Mobility Effect on Different MIMO Modes and Scheduler Schemes under Different Network Layout in Downlink LTE-A

by

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Dedicated to my parents

Who

have the most influence on me.

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List of Abbreviation of Technical Terms

QoS	Quality of Service
PDSCH	Physical Downlink Shared Channel
RLC	Radio Link Control
QPSK	Quadrature Phase Shift Keying
TTI	Transmission Time Interval
UMTS	Universal Mobile Telecommunications System
WCDMA	Wideband Code Division Multiple Access
Wi-Fi	Wireless Fidelity
RF	Radio Frequency
QAM	Quadrature Amplitude Modulation
PHICH	Physical Hybrid ARQ Indicator Channel
VoIP	Voice over Internet Protocol
RB	Resource Block
RAT	Radio Access Technology
FDD	Frequency Division Duplex
FDM	Frequency Division Multiplexing
FDMA	Frequency Division Multiple Access
BER	Bit Error Rate
BLER	Block Error Rate
BPSK	Binary Phase Shift Keying
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communication
E-UTRA	Evolved UMTS Terrestrial Radio Access
E-UTRAN	Evolved UMTS Terrestrial Radio Access Network

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ABSTRACT

Modern wireless communication systems have to meet the demand of very high data rates. Unlike conventional methods, LTE addresses the higher data rate by introducing several Multiple-Input and Multiple-Output (MIMO) transmission modes. Transmit diversity and Spatial multiplexing techniques are the most popular techniques that are used now- a -days. Open loop and closed loop spatial multiplexing techniques can both transmit multiple data streams in a single time interval. This significantly enhances the data rate and channel capacity. In addition, closed loop spatial multiplexing uses a Pre-coding matrix indicator which is fed back from the UE to the base station and this optimizes the data transmission. Resource scheduler type also has a significant impact on the system performance because the scheduler performance ranges from optimizing the UE fairness to maximizing the UE throughput. In practical, many User Equipments (UEs) can move at high velocities and which affects the overall performance of scheduler. Thus, UE mobility must be taken into account for a fair comparison between different schedulers and transmission modes. Therefore, thorough performance analysis with different combination of transmission modes, scheduling types and network layouts can be greatly helpful. The performance analysis can be done using computer simulations instead of real network to save the cost. The results of the analysis can be used for proper settings in the real network. In other words, for optimizing the network system and reducing the operational cost of the operator, performance analysis must be done for choosing the right scheduler and transmission modes for different network layout under mobility. In this work, a thorough performance analysis has been done for various LTE downlink performance parameters between several MIMO techniques to find which MIMO mode is best suited for mobile users and dense urban environment under different scheduling algorithms in different network Layouts.

Chapter 1
Introduction and Background

1.1Introduction

LTE is a 3rd Generation Partnership Project (3GPP) standard built to drive cellular technology to the next level by providing additional network coverage, power, efficient use of spectrum, lower latency and fast data speeds. In addition, LTE assigned bandwidths, ranging from 1.4 MHz to20 MHz, are provided in unpaired TDD and paired FDD spectrums. Orthogonal Frequency Division Multiple Access (OFDMA) scheme is used to get a better throughput and spectral efficiency for downlink transmission. On the other hand, for getting low Peak to Average power ratio (PAPR) Single Carrier Frequency Division Multiple Access (SC-FDMA), scheme is used in uplink transmission [1]. LTE provides multiple MIMO modes in both the uplink and downlink to achieve high data rate and better spectral efficiency for the UEs. In downlink and uplink respectively for a 20 MHz channel a peak data rate of 326.4 Mbps and 86.4 Mbps can be achieved [2]. Conventional macro cell network has many problems with widespread coverage especially in urban areas. In fact, with increased user density, macro-cell power depletion is unavoidable. LTE implemented multiple features in order to solve these and other similar barriers to better performance in the UEs [3]. The Rank Indicator (RI) is associated with spatial multiplexing techniques and indicates the number of separate data streams simultaneously distributed by LTE that have introduced various network improvements to increase the UE data rate [4].

One of the features is femto cell which acts as a low power base station. Femto cells are positioned in reduced regions of coverage within the macro cell network. It increases existing macro cell network ability. The heterogeneous network (HetNet) is defined as a mix of femtocells and macrocell network. A proper delivery technique is needed in order to assign system resources to the UEs in order to obtain a high data rate and to serve equally all the UE. This resource scheduling is carried out in BS 'Medium Access Control (MAC) layer. Several algorithms for the scheduling have been developed. Among these are very commonly used proportional fair (PF) and round robin (RR), each aimed at enhancing some of the above listed parameters. The user's broad mobile access, higher data rate and wideband coverage requirements are increasing rapidly, which has raised stakes in developing an effective resource allocation strategy that shares the equal resource in networks and ensures customer satisfaction [5–7].One of the most recent technologies in cellular networks is heterogeneous small cell networks that offer high data rates and increased coverage area for mobile edge users with macro cell ability [8–10]. LTE-Advanced heterogeneous small cell networks play an significant role in the ultra dense deployment networks. Multiple base stations of varying size and power are installed in the heterogeneous small cell to provide the high throughput and efficient use of spectrum provided by next-generation networks [11, 12]. Femtocell has become one of the most popular low-cost small cell and low-power base stations / data access point (AP) or femto access point (FAP) that delivers a high-quality signaling for home users or a specific region. It is very easy to deploy and sustain a femtocell, which lowers running and maintenance costs compared to other base stations such as macrocell, microcell, and Picocell[10, 13]. Femtocell 's access strategy classified into open access, restricted access and hybrid access. Any user in the range can access the network in open access, while in closed access a user list belongs to the femtocell which can access the networks[14–17]. Hybrid access blends open access and closed community access. In certain agreements the customer can access the femtocell hybrid network. But such advantages are not easy to achieve because there are many problems where a significant number of femto cells are installed in overlaid macrocell OFDM networks. In OFDM, multi-carrier is allocated to the different users that caused the network interference and concealed the above-mentioned benefit [14]. In addition, high intercell interference degrades overall network efficiency. Interference is classified into Cross-tier and co-tier. Cross-tier interference occurs between femto and macro networks and co-tier interference between femto and femto base station [18, 19] in the large deploy of small cell heterogeneous networks. The interference effect depends on the resources distributed to both the macro and femto cell. The key challenge in allocating radio resources is to prevent interfering with the co-channels and cross-channels [20]. To prevent and control CI (channel interference), the resource allocation techniques use specific code, parameters and algorithm. This scheme is implemented in multi-user multi-carrier system that likes heterogeneous networks, where more than one user in an adjacent cell uses the same spectrum and frequency [21–23].

1.2 Problem identification and motivation to work

3GPP doesn't identify a specific LTE-advanced resource scheduling algorithm[24].Capozzi et al.[25] highlighted the major problems that are posed in LTE / LTE-Advanced networks when allocating resources. By taking close loop multiplexing ,Habafbi et al. [26] compared the proportional fair, round robin and best channel quality indicator scheduling. For comparing different scheduling techniques, Block error rate and channel quality indicator were the key performance metric Analysis indicate that the Best Channel Quality Indicator across all achieved the highest throughputs .The performance of round robin, Best channel quality indicator, proportional fair, Max TP, resource fair and max–min scheduling algorithms was analyzed by Jabbar et al.[27] in LTE wireless sensor based network. Throughput, block error rate and fairness metric used in performance evaluation of the system. Result represented the better performance of proportional fair and max-min scheduler than of other scheduler. Stefan Schwarz et al. [28,29] suggested a new scheduling method (PS), KMT, AMT and assessed BCQI, RR, RF, PF Max – MIN, MIMO and CLSM / OLSM efficiency using cell throughput and fairness index. Results showed that the scheduler that proposed produced enhanced performance. Salman et al.[30] introduced RR-BCQI and RR-CQI, improved round robin version with BCQI and CQI, findings showed that RR-CQI had a better performance in terms of cell throughput and fairness. Proportional fair scheduler from time domain to multicarrier transmission systems was improved by Hoon Kim et al. [31]. The proposed algorithms choose a user carrier mapping where algorithm sum rate value was high. Depending on this Sun et al.[32], Kwan et al.[33], suggested an optimal reduced-complexity Proportional fair resource methodology for multiple access orthogonal frequency division networks.. This method is derived from KKT condition for fair power distribution among all users. This scheme provided significant network benefits. This approach also bases our proportional fair scheduling performance. Coskun Deniz et al.[34] suggested a new technique that would improve the proportional fair scheduling algorithm for the edge of the cell without any degradation of the method. Results showed that the scheduler proposed worked better for edge throughput, fairness and average cell throughput. The behavior of the cellular macro-femto network with different transmission power and scheduling algorithms have analyzed by Krasniqi et al. [35] .The key performance metrics used for this analysis were average throughput and wideband SINR Result showed that between all schedulers BCQI and Max TP had higher throughput. A modified proportional fair scheduler for LTE-femtocell networks was proposed by Ismail et al. [36]. The proposed algorithm provided the best results in terms of both spectral efficiency and throughput.

Most UEs are moving with varying speeds, in reality. Therefore it is important to consider the EU mobility to evaluate a system output. But this introduces simulation complexity therefore in most research works UE mobility is not taken into account. Considering real scenario, transmit diversity and spatial multiplexing with their features is explored in [37]. To increase UE data rate by spatial multiplexing, the benefits of feedback in MIMO is addressed in [38]. The benefit of femto cell and its deployment strategies are briefly described in [39]. Martin Klause consider RR,PF, Proposed avg. Delay resource scheduler for their simulation .They also consider different user density for their simulation and 2*2 system is used but velocity is not taken into account[41]. Lijana Gavrilovska compared between BCQI and proposed scheduler (SNF) under 1*1system. Cell throughput and cell BLER were taken as performance matric but here also user mobility is not taken for their simulation [42]. Raymond Kwan also compared BCQI and proposed scheduler considering SISO system [43].Mohammad escheikh compared among different scheduler by taking cell throughput, CQI and BCQI as performance matric for still cases[44]. Gbolahan compared between CAQA(proposed scheduler) and PF taking different UE density[45]. But parameter of mobility is not taken on their research.

Many research works have focused on the performance of various scheduling schemes. But they were all conducted under low UE velocity. But in reality, many UEs can move at high speeds which affect the scheduler's overall efficiency. For a realistic comparison between different schedulers and transmission modes, then EU mobility must be taken into consideration. Therefore, performance analysis is required to improve the system. This work has been done for downlink purposes not for the uplink purposes as most of the control signaling is transmitted in downlink. So, for optimizing the network system and reducing the operational cost of the operator, performance analysis must be done for choosing the right scheduler and transmission modes for different network layout under mobility. Here, performance analysis has carried out for choosing the right parameter for improving the existing network system and connectivity.

1.3 Thesis objectives

The main objective of this thesis is to find the most favorable resource scheduler and transmission modes for heterogeneous and small cell network under mobility for downlink LTE-A .However, more particularly, the objectives include:

- Performance analysis of a suitable resource scheduling algorithm between PF and RR for different velocity users.
- Comparison of different spatial multiplexing transmission modes and effect of Pre-coding Matrix Indicator (PMI) for CLSM mode under mobility.
- Performance analysis of several MIMO modes for different velocity users in Heterogeneous Network (HetNet).
- Performance analysis between small cell network (ScNet) and Heterogeneous network (HetNet) to find which network topology is suitable for high velocity UEs and densely populated region.

1.4 Thesis organization

This thesis is organized as follows:

- In **Chapter 1**, introduction and back ground of the work is discussed. Motivation, problem Identifications and thesis objectives are discussed in the later portion.
- In **Chapter 2**, LTE basics and key features are described. Then multi antenna transmission, scheduling and link adaptation, resource allocation are discussed. Also LTE protocol layers are described on the later portion.
- In **Chapter 3**, methodology for different types of resource schedulers' especially proportional fair, round robin, max CQI are discussed. Later methodology for different MIMO modes are discussed. Then key performance indicators are described in elaborate form.

- In **chapter 4,** proposed network model for different parameters are described. And later results for different scenario are discussed.
- **Chapter 5** contains the conclusion of the thesis, where the summary of the results is given with some recommendations for future works.

Chapter 2
LTE Fundamentals

2.1. Introduction to LTE basics and Key features

LTE, an abbreviation for Long-Term Evolution which is widely known as 4 G LTE, is a standard for high-speed cellular data communication for mobile phones and computer terminals. This is based on the network technologies GSM / EDGE and UMTS / HSPA, improving flexibility and speed by using a new radio interface along with enhancements to the core network. The specification is defined by the 3GPP (3rd Generation Partnership Project) and stated in its Release 8 document series, with minor improvements outlined in Release 9.LTE is the normal upgrade path for carriers of both GSM / UMTS and CDMA2000 networks. The various LTE frequencies and bands used in different countries would mean that only multi-band telephones will use LTE in all countries where it is licensed. LTE stands for Long Term Evolution and is a trade mark held by ETSI (European Telecommunications Standards Institute) for cellular data transmission technology and implementation of GSM / UMTS standards. Other nations and businesses do play an active role in the LTE project though. LTE's goal was to increase wireless data network capacity and speed using new DSP(digital signal processing) techniques and modulations that were developed around the turn of the millennium .Another goal was to restructure and simplify the network infrastructure to an IP-based framework with greatly decreased transmission latency relative to the 3 G infrastructure. The LTE wireless interface is incompatible with 2 G and 3G networks, so running on a different radio spectrum is necessary. To meet the ambitious performance goals that have been set for LTE, several main features are required. In the text that follows we complement the basic description of several individual key features with the specific targets they address.

2.1.1. Spectrum Flexibility

Radio spectrum for mobile contact is available in various frequency bands in different bandwidths, and comes as paired and unpaired spectrum, depending on regulatory aspects in different geographical areas.

2.1.2. Radio Interface Basics

An inherent feature of radio communication is that the efficiency of instantaneous radio-channels varies in time, space, and frequency. It involves fairly fast variations due to propagation on multi paths. Therefore the efficiency of the radio-channel depends on the precise structure of the reflected radio waves (Figure 2.1). Traditionally; approaches have been used to minimize these differences (i.e., various forms of transmission of diversity) to maintain a constant data rate over the radio link. For packet-data systems, however, end-users usually do not note rapid short-term fluctuations in the instant data rate. Consequently one of the key features of LTE radio access

is one of the fundamental principles operating under all these conditions. In addition to being able to work in various frequency bands, LTE can be implemented with different bandwidths ranging from approximately 1.25MHz (suitable for initial migration of, say, cdma2000/1xEVDOsystems) to approximately 20MHz. In addition, LTE can work in both paired and unpaired spectrum by delivering a single radio access system that facilitates duplex frequency-division (FDD) operation as well as duplex time-division (TDD).

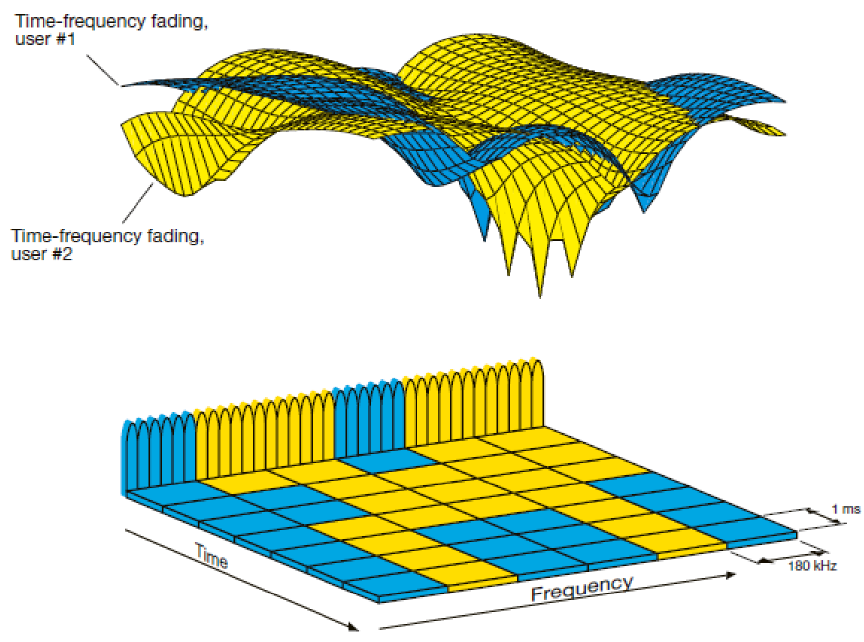


Fig 2.1**:** Channel-quality variations in frequency and time [1]

The FDD can be controlled in full and half-duplex modes where terminals are concerned. Half duplex FDD, in which the terminal separates infrequency and time of transmission and receipt

(Figure 2.1), is useful as it enables terminals to work with relaxed duplex-filter specifications. This effectively reduces terminal costs by allowing the use of FDD frequency bands that could not otherwise be used (too limited duplex distance). Together these approaches allow LTE to suit nearly random spectrum allocations.

One difficulty when developing a scalable spectrum radio-access system is to maintain commonality between modes of spectrum and duplexing. The frame structure used by LTE is the same for different bandwidths, and identical for FDD and TDD.

2.1.3. Multi-antenna transmission

In mobile communications systems, the use of multi-antenna transmission techniques enhances system performance, service capabilities or both. At its highest level, multi-antenna LTE transmission can be split into

- transmit diversity and
- (pre-coder-based) multi stream transmission including beam forming as a special case.

2.1.4. Scheduling and link adaptation

Scheduling usually refers to the process by which resources are separated and allocated between users with data to pass. For dynamic scheduling (1ms), both uplink and downlink are introduced for LTE. Scheduling should achieve a balance between perceived end-user flexibility and overall system performance. The use of channel-dependent scheduling achieves a high cell throughput.

Transmissions can be conducted at higher data rates (the result of using higher-order modulation, less coding scheme, more streams, and less re-transmission) by delivering resources on time or on frequency with fairly good channel conditions. Therefore less radio resources (less time) are consumed for any given amount of information transferred, resulting in improved overall system efficiency.

The control signaling needed for dynamic scheduling can be ridiculously high proportion to the total of user data transmitted for services with small payloads and usual packet arrivals. For this purpose, LTE also supports constant scheduling (except dynamic scheduling). Persistent scheduling means that radio resources for a given set of sub-frames are assigned to a user. Link-adaptation approaches are used to optimize the instantaneous efficiency of the channels. In fact, the adaptation of the link adapts the modulation choice and channel coding schemes to current channel conditions. This in turn defines the possibilities of data rate or error for each link.

2.1.5. Uplink power control

Power control is all about establishing transmit power levels, typically to improve system capacity, coverage and decrease energy usage. To achieve these goals, power-control mechanisms usually aim to optimize the power received from desired signals while minimizing interference. The LTE uplink is orthogonal, that is, there is no interference between users in the same network, at least in the ideal case. Among other things, the amount of interaction with neighboring cells depends on the location of the mobile terminal – more precisely, the pathway gain from the terminal to these cells. Generally speaking, the closer a terminal is to a neighboring cell, the greater the interference with that cell. Consequently, terminals farther from the neighboring cell can transmit with greater power than terminals close to the cell. Furthermore, a connection exists between proximity to the serving cell and distance from the neighboring cells. The LTE uplink power control takes all these characteristics into consideration. The orthogonal LTE uplink makes it possible to multiplex signals from terminals with different received uplink power in the same cell.

In the short term, this means that instead of offsetting multi-path fading peaks by reducing power , these peaks can be exploited to increase data rates through scheduling and linking adaptation. In the long run, one might set the power level destination host on the path gain to the serving cell, giving terminals that produce little interference to a larger power target received. In the context of Figure 2.2, this corresponds to raising the average signal level.

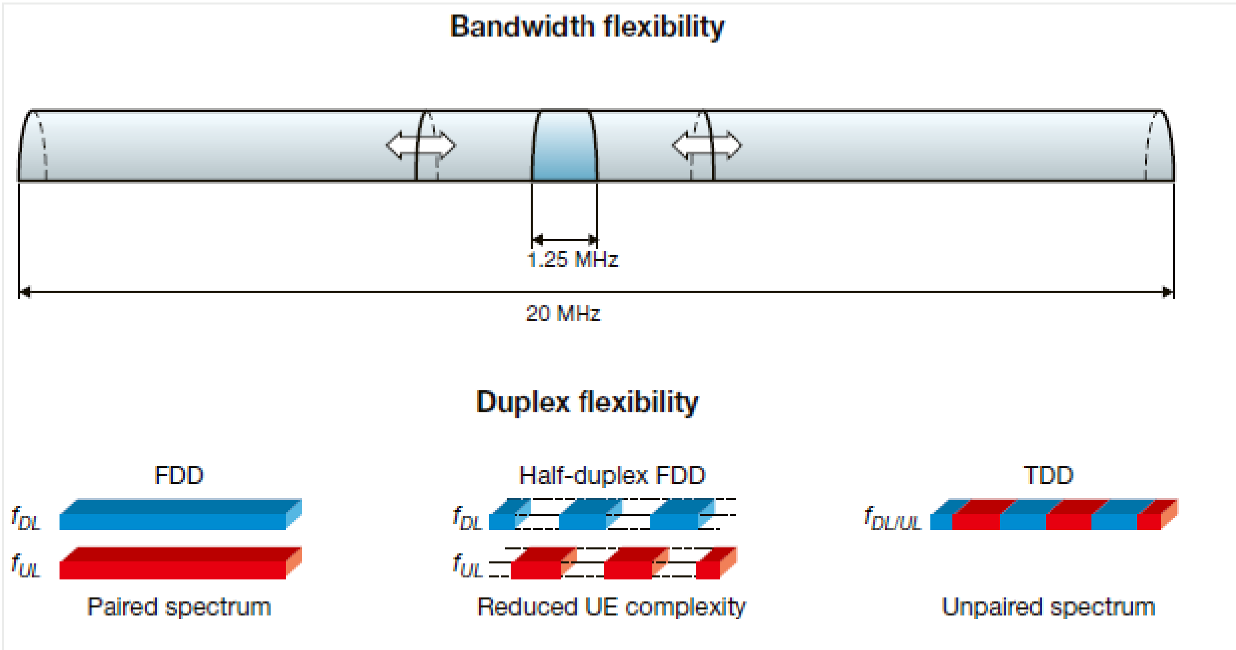


Fig2.2: LTE spectrum (bandwidth and duplex) flexibility. Half-duplex FDD is seen from a terminal perspective [1].

2.2. Error Correction Technique in LTE

In telecommunication, information theory, and coding theory, forward error correction (FEC) or channel coding is a technique used for controlling errors in data transmission over unreliable or noisy communication channels. The central idea is the sender encodes his message in a redundant way by using an error-correcting code (ECC). In the 1940s the American mathematician Richard Hamming pioneered this field and in 1950 invented the first error-correcting code: the Hamming code (7, 4).

In the 1940s the American mathematician Richard Hamming pioneered this field and in 1950 invented the first error-correcting code: the Hamming code (7, 4). The redundancy allows the recipient to identify a limited amount of errors that can occur anywhere in the message and often, without retransmission, to correct these errors. FEC allows the receiver the capacity to correct errors without having a reverse channel to request data retransmission but at the expense of a fixed, higher forward channel bandwidth. Consequently, It is implemented in circumstances where retransmission is expensive or impractical, such as single-way communication links and multi-cast transmission to multiple receivers Usually, FEC information is added to mass storage devices to enable corrupted data to be recovered, and is widely used in modems. FEC processing in some kind of a receiver may be applied to a digital bit stream or a digitally modulated carrier demodulation. FEC is for the latter an integral part of the receiver's initial analog-to - digital conversion.

A soft-decision algorithm is implemented by the Viterbi decoder to demodulate digital data from an analog signal distorted by noise. Most FEC coders can also produce a bit error rate (BER) signal that can be used as feedback to fine-tune the electronics receiving the analog.

The noisy-channel coding theorem sets limits on a channel's theoretical potential rate of information transmission with any specified level of noise. Some advanced FEC systems approach the theoretical limit.

The FEC code specification specifies the maximum fractions of errors or missing bits that can be corrected, and different forward error correction codes are appropriate for different situations.

2.2.1. Hybrid automatic repeat request (HARQ)

Hybrid Automatic Repeat Request (HARQ or Hybrid ARQ) is a mix of high rate error-correcting coding and error-control ARQ. Using error detection (ED) code, such as a cyclic redundancy test (CRC), redundant bits are applied to data to be transmitted in standard ARQs. Receivers detecting a corrupted message will ask the transmitter for a new message. In Hybrid ARQ, the actual data is encoded with a forward error correction (FEC) code, and the parity bits are just sent immediately along with the message or only transmitted when a receiver detects an inaccurate message on requestIn addition to error detection, such as a Reed-Solomon code, the ED code may be omitted when using a code that can perform both forward error correction (FEC) The FEC code is used to correct an estimated subset of all potential errors, whereas the ARQ approach is used as a fall-back to fix uncorrectable errors using only the redundancy sent during the initial transmission. As a result, in bad signal conditions hybrid ARQ performs better than ordinary ARQ, but in its simplest form this comes at the cost of slightly lower throughput under good signal conditions. There's usually a cross-over point of signal strength below which is better for simple hybrid ARQ and above which is better for basic ARQ.

2.3 Resource allocation technique

The eNodeB MAC layer is responsible for scheduling the resources for both uplink and downlink. The scheduler seeks to make the correct distribution of resources as follows with other targets:

- Load allocation among cells.
- Ensuring high cell throughput by providing optimized spectral efficiency under existing channel conditions.
- Required Quality of service for applications.
- Among UEs and applications, Fairness must be maintained.
- Reducing the effectof interference through special handling of cell edge users.

Each Transmission Time Interval (TTI) which is a subframe can be modified to the scheduling decision. The Resource block is both downlink and uplink 's simple scheduling structure.

2.4. LTE protocol layer:

2.4.1. LTE protocol structure:

For LTE, very important topic is the radio protocol architecture. For DRX mechanism layer 2 and layer 3 are most relevant, since the DRX mechanism is responsible for these two layers.

The architecture of the LTE radio protocol can be divided into control plane architecture and user plane architecture as shown below:

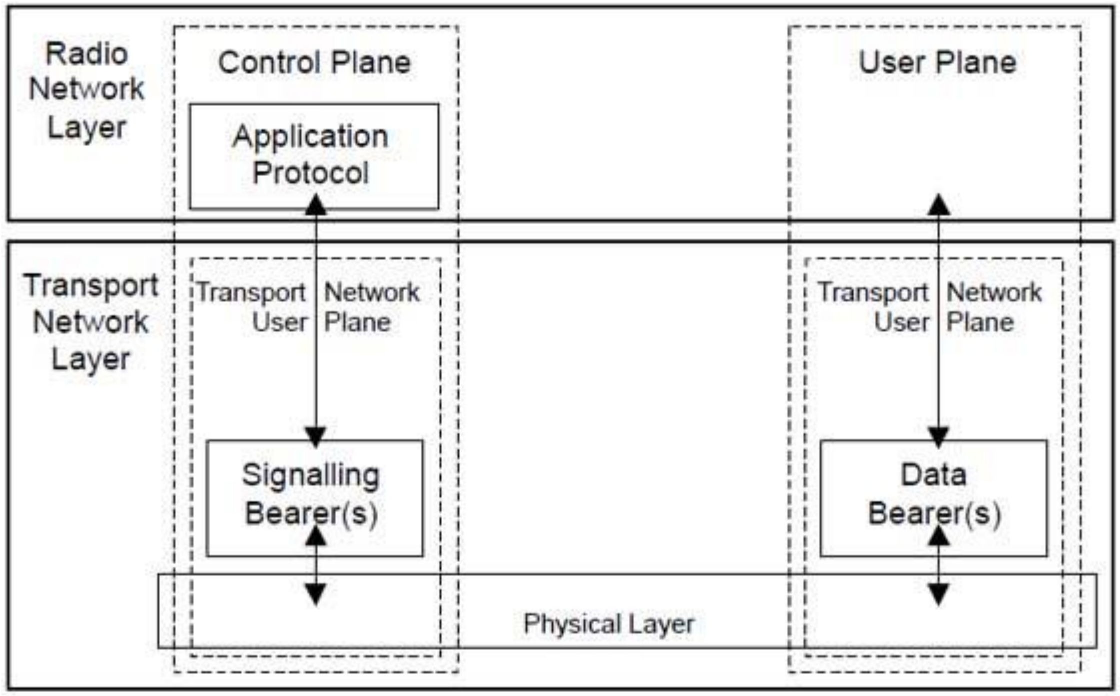


Fig 2.3: The radio protocol architecture for LTE.[3]

On the user plane side, the program generates data packets that are processed in the control plane by protocols such as TCP, UDP and IP; the Radio Resource Control (RRC) protocol writes signals that are shared between the base station and the device. In both situations, the data is provided through the Packet Data Convergence Protocol (PDCP), the Radio Link Control (RLC) protocol and the Medium Access Control (MAC) protocol, before being transferred to the transmission physical layer.

2.4.1.1. User Plane

The user plane protocol stack between e-Node B and UE is comprised of the sub-layers below.

- PDCP (Packet Data Convergence Protocol)
- Medium Access Control (MAC)
- RLC (radio Link Control)

On the user plane packets are encapsulated in a specific EPC protocol in the core network (EPC) and tunneled between the P-GW and the eNode B. Depending on the interface various tunneling protocols are used. On the S1 interface between eNodeB and S-GW, and on the S5 / S8 interface between S-GW and P-GW, GPRS Tunneling Protocol (GTP) is used.

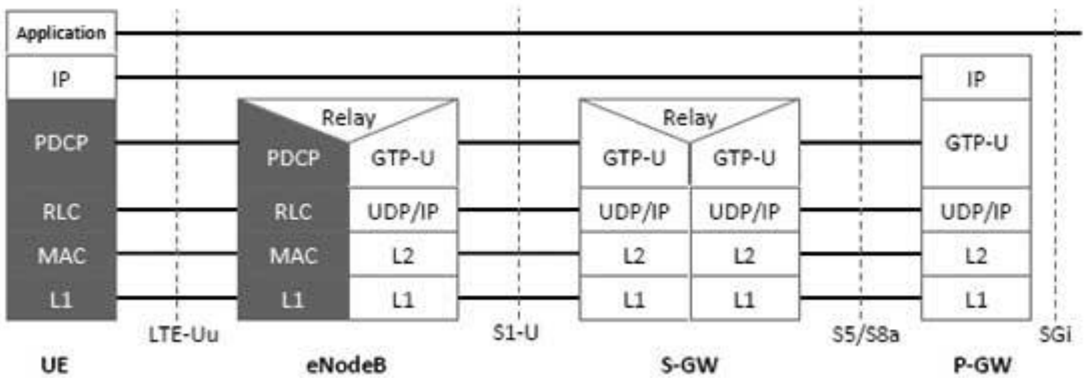


Fig 2.4: User plane architecture.[3]

Packets collected by a layer are called Service Data Unit (SDU), whereas a layer's packet output is referred to by Protocol Data Unit (PDU) and IP packets flowing from the top to the bottom layers at the user level.

2.4.1.2. Control Plane

Additionally, the control plane involves the Radio Resource Control Layer (RRC), which is useful for establishing the example of the lower layers as the MAC layer for the DRX mechanism.
The Control Plane manages radio-specific functionality depending on the state of the user equipment that also includes two states: idle or connected.

Mode	Description
Idle	After a cell selection or reselection process, the user equipment camps on a cell where factors such as nature of the radio connection, cell status and radio access technology are considered. The UE also tracks a paging channel to detect incoming calls and to obtain information about program. Control plane protocols include procedures for selecting cells and reselecting them in this mode.

Connected	The UE provides the E-UTRAN with downlink channel quality channel and nearby cell info so that the E-UTRAN can find the most appropriate cell for the EU. Throughout this case the Radio Link Control (RRC) protocol includes the control plane protocol.

The protocol stack between UE and MME for the check plane is shown below. The stack's grey region indicates protocols for the access stratum (AS). The lower layers serve the same purpose as the user plane except that the controll plane does not have a header compression feature.

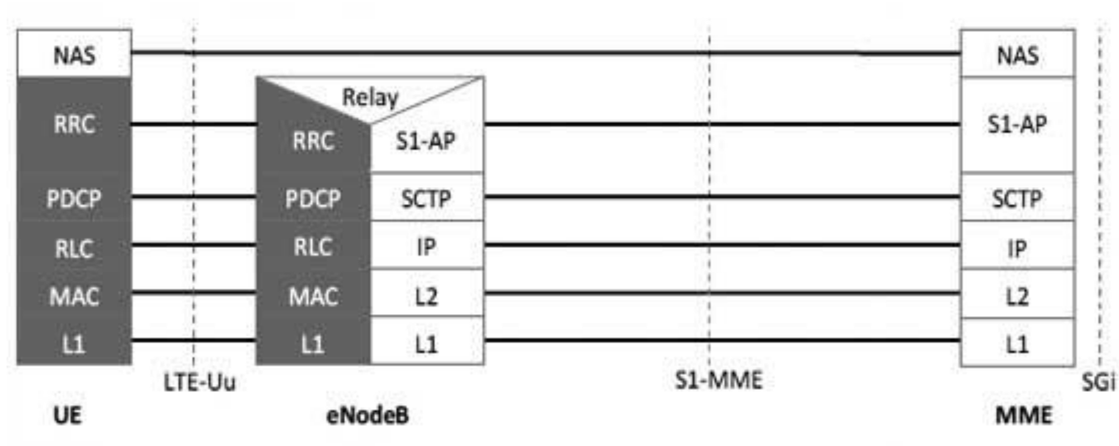


Fig 2.5: Control plane architecture.[3]

2.4.2. LTE Protocol Layer (Physical):

Let's take a closer look at all the layers in E-UTRAN Protocol Stack that we saw in the previous chapter. Below is a more detailed E-UTRAN Protocol Stack diagram(Fig2.6)

2.4.2.1. Physical Layer (Layer 1)

Physical Layer bears all information from the MAC transport channels over the communication channel, takes care of the RRC layer 's connection adaptation (AMC), power control, cell search (for initial synchronization and transfer purposes) and other measurements (both within and between the LTE systems).

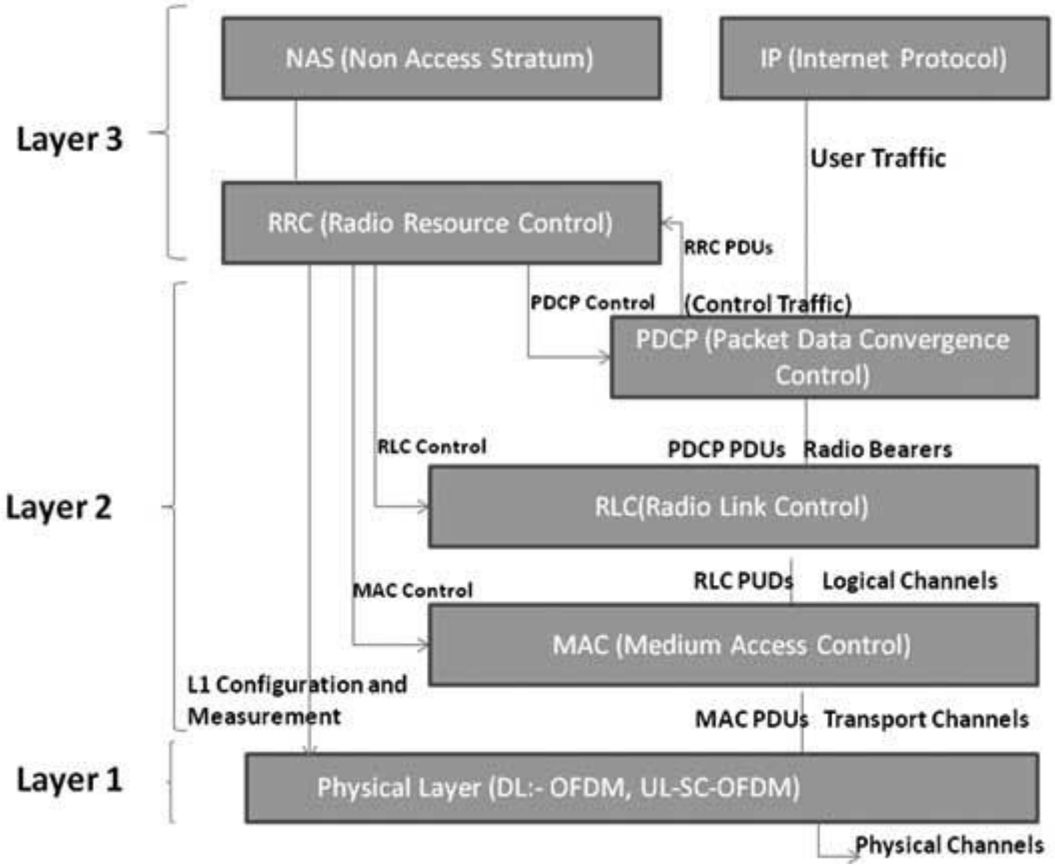


Fig 2.6: Layers of E-UTRAN Protocol Stack.[3]

2.4.2.2. Physical Layer (Layer 2)

2.4.2.2.1. Medium Access Layer (MAC)

MAC layer is accountable for modeling between logical channels and transport channels, multi-pathing of MAC SDUs from one or more physical layer on transport blocks (TBs) to be supplied to the physical layer on transport channels, multiplexing of MAC SDUs from one or more logical transport block channels (TBs) supplied from the physical layer on transport channels; Scheduling reporting of information, error detection by HARQ, list of priorities handling between UEs through dynamic scheduling, priority handling between one EU logical channels, prioritization of the logical channel.

2.4.2.2.2. Radio Link Control (RLC)

RLC operates in three operating modes: Transparent Mode (TM), Unrecognized Mode (UM), and Acknowledged Mode (AM).

RLC Layer is responsible for the transmission of upper layer PDUs, error correction through ARQ (AM data transfer only), concatenation, differentiation and installation of RLC SDUs (UM and AM data transmission only).

RLC is also responsible for re-segmenting RLC data PDUs, reordering RLC data PDUs (Only for UM and AM data transfer), duplicate detection (Only for UM and AM data transfer), RLC SDU discarding (Only for UM and AM data transfer), RLC re-establishment and protocol error detection (Only for AM data transfer).

2.4.2.3. Physical Layer (Layer 3)

2.4.2.3.1. Radio Resource Control (RRC)

The main services and functions of the RRC sub layer include broadcast of System Information related to the non-access stratum (NAS), broadcast of System Information related to the access stratum (AS), DRX, Paging, establishment, maintenance and release of an RRC connection between the UE and E-UTRAN, Security functions including key management, establishment, configuration, maintenance and release of point to point Radio Bearers.

2.4.2.3.2. Packet Data Convergence Control (PDCP)

PDCP layer is accountable for header compression and expansion of IP data , data exchange (user plane or control plane), maintenance of PDCP sequence numbers (SNs), in-sequence distribution of upper layer PDUs when re-establishing lower layers, duplicate removal of lower layer SDUs when re-establishing lower layers for radio bearers mapped on RLC AM, Ciphering and decoding user plane data and control plane data, credibility protection and control plane data verification, timer-based discarding, duplicate discarding, PDCP is used for SRBs and DRBs mapped on the logical channel type DCCH and DTCH.

2.4.2.3.3. Non Access Stratum (NAS) Protocols

The protocols of the non-access stratum (NAS) form the highest control plane stratum between the user equipment (UE) and MME.

NAS improve particular UE mobility and session control measures to establish and maintain EU-PDN GW IP connectivity. Below is a logical diagram of E-UTRAN Protocol layers with a representation of data flow across different layers:

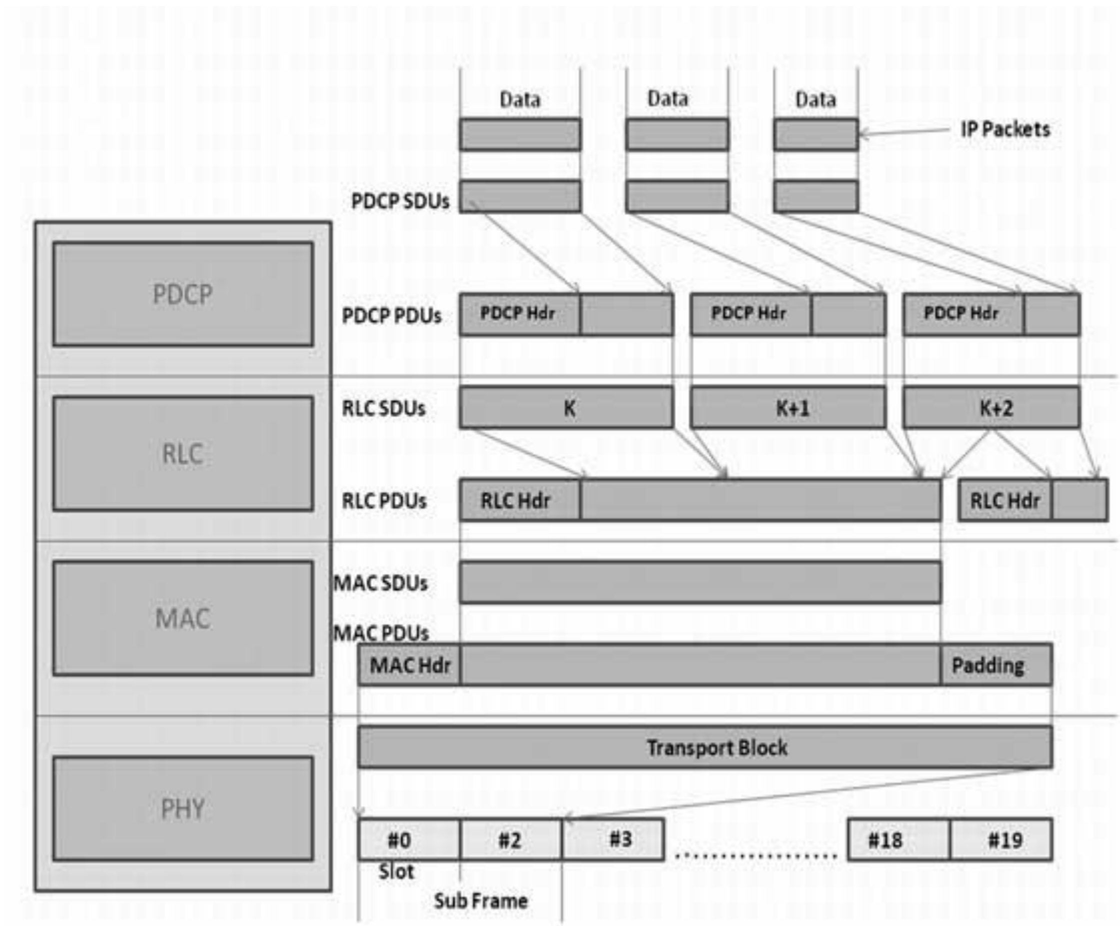


Fig 2.7: logical diagram of E-UTRAN Protocol layers [3]

Packets transmitted via a layer are called Service Data Unit (SDU) while a layer's packet output is related to Protocol Data Unit (PDU). Let's see the flow of data from top to bottom:

The IP Layer needs to submit to the PDCP layer PDCP SDUs (IP Packets). PDCP layer compresses headers and adds PDCP headers to those PDCP SDUs. PDCP Layer submits PDCP PDUs (RLC SDUs) to RLC layer.

2.4.2.3.4. PDCP Header Compression:

PDCP removes PDU's IP header (Minimum 20 bytes) and adds 1-4 bytes of Token, which provides tremendous savings in the quantity of header that would otherwise need to go over the air.

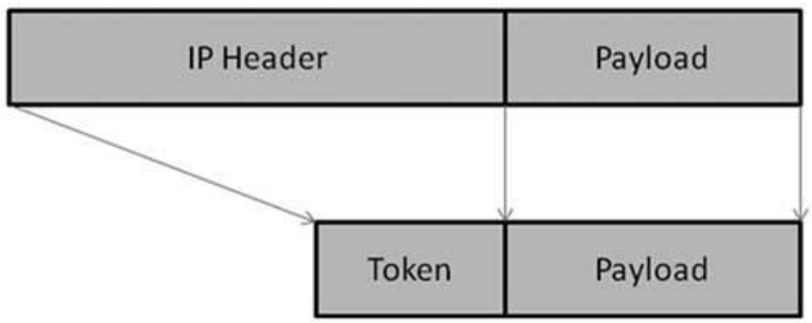


Fig 2.8: PDCP Header Compression [3]

RLC layer does these SDUS segmentation to create the RLC PDUs. RLC attaches header to service mode based on RLC. RLC needs to submit these MAC-layered RLC PDUs (MAC SDUs).

2.4.2.3.5. RLC Segmentation:

- The RLC SDU may be split between several RLC PDUs if an RLC SDU is large or the available radio data rate is low (resulting in small transport blocks). If the RLC SDU is small, or the radio data rate available is high, several RLC SDUs may be packed into a single PDU.
- In TTI, MC layer adds header and padds to fit this MAC SDU. MAC layer submits MAC PDU for transmission to physical layer.
- • This data is transmitted via physical channel into subframe spaces.

Chapter – 3

Methodology for the performance analysis of Different Resource schedulers, Transmission modes and Key performance Indicator

3.1 Introduction to Resource Scheduling

Scheduling technique is necessary to allocate the system resources such that high efficiency of the system is achieved across all the UEs. However the scheduler must always serve all UEs equally in doing so.

The spectrum in an LTE network is divided into fixed size chunks called Resource Blocks(RBs). One or more RBs can be activated to meet an application request subject to the resource availability and network policy. The following discussion is based, unless otherwise specified, on the assumption that the underlying system under consideration is LTE. The scheduling of the radio services in LTE is allocated in both the time and frequency domain. The LTE air interface elements are given in Fig. 3.3.The DL channels in the air interface are divided into frames of 10 ms each in the time domain. The Frame comprises 10 subframes each of 1ms. Each subframe consists of 2 Slots of 0.5ms. The total available network bandwidth in frequency domain is divided into sub-channels of 180 kHz with each sub-channel having 12 consecutive evenly spaced OFDM sub-carriers of 15 KHz each.

The Resource Block (RB) is a time-frequency radio resource that occupies over 0.5 ms slots in the time domain and over 180 KHz sub-channel in the frequency domain. Within the 1.4 MHz bandwidth, the LTE affects up to 20 MHz, with the number of RBs varying from 6 to 100 for bandwidths from 1.4 MHz to 20 MHz respectively.

In the following, the description of different scheduling algorithms is given, these are: Proportional Fair (PF), Round Robin (RR), Best CQI.

3.1.1 Proportional Fair (PF)

By selecting the user, the PF scheduling algorithm provides a good balance between system throughput and fairness. For this algorithm, the metric is given by:

$$j = max\frac{U_i(t)}{U_i} \qquad (3.1)$$

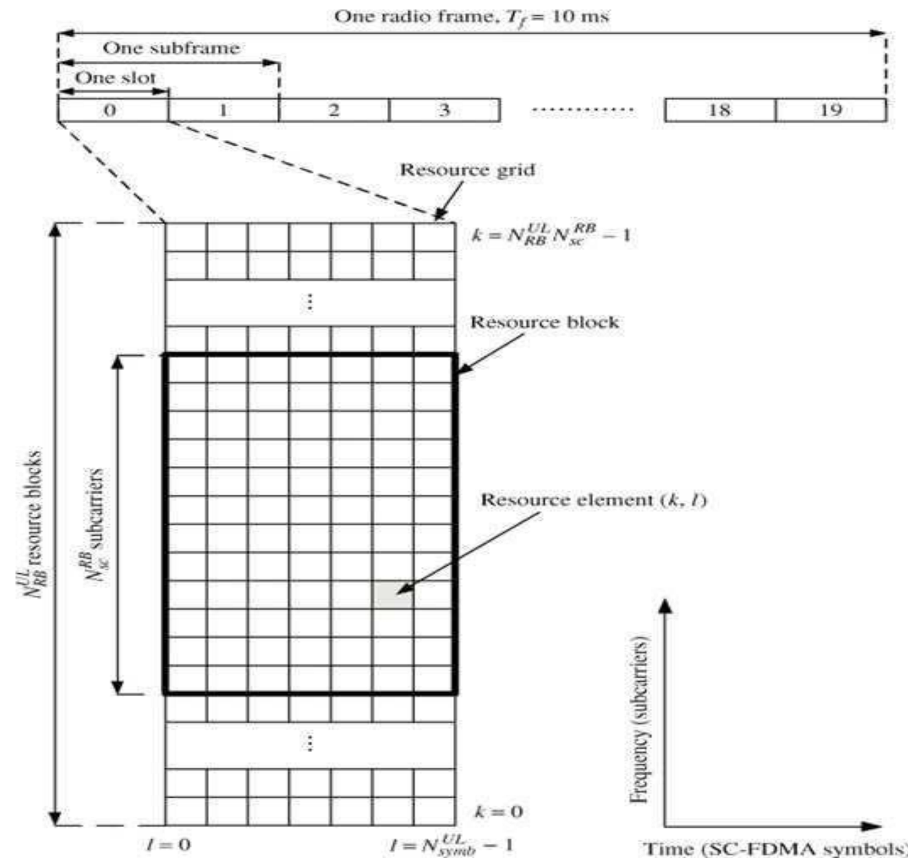


Fig. 3.1: The structure of the downlink resource grid.[3]

Where U_i is the rate of the mean fading level of user i and $U_i(t)$ is the state of the user's channel i at the time t. Proportional fair scheduler (PF) is used to assign resources between the UE that helps to achieve a high UE data rate and a good index of fairness. The system aims to achieve a maximum overall data size, depending on the EU requirement, and also offers a desired fairness index for all the EUs. Within the PF system, each UE is treated as the priority coefficient of the priority function:

$$P = \frac{T^{\alpha}}{R^{\beta}} \qquad (3.2)$$

Here the probable throughput is regarded as T and average data rate as R for a time period, where α and β are the parameter for modifying fairness. For PF scheduler, $\alpha \approx 1$, $\beta \approx 1$ should be taken.

In practice, proportional fair (PF) scheduling is used to stabilize the throughput and fairness. Among all users in a network It optimizes cell throughput and retains fairness [43].Proportional fair scheduler(PF) that meet the condition of karush – Kuhn – Tucker (KKT), is used for performance evaluation [31, 32, 46] for their simulation. This proposal stands on greedy utility Proportional fairness function [31, 42, 44].

3.1.2 Round Robin (RR)

Round robin scheduling algorithm is one of the simplest scheduling techniques which do not take the channel condition of a UE into account. It handles all UEs with equal priorities under a BS, and cyclically allocates system resources to all UEs. This results help to gain the best fairness among all the UEs at a cost of lower UE throughput. The fairness parameters of the RR scheduler are $\alpha = 0$ and $\beta = 1$.

Therefore, channel conditions does not taken into account for Round robin (RR), so it responses quick, fast, fair but offers a lower data rate. In comparison, PF takes full advantage of the channel's state, and prefers providing the UE with better quality of channel. This improves user's data rate at the cost of fairness. Round Robin is a aware, efficient scheduling method where one-by-one resource blocks are allocated until no user has data to transmit. The scheduler checks the list of all scheduled users before each transmission time interval (TTI) to figure out how many bits are left [30]. If queue is empty then round robin assigns no resource block to empty user of queue. Round robin scheduler implementation may exist in the time and frequency domain, in the frequency domain only one user has scheduled all the frequency for a particular period and other users are waiting in a queue. On the other hand, multiple users distribute the resource in a particular transmission time interval in the time domain [26, 47].

3.1.3 Best CQI

This scheduling algorithm is used as a method for allocating resource blocks to users with the best conditions for radio connections. The resource blocks allocated to the user by the Best CQI would have the highest CQI at that RB. Terminals send Channel Quality Indicator (CQI) to the base station (BS) to perform the scheduling. The BS transmits the reference signal (downlink pilot) to the terminals basically in the downlink. The UEs use these reference signals for measuring the CQI. A higher CQI value means improved condition of the channel.

Channel Quality Indicator measures downlink signal quality. It contains the information that is sent to base station from user equipment. User equipment transfers this information via a communication channel for physical uplink and physical uplink control channel. The channel quality indicator is a 4-bit integer value, determined on a specific modulation and coding scheme by signal to interference noise ratio [26,34]. There are 0 to 15 separate CQI's [$(2)^4 = 16$]. For estimating the CQI to select the Block error rate (BLER) and modulation scheme (QPSK, 16QAM, 64 QAM), adaptive modulation and coding (AMC) scheme used [28, 42, 48].

3.2 Transmission modes (TMs)

The word Transmission Mode describes the direction of the information flow between two communication devices, i.e. the direction of signal flow between the two devices is indicated. It is also called the mode of communication with the data. This shows the direction of information flow often also called directional mode for data transmission.

Many MIMO modes had been taken for the contrast of various transmission modes. Comparison between spatial multiplexing and transmit diversity had been done in order to find out which mode works best under mobility.

3.2.1 Classification of Transmission modes (TMs) in LTE

The transmission modes are categorized according to the number of antennas on the transmit and receive side: There are multiple transmission modes in LTE depending on the number of antennas involved,

1. **SISO** – **Single input, single output**: Where a single output corresponding to a single input would be in. Only one antenna is appropriate for this mode, both on the transmit and receive sides.
2. **SIMO** – **Single input, multiple output**: Here multiple outputs are extracted from single input, that is, multiple output antennas are used for a single data stream. This is where the gain is in the form of transmit diversity.
3. **MISO** – **Multiple input, single output**: Rarely used in LTE though a reliable wireless communication transmission mode.
4. **MIMO** – **Multiple input, multiple output**: Multiple input, single output: for multiple different inputs, multiple outputs are available. Here, we will get the gain in the form of multiplexing spatially.
5. **Beam forming** – A particular way of transmission, in which the various antenna side lobes are used to channel the signal in a specific direction.

3.3 Single Antenna mode

Here only a single PDSCH transport block is encoded and delivered on a single antenna and this is the most simple LTE-supported transmission mode. Any time a PDSCH is transmitted on a single antenna, the associated DCI is transmitted in either DCI 1, 1A, 1C or 1D format.

3.4 Spatial Multiplexing mode

Open-loop MIMO technique, commonly known as spatial multiplexing system in LTE and wireless network . By using both the antennas, different data stream will be sent. In Figure 3.2, The 2 x 2 spatial multiplexing systems is given:

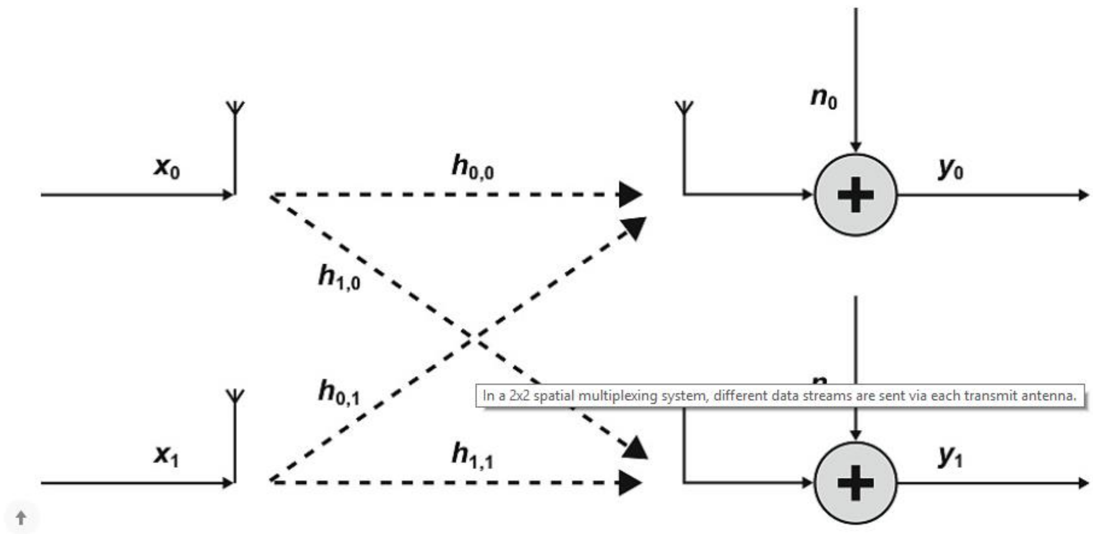


Fig 3.2: In a 2x2 spatial multiplexing system, different data streams are sent via each transmit antenna.

For a simple wireless network, it will have one transmit and receive antenna. This configuration is known as Single Input and Single Output (SISO). For a SISO program the Shannon capability C is described by the following equation:

$$C = Blog_2\left(1 + \frac{S}{N}\right) \quad (3.3)$$

where, B is defined as the channel bandwidth and S/N is the signal-to noise ratio.

The information to be delivered is divided into several different data sources in a spatial multiplexing operation. The number of M transmitted data streams at any given time is generally equal to or less than the minimum number of antennas. For example, a 4x2 system may convey two or less streams of data. The channel capacity C in a spatial multiplexing scheme rises linearly with the number of data streams M, and is described by the following equation:

$$C = \mathrm{MBlog}_2\left(1 + \frac{S}{N}\right) \quad (3.4)$$

3.4.1 Open Loop Spatial Multiplexing (OLSM):

MIMO's open loop configuration does not have feedback, as shown in Fig 3.3(a). Through open loop operation the BS earns a rank indicator (RI) and a channel consistency indicator (CQI) from the UE. The CQI reflects the conditions for the channel and is used by the BS to choose an acceptable modulation and coding scheme (MCS) to forward data to the UE. The Rank indicator indicates the amount of layers that can be supported under the current channel and MCS conditions. Using the UEs, the BS then transmits data on the CQI and RI reported. Closed loop spatial multiplexing (CLSM) provides a feedback information path which for OLSM feedback is not there, as shown in Fig. 3.3.b. In a CLSM configuration, UE analyzes and records a CQI, RI and a pre-coding matrix indicator (PMI) to the BS. PMI helps the BS to respond quickly to change channel state. It gives in the CLSM a higher data rate than OLSM.

In OLSM, Cyclic delay diversity (CDD) is also applied among the transmitted data [49]. The modified copies of the signal are transferred by the CDD in the time direction and are distributed over different transmit antennas. To stop inter-symbol interference (ISI), the time-shift is applied in a cyclic fashion. For two antenna system the transmission vector at a time instant k, of a symbol vector x_k of length v symbols is given by:

$$y_k = W D_k U x_k \tag{3.5}$$

Where, *W*, D_k and *U* are defined as [11]:

$$W = \frac{1}{\sqrt{2}}\begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}, D_k = \begin{bmatrix} 1 & 0 \\ 0 & e^{-i2\pi k/2} \end{bmatrix}, U = \frac{1}{\sqrt{2}}\begin{bmatrix} 1 & 1 \\ 1 & e^{-i2\pi/2} \end{bmatrix} \tag{3.6}$$

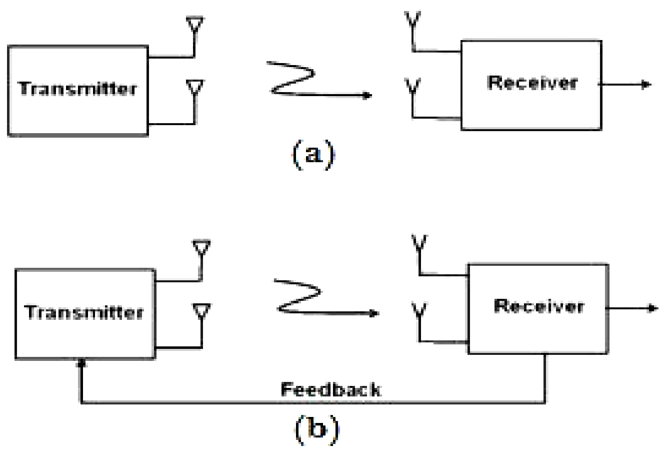


Figure.3.3: (a) OLSM configuration; (b)CLSM configuration

x_k includes two independent data stream inputs to the antenna, D_k is the delay matrix which cyclically shifts the delay based on the time index *k*, *U* adjusts the signal copy so that the same data stream does not interfere with each other when transmitted and W executes the multiplexing process.

3.4.2 Close Loop Spatial Multiplexing (CLSM):

Through CLSM, the UE information is split into several data streams and transmitted independently through multiplexing over spatially separated antennas to increase the ability of the channel. At any given time , the maximum number of data streams R in a M transmitter and N receiver network (MxN) that can be transmitted:

$$R \leq \min(M,N) \qquad (3.7)$$

CLSM is a transmission system dependent upon feedback. Under the CLSM configuration consumer analyzes and reports back to the channel quality indicator (CQI), rank indicator (RI) and a pre-coding matrix indicator (PMI) in conjunction with the number of required layers to the BS. Channel condition is reflected by the CQI and is used to choose a suitable modulation by the BS and coding scheme (MCS) for transmission of data to the user.

The RI refers to the number of layers that can be allowed under the current channel and MCS form, while the PMI lets the BS adjust quickly to changing channel state which is experienced by the user. The pre-coder index, selected from a predefined codebook, is forwarded to the BS as feedback. For the two transmit antennas scenario, the LTE codebook comprises of four pre-coders (v = 1) and two pre-coders (v = 2) in CLSM are tabulated in table-3.1.

Layers (v)	Precoder codebook
1	$\frac{1}{\sqrt{2}}\begin{bmatrix}1\\1\end{bmatrix}$, $\frac{1}{\sqrt{2}}\begin{bmatrix}1\\-1\end{bmatrix}$, $\frac{1}{\sqrt{2}}\begin{bmatrix}1\\i\end{bmatrix}$, $\frac{1}{\sqrt{2}}\begin{bmatrix}1\\-i\end{bmatrix}$
2	$\frac{1}{2}\begin{bmatrix}1 & 1\\1 & -1\end{bmatrix}$, $\frac{1}{2}\begin{bmatrix}1 & 1\\i & -i\end{bmatrix}$

Table 3.1–Lte Codebook for ClSM Mode and Two Transmit Antennas

3.5 Transmit Diversity (TxD)

A single transmit block on PDSCH is encoded in this transmission mode and transmitted on two separate antennas. Pre-coding is performed to distinguish between the two different antennas. Here again the DCI formats used either of 1, 1A, 1C. So if the number of transmit antenna on eNodeB is greater than 1 and the UE finds a DCI in any of the above formats, then UE will try to decode PDSCH using Transmit diversity.

Downlink Transmission modes in LTE Release 12			
Transmission modes	**Description**	**DCI**(Main)	**Comment**
1	Single transmit antenna	1/1A	single antenna port port 0
2	Transmit diversity	1/1A	2 or 4 antennasports 0,1 (…3)
3	Open loop spatial multiplexing with	2A	2 or 4 antennasports 0,1 (…3)

	cyclic delay diversity (CDD)		
4	Closed loop spatial multiplexing	2	2 or 4 antennasports 0,1 (…3)
5	Multi-user MIMO	1D	2 or 4 antennasports 0,1 (…3)
6	Closed loop spatial multiplexing using a single transmission layer	1B	layer (rank1),or 4antennasports 0,1 (…3)
7	Beamforming	1	single antenna port, port 5 (virtual antenna port, actual antenna configuration depends on implementation)
8	Dual-layer beamforming	2B	dual-layer transmission, antenna ports 7 and 8
9	8 layer transmission	2C	Up to 8 layers, antenna ports 7 – 14
10	8 layer transmission	2D	Up to 8 layers, antenna ports 7 – 14

Table 3.2: Overview of the ten downlink transmission modes in LTE Release 12.[4]

3.6 Coordinated multipoint(ComP)

Now-a-days, to improve cell edge user data rate and spectral efficiency, Coordinated multipoint or cooperative MIMO is used as one of the promising concept. Multiple-Input Multiple-Output (MIMO)-Orthogonal Frequency-Division Multiplexing (OFDM) is used by mobile WiMAX and Long Term Evolution (LTE) to achieve enhanced spectral efficiency within a single cell. Coordination of base stations to prevent interference and constructive exploitation of interference is achieved in this system by effective co-operation of base stations. Conceptually, we expand single-cell MIMO strategies to multiple cells, such as multi-user (MU-MIMO). The collaboration strategies are aimed at preventing or minimizing interference to increase the cell edge and average data levels. CoMP is valid in both uplink and downlink. Coherent transmission with synchronized base stations will greatly increase both cell average and cell edge data rate through the use of CoMP. Analysis can be done using system-level simulations in COMP with hexagonal cells and evaluation methodologies customary in the 3GPP, Next Generation Mobile Networks (NGMN), and International Telecommunication Union (ITU).

3.6.1 CoMP Architecture

Coordination between eNBs is a very useful approach in downlink and uplink networks for reducing inter-cell conflict. CoMP is implemented in downlink by performing a coordinated transmission from the base station, whereas a coordinated eNB reception will reduce uplink interference. Most CoMP techniques share the need to exchange some scheduling details about users at the various base stations between them. This means that very-low-latency links are required so that data between coordinated nodes can be shared in the order of milliseconds. CoMP architectures deal with the simple way CoMP set BSs are designed to handle interference leading to increased throughput. Typically there are two different types of CoMP architectures.

Centralized Coordinated scheduling architecture

- Distributed Coordinated scheduling architecture
  - Semi distributed architecture
  - Fully distributed architecture

3.7 Key Performance Indicator (KPI)

This simulation results are based on Average UE throughput, Avg.edge throughput, fairness index, spectral efficiency and cell throughput of different scheduling scheme on different transmission modes. Considering these KPI, comparison between different network layout has also be done.

3.7.1 Average UE throughput:

Mobile UE travels with respect to its corresponding BS. According to its location inside the cell, the UE can experience different channel qualities. Therefore, analysis should be done for an overall UE performance which is defined as average UE throughput (T_{avg}). The data rate of user k at the time t is:

$$T_k(t) = \sum_{n=1}^{N} \rho_{k,n}(t) r_{k,n}(t) \qquad (3.8)$$

Where, $\rho_{k,n}(t)$ = 1 when the subcarrier n is assigned to the user k, otherwise $\rho_{k,n}(t)$ = 0. $r_{k,n}(t)$, is the data rate of user k on subcarrier n. Now the average throughput of n UEs is given by:

$$T_{avg} = \frac{1}{t_s} \sum_{t=1}^{t_s} \left(\frac{1}{n} \sum_{k=1}^{n} T_k(t) \right) \qquad (3.9)$$

Here, T_k is represented as the total throughput for k^{th} user, n is the total number of users and t_s is the duration of the TTI simulation.

3.7.2 Cell edge throughput:

The Inter-Cell Interference (ICI) is maximal at the edges of a cell. The signal-to - noise ratio at the edges of a cell is lowest, as it is located too far from BS with additional inter-cell interference from neighboring cells. Overall, therefore, the data rate is the least in this area Therefore, a minimum cell edge throughput is needed to prevent call drops during cell handover. The result at the edges of a cell is known as the fifth percentile point of the Cumulative Distribution Function (CDF) of the UE throughput.

3.7.3 Spectral efficiency:

Spectral efficiency is defined by the amount of data that can be successfully transmitted over a given bandwidth:

$$S = \frac{\sum_{k=1}^{n} T_k}{BW} \quad (3.10)$$

Here, T_k is represented as throughput for k^{th} user and BW is the system bandwidth.

3.7.4 Fairness index:

The Fairness Index is being used to determine how the network resources blocks are allocated among the UEs. For a given channel conditions, the available system resources have to be allocated in a way that benefits all the UEs. The quantitative measure of the fairness index of n UEs can be defined as:

$$J(T) = \frac{\left[\sum_{k=1}^{n} T_k\right]^2}{n\left[\sum_{k=1}^{n} {T_k}^2\right]} \quad (3.11)$$

Where, T_k is denoted as throughput for k^{th}user and n is the number of users. With this equation it can be measured that how fair the distribution of the channel is.

3.7.5 Fairness Index properties:

Scale independent: Standard deviation (Throughput) = 10 Mbps = 10^4 kbps

Bounded: Variance between 0 and 1 or 0 and 100 per cent, standard deviation and relative distance are not limited.

Direct relationship: Higher index → More Fair ; Higher variance → Less fair

Continuous

- Min./max is not continuous
- The index will be continuous. Every minor allocation adjustment will appear in the Index of Fairness. In the example above, if the uniform throughput is 1, 4 , and 5 accordingly, the fairness would obviously be different, but it is not expressed in the min-max ratio that remains 1/5.

3.7.6 Area throughput:

Average UE throughput reflects on the UE performances only. A new parameter, area throughput (T_{area}), is introduced to gain an insight on the performance of different radio planning strategies under various user densities. Area throughput is calculated as:

$$T_{area} = \frac{\sum_{k=1}^{n} T_k}{Geometrical\ area} \qquad (3.12)$$

Chapter 4

Network models and Simulation results

4.1 Introduction to Heterogeneous Network

A heterogeneous network is a network connecting computers and other devices with different operating systems and/or protocols. Heterogeneous networks (HetNets) are a powerful solution to handle the rapidly increasing demand for mobile broadband bandwidth and are a key concept of Alcatel-Lucent's light RadioTM strategy. HetNets consist of small cells embedded in a microcellular network and enable flexible and scalable capacity enhancements.

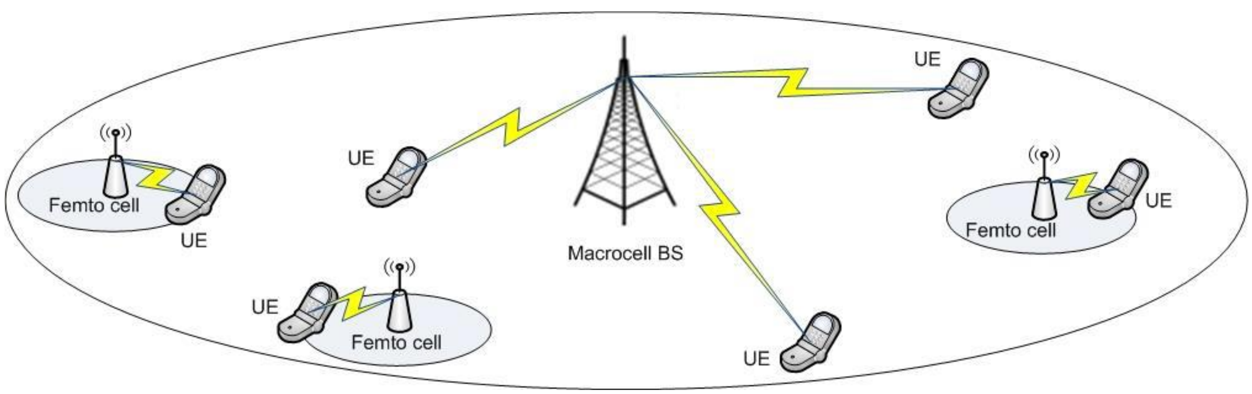


Fig 4.1: A two-tier HetNet architecture.

4.2 Network model used for Proportional Fair (PF) and Round Robin (RR) Comparison

In our simulation, to compare the performance of different types of Resource schedulers and transmission modes, Heterogeneous Network (HetNet) layout was considered. For forming the heterogeneous network, macro cells with femto cells were deployed where the macro cells consisting of 19 BSs are placed hexagonally and having the inter BS distance of 500 m. Femtocells with single antenna are placed in coverage depleted area and 20 femto cells are placed surrounding the UEs. Figure 4.1 illustrates three-sector antenna BSs as well as UEs. A LTE system level simulator [50] was used to evaluate the performance of a HetNet for a 2x2 MIMO system. Transmission diversity mode (TxD) was selected because it performs better in various fading conditions. Mutual information based effective SINR mapping (MIESM) technique was adopted to predict the channel quality indicator (CQI) of the UEs. An urban environment was considered and the macroscopic propagation model used for both macrocell BS and femto cell is given by the following equation:

$$L = 40(1 - 4 * 10^{-3} h_{BS}) log_{10}(R) - 18 log_{10}(h_{BS}) + 21 log_{10}(f) + 80\ db \qquad (4.1)$$

Where R is the BS-UE separation in kilometers, f is the carrier frequency in MHz and h_{BS} is the height of BS in meters. For UE mobility we have considered the random walk model. Additional simulation parameters are presented in Table-4.1.

To compare the performance of PF and RR scheduling schemes under user mobility, simulation was realized for 570 UEs placed randomly within the HetNet and for a UE velocity range of 0-125kmph. Then to analyze the effect of UE density on the scheduler performance number of UEs was varied from 10-100 per cell and to observe a cumulative effect of UE velocity and UE density three velocity were considered namely 3kmph for pedestrians, 60kmph for medium UE velocities and 120kmph for high UE velocities. For greater than 120km/hr, the behavior of the Transmission modes and Resource Schedulers remain same. Finally a simulation was carried out for both schedulers under all the system bandwidths (1.4MHz, 3MHz, 5MHz, 10MHz, 15MHz and 20MHz)supported by LTE for three velocity cases mentioned above to determine how effectively the schedulers utilizes the available spectrum to transmit data under user mobility.

Simulation parameters	
Channel model	winner+
Pathloss Model	Urban Macroscopic Model
Macroscopic Path loss Model	TS36942
Frequency	900MHz
Bandwidth	1.4,3,5 ,10,15,20 MHz
No. of transmitter	2
No. of receiver	2
Transmission mode	Transmit diversity (TxD)
Antenna Model	Kathrein 742215
Scheduling Technique	Proportional Fair, Round Robin
BS height	20m
BS power	45dB
Receiver height	1.5m
Adaptive RI	2
Antenna azimuth offset	30º
Antenna Gain	15dBi
BS Transmitter power	45dBm
Femto cell transmission power	20 dbm
Noise Power Density	-174 db
User Density	10-100
Simulation time	50 TTI
Inter BS distance	500 m

TABLE 4.1 –SIMULATION PARAMETERS FOR PF AND RR COMPARISON IN HETEROGENEOUS NETWORK

4.2.1Antenna Gain

The Kathrein 742215 gain pattern resembles the tri-sector antennas, with horizontal (Gh) and vertical (G_v) gains from:

$$G_h(\varphi) = -\min\left(12\left(\varphi / HPBW_h\right)^2, FBR_h\right) + G_m \quad (4.2)$$

$$G(\theta) = \max\left(-12\left((\theta - \theta_{etilt}) / HPBW_v\right)^2, SLL_v\right) \quad (4.3)$$

where θ is the elevation angle from$-90^0 \leq \theta \leq 90^0$, θ_{etilt} is the electrical tilt angleand $180^o \leq \varphi \leq 180^o$.

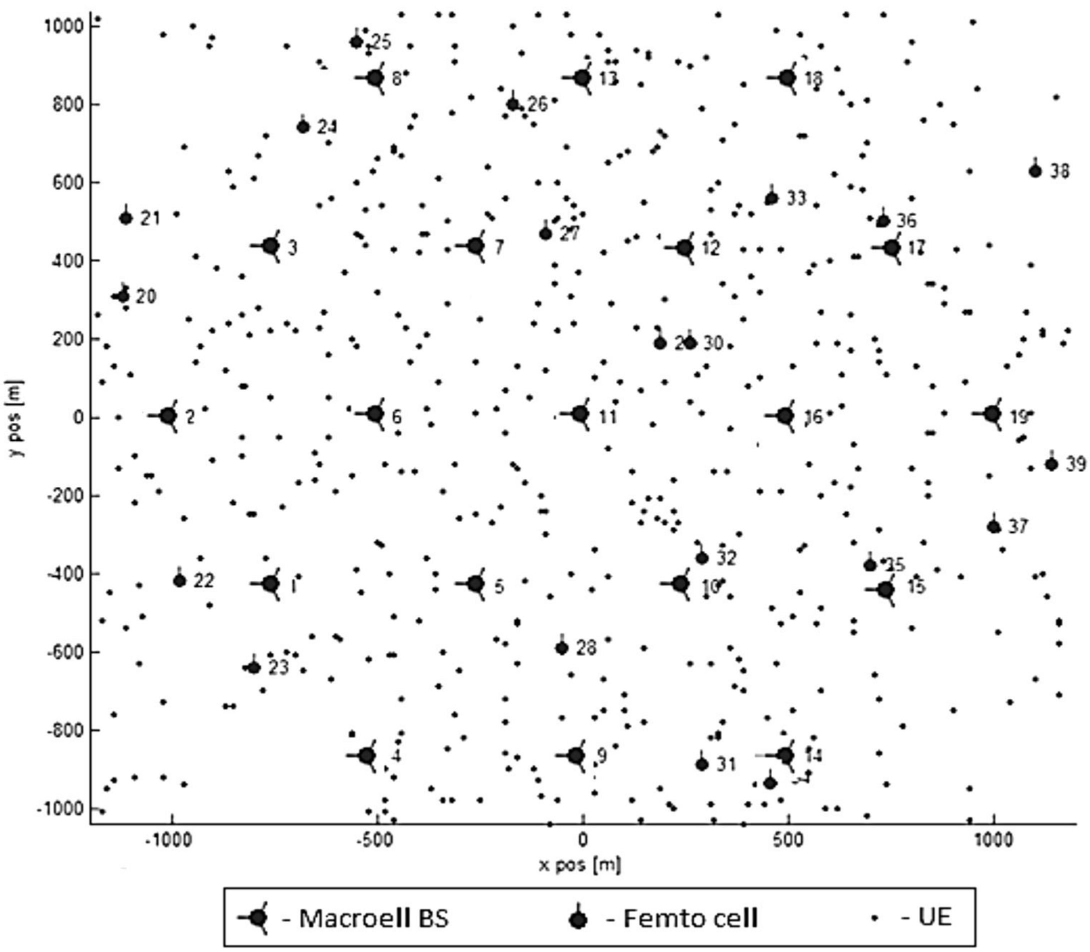


Fig4.2 : Heterogeneous network (HetNet) deployment.

Half power beam width (horizontal), half power beam width (vertical) and the front back ratio are denoted as $-HPBW_h$,$HPBW_v$, FBR_h, respectively. SLL_v, is denoted as side lobe level (vertical) and G_m is the maximum gain. The mathematical models and the other parameters are taken from [51].

4.2.3 Results for Proportional Fair and Round Robin Comparison under mobility

The average UE throughput decreases with an increase in UE velocity under both scheduler techniques, as depicted in Fig 4.3. For low velocity PF performs better but as the velocity increases RR dominates PF and approaches a minimum UE throughput whereas the latter experiences constant performance degradation. As RR does not consider the channel conditions of the UEs therefore for rapid changes in UE link quality at high velocities it outperforms PF.

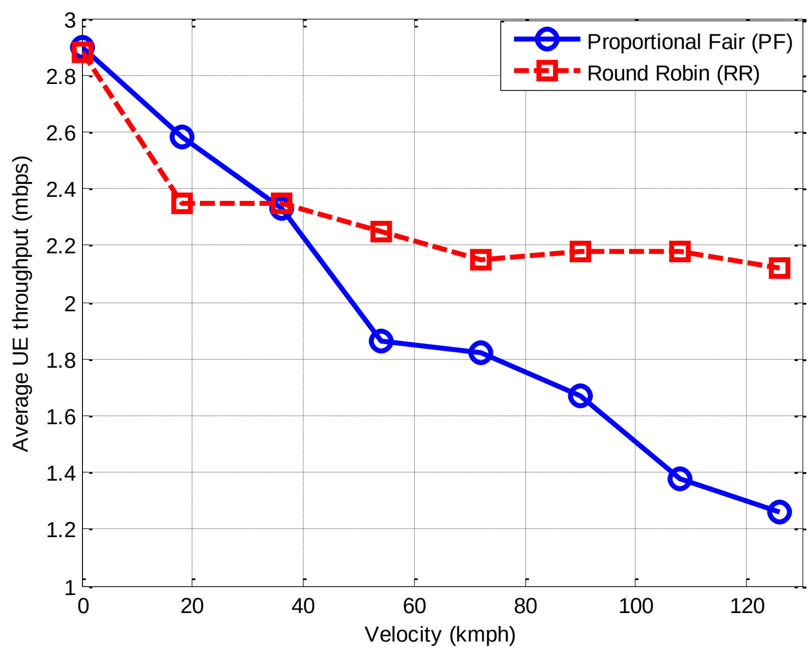


Fig 4.3:Average UE throughput vs. UE velocity under PF and RR scheduler algorithm.

The performance of both the schedulers in terms of cell edge throughput, as shown in Fig. 4.4 also undergoes a declining trend with increase in UE velocity. In contrast to UE throughput, at low UE velocities or at stationary RR provides better data rate than PF at cell edges. This is because PF takes UE channel conditions into account and therefore as cell edge UEs are located distant away from the BS their CQI feedback will be low due to high pathloss. A low CQI means PF allocates least resources to UEs at cell edges. As the UE velocity increases cell edge throughput under PF technique falls rapidly and reaches zero. On the other hand RR faces a slow decline but still is able to support a low data rate at high velocities.

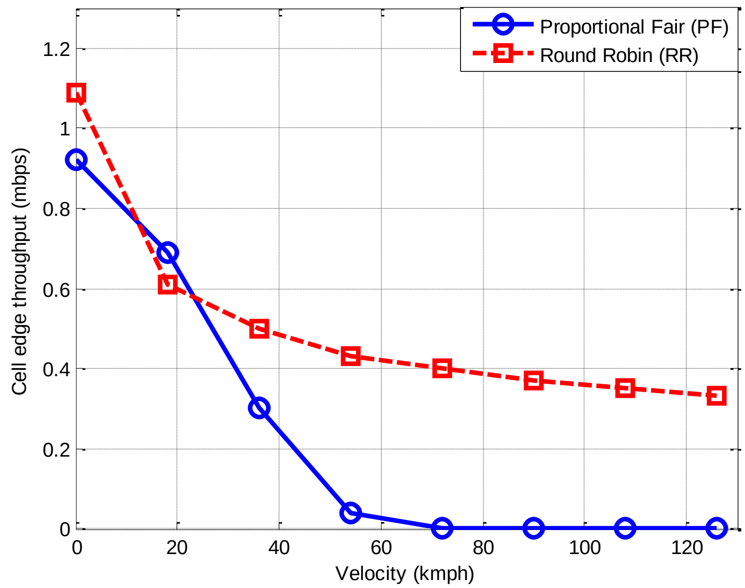


Fig 4.4: Average cell edge throughput vs. UE velocity under PF and RR scheduler algorithm.

Fig 4.5 illustrates that as the velocity of the UE increases then for a given system bandwidth the spectrum is less efficiently utilized.

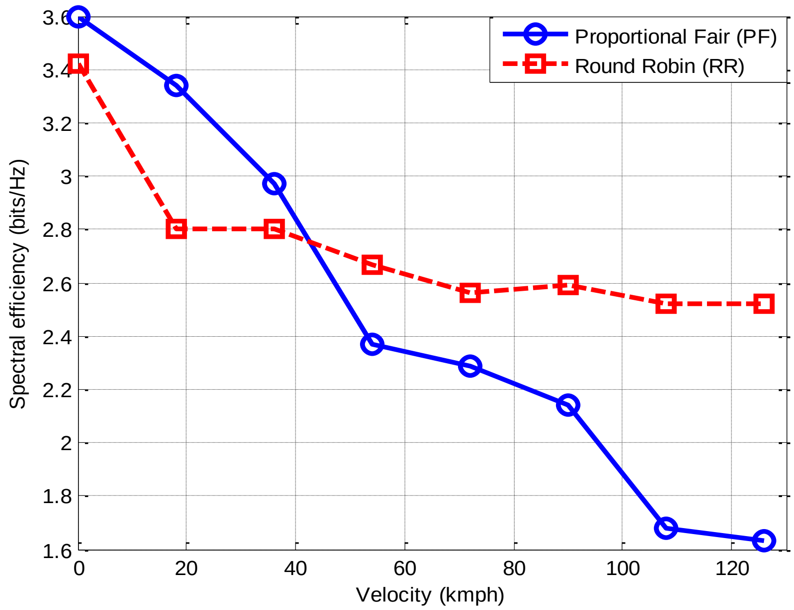


Fig 4.5: Spectral efficiency vs. UE velocity under PF and RR scheduler algorithm.

As mentioned above that for low UE velocity PF delivers higher average UE throughput thereby achieving a better spectral efficiency than RR. But at high velocities RR provides better throughput therefore achieves a higher spectral efficiency.

The results depicted in Fig 4.6 shows that although fairness deteriorates as the velocity of the UE increases the cyclic nature of UE serve in RR always delivers a higher fairness than PF.

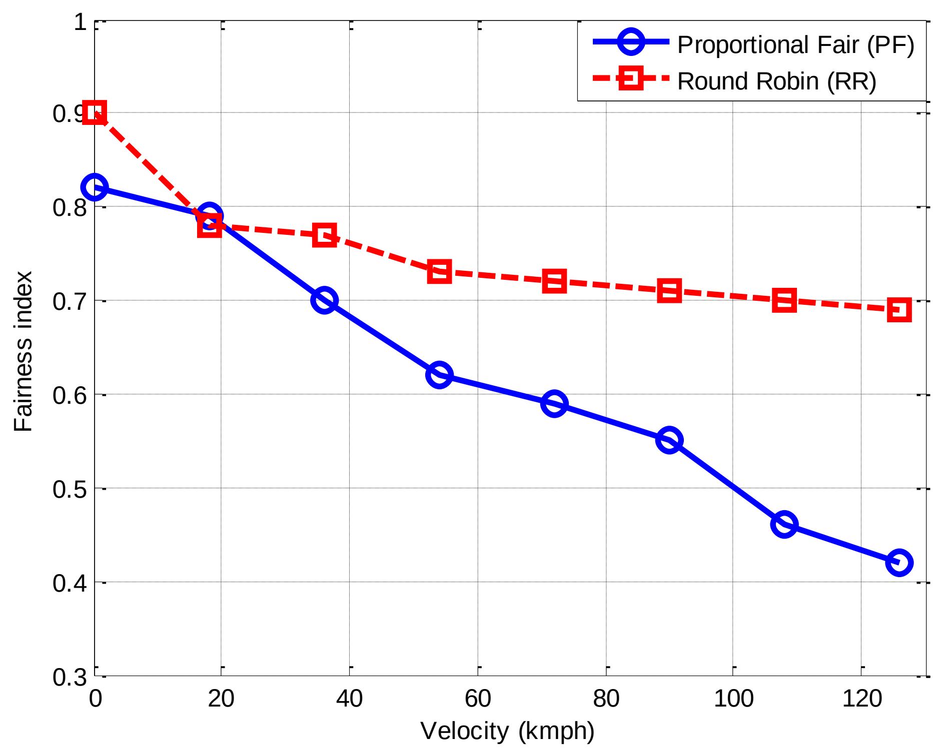


Fig 4.6: Fairness index vs. UE velocity under PF and RR scheduler algorithm.

Fig 4.7: illustrates that with increase in UE density the average UE throughput provided by either PF or RR decreases rapidly and becomes constant at high velocities. The results also show that for high UE densities velocity has a minor impact on the performance of either scheduler in delivering resources to the UEs.

The average cell edge throughput decreases with increase in UE densities as shown in Fig 4.8: but the effect is more significant on PF for low UE velocity. For medium and high velocity cases PF fails to deliver any data rate to cell edge UEs. On the other hand RR provides similar cell edge performances for high UE densities.

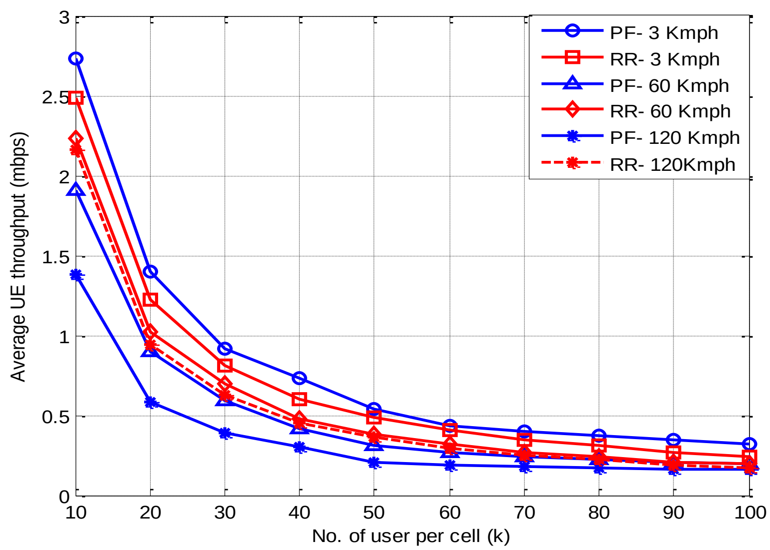


Fig 4.7: Average UE throughput vs. UE density under PF and RR scheduler algorithm for low, medium and high velocity UE cases.

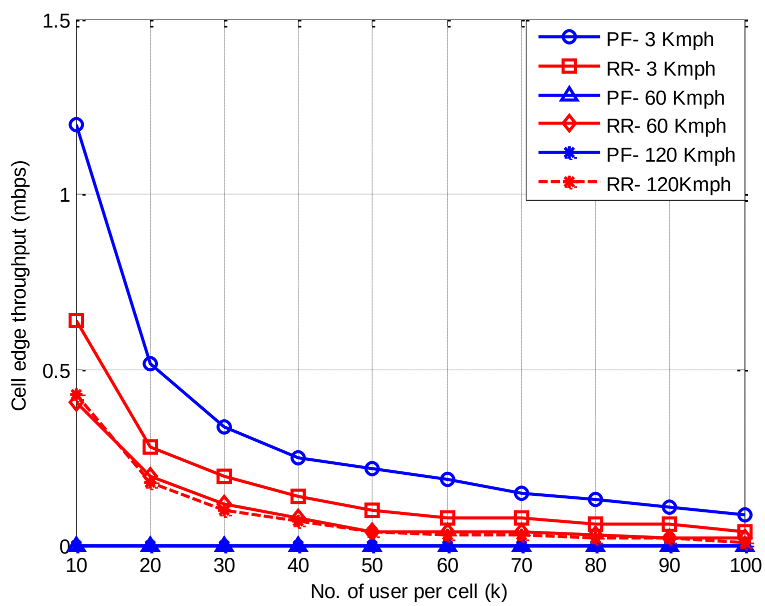


Fig 4.8: Average cell edge throughput vs. UE density under PF and RR scheduler algorithm for low, medium and high velocity UE cases

Fig 4.9: Spectral efficiency vs. UE density under PF and RR scheduler algorithm for low, medium and high velocity UE cases. UE density does not have a significant effect on the performance ofPF or RR in terms on spectral efficiencies, shown in Fig 4.9 and fairness indexes, depicted in Fig 4.10. The impact of UE density on these metrics is not as severe as UE velocity.

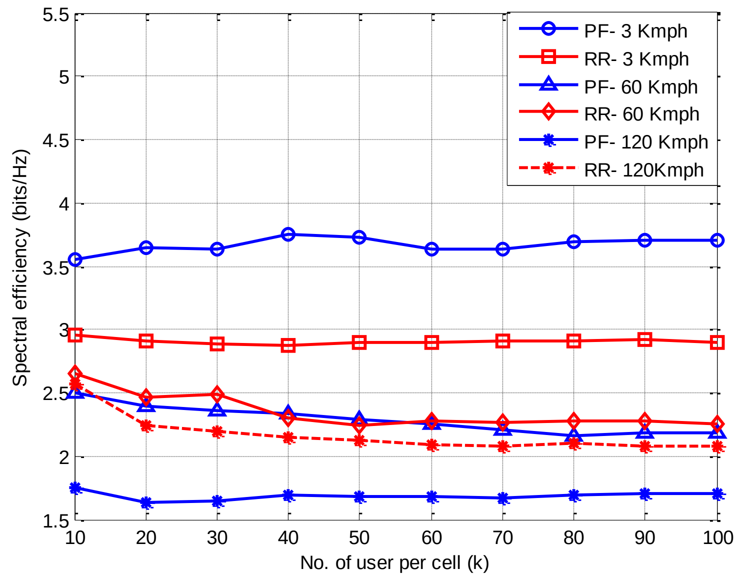


Fig 4.9: Spectral efficiency vs. UE density under PF and RR scheduler algorithm Spectral efficiency vs. UE density under PF and RR scheduler algorithm.

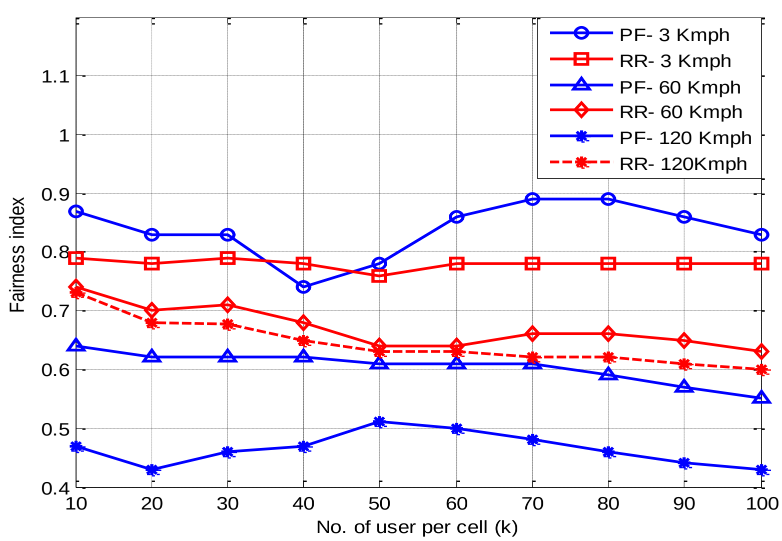
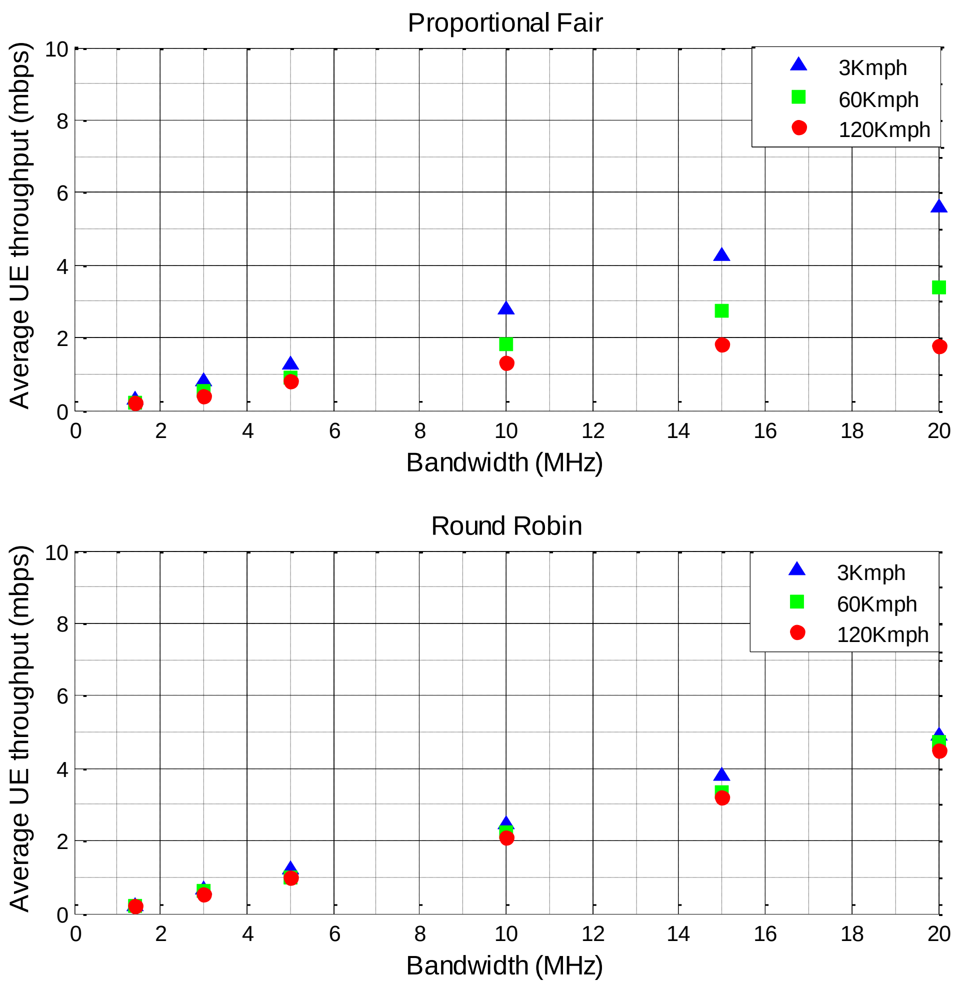


Fig 4.10: Fairness Index vs. UE density under PF and RR scheduler algorithm for low, medium and high velocity UE cases.

Fig 4.11: illustrates a better understanding on the utilization of the system bandwidth by the schedulers under different UE velocities. It is observed that for RR the ratio of the average UE throughputs with various system bandwidths is almost constant indicating that similar spectral efficiencies are obtained by RR at different system bandwidths which is not much affected by UE velocity. On the other hand the spectral efficiencies for various system bandwidths decrease with increase in UE velocity under PF algorithm.



4.11: Average UE throughput vs. system bandwidth under PF and RR scheduler algorithm for low, medium and high velocity UE cases.

4.2.4 Analysis of the results for resource scheduler comparison:

From the above performance analysis it can be said that, for choosing resource scheduler among proportional fair (PF) and round robin (RR), RR will be used for high velocity users as it provides equal RBs to all the user and cell edge throughput is higher for RR than proportional fair. And proportional fair performs well for low velocity users [54].

4.3 Network model used for spatial multiplexing (OLSM and CLSM) Transmission modes (TMs) Comparison under mobility

Simulation carried out by LTE system level simulator [50] which gives a real time experience under mobility. For a detailed comparison between the performances of spatial multiplexing techniques, simulations are carried out in two phases. Random walk model and PF requires longer simulation time to reach a stable state therefore all the simulations are carried out for 50 TTIs. The effect of UE velocity is observed in the first step, for a speed range of 0-110 kmph. Simulation was done with 10 UEs per sector, with a total of 570 UEs positioned randomly within the network geometry. The second step takes into account the impact of density in the UE. In this case the number of UEs per sector ranges from five UEs to thirty UEs and the performance of spatial multiplexing techniques for each UE density is observed for low speed / pedestrian (3 kmph), medium speed (60 kmph) and high speed (120 kmph) of the UEs. Random walk method was considered to model the mobility of the UEs. All simulations are conducted for scheduling algorithms of PF and RR. Because of its better accuracy over other mapping techniques, the mutual knowledge based successful SINR mapping (MIESM) scheme is used for link prediction of UEs [52-53].

Simulation parameters	
Channel model	winner+
Pathloss Model	Urban Macroscopic Model
Macroscopic Path loss Model	TS36942
Frequency	900MHz
Bandwidth	10MHz
No. of transmitter	2
No. of receiver	2
Transmission modes	OLSM(2*2) and CLSM(2*2)
Antenna Model	Kathrein 742215
Scheduling Technique	PF,RR
BS height	20m
BS power	45dB
Receiver height	1.5m
Adaptive RI	2
Antenna azimuth offset	30º
Antenna Gain	15dBi
BS Transmitter power	45dBm
Femto cell transmission power	20 dbm
Noise Power Density	-174 db
User Density	10-100
User Velocity	0-120 km/h

Simulation time	50 TTI
Inter BS distance	500 m

TABLE 4.2 – SIMULATION PARAMETERS FOR THE COMPARISON OF OLSM & CLSM IN HETEROGENEOUS NETWORK

4.3.1 Results for for spatial multiplexing (OLSM and CLSM) Transmission modes (TMs) Comparison under mobility

Average UE throughput for both CLSM and OLSM decreases with an increase in UE velocity, as shown in Fig. 4.12. CLSM achieves better throughput than OLSM at all velocities. In contrast, at low UE velocity PF under either MIMO mode performs better but with the increase in UE velocity, RR dominates.

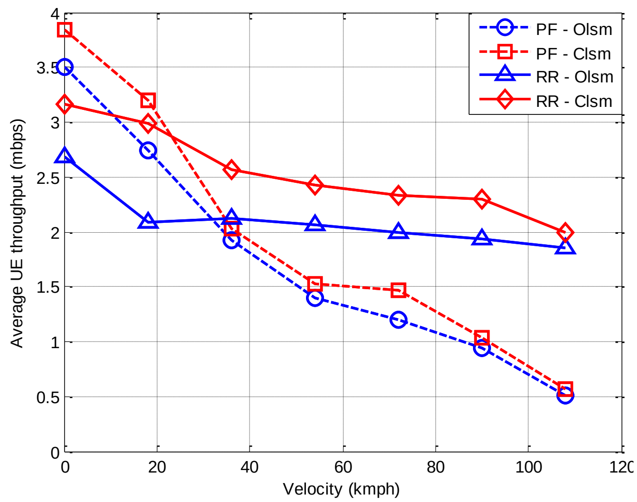


Fig.4.12: Average UE throughput vs. UE velocity for OLSM and CLSM under PF and RR scheduling algorithm

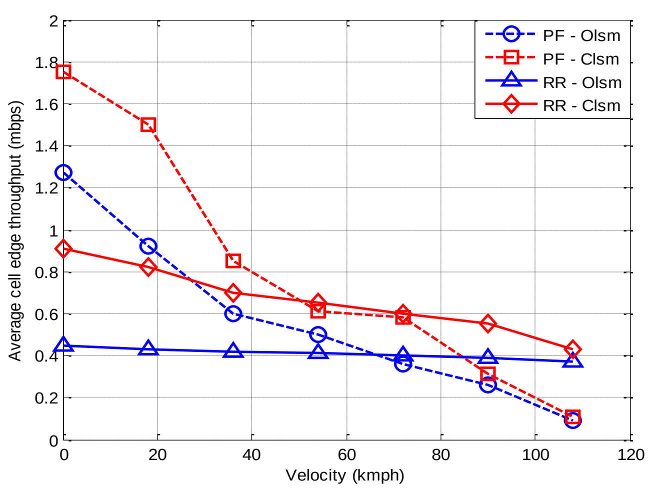


Fig. 4.13: Cell edge throughput vs. UE velocity for OLSM and CLSM under PF and RR scheduling algorithm.

It can also be noted that the performance of the CLSM and OLSM becomes similar as the velocity of the UE increases. CLSM provides better cell edge throughput than OLSM, as depicted in Fig. 4.13. The performance at the edge of a cell decreases as the velocity of the UE increases. PF provides better cell edge throughput at low UE velocity while at high velocity RR outperforms PF.

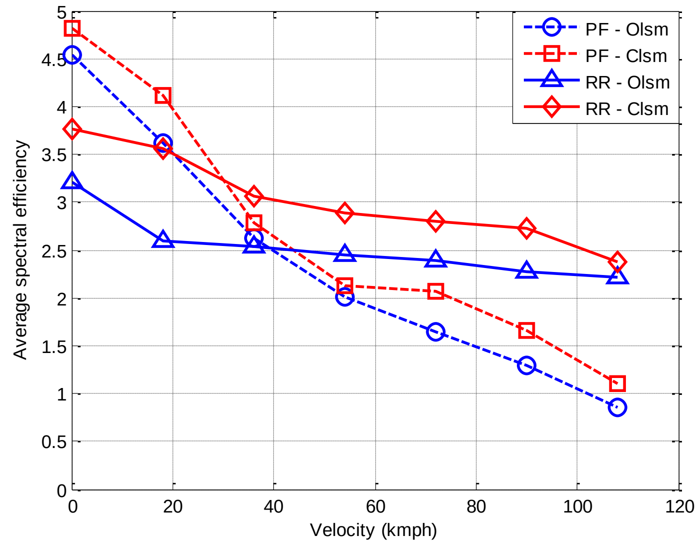


Fig. 4.14: Average spectral efficiency vs. UE velocity for OLSM and CLSM under PF and RR scheduling algorithm.

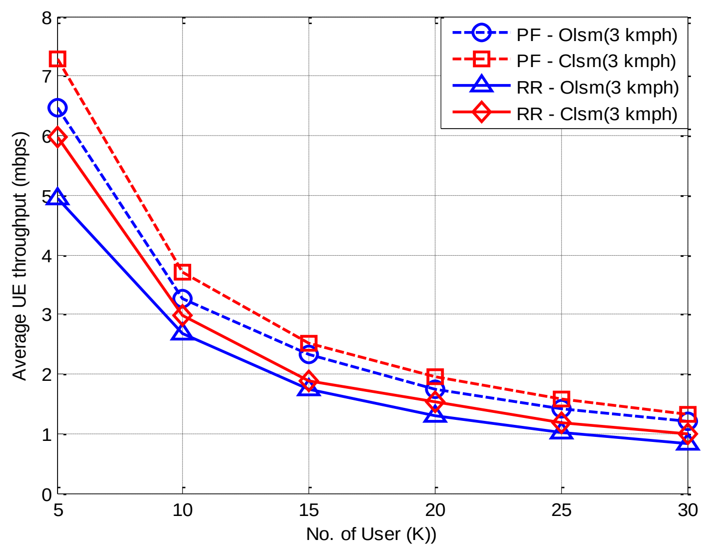


Fig. 4.15: Average UE throughput vs. UE density for OLSM and CLSM under PF and RR scheduling algorithm at 3 kmph.

Spectral efficiency also experiences a decline in performance as the velocity increases, shown in Fig.4.14. In this case also CLSM performs better than OLSM and at low UE velocity PF provides better spectral efficiency while at high UE velocity RR dominates PF.The extra PMI information which is fed back to the BS by the UE in CLSM allows it to adapt according to the changing channel conditions due to the mobility of the UEs.

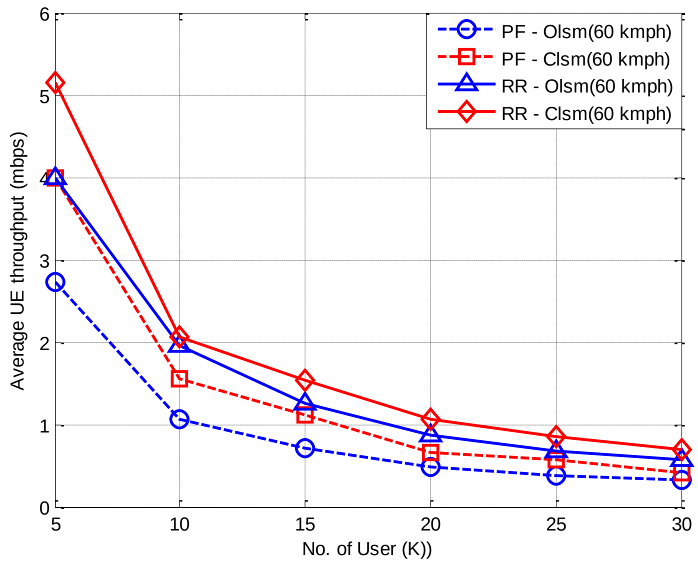


Fig. 4.16: Average UE throughput vs. UE density for OLSM and CLSM under PF and RR scheduling algorithm at 60 kmph.

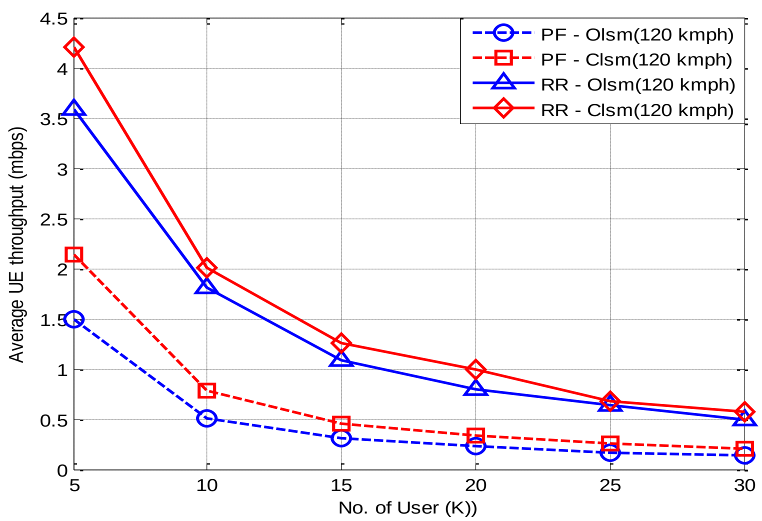


Fig. 4.17: Average UE throughput vs. UE density for OLSM and CLSM under PF and RR scheduling algorithm at 120 kmph.

This allows CLSM to provide a higher average UE throughput and cell edge throughput than OLSM hence efficiently using the system bandwidth than OLSM.

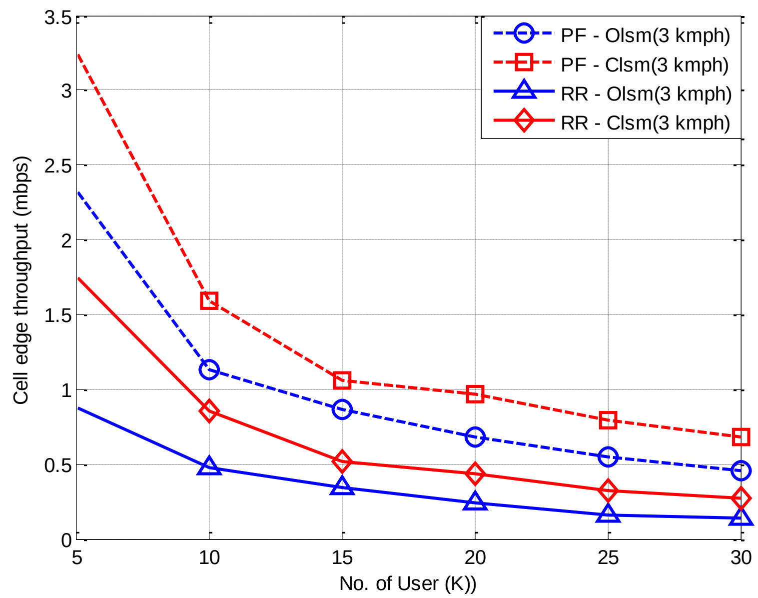


Fig. 4.18: Cell. edge throughput vs. UE density for OLSM and CLSM under PF and RR scheduling algorithm at 3 kmph.

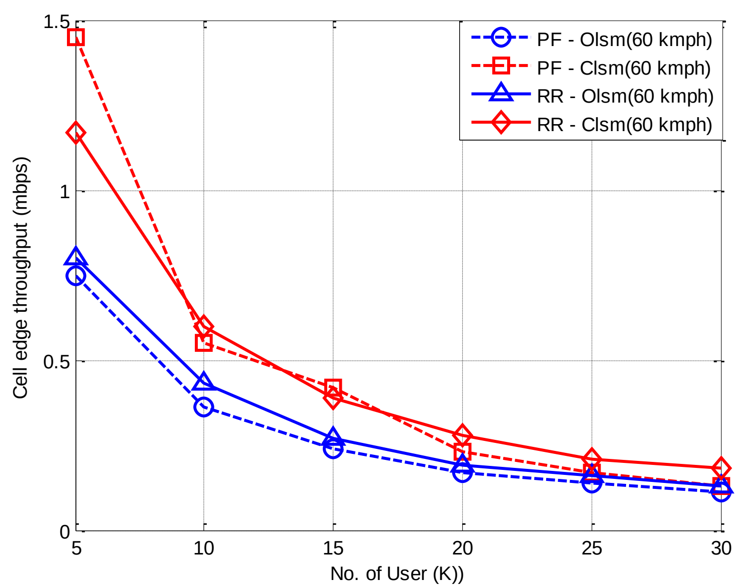


Fig. 4.19: Cell edge throughput vs. UE density for OLSM and CLSM under PF and RR scheduling algorithm at 60 kmph.

Fig. (4.15-4.17) illustrates that the average UE throughput achieved under both CLSM and OLSM decreases with an increase in UE density, but CLSM performs slightly better than OLSM. Also at low velocity PF performs better but a medium and high velocity RR outperforms PF at all UE densities irrespective of the spatial multiplexing type. Cell edge performances, as depicted in Fig. (4.18-4.20), also declines with an increase in UE density. In this case also CLSM performs better than OLSM and at low UE velocity PF provides better cell edge throughput while at medium and high velocity RR provides better throughput at the cell edges.

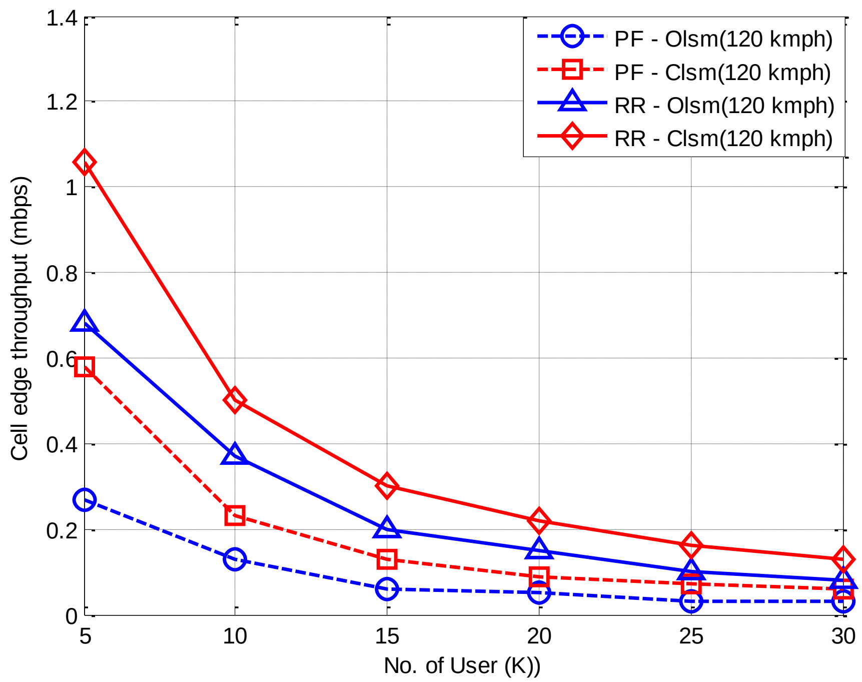


Fig.4.20 : Cell edge throughput vs. UE density for OLSM and CLSM under PF and RR scheduling algorithm at 120 kmph.

4.3.2 Analysis of the results for spatial multiplexing mode comparison:

At low velocity, Close loop spatial multiplexing (CLSM) performs better than Open Loop spatial multiplexing (OLSM) .CLSM-PF is the optimum combination for low velocity users but at high velocity, PF-OLSM and PF-CLSM behave similar. And also for RR resource scheduler, RR-CLSM and RR-OLSM behave similar. As the Close loop spatial multiplexing designing is little bit complex ,it is preferable to use OLSM at high velocity rather than CLSM[55].

4.4. Network model used for spatial multiplexing and transmit diversity transmission modes (TM) Comparison under mobility

LTE system level simulator [50] is used to evaluate the performance of a HetNet and ScNet for a 2x2 MIMO system. Mutual information based effective SINR mapping (MIESM) technique was adopted to predict the channel quality indicator (CQI) of the UEs. An urban environment was considered and the macroscopic propagation model was used for both macro cell BS and femto cell. For UE mobility we have considered the random walk model. To analyze the performance of different resource schedulers and MIMO modes in small cell and heterogeneous network, distinct strategies were employed. For the construction of small cell network (ScNet), 19 BSs are deployed in hexagonal order where each BS is separated from each other by 150m.For heterogeneous network (HetNet), we have used 20 femto cells that are placed by Poisson point process (PPP) and 19 BSs which are placed in hexagonal order as macro cell. In HetNet, single antenna represents femto cell and tri sector antenna represents macro cell. Here the macro cells are separated from each other by 500m.

Additional simulation parameters are presented in Table-4.3.

Simulation parameters	
Channel model	winner+
Pathloss Model	Urban Macroscopic Model
Macroscopic Path loss Model	TS36942
Frequency	900MHz
Bandwidth	10MHz
No. of transmitter	2
No. of receiver	2
Transmission modes	Transmit Diversity(Txd), Open Loop Spatial Multiplexing(OLSM) and Close Loop Spatial Multiplexing(CLSM)
Antenna Model name	Kathrein 742215
Scheduling Technique	PF,RR
BS height	20m
BS power	45dB
Receiver height	1.5m
Adaptive RI	2
Antenna azimuth offset	30^{o}
Antenna Gain	15dBi
BS Transmitter power	45dBm
Femto cell transmission power	20 dbm

Noise Power Density	-174 db
User Density	10-100
User Velocity	0-120 km/h
Simulation time	50 TTI
Inter BS distance	500 m

TABLE 4.3 –SIMULATION PARAMETERS FOR TXD, OLSM AND CLSM COMPARISON IN HETEROGENEOUS NETWORK

4.4.1 Results for MIMO (Txd , OLSM &CLSM) Transmission modes (TM) Comparison under mobility

Fig. 4.21 illustrates that x-axis denotes velocity in kmph and y-axis denotes Average UE throughput in mbps. Average UE throughput decreases as the No. of velocity increases. RR of CLSM and OLSM achieve better throughput than PF of CLSM and OLSM. This is due to the PMI which allows CLSM to be more robust, to varying channel condition, over OLSM. PF performs better than RR at CLSM at low velocities, whereas RR performs better than PF at CLSM at high velocities. PF at OLSM performs better than RR at low velocities, whereas RR performs far better than PF at high velocities. RR at Txd and OLSM becomes similar at all velocities. PF at OLSM and CLSM almost merge at high velocities. PF at Txd and CLSM intersect at low velocity, it also merges at some point at high velocity. RR at Txd and OLSM intersect at some point at low velocities. PF at OLSM and Txd intersect at some point at low velocity, and it becomes similar at some point at high velocities. RR at Txd and CLSM intersects at high velocities. RR at CLSM intersects with PF at CLSM and OLSM. PF at CLSM and OLSM intersect with PF at Txd at low velocities and again intersect with RR at Txd and OLSM at low velocities. The cell edge at RR is better than RR at low velocities. The cell edges of RR and PF are the same at high velocities.

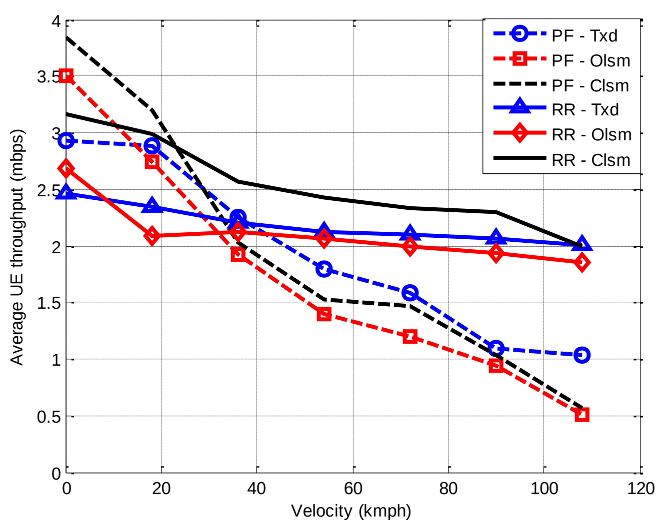


Fig 4.21: Average UE throughput vs UE Velocity under PF and RR Scheduler Algorithm.

Fig. 4.22 illustrates that x-axis denotes velocity in kmph and y-axis denotes Average cell edge throughput in mbps. Average UE throughput decreases as the velocity increases. RR of CLSM achieves better performance than PF of CLSM. RR of OLSM achieves better performance than PF of OLSM. This is due to the PMI which allows CLSM to be more robust, to varying channel condition, over OLSM. PF at Txd intersects with PF at OLSM at low velocities and with PF at CLSM at some midpoint of velocity and at high velocities. PF at OLSM intersects with RR at Txd twice at some velocities and with RR at OLSM at some velocities. PF at OLSM and Txd becomes similar at high UE velocities. RR at Txd intersects with PF at Txd and RR at CLSM at some velocities. RR at OLSM intersects with PF at Txd and CLSM. The cell edge of PF is better than RR at low velocities, whereas the cell edge of PF is better than RR at high velocities.

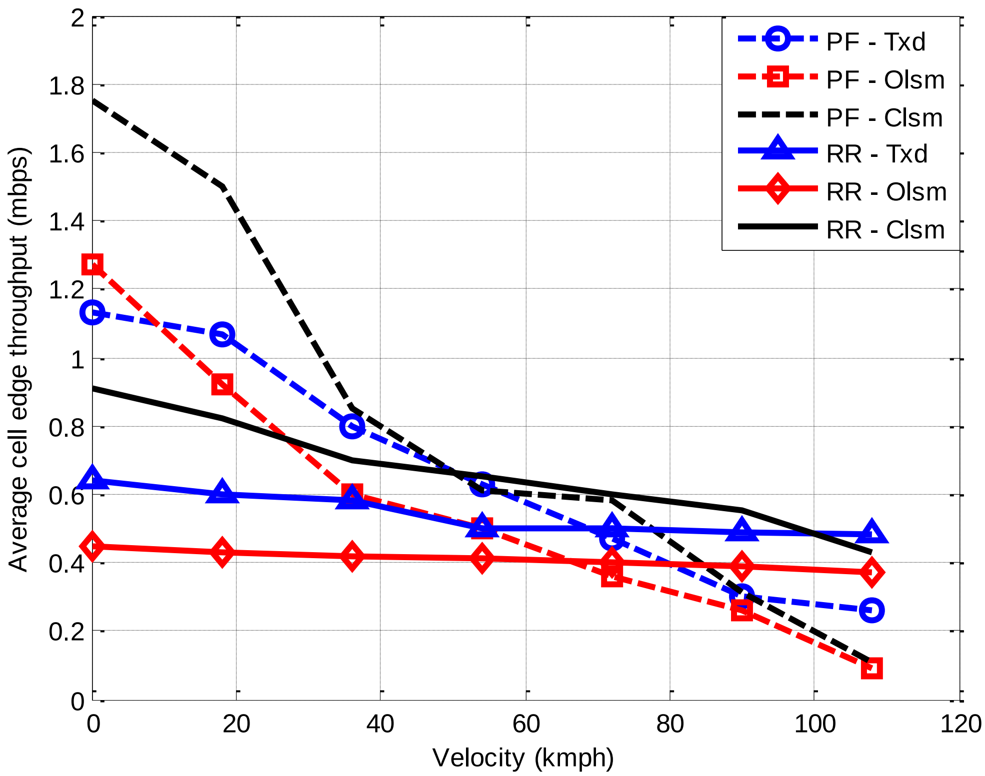


Fig. 4.22: Average cell edge throughput vs UE Velocity under PF and RR Scheduler Algorithm.

Fig. 4.23 illustrates that x-axis denotes velocity in kmph and y-axis denotes Fairness Index. Average UE throughput decreases as the velocity increases. CLSM achieves better Fairness Index than OLSM at all velocities. This is due to the PMI which allows CLSM to be more robust, to varying channel condition, over OLSM. RR achieves better performance than PF at OLSM. RR has much better performance than PF at CLSM. PF has better performance than RR at Txd. RR has better Fairness Index at all velocities than PF. PF and RR at Txd becomes similar at high velocities. PF at Txd intersects with RR at CLSM at the low velocity. RR at CLSM intersects with RR at Txd at four points at some velocities. PF at CLSM intersects with RR at

OLSM three times at some velocities. PF at OLSM intersects with RR at OLSM two times; once at the high velocities and then once at lower velocities. PF at CLSM and OLSM intersects twice; once at low velocity and once at high velocity.

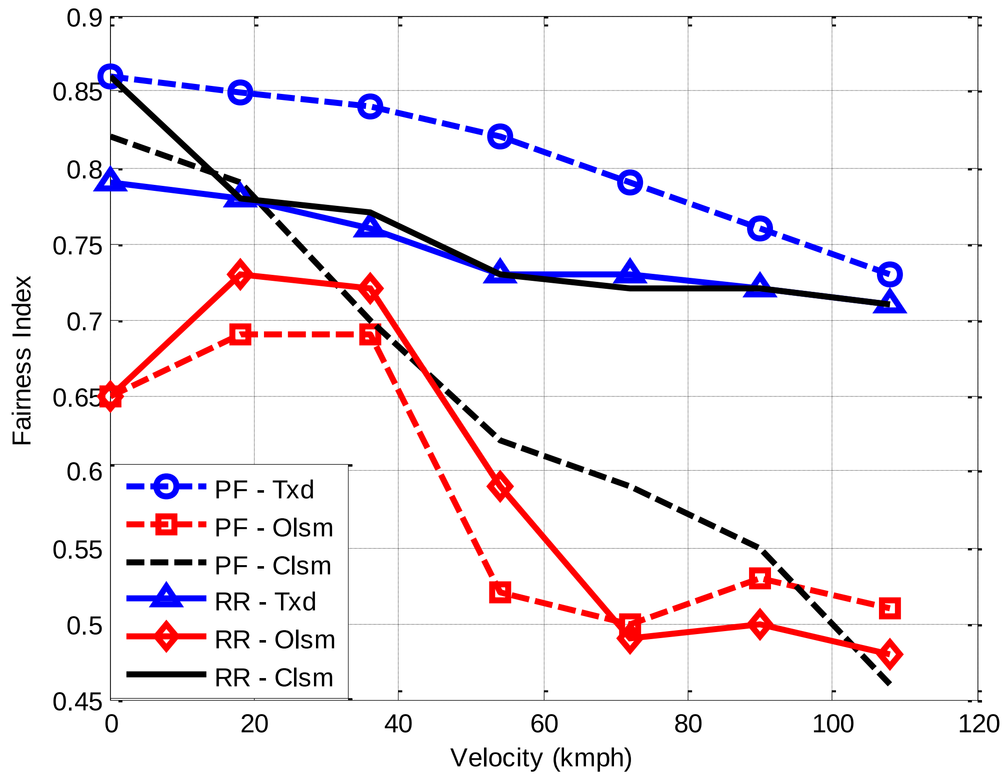


Fig. 4.23**:** Fairness Index vs UE Velocity under PF and RR Scheduler Algorithm.

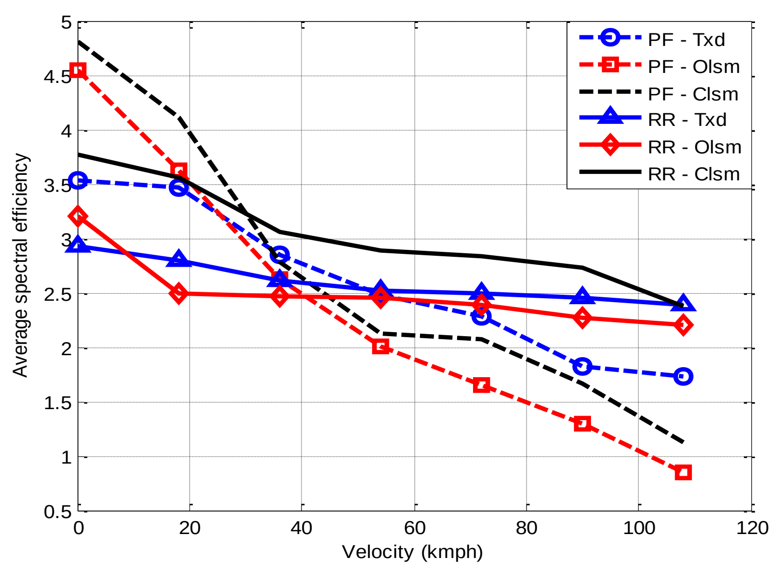


Fig. 4.24: Average spectral efficiency vs UE Velocity under PF and RR Scheduler Algorithm.

Fig. 4.24 illustrates that x-axis denotes the velocity in kmph and the y-axis denotes the Average spectral efficiency. PF in CLSM performs better than RR in CLSM. PF performs better than RR in OLSM. RR performs better than PF in Txd. PF in CLSM intersects with PF at Txd, and with RR at Txd and OLSM and CLSM at various velocity points. RR at Txd and CLSM meets at high velocities. PF in OLSM intersects with PF and RR at CLSM at the low velocities. PF at OLSM intersects with RR at Txd and OLSM at the midlevel of velocities. PF at Txd intersects with PF at OLSM and with RR at OLSM and Txd and also with PF at CLSM. RR at OLSM intersects with PF at OLSM, CLSM and Txd. RR at OLSM intersects four times with RR at Txd in various velocity points.

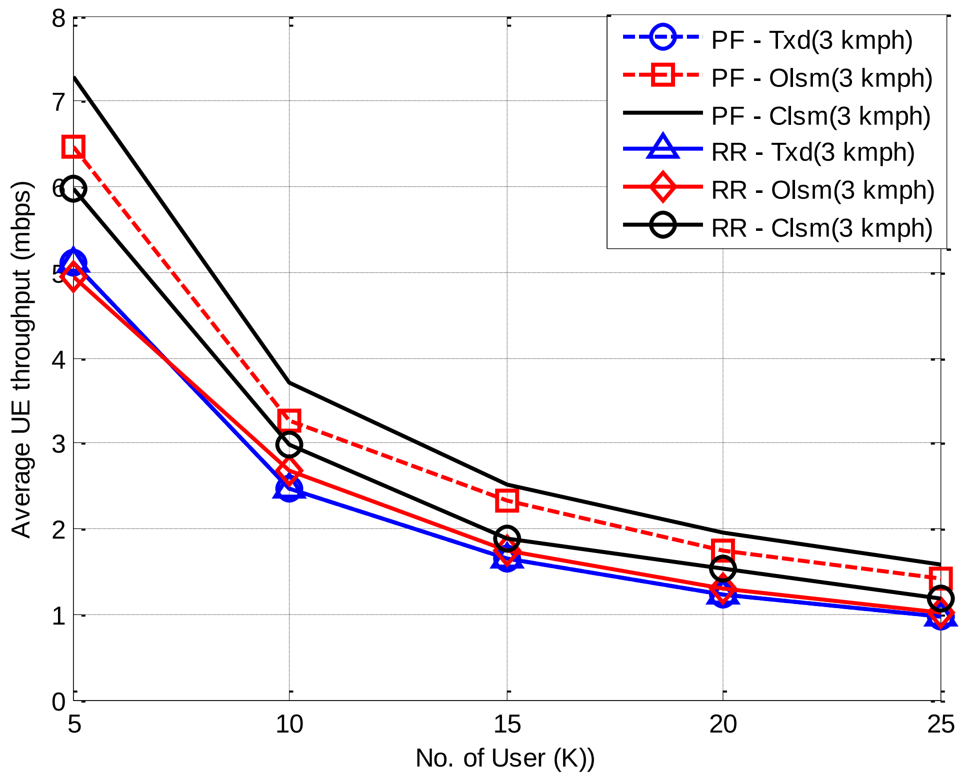


Fig. 4.25: Average UE throughput vs UE density under PF and RR Scheduler Algorithm for 3 kmph UE cases.

As Illustrates that the fig 4.25 above, the x-axis denotes the no. of User in K and the y-axis denotes the Average UE throughput in mbps. Average UE throughput experiences a decline with increasing UE density. CLSM achieves better throughput than OLSM at all densities. This is due to the PMI which allows CLSM to be more robust, to varying channel condition, over OLSM. At all densities, PF performs better than RR at either MIMO modes, whereas, the RR performs better than PF at Txd. Performance of the RR at OLSM and Txd become similar at all UE densities, and intersect five times at various densities. PF at CLSM and Txd becomes similar as the UE densities increases, and these two curves intersect four times at various densities. PF has better cell edge than RR at low UE densities, whereas RR has better cell edge at high densities at either MIMO.

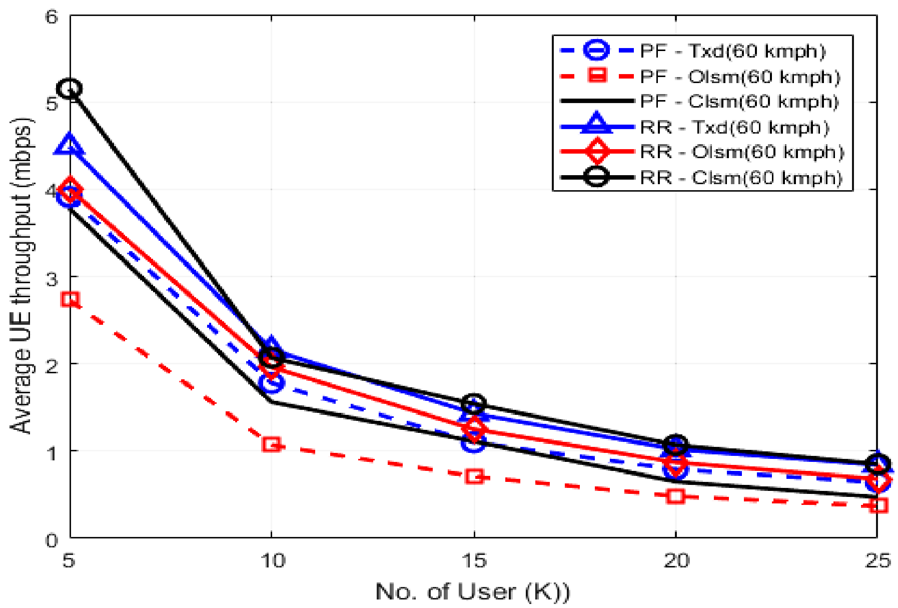


Fig. 4.26: Average UE throughput vs UE density under PF and RR Scheduler Algorithm for 60 kmph UE cases.

As Illustrates that Fig. 4.26, x-axis represents the No. of Users in K and the y-axis represents the Average UE throughput in mbps. Average UE throughput decreases as the No. of Users increases. CLSM achieves better throughput than OLSM at all densities. This is due to the PMI which allows CLSM to be more robust, to varying channel condition, over OLSM. At all UE densities, performance of RR is better at all MIMO modes than PF, whereas, RR performs better than PF at Txd. Performance of RR at CLSM and RR at Txd becomes similar at high densities, they intersect each other four times at varius points of densities. Performance of RR at OLSM, PF at CLSM and PF at Txd are similar at low UE densities. RR has better cell edge at all densities than PF at either MIMO.

Fig. 4.27 illustrates that x-axis denotes No. of User in K and y-axis denotes Average UE throughput in mbps. Average UE throughput decreases as the No. of Users increases. CLSM achieves better throughput than OLSM at all densities. This is due to the PMI which allows CLSM to be more robust, to varying channel condition, over OLSM. At all UE densities, RR performs better than PF at all MIMO modes, whereas RR performs better than PF at Txd. RR at Txd and CLSM becomes similar at all UE densities and intersect five times altogether at all densities. RR at CLSM and OLSM becomes similar at high UE densities, and intersects at low UE densities. RR has better cell edge than PF at low UE density, whereas PF has better cell edge than RR at high UE density at all MIMO modes.

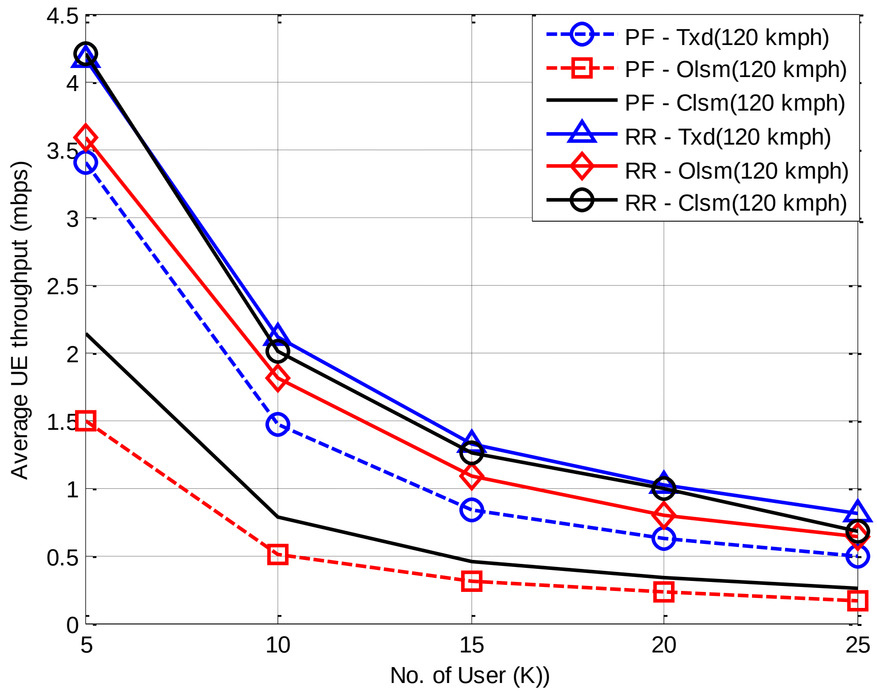


Fig. 4.27 : Average UE throughput vs UE density under PF and RR Scheduler Algorithm for 120 kmph UE cases.

4.4.2 Analysis of the results for spatial multiplexing and Transmit Diversity mode comparison:

At low velocity, CLSM performs better than OLSM and TXD among the transmission modes. CLSM-PF is the optimum combination for low velocity users and at high velocity RR-all MIMO mode behave similar but PF-TXD performs better than PF-OLSM, PF-CLSM.

4.5 Performance analysis and parameter settings for Small Cell (ScNet) and Heterogeneous network (HetNet) comparison

To compare the performance of ScNet and HetNet distinct strategies were employed. Fig. 4.28 illustrates the ScNet deployment strategy with UE positions. In our simulation we have designed a ScNet comprising of 19 BSs, forming a hexagonal geometry, with an inter BS separation of 150m. Each small cell has a BS with tri-sectored antennas. Fig.4.29 demonstrates the HetNet deployment plan with UE positions. Here we have a macro cell with 19 BSs and 20 femto cells. The inter BS distances in the macro cell is 500m and have tri-sector antennas whereas femto cells have single antennas respectively.LTE system level simulator was used to simulate ScNet and HetNet. Simulation was carried out using a total number of 570 UEs randomly placed within the simulation geometries for a velocity range of 0-125 kmph. For UE mobility we have considered the random walk model. Multiple MIMO techniques are available e.g. transmit diversity (TxD), closed loop spatial multiplexing (CSLM) to improve the overall UE throughput. In this paper we have considered the TxD mode for a 2x2 MIMO system, to compare the various

throughputs between ScNet and HetNet, because of its robustness under different fading scenarios. Link quality prediction in response to UE SINRs was performed using the mutual information based effective SINR mapping (MIESM) procedure as it is more accuratethan some other well-known methods such as exponential effective SINR mapping (EESM) [52-53].
Resource scheduling procedure for the UEs has to address the tradeoff between throughput and fairness. RR provides best fairness at the expense of a lower throughput. In contrast PF provides a higher throughput with an acceptable fairness index therefore PF was used for UE resource scheduling [16]. In HetNet, homogeneous spatial distribution of femto cells is considered.

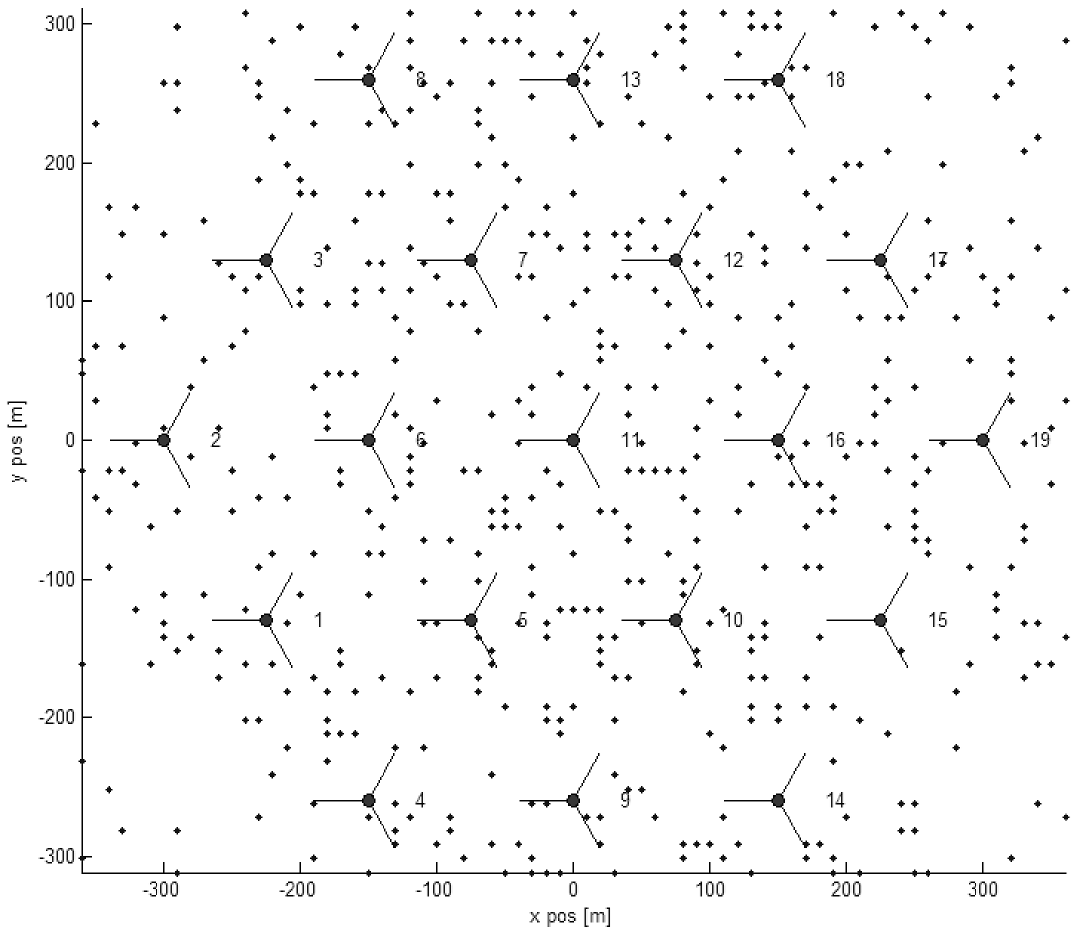


Fig. 4.28: Small cell network (ScNet) deployment.

Macroscopic pathloss model of urban environment considered for both femto cells and macrocell BSs are given below :

$$L = 40(1 - 4 \times 10^{-3} h_{BS}) \log_{10}(R) - 18 \log_{10}(h_{BS}) + 21 \log_{10}(f) + 80dB$$

where R is the BS-UE separation in kilometers, f is the carrier frequency in MHz and h_{BS} is the height of BS in meters.

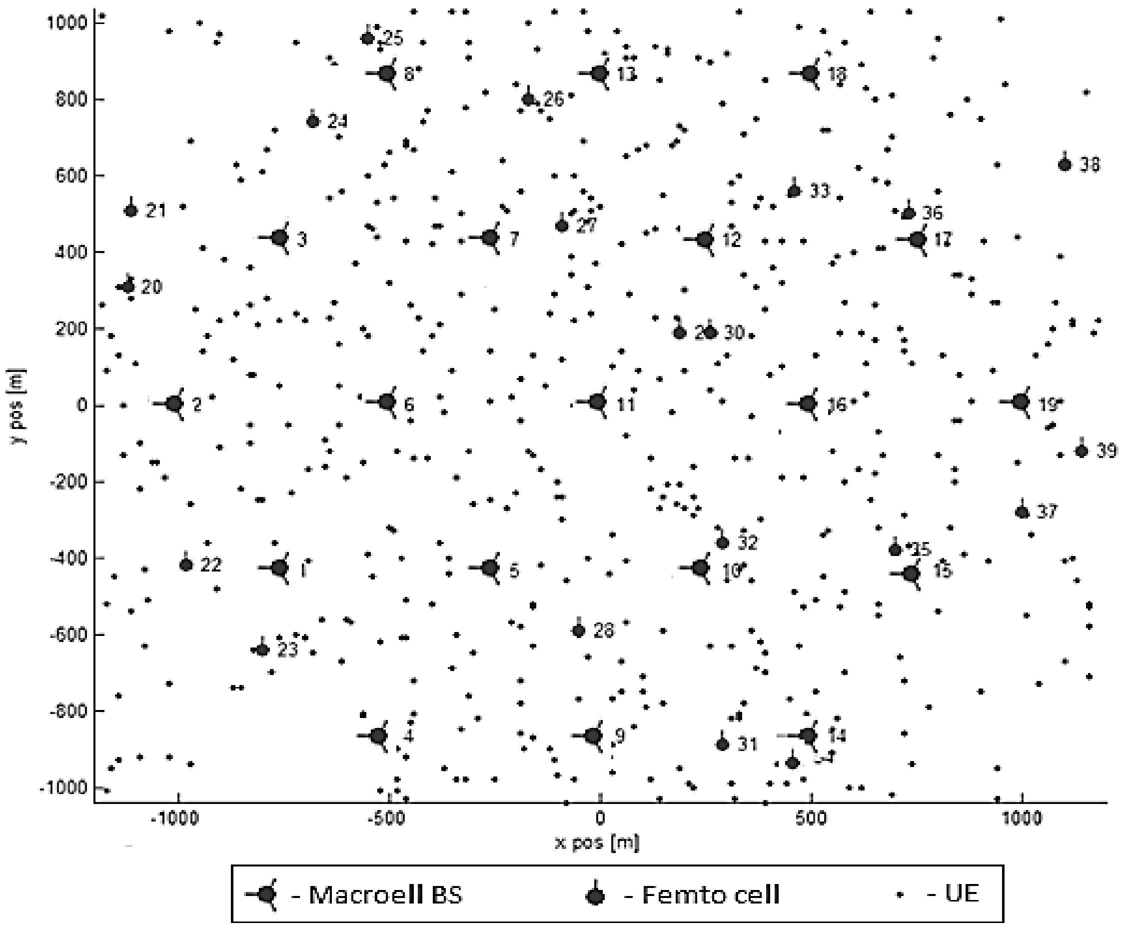


Fig.4.29: Heterogeneous network (HetNet) deployment.

Additional simulation parameters implemented are tabulated in table-I.

Simulation parameters	
Channel model	winner+
Pathloss Model	Urban Macroscopic Model
Macroscopic Path loss Model	TS36942
Frequency	900MHz
Bandwidth	10MHz
No. of transmitter	2
No. of receiver	2
Transmission modes	Transmit Diversity(Txd)
Antenna Model name	Kathrein 742215
Scheduling Technique	PF,RR
BS height	20
BS power	45dB
Receiver height	1.5m

Adaptive RI	2
Antenna azimuth offset	30º
Antenna Gain	15dBi
BS Transmitter power	45dBm
Femto cell transmission power	20 dbm
Noise Power Density	-174 db
User Density	10-100
User Velocity	0-120 km/h
Simulation time	50 TTI
Inter BS distance	500 m

TABLE 4.4–SIMULATION PARAMETERS FOR SMALL CELL AND HET NET COMPARISON

4.5.1 Results for Small cell and Heterogeneous network comparison under mobility

To compare the performance of ScNet and HetNet distinct strategies were employed. The simulation results suggest that average UE throughput, depicted in Fig. 4.30, for HetNet is higher than ScNet. This may be due to the additional low power BSs in HetNet that improves the rate at which data is transmitted to the UEs. Moreover, the result of the ScNet indicates its independency to the type of scheduler used to allocate resource to users.

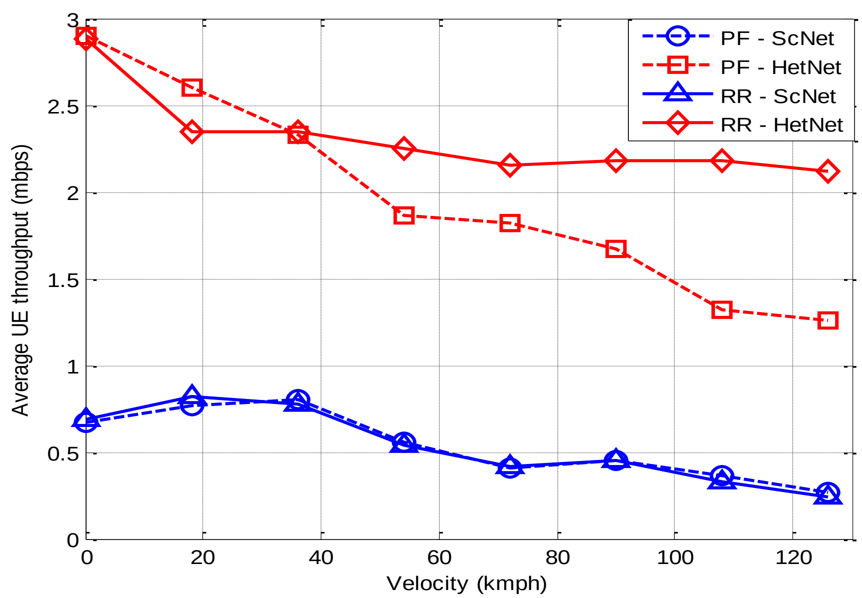


Fig. 4.30: Average UE throughput in ScNet and HetNet for mobile users

Also the result of the HetNet implies that RR scheduler is more robust to UE mobility and provides better throughput for high velocity users because it does not consider the UE channel quality. The results of the average cell edge throughput are shown in Fig. 4.31. For ScNet, demonstrates similarities for both types of scheduler.

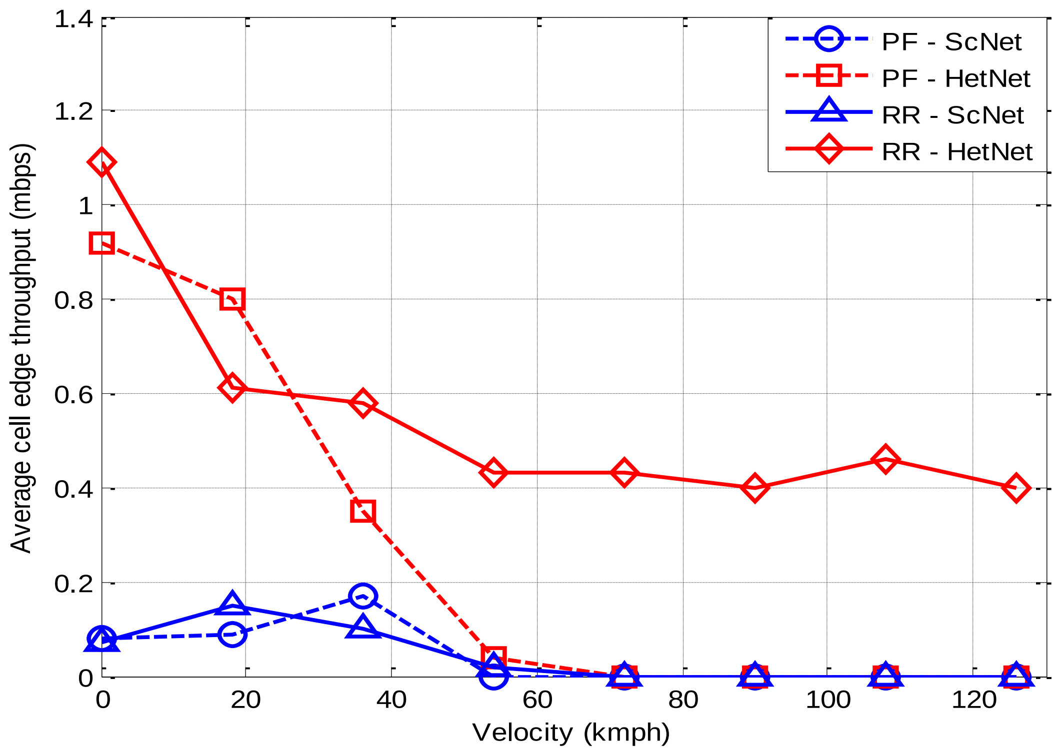


Fig. 4.31: Average cell edge throughput in ScNet and HetNet for mobile users

In contrast to ScNet, where the edge throughput reduces to zero for high velocity users, HetNet under RR scheduling technique is able to provide a fair amount of data rate to its cell edge users under a diverse range of velocities. This is significant to obtain a seamless network that can avoid call drop due to the lack of data rate during cell handovers.

Area throughputs for different network layouts under multiple scheduling schemes are shown in Fig. 4.32. It is evident that ScNet provides higher throughput per unit coverage area but this is sensitive to UE mobility and the area throughput decreases with an increasing UE velocity. On the other hand HetNet delivers almost similar area throughput for a wide range of velocities and is not significantly affected by UE mobility. Moreover the results show that area throughput is not affected by the type of scheduling algorithm.

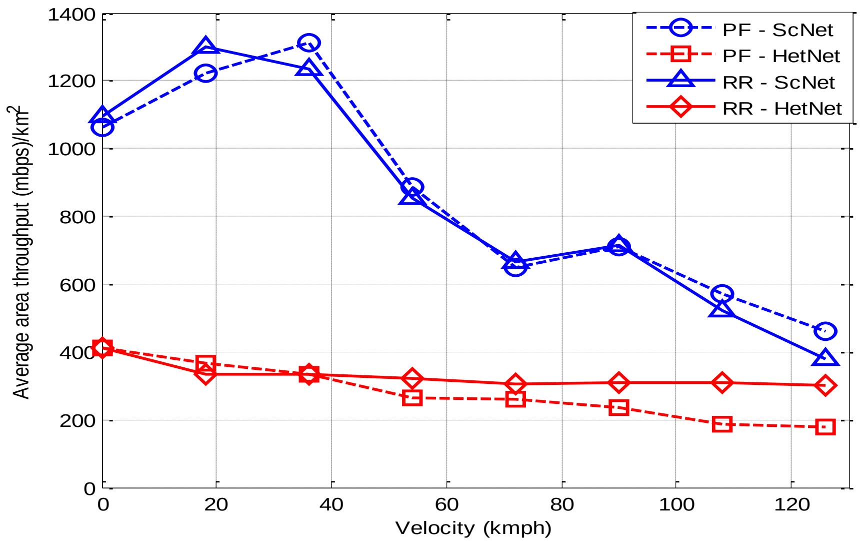


Fig. 4.32: Average area throughput in ScNet and HetNet for mobile users

Fig. 4.33 Stipulates that bandwidth is more efficiently utilized in HetNet for data transfer, since it supports more BSs for this purpose.

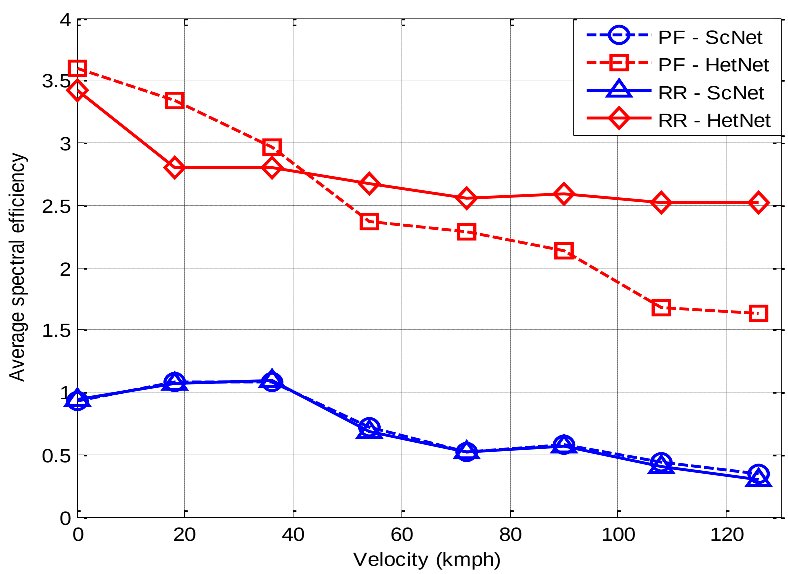


Fig. 4.33: Average spectral efficiency in ScNet and HetNet for mobile users

The spectral efficiencies attained for different scheduler types are similar in ScNet. On the contrary, in HetNet PF provides higher efficiency for low velocity users but for high velocity case RR dominates.

The simulation has also done for the same network parameter for the CLSM modes. On that cases, The probability distribution function (PDF) of the UEs SINR in small cell and Heterogeneous network are depicted in figure 4.34 and figure 4.35 respectively.

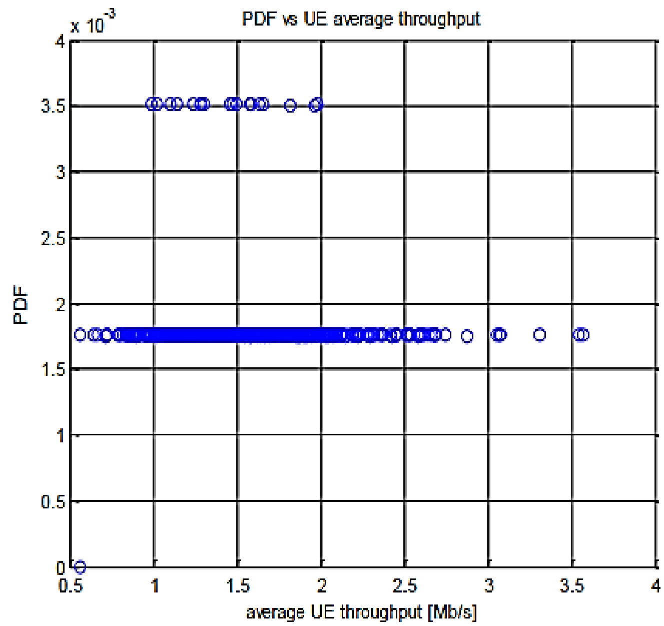


Figure 4.34: PDF Vs Average UE throughput for small cell network

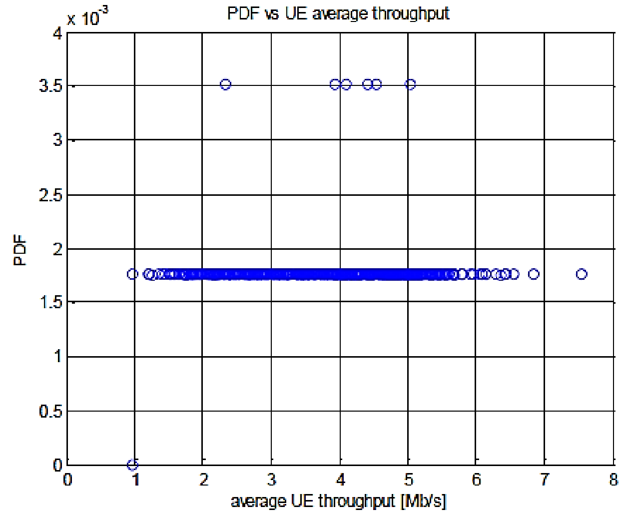


Figure 4.35: PDF Vs Average UE throughput for Heterogeneous network

From the above figures we can observe that UEs under Heterogeneous network experiences better SINR therefore achieving a higher channel quality. From the throughput-SINR relations for small cell and heterogeneous network respectively shown in figure 4.36 and figure 4.37, it is clear that a comparatively higher throughput can be achieved using Heterogeneous network.

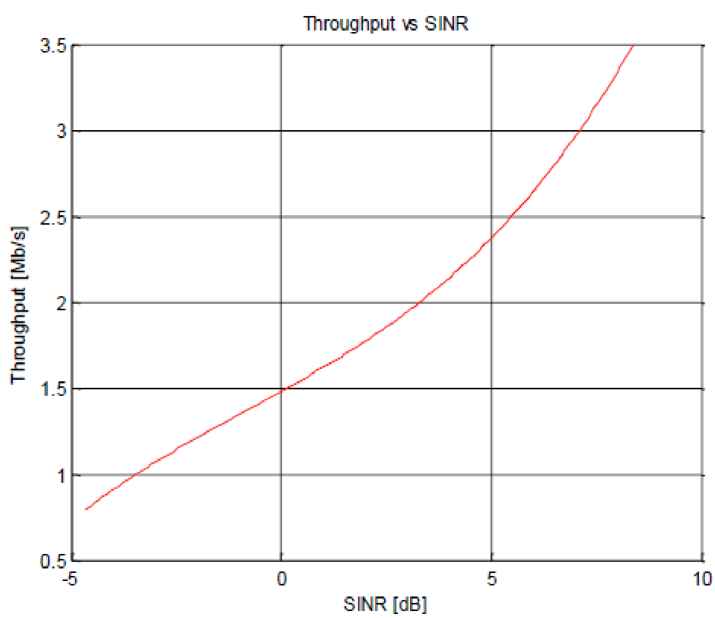


Figure 4.36: Average UE throughput vs. SINR for small cell network

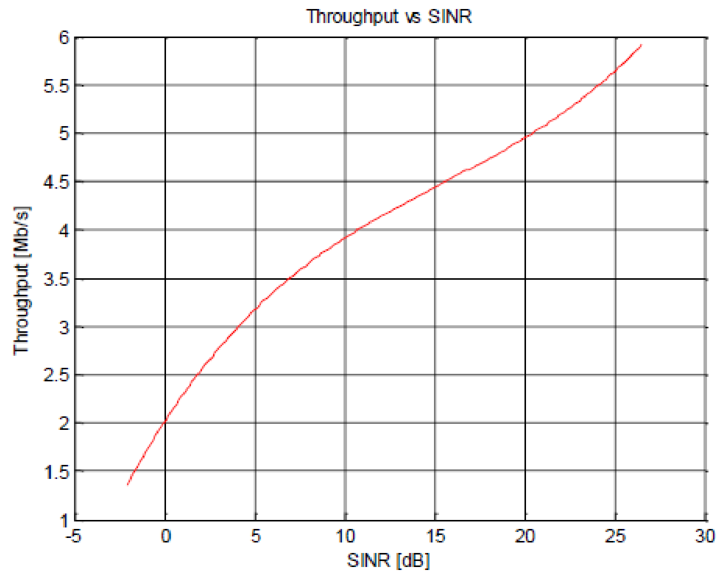


Figure 4.37: Average UE throughput vs. SINR for Heterogeneous network

As the femto cells position in heterogeneous network are random and located closer to the UEs and a better channel quality with more Cells results in a higher average UE, average cell and peak UE throughputs. Peak UE throughput is obtained with 95% of throughput ECDF and cell edge throughput with 5% throughput ECDF.A higher average UE throughput for a given bandwidth leads to a greater average spectral efficiency for heterogeneous network UEs comparatively than small cell network UEs.

4.5.2 Analysis of the results for Different Network Layout comparison:

For choosing a network layout under UE mobility, average throughput for Heterogeneous network –TXD mode is much higher than small cell-TXD mode. But, area wise throughput is much higher for small cell network than heterogeneous network.[56,57]

Chapter 5

Conclusion and Future Scopes

5.1 Conclusion

According to the simulation results, RR outperforms PF at high UE velocity and provides higher UE throughout and better fairness. Moreover at cell edges and at high velocity RR provides a low throughput which is very important to maintain a seamless network connection especially during UE handovers to prevent call drops. On the other hand PF fails to serve any UEs, moving at high velocity, at cell edges. RR also achieves higher spectral efficiency and better fairness at high UE velocity. Moreover our results show that the average UE throughput and cell edge throughput are sensitive to UE density and both the metrics decrease with an increase in UE density. In contrast spectral efficiency and fairness index are not significantly affected by a change UE density. Therefore for UEs moving at high velocities resource scheduling should be done using RR algorithm to achieve higher performances.

In addition, simulation has been performed in HetNet for CLSM and OLSM schemes for PF and RR scheduling using femto cells under UE mobility. Results from simulation show that CLSM works better than OLSM while PF provides better performance at low UE velocity and RR works better for high mobility UEs. This means that RR scheduling algorithm can be used to achieve better UE efficiency under high velocity, which will offer an additional benefit by having a better cell edge throughput. This decreases the risk of call drops during cell handover for high-velocity UEs. The average UE throughput results also show that CLSM performs slightly better at low UE speed than OLSM, but both spatial multiplexing modes provide similar performance at high speed. Thus it could be proposed that data may be transmitted to high mobility UEs using OLSM instead of CLSM technique. PF can utilize the channel conditions to achieve a higher data rate at low UE velocity, but its performance deteriorates at high velocities. On the other hand, RR dominates PF at high velocities in terms of throughput. This is because, RR performs independent of the channel quality and equally serves all the UEs. Therefore, it can be concluded that, in a HetNet at low UE velocity CLSM-PF can be the desired MIMO-scheduler combination, whereas at high velocities OLSM-RR can be the preferred combination. This also simplifies transmission complexity at the BS. Moreover, for different MIMO modes, CLSM performs better at low velocity where at high velocity TXD-PF performs better than OLSM-PF and CLSM-PF.

Later, simulation environment has developed for HetNet using femto cell and ScNet, where simulation has carried out for two different resource scheduling algorithms under UE mobility. Simulation results revealed that average UE throughput under HetNet is higher than ScNet. Moreover RR achieves better UE performance for high velocities and in HetNet provides an acceptable throughput at cell edges over a larger range of UE velocities which PF in HetNet and ScNet under both scheduling algorithm fails to achieve. On the other hand if throughput density is considered then ScNet outperforms HetNet even considering for mobile UEs. Therefore ScNet can be considered in densely populated areas, where network exhaustion is more of a concern than UE performance, using either PF or RR. In contrast if better UE performance is required at high velocities than HetNet can be used under RR scheduling to avoid call drops at cell edges and to achieve high UE throughput. In addition HetNet performs better for higher user densities and under RR provides higher UE performance than PF at high velocities. In terms of average UE throughput at high velocity and for high UE density both schedulers have similar performances. HetNet also provides better cell edge throughput than ScNet for high UE densities and RR performs best in case of cell edge throughput for densely populated high velocity UEs.

5.2 Future Scope

In future, research can be continued with coordinated multipoint (ComP), analyzing the coordinated scheduling (CS) schemes and comparing different LTE downlink performance parameters for a large range of UE density and system bandwidth under multiple UE velocity. It may help us to realize the actual performance of these types of cooperation upon the implementation of coordinating scheduling in the practical scenario, as in reality, most of the UEs are moving and they may also move with different velocities.

References

1. Tara Ali-Yahiya, "Understanding LTE and its performance", *Springer* 2011.

2. Rohde & Schwarz: Introduction to MIMO, Application Note 1MA142, July 2009.4G Americas, "Mobile Broadband Evolution Towards 5G: Rel-12 & Rel-13 and Beyond", June 2015.

3. Technical Specification Group Radio Access Network; Physical Channels and Modulation, Release 10; 3GPP TS 36.211 V 12.5.0, March 2015.Evolved Universal Terrestrial Radio. "Physical layer procedures." (2008).

4. 4G Americas, "Mobile Broadband Evolution Towards 5G: Rel-12 & Rel-13 and Beyond," June 2015.

5. Mo, J., &Walrand, J. ,"Fair end-to-end window-based congestion control",*IEEE/ACM Transactions on Networking*, 8(5), Page-556–567,June 2000.

6. M. Ghorbanzadeh,"Utility function and radio resource allocation, cellular communication systems in congested environment", Berlin,*Springe*,2000.

7. V Kavitha,A.Eitan, El-Azouzi, R., &Sundaresan, R. , "Fair scheduling in cellular systems in the presence of noncooperative mobiles" ,in Proceedings *IEEE INFOCOM*, San Diego, CA, USA.

8. D.Moraes, T. M., Nisar, M. D., Gonzalez, A., &E.Seidel, "Resource allocation in relay enhanced LTE-advanced networks",*EURASIP Journal on Wireless Communications and Networking*,P1–12 ,2012.

9. Holma, H., Toskala, A., &Reunanen, J. (2016). LTE small cell optimization, 3GPP evolution to release13 New York: Wiley.

10.V.Chandrasekhar& Andrews, J. G.,"Femtocell networks: A survey",*IEEE Communication Magazine*, 46(9), 59–67, 2008.

11. F. B.Frederiksen, Ramjee Prasad. , "An overview of OFDM and related techniques towards development of future wireless multimedia communications", *in Proceedings RAWCON 2002. 2002 IEEE radio and wireless conference*(Cat. No. 02EX573), (pp. 19–22),2002.

12. S.Nagaraj, Sarkar, M., &Biswash, S. K. ,"A heterogeneous cellular communication system for moving users: A 5G prospective",*WINNCOMM SDR*, 15, 164–171,2015.

13. S. A.Mahmud,G. M Khan, H. Zafar,K.Ahmad, &N.Behttani , "A survey on femtocells: Benefits deployment models and proposed solutions",*Journal of Applied Research and Technology*, 11(5), 733–754, 2013.

14. G.de la Roche, A.Valcarce,D. Lopez-Perez, &J.Zhang, " Access control mechanisms for femtocells", IEEE Communications Magazine, 48(1), 33–39,2010.

15. M.Taranetz,M. Rupp," Performance of femtocell access point deployments in user hot-spot scenarios", In *Australasian Telecommunication Networks and Applications Conference (ATNAC)*, Brisbane, QLD, Australia,2012.

16. M.Taranetz, J. C. Ikuno&M. Rupp, "Sensitivity of OFDMA-based macrocellular LTE networks to femtocell deployment density and isolation", In *ISWCS, the tenth international Symposium on Wireless Communication System*,Ilmenau, Germany,2013.

17. L .Weifeng, Y .Li,Z.Qihua, &C.Siguang, "Performance analysis of cell selection solution in macro-pico heterogeneous networks", In *2nd IEEE international conference on computer and communications (ICCC)*, Chengdu, China (pp. 1530–1534),2016.

18. D Claussen,H.Claussen,H.Uzunalioglu, "On femto deployment architectures and macrocell offloading benefits in joint macro-femto deployments",*IEEE Communications Magazine*, 48, 26–32 , 2010.

19. Cheng, S.-M., Lien, Shou-Yu., Chu, F.-S., & Chen, K.-C., " On exploiting cognitive radio to mitigate interference in macro/femto heterogeneous networks",*IEEE Wireless Communications*, 18(3), 40–47,2011.

20. D.Lopez-Perez ,Valcarce, A., de la Roche, G., & Zhang, J.,"OFDMA femtocells: A roadmap on interference avoidance", *IEEE Communications Magazine*, 47(9), 41–48,2009.

21. P. K. Mishra, Pandey, S., &S. K.Biswash, "Efficient resource management by exploiting D2D communication for 5G networks", *IEEE Access*, 4, 9910–9922,2016.

22. K.C.Balachandran, , D. Joshi, N.S., Kang, J. H., &A. Kogiantis, " Method of resource allocation in a wireless communication system", US Patent App. 11/534,271,2008.

23. Shao-Yu Lien, Yu-Yu ,& K.C. Lin, "Cognitive and game-theoretical radio resource management for autonomous femtocells with QoS guarantees. *IEEE Transactions on Wireless Communications*, 10(7), 2196–2206,2011.

24. GPPTS 36.300v8.12.0 Release 8. Evolved Universal Terrestrial Radio Access (E-UTRA) and (E-UTRAN). Overall description. Stge2.

25. F.Capozzi, G.Piro,L. A.Grieco, G.Boggia& P .Camarda ,"Downlink packet scheduling in LTE cellular networks: Key design issues and a survey",*IEEE Communications Surveys and Tutorials*, 15(2), 678–900,2013.

26. M. H. Habafbi, J.Chebil,A. G.Sakkaf, T. H.Dahawi,"Comparison between scheduling techniques in long term evolution",*IIUM Engineering Journal*, 14(1), 66–75,2013.

27. Jabbar, A. I. A., & Abdullah, F. Y.. Long term evolution (LTE) scheduling algorithms in wireless sensor networks (WSN*). International Journal of Computer Applications*, 121(10), 12–16,2015.

28.S.Schwarz, C.Mehlfuhrer&M. Rupp, "Throughput maximizing multiuser scheduling with adjustable fairness", In *IEEE international conference on communications (ICC),* Kyoto, Japan,2011

29. S.Schwarz, C.Mehlführer, &M. Rupp , "Low complexity approximate maximum throughput scheduling for LTE",*In Conference record of the forty fourth Asilomar conference on signals, systems and computers,* Pacific Grove, CA, USA (pp. 1563–1569),2010.

30. S. A. Alqahtani, M.Alhassany, "Performance modeling and evaluation of novel scheduling algorithm for LTE networks",*In IEEE 12th international symposium on network computing and applications,* Cambridge, MA, USA (pp. 101–105),2013.

31. H.Kim&Y.Han, "A proportional fair scheduling for multicarrier transmission systems",*IEEE Communications Letters,* 9(3), p210–212,2005.

32. Z.Sun, C.Yin, G.Yue, "Reduced-complexity proportional fair scheduling for OFDMA systems",*In IEEE international conference on communications, circuits, and systems* (pp. 121–1225),2006.

33. R.Kwan, C.Leung&J.Zhang,"Resource allocation in an LTE cellular communication system",*In IEEE international conference on communications,* Dresden, Germany,2009.

34. C.Deniz, O. G.Uyan, &V. C.Gungor, "On the performance of lte downlink scheduling algorithms: A case study on edge throughputs*", Elsevier Journal of Computer Standards Interference,* 59, 96–108,2018.

35. B. Krasniqi and B.Rexha, "Analysis of macro-femto cellular performance in LTE under various transmission power and scheduling schemes", *Journal of Communications*, 13(3), 119–123,2018.

36.M. K.Ismail, A. A. M.Isa, , M. S. Johal,M. R. Ahmad, M. S. I. M. Zin, , M. I. M.Isa,"Design and analysis of modified-proportional fair scheduler for LTE femtocell networks". *Journal of Telecommunication, Electronic and Computer Engineering,* 9(2–5), 7–11,2017.

37. A. Lozano & N. Jindal, "Transmit Diversity vs. Spatial Multiplexing in Modern MIMO Systems*", IEEE Transactions on Wireless Communications*, Vol. 9, Issue 1, pp. 186-197, 2010.

38.D. Love, R. Heath, V. Lau, D. Gesbert, B. Rao, and M. Andrews, "An overview of limited feedback in wireless communication systems," *IEEE J. Sel. Areas Commun*., Vol. 26, Oct. 2008.

39. D.Calin, H.Claussen, and H.Uzunalioglu, "On Femto Deployment Achitectures and Macrocell Offloading Benefits in Joint Macro-Femto Deployments," *IEEE Communication Magazine,* vol. 48, no. 1, pp. 26 – 32, Jan. 2001

40. C.Kosta, B. Hunt, A.UlQuddus& R.Tafazolli, "On interference avoidance through intercell interference coordination (ICIC) based on OFDMA mobile systems",*IEEE Communication Surveys and Tutorials*, 15(3), 973–995,2013.

41. M. K.Muller, S.Schwar,&M. Rupp, ",QoSInvestigation of Proportional Fair Scheduling in LTE Networks",*IEEE Poster: Wireless Days*, Valencia, Spain,2013.

42. L.Gavrilovska&D.Talevski, "Novel scheduling algorithms for LTE downlink transmission",*In 19th telecommunications forum (TELFOR) proceedings of papers* (Vol. 4(1), pp. 20–25), Belgrade, Serbia,2011.

43. R.Kwan, ,C. Leung, J. Zhang, "Proportional fair multiuser scheduling in LTE",*IEEE Signal Processing Letters*, 16(6), 461–464,2009.

44. M.Escheikh, H.Jouini, &, K.Barkaoui, "Performance analysis of a novel downlink scheduling algorithm for LTE systems",*In International conference on advanced networking distributed systems and applications,*Bejaia, Algeria (pp. 13–18),2014.

45. G.Aiyetoro, ,FTakawira, "A new user scheduling scheme in LTE/LTE-a networks using cross-layer design approach", *In MILCOM 2015–2015 IEEE military communications conference,* Tampa, FL, USA (pp. 689–694),2015.

46. M.Rupp, S.Schwarz&M.Taranetz, "The Vienna LTE-advanced simulators: Up and downlink, link and system level simulation",*Springer: Signals and Communication Technology*,2016.

47. M. H.LukmanhakimSukeran,M. M. Al-HarethZyoud, S. H.Ahmad, , M. DAmelia Wong&,R.Islam, " Performance evaluation of LTE scheduling techniques for heterogeneous traffic and different mobility scenarios", *SpringerAdvanced Computer and Communication Engineering Technology, Lecture Notes in Electrical Engineering*, v-315, p141–150,2014

48. G. J. M.Janssen,P. A.Stigter&R.Prasad , "Wideband indoor channel measurements and BER analysis of frequency selective multipath channels at 2.4, 4.75, and 11.5 GHz",*IEEE Transactions on Communications*, 44(10), 1272–1288,1996.

49. LTE System Level Simulator v1.6r885 by Institute Of communication and Radio Frequency Engineering, Vienna University of Technology, Vienna

50. Technical Specification Group RAN, "E-UTRA; LTE RF system scenarios," 3rd Generation Partnership Project (3GPP), Tech. Rep. TR 36.942 version 10.2.0 Release 10, 2011

51. F. Gunnarsson, M.N. Johansson, A. Furuskar, M. Lundevall, A. Simonsson, C. Tidestav, M. Blomgren, "Downtilted base station antennas – a simulation model proposal and impact on HSPA and LTE performance", *in IEEE 68th Vehicular Technology Conference VTC*, Calgary, Canada, 2008.

52. L. Wan,S. Tsai,and M. Almgren, "A Fading-Insensitive Performance metric for a United Link Quality Model*," Proceedings of Wireless Communication and Networking Conference (WCNC*) , pp. 2110-2114, 3-6 April, 2006.

53. S. Sesia, I. Toufik and M. Baker, "LTE - The UMTS Long Term Evolution - from theory to practice," *Wiley,* 2009.

54. Abdullah Bin Shams,**Syed Rafiee Abied**, Md. Ashraful Hoque., " Impact of user mobility on the performance of downlink resource scheduling in Heterogeneous LTE cellular networks", *International Conference on Electrical Engineering and Information Communication Technology ICEEICT*, Vol: , Page No: 1, Issue: 3, Year: 2016 DOI: 10.1109/CEEICT.2016.78730

55. A. B. Shams,S.R.Abied,MdAsaduzzaman, Md. Farhad Hossain ,"Mobility effect on thedownlink performance of spatial multiplexing techniques under different scheduling algorithms in heterogeneous network", *International Conference on Electrical Computer and Communication Engineering ECCE*, Vol: , Page No: 905, Issue: 1, Year: 2018

56. A.B. Shams,S.R. Abied, Md.Farhad Hossain , "Performance comparison of network layouts with mobile users under different resource scheduling techniques in downlink LTE", *5th International Conference on Informatics Electronics and Vision ICIEV 2016*, Vol: , Page No: 949, Issue: 5, Year: 2016

57. S. R. Abied, A. B. Shams, Mohammad T Kawser , "Comparison of the LTE Performance Parameters in Different Environments under Close Loop Spatial Multiplexing (CLSM) Mode in Downlink LTE-A", *Journal of Computer and Communications,* Vol: , Page No: 117, Issue: 9, Year: 2017 .

Publications

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- Abdullah Bin Shams, **Syed Rafiee Abied**, ,MdAsaduzzaman, Md.Farhad Hossain ,"Mobility effect on the downlink performance of spatial multiplexing techniques under different scheduling algorithms in heterogeneous network", *International Conference on Electrical Computer and Communication Engineering ECCE*, Vol: , Page No: 905, Issue: 1, Year: 2018 DOI:10.1109/ECACE.2017.7913032
- Abdullah Bin Shams, **Syed Rafiee Abied**, Md.Farhad Hossain , "Performance comparison of network layouts with mobile users under different resource scheduling techniques in downlink LTE", *5th International Conference on Informatics Electronics and Vision ICIEV 2016*, Vol: , Page No: 949, Issue: 5, Year: 2016 DOI: 10.1109/ICIEV.2016.7760140
- Abdullah Bin Shams,**Syed Rafiee Abied**, Md. Ashraful Hoque., " Impact of user mobility on the performance of downlink resource scheduling in Heterogeneous LTE cellular networks", *International Conference on Electrical Engineering and Information Communication Technology ICEEICT*, Vol: , Page No: 1, Issue: 3, Year: 2016 DOI: 10.1109/CEEICT.2016.7873091