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1. INTRODUCTION

1.1 WIRELESS COMMUNICATION

The evolution of wireless technology has brought many advancements with its effective features. • The transmitted distance can be anywhere between a few meters (for example, a television's remote control) and thousands of kilometers (for example, radio communication) • Wireless communication can be used for cellular telephony, wireless access to the internet, wireless home networking, and so on. • Other examples of applications of radio wireless technology include GPS units, garage door openers, wireless computer mice, keyboards and headsets, headphones, radio receivers, satellite television, broadcast television and cordless telephones.

Wireless Advantages:

Wireless communication involves transfer of information without any physical connection between two or more points. Because of this absence of any 'physical infrastructure', wireless communication has certain advantages. This would often include collapsing distance or space. Wireless communication has several advantages; the most important ones are discussed below:

Cost effectiveness Wired communication entails the use of connection wires. In wireless networks, communication does not require elaborate physical infrastructure or maintenance practices. Hence the cost is reduced. Example - Any company providing wireless communication services does not incur a lot of costs, and as a result, it is able to charge cheaply with regard to its customer fees.

Flexibility Wireless communication enables people to communicate regardless of their location. It is not necessary to be in an office or some telephone booth in order to pass and receive messages. Miners in the outback can rely on satellite phones to call their loved ones, and thus, help improve their general welfare by keeping them in touch with the people who mean the most to them.

Convenience Wireless communication devices like mobile phones are quite simple and therefore allow anyone to use them, wherever they may be. There is no need to physically connect anything in order to receive or pass messages. Example - Wireless communications services can also be seen in Internet technologies such as Wi-Fi. With no network cables hampering movement, we can now connect with almost anyone, anywhere, anytime.

Speed Improvements can also be seen in speed. The network connectivity or the accessibility were much improved in accuracy and speed. Example – A wireless remote can operate a system faster than a wired one. The wireless control of a machine can easily stop its working if something goes wrong, whereas direct operation can't act so fast. Accessibility The wireless technology helps easy accessibility as the remote areas where ground lines can't be properly laid, are being easily connected to the network.

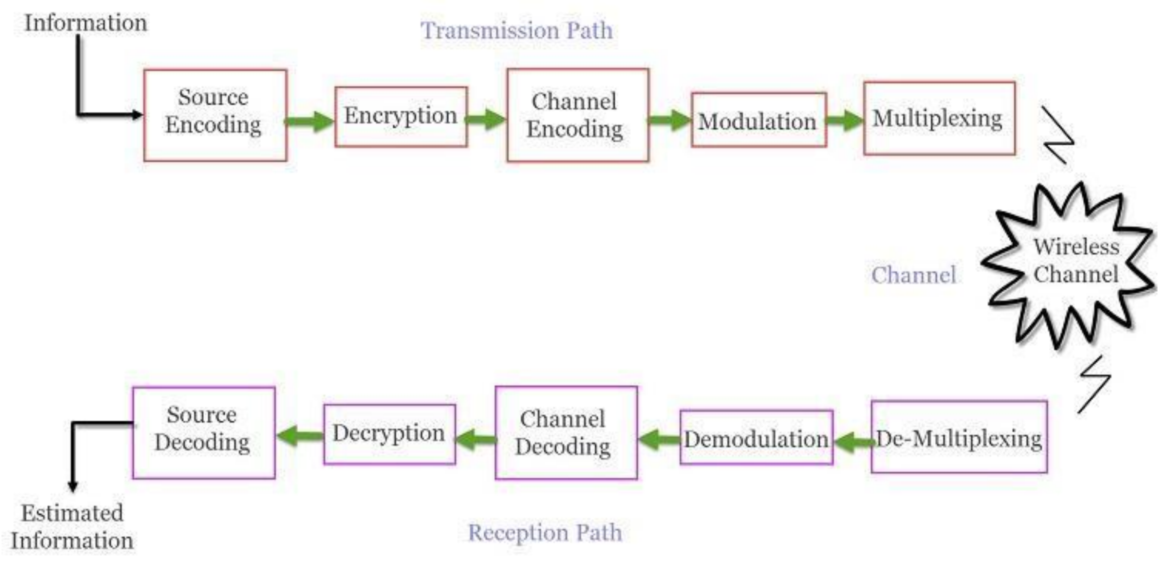


Fig 1.1 WIRELESS COMMUNICATION SYSTEM

The development of mobile companies and the enrichment of the services they offer is directly related to the development of mobile networks. Mobile communication is the transfer of information at a distance without the use of cables. The distance may be short, up to a few feet like in the case of television remote controls, or it may be long as many thousands or miles of kilometres as in radio communication. Wireless communication encompasses various types of networks such as fixed and mobile, portable two-way radios, mobile phones, PDAs, and so on. The mobile network industry has its beginnings in the 1970s. In recent decades, mobile technology has gone through 4 to 5 generations, labelled 1G, 2G, 3G, 4G and 5G. The mobile concept was introduced for the first time with 1G technology. Digital wireless communication improved with the use of 2G networks. Communication data besides voice communication has focused on 3G technology, which created a network that converged voice and data communication. 4G network specifications focus on the highest quality of services. Priorities are: better signal and less information and data lost during the exchange. 5G technology is a new mobile revolution in the mobile phone market, the 5G network provides opportunities for testing the quality of services and storing information in the mobile data terminal databases.

1.2 MIMO SYSTEMS

Wireless communication technology such as Wireless Local Area Network (WLAN) is an overgrowing standard for communication over indoor environments. Currently, the IEEE 801.11ac WLAN has the highest capacity at 5 GHz with data rates reaching 1.3 Gbps. The WLAN system uses wireless channels that are susceptible to some disruptions such as delay, attenuation, noise, interference, and fading that can degrade the network performance. The IEEE 801.11ac WLAN standard is supported by the Multiple Input Multiple Output (MIMO) system to improve performance and increase throughput up to 1 Gbps. However, MIMO systems have limitations of the size, cost, and complexity of the devices. Diversity technique is a method to overcome the influence of fading and increase system capacity. The MIMO system adopts this diversity technique, where information is transmitted through several paths to help the process of detection signal damage at the destination.

However, the MIMO system has limitations in practical application. Thus, another diversity technique has been studied, known as a cooperative communication system. In the system, the information signal is transmitted to several nearby relays, and the received signals by the relays are passed to the destination. This concept is also known as a virtual MIMO system. In general, the cooperative communication system is a promising technology for use on WLAN to improve the performance, capacity, and speed of data. In the future, mobile cooperative WLAN will support the development of 5G technology. Relay mechanism is a core part of the cooperative communication systems.

In general, there are three main relay protocols, including Amplify and Forward (AF), Decode and Forward (DF), and Quantize and Forward (QF). However, this paper focuses only on the AF relay protocol since it has a low complexity system and very easy to implement. In this protocol, relay only amplifies the received signal from the source and then forward it to the destination.

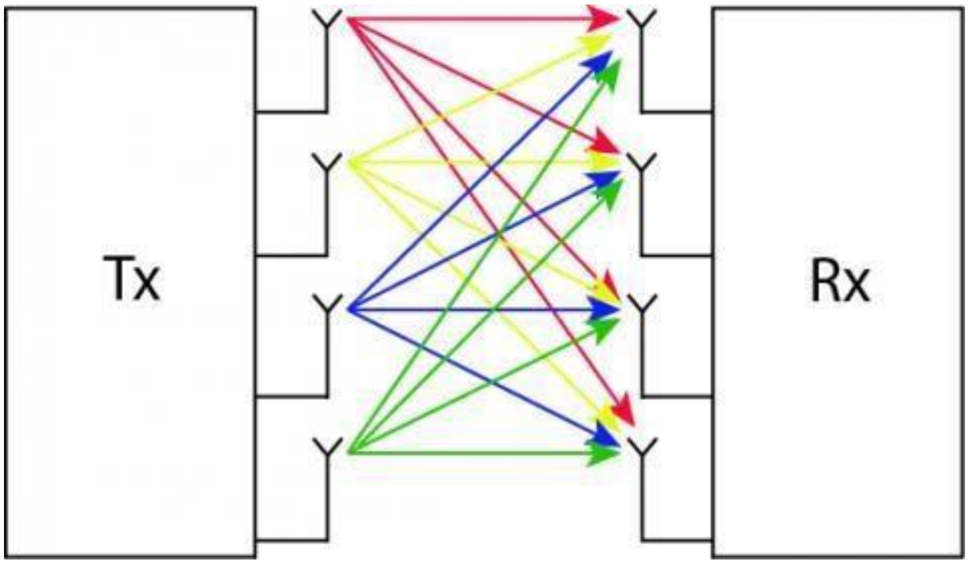
The AF relay has two types of protocols:

1.) Non-Orthogonal Amplify and Forward (NAF)

2.) Orthogonal Amplify and Forward (OAF).

NAF is a protocol that combines a non-orthogonal transmission at AF relay to generate high throughput with high signal strength and increase Diversity Multiplexing Tradeoff (DMT) to gain a more optimal transmission. The OAF is a protocol that combines orthogonal transmission with AF relay protocol to produce high Signal to Noise Ratio (SNR). The application of NAF and OAF to WLAN has been made in previous studies. However, these studies focus on a single-relay and one-way transmission for cooperative communication systems. Currently, WLAN technology required to provide multi-media services with high performance and data rates. Thus, the application of WLANs with two-way transmission modes and the help of many relays on cooperative communication systems are necessary and important to study.

Multi-relay communication systems in two-way mode have been proved to increase the throughput and spectral efficiency of the cooperative WLAN. This report examines the performance of multi-relay OAF (MR-OAF) and multi-relay NAF (MR-NAF) on a two-way WLAN cooperative network. To our best knowledge, there has been no application of the proposed system, especially for WLANs. The OAF protocol produces low computational complexity, reducing delay during transmission and can be classified according to Channel State Information (CSI) on relay nodes. The benefits of the proposed work can minimize outage probability and increase throughput, so finally can gain a faster transmission of the information.

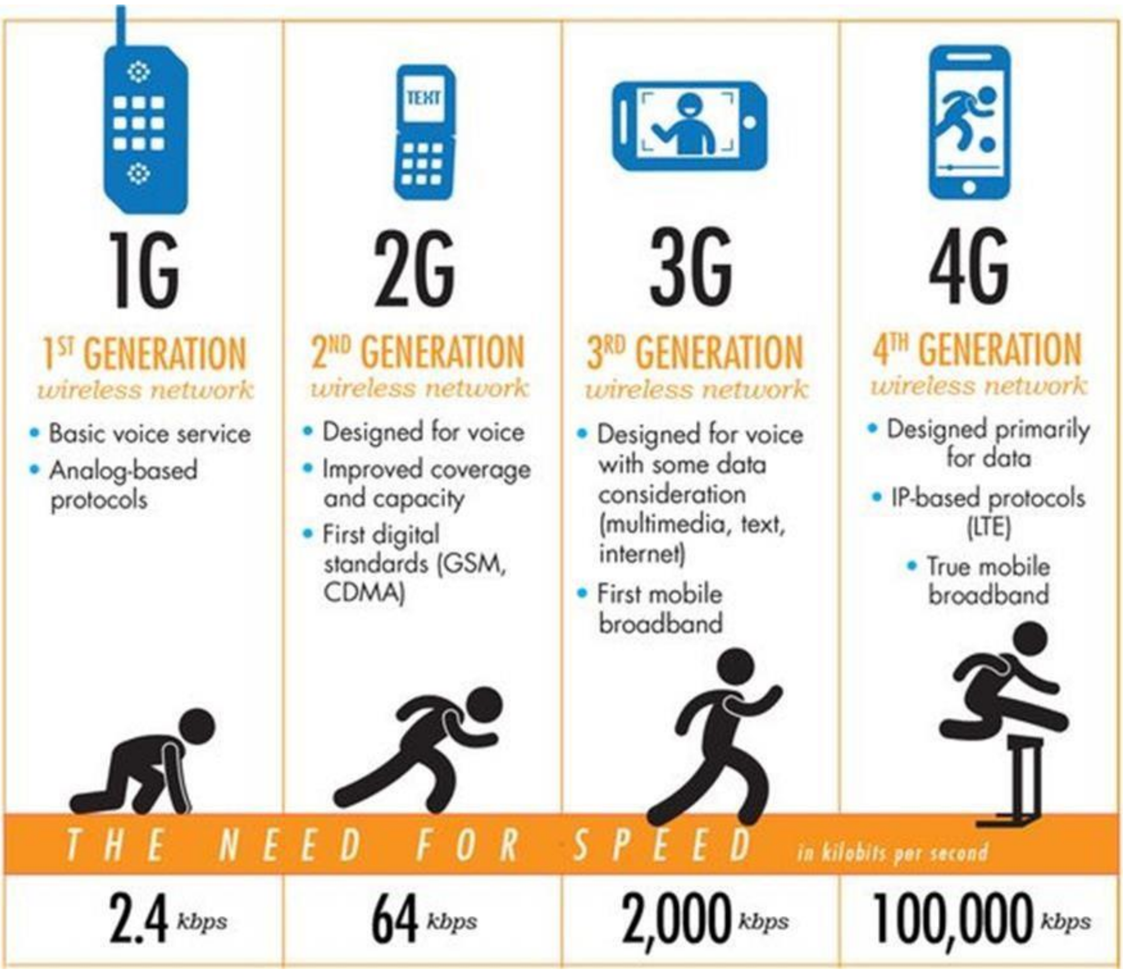


1.3 EVOLUTION OF MOBILE NETWORKS

Our analysis has shown that security policies and technology decisions made 25 years ago still determine the security level of mobile networks today. In other areas, such as Wi-Fi, the old technology security has disappeared and replaced with modern security technology. There is also a modern force where security technology is entering mobile networks, but for business and political reasons it seems impossible to curb old- fashioned technology. Finally, governments and mobile network operators can deploy sensors in specific geographic areas to detect attacks.

Comparison of the 2G and 3G-2G networks served as a revolutionary path where this newly-formed technology provided voice clearing and a transfer speed of up to 64 Kbps. Then came the 2.5G technology with a slightly higher speed up to 144 Kbps. Compared to the 2G network speed, 3G network speeds provided the video object as well as a much high.er speed where its speed reached up to 3Mbps, then it was enhanced with 3.5G, with its speed reaching 14.4 Mbps [1]. Comparison of 3G and 4G networks - In ITU-based or International Telecommunication Technology 3G technology allows operators to provide a greater range of services to the users as it becomes larger. Broadband wireless voice and wireless broadband information included within the mobile environment. While the 4G technology which was launched within the cable television industry in 2009, which make users explore new download speeds and capabilities.

The use of LTE broadband mobile technology is an opportunity for the corporation to expand its horizons on 4G territory, enhancing its current 3G capabilities [2]. Comparison of 4G and 5G networks - Technology is further shifted to 4G and has to do with a higher luxury of videos and providing a speed of up to 100 Mbps. While the technology that is expected to come into play is 5G which offers up to 1 Gbps speed. 5G is expected to make a significant difference where I will add services and benefits to the world built on 4G technology [3]. This technology is expected to be more advanced and accessible worldwide in wireless technology, and we will be able to connect your phone with laptop and have access in the Internet. This technology has a generous bandwidth where users have not had the opportunity to encounter before and possesses all the advanced features that it does as a powerful tool for a wireless device.



1.3.1 FIRST GENERATION

1G refers to the first generation of wireless cellular technology (mobile telecommunications). These are the analog telecommunications standards that were introduced in the 1980s and continued until being replaced by 2G digital telecommunications. The main difference between the two mobile cellular systems (1G and 2G), is that the radio signals used by 1G networks are analog, while 2G networks are digital.

Although both systems use digital signalling to connect the radio towers (which listen to the handsets) to the rest of the telephone system, the voice itself during a call is encoded to digital signals in 2G whereas 1G is only modulated to higher frequency, typically 150 MHz and up. The inherent advantages of digital technology over that of analog meant that 2G networks eventually replaced them everywhere.

One such standard is Nordic Mobile Telephone (NMT), used in Nordic countries, Switzerland, the Netherlands, Eastern Europe and Russia. Others include Advanced Mobile Phone System (AMPS) used in North America and Australia,[1] TACS (Total Access Communications System) in the United Kingdom, C-450 in West Germany, Portugal and South Africa, Radiocom 2000 in France, TMA in Spain, and RTMI in Italy. In Japan there were multiple systems. Three standards, TZ-801, TZ-802, and TZ-803 were developed by NTT (Nippon Telegraph and Telephone Corporation[2]), while a competing system operated by Daini Denden Planning, Inc. (DDI)[2] used the Japan Total Access Communications System (JTACS) standard.

The antecedent to 1G technology is the mobile radio telephone.

First Generation (1G): Refers to the non-cable telecommunication technology, known as the "cellphones", which is no longer present nowadays. Standards developed in the 1980s replaced the 0G technology with that 1G. The only service that was offered at that time was only voice communication, anyway, 1G has low capacity, low voice connection, and was considered unsafe since calls were made through the towers of radios.

1.3.2 SECOND GENERATION

2G (or **2-G**) is short for second-generation cellular network. 2G cellular networks were commercially launched on the GSM standard in Finland by Radiolinja (now part of Elisa Oyj) in 1991.[1] Three primary benefits of 2G networks over their predecessors were that:

1. phone conversations were digitally encrypted.
2. significantly more efficient use of the radio frequency spectrum enabling more users per frequency band.
3. Data services for mobile, starting with SMS text messages.

2G technologies enabled the various networks to provide the services such as text messages, picture messages, and MMS (multimedia messages). All text messages sent over 2G are digitally encrypted, allowing the transfer of data in such a way that only the intended receiver can receive and read it.

After 2G was launched, the previous mobile wireless network systems were retroactively dubbed 1G. While radio signals on 1G networks are analog, radio signals on 2G networks are digital. Both systems use digital signalling to connect the radio towers (which listen to the devices) to the rest of the mobile system.

With General Packet Radio Service (GPRS), 2G offers a theoretical maximum transfer speed of 40 kbit/s.[2] With EDGE (Enhanced Data Rates for GSM Evolution), there is a theoretical maximum transfer speed of 384 kbit/s.[2]

The most common 2G technology was the time division multiple access (TDMA)-based GSM, originally from Europe but used in most of the world outside North America. Over 60 GSM operators were also using CDMA2000 in the 450 MHz frequency band (CDMA450) by 2010.[3]

2.5G ("second and a half generation"[4]) is used to describe 2G-systems that have implemented a packet-switched domain in addition to the circuit-switched domain. It doesn't necessarily provide faster service because bundling of timeslots is used for circuit-switched data services (HSCSD) as well.

1.3.3 THIRD GENERATION

3G (short for third generation) is the third generation of wireless mobile telecommunications technology. It is the upgrade for 2.5G and 2.5G GPRS networks, for faster data transfer.[1] This is based on a set of standards used for mobile devices and mobile telecommunications use services and networks that comply with the International Mobile Telecommunications-2000 (IMT-2000) specifications by the International Telecommunication Union. 3G finds application in wireless voice telephony, mobile Internet access, fixed wireless Internet access, video calls and mobile TV.[1]

3G telecommunication networks support services that provide an information transfer rate of at least 144 kbit/s.[2][3][4] Later 3G releases, often denoted 3.5G and 3.75G, also provide mobile broadband access of several Mbit/s to smartphones and mobile modems in laptop computers. This ensures it can be applied to wireless voice telephony, mobile Internet access, fixed wireless Internet access, video calls and mobile TV technologies.

A new generation of cellular standards has appeared approximately every tenth year since 1G systems were introduced in 1979 and the early to mid-1980s. Each generation is characterized by new frequency bands, higher data rates and non–backward-compatible transmission technology. The first commercial 3G networks were introduced in 2001.

Enables network operators to provide users with a wide range of advanced services while reaching greater network capacity through improved spectrum efficiency. Services include broadband nonwireline telephony, video calling, and broadband wireless data. It reverses or replaces 2G and precedes 4G. 2.5G was a temporary bridge between 2G and 3G. 3G is mainly used with mobile phones. 3G technology offers other security features and services. The purpose of the 3G security architecture is to build an equivalent system with flexible adaptation of future changes. There is also a lot of confusion within the wireless network as to what exactly makes 3G, due to increased use by some 4G industry players. A number of so-called 4G technologies are in fact 3G technology developments.

1.3.4 FOURTH GENERATION

4G is the fourth generation of broadband cellular network technology, succeeding 3G. A 4G system must provide capabilities defined by ITU in IMT Advanced. Potential and current applications include amended mobile web access, IP telephony, gaming services, high-definition mobile TV, video conferencing, and 3D television.

The first-release Long Term Evolution (LTE) standard was commercially deployed in Oslo, Norway, and Stockholm, Sweden in 2009, and has since been deployed throughout most parts of the world. It has, however, been debated whether first-release versions should be considered 4G LTE.

In the field of mobile communications, a "generation" generally refers to a change in the fundamental nature of the service, non-backwards-compatible transmission technology, higher peak bit rates, new frequency bands, wider channel frequency bandwidth in Hertz, and higher capacity for many simultaneous data transfers (higher system spectral efficiency in bit/second/Hertz/site).

New mobile generations have appeared about every ten years since the first move from 1981 analog (1G) to digital (2G) transmission in 1992. This was followed, in 2001, by 3G multi-media support, spread spectrum transmission and, at least, 200 kbit/s peak bit rate, in 2011/2012 to be followed by "real" 4G, which refers to all-Internet Protocol (IP) packet-switched networks giving mobile ultra-broadband (gigabit speed) access.

While the ITU has adopted recommendations for technologies that would be used for future global communications, they do not actually perform the standardization or development work themselves, instead relying on the work of other standard bodies such as IEEE, WiMAX Forum, and 3GPP.

In the mid-1990s, the ITU-R standardization organization released the IMT-2000 requirements as a framework for what standards should be considered 3G systems, requiring 200 kbit/s peak bit rate. In 2008, ITU-R specified the IMT Advanced (International Mobile Telecommunications Advanced) requirements for 4G systems.

The fastest 3G-based standard in the UMTS family is the HSPA+ standard, which is commercially available since 2009 and offers 28 Mbit/s downstream (22 Mbit/s upstream) without MIMO, i.e. only with one antenna, and in 2011 accelerated up to 42 Mbit/s peak bit rate downstream using either DCHSPA+ (simultaneous use of two 5 MHz UMTS carriers)[3] or 2x2 MIMO. In theory speeds up to 672 Mbit/s are possible, but have not been deployed yet. The fastest 3G-based standard in the

CDMA2000 family is the EV-DO Rev. B, which is available since 2010 and offers 15.67 Mbit/s downstream.

Generic Terminology generally refers to a fundamental change in the nature of service. The 4G technology refers to all "IP packet switch" networks with super wide access (gigabit speeds) and "multi-carrier" transmissions. 4G generation priority is the best signal and less information and data lost during the exchange. The ITU has pointed out that 4G requires additional enhancements to MMS, including video services, in order to approve the next generation. ITU also requires interactive roaming between networks. 4G includes several standards under a common cover. 4G is the next generation after 3G. Currently, the security issue has been resolved using multiple layers of protocol encryption. There are shortages in power consumption and a great delay in transmission. In 4G there is a concept of interlayer security where only one layer will be configured to make data encryption.

1.3.5 FIFTH GENERATION

In telecommunications, 5G is the fifth generation technology standard for cellular networks, which cellular phone companies began deploying worldwide in 2019, the planned successor to the 4G networks which provide connectivity to most current cellphones.[1] Like its predecessors, 5G networks are cellular networks, in which the service area is divided into small geographical areas called *cells*. All 5G wireless devices in a cell are connected to the Internet and telephone network by radio waves through a local antenna in the cell. The main advantage of the new networks is that they will have greater bandwidth, giving faster download speeds,[1] eventually up to 10 gigabits per second (Gbit/s).[2] Due to the increased bandwidth, it is expected that the new networks will not just serve cellphones like existing cellular networks, but also be used as general internet service providers for laptops and desktop computers, competing with existing ISPs such as cable internet, and also will make possible new applications in IoT and M2M areas. Current 4G cellphones will not be able to use the new networks, which will require new 5G enabled wireless devices.

The increased speed is achieved partly by using higher frequency radio waves than current cellular networks.[1] However, higher frequency microwaves have a shorter range than the frequencies used by previous cell phone towers, requiring smaller cells. So to ensure wide service, 5G networks operate on up to three frequency bands, low, medium, and high.[3][1] A 5G network will be composed of networks of up to 3 different types of cell, each requiring different antennas, each type giving a different tradeoff of download speed vs distance and service area. 5G cellphones and wireless devices will connect to the network through the highest speed antenna within range at their location:

Low-band 5G uses a similar frequency range as current 4G cellphones, 600 - 700 MHz giving download speeds a little higher than 4G: 30-250 megabits per second (Mbit/s).[3] Low-band cell towers will have a similar range and coverage area to current 4G towers. Mid-band 5G uses microwaves of 2.5-3.7 GHz, currently allowing speeds of 100-900 Mbit/s, with each cell tower providing service up to several miles radius. This level of service is the most widely deployed, and should be available in most metropolitan areas in 2020. Some countries are not implementing lowband, making this the minimum service level. High-band 5G uses frequencies of 25 - 39 GHz, near the bottom of the milli meter wave band, to achieve download speeds of 1 - 3 gigabits per second (Gbit/s), comparable to cable internet. However milli meter waves (mmWave or mmW) only have a range of about 1 mile (1.6 km), requiring many small cells, and have trouble passing through some types of building walls. Due to their higher costs, current plans are to deploy these cells only in dense urban environments, and areas where crowds of people congregate such as sports stadiums and convention centres. The above speeds are those achieved in actual tests in 2020, speeds are expected to increase during rollout.[3]

The industry consortium setting standards for 5G is the 3rd Generation Partnership Project (3GPP).[1] It defines any system using 5G NR (5G New Radio) software as "5G", a definition that came into general use by late 2018. Minimum standards are set by the International Telecommunications Union (ITU). Previously, some reserved the term 5G for systems that deliver download speeds of 20 Gbit/s as specified in the ITU's IMT-2020 document.

It includes all kinds of advanced features that make the 5G technology more powerful. The 5G's overall vision is for PDAs, laptops and mobiles to use a union of Bluetooth, IEEE 802.11, and cellular standard from 1G to 4G as per user needs based on the type of application. Another aspect of 5G networks is that special services such as site-based services are automatically activated at the moment they are needed. The main emphasis of 5G networks is the collection of information that can be used to make decisions. 5G offers services in engineering, documentation, electronic transactions etc. Searching for new technology is always the main motive of leading giants of mobile phones to pass their competitors. The ultimate goal of 5G technology is to design a truly wireless world that is free from previous generation barriers. This requires networking and high security.

2. BACKGROUND

- Resource scheduling is a vast field. On one hand, the existing work deals with the multiparametric approaches to optimize throughput using methods such as estimation [2], prediction [3], resource allocation, machine learning, fuzzy logic [4], [5] and so on. While on the other hand, research has also focused on measurement wherein different algorithms are compared at different settings to find the best possible combination of inputs for a desired output [6], [7].
- Currently, the work has evolved when MIMO has taken the precedence over the existing techniques
- . With the combination of multiple input and output antenna arrays, it is feasible to achieve the higher throughput than the traditional transceivers when the beams are properly aligned. Moreover, using the software-based MIMO enabled using the mmWave [11], [12], it is possible to create a fully software defined system thus able to control and coordinate from anywhere.
- The software-based automation has provided more mean- ingful avenues for optimization than ever. The controllable experiments and practical systems can now run under a variety of settings that can be triggered or trimmed in short time. This flexibility encourages us to evaluate the feasibility of having a MIMO system that can be analyzed for different that can be dynamically changed to provide a real-time feedback to the system based upon user mobility and network fluctuations.

In this paper we evaluate the MIMO system for various parameters. The experiment considers the UE mobility and correlated with the network parameters to calculate the throughput while keeping QoS under considerations. Further, the system is evaluated with and without MIMO using a real mobility dataset. Our work is distinguished from earlier approaches as it lies at the intersection of evaluation-based enhancement for MIMO that is a key design choice in the 5G networks.

3. OBJECTIVE

It has been seen how important it is to have mobile networks in various fields. Usage of mobile networks have tremendous role in our day to day life. The networking techniques which will be used further in our lives will have a huge impact like say 5g and beyond. Satisfying quality of service (QoS) is absolute challenging in such a dense network for now, multiple technology like LTE, Wi-Fi and 5G. This project attempts to optimize the radio resource allocation in heterogeneous wireless networks in a particular area by finding the actual throughput while maintaining QoS. Specifically, the project uses different parameters like RSSI, RSRP, RSRQ in calculating the throughput of a user equipment in a specified area. It is observed that when the same is done in MIMO systems, there is a hike in the overall throughput. Enhancing the throughput using different values of the parameters is the main motive or the objective behind the project.

4. REVIEW OF LITERATURE

Technology and mobile networks are already existing as well as prominent aspects in future. Our motivation behind coming up with this project is to combine both these and to develop an integrated system that will monitor and track the user equipment in a local area with a particular network. To understand this, we will have to learn few concepts that include It includes

- LTE and LTE Scheduler
- LTE Scheduling Algorithms
- Resource Blocks
- Parameters of the signal

4.1 LTE and LTE Scheduler

In telecommunications, **Long-Term Evolution** (**LTE**) is a standard for wireless broadband communication for mobile devices and data terminals, based on the GSM/EDGE and UMTS/HSPA technologies. It increases the capacity and speed using a different radio interface together with core network improvements.[1][2] The standard is developed by the 3GPP (3rd Generation Partnership Project) and is specified in its Release 8 document series, with minor enhancements described in Release 9. LTE is the upgrade path for carriers with both GSM/UMTS networks and CDMA2000 networks. The different LTE frequencies and bands used in different countries mean that only multi-band phones are able to use LTE in all countries where it is supported.

LTE has been marketed both as "4G LTE" and as "Advanced 4G",[*citation needed*] but it does not meet the technical criteria of a 4G wireless service, as specified in the 3GPP Release 8 and 9 document series for LTE Advanced. LTE is also commonly known as **3.95G**. The requirements were originally set forth by the ITU-R organisation in the IMT Advanced specification. However, due to marketing pressures and the significant advancements that WiMAX, Evolved High Speed Packet Access, and LTE bring to the original 3G technologies, ITU later decided that LTE together with the aforementioned technologies can be called 4G technologies.[3] The LTE Advanced standard formally satisfies the ITU-R requirements to be considered IMT-Advanced.[4] To differentiate LTE Advanced and WiMAX-Advanced from current 4G technologies, ITU has defined them as "True 4G".

Long Term Evolution[7] and is a registered trademark owned by ETSI (European Telecommunications Standards Institute) for the wireless data communications technology and a development of the GSM/UMTS standards. However, other nations and companies do play an active role in the LTE project. The goal of LTE was to increase the capacity and speed of wireless data networks using new DSP (digital signal processing) techniques and modulations that were developed around the turn of the millennium. A further goal was the redesign and simplification of the network architecture to an IP-based system with significantly reduced transfer latency compared with the 3G architecture. The LTE wireless interface is incompatible with 2G and 3G networks, so that it must be operated on a separate radio spectrum.

LTE was first proposed in 2004 by Japan's NTT Docomo, with studies on the standard officially commenced in 2005.[8] In May 2007, the LTE/SAE Trial Initiative (LSTI) alliance was founded as a global collaboration between vendors and operators with the goal of verifying and promoting the new standard in order to ensure the global introduction of the technology as quickly as possible.[9][10] The LTE standard was finalized in December 2008, and the first publicly available LTE service was launched by TeliaSonera in Oslo and Stockholm on December 14, 2009, as a data connection with a USB modem. The LTE services were launched by major North American carriers as well, with the

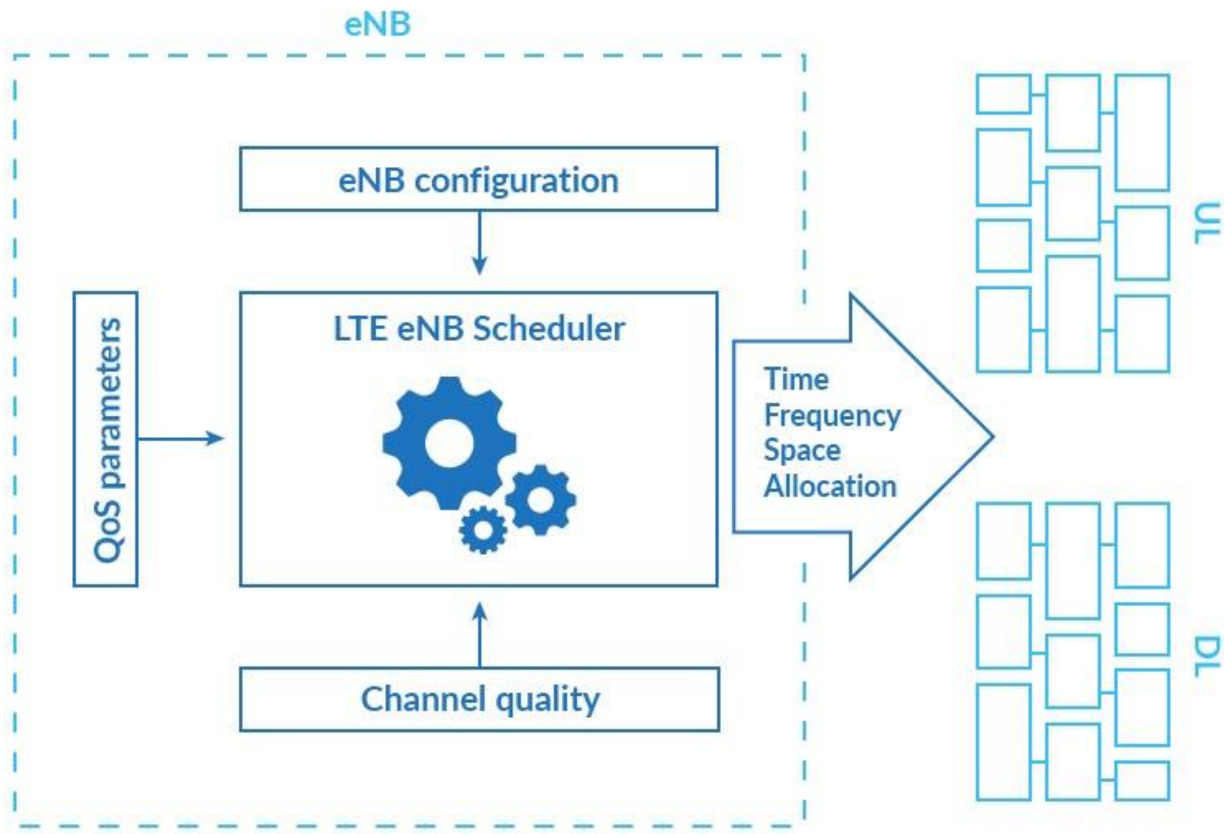
Samsung SCH-r900 being the world's first LTE Mobile phone starting on September 21, 2010,[11][12] and Samsung Galaxy Indulge being the world's first LTE smartphone starting on February 10, 2011,[13][14] both offered by MetroPCS, and the HTC ThunderBolt offered by Verizon starting on March 17 being the second LTE smartphone to be sold commercially.[15][16] In Canada, Rogers Wireless was the first to launch LTE network on July 7, 2011, offering the Sierra Wireless AirCard 313U USB mobile broadband modem, known as the "LTE Rocket stick" then followed closely by mobile devices from both HTC and Samsung.[17] Initially, CDMA operators planned to upgrade to rival standards called UMB and WiMAX, but major CDMA operators (such as Verizon, Sprint and MetroPCS in the United States, Bell and Telus in Canada, au by KDDI in Japan, SK Telecom in South Korea and China Telecom/China Unicom in China) have announced instead they intend to migrate to LTE. The next version of LTE is LTE Advanced, which was standardized in March 2011.[18] Services are expected to commence in 2013.[19] Additional evolution known as LTE Advanced Pro have been approved in year 2015.[20]

The LTE specification provides downlink peak rates of 300 Mbit/s, uplink peak rates of 75 Mbit/s and QoS provisions permitting a transfer latency of less than 5 ms in the radio access network. LTE has the ability to manage fast-moving mobiles and supports multi-cast and broadcast streams. LTE supports scalable carrier bandwidths, from 1.4 MHz to 20 MHz and supports both frequency division duplexing (FDD) and time-division duplexing (TDD). The IP-based network architecture, called the Evolved Packet Core (EPC) designed to replace the GPRS Core Network, supports seamless handovers for both voice and data to cell towers with older network technology such as GSM, UMTS and CDMA2000.[21] The simpler architecture results in lower operating costs (for example, each E-UTRA cell will support up to four times the data and voice capacity supported by HSPA).

Scheduling is a process through which eNodeB decides which UEs should be given resources (RBs), how much resource (RBs) should be given to send or receive data. In LTE, scheduling is done at per subframe basis i.e. every 1 milisecond. The entity which is govern this is known as **scheduler**.

A scheduler takes input from OAM as system configuration e.g. which scheduling algorithm is to be enable (round robin, Max C/I, Proportional Fair, QoS aware etc), consider QoS information (Which QCI, GBR/N-GBR etc.) and channel quality information (CQI, Rank, SINR etc) to make the decisions. A LTE scheduler performs following function for efficient scheduling:

- **Link Adaptation**: It selects the optimal combination of parameters such as modulation, channel Coding & transmit schemes i.e. Transmission Mode (TM1/TM2/TM3/TM4) as a function of the RF conditions.
- Rate Control: It is in charge of resource allocation among radio bearers of the same UE which are available at the eNB for DL and at the UE for UL.
- Packet Scheduler: It arbitrates access to air interface resources on 1ms-TTI basis amongst all active
  Users (Users in RRC Connected State).
- Resource Assignment: It allocates air interface resources to selected active users on per TTI basis.
- Power Control: Provides the desired SINR level for achieving the desired data rate, but also controls the interference to the neighbouring cells.
- HARQ (ARQ + FEC): It allows recovering from residual errors by link adaptation.

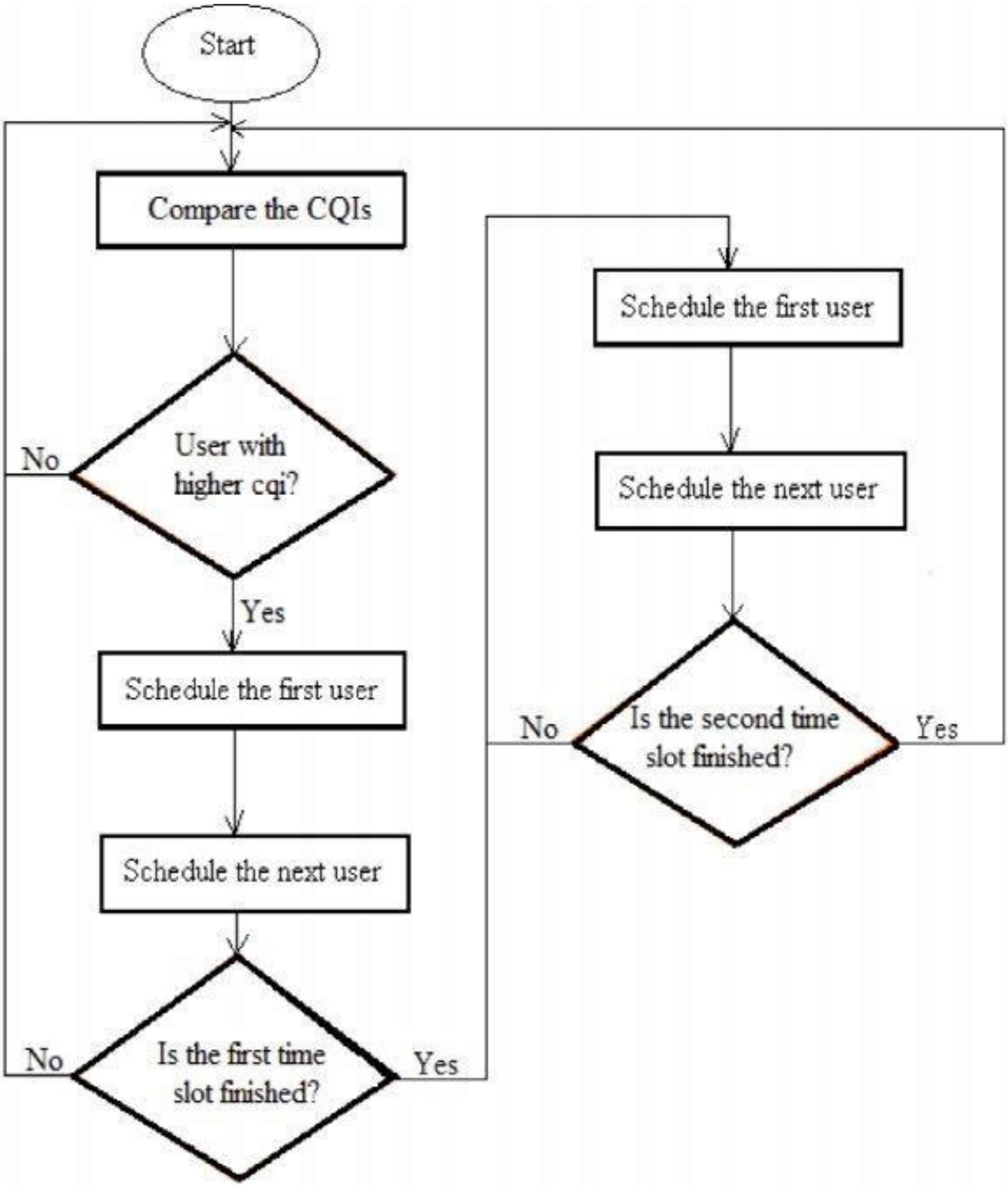


4.2 LTE SCHEDULING ALGORITHMS

In LTE system, the scheduling algorithms assume that the eNodeB would receive the CQI feedback, every TTI, as a matrix with dimensions Number_UEs x RB_grid_size. The value of each field in the matrix is the CQI feedback of each user for each RB [6]. The different scheduling algorithms are :

4.2.1 BEST CQI

Scheduler allocates the resource blocks to the UEs with highest CQI on RB during a TTI [15]. The best CQI algorithm is efficient, but it is not fair to all users. The UEs, such as those at the cell edges, which face bad channel conditions, will always not get RBs allocated. Hence such users always starve of radio resources, which is practically not acceptable. So, fairness should also be taken into account along with focus on spectral efficiency.

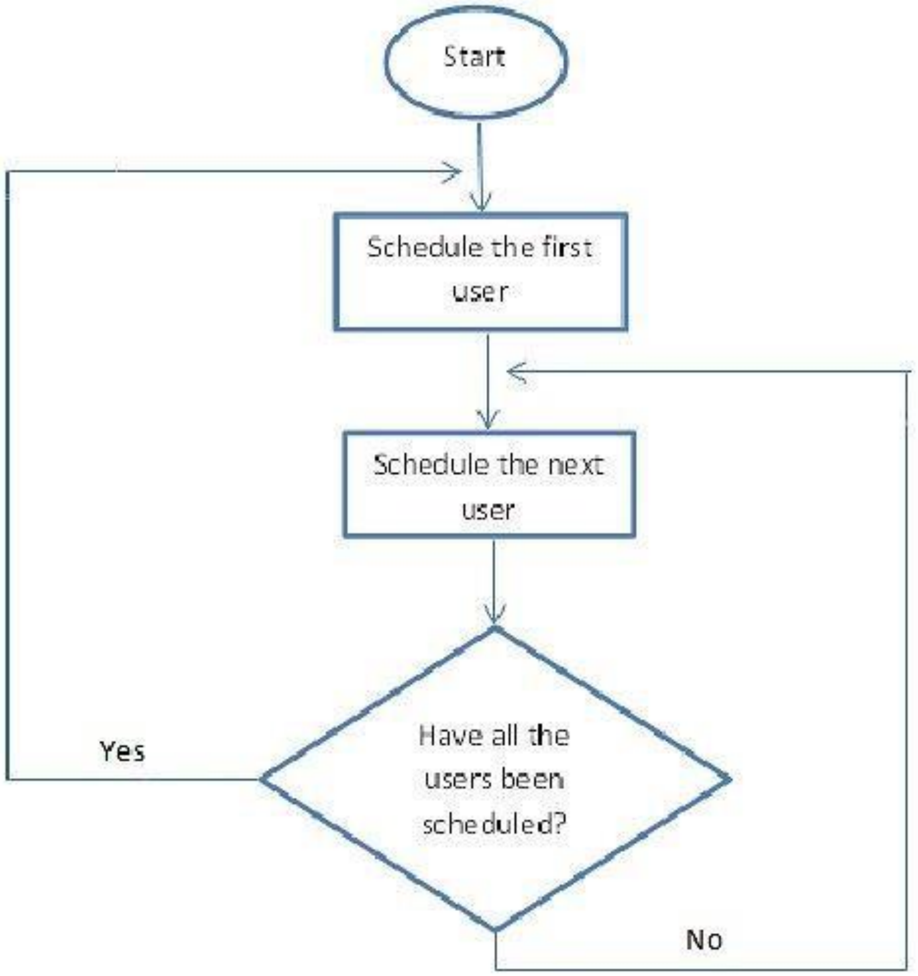


Flow chart of the B-CQI scheduler:

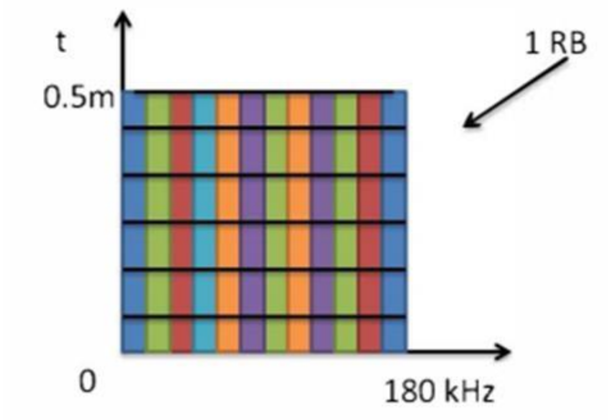
1. The base station sends the reference signals to the users.
2. The users compute the channel quality indicator.
3. If the channel quality indicator is the highest value, then the resource block is assigned to it; otherwise, it is not.
4. The resource block is given to the user equipment when they have the best CQI.

4.2.2 ROUND ROBIN SCHEDULING

In this scheduling algorithm, the CQI is not considered, and all the resource blocks are allocated irrespective of the channel conditions [7]. Hence, there will be lower throughput and more fairness. The scheduling is done according to the resource blocks available. The resource blocks are allocated to the users on a first come, first served basis. Implementation of this round robin algorithm is very easy and fairness is guarantees fairness [32]. The 35channel quality indicator is not taken into account and throughput of this scheduler is less when compared to the B-CQI scheduling algorithm.



4.3 RESOURCE BLOCKS

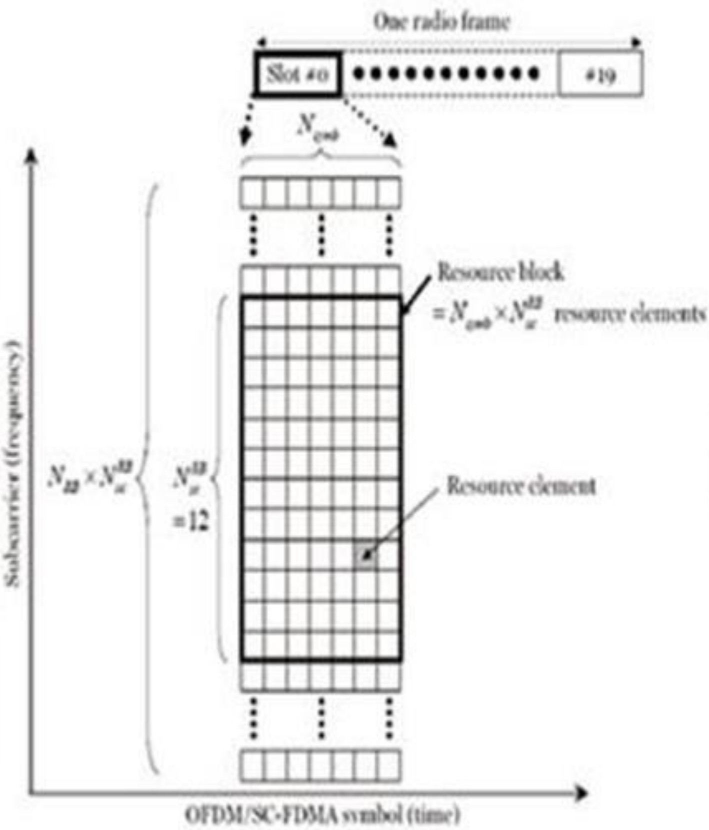


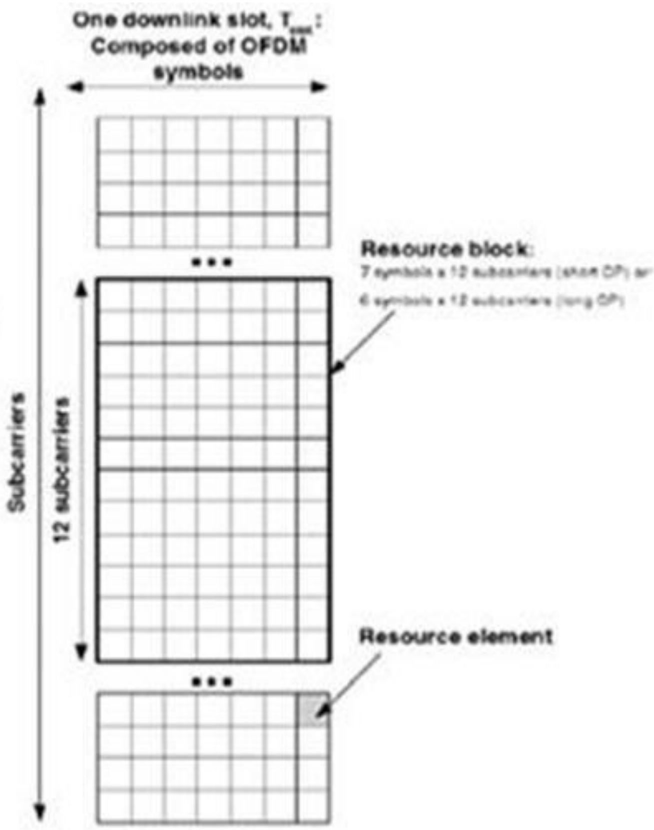
Each user is allocated a number of so-called resource blocks (RBs) in the time frequency grid. User's bit rate depends upon the number of RBs and the modulation scheme used [6]. The number of RBs and the kind of resource blocks a user gets allocated is purely dependent on the scheduling algorithm which we use in time and frequency dimensions.

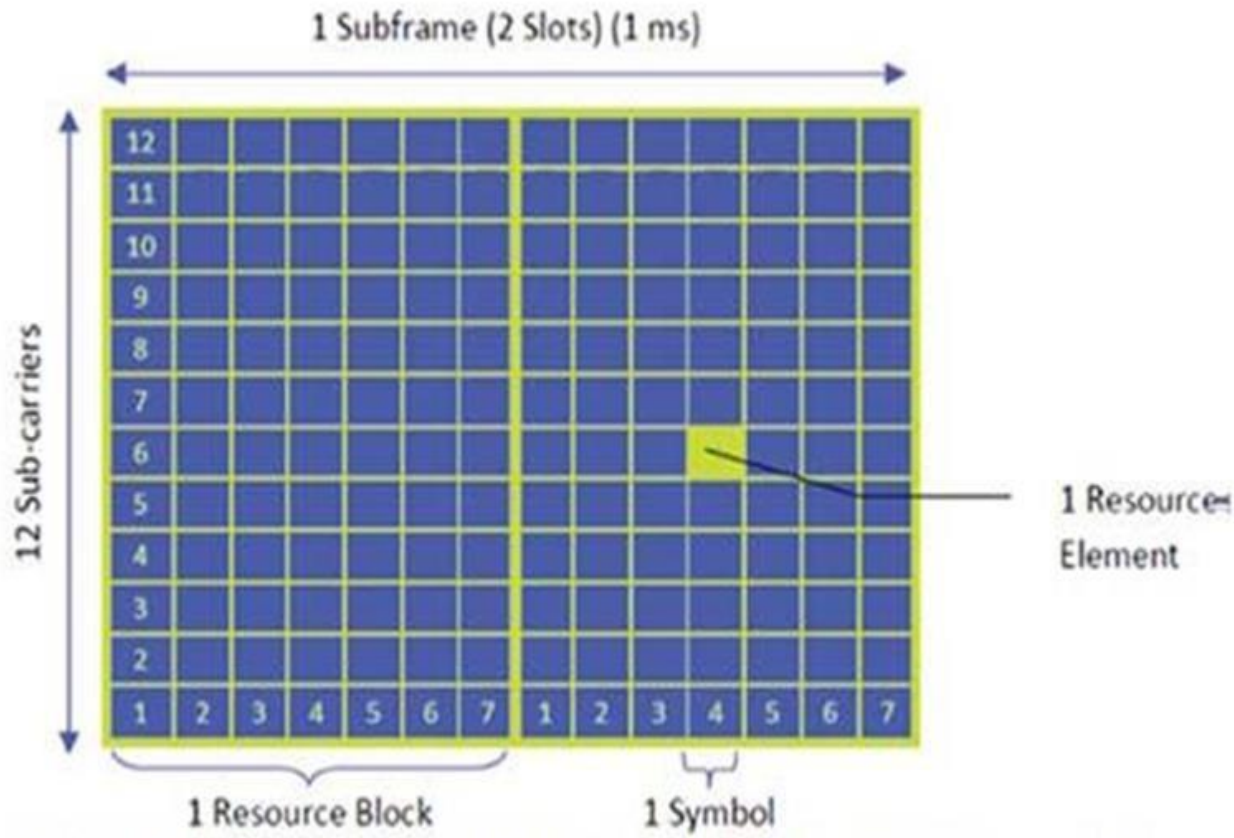
As shown in Fig. 1.1, physical resource block (PRB) is the basic block or unit of LTE and the allocation of all these PRBs is based on the scheduling algorithm at the evolved EnodeB (eNB). Each LTE sub-frame is of Ims duration and consists of two slots, with each slot being 0.5ms. Totally there are seven OFDM symbols in the time domain of each slot.

In control information or more specifically inside downlink control information (DCI), eNodeB sends the details of resources through which UE can decode its downlink data or UE can send their uplink data. Furthermore, the control information data is made up of CCE's and actual data information is composed of RBs [7].

LTE has 20 MHz bandwidth and 100 RBs. If eNB wants to allocate only 20 RB's to UE, the information inside DCI will enable UE to calculate exact RBs allocated to it. In case eNodeB needs to send 100 bits (each bit representing I RB), the procedure will increase control information data. In order to reduce the size of control information, LTE introduces different resource allocation strategies as follows: (I) Resource Allocation Type 0; (2) Resource Allocation Type I; (3) Resource Allocation Type 2 which can further be classified as either localized or distributed







RESOURCE BLOCK AND RESOURCE ELEMENT DEFINITION (NORMAL CP MODE)

The smallest time-frequency resource unit used for downlink/uplink transmission is called a resource element, defined as one sub-carrier over one OFDM/SC-FDMA symbol [107,116]. For both TDD and FDD duplex schemes, as well as in both downlink and uplink, a group of 12 sub-carriers contiguous in frequency over one slot in time form a Resource Block (RB), as shown in Figure 9-67 (corresponding to one slot in the time-domain and 180 kHz in the frequency-domain). Transmissions are allocated in units of resource blocks. One downlink/uplink slot using the normal CP length contains seven symbols. There are 6, 15, 25, 50, 75, and 100 resource blocks corresponding to 1.4, 3, 5, 10, 15, and 20 MHz channel bandwidths, respectively [107]. Note that the resource block size is the same for all bandwidths. The resource blocks are allocated in pairs in the time-domain by the scheduler.

5.METHODOLOGY

A. Inverse Weighted Fair Queuing (IWFQ)

The matrix entries must be swapped in order to account for BET and hence the weights associated with each entry will be directly proportional to throughput. Therefore, in this algorithm the resources are shared proportionately among users by taking inverse of their weights (premium or traffic classes) attached to it. The throughput values are inversed and stored in a matrix. Analytically, we show this as,

$$y_{i,l}^{IWFQ} = (1/w_i).\, y_{i,l}^{RR}$$

where, 'w_i' is the specific weight associated with the i^{th} user. '$y_{i,l}^{RR}$' is the specific RR metric for the i-th user and l^{th} resource block.

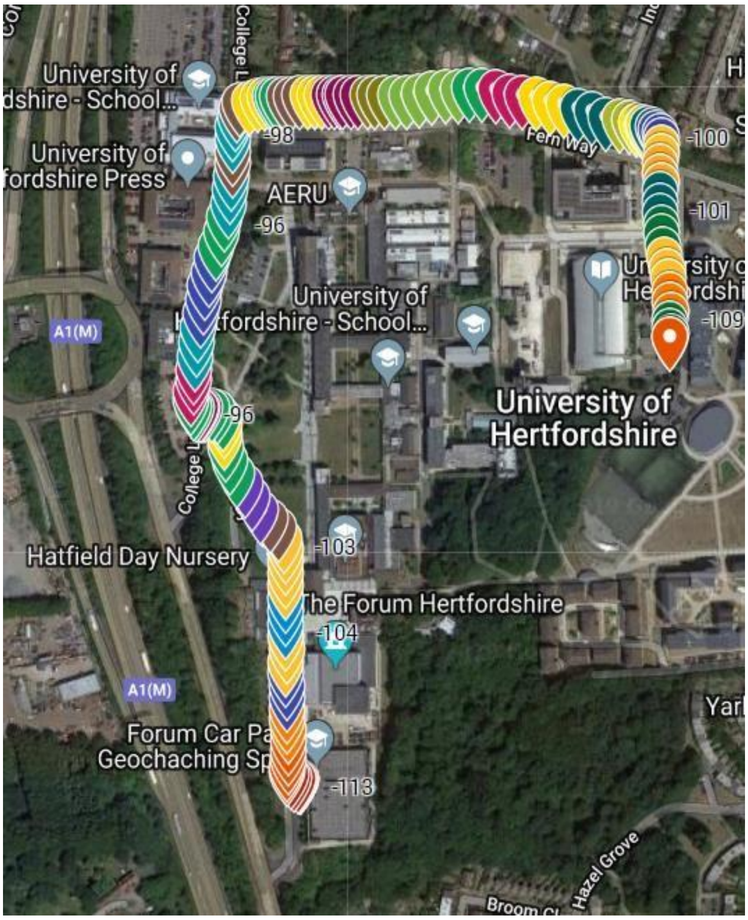
B. Proportional Inverse Weighted Fair Queuing (PIWFQ)

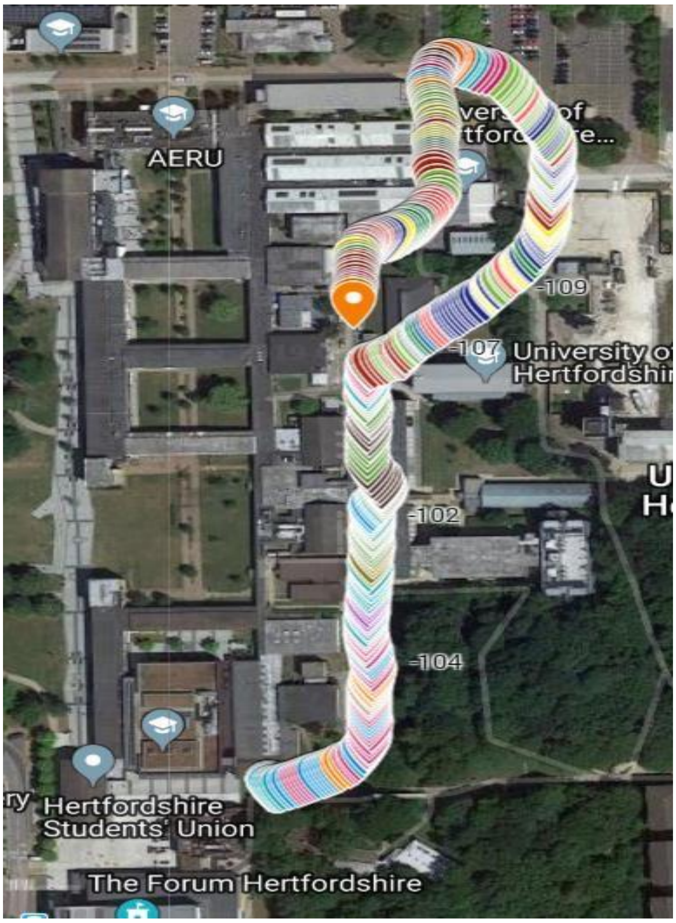
We consider here the advantageous part of all three algorithms, i.e. BET, PF and IWFQ method and thus, propose a novel PIWFQ method which can be shown as follows:

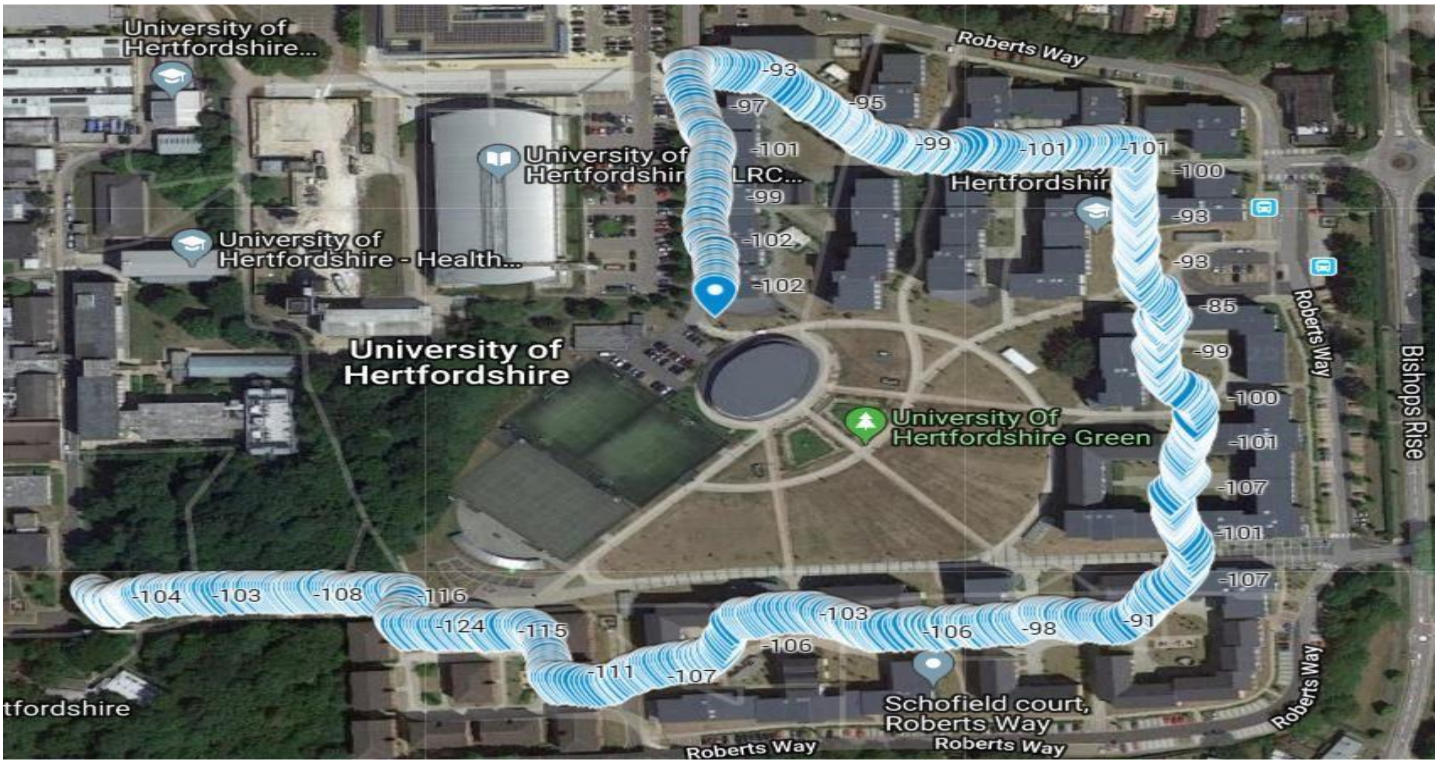
$$G_{i,l}^{PIWFQ} = G_{i,l}^{MT} . G_{i,l}^{BET} . y_{i,l}^{IWFQ} = \frac{g_l^i(T)}{f^i(T-1)} . \frac{1}{w_i} . y_{i,l}^{RR}$$

5.1 Plotting

The figures plotted below represent the locations, where we are calculating the Throughput.







5.1.1 PARAMETERS OF THE SIGNAL

The Project is based on the real data-set, where a person is moving in a particular location with respect to time. Then the data speed is calculated for the given location in terms RSSI, with the help of RSRP and RSRQ as explained below. These parameters play a very important role in determining the signal strength. We can easily plot, RSSI, RSRQ, RSRP for different measurement slot such as: x-axis (TIME i.e., person moving in a given location) and y-axis (measured and calculated RSSI, RSRQ, RSRP)

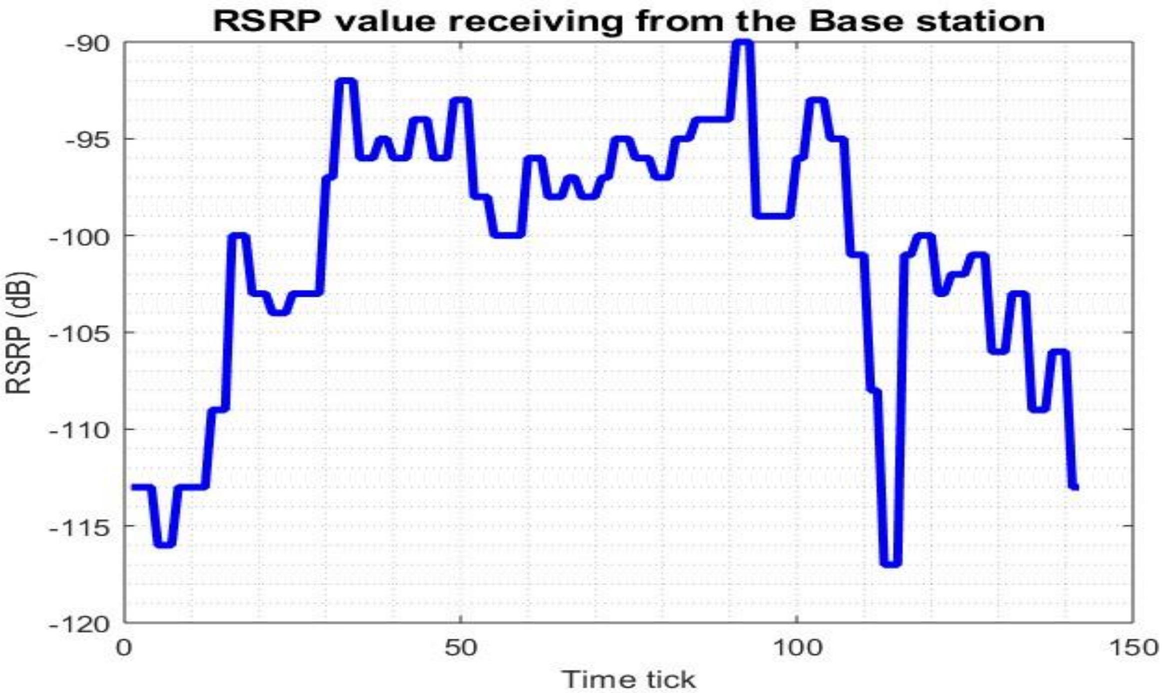
5.2.1 RSRP (REFERENCE SIGNAL RECEIVED POWER)

RSRP is the key measure of signal level and quality for modern LTE networks. In cellular networks, when a mobile device moves from cell to cell and performs cell selection/reselection and handover, it has to measure the signal strength/quality of the neighbour cells.

- RSRP does a better job of measuring signal power from a specific sector while potentially excluding noise and interference from other sectors.
- RSRP levels for usable signal typically range from about -75 dBm close in to an LTE cell site to -120 dBm at the edge of LTE coverage.

5.2.1.2 RSRP Plotting

Let's Plot the RSRP value Vs Time tick, that we are receiving from the Base Station in MATLB.



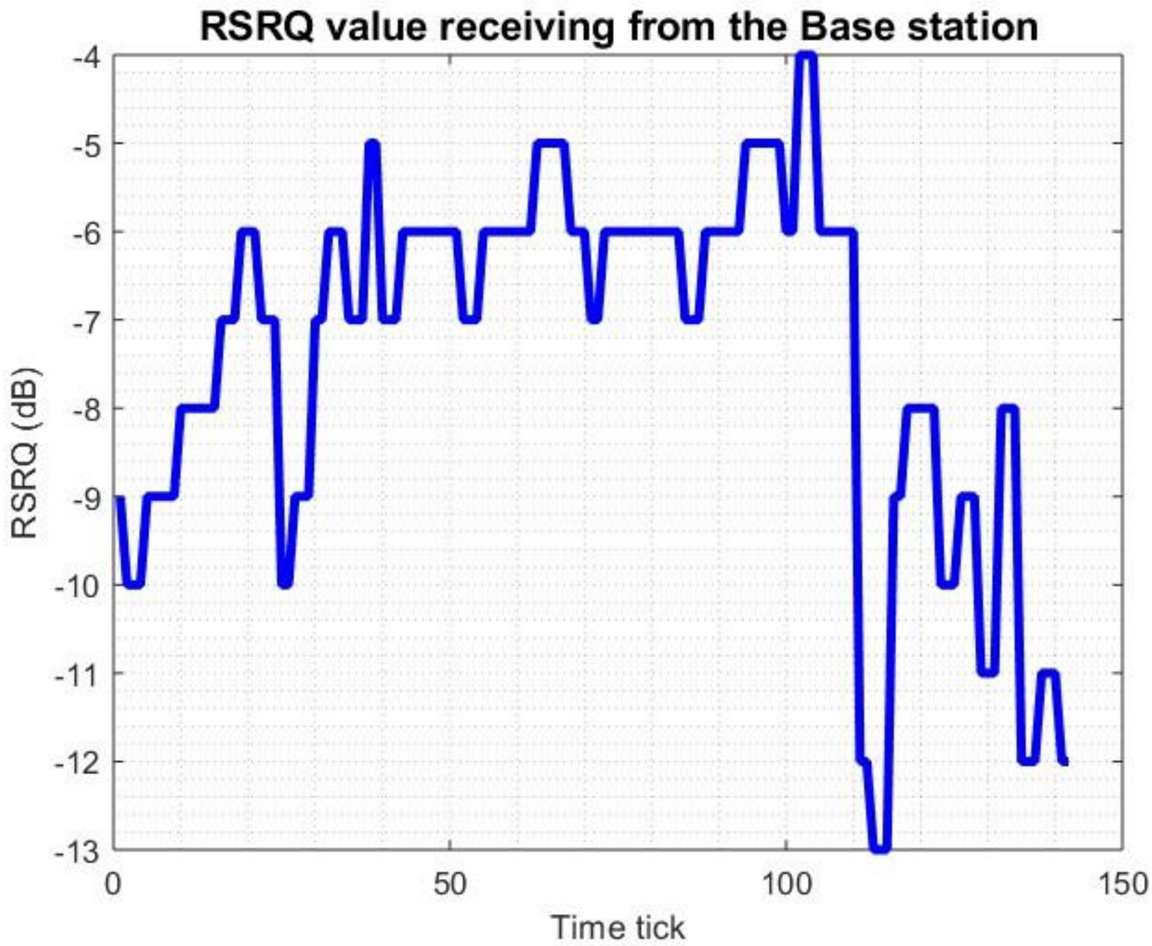
5.2.2 RSRQ (REFERENCE SIGNAL RECEIVED QUALITY)

Reference Signal Received Quality: Quality considering also RSSI and the number of used Resource Blocks (N) RSRQ = (N * RSRP) / RSSI

measured over the same bandwidth. RSRQ is a C/I type of measurement and it indicates the quality of the received reference signal. The RSRQ measurement provides additional information when RSRP is not sufficient to make a reliable handover or cell reselection decision.

5.2.2.2 RSRQ Plotting

Let's Plot the RSRQ value Vs Time tick, that we are receiving from the Base Station in MATLB



5.2.3.1 RSSI (REFERENCE SIGNAL STRENGTH INDICATOR)

RSSI represents the total received wide-band power measured over entire bandwidth by UE. RSSI is not reported to eNodeB. It is computed to be used for the calculation of RSRQ in LTE system. RSSI is also a power and its measurement unit are dBm same as RSRP.

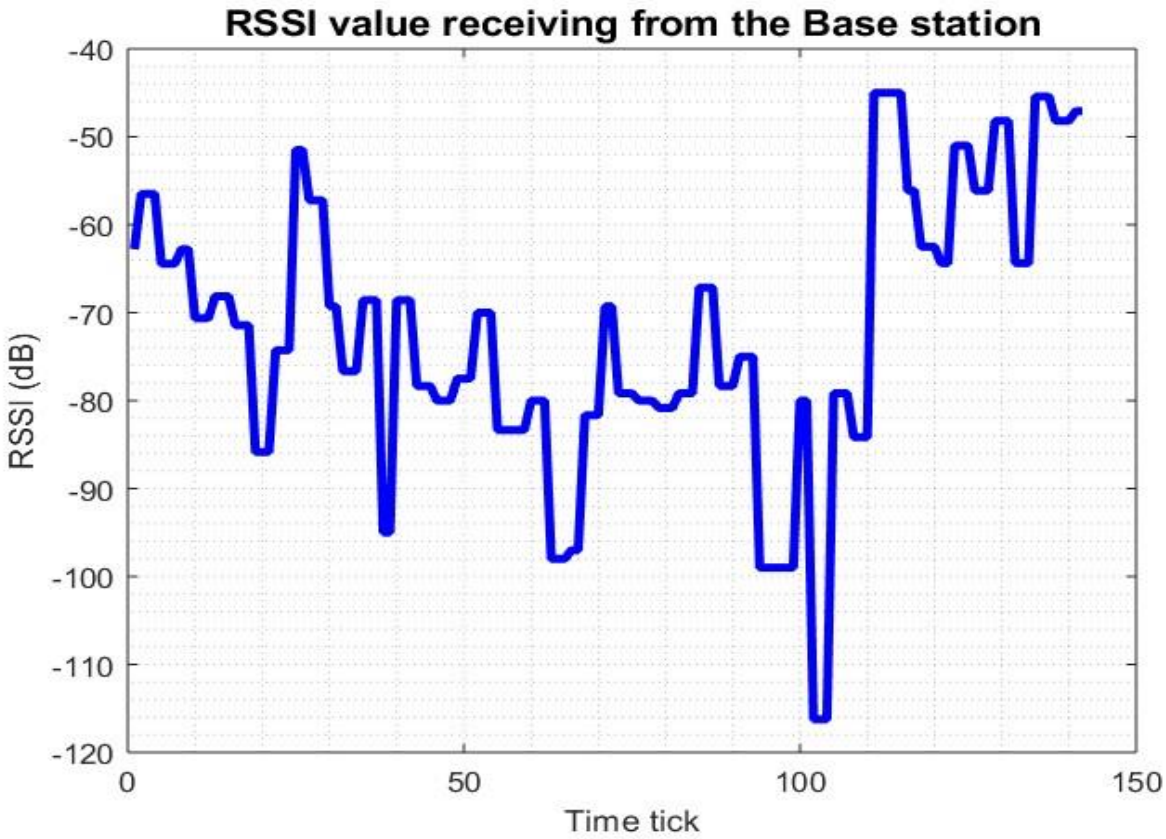
RSSI=Serving Cell Power + Neighbour Co-Channel Cells Power+ Thermal Noise

- RSSI varies with LTE downlink bandwidth. For example, even if all other factors were equal, VZW10MHz LTE bandwidth RSSI would measure 3dB greater than would Sprint 5MHz LTE bandwidth RSSI. But that does not actually translate to stronger signal to the end-user.

- RSSI varies with LTE subcarrier activity—the greater the data transfer activity, the higher the RSSI. But, again, that does not actually translate to stronger signal to the end user

5.2.3.2 RSSI Plotting

Let's Plot the RSSI value Vs Time tick, that we are receiving from the Base Station in MATLB.



5.2.4 SINR (SIGNAL TO INTERFERENCE NOISE RATIO)

SINR is a measure of signal quality as well but it is not defined in the 3GPP specs but defined by the UE vendor.

It is not reported to the network. SINR is used a lot by operators, and the LTE industry in general, as it better quantifies the **relationship between RF conditions and**

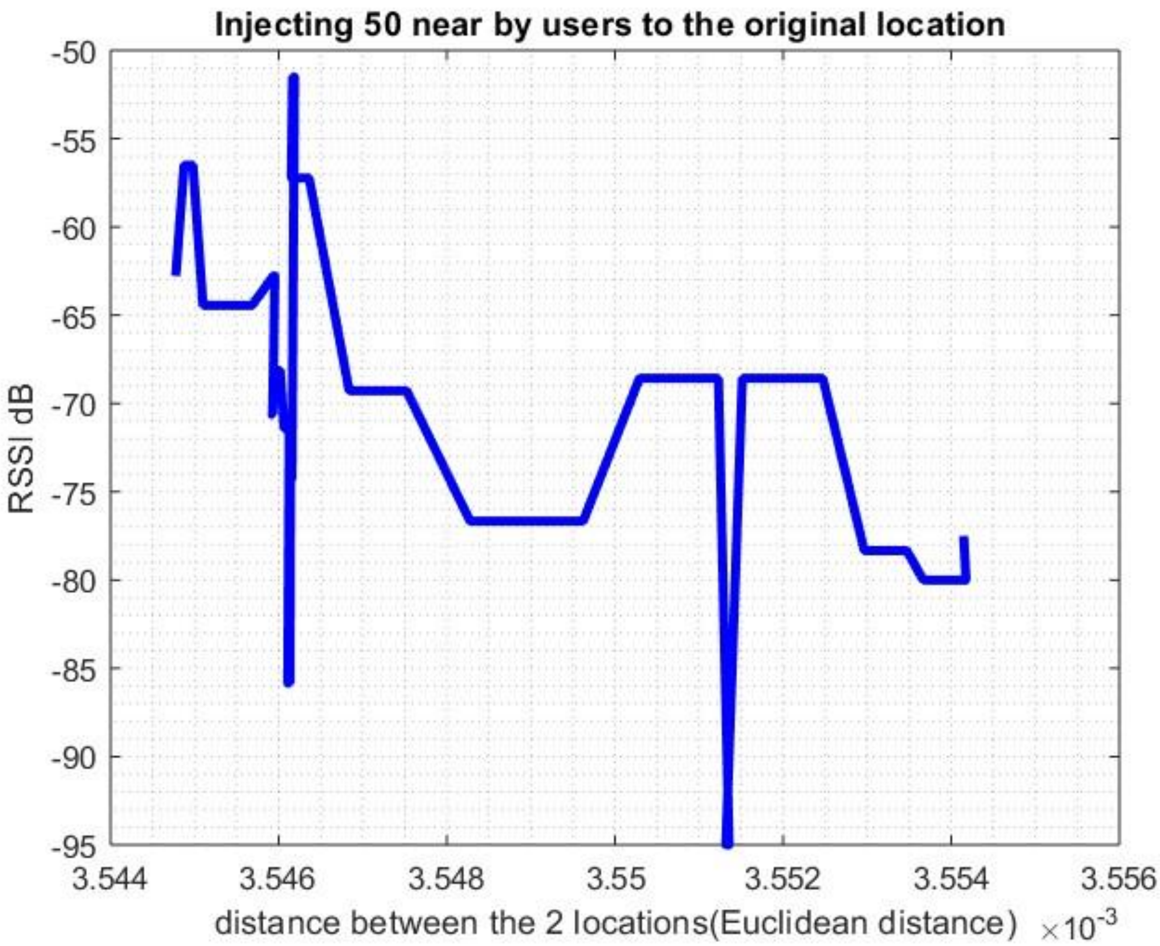
Throughput. LTE UEs typically use SINR to calculate the CQI (Channel Quality Indicator) they report to the network.

It is a common practice to use Signal-to-Interference Ratio (SINR) as an indicator for network quality. It should be however noted that 3GPP specifications do not define SINR and therefore UE does not report SINR to the network. SINR is still internally measured by most UEs and recorded by drive test tools.

		RSRP (dBm)	RSRQ (dB)	SINR (dB)
RF Conditions	Excellent	>=-80	>=-10	>=20
	Good	-80 to -90	-10 to -15	13 to 20
	Mid Cell	-90 to -100	-15 to -20	0 to 13
	Cell Edge	<=-100	<-20	<=0

5.2.5 INJECTING 50 USER TO THE GIVEN LOCATION

Now we have RSSI value of a given location, we have to inject 50 users to that location, to check whether we are getting same or different RSSI value in that location. It can be easily plotted with RSSI value along the Y-axis and Euclidean distance between original location and injected user location along the X-axis.



From the above plot we can say that, we almost got the nearby RSSI value for the injected users, as compared to the Original RSSI value that we got from the Base Station.

5.3 CQI (CHANNEL QUALITY INDICATOR)

After calculating the RSSI value for 50 users, now we are going to calculate the down-link data speed in terms Mbps for the 50 different users with the help of CQI value.

CQI: The Channel Quality Indicator (CQI) contains information sent from a UE to the eNode-B to indicate a suitable down-link transmission data rate, i.e., a Modulation and Coding Scheme (MCS) value.

CQI is a 4-bit integer and is based on the observed signal-to-interference-plus-noise ratio (SINR) at the UE.

The CQI estimation process takes into account the UE capability such as the number of antennas and the type of receiver used for detection.

RSSI	CQI	Modulation Scheme
Excellent	10- 15	64 QAM
Good	7-9	16 QAM
Fair	1-6	QPSK
Poor	0	Out of Range

TABLE I
MODULATION SCHEME BASED ON CQI VALUE

5.4 CHOOSING THE BANDWIDTH

CQI value determines the how good or bad the signal is. Based on the CQI value Modulation Scheme is assigned. As given in the table I. After determining the Modulation Scheme with the help of CQI value, we need to choose the Bandwidth (M Hz) based on the Number of resource blocks. As given in the table below.

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

Based on the Modulation Scheme, a random Modulation index is assigned by the eNodeB and according to that index value, a respective TBS (Transport Block Size) index value is assigned. As given in the table below.

MCS Index	Modulation	TBS Index
0	QPSK	0
1		1
2		2
3		3
4		4
5		5
6		6
7		7
8		8
9		9
10	16QAM	
11		10
12		11
13		12
14		13
15		14
16		15
17	64QAM	15
18		16
19		17
20		18
21		19
22		20
23		21
24		22
25		23
26		24
27		25
28		26
29	QPSK	Reserved
30	16QAM	
31	64QAM	

In order to calculate the Throughput, we need to know how many bits/subframe is allowed for the given TBS index and Number of Physical Resource Blocks and these values are allocated by the eNodeB based on the traffic, UE category and RF conditions. A standard bits/subframe are allocated in 3GPP for different resource blocks and TBS index value as given in the table IV below for 50 and 100

TRANSPORT BLOCK SIZE TABLE

I TBS	N PRB									
	41	42	43	44	45	46	47	48	49	50
0	1128	1160	1192	1224	1256	1256	1288	1320	1352	1384
1	1480	1544	1544	1608	1608	1672	1736	1736	1800	1800
2	1800	1864	1928	1992	2024	2088	2088	2152	2216	2216
3	2408	2472	2536	2536	2600	2664	2728	2792	2856	2856
4	2984	2984	3112	3112	3240	3240	3368	3496	3496	3624
5	3624	3752	3752	3880	4008	4008	4136	4264	4392	4392
6	4264	4392	4584	4584	4776	4776	4968	4968	5160	5160
7	4968	5160	5352	5352	5544	5736	5736	5992	5992	6200
8	5736	5992	5992	6200	6200	6456	6456	6712	6968	6968
9	6456	6712	6712	6968	6968	7224	7480	7480	7736	7992
10	7224	7480	7480	7736	7992	7992	8248	8504	8504	8760
11	8248	8504	8760	8760	9144	9144	9528	9528	9912	9912
12	9528	9528	9912	9912	10296	10680	10680	11064	11064	11448
13	10680	10680	11064	11448	11448	11832	12216	12216	12576	12960
14	11832	12216	12216	12576	12960	12960	13536	13536	14112	14112
15	12576	12960	12960	13536	13536	14112	14688	14688	15264	15264
16	13536	13536	14112	14112	14688	14688	15264	15840	15840	16416
17	14688	15264	15264	15840	16416	16416	16992	17568	17568	18336
18	16416	16416	16992	17568	17568	18336	18336	19080	19080	19848
19	17568	18336	18336	19080	19080	19848	20616	20616	21384	21384
20	19080	19848	19848	20616	20616	21384	22152	22152	22920	22920
21	20616	21384	21384	22152	22920	22920	23688	24496	24496	25456
22	22152	22920	22920	23688	24496	24496	25456	25456	26416	27376
23	23688	24496	24496	25456	25456	26416	27376	27376	28336	28336
24	25456	25456	26416	26416	27376	28336	28336	29296	29296	30576
25	26416	26416	27376	28336	28336	29296	29296	30576	31704	31704
26	27376	27376	28336	29296	29296	30576	31704	31704	32856	32856

6.

RESULTS and DISCUSSION

6.1 THROUGHPUT CALCULATION

Now we know the MCS index, TBS index, CQI value and PRBs. Let's calculate the Throughput.

Let's say RSSI is Excellent ,so we can choose the Modulation Scheme as 64 QAM as given in the table I. For a 64 QAM a random MCS index value is allocated by the eNodeB as well as PRBs. Let's say MCS index 28,then the respective TBS index value 26 will be chosen as given in the table III. We are considering the 50 PRBs, so for 26 TBS index value 32856 bits/subframe (1ms) is allocated to the user.

Therefore 32856*1000=32856000 bits/sec.

=32.85 Mbps i.e, for a 10 MHz bandwidth we are getting approx 32Mbps Throughput, assuming all the 50 resource blocks are given to one user. We can enhance or increase the throughput with the help of MIMO technology.

MIM0: Multiple Input Multiple Output

Consider 101101 data is transmitted through a channel with deep fades. Due to fluctuations in the channel quality, the data stream may get lost or severely corrupted that the receiver cannot recover it. The solution to combat the rapid fluctuation is to, add independent fading channels by increasing the number of Transmitting or Receiver Antenna or Both.So in brief spacial diversity technique, where same information sent or receive across independent channel to combat fading. The Diversity Gain =Number of transmitting antenna * Number of receiving antenna.

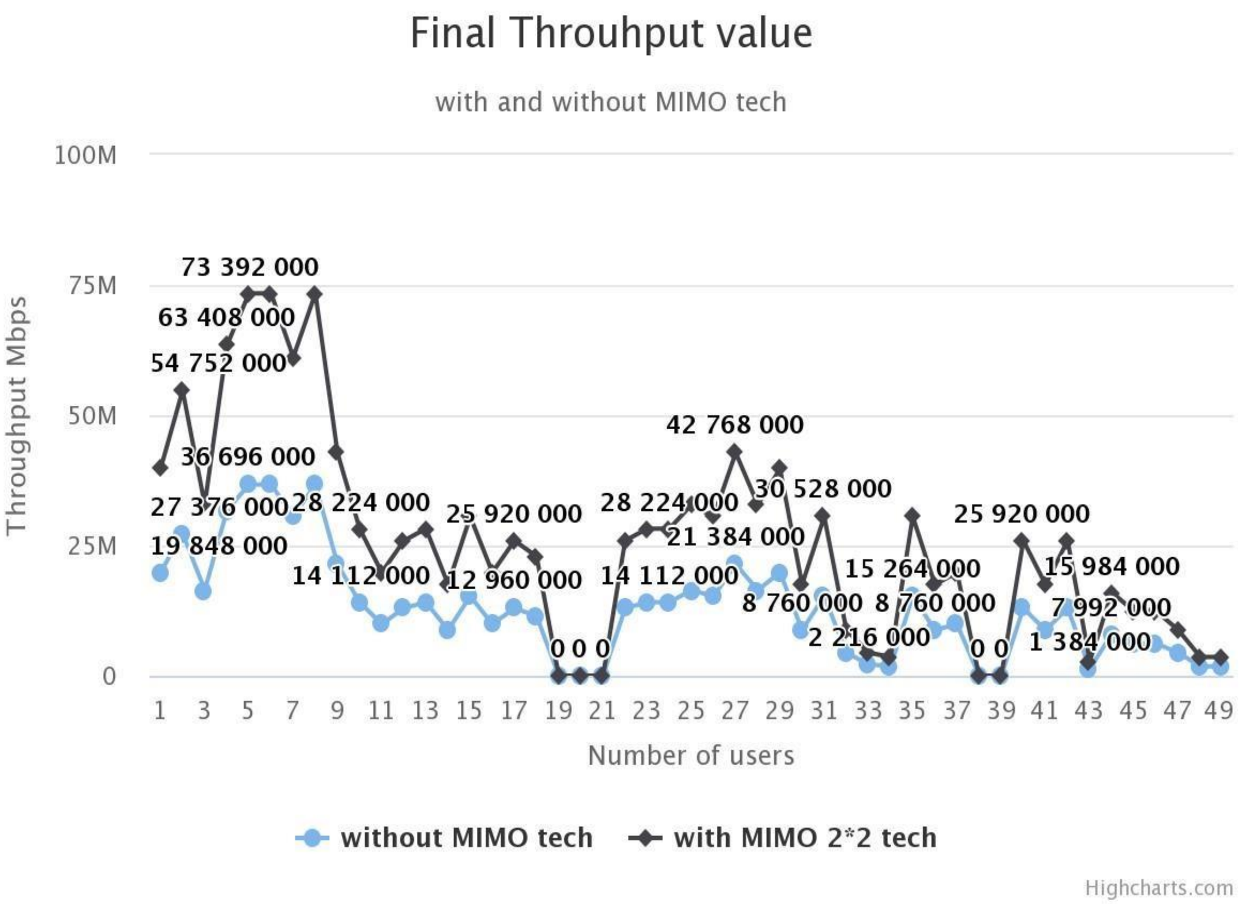
Which is equal 1. Let's increasing Tx and Rx antenna by 2.

Therefore, the Diversity Gain =2*2. Adding the independent fading channel increases the Reliability of the transmission link. Therefore if we use this MIMO 2*2 technology for calculating the same Throughput for above mentioned i.e instead of 32 Mbps the user will get approx, 75 Mbps.

6.2 SIMULATION

The Simulation is done for calculating the Throughput for, with and without MIMO technology, same as explained in the methodology. The entire procedure to calculate throughput, is written as code in JavaScript using a Visual Studio Code. NPM (node package manager) Run-time environment is used, to run the code. High chart is used to plot the simulated graph and Localhost:8000 is used to show the simulated output in a browser.

We have injected 50 users and calculated RSSI value for these users, as explained in the methodology. And we need to calculate Throughput for these users with and without MIMO technology, procedure is explained in the Throughput Calculation section.



Final Throughput value AVERAGE for without MIMO Tech : 12563200

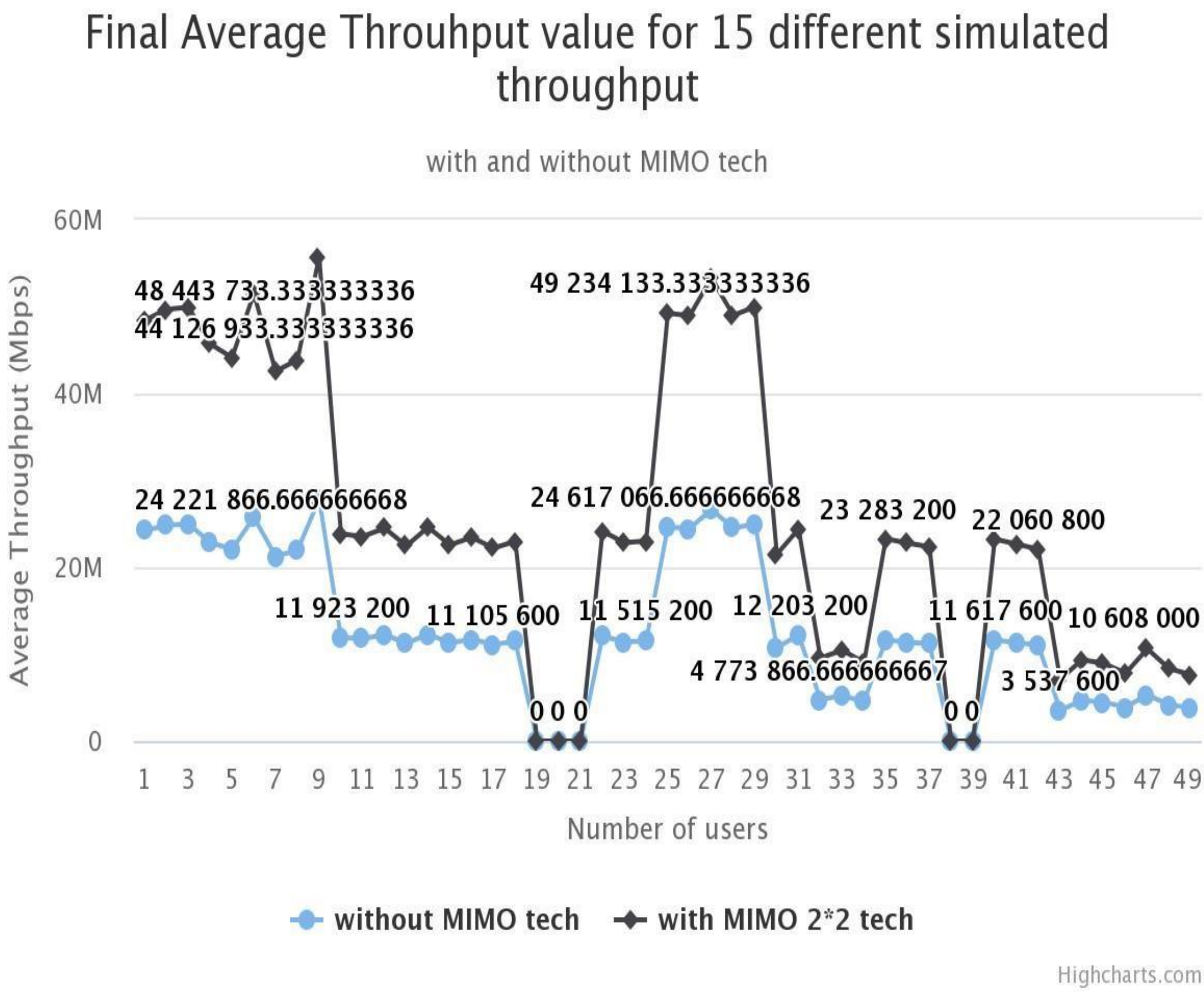
Final Throughput value AVERAGE for with MIMO Tech :25126400

From the above the simulated graph, we can say that Throughput is doubled when we are using the MIMO 2*2 technique as compared to without MIMO technique.

Because of the MCS index value is randomly given by the Base station as explained in methodology. So, we will get different Throughput value each time we run the code.

Therefore, let's run the code for 15 times and take average for those 15 different simulated throughputs and show the simulation using the same High chart.

The below figure shows the same.



7. CONCLUSION

Mobile networks have tremendous role in our day to day life. In the currently evolving networks such as 5G, satisfying quality of service (QoS) is a challenging problem due to the dense network deployment. Moreover, multiple technology such as LTE, Wi-Fi and 5G contending and cooperating make the resource al- location a complex problem. This paper attempts to optimize the radio resource allocation in heterogeneous wireless networks in a particular geographical region by finding the throughput while maintaining QoS using a combination of network parameters. Specifically, the paper uses different parameters such as RSSI, RSRP, RSRQ in calculating the throughput of a user equipment in a specified area. The feedback enabled method (FETE) is then compared with and evaluated for the MIMO system where it is observed that an overall throughput gain can be obtained when using right optimization technique for different parameters

After the calculation of the throughput using the MCS index, TBS index, CQI value and the PRBs it has been observed that the overall gain of the throughput is much increased for the MIMO in comparison to that of the one without MIMO. Comparison of the feedback enabled method with that of the evaluation of the MIMO systems where in the throughput is achieved with the absolute amount of optimization that leads to great efficiency.

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FETE: Feedback Enabled Throughput Evaluation for MIMO Emulated over 5G Networks

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***Abstract*—Mobile networks have tremendous role in our day to day life. In the currently evolving networks such as 5G, satisfying quality of service (QoS) is a challenging problem due to the dense network deployment. Moreover, multiple technology such as LTE, Wi-Fi and 5G contending and cooperating make the resource allocation a complex problem. This paper attempts to optimize the radio resource allocation in heterogeneous wireless networks in a particular geographical region by finding the throughput while maintaining QoS using a combination of network parameters. Specifically, the paper uses different parameters such as RSSI, RSRP, RSRQ in calculating the throughput of a user equipment in a specified area. The feedback enabled method (FETE) is then compared with and evaluated for the MIMO system where it is observed that an overall throughput gain can be obtained when using right optimization technique for different parameters.**

***Index Terms*—MIMO, LTE, 5G, Network Evaluation, Throughput, Scheduling**

I. Introduction

The tremendous growth of 5G due to its better performance in terms of capability, capacity, data-rate, and latency when compared with other co-existent technologies such as 3G, LTE and LTE-Advanced, is incomparable. The rapidly evolving 5G networks have the risk of overcrowding the frequency range of wireless spectrum as multitude of devices attempt to connect to a single frequency channel. Furthermore, the overly-dense deployment of 5G present complex challenges when accompanied with the heterogeneity, scale and diverse quality of service (QoS) requirements.

Existing techniques of throughput optimization depend upon maximizing the usage of available network resources. However, due to lack the optimizations based on a geographical region while using MIMO leave some resources non-utilized or under-utilized specifically when paired with the user mobility. Therefore, there is a need to use better techniques which can support the increase in the overall throughput received by the user equipment (UEs) which are mobile. Several schemes are proposed in the literature for improving throughput using different parameters such as channel quality indicator (CQI), round robin (RR) scheduling for UEs resource blocks (RBs), first in first out (FIFO) based on UE connections, and blind equal throughput (BET) to achieve fairness [1]. Despite these approaches, the QoS is always constrained due to inherently low resources available to fulfill the usage requirements specifically when targeting high throughput and low-latency applications. The resource scarcity in part is addressed using relatively newer efficient solutions that optimize the use of resources based on machine learning and other estimation techniques. Depending on the QoS, these techniques can be classified as user-based or network-based or both.

The existing techniques among other factors, also lack an integrated approach or the systems view when dealing with the scarce resources. For example, the BET scheduler aims to provide equal throughput to all UEs under a eNB which in turn lacks the fairness or support to a specific application that is resource hungry. The RR scheduling or best CQI again fails to enhance the throughput of the UEs when additional inputs are required to be captured to provide a holistic view on the network.

To optimize upon the available resources and provide an optimal output for the throughput using the inputs from UEs in a particular area a closed loop feedback based system is essential. In such a system, the additional inputs can be seamlessly added that play critical role in increasing the overall throughput and supporting low-latency. Supporting these views of inputting additional inputs to improve the throughput, in this paper we propose how to optimize the mobile networks for a multiplicity of parameters for the mobile UEs. Furthermore, 5G studies are incomplete without a discussion on MIMO. Therefore, we evaluate the system for the MIMO and show that additional improvements can be obtained using the same. Figure 1 shows that there is a potential of throughput improvement when considering multiple parameters along with the MIMO capabilities when a feedback based mechanism is used. This paper proposes FETE, a feedback enabled throughput evaluation method for the MIMO systems.

The rest of the paper is organized as follows. Section 2 summarizes the existing techniques used previously in the literature. Section 3 illustrates the experiment methodology to evaluate the throughput performance. Section 4 details the simulations carried out to calculate the throughput, with or without MIMO by injecting a number of users. The evaluation results are presented in Section 5. Section 6 concludes the

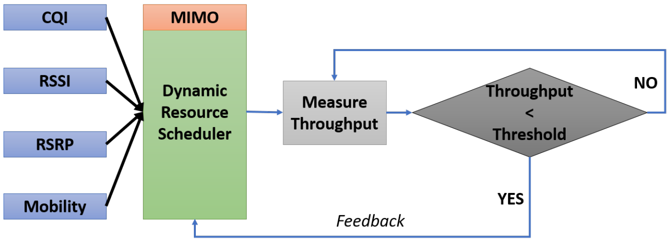

Fig. 1. Feedback Based Throughput Improvement in 5G

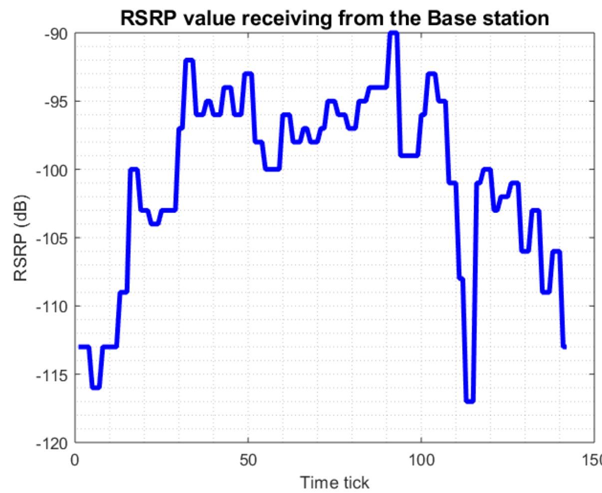

Fig. 2. RSRP Values Received at a UE from the Base Station

paper with a view on our future work.

II. Background

Resource scheduling is a vast field. On one hand, the existing work deals with the multi-parametric approaches to optimize throughput using methods such as estimation [2], prediction [3], resource allocation, machine learning, fuzzy logic [4], [5] and so on. While on the other hand, research has also focused on measurement wherein different algorithms are compared at different settings to find the best possible combination of inputs for a desired output [6], [7].

Currently, the work has evolved when MIMO has taken the precedence over the existing techniques

. With the combination of multiple input and output antenna arrays, it is feasible to achieve the higher throughput than the traditional transceivers when the beams are properly aligned. Moreover, using the software based MIMO enabled using the mmWave [11], [12], it is possible to create a fully software defined system thus able to control and coordinate from anywhere.

The software based automation has provided more meaningful avenues for optimization than ever. The controllable experiments and practical systems can now run under a variety of settings that can be triggered or trimmed in short time. This flexibility encourages us to evaluate the feasibility of having a MIMO system that can be analyzed for different that can be dynamically changed to provide a real-time feedback to the system based upon user mobility and network fluctuations.

In this paper we evaluate the MIMO system for various parameters. The experiment considers the UE mobility and correlated with the network parameters to calculate the throughput while keeping QoS under considerations. Further, the system is evaluated with and without MIMO using a real mobility dataset. Our work is distinguished from earlier approaches as it lies at the intersection of evaluation based enhancement for MIMO that is a key design choice in the 5G networks.

III. Methodology

This section provides the method used in this work to calculate the throughput.

A. Dataset Description

In this paper, vehicular movement data collected and emulated using ETSI API for 5G using an LTE eNB at the University of Hertfordshire are used. The various scrambling codes are as follows. For uplink it is 54 with the target SIR of 17.3. The minimum uplink channelization code length is 8. The downlink scrambling code is 1 with the channelization code of 15. The maximum downlink power is 10.1 and minimum is 9.3 dBm. On a pre-set path, the UEs move across the eNB wherein the RSSI and throughput are collected for each time tick. The GPS coordinates are also logged for each location at the time tick. Thus, for various UEs, we have the real dataset with their location with respect to time.

B. Exploration and Extrapolation

The dataset lacks the measurements at some of the GPS location for some UEs. Therefore, before using, the data is cleaned by removing any anamoly and for some points, the throughput is calculated at a given location by considering the available parameters like RSSI, RSRP and RSRQ whichever were available.

C. Analytical Model

The parameters obtained from the dataset are plotted as follows.

RSRP: Reference Signal Received Power (RSRP) is defined as the linear average over the power contributions (in [W]) of the resource elements that carry cell-specific reference signals within the considered measurement frequency bandwidth. UE measures the power of multiple resource elements used to transfer the reference signal but then takes an average of them rather than summing them. Figure 2 shows the received RSRP (in dB) for a sample mobile UE.

RSRQ: Reference Signal Received Quality (RSRQ) is a C/I type of measurement and it indicates the quality of the received reference signal. The RSRQ measurement provides additional information when RSRP is not sufficient to make a reliable handover or cell re-selection decision. Figure 3 shows the RSRQ (in dB) for a sample mobile UE connected with a base station at different time ticks.

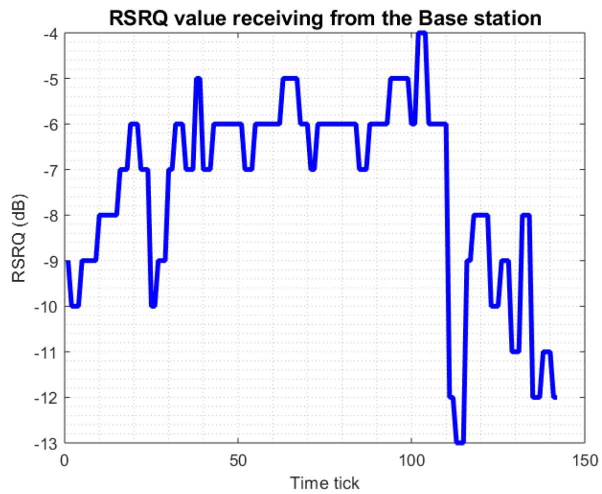

Fig. 3. RSRQ Values Received at a UE from the Base Station

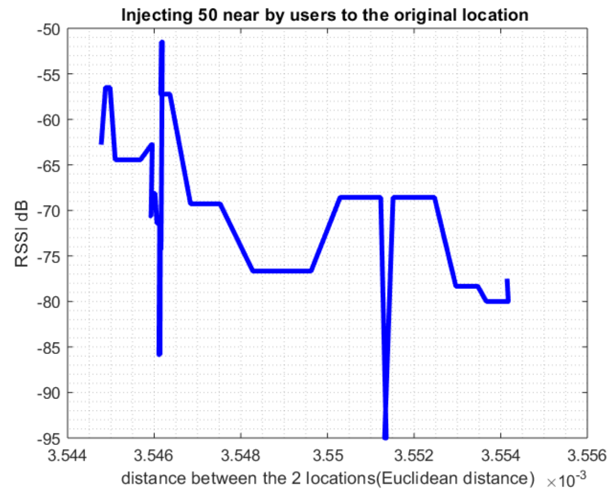

Fig. 5. Euclidean Distance vs. RSSI for Different Users

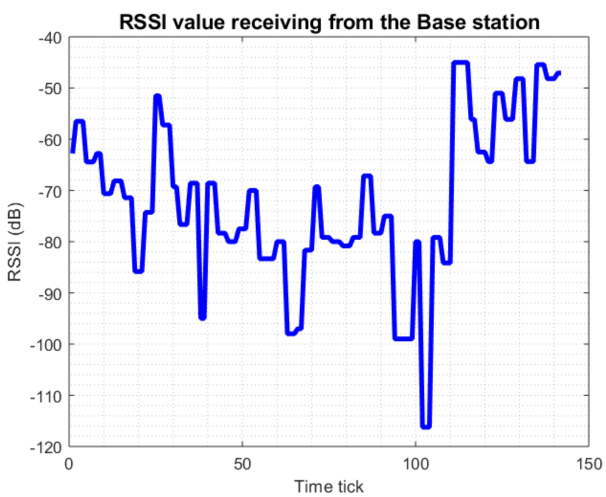

Fig. 4. RSSI Values for a Sample UE from the Base Station

RSSI: The carrier RSSI (Receive Strength Signal Indicator) measures the average total received power observed only in the OFDM symbols containing reference symbols for antenna port 0 (i.e., OFDM symbol 0 and 4 in a slot) in the measurement bandwidth over N resource blocks. The total received power of the carrier RSSI includes the power from co-channel serving and non-serving cells, adjacent channel interference, thermal noise, etc.

The total RSSI is measured over 12-sub-carriers including the signals from serving cell, and the traffic in the serving cell. The relationship between RSSI, RSRP and RSRQ is given in the Equation 1 where N are the number of resource blocks.

$$RSSI = N * (RSRP/RSRQ) \tag{1}$$

Figure 4 shows the calculated RSSI values using Equation 1.

D. Signal Continuity

After obtaining RSSI values at discrete locations, we inject 50 users at the random coordinates in the map area. The RSSI values of these users are correlated with the RSSI dataset by matching them with the closest geographical location and incorporating error corrections.

It can be easily plotted with RSSI value along the Y-axis and Euclidean distance between original location and injected user location along the X-axis. Figure 5 plots the Euclidean distance between any two users in the system and their respective RSSI value. This provides us a capability of obtaining RSSI at any given location in the map.

IV. FETE: Feedback Enabled Throughput Evaluation

The feedback enabled throughput evaluation (FETE) develops a mechanism through which a the continuous values of throughput can be obtained in a closed MIMO system.

A. System Information

Using the RSSI values for 50 users, the downlink data rate is calculated using transitional CQI value.

CQI: The Channel Quality Indicator (CQI) contains information sent from a UE to the eNB/gNB to indicate a suitable downlink transmission data rate, i.e., a Modulation and Coding Scheme (MCS) value. CQI is a 4-bit integer and is based on the observed signal-to-interference-plus-noise ratio (SINR) at the UE. The CQI estimation process takes into account the UE capability such as the number of antennas and the type of receiver used for detection.

Using the RSSI values obtained using the RSRQ and RSRP, the CQI values are determined using Table I. The CQI values are granulated using the RSSI values to determine if a singal is good or bad for the UE. Based on the CQI values, the

TABLE I
MODULATION SCHEME BASED ON THE CQI VALUE

RSSI	CQI	Modulation Scheme
Excellent	10-15	64 QAM
Good	7-9	16 QAM
Fair	1-6	QPSK
Poor	0	Out of Range

TABLE II
BANDWIDTH BASED ON THE NUMBER OF RESOURCE BLOCKS

Number of Resource Blocks	Channel Bandwidth (M Hz)
6	1.4
15	3
25	5
50	10
75	15
100	20

modulation scheme is assigned ranging from 64-QAM, to 16-QAM and QPSK. For a low CQI value, corresponding to the poor RSSI range, the UE is considered as out of range.

To calculate the modulatio scheme given in the Table I, the channel bandwidth is to be considered as provided in the Table V.

Based on the modulation scheme, a modulation index is assigned by the eNB/gNB and according to that index value a respective TBS (Transport Block Size) index value is assigned as given in the Table III.

Finally, to for the throughput calculation, the allowed rate of bits in each subframe for the the given TBS index and number of Physical Resource Blocks (PRBs) is to be determined. The bits/subframe are allocated by the eNB/gNB based on the traffic conditions, UE category (priority, services, etc.) and RF conditions. The standard bits/subframe allocation as per 3GPP for different RBs and TBS index value is given in the Table IV for 50 and 100 RBs, respectively.

B. Throughput Calculation

Using the MCS index, TBS index, CQI value and PRBs, the throughput is calculated as follows.

For example, when the RSSI value is excellent, the 64-QAM modulation can be chosen as per the Table I. For the 64-QAM, a granulated MCS index value is allocated by the eNB/gNB along with the PRBs. Consider for example that the MCS index is 28 in which case the respective TBS index value of 26 will be chosen as given in the table III. For a system with 50 PRBs, for the chosen 26 TBS index value, 32856 bits/subframe (1ms) are allocated to the UE. In turn, a throughput of $32856 * 1000 = 32856000$ bits/sec, i.e. 32.85 Mbps can be obtained. In this particular example, for a 10 MHz bandwidth we can obtain around 32Mbps throughput when assuming that all 50 resource PRBs are allocated to a single UE.

C. Improved Throughput using MIMO

We can enhance the system efficiency or increase the throughput with the help of MIMO technology.

TABLE III
MODULATION INDEX AND TBS INDEX

Modulation Index	Modulation	TBS index
0	QPSK	0
1		1
2		2
3		3
4		4
5		5
6		6
7		7
8		8
9		9
10	16QAM	9
11		10
12		11
13		12
14		13
15		14
16		15
17	64QAM	15
18		16
19		17
20		18
21		19
22		20
23		21
24		22
25		23
26		24
27		25
28		26
29	QPSK	Reserved
30	16QAM	Reserved
31	64QAM	Reserved

MIMO: Multiple Input Multiple Output (MIMO) allows multiple inputs and output antenna to be used simultaneously, thus theoretically improving the capacity manifolds. Consider that 101101 data is transmitted through a channel with deep fades. Due to the fluctuations in the channel quality, the data stream may get lost or severely corrupted that the receiver cannot recover it. The solution to combat the rapid fluctuation is to add independent fading channels by increasing the number of transmitting or receiver antennas or both. The use of spacial diversity technique, where same information sent or receive across independent channel can help to combat fading is particularly useful in MIMO. The diversity gain in MIMO is obtained using Equation **??** where N_{tx} and N_{rx} are the number of transmitting and number of receiving antennas respectively.

$$G_{diversity} = N_{tx} * N_{rx} \tag{2}$$

In an ideal condition, for $N_{tx} = 2$ and $N_{rx} = 2$, diversity gain is 4. This gain can be obtained by adding the independent fading channel that increases the reliability of the transmission link. Therefore if we use this MIMO 2*2 technology for calculating the same throughput for above mentioned UE, the user will receive around 75 Mbps throughput. The evaluation

TABLE IV
THE BITS/SUB-FRAME BASED ON NUMBER OF PHYSICAL RESOURCE BLOCK TABLE

TBS_{index}	N_{PRB}50	N_{PRB}100
0	1384	2792
1	1800	3624
2	2216	4584
3	2856	5736
4	3624	7224
5	4392	8760
6	5160	10296
7	6200	12216
8	6968	14114
9	7992	15840
10	8760	17568
11	9912	19848
12	11448	22920
13	12960	25456
14	14112	28446
15	15264	30576
16	16416	32856
17	18336	36696
18	19848	39232
19	21384	43816
20	22920	46888
21	25456	51024
22	27376	55056
23	28336	57336
24	30576	61664
25	31706	62776
26	32856	75376

of throughput with and without MIMO is presented in the next section.

V. EVALUATION AND RESULTS

The simulation is carried out for calculating the throughput for, with and without MIMO technology using FETE. The entire procedure to calculate throughput is written as in the JavaScript language using the Visual Studio Code software. The NPM (node package manager) run-time environment is used to run the code. The plotting is done using Highchart and localhost:8000 is used to show the simulated output in a browser.

By injecting 50 users into the map area, the throughput with and without MIMO is calculated. The simulation code is flexible and incorporates multiple parameters in real-time. Figure 6 shows the simulation output for a single run for different number of users. It can be observed that the throughput is higher when using MIMO.

Table V presents the average throughput calculated for both, with, and without MIMO cases for the 1st nine locations in Fig. 6. The throughput using MIMO is twice of that without the MIMO.

As the MCS index value is randomly chosen, different results are obtained for various simulation runs. Therefore, Figure 7 shows the average over 15 simulation runs for the throughput with and without MIMO. As it can be observed, the overall gain of the throughput is much higher for the MIMO as compared to the one without it.

The project code for this work is available at [13].

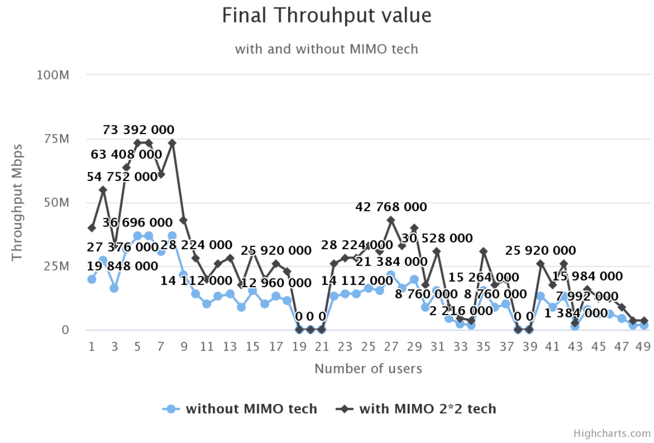

Fig. 6. Throughput for MIMO and without MIMO for Different Users

TABLE V
AVERAGE THROUGHPUT CALCULATION

Throughput without MIMO	Throughput with MIMO
31704000	63408000
28336000	56672000
25456000	50912000
21384000	42768000
30576000	61152000
15264000	30528000
16416000	32832000
27376000	54752000
21384000	42768000
Avg=21383111 (21Mbps)	Avg=42766222 (42.7 Mbps)

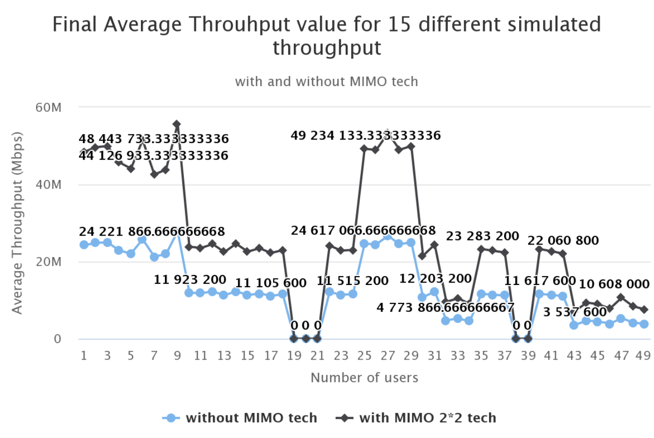

Fig. 7. Average System Throughput Comparison

VI. CONCLUSION

After the calculation of the throughput using the MCS index, TBS index, CQI value and the PRBs it has been observed that the overall gain of the throughput is much increased for the MIMO in comparison to that of the one without MIMO. Comparison of the feedback enabled method with that of the evaluation of the MIMO systems where in the throughput is achieved with the absolute amount of optimization that leads to great efficiency.

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