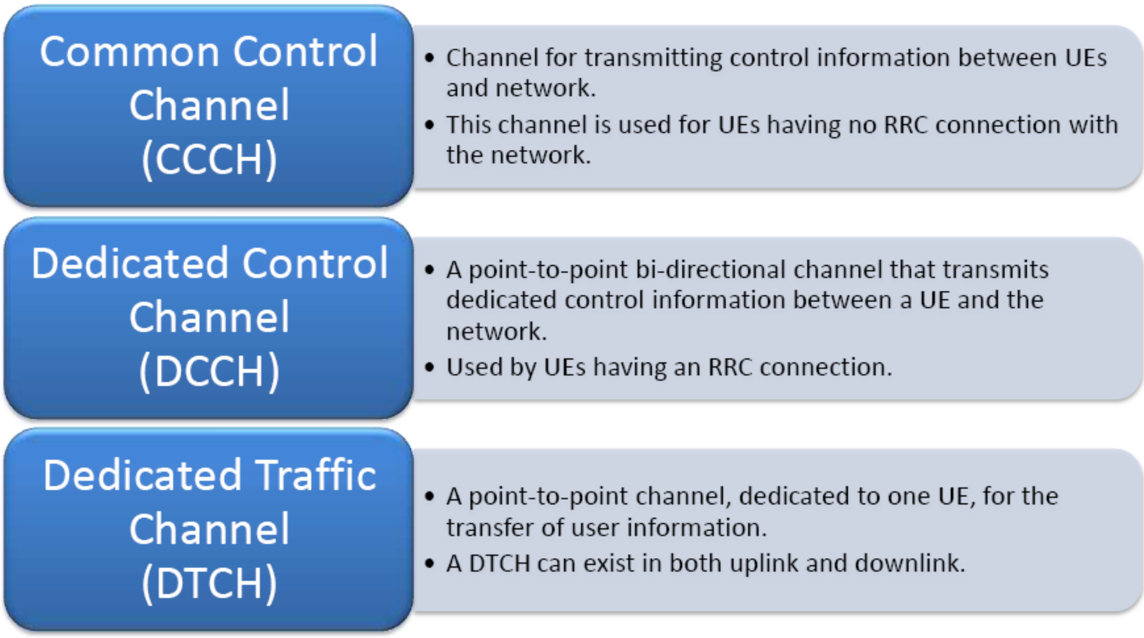
Logical channels further can be divided into two categories as control channels and traffic channels. control channels carry signalling messages in the control plane and they can be either common channel or dedicated channel. A common channel means common to all users in a cell (Point to multipoint) whereas Dedicated channels means channels can be used only by one user (Point to Point).

Traffic channels carry data in the user plane, while logical control channels carry signaling messages in the control plane. In LTE there are 7 logical channel in Downlink and 3 Logical channels in Uplink

DOWNLINK LOGICAL CHANNEL : In Downlink there are four Control channel which carried Common channel information as well as dedicated channel information and two Traffic channels.



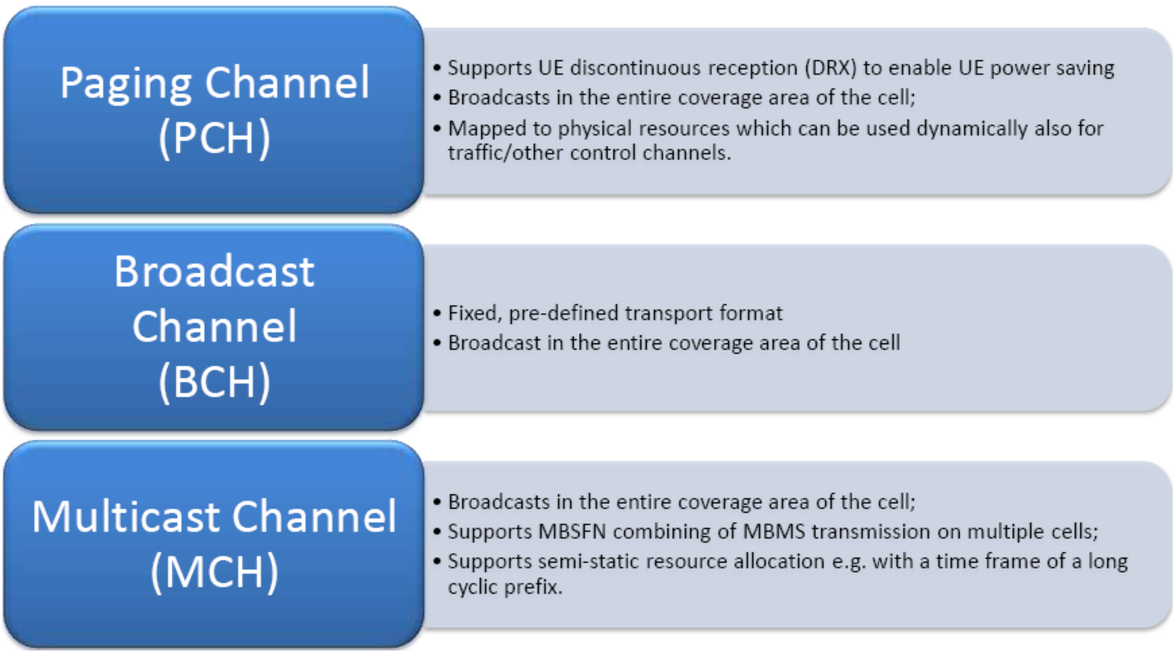
UPLINK LOGICAL CHANNEL : In Uplink there are two control channels and one traffic channel.

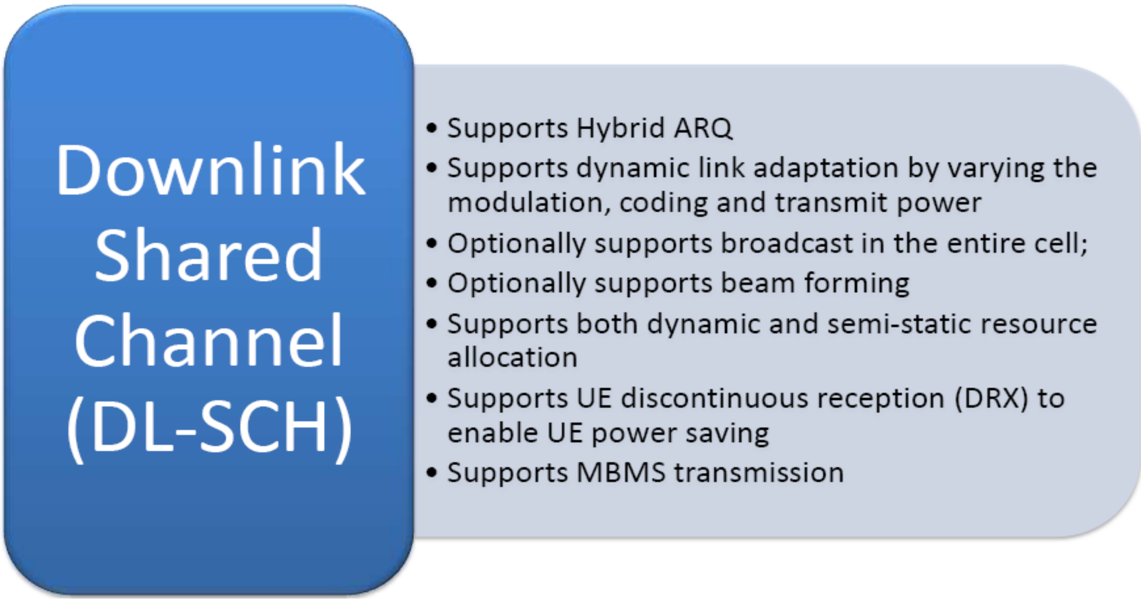


Transport Channels

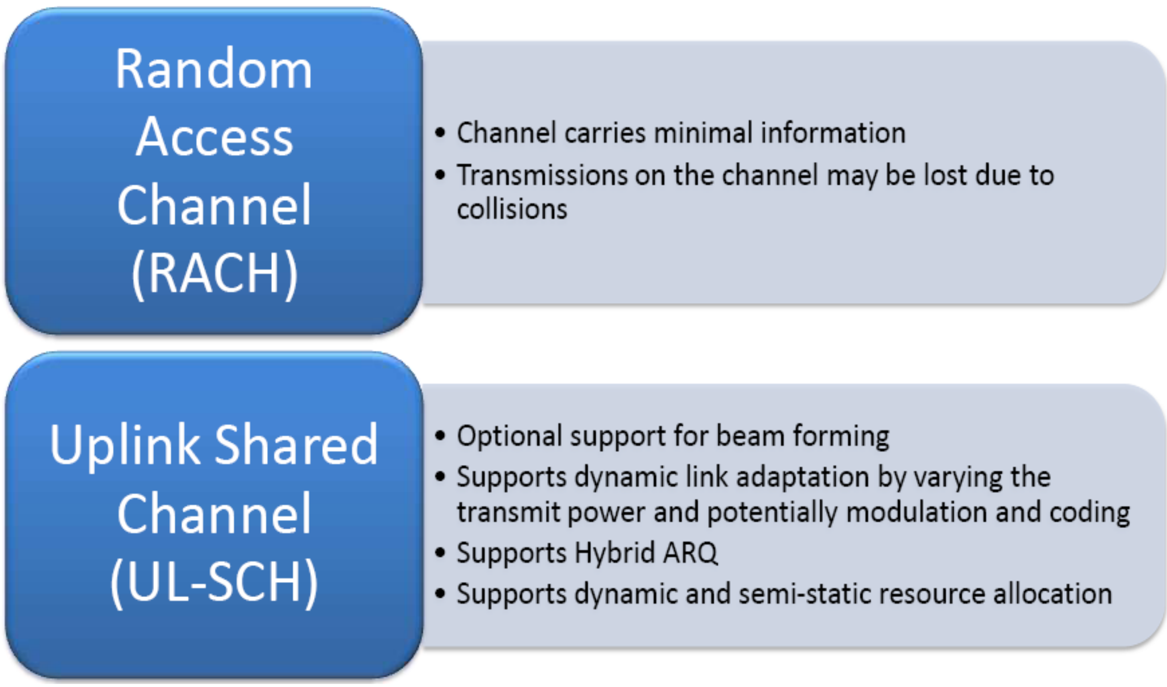
Transport channels define how and with what type of characteristics the data is transferred to the physical layer. Data and signaling messages are carried on transport channels between the MAC and the physical layer.

DOWNLINK TRANSPORT CHANNELS





UPLINK TRANSPORT CHANNEL



Physical Channels

These channels are also in both direction downlink and uplink directions. So we can divide these into Downlink Physical channels and uplink Physical Channels. Based on Data and signalling messages are carried on physical channels in LTE ,we can further classified as

- Physical Data channels (DL, UL)
- Physical Control Channels (DL,UL)

DOWNLINK PHYSICAL CHANNELS

Physical Downlink Shared Channel (PDSCH)

- Carries the DL-SCH and PCH
- QPSK, 16-QAM, and 64-QAM Modulation

Physical Downlink Control Channel (PDCCH)

- Informs the UE about the resource allocation of PCH and DL-SCH, and Hybrid ARQ information related to DL-SCH
- Carries the uplink scheduling grant
- QPSK Modulation

Physical Hybrid ARQ Indicator Channel (PHICH)

- Carries Hybrid ARQ ACK/NAKs in response to uplink transmissions.
- QPSK Modulation

Physical Broadcast Channel (PBCH)

- The coded BCH transport block is mapped to four sub-frames within a 40 ms interval. 40 ms timing is blindly detected, i.e. there is no explicit signalling indicating 40 ms timing
- Each sub-frame is assumed to be self-decodable, i.e. the BCH can be decoded from a single reception, assuming sufficiently good channel conditions.
- QPSK Modulation

Physical Multicast Channel (PMCH)

- Carries the MCH
- QPSK, 16-QAM, and 64-QAM Modulation

UPLINK PHYSICAL CHANNELS

Physical Radio Access Channel (PRACH)

- Carries the random access preamble
- The random access preambles are generated from Zadoff-Chu sequences with zero correlation zone, generated from one or several root Zadoff-Chu sequences.

Physical Uplink Shared Channel (PUSCH)

- Carries the UL-SCH
- QPSK, 16-QAM, and 64-QAM Modulation

Packet Uplink Control Channel (PUCCH)

- Carries Hybrid ARQ ACK/NAKs in response to downlink transmission
- Carries Scheduling Request (SR)
- Carries CQI reports
- BPSK and QPSK Modulation

1.3 Scheduling in LTE .

1.3.1 Round Robin (RR) Scheduler

Round robin algorithm uses a principle of sharing resources on an equal time slots basis and does not consider the channel quality information from participating user equipment . Each active UE in a cell have equal access to resources and services at equal amount of timeslots. This means that the same amount of radio resources is given to each communication link but it might not achieve a fair results in the sense of providing the same service quality to all communication links because the users are not transmitting the same data type or belong to the same traffic class.

1.3.2 The Modified Largest Weighted Delay First (MLWDF) Algorithm

This algorithm ensures higher system throughput and maintains acceptable fairness to the users. MLWDF largely depends on QoS requirement of the user and packet delay. In long-term evolution (LTE) downlink transmission, modified least weighted delay first (MLWDF) scheduler is a quality of service (QoS) aware scheduling scheme for real-time (RT) services. Nevertheless, MLWDF performs below optimal among the trade-off between strict delay and loss restraints of RT and non-RT traffic flows, respectively. This is further worsened with the implementation of hybrid automatic retransmission request (HARQ). As these restraints grow unabated with increasing number of user demands, the performance of MLWDF further reduces. In order to ameliorate this situation, there is a need to directly incorporate the variations in user demands and HARQ implementation as parameters to the MLWDF scheduler. In this work, an improvement to the MLWDF scheduler is proposed. The improvement entails adding two novel parameters that characterize user demand and HARQ implementation. The scheduler was tested using varying three classes of service in QoS class identifiers (QCIs) table standardized by Third Generation Partnership Project for LTE network to characterize different services. It was also tested on the basis of packet prioritization. The proposed scheduler was simulated with LTE-SIM simulator and compared with the MLWDF and proportional fairness schedulers. In terms of delay, throughput and packet loss ratio, the proposed scheduler increased overall system performance.

1.3.3 Proportional Fair Scheduler

Proportional fair scheduler is a compromise between RR and Maximum Best CQI. Its main targets are to provide maximum rate and to prevent UE starvation. A priority function is used to position the UEs and thereafter, the UE with the highest priority is assigned resources . This scheduling algorithm assigns the RBs to the UE with the best relative channel quality. There are various versions of PF scheduling based on values that it takes into account. The main goal of this scheduling algorithm is to achieve a balance between maximizing the cell throughput and fairness by allowing all users achieve a minimum QoS.

Chapter 2

LITERATURE SURVEY

2.1 Downlink Packet Scheduling in LTE Cellular Networks: Key Design Issues and a Survey

--- F. Capozzi, G. Piro, Student Member, IEEE, L.A. Grieco, Member, IEEE, G. Boggia, Senior Member, IEEE, and P. Camarda

Future generation cellular networks are expected to provide ubiquitous broadband access to a continuously growing number of mobile users. In this context, LTE systems represent an important milestone towards the 4G cellular networks. A key feature of LTE is the adoption of advanced Radio Resource Management procedures in order to increase the system performance up to the Shannon limit. Packet scheduling mechanisms play a fundamental role, because they are responsible for choosing, with fine time and frequency resolutions, how to distribute radio resources among different stations, taking into account channel condition and QoS requirements. This goal should be accomplished by providing, at the same time, an optimal trade-off between spectral efficiency and fairness.

This paper provides an overview on the key issues that arise in the design of a resource allocation algorithm for LTE networks. It covers the topic from basics to advanced aspects. The downlink channel under frequency division duplex configuration is considered as an object of our study, but most of the considerations are valid for other configurations as well. In this paper ,an extensive survey on downlink packet allocation strategies recently proposed for LTE networks, highlighting at the same time key issues that should be considered when designing a new solution is provided.

LTE is a breakthrough technology with respect to previous generations of cellular networks, as it is based on an all- IP architecture that aims at supporting several high quality services such as video streaming, VoIP, online gaming, and everything related to wideband Internet access. Given this ambitious objective, the desired performance can only be achieved by implementing a series of procedures at physical and MAC layers, able to exploit the wireless link capacity up to the Shannon limit. The most important RRM task is performed by the packet scheduler which is in charge of distributing radio resources among users in an efficient way, taking into account both flow requirements and physical constraints.

From a spectral efficiency point of view, the best solution is to allocate a RB to the user that is expected to exploit it at the best, thus maximizing the cell capacity. However, every other issue, such fairness, computational complexity, cell-edge coverage, QoS provisioning, and energy savings, could be solved always at the cost of reducing the overall cell capacity. The design of an allocation strategy often lies in the capacity of finding a good trade-off among the system spectral efficiency and the goals that the network operator wants to reach. A good algorithm should be easily implemented and should require very low computational cost. If the allocation scheme is based on a complex optimization problem, it guarantees high performance, but it also loses the fundamental capability of rapidly responding to network changes due to the computational overheads required by each decision.

In the first part of the paper, the understanding of the resource sharing problem in LTE networks, starting from the basics and then adding more and more details in order to explain always complex aspects of the system. The same approach has been followed while surveying the state of the art on allocation policies, classified according to their targets. We showed that, having to deal with the wireless environment, we need to take into account the variable channel conditions. It is also shown that metrics already available for operating systems and cabled networks, such as those using past throughput and delay sensitivity, remain useful to shape the behaviour of enhanced strategies, according to the desired outcome.

Furthermore, with the introduction of the need for strong QoS support, existing solutions have been demonstrated to be unsuitable for dealing with bounded delays and minimum data-rate requirements. This leads to the introduction of QoS- aware solutions that, from our point of view, are very interesting and promising. Moreover, they are able to describe flows requirements and to meet the desired performance targets. However, also in this case, it was possible to note a strong presence of channel-unaware and basic channel-aware variables.

The dependence of the scheduler working rationales on parameter settings is a problem that needs to be carefully addressed. A robust strategy should guarantee the ability to work in very different scenarios. Therefore, it should require no strong parameter settings, or it should at least dynamically adapt such parameters to environmental changes.

2.2 Uplink-Downlink LTE Multi Cell Capacity: A Performance Analysis in the Presence of ICI, Imperfect Channel Information and Reuse-1 Plan

-----Belal Abuhaija, IEEE member Sensor Networks and Cellular Systems (SNCS) Research Centre University of Tabuk, Saudia Arabia

Long Term Evolution (LTE) technology is based on Orthogonal Frequency Division Multiple Access (OFDMA) technique in the downlink to support multiple users in the same cell at the same time. This is known to be susceptible to Inter Cell Interference (ICI) in the downlink. The uplink technology of choice, has been SC-FDMA due to low power consumption requirement by the mobile terminal. In order to deliver higher data rates anywhere in the cell in the downlink, especially at the cell edge, many algorithms have been proposed for interference mitigation and avoidance which impose additional complexity on the system and yield minimum capacity enhancements. MIMO techniques have proven to be more efficient than such algorithms.

In this paper, a performance analysis of LTE cell capacity is conducted in the presence of several MIMO deployments, where multiple antennas at both the transmitter and the receiver are considered. A comprehensive simulation study of different multiple antenna configurations in the presence of uplink and downlink ICI and cell edge throughput is presented. We also provide insights into the MIMO deployment of choice based on users SINR. Different multiple antenna systems have been considered for scheduling radio resources in LTE base stations under flat transmit power spectrum. Open-Loop modes for different situations under the assumption that the UE in heavy loading conditions will not be able to send timely feedback information to eNodeB. Simple implementation of MIMO techniques under dynamic PRBs allocation for the period of service is provided. The results obtained show that multi antenna techniques can be used to significantly enhance overall system performance. Simulation results were carried out at the system level and in accordance with LTE standards. Inter cell interference is accounted for in a random manner as the randomization on the interference can produce interference diversity gain. From the simulation studies, it is noticed that, in terms of enhancing the cell throughput, increasing the power in the form of SINR has limited contribution to data rate increase. However, when more than one antenna is used in transmitting and or receiving, the cell's throughputs are enhanced and, in some cases, have been almost doubled , antenna configurations is shown in the figure below. This is a strong indication that the capacity increases linearly with the number of antennas deployed when using spatial multiplexing and increases logarithmically with the diversities of the transmit and receive.

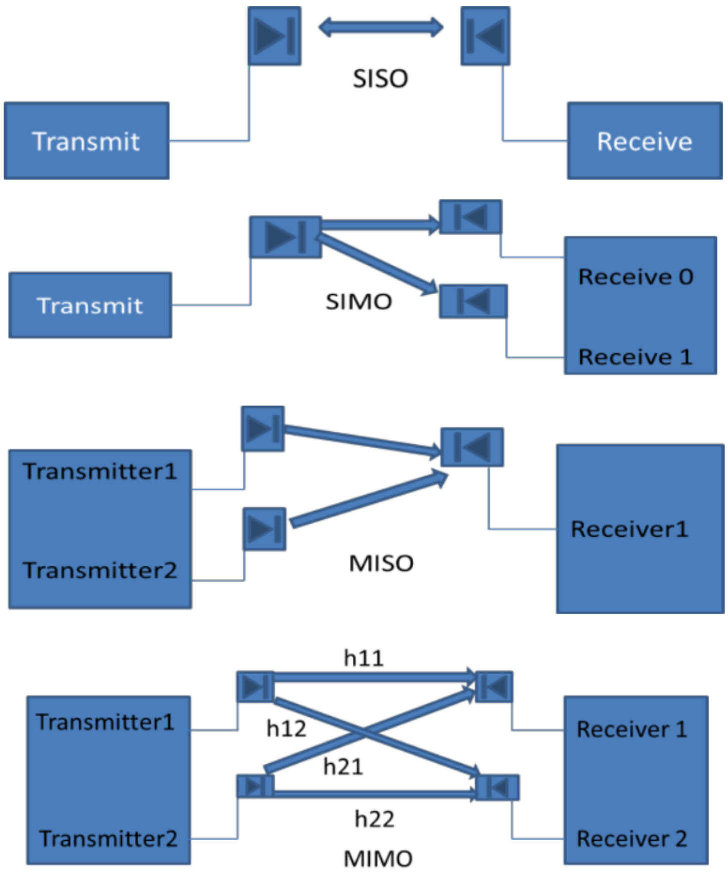


Figure 2.1 : Antenna Configuration

It is concluded in this paper that transmit diversity technique is most beneficial for customers with SINR gain around 10dB-12dB while spatial multiplexing is more beneficial when SINR gain is around 17dB-18dB or more. And with MIMO, the system performance as well as the capacity and/or quality of the service signal is enhanced.

2.3 On Coverage Analysis For LTE-A Cellular Networks

--- Jaafar A. Aldhaibani , A.Yahya , R.B.Ahmab , A.S. Md Zain , M.K.Salman , Riad Edan School of Computer & Communication Engineering University Malaysia Perlis (UniMAP) Kangar, Perlis, Malaysia Ministry of Science & Technology, Iraq, Baghdad

In this paper the coverage area for LTE-A cellular network by taking into account the interference of first tier and frequency reuse planning is analyzed . It is considered that the numerical calculations and simulation results to measure the received signal strength at the users for downlink and uplink performances. It has been shown from results that there is degradation in the received signal strength at cell boundaries from-34dBm at the center to -91dBm at the boundaries with spectral efficiency from (4.3 to 0.5) bps/Hz at cell edge. The mathematical model is verified by using the ATDI simulator for the LTE radio planning that deals with a real digital cartographic and contains standard formats for propagation loss.

The performance analyses in coverage and capacity of LTE cellular network have been simulated and evaluated .The numerical analysis of the spectral efficiency and signal strength at users for two way mode transmission (uplink and downlink) has been studied. The coverage estimated for dense urban area by using the ATDI RF planning software platform for the LTE Radio Planning that is approved the numerical analysis for proposed scheme.

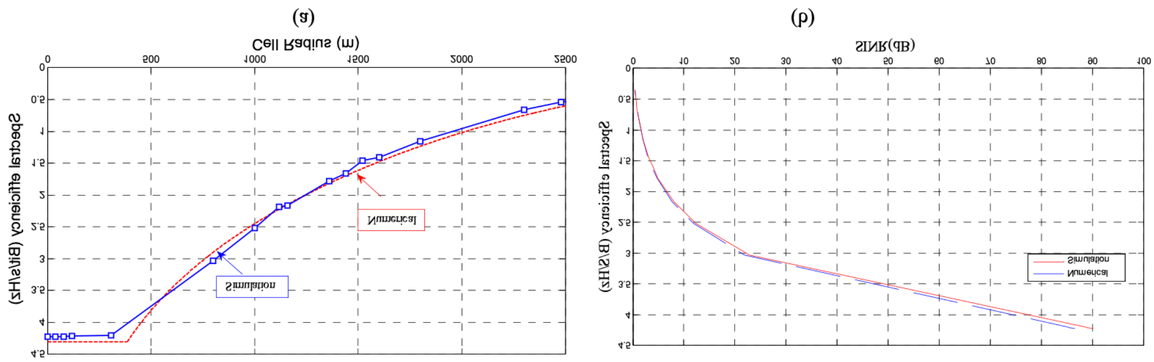


Figure 2.2 : Spectral efficiency versus the cell radius.(a) numerical and ATDI simulation results (b) The SINR versus with spectral efficiency

2.4 Analysis of throughput performance statistics for benchmarking LTE networks.

----- *V. Buenestado, J. M. Ruiz-Avilés, M. Toril, S. Luna-Ramírez, And A. Mendo*

In this paper, a comprehensive analysis of throughput performance statistics in a live LTE network is presented. The analysis shows the relationship between several widely accepted throughput performance indicators, i.e., the user throughput, the cell throughput, and the radio link throughput, and how these indicators are related to signal quality statistics. The analysis is performed on a per-cell and per-connection basis. For this purpose, throughput and signal quality statistics are collected from network performance counters and call traces in cells of a live LTE system. Results show that all throughput measures are strongly affected by chatty applications dominating current LTE networks due to the last transmission time interval transmissions and the outer loop link adaptation mechanism. A comprehensive analysis of several widely accepted throughput network performance indicators in LTE is presented, based on counters and call traces of a live network. The aim is to understand how throughput performance indicators differ and how much they are correlated with signal quality indicators.

To assess a cellular network, an operator must combine different throughput performance indicators to check user date rates, network capacity and spectral efficiency. In this paper, several throughput performance indicators have been analyzed based on measurements of a live LTE network. Results have put into evidence the impact of last TTI transmissions and OLLA on throughput statistics. A preliminary analysis of traffic statistics has shown the large share of last TTI transmissions originated by chatty applications dominating recently deployed LTE networks. Then, the analysis of counters has shown that averages of user throughput, cell throughput and radio link throughput may not be correlated in hours with low scheduler activity due to last TTI transmissions. Moreover, the analysis has pointed out the weak correlation of all throughput indicators with average CQI. The analysis of call traces has proved that such a weak correlation is partly due to OLLA in short connections. Not shown is the fact that the analysis has been repeated for other scenarios and ROPs, leading to the same conclusions. This situation might change when data hungry applications become popular. The analysis can be extended to delay and quality-of-experience statistics, which better reflect the quality of audio visual media services, once these statistics are available on a service basis.

2.5 SINR, RSRP, RSSI AND RSRQ Measurements in Long Term Evolution Networks

---- Farhana Afroz, Ramprasad Subramanian and Solaiman Ahmed.

The four basic Radio Resource Management (RRM) measurements in Long Term Evolution (LTE) system are Channel Quality Indicator (CQI), Reference Signal Received Power (RSRP), Reference Signal Received Quality (RSRQ), and Carrier Received Signal Strength Indicator (RSSI). A measurement of channel quality represented by Signal to Interference plus Noise Ratio (SINR) is used for link adaptation along with packet scheduling, whereas RSRP and RSRQ are needed for making handover decision during intra-eUTRAN (evolved Universal Terrestrial Random Access Network) handover in LTE. In this paper, some practical measurement results recorded from a live LTE network of Australia using a commercial measurement tool namely NEMO Handy are analysed to verify the possible relationships among SINR, RSRP, RSSI and RSRQ as well as to evaluate the effects of SNR on throughput. In addition, the intra- eUTRAN handover events occurred during the test period within the test area are studied. The analysis yields some useful information such as : if the SINR is good for a measurement slot, higher throughput is achieved; RSRP and SNR are proportional to each other on average; and lesser is the difference between RSSI and RSRP, better is the RSRQ – each of which is consistent with theory. All the measurement results are evaluated using computer programs built on MATLAB platform.

In this work, an analysis of some practical measurement results recorded from a live LTE FDD network of Australia are presented to verify the possible relationships among LTE measurements such as SINR, RSRP, RSSI and RSRQ as well as to evaluate the effects of SNR on throughput. Furthermore, the handover events occurred within LTE-eUTRAN during the test period are studied. It is observed that RSRP and SNR are proportional to each other on average, and lesser the difference between RSSI and RSRP, better is the RSRQ, and if the SINR is better for a measurement slot, higher throughput is achieved. It is also noticed that when the RSRP and/or RSRQ of a serving cell drops below the RSRP/RSRQ of neighbor cell, the handover event occurs to maintain the ongoing call or data session. All of these observations are found to be consistent with theory. Future work includes the performance analysis of a live LTE TDD network based on practical measurement results.

2.6 CQI-MCS Mapping For Green LTE Downlink Transmission

----- Mustafa Ismael Salman , Chee Kyun Ng, Nor Kamariah Noordin, Borhanuddin Mohd Ali and Aduwati Sali (Department of Computer and Communication Systems Engineering, Faculty of Engineering, University Putra Malaysia, Malaysia)

Maximizing the data rate and spectral efficiency are the main targets in LTE cellular systems. However, any increase in data rate or spectral efficiency will result in an undesirable increase in energy consumption. Hence, both energy efficiency (EE) and spectral efficiency (SE) necessitate to be optimized. In this paper, a multi-objective optimization framework is formulated to prove the trade-off between both EE and SE in LTE downlink transmission. A new mapping algorithm between channel quality indicator (CQI) and modulation and coding scheme (MCS) is proposed by using a multi-criteria decision making technique. The proposed CQI- MCS mapping algorithm will search for the most suitable MCS according to the reported CQI value by considering the trade-off between SE and EE while keeping block error rate (BLER) below its threshold value. Simulation results have shown that the proposed mapping algorithm can provide an efficient compromise solution compared to the existing 3GPP-LTE mapping. Therefore, the proposed CQI-MCS mapping can optimize the EE and SE based on different mapping values depending on the operator preferences.

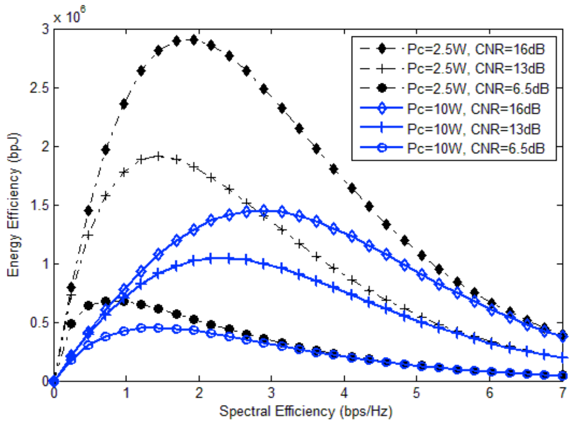


Figure 2.3 : The relation between EE and SE with different channel condition.

Also, the influence of AMC on system performances is highlighted. A new CQI-MCS mapping has been proposed based on multi-criteria decision making algorithm “VIKOR”. It is shown that the proposed mapping can optimize the EE-SE trade-off. This mapping can be adapted according to network operator priority by simply changing the weighting factor which associated to the competed criteria. The proposed mapping can be self-optimized according to traffic load condition, and accordingly, the performance of the whole system will be enhanced. Unlike the conventional AMC proposed by 3GPP, the proposed CQI-MCS mapping will let the MCSs to be adapted according to channel and traffic load conditions.

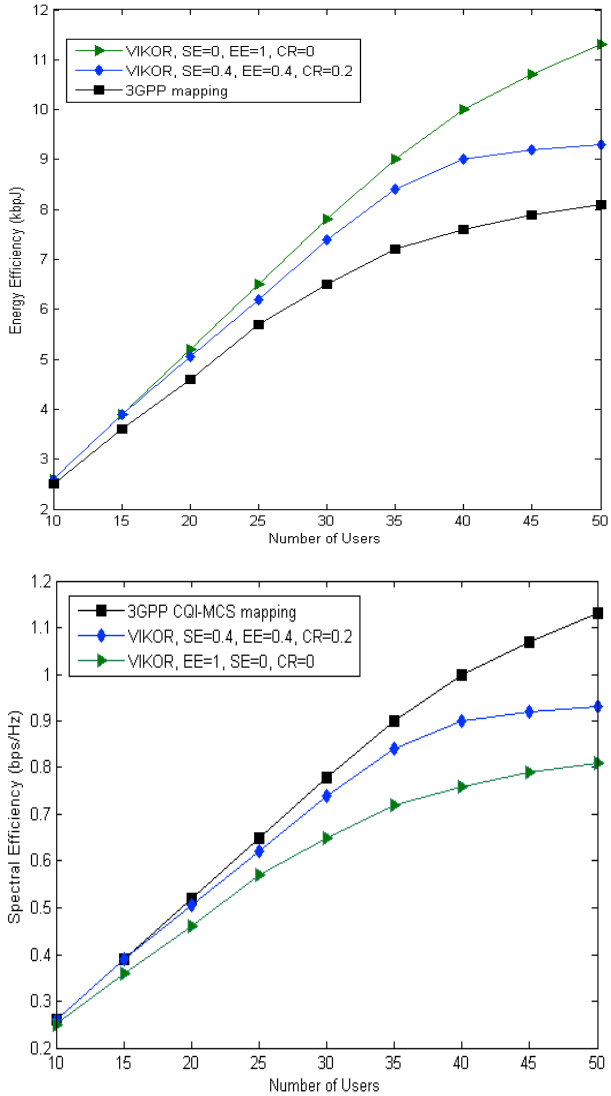


Figure 2.4 : The relationship between the number of users and (a) EE and (b) SE.

2.7 Beyond Throughput: A 4G LTE Dataset With Channel And Context Metrics

----- Darijo Raca, Jason J. Quinlan, Ahmed H. Zahran, Cormac J. Sreenan

Department of Computer Science, University College Cork, Cork, Ireland

In this paper, a 4G trace dataset composed of client-side cellular key performance indicators (KPIs) collected from two major Irish mobile operators, across different mobility patterns (static, pedestrian, car, bus and train) are presented . The 4G trace dataset contains 135 traces, with an average duration of fifteen minutes per trace, with viewable throughput ranging from 0 to 173 Mbit/s at a granularity of one sample per second. The traces are generated from a well- known non-rooted Android network monitoring application, G- Net Track Pro. This tool enables capturing various channel related KPIs, context-related metrics, downlink and uplink throughput, and also cell-related information.

To supplement the real-time 4G production network dataset, a synthetic dataset generated from a large-scale 4G ns-3 simulation that includes one hundred users randomly scattered across a seven-cell cluster is also provide. The purpose of this dataset is to provide additional information (such as competing metrics for users connected to the same cell), thus providing otherwise unavailable information about the e-NodeB environment and scheduling principle, to end user. In addition to this dataset, also the code and context information to allow other researchers to generate their own synthetic datasets is provide.

In this paper, presentation of both production and synthetic 4G trace dataset, with low bandwidth throughput sampling granularity, and invaluable client-side cellular channel and context information, from a diverse set of routes across two mobile operators (production) and a large range of clients in a multi-cell cluster (synthetic). The throughput values of both datasets permit detailed analysis with respect to oscillation in the transmission medium, while the channel and context metrics of the production dataset far exceed the original goal of the dataset with respect to HAS evaluation for throughput prediction. A high-level overview of the dataset which provides insight into different mobility patterns across both mobile operators, with respect to application throughput, average and variation in bandwidth, and channel and context metrics is provided.

2.8 Throughput Enhancement in Downlink MU-MIMO Using Multiple Dimensions

----- Jong-Gyu Ha, Jae-Hyun Ro and Hyoung-Kyu Song(Department of Information and Communication Engineering, uT Communication Research Institute, Sejong University, Korea)

This paper focuses on the throughput performance enhancement in the single cell multi-user MIMO (MU-MIMO) downlink system model. For better quality of service, this paper proposes the scheme that increases system throughput and improves the spectral efficiency. Specifically, the signal transmission and detection schemes are proposed by using multiple dimensions. At the transmitter side, two dimensions (power and space) are adopted at the same time. To achieve multiple access (MA), the space domain is exploited by using a block diagonalization (BD) precoding technique, and the power domain is exploited to transmit more data symbols. At the receiver, the signal detection structure corresponding to a transmitter is also proposed. In the simulation results, comparisons of throughput performance are presented in various aspects. As a result, the proposed scheme outperforms the conventional schemes using only one dimension in terms of throughput. This paper shows strong performance in MU-MIMO scenarios by adopting multiple dimensions.

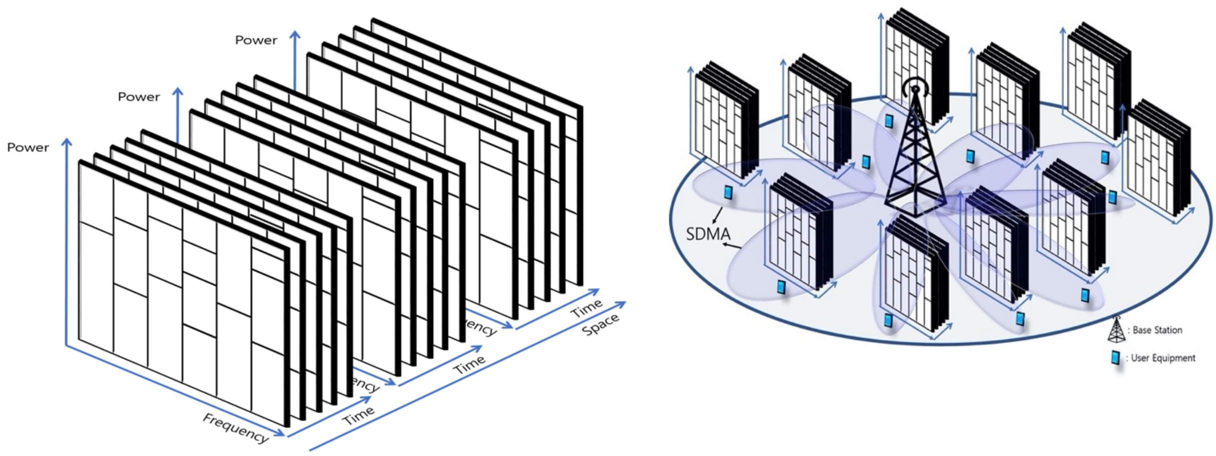


Figure 2.5 : The spectral efficiency using multiple dimensions and The downlink single-cell MU-MIMO system..

This paper suggests multi-dimensionality and a methodology to improve the throughput in an MU-MIMO system. This paper also presents the transceiver structure of the proposed scheme. As a result, the multiple dimensions (space and power) are exploited at the same time, and the overall system spectral efficiency is improved. If more dimensions are used without degradation or with a little trade-off in performance, the system throughput can be increased. Also, various system models can be implemented by using additional dimensions.

2.9 Performance Evaluation Of A Live Multi-Site LTE Network

------ Gediz Sezgin, Yagmur Coskun, Ertugrul Basar , (Senior Member, IEEE). And Gunes Karabulut Kurt, (Senior Member, IEEE),

In this paper, to quantify the field performance of a live long term evolution (LTE) network, design and implementation of a multi-layered performance monitoring system is performed. This monitoring system delivers an accurate and thorough picture of the network behaviour including switching, cellular, transmission, IP, and data networks. The designed system enables measurement results gathered from different network layers and from both user and control planes through a mediation platform, paving the way for the collection of synchronous performance measurement results, including latency, handover ratios, and throughput from network entities. Network performance metrics and the terminal-based measurement are jointly reported to reflect the subscriber perspective. Two field trials are conducted to highlight performance results of LTE networks, in a congested multi-cell with release 12 support, and a sparsely populated cell with release 14 support. Different multiple-input multiple-output (MIMO) configurations, including spatial multiplexing, transmit diversity, beamforming, and 64 × 64 massive MIMO support, along with a selection of bandwidths and frequency bands are considered. The measurement results show that, without any significant latency cost, using more antenna elements provides higher user throughput, which also affects the overall cell throughput. However, doubling the number of antennas may not necessarily double the average data rates. Additionally, the average intra-frequency and inter-frequency handover success ratios are observed to be acceptable, hence the changes among the selected the diversity and multiplexing technique does not have a visible deteriorating effect on the handover performance.

In order to investigate the performance of LTE networks from the subscriber perspective, they have designed and implemented a multi-layered performance monitoring system. This system enabled us to conduct comprehensive field tests. In this work, we have presented the impact of MIMO configurations and the carrier frequencies along with the allocated bandwidth on the performance of LTE networks through the use of the performance monitoring platform. By quantifying the performance of different MIMO TMs, we have observed that interference levels directly affect the system performance. The lower interference results in a higher order of TMs, which leads to increased throughput. Also, as expected, MIMO antenna configurations affect the throughput, however not in the same order as the number of used antenna elements, while a significant improvement is observed with the use of massive MIMO support. The latency measurements have been observed around 6 milliseconds, depending on the congestion level of traffic utilization, with almost 100% handover success rates.

2.10 LTE Physical Layer: Performance Analysis And Evaluation

----H. Mousavi , Iraj S. Amiri, M.A. Mostafavi , C.Y. Choon

3GPP LTE was proposed by cooperation between groups of telecommunications consortium named as 3rd Generation Partnership Project to improve the Universal Mobile Telecommunications System (UMTS) standard. It supports up to 300Mbps of data transmission in downlink using the Orthogonal Frequency Division Multiplexing (OFDM) modulation as well as up to 75 Mbps throughput for uplink using the Single Carrier-Frequency Division Multiple Access (SC-FDMA) modulation schemes.

In this paper, the study of LTE PHY layer performance evaluation is conducted for downlink transmission utilizing Single-Input and Single-Output (SISO) and Multi-Input and Multi-Output (MIMO) techniques. They presented a comprehensive investigation of the LTE performance analysis, where the Bit Error Rate (BER), Block Error Rate (BLER) and throughput performance results of LTE PHY layer provided. This study focused on the main parameters of LTE physical layer as well as the most frequent scenarios for mobile communications. Several techniques and technologies such as OFDM, OFDMA, SC- FDMA, and MIMO for the cellular systems were studied using a Link Level Simulator based on MATLAB program.

A reduction of system BER and BLER can be achieved in LTE downlink transmission. The effects of different numbers of HARQ retransmissions and turbo code iterations were investigated for SISO mode. Different user speeds were simulated and analyzed in terms of BER, BLER, and throughput in SISO systems, where MMSE channel estimator has a much better consequence on transmission than the LS channel estimator. A system experiencing AWGN channel condition results in a significant BER and throughput improvement compared to systems involving with PedB, VehB or Flat Rayleigh channel types. The system involving with PedB channel results in a better performance. In MIMO systems, increasing the system bandwidth is a very effective way, but this solution obviously is significantly costly for service providers. Moreover, evaluation of physical layer throughput can be performed for next Release(s) of 3GPP, since some effective modern technologies such as bandwidth extension up to 100 MHz and supporting more antenna ports can highly impact the performance.

Chapter 3

SOFTWARE

MATLAB is a programming language widely used in academic and industry areas. It has been developed by MathWorks and allows a numerical computing environment. MATLAB is characterized by the following properties:

- Complete tools to analyse data, develop different applications by the use of algorithms. Also data visualization is available.
- Create user interfaces.
- Interface with other languages such as C, Java or FORTRAN, among others.
- Different toolboxes available: specific sort of functions and script oriented to a specific area.

These allow the end-user to take profit of the MATLAB capabilities . In this project an academic license of MATLAB R2019a version has been used. Wireless communication toolboxes available in this version have been listed just below:

- Communications Toolbox.
- WLAN Toolbox.
- LTE Toolbox.
- 5G Toolbox.

3.1Communications Toolbox.

It Designs and simulates the physical layer of communications systems. Communications Toolbox provides algorithms and apps for the analysis, design, end-to-end simulation, and verification of communications systems. Toolbox algorithms including channel coding, modulation, MIMO, and OFDM enable you to compose and simulate a physical layer model of your standard-based or custom-designed wireless communications system.

The toolbox provides a waveform generator app, constellation and eye diagrams, bit-error-rate, and other analysis tools and scopes for validating your designs. These tools enable you to generate and analyze signals, visualize channel characteristics, and obtain performance metrics such as error vector magnitude (EVM). The toolbox includes SISO and MIMO statistical and spatial channel models. It also includes RF impairments, including RF nonlinearity and carrier offset and compensation algorithms, including carrier and symbol timing synchronizers. These algorithms enable you to realistically model link-level specifications and compensate for the effects of channel degradations.

3.2 WLAN Toolbox.

It Simulates, analyses, and tests WLAN communications systems. WLAN Toolbox provides standards-compiant functions for the design, simulation, analysis, and testing of wireless LAN communications systems. It includes configurable physical layer waveforms for IEEE® 802.11ax/ac/ad/ah and 802.11b/a/g/n/j/p standards. It also provides transmitter, channel modelling, and receiver operations, including channel coding (BCC and LDPC), modulation (OFDM, DSSS, and CCK), spatial stream mapping, channel models and MIMO receivers.

The toolbox provides reference designs to help you perform baseband link-level simulations and multi-node system-level simulations. You can generate and parse common MAC frames. You can also perform signal measurements such as channel power, spectrum mask, and occupied bandwidth, and create test benches for the end-to-end simulation of WLAN communications links.

3.3 LTE Toolbox.

It Simulates, analyses, and tests the physical layer of LTE and LTE-Advanced wireless communications systems. LTE Toolbox provides standard-compliant functions and apps for the design, simulation, and verification of LTE, LTE-Advanced, and LTE-Advanced Pro communications systems. The toolbox accelerates LTE algorithm and physical layer (PHY) development, supports golden reference verification and conformance testing, and enables test waveform generation.

With the toolbox we can configure, simulate, measure, and analyse end-to-end communications links. we can also create and reuse a conformance test bench to verify that your designs, prototypes, and implementations comply with the LTE standard.

3.3.1 Wireless Waveform Generator

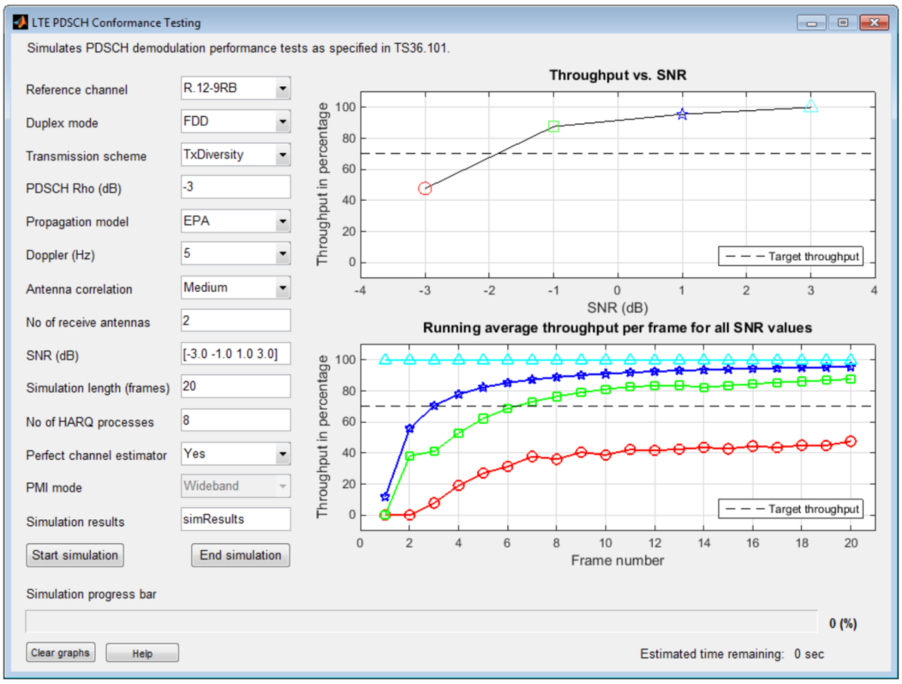
The Wireless Waveform Generator app enables you to create , impair, visualize , and export modulated waveforms. Using the app, we can :

- Generate custom OFDM, QAM, and PSK modulated waveforms.
- Generate sine wave test waveforms.
- Generate LTE modulated waveforms.
- Distort the waveform by adding RF impairments, such as AWGN, phase offset, frequency offset, DC offset, IQ imbalance, and memoryless cubic nonlinearity.
- Visualize the waveform in constellation diagram, spectrum analyser, OFDM grid, and time scope plots.
- Export the waveform to your workspace as a structure, to a .mat or a .bb file, or to a runnable MATLAB script.

Functions : `lteRMCDLTool` | `lteRMCULTool` | `lteTestModelTool`

3.3.2 LTE Throughput Analyzer

It Generates throughput curves for physical downlink shared channel (PDSCH) conformance test analysis. The LTE Throughput Analyzer app performs PDSCH demodulation performance testing. The app also performs analysis and testing for custom user-defined measurement channels settings.



RMC and Conformance – Functions

lteRMCDL	Downlink reference measurement channel configuration
lteRMCUL	Uplink reference measurement channel or FRC configuration
lteTestModel	Downlink test model configuration structure
lteRMCDLTool	Generate downlink RMC waveform
lteRMCULTool	Uplink RMC or FRC waveform generation
lteTestModelTool	Generate downlink test model waveform
lteDLConformanceTestTool	Opens the LTE Throughput Analyzer app for performing downlink PDSCH demodulation conformance tests

3.4 5G Toolbox.

Simulates, analyses, and tests 5G communications systems. 5G Toolbox provides standard-compliant functions and reference examples for the modelling, simulation, and verification of 5G New Radio (NR) communications systems. The toolbox supports link-level simulation, golden reference verification, conformance testing, and test waveform generation.

With the toolbox you can configure, simulate, measure, and analyse end-to-end 5G NR communications links. You can modify or customize the toolbox functions and use them as reference models for implementing 5G systems and devices.

The toolbox provides functions and reference examples to help you characterize uplink and downlink baseband specifications and simulate the effects of RF designs and interference sources on system performance. You can generate waveforms and customize test benches, either programmatically or interactively using the Wireless Waveform Generator app. With these waveforms, you can verify that your designs, prototypes, and implementations comply with the 3GPP 5G NR specifications.

Chapter 4

PROPOSED SYSYTEM

4.1 Scheduling Factors

- **Channel quality indicator**: The user gives the channel quality information to base station in the uplink in the form of a four digit number. By using this information, the base station assigns the specific modulation and coding technique and the suitable resource block to the user.
- **Buffer status report**: When the user has definite data in its buffer it has to inform the base station that there is some data and request a grant from the network to share that data. This is the user's way of informing base station about the data in the user terminal.
- **Quality of service:** Quality of service is a measure of functionality between the PDN gateway and the user. It defines how the data should be treated in the network. For example, a voice packet is given more priority than web browsing traffic. The user computes the CQI value in the downlink channel and sends it to the base station. The buffer status report (BSR) is also sent to the base station. Based on these factors (BSR, CQI, and QoS), modulation and coding scheme values and the Physical resource block (PRB) mapping are computed and sent to the user.

4.2 Sequence of operations in a Packet Scheduler

The radio resource management modules interact with the scheduler and this sequence is continuously repeated, as shown in Figure 4.1.

- The user equipment takes the reference signal and, calculates the channel quality and this is sent to the base station.
- The base station takes the allocation decision by using the channel quality value and fills the resource block.
- The user reads the PDCCH channel payload.

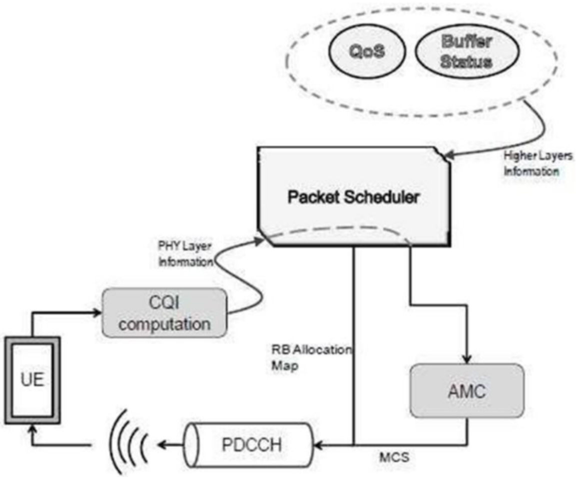


Figure 4.1: Packet Scheduler

4.3 Proposed Scheduling Algorithm.

In Proposed System, we propose a downlink scheduling algorithm based on Deficit-Drop Fairness algorithm to improve the performance of the cell-edge user and all other users in the cell. The cell is divided into two regions namely outer and inner to differentiate the user in this proposed algorithm. This algorithm also takes into account the packet delay and the packet loss probability which are important parameters to serve the cell-edge user. The packet scheduling algorithm located in the eNB plays a significant role to the overall performance of the system. This can be done by allocating the RB efficiently to the user based on the priorities, current network situation and channel condition. RB is the basic unit that an eNB can allocate to the users and it consists of time and frequency. Each RB is 0.5ms and 180 kHz long in time and frequency domain, respectively.

Advantages:

- ✓ Lower operation and maintenance costs with less environmental impacts.
- ✓ It is flexible.
- ✓ It is very efficient.

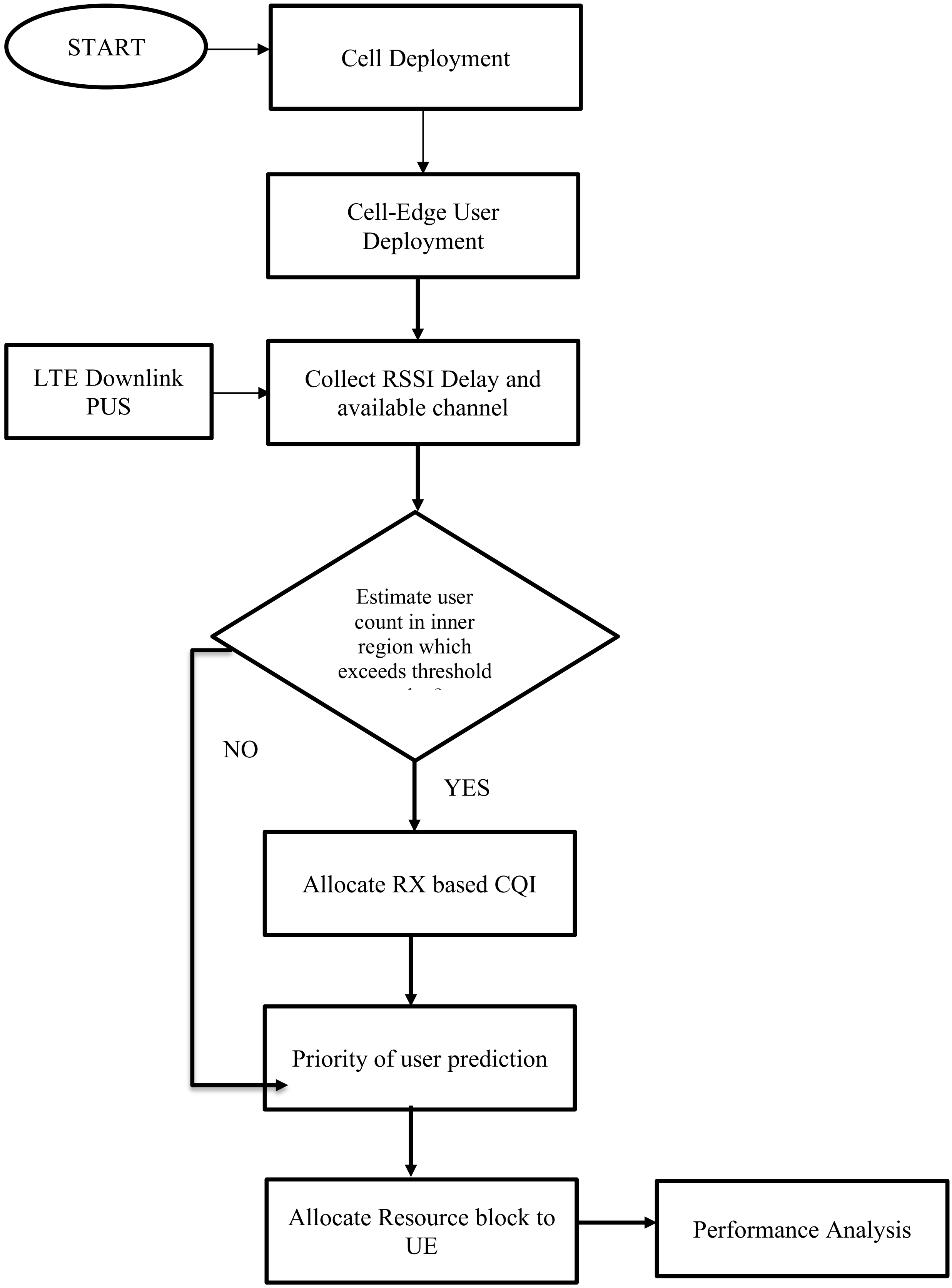


Figure 4.2 : Proposed Scheduling Algorithm Flowchart

4.4 System model

In this model uses multiuser downlink in LTE-A net-works with an E-UTRAN NodeB (eNB)) with active UEs(x). This is considered as a full buffer traffic model, since the eNB transmits data over each UE at given TTI. The CCs are used by the eNB during data transmissions and the data reception is done by other set of CCs. The CCs has same bandwidth over the RB, z and simultaneously at each TI, the downlink is performed. The main idea is to clearly separate the users according to their locations and to give more priority to the users who locate in the cell-edge area. Giving priority to the cell-edge users with low RSS will increase their throughputs. However, it also can affect the performance of other users and the system spectral efficiency. Threshold values for number of user in regions and distance of the user from eNB are considered in the proposed algorithm to make sure that the algorithm can perform well in all possible conditions.

4.5 Performance Analysis.

- **Throughput:** It is the rate of production or the rate at which something is processed. Throughput is essentially synonymous to digital bandwidth consumption; it can be analysed mathematically by applying the queuing theory, where the load in packets per time unit is denoted as the arrival rate (λ), and the throughput, where the drop in packets per time unit, is denoted as the departure rate (μ).
- **Fairness Index:** A totally fair system will allocate resources such that all xi's are equal to 1. The fairness index measures the "equality" of the resource allocation and, if not equal, it tells how far the allocation is from equality.
- **Spectral Efficiency:** Spectral efficiency usually is expressed as “bits per second per hertz,” or bits/s/Hz. In other words, it can be defined as the net data rate in bits per second (bps) divided by the bandwidth in hertz. Net data rate and symbol rate are related to the raw data rate which includes the usable payload and all overhead.

4.6 Deficit-Drop Fairness Scheduling.

The main idea is to clearly separate the users according to their locations and to give more priority to the users who locate in the cell-edge area. Giving priority to the cell-edge users with low RSS will increase their throughputs. However, it also can affect the performance of other users and the system spectral efficiency. Threshold values for number of user in regions and distance of the user from eNB are considered in the proposed algorithm to make sure that the algorithm can perform well in all possible conditions. we propose a downlink scheduling algorithm based on Deficit-Drop Fairness algorithm to improve the performance of the cell-edge user and all other users in the cell. The cell is divided into two regions namely outer and inner to differentiate the user in this proposed algorithm. This algorithm also takes into account the packet delay and the packet loss probability which are important parameters to serve the cell-edge user. The proposed algorithm prioritizes the cell-edge user with low RSS if there are more users in the outer region. In that case, the user with lower RSS will have higher metric value and the user will have higher chance to get the RBs. However, when there are many active users in the inner region, prioritizing the outer region user will lead to lower spectral efficiency and poor system performance. Therefore, a threshold value is considered in this case to avoid the possible waste of available RBs.

The model in considers the error probability ε_i, probability from failure state to success state P_i and delay threshold τ_i as defined in

$$\delta_i = \varepsilon_i \left(1 - P_i\right)^{\tau_i}$$

4.7 Throughput Calculation

The simplest way how to calculate LTE throughput, the following calculations are made for user data bit rates on IP layer (including IP headers and LTE overhead, i.e. real user bit rate will be a bit lower). LTE throughput depends on the following parameters:

- **Bandwidth.** According to 3GPP specifications LTE channel bandwidth can be 1.4, 3, 5, 10, 15, 20 MHz. The wider bandwidth the higher throughput. All available spectrum is divided into Resource Blocks (RB). A table to map bandwidth on number of available RB is presented below.

	Channel bandwidth, MHz					
	1.4	3	5	10	15	20
Number of Resource Blocks	6	15	25	50	75	100

- **Channel quality.** Radio conditions impact user bit rates. The better radio conditions the higher throughput is available and vice versa. eNB (eNodeB, base station) selects Modulation and Coding Scheme (MCS) based on current radio conditions. The higher MCS the more bits can be transmitted per time unit. UE (User Equipment, mobile terminal) measures radio channel quality and sends CQI (Channel Quality Indicator) to eNB. eNB selects MCS based on the following table (it's presented for information only and will not be used for further throughput calculations).

	Before Rel.12		Rel.12 and beyond	
CQI	Modulation	Code rate	Modulation	Code rate
0	Out of range			
1	QPSK	0.0762	QPSK	0.0762
2	QPSK	0.1172	QPSK	0.1885
3	QPSK	0.1885	QPSK	0.4385
4	QPSK	0.3008	16QAM	0.3691
5	QPSK	0.4385	16QAM	0.4785
6	QPSK	0.5879	16QAM	0.6016
7	16QAM	0.3691	64QAM	0.4551
8	16QAM	0.4785	64QAM	0.5537
9	16QAM	0.6016	64QAM	0.6504
10	64QAM	0.4551	64QAM	0.7539
11	64QAM	0.5537	64QAM	0.8525
12	64QAM	0.6504	256QAM	0.6943
13	64QAM	0.7539	256QAM	0.7783
14	64QAM	0.8525	256QAM	0.8634
15	64QAM	0.9258	256QAM	0.9258

Also depending on radio conditions various multi-antenna techniques can be applied, e.g. MIMO 2x2 (Multiple Input Multiple Output) or MIMO 4x4. These techniques help to increase throughput as well (almost in 2 or 4 times respectively).

- **Network load**. Available radio resources are divided among active subscribers. So the more subscribers are active and receive/transmit data the less resources are allocated to a given subscriber. It also depends on subscriber and connection (bearer in terms of LTE) priorities.

MCS Index	Modulation	TBS Index
0	QPSK	0
1		1
2		2
3		3
4		4
5		5
6		6
7		7
8		8
9		9
10	16QAM	
11		10
12		11
13		12
14		13
15		14
16		15

MCS Index	Modulation	TBS Index
17	64QAM	15
18		16
19		17
20		18
21		19
22		20
23		21
24		22
25		23
26		24
27		25
28		26
29	QPSK	Reserved
30	16QAM	
31	64QAM	

To calculate LTE throughput the following steps should be performed:

- Define bandwidth. It can be 1.4, 3, 5, 10, 15 or 20 MHz. Then map it to a number of Resource Blocks using the table above.
- Choose/define radio link quality. To calculate throughput we need to know MCS Index. MCS Index depends on CQI. However association between MCS Index and CQI is vendor specific. The following table can be used to choose MCS Index. where TBS means Transport Block Size. It's a number of bits which can be transmitted per 1 TTI (=1ms).

The last step is to take a look at Transport Block Size table to determine how many bits can be transmitted per 1 TTI and multiply it by 1000 to get bps .

Chapter 5

RESULTS

The value of throughput, fairness index and spectral efficiency is calculated and compared with RR, PF, and MLWDF algorithm. The parameters of the simulation are stated in Table

Parameter	Value
Bandwidth	20 MHz
Operating frequency	1800MHz
Antenna configuration	2x2
Transmission Mode	CLSM
Simulation time	1000 TTI
Macroscopic path loss model	Macrocell Urban Model
User distribution	Random in the cell area
eNB power transmission	46dBm
MCS Index	According to 3GPP standard [21]
Number of user	10 - 50
user thermal noise density	-174dBm
Average user speed	5 kmph
Data Type	Mixed (Video, Gaming, VoIP)
Delay Threshold	Video: 100ms, Gaming: 50ms, VoIP: 100ms

Table 5.1: Simulation settings

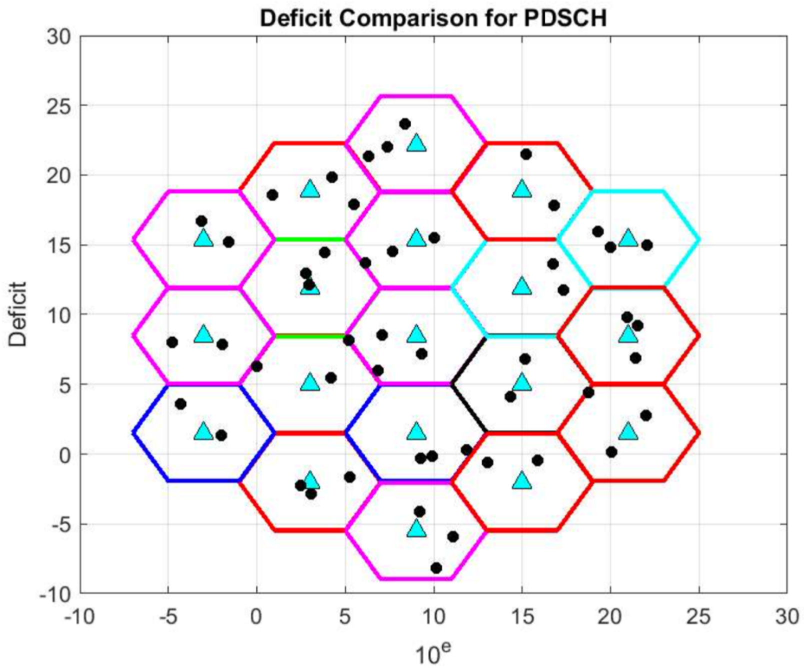


Figure 5.1: Cluster Of Cells

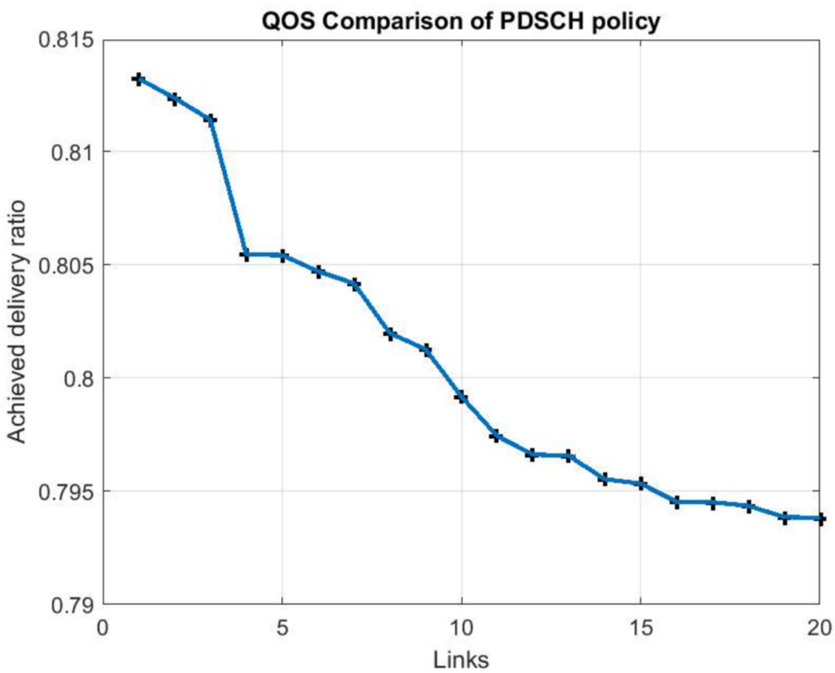


Figure 5.2: QOS Comparison

The cell-edge user throughput is measured for different number of user in Figure 5.3. Although the cell-edge throughput is dropping as the number of user is increasing, the proposed model achieves better throughput than RR and MLWDF . The QoS unaware scheduler PF has the lowest cell-edge throughput as it does not consider any delay parameters or packet loss probability. RR algorithm has higher throughput than PF due to the consideration of packet delay. RR has marginally better cell-edge throughput than MLWDF as it serves all user by rotation.

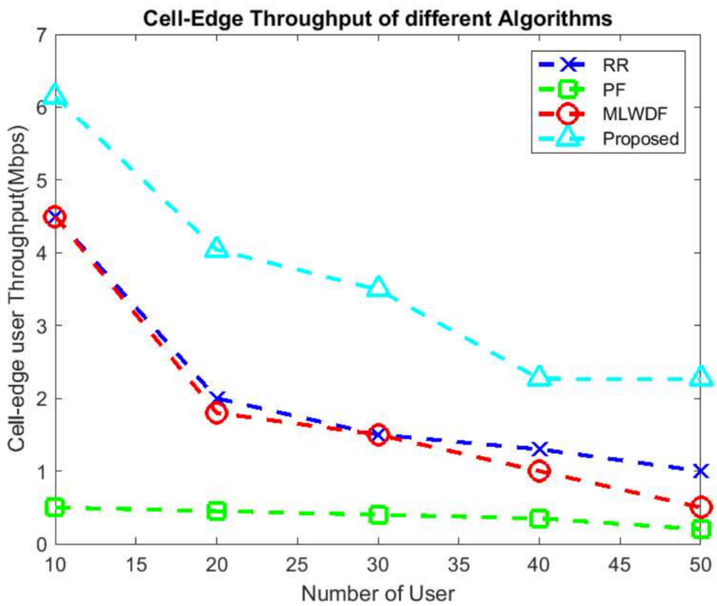


Figure 5.3 : Cell-Edge throughput for different algorithms

Figure 5.4 , shows the comparison of average user throughput for different algorithms. The average user throughput is calculated by considering all active users in the cell area. The comparison clearly shows that the proposed algorithm performs better than existing algorithms.

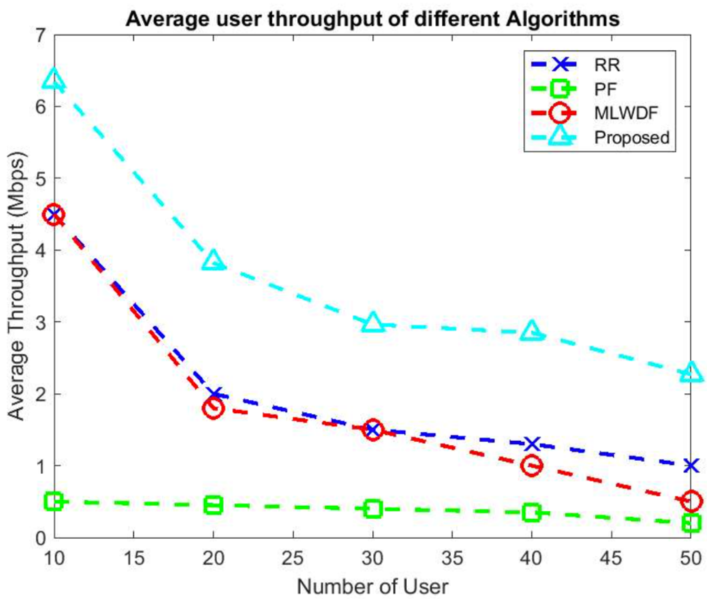


Figure 5.4 : Average user throughput of different algorithms

The average cell throughput is the aggregated throughput of all user in the cell including active and inactive user. Figure 5.5 shows the average cell throughput for different algorithms. The proposed algorithm increases the cell throughput overall compared to the other algorithms as this algorithm ensures that more user have higher number of RBs when there are fewer user in the cell and when the number of inner region user increase the cell-edge users do not have higher priority to best use of available RBs. Other algorithms do not consider this user congestion approach. Therefore, they have comparatively lower cell throughput.

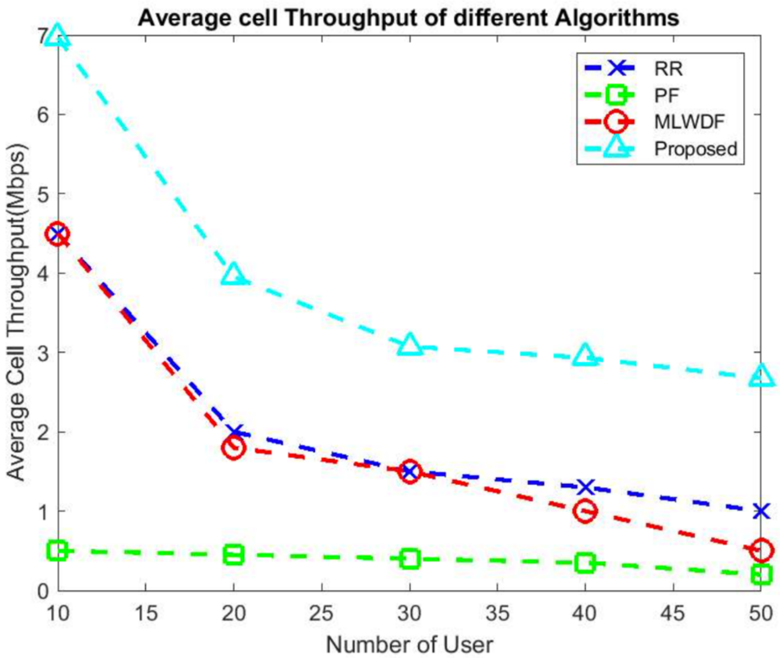


Figure 5.5 : Average cell throughput of different algorithms

In the Figure 5.6 , shows the comparison of fairness index for different algorithms. The comparison clearly shows that the proposed algorithm has a better fairness index than the existing algorithms.

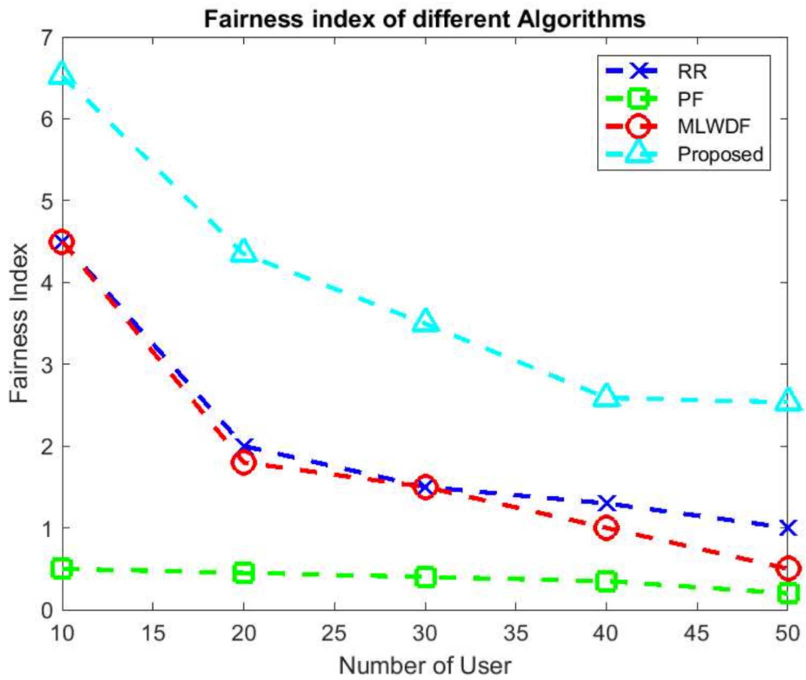


Figure 5.6 : Fairness index of different algorithms

Figure 5.7 , shows the comparison of Spectral efficiency for no. of users in a cell for different algorithms. The comparison shows that the proposed algorithm has a better spectral efficiency than the other algorithms.

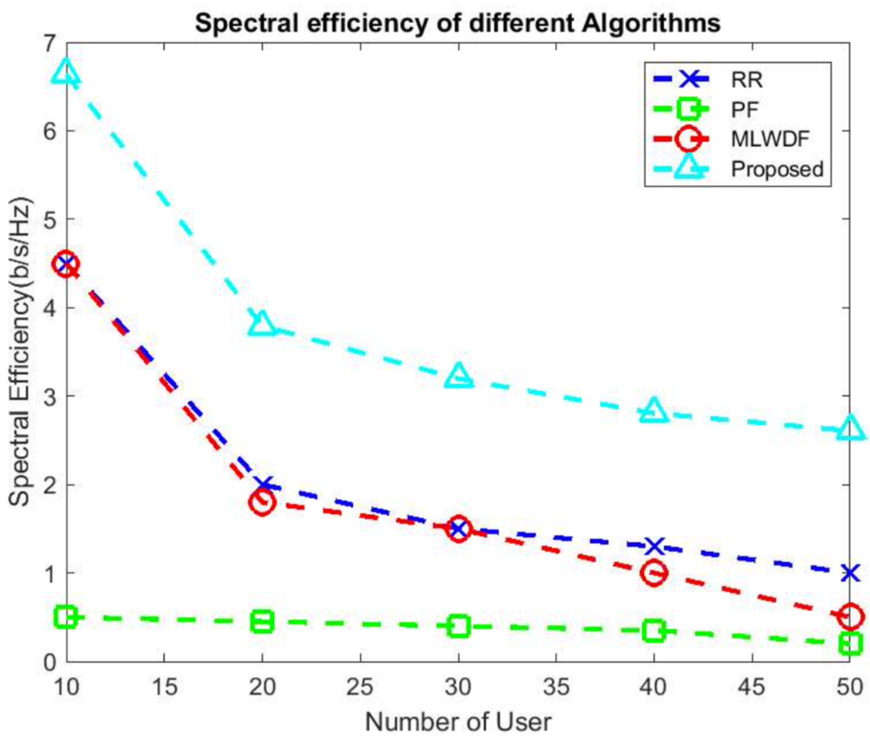


Figure 5.7 : Spectral efficiency of different algorithms

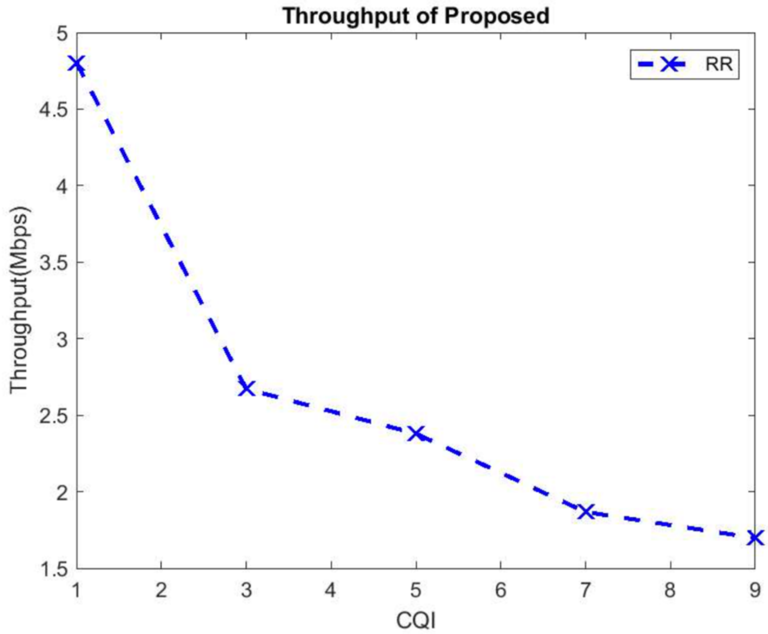


Figure 5.8 : Throughput and CQI for the proposed algorithm

In this work, we devised an improved long term evolution downlink planning algorithm and assessed the throughput, fairness and spectral efficiency exhibitions of the proposed algorithm with the four distinctive prevailing scheduling methods.

Chapter 6

DISCUSSION AND CONCLUSION

To study the Long Term Evolution Downlink Scheduling Algorithms. It is necessary to know about these scheduling algorithms. There are many enabling technologies in the LTE standard that help in improving the capacity of the system and their coverage. OFDM is one of the enabling technologies used in the downlink transmission, where the total bandwidth is partitioned into a number of time-frequency resource elements. The scheduler is a crucial constituent present in the base station, which helps in allocating the time-frequency resources to the users.

In this project , we proposed a Deficit-Drop Fairness based packet scheduling algorithm is proposed for LTE network to enhance the performance of cell-edge user and the overall system. The proposed algorithm prioritizes the users who are located in the cell-edge area by dividing the cell into two regions. Two additional parameters RSS and threshold constant which varies based on the number of users in different region are introduced to the basic equation. Distance from eNB to user is also taken into account to calculate the metric value. When there is less user in the inner region, the cell-edge user gets higher priority. If the number of user in the inner region exceeds the threshold constant, the proposed algorithm allocates RBs according to the channel condition to maintain the overall system performance.

Chapter 7

SCOPE FOR FUTURE WORK

The proposed algorithm shows significant improvement to make sure that the cell-edge users are taken care by the scheduler. However, this modified algorithm is designed for Real Time (RT) user. Therefore, Near Real Time (NRT) user will experience delay due to the consideration of RT packets while calculating the scheduling metric. In future, throughput can be enhanced for all users in the cell area including NRT user.

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