ENHANCING THE QoS PERFORMANCE FOR MOBILE STATION OVER LTE AND WiMAX NETWORKS

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ABSTRACT

Nowadays, one of the most important challenges in heterogeneous networks is the connection consistency between the mobile stations and base stations while maintaining a high degree of quality of service. Furthermore, along the roaming process between the mobile station and the base station, the system performance degrades significantly due to interferences from neighboring base stations, handovers to inaccurate base station, inappropriate technology selections and insufficient scheduling schemes.

In this study, several algorithms are proposed to guarantee high efficiency of resource allocations among a variety of smart grid applications (flat priority based and specific priority based scheduling algorithms), such as distribution automation, voice, video surveillance and advanced metering infrastructure. These algorithms can improve mobile stations' quality of service as well as guarantee seamless mobility across the Long-Term Evolution (LTE) and Worldwide Interoperability for Microwave Access (WiMAX) technologies.

Firstly, to solve the handover issues (prediction target base station, and selection best target technology), the enhanced global positioning system (GPS) and the novel received signal strength (RSS) prediction algorithms are utilized to accurately predict the target base station. Then, a multi criteria with two-threshold algorithm is proposed to prioritize the selection between the LTE and WiMAX as target technologies. In addition, this thesis also covers the inter-cell and co-channel interference reduction by adjusting the frequency reuse ratio 3 (FRR3) to work with LTE and WiMAX. Moreover, in terms of flat priority based scheduling issues, this thesis proposes a two level scheduling scheme composed of cooperative game theory (bankruptcy and

shapely) and Technique for Order Performance by Similarity to Ideal Solution method (TOPSIS). On the first level, bankruptcy and shapely value algorithm fairly distribute resources among smart grid applications. On the second level, TOPSIS algorithm allocates resources among an application's user based on their criteria and the application's preferences. The proposed algorithms provide an effective scheduling technique for smart grid applications. Whereas for specific priority based scheduling issues, the bandwidth estimation and allocation along with multi-attributes decision making are proposed.

The results obtained show that in terms of handover issues, a modified multi criteria with two threshold algorithm increases the efficiency of target network selection. The selection is based on the user preferences since it uses a self-learning algorithm to determine triggers and handover thresholds dynamically. In addition, by adding the FRR3 technique to the system, the efficiency of prediction of target base station and selection of target technology are increased, and the delay is decreased by approximately 15%. Similarly, in terms of flat priority based scheduling issues, the proposed algorithm also is found to be of higher performance up to 42 users for video applications and 60 users for the metering data applications. Finally, the novel algorithm shows the lowest delay and the highest fairness of approximately 0.98 whereas for specific priority based scheduling issues, the simulation results demonstrate that the proposed mechanism achieves higher throughput, lower delay and lower packet loss rate for real time applications as well as provides a degree of service for non-real time applications. In terms of fairness, the proposed algorithm shows 3%, 7 % and 9% better performance compared to exponential rule, modified-largest weighted delay first and exponential/proportional fairness, respectively.

ABSTRAK

Pada masa kini, salah satu cabaran yang paling penting dalam rangkaian heterogen adalah konsistensi sambungan antara stesen mudah alih dan stesen pangkalan di samping mengekalkan tahap kualiti perkhidmatan yang tinggi. Tambahan pula, di sepanjang proses perayauan antara stesen mudah alih dan stesen pangkalan, prestasi sistem merosot dengan ketara disebabkan oleh gangguan dari stesen pangkalan berdekatan, penyerahan ke stesen pangkalan yang tidak tepat, pemilihan teknologi yang tidak sesuai dan skim penjadualan yang tidak mencukupi.

Dalam kajian ini, beberapa algoritma telah dicadangkan untuk menjamin kecekapan tinggi peruntukan sumber di kalangan pelbagai aplikasi grid pintar (algoritma penjadualan berasaskan keutamaan rata dan berdasarkan keutamaan tertentu), seperti suara, pengawasan video, automasi pengedaran, penyimpanan sistem tenaga teredar dan infrastruktur pemeteran maju. Algoritma ini dapat meningkatkan kualiti perkhidmatan stesen mudah alih serta jaminan mobiliti tanpa had bagi teknologi Evolusi Jangka Panjang (LTE) dan Kebolehoperasian Sedunia bagi Akses Gelombang Mikro (WiMAX).

Pertama sekali, untuk menyelesaikan isu-isu penyerahan (ramalan stesen pangkalan sasaran, dan pemilihan teknologi sasaran terbaik), Sistem Kedudukan Global (GPS) yang dipertingkatkan dan algoritma ramalan baru bagi Kekuatan Isyarat Diterima (RSS) digunakan untuk meramalkan dengan tepat sasaran stesen pangkalan. Kemudian, satu kriteria berbilang dengan algoritma dua ambang adalah dicadangkan untuk mengutamakan pemilihan antara LTE dan WiMAX sebagai teknologi sasaran. Di samping itu, tesis ini juga meliputi antara sel dan pengurangan gangguan saluran

bersama dengan melaraskan nisbah penggunaan semula frekuensi 3 (FRR3) untuk berfungsi dengan LTE dan WiMAX.

Selain itu, dari segi isu-isu penjadualan berdasarkan keutamaan rata, tesis ini mencadangkan satu skim penjadualan dua tahap yang terdiri daripada teori permainan berkerjasama (muflis dan berbentuk) dan Teknik untuk Prestasi Perintah oleh Persamaan kepada Penyelesaian Ideal (TOPSIS). Pada peringkat pertama, algoritma kebankrapan dan nilai bentuk mengagihkan secara adil sumber antara aplikasi grid pintar. Pada peringkat kedua, algoritma TOPSIS memperuntukkan sumber-sumber di kalangan pengguna applikasi berdasarkan kriteria mereka dan pilihan aplikasi. Algoritma yang dicadangkan menyediakan satu teknik penjadualan berkuat kuasa bagi applikasi grid pintar. Manakala bagi isu-isu penjadualan berdasarkan keutamaan tertentu, anggaran lebar jalur dan peruntukan bersama-sama dengan pelbagai ciri-ciri membuat keputusan adalah dicadangkan.

Keputusan yang diperolehi menunjukkan bahawa dari segi isu-isu penyerahan, kriteria berbilang yang diubahsuai dengan dua algoritma ambang menghasilkan peningkatan dalam kecekapan pemilihan rangkaian sasaran. Pemilihan adalah berdasarkan pilihan pengguna kerana ia menggunakan algoritma pembelajaran sendiri untuk menentukan pencetus dan ambang penyerahan secara dinamik. Di samping itu, dengan menambah teknik FRR3 kepada sistem, kecekapan ramalan sasaran base station dan pemilihan teknologi sasaran dinaikkan, dan kelewatan itu menurun sebanyak kira-kira 15%. Begitu juga, dari segi isu-isu penjadualan berdasarkan keutamaan rata, algoritma yang dicadangkan juga didapati menunjukkan prestasi yang lebih tinggi sehingga 42 pengguna untuk aplikasi video dan pengguna 60 untuk aplikasi data pemeteran. Akhir sekali, algoritma baru menunjukkan kelewatan yang paling rendah dan keadilan yang paling tinggi kira-kira 0.98. Manakala bagi isu-isu penjadualan berdasarkan keutamaan tertentu, keputusan simulasi menunjukkan bahawa mekanisme yang dicadangkan mencapai pengeluaran yang lebih tinggi, kelewatan yang lebih rendah dan kadar kehilangan paket lebih rendah untuk aplikasi masa nyata dan juga menyediakan tahap perkhidmatan untuk aplikasi bukan masa sebenar. Dari segi keadilan, algoritma yang dicadangkan menunjukkan 3%, 7% dan 9% prestasi yang lebih baik berbanding dengan kaedah eksponen, kelewatan tertimbang terbesar pertama yang diubah suai dan keadilan eksponen/berkadar, masing-masing.

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LIST OF ABBREVIATIONS

4G	Fourth Generation
ASFR	Adaptive Soft Frequency Reuse
BAC	Boundary Area of Cell
BS	Base Station
BWA	Broadband Wireless Access
CCI	Co-Channel interference
CCU	Cell Center User
CDD	Cyclic Delay Diversity
CEU	Cell Edge User
DA	Distribution Automation
DER	Distributed Energy system and Storage
DL	Downlink
EV	Electrical Vehicle
EXP/PF	Exponential/Proportional Fairness
EXP-Rule	Exponential-Rule
FFR	Fractional Frequency Reuse
FFR 3	Fractional Frequency Reus 3
FRF	Frequency Reuse Factor
GPRS	General Packet Radio Service
GPS	Global Positioning System
HHO	Horizontal Handover
ICI	Inter-Cell Interference
ICIC	Inter-Cell Interference
LDA-SFR	Load Distribution of Soft Frequency Reuse
LTE	Long-Term Evolution

MADM	Multiple Attribute Decision-making
MAN	Metropolitan Area Networking
MC	Multi Criteria
MCS	Modulation and Coding Scheme
MDP	Markov Decision-making Process
M-LWDF	Modified-Largest Delay First
MMSE	Minimum Mean Square
MMTT	Modified Multi criteria with Two handover Thresholds
MRC	Maximum Ratio Combining
MS	Mobile Station
OFDM/A	Orthogonal Frequency-Division Multiple /Access
PF	Proportional Fairness
PFR	Partial Frequency Reuse
QoE	Quality of Experience
QoS	Quality of Service
RB	Resource Block
RCAC	Radius of Central Area of Cell
RCU	Radio Control Unit
RR	Round Robin
RRM	Radio Resource Management
SAW	Simple Additive Weighting
WiMAX	Worldwide Interoperability for Microwave Access

CHAPTER ONE

INTRODUCTION

With the increasing requirement for wireless applications and number of wireless technologies, providing always the best connection for the mobile stations is a decisive project for the developers, especially when the mobile is in roaming (Gustafsson & Jonsson, 2003). So to resolve that many scholars have influenced in different ways to resolve the related issues such as noise between different technologies, handover and scheduling events. In this thesis, an optimal answer for each one of the mentioned issues for fourth generation networks is aimed. These problems are answered in order starting from the handover, interference to schedule. It is worth to mention that, while we were working on our research, the problems came on sequence like when we were going on the handover we found that the delay becomes a large topic and needs to be resolved or the handover will be delayed to a greater extent than what it's supposed to be. So for that, we proposed a complete system model which contains the prediction of the target base station and then the selection of the most appropriate available technology as a target technology to handover. After testing our new system in the high attenuation area, it has been found that the connection was missed then the interference issue has been resolved by giving the fractional frequency reuse technique.

This chapter takes the brief introduction to each topic as it is exemplified in Figure 1.1. In the first part, the explanation about the handover approaches and the obstacles which can be challenged the researchers are illustrated. Moreover, the interference issues are studied for 4G networks, especially for LTE and WiMAX networks. Finally the scheduling issues will be deeply deliberated.

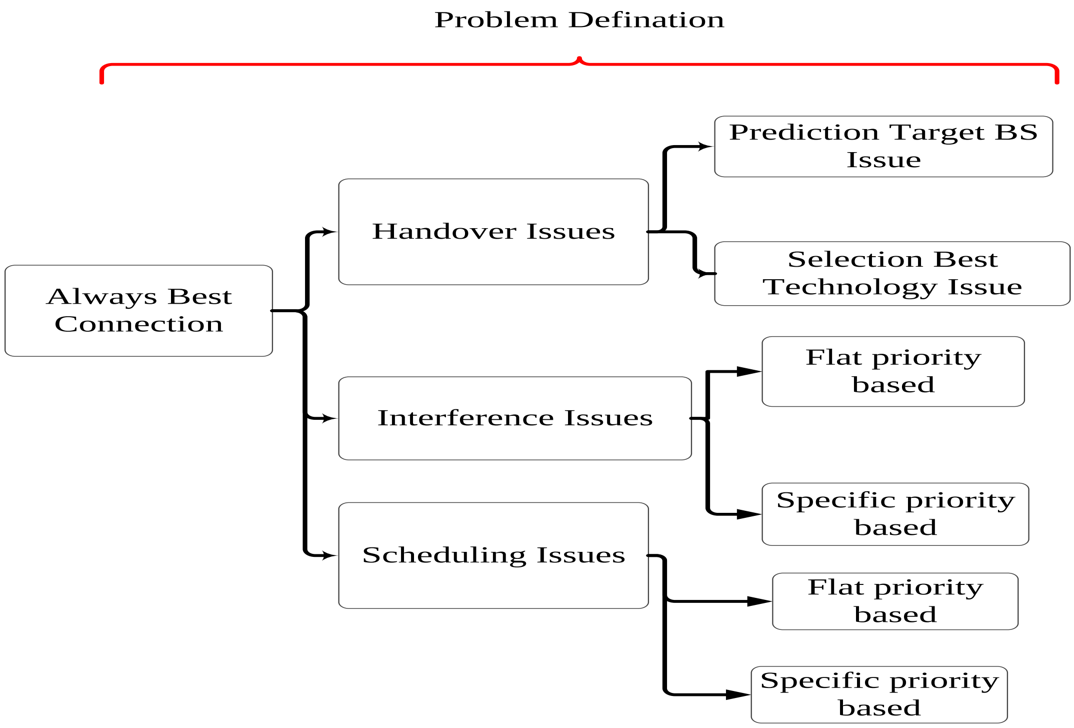

Figure 1.1: Illustration of the Problem Definition

1.1 OVERVIEW ON HANDOVER

The dramatic development of the wireless networks in the past few years is opening a route towards the unification of all IP-based networks, which serves to form the Next Generation Networks (NGN). Referable to the increasing demand of these meshes in our daily life, users' demands are likewise increased and service operators are racing to provide different services to fill their customers for a better level of service. Nevertheless, user's demands cannot be met by a single operator especially while the user is roaming. In the roaming, the users cross over a number of available networks, which are called heterogeneous wireless networks. These networks have different capability in terms of available bandwidth, achievable data rate, etc., and support several types of services such as email, live video streaming, etc. The user handovers between different networks to satisfy its quality of service demands while the user is roaming. This procedure is usually experienced as a vertical handover (VHO) due to the handover among different type of wireless networks to attain better quality of service and quality of experience for the end user (H.-H. Choi, 2010; C. W. Lee, Chen, Chen, & Sun, 2005; Tamea, Biagi, & Cusani, 2011; Xia, Ling-ge, Chen, & Hong-Wei, 2008; K. Yang, Gondal, & Qiu, 2008).

The handoff research direction among network generations have shifted during the previous years, where for the first three generations evolved to contribute in increasing data rates and enriched communication experiences, whereas a 4G network technology aimed at providing extended mobility features with optimized and enhanced data rates and services. That is a resolution of progressing to heavy use of heterogeneous networking technologies in order to provide mobile seamless mobility between multi-service networks for users such as seamless connection to the internet by means of heterogeneous wireless networks, navigation services, localization-aware services and IP based real-time multimedia.

Progressing to a handover decision is one of the most significant and crucial aspects of any handover mechanism. A vertical handover decision may be subjective by many issues that associated with the network to which a mobile station is at present connected and the base station will perform a handover in the hereafter. For instance, if a mobile station decides to perform a handover, then it may well be demanded with the help of a VHO agent that is installed in the mobile station, based on the pre-recorded policies such as available bandwidth, network load, network coverage area, monetary cost, web security, QoS or/and user preferences. User preferences are significant when performing VHOs. Let us presume, if the candidate network handover to which a mobile station intends to switch does not provide any security mechanism, then the mobile station may possibly decide to stay plugged into its old network. Likewise, if we consider network coverage, a mobile user may desire to use a secure and expensive connection to its electronic mail traffic flow (like a General Packet Radio Services 2 link) but may still take an affordable connection for accessing web information (like a Wireless Local Area Network 3, link). In the following part, details of some existing vertical handover decision approaches are presented. We have categorized these VHO approaches based on their parameters which are responsible for the handover decision.

1.1.1 HANDOVER CHARACTERISTICS AND HANDOVER DECISION METRICS

Different handover strategies have different nature of a handover, which can be soft, hard or seamless. According to recent trends, a lot of researchers have worked on supplying a seamless handover for continuous service stability. One of the central features of ubiquity is to facilitate mobile users with the opportunity to travel freely and to supply them some means to communicate with the access applications using different thinking and interactive equipment like mobile phones, PDAS4 and digital TV sets. Nevertheless, switching across different access networks is not an easy undertaking and it necessitates a proper mechanism for accommodating user and application needs, particularly in terms of QoS.

There are many criteria have been used to make the handover decision. In order to keep users always best connected, various QoS parameters are considered that affect the VHO decision. Due to make VHO decisions, some of the following QoS parameters are suggested:

Received Signal Strength (RSS): RSS is a traditional and unavoidable factor for making handover decisions. It supplies data about the power level being received by the transmitting aerial. It decreases when a user goes away from the servicing base station. The mobile user has to handover to some other available network before the connectivity is lost (Pahlavan et al., 2000; Sgora & Vergados, 2009; Zekri, Jouaber, & Zeghlache, 2012).

Monetary Service Cost: Every network provides certain services to its users, which are usually charged at cost. Usually, the higher cost for better QoS, but if we have two technologies offer the same degree of QoS, the lowest network cost will be favored (Chai, Zhou, Chen, & Tang, 2009; Fernandes & Karmouch, 2012; Yan, Şekercioğlu, & Narayanan, 2010).

Handover Delay/Latency: Normally Layer-2 events occur to induce a new connection with the new network and this procedure might take larger delays (sometimes up to a brace of seconds) also bore on to as handover latency. Real-time services (e.g., television streaming, voice call) are ordinarily accepted as delay sensitive and this degrades their overall functioning. During handover, packets are usually buffered by the network till the next wireless station is inclined to take them. This delay proliferates to higher layers and causes sudden upsurges in packet delays (Emmelmann, Langgäertner, & Sonnemann, 2008; Rajule, Ambudkar, & Dhande, 2013).

Protection Control: It is one of the main events that arises when networks converged are interconnected. This is because each network has its own security and privacy options and a mobile user must comply with them during the handover procedure. This calls for harmonization of diverse security policies in heterogeneous wireless networks as networks and terminals have different security layers and security related characteristics. The handover process requires improved security and privacy by spying, registration hijacking, session tear-down and Denial of Service (DOS) attacks (Lin, Wang, & Lin, 2008; TalebiFard, Wong, & Leung, 2010).

Throughput: It refers to the data rate provided to the mobile stations in a network. Mobile stations generally prefers a candidate network that offers higher throughput for their concurrent applications (Salam, Mushtaq, Khalid, Ali, & Amin, 2011; H. Wang et al., 2010; X. Yang & Owens, 2008).

Bit error rate (BER): BER is the ratio of the number of receiving bits that have been attenuated due to noise and interference (e.g. thermal noise, co-channel noise and inter-cellular telephone interference) to the entire number of transferring bits during a transition time interval (Tawil, Pujolle, & Salazar, 2008).

Signal to Noise Ratio (SNR): SNR is a ratio to test the power of the received SNR at the studied mobile station. It is widely applied to define the proper modulation and coding system (Jun, 2009).

1.1.2 HANDOVER DECISION SCHEMES

In this work, we have chosen to divide VHO decision schemes into four classes based on the handover decision making criteria and the methodology employed to swear out the handover parameters. These classes are RSS based schemes, QoS based schemes, Decision Function based schemes and Network Intelligence based schemes. Each measure of the handover decision making has different nature either static or dynamic, where static criteria such as the monetary cost of the heterogeneous networks. On the other hand, the dynamic criteria can be the velocity and RSS.

1) RSS based Schemes:

In RSS based decision algorithms, RSS of the current attachment point is compared with the RSS of the other available networks for carrying in a handover decision. The first initial network scanning is performed by the mobile node to control the availability of candidate wireless networks in the region. Then, their RSS levels are assessed and compared either with the RSS of the current network or a predefined RSS threshold. If these measurements give a satisfactory result for RSS, then a handover is done otherwise, the process switches back to the network discovery phase (B.-J. Chang & Chen, 2008; B.-J. Chang, Chen, Hsieh, & Liang, 2009; Pahlavan et al., 2000; Ylianttila, Mäkelä, & Pahlavan, 2005).

2) QoS Based Schemes:

The main focus of this path of study is in the schemes that tends to optimize the QoS using the parameters such as available bandwidth and Signal-to-Interference-Noise-Ratio (SINR) for making an optimal handover decision (Bazzi, 2010; C. W. Lee et al., 2005; K. Yang et al., 2008).

3) Decision functions based schemes:

A vertical handover decision function is a measurement of the advantages derived by switching over towards a specific wireless network. It is evaluated for each network that encompasses a specific service area of a mobile station. More frequently than not, it is a weighted aggregate of specific network parameters (Ashtiani, Haghighirad, Makui, & ali Montazer, 2009; J. M. Lee, Yang, Choi, Lim, & Heo, 2006; Ormond, Murphy, & Muntean, 2006; H. J. Wang, Katz, & Giese, 1999; Xu, Hao, Tao, Wang, & Zhang, 2008).

i. Utility Function based Schemes

In the access network selection and decision management, the user's satisfaction level is evaluated corresponding to a set of characteristics of a wireless network, including the allocated resource parameters.

ii. Cost Function based Schemes

The full monetary value of a candidate network is estimated using the summation cost of available QoS parameters like bandwidth, battery consumption and network time lag. The mobile user is handed-over to the network that puts up the lowest monetary value for maximum services.

iii. Network Score Function based Schemes

Multiple Attribute Decision Making (MADM) is an algorithmic way of suitably realizing the network interface selection and handover decision using different alternatives and their respective attributes. The proposed procedure helps in achieving reduced handover blocking, higher throughput and optimized handover decision delay. It is important to shape out the handover decision processing delay on the network.

4) Network Intelligence based Schemes:

The concept of network intelligence comes when the handover decision is based on the information visibility and by considering the real-time network traffic. These solutions usually require some tools for correlating, analyzing and reporting. The network uses some sources and inputs to provide efficient handover decision.

i) Fuzzy Logic: The fuzzy logic concept provides a robust mathematical framework where vertical handover decision can be phrased as a fuzzy MADM (Kang, Strassner, Seo, & Hong, 2011; Kassar, Kervella, & Pujolle, 2008; Xia, Jiang, & He, 2007).

1.2 FRACTIONAL FREQUENCY REUSES FOR OFDM NETWORKS

Today, Macro-cellular networks suffer from high attenuation of the Inter-Cell Interference (ICI) and Co-Channel Interference (CCI) at the cell edges of the same operation frequency and from neighboring base stations which may have uneven distribution of throughput to User Equipments (UEs). Accordingly, Fractional Frequency Reuse (FFR) technique is studied in Orthogonal Frequency Division Multiple Access -based networks to overcome the CCI and ICI problems by many scholars (R. Y. Chang, Tao, Zhang, & Kuo, 2009; Gamage & Rajatheva, 2011; Geirhofer & Oyman, 2008; González González, Garcia-Lozano, Ruiz Boqué, & Olmos, 2012; W.-I. Lee, Lee, Lee, & Bahk, 2005; López-Pérez, Juttner, & Zhang, 2009). OFDMA has been quickly deployed in various emerging cellular systems and has become an attractive technology to attain a high data communication rate in wireless and cellular organizations. The OFDMA FFR, in fact divides both frequency and time resources into various sub-bands to mitigate interference. FFR schemes can be utilized in both Uplink (UL) and Downlink (DL). It is most usually considered for downlink channels. It bases on dividing the radio cell into inner and outer parts. Inner region is determined as a region which is near to the Base Station (BS) and outer region is situated to the boundaries of the cell (Bilios, Bouras, Kokkinos, Papazois, & Tseliou, 2012b; Gok & Koca, 2014; Perez, Riera-Palou, & Femenias, 2013). In order to allocate the frequencies to those areas, the whole frequency band then split into sub-sets. Nevertheless, the number reuse factors can be achieved by setting the frequency band allocation to each area and the transmission power of each band. Moreover, on that point is some trade-off between improvement in reporting and rate in the outer region for the users and the total overall throughput by using these FFR schemes. Additionally, interference avoidance technique can be applied to avert the same frequency collisions in neighboring base stations (Babu & Amudha, 2014; Huq et al., 2013; Ostermann, Prodan, Schuller, & Mayr, 2014). FFR can be performed either in static or in a dynamic way. Static mode is by allocating Frequency Reuse Factor (FRF) greater than one in neighboring cells and dynamic path is caused by putting an intelligent scheduler (N.-H. Lee & Bahk, 2007; Martínez, Andrade, & Martínez, 2010). Withal, the static method is broadly accepted in real-world network deployments due to low load of the signaling overhead and less complexity comparing with implementing the dynamic scheduler.

In recent years, the majority of the researches have been performed regarding the FFR is based on OFDMA systems in both cellular standardizations of 3rd Generation Partnership Project (and Third Generation Partnership Project 2 and WiMAX network. The WiMAX Forum has been proposed based on IEEE standard 802.16 (Ghosh, Wolter, Andrews, & Chen, 2005). In addition, two types of WiMAX technologies named fixed/nomadic and mobile are available which are classed based on version 802.16-2004 of the standard and the latter is featured by an amendment, 802.16e (So-In, Jain, & Tamimi, 2009). The cell throughput is the main issue as WiMAX technology provides broadband access to the cellular networks. Both parameters named SINR and bandwidth of frequency reuse have to be maximized for achieving the promising cell throughput in the network. Cell throughput can be increased by completing utilization of available bandwidth in each sector with maintaining a minimum SINR level which is required for connecting service. Whereas, the outcome of frequent repositioning scheme has been analyzed based on non-scattered cells in (S. Kim, Lee, Yoo, & Shin, 2009). Whereas, 3rd Generation Partnership Project Long Term Evolution (3GPP-LTE) is characterized as the 4th Generation (4G) of wireless system which provides high capacity and better quality of service and is contrived to accommodate small, power-efficient and high performance end-user devices. 3GPP released its first work on Long Term Evolution in “release 7” in December 2007 and it becomes a hot research topic nowadays (Holma, Toskala, Ranta-Aho, & Pirskanen, 2007). OFDMA technique has been adopted by LTE for downlink and this technology has been drawing enormous attention of researchers in recent years for achieving high data transmission rate in wireless and mobile communications. To meet rapidly growing demands of mobile users due to its flexible frequency allocation, OFDMA offers greater spectrum efficiency. In LTE each OFDMA traffic channel is set to one user at a time exclusively, which provides high spectrum efficiency and flexibility in allocating the frequency to end users (Jungnickel et al., 2009). However, an OFDMA based LTE network with multi-cells; the system performance is seriously deteriorated by the ICI due to same frequency reuse and CCI due to more than one radio transmitters use the same frequency (Ghaffar & Knopp, 2010). FFR has become an area of active inquiry by many researchers in OFDM and OFDMA based networks to overcome both ICI and CCI (Bilios, Bouras, Kokkinos, Papazois, & Tseliou, 2012a; Chhorn, Seo, Kim, Lee, & Cho, 2015; Hossain, Le, & Niyato, 2014; Jin, Zhang, & Hanzo, 2013; Z. Li, Wang, Pan, Liu, & You, 2014; T. D. Novlan, Ganti, Ghosh, & Andrews, 2012). The primary target of FFR is to separate the cell space into an inside and outer region to mitigate CCI and ICI.

FFR is a variety of dissimilar cases of frequency reuse scheme such as traditional Frequency Reuse (FR) factor and FFR3. One of the primary objectives of LTE is to use the whole of the system’s bandwidth to achieve high spectral efficiency. This method is recognized as traditional FR where all available bandwidth is fully assigned into each cell. In FRR3, on the other hand, the available bandwidth is split up into 3 equal sub-bands and each of these sub-bands will be allocated in a fashion to the cells in a cluster so that no adjacent cells will cause the same sub-band. To increase, traditional FR can be used by the mobile stations which are placed around the base stations or in particular in the cell inner region and FRR3 is allocated to the cell edge users which will be decreased as the interference, but data rate also will be lessened due to the fact that the total frequency band is not used by this method. OFDM/OFDMA allows the dynamic allocation of subcarriers (called OFDM/OFDMA traffic channel) to different users at different time instances (Dahlman, Parkvall, Skold, & Beming, 2010).

1.3 SCHEDULING ALGORITHM FOR 4G NETWORKS

The growing need for network services, such as Voice over IP, network browsing, video telephone, video streaming and smart grid applications with constraints on delays, reliability and bandwidth requirements adds new challenges to the conception of the future generation cellular networks. WiMAX and LTE are proposed as an answer to this demand, aiming at matching performance goals, defining new packet-optimized and all-IP architecture for the radio access and core networks. According to (Mcqueen, 2009), more than 32 million LTE subscribers are foreseen by 2013. For this understanding, both research and industrial communities are more emphasis on the study of LTE systems than WiMAX. They are working days and nights to propose new and innovative advances in order to study and better their functioning.

1.3.1 OVERVIEW ON LTE NETWORKS

The principal characteristics of LTE network are a system architecture with protocol stack, OFDMA air interface with related scheduling issues along with the description RRM procedure.

i) System Architecture and Radio Access Network:

LTE flat architecture is very useful to sustain mobility and high speed delivery of data and signaling also known as service architecture evolution, which comprises the evolved packet core and wireless access network (E-UTRAN). Evolved packet core consists of SGW, Packet Data Network Gateway (PGW), and MME.SGW performs the routing, forwarding and handover management of user data packets among LTE nodes, user LTE and other 3GPP technologies, respectively. PGW holds UEs interconnect with the external packet data network through the LTE network connects to other networks of the world. MME is responsible for user mobility, intra-LTE handover, tracking and paging procedures of UEs upon connection establishment. Evolved Node B (ENB) is the only device which using the tuner interface for radio resource management and control procedures makes its architecture different from other cellular networks. Taking related aspect of LTE with radio resource management.

ii) Radio Bearer Management and Protocol Stack:

A radio bearer is a logical channel between UE and eNB having the responsibility of managing and provisioning of QoS on the radio access network interface, known as E-UTRAN including two types of bearers, namely default and dedicated bearer (Ekstrom, 2009).

For the first time when a UE joins a network, a default barrier is made up for the full lifetime of connection, providing connect and exchange information such as the control message. While dedicated bearer setups at every time for a specific new service, according to QoS requirements. Dedicate bearer is further split into two sub-bearers namely guaranteed bit-rate (GBR) and non-guaranteed bit rate (non GBR). Each bearer having a specific set of QoS according its applications' data which offers to differentiate among flow. LTE introduces some characters of protocols like RRC radio resource control, Packet Data Control Protocol, Radio Link Control (RLC) and Medium Access Control (MAC). Where MAC provides multiplexing/de-multiplexing, random access, radio resource allocation and scheduling requests procedures for the LTE radio interface.

iii) Physical layer:

One of the most significant characteristics of LTE is its flexibility offered to support several bandwidth ranges from 1.4 MHz up to 20 MHz. LTE using two different schemes (SC-FDMA) and (OFDMA) for uplink and downlink, respectively. Due to low power consumption SC-FDMA increases power efficiency of user equipment. Time/frequency domain is used to allocate radio resources. This apportioning of the time domain consists of transmission time interval (TTI) having a length of 1ms. TTI including two time slots, each of length 0.5 manuscript and 7 OFDM symbols. Furthermore, 10 consecutive TTIs make a shape which represents time. Frequency domain is made of sub channels on each of 180 kHz with 12 consecutive and equally spaced OFDM sub-carriers. The smallest radio resource unit composed of 1 TTI (2-time slots) and one sub-channel is called Radio RB and it can be attributed to a UE for data transmission in LTE networks. The number of resource blocks increases as the offered bandwidth increases (Access, 2008).

The LTE radio interface supports two kinds of frame structure according duplexing schemes that are frequency division duplexing and time division duplexing. In frequency division duplexing method, the bandwidth divided into two sections to support both links data transmissions simultaneously. Similarly for time division duplexing dividing. The sub frame into two divisions each of duration 0.5ms supports different numbers of resources for downlink and uplink data transmission followed frame configurations. In LTE network, RRM procedure performs a really significant and central part in many aspects like CQI reporting, link adaptation, Hybrid Automatic Retransmission Request (HARQ) and power control. Using physical and MAC layers, the efficient exercise of available resources is increased. CQI reporting; one of the important characteristics of LTE networks and worked out as a quantized and scaled measure of the experienced SINR which is applied to estimate channel quality at ENB. A good trade-off between precise channel quality estimation and a reduced signaling overhead is the main issue related to CQI reporting procedure.

iv) AMC and Power Control:

Adaptive Modulation and Coding (AMC) maximizes the supported throughput of a given target Block Error Rate (BLER) by the proper selection of Modulation and Coding Scheme (MCS). The number of allowed modulation and coding schemes is determined. Hence, the system throughput is upper-bounded due to which there is no growth in throughput while increasing SINR over a certain threshold. To defeat such an issue the AMC works together with the power control module. Power control handles the instantaneous variations in channel conditions through the routine that adjusts transmission power on the radio-link dynamically. They propose to deliver energy with a constant bitrate or selection of higher MCS with high bitrate which is called power reduction and power boosting, respectively, while keeping the BLER value smaller than a verge. Every TTI repeats the operation of RRM with downlink packet scheduling in LTE network described in the following sequence (Dahlman et al., 2010).

1) Each UE decodes the reference signals, computes the CQI, and transmits it back to the ENB.

2) The ENB uses the CQI information for the allocation decisions and fills up a RB “allocation mask”.

3) The AMC module selects the best MCS that should be applied for data transmission by scheduled users.

4) The information about these users, the allocated RBs and the selected MCS are sent to the UEs on the PDCCH.

5) Each UE reads the PDCCH payload and in case it has been scheduled, it accesses to the proper PDSCH payload. In LTE, the uplink work is different from the downlink because there is no need of more information about channel quality at ENB.

v) Complexity and Scalability:

Low complexity and scalability are the basic factor to decrease processing time and memory use. The LTE scheduler takes time in one TTI that is 1ms for allocation decision. FDPS are used in the allocation decision to keep off the computational cost, time and reduce complexity which is founded on the calculation of pre-RB metrics for each user. RB is allocated to the highest metric user is independent of other RBs offer to cut complexity (Kwan, Leung, & Zhang, 2008).

vi) Spectral Efficiency:

Efficient usage of wireless resources is one of the main goals to be accomplished. For this purpose, several types of performance indicators can be considered. For instance, a specific policy could aim at maximizing the number of users served in a given time interval or, more usually the spectral efficiency (expressed in bit/s/Hz) by always serving users that are having the best groove conditions. One of the most used efficiency indicators is the user goodput, which is a standard of the actual transmission data rate without including layer two overheads and packet retransmissions due to physical errors.

vii) Fairness:

A blind maximization of the overall cell throughput surely enables effective channel utilization in terms of spectral efficiency, but also brings to very unfair resource sharing among users. Fairness is therefore a major requirement that should be taken into account to guarantee minimum performance also to the cell-edge users (or in general to users experiencing bad channel conditions).

viii) QoS Provisioning:

As well-known, QoS provisioning is very important in next generation mobile networks. It is a major feature in all-IP architecture. LTE maps QoS constrained flows to dedicate radio bearers that, depending on their QCIs, the enabling of the special RRM procedures is done. Thus, it is significant to define QoS-aware schedulers. Nevertheless, the LTE access network has been projected to provide high data rates, low latency, and an improved spectral efficiency with regard to previous generation networks. To accomplish these goals, the Radio Resource Management (RRM) block exploits a mix of advanced MAC and Physical functions, like resource sharing, CQI reporting, link adaptation through AMC and HARQ. In this setting, the design of efficient resource allocation strategies becomes important. In fact, the effective utilization of wireless resources is essential to match the system performance targets and to satisfy user demands, according to specific QoS requirements (Laselva et al., 2009). The packet scheduler works of the radio base station, namely the ENB, and it is in charge of putting portions of spectrum shared among users, by following specific policies. In a wireless scenario, the packet scheduler plays an additional fundamental role. It aims to maximize the spectral efficiency through an effective resource allocation policy that turns off or makes negligible the impact of channel quality drops. In fact, on wireless links the channel quality is open to high variability in time and frequency domains due to various reasons, such as fading effects, multipath propagation, Doppler effect and hence along. For these reasons, channel-aware solutions are commonly adopted in OFDMA systems because they are capable to exploit channel quality variations by assigning higher priority to users experiencing better channel conditions. However, many issues arise in the conception of such solutions in LTE systems, crossing from the provisioning of high cell capacity to the satisfaction of fairness and QoS requirements.

1.3.2 OVERVIEW ON WIMAX NETWORKS

IEEE 802.16 is a broadband wireless access (BWA) commonly known as Worldwide Interoperability for Microwave Access (WiMAX). It is a recent wireless broadband standard that has promised high bandwidth over the long-range transmission. The standard defines the air interface, including the MAC and PHY layers of BWA. The key development in the PHY layer includes OFDM in which multiple access is accomplished by specifying a subset of subcarriers to each single user. This seems to be code division multiple access (CDMA) spread spectrum in what we can offer you the QoS for each different user; reach users different data rates for different code spreading factors or assign a different number of spreading codes (Zhang & Chen, 2007). In an OFDM system, the data are divided into multiple sub-streams in parallel with a lower data rate, and each is modulated and diffusion in separate modified orthogonal. This symbol duration increases and improves the robustness of the system. OFDM is achieved by providing user data streams multiplexing in transmissions both uplink and downlink order. Mobile WiMAX, adds significant enhancements:

- NLOS coverage improves using advanced antenna diversity systems and HARQ.
- It adopts dense sub-channelization. So the system increases and improves within the penetration.

• It uses Adaptive Antenna Systems (AAS) and Multiple Input Multiple Output devices (MIMO) technologies to improve coverage.

• It introduces a downlink sub-channelization arrangement, allows better coverage and capacity trade-off. This brings potential benefits in terms of coverage, energy consumption, one-time installation, frequency reuse and bandwidth efficiency.

One of the key complications is that the inconsistency in the newly introduced Scalable OFDM (SOFDM) in IEEE 802.11e with the original OFDM scheme forces equipment manufacturers to come up with mechanisms to ease the passage.

1.3.2.1 QUALITY OF SERVICE

QoS provisioning is one of the essential features in IEEE 802.16. However, there are differences in the standard specs, specifically, in IEEE 802.16-2004 and IEEE 802.16e. These QoS parameters are utilized for transmission and programming. Service flows are typically identified by sub-stations and BSs based on their SFID (Cicconetti, Lenzini, Mingozzi, & Eklund, 2006). There are three basic cases of service flows: provisioned service flows, admitted service flows and active inspection-repair flows. A provisioned service flow can be delimited in the scheme with an SFID, but it may have no traffic present. It may be waiting to be activated for usage. An admitted service flow undergoes the process of energizing. In reaction to an external request for a specific service flow, the BS/MS will check for available resources based on the QoS parameters to determine if it can confirm the request. If there are sufficient resources, the service flow will be deemed accepted. The resources assigned to this service flow may still be practiced by other services. A service flow will be alive when all checks are completed and the resources are apportioned. Packets will flow through the connection allocated to the service flow. The purpose of service flows is the principal mechanism used in QoS provisioning. Packets traversing the MAC sublayer are associated with service flows as identified by the CID when QoS is needed. Bandwidth grant services define bandwidth allocation based on the QoS parameters associated with a link. In downlink transmissions, a BS has sufficient data to perform scheduling, but in uplink transmissions a BS performs the scheduling of various service transmissions based on data gathered from MSs. In such cases an MS will request uplink bandwidth from the BS, and the BS will allocate bandwidth on an as required basis. For proper allocation of bandwidth, four services are defined to hold different types of data streams:

i) *Unsolicited Grant Service (UGS):* UGS is planned to support real-time constant bit rate (CBR) traffic such as VoIP; this provides fixed size, transmission opportunities at regular time interval without the need for requests or polls.

ii) *Real-Time Polling Service (rtPS):* rtPS is planned to support variable bit rate (VBR) traffic such as MPEG video. In this service, BS the SS periodic request opportunities to show the needed bandwidth.

iii) *Non-Real-Time Polling Service (nrtPS):* nrtPS is to delay-tolerant data service with a minimum data rate, such as FTP. This service allows an MS to use contention request and unicast request opportunities as a bandwidth request.

iv) *Best effort (BE) service:* It does not narrow down any service related requirements. Similar to when the NrtPS, it provides options for conflict request and unicast request, but it offers no bandwidth reservation or regular unicast surveys.

1.3.2.2 PHYSICAL LAYER ENHANCEMENTS

This piece carries an overview of some physical layer enhancements that are currently being considered for inclusion in future systems. Because the development of the 802.16m standard is even so in a comparatively early phase, the focal point is on delivering the concepts and the principles on which the proposed enhancements will be grounded, rather than on providing specific implementation details (Andrews, Ghosh, & Muhamed, 2007). Although the precise level of sophistication of the new additions to the standard cannot be safely predicted, it is expected that additions will get some use of the concepts described below.

Flexibility enhancements to support heterogeneous users because the goal of future wireless systems is to cater to the needs of different users, efficient and flexible patterns are required. For some users (such as streaming low-rate applications) link reliability may be more significant than high data rates, whereas others may be interested in reaching the maximum data rate even if a retransmission is consequently thus additional delay may be needed.
In addition, the coexistence of different users can be achieved with relatively low overhead control. For these reasons, the frame format of the carrier is adjusted allocation arrangements for 802.16m related to 802.16e.

Each 802.16e frame composed by the symbol for an OFDMA a DL and part of the UL in the time, separately and is a variable-size. The (DL or UL) frame begins by manipulating information that all users employ to synchronize and to find out if and when they should receive or convey in the rendered form. Control data are accompanied by data transmission by the infrastructure station (in the DL sub-material body) or the mobile stations (in the UL sub-frame). For each mobile station, transmission or reception occurs in blocks that are built from basic units called slots. Each slot can be thought of as a two-dimensional block, one dimension being the time, the other dimension being the frequency. In general, a slot extends over one sub-channel in the frequency, direction and over 1 to 3 OFDMA symbols in the time direction, depending on the permutation scheme. The sub-channels are groups of OFDMA subcarriers. The number of subcarriers per sub-channel and the dispersion of the subcarriers that make up a sub-channel in the OFDMA symbol are defined based on the permutation scheme. As explained in more detail, the subcarriers of a given sub-channel is not always consecutive frequency. DL and UL sub-shapes can be split into different zones where different permutation schemes are employed. In Partial Usage of Sub-channels (PUSC) zone that is mandatory, the priority is to improve diversity and to spread out the outcome of inter-cellular interference. Each slot extends over 2 OFDMA symbols, and a sub-channel consists of 24 data subcarriers that are spread over the entire signal bandwidth (OFDMA symbol). Therefore, each sub-channel has approximately the same channel quality in terms of the channel gain and the inter-cellular interference.

To reduce the effect of the inter-cell interference, when PUSC is used, the available sub-channels are distributed among base stations so that adjacent base stations are not using the same sub-channels. When the inter-cell interference is not significant, as in the case of mobile stations located close to a base station, it may be advantageous to employ full usage of Sub-channels (FUSC). The goal of the FUSC permutation scheme is similar to PUSC, i.e., to improve diversity and to spread out the effect of inter-cell interference. Yet, as the name indicates in the FUSC zone all sub-channels are used by a base station. For this reason, the purpose of the pilot pattern for the FUSC zone is somewhat more effective compared to PUSC. A sub-channel in the FUSC permutation zone consists of 48 data subcarriers and the slot only comprises one OFDMA symbol. For users with high rate requirements, the AMC zone is utilized instead of PUSC or FUSC. AMC makes it easier to exploit multiuser diversity by using adjacent subcarriers to form a sub-channel. Sub-channels made of adjacent subcarriers vary in tone across the frequency spectrum. Thus, the system can employ opportunistic schemes that do not do well when the transmission bandwidth is averaged (as is the case when subcarriers are spread out). A sub-channel in the AMC zone consists of 16 data subcarriers. The frame structure is being redefined in 802.16m to make the allocation of transmission resources between the downlink and the uplink more flexible. 802.16m consists of a 20-ms super frame, divided into equally sized 5-ms radio frames using either Time division duplex (TDD) or frequency division duplexing (FDD). Each frame 5-ms is further sub divided into 8 sub frames using OFDMA. Each sub frame to downlink or uplink transmission, the decision is on the basis of assigned QoS. When more capacity is required for the downlink, the scheduler allocates more sub-frames for the downlink. Moreover, reaction time demands can be satisfied via proper sub frame allocation between the downlink and the uplink. Although some additional control overhead will be needed to signal the transitions between downlink and uplink and, vice versa, overall the system can benefit from the improved flexibility in rate allocation and response time guarantees. Moreover, for procedure to trim the overhead that is demanded for the positioning, an effort is under way in 802.16m to be fine the same basic unit for all permutation schemes and to improve the tractability of the organization. This will be accomplished by separating the subcarrier allocation mode from the transmission system. More specifically, a localized (contiguous) and a spread (non-contiguous) resource unit permutation mode is defined in 802.16m. As the figure suggests, localized (contiguous) permutation mode employs groups of contiguous subcarriers, whereas for the broadcast (non-contiguous) permutation mode the subcarriers of each group are spread away.

1.3.2.3 MEDIUM ACCESS CONTROL LAYER

The IEEE 802.16 standard is a connection-oriented wireless network (Alinejad, Philip, & Istepanian, 2012). Resources (either in the specific kind of grants or contention periods) have a scheduling algorithm for each service flow (or connection) taking into account that quality of service demands. Further extensions of the first design of the IEEE 802.16-2004 contain mobility (that is associated with functions, handovers and energy efficient algorithms), relaying, efficient localization and various other MAC layer functions. The MAC is divided into three sublayers:

i) Convergence sublayer (CS)

ii) Radio Resource Control and Management (RRCM) sublayer

iii) Medium Access Control (MAC) sublayer

i. Convergence sublayer:

The Convergence Sublayer (CS) resides on top of the MAC CPS (Common Part Sublayer). The Packet CS is responsible for accepting data units from higher layers, classifying, processing based on sorting, and delivering CS Protocol Data Units (PDU) to the appropriate MAC SAP (Service Access Point). In reality, it is the sublayer that unites the IEEE 802.16 MAC with the network layer. MAC CPS creates its protocol control information (MAC header) and it is responsible for the delivery of MAC PDUs to its peer MACCPS according to the QoS demands of the particular Service Flow (SF).

ii. Radio Resource Management:

It is responsible for the adjusting radio network parameters that related to the traffic load, and includes any other QoS-related functionalities, such as the load, admission and interference control (Saquib, Hossain, Le, & Kim, 2012). As well as the mobility management that is related to handover.

iii. MAC sublayer:

The functionality of the MAC sublayer refers to PHY control (cross layer functions, such as HARQ ACK/NACK, etc.). The control signaling block is responsible for the allocation of resources by the exchange of messages such as DLMAP and UL-MAP (El-Shennawy, Fahmy, El-Derini, & Yousef, 2014). The QoS block allows specific input traffic to different traffic classes based on the Resource Block (RB) planning and resource according to the SLA guarantees. The name of the other blocks, such as fragmentation/packaging, multi radio co-existence and MAC PDU-formation, clearly describe its purpose described. The MAC sublayer is also state-of-the-art power-storing and handover mechanisms for mobility to and connections at speeds up to 350 km/h. Because newer mobile devices tend to comprise from a growing number of functionalities. In a WiMAX network includes the energy saving implementation service differentiation on power classes. A natural consequence of any sleeping mechanism is the increase of the delay. Thus, delay-prone and non-delay-prone applications are allocated to different classes, such that the energy savings are optimized, while satisfying the appropriate QoS (e.g., those support web page, downloading or emails).

MAC addresses play the role of identification of individual stations. IEEE 802.16m introduces two different types of addresses in the MAC sublayer. 1) The IEEE 802 MAC address that has the generic 48-bit format and 2) two MAC logical addresses that are assigned to the mobile station by management messages from the base station. These addresses are used for resource allocation and management of the mobile station and are called “Station Identifiers” (assigned during network entry) and “flow identifiers” (assigned for QoS purpose).

1.4 PROBLEM IDENTIFICATION

In the following section, handover, bandwidth estimation-allocation and scheduling issues have been deeply analyzed.

1- Handover Issues.

i) To which base station the mobile station supposed to handover?

ii) Which is the best technology that guarantees higher quality of experience to the mobile station?

iii) How does the MS can work efficiently in the high attenuations area?

2- Bandwidth Estimation and Allocation Issues.

i) What is the amount of resource blocks the scheduler should offer for each application to satisfy its demand?

ii) What is the amount of resource blocks should be given to practical application (priority based application) to satisfy our demands?

3- Scheduling Issues.

i) How can the scheduler be able to schedule users based on their applications’ demands?

ii) How can the scheduling decision dynamically change once the requirements are changed?

1.5 OBJECTIVES

1) To predict the proper target base station and to select the most appropriate technology, which can match the user’s preferences.

2) To utilize the game theory approach and to propose an algorithm for resource allocation of flat priority based and specific priority based applications, respectively.

3) To define the new concept for scheduling namely multi-attribute decision making which can scheduler users efficiently based on applications' demands.

The proposed algorithms, approaches and methods can be useful solution to many issues, for instance the less number of relay base stations is required since the number of users which can be supported by a single base station is sharply increased. In addition, the good performance is guaranteed, especially at high attenuation area. In terms of quality of service issue (scheduling and handover issues), the service can be provided to identically match the user's performance (i.e., cost, delay, offering data rate, etc.).

1.6 THESIS OUTLINE

This study describes an efficient model for providing always best connection. The proposed model considers the handover issues, bandwidth estimation-allocation issues and scheduling issues. The organization of the study can be depicted as the following chapters.

The current chapter briefly focuses on the research work. It describes the challenges and limitations regarding handover, bandwidth estimation-allocation and scheduling issues. The motivation and purposes of this study have been included here. A brief overview of each issue has been depicted. This chapter also addresses the future scope of the study.

Chapter 2 describes the details for the existing research work regarding to handover, bandwidth estimation-allocation and scheduling issues. It defines and summarize the advantages, dis-advantages and limitation for each studied issue.

Chapter 3 provides a comprehensive discussion about the proposed methodology on handover issues between LTE and WiMAX, bandwidth estimation-allocation and scheduling issues for flat priority based applications and specific priority based applications.

Chapter 4 analyzes the generated results of handover and scheduling issues. Some simulation has also been presented. It also deals with the comparative study of the proposed methodology with the existing ones. The proposed prediction techniques, selection approach and scheduling algorithms have been proved superior in terms of execution time, prediction accuracy and performance.

Finally, Chapter 5 states the conclusions drained from this study. It presents a summary of the generated results found from the previous chapter to prove the superiority of the proposed algorithms. The application and future improvement scopes are also suggested in this chapter.

CHAPTER TWO

LITERATURE REVIEW

2.1 HANDOVERS AMONG HETEROGENEOUS NETWORKS

Many algorithms have been proposed for vertical handover procedure based on a number of criteria, such as available bandwidth, RSS, SINR, connection cost, handover delay, mobile station’s velocity, battery consumption and QoS. For instance, in (!!! INVALID CITATION !!!), the mobile station checks surrounding base stations and then handoffs to the one which can offer the lowest delay and the highest bandwidth. It is so clear that it is not possible to transfer an appropriate decision only by evaluating these criteria (delay, bandwidth) leads to an increase in the false handover prediction ratio. Whereas (He et al., 2011), the handover technique offers with less complex algorithm while maintaining a decision robust vertical handover between heterogeneous networks. In addition, this method is based on an assessment of the criteria of the multi retrieved the neighboring base stations and determines the potential target base station. These criteria are the available bandwidth, cost of the service, received signal strength, expected stay time in practical network and energy/power consumption.

For reducing the number of unnecessary handovers, described authors in (Yan, Mani, & Sekercioglu, 2008) a handover decision scheme that threatens the time a mobile node spends in a WLAN. This mechanism is highly dependent on the assessment of the traveling time users within a WLAN and the calculation of the threshold of a time. Handover to a WLAN only if its cover is present and if user travel estimated time in that specific network is greater than the predefined threshold time is started. If a handover to a cellular network is intended, it should qualify for two conditions, (i) RSS of the

WLAN is constantly humiliating and (ii) mobile station has reached the cell border due to its high speed and a handover should be started. This arrangement reduces unnecessary interruptions, handover and also reduces the ratio of handover failures. However, higher handover delays are observed because authors use sampling on average of RSS that is a time-consuming process. Cheng et al. (C. W. Lee et al., 2005) proposed that a QoS based vertical handover seen with available bandwidth and user decision scheme by preferences for deciding the direction of the handover of a WLAN to WWAN8 and inverse. When a mobile station is connected to a WLAN, the proposed scheme is initiated by checking the status of the terminal and by comparing the RSS-level with advance defined thresholds. If the mobile node is found the idle position, then the handover is carried out to the desired access network otherwise an offer of application type is considered for handover. For delay-sensitive applications, takes place a handover only if the current serving network may not be suitable in terms of QoS is to run applications. In the same way as WWAN offers higher bandwidth compared to WLAN so handover is performed for delay-tolerant applications. The proposed methodology with higher throughput and lower latency of the handover are the result of using of the available bandwidth and application type as main handover criteria.

Measuring the bandwidth in cellular networks, however, is a complex task as mentioned by the authors themselves in (C. W. Lee et al., 2005). Also, this scheme leads to high blocking rate for new upcoming handover applications due to sin idle state. Bazzi in (Bazzi, 2010) proposes a new definition of the softer vertical handover together with an algorithm for heterogeneous wireless systems to support the discussion. This definition takes into account the network conditions of user mobility, available bandwidth and application type. The proposed definition is mainly focused on the best effort service into the UMTS networks using different mobility scenarios. An analytical model also proposes that works for multi-mode terminals and some dynamic lists that measure the observed handover of the connected terminals for the best network selection. The proposed algorithm improves the overall throughput for a softer handover, however, other aspects of the QoS as handover delay, packet loss, etc., seem to be completely ignored in all scenarios. Using a very similar technique in (K. Yang, Gondal, Qiu, & Dooley, 2007), the authors presented a bandwidth decision handover scheme between WLAN and WCDMA.

For the case where the handover is triggered to network that exhibits larger SINR values. Usually, SINR oriented handovers provide users with higher overall throughput than the RSS based ones as a result of direct dependence on throughput over SINR. This is the reason that the proposed schemed a task of load balancing in these two heterogeneous networks. However, this can also result in excessive handovers as a result of the variation of the SINR and it causes the Ping-Pong effect. Authors in (H.-L. Wang & Kao, 2011) have also presented a SINR-based approach by considering the available data rate and back haul bandwidth for calculating the handover decision time and optimizing the resource allocation in the available network. However, some latency is induced in their proposed scheme because of improper network selection.

Both (Bhebhe, 2008) and (Ahmavaara, Haverinen, & Pichna, 2003) presented the state of the LTE-WLAN “interworking” technologies and gave an overview of the network architecture. The author has on (Ahmavaara et al., 2003), some of the “interworking” architecture issues around the network discovery and selection, safety and mobility and gave some recommendations, however there is no solid solution for any of them.

In (Haider, Gondal, & Kamruzzaman, 2011), the authors propose a novel handover technique for reduction of handover failure probability and the elimination of unnecessary handovers. With a view to these features, they have fused together three different techniques: (1) Signal trend detection; it indicates the need for upward or downward vertical handovers. For example, if a mobile station enters into a WLAN coverage area and RSS is raising, then the handover will start to the nearest WLAN access point. (2) Adaptive threshold setting; it is used as a trigger for variations in mobile station that adjusts speed and channel parameters and it also estimates the possible handover delay. (3) A Dwell Timer for fast moving terminals; it is beneficial at high speeds a mobile station case where the mobile station knows if it should handover immediately or stay connected to the current base station based on the coverage area of a specific network. This timer helps in fast handover and reduces the waiting time. This arrangement reduces successfully handover failure and Ping-Pong effect, but an excess amount of signaling is observed which makes packet loss as well.

Mohantyet et al. (Mohanty & Akyildiz, 2006) proposed a handover decision algorithm of WLAN to 3G networks based on the comparison of the current RSS threshold level and a dynamic RSS threshold level, RSS in a scenario where, a mobile station is connected to a WLAN access point. Using a dynamic RSS threshold helps to reduce the number of unnecessary handover and it also keeps the number of failure probability under predefined limits. The authors have shown that the handover failure probability increases in cases where either velocity or handover signaling delay increases, when a fixed value of RSS threshold is used.

Nevertheless, handover failure chance of a 3G network in WLAN in this scheme reflected as 0 because the authors have considered the availability of 3G networks as ubiquitous. This is the reason that in the proposed scheme handover to a WLAN constantly is essential every time the mobile station arrives in the WLAN network coverage area. However, this is not always convenient because such a handover can result in consumption of additional network resources because the overall efficiency of the proposed approach degrades if the moment time of mobile station in WLAN is less than the handover latency. Authors in (Pahlavan et al., 2000) and (Ylianttila et al., 2005) proposal for the coordination of the mobile station use to activate vertical handovers. They compared to two approaches regarding data rates velocity and handover delay for both roaming situations (i.e., roaming in and out). They studied a variable length of the dwell timer who lives in joining and leaving a practical network, and compared to its advantages and dis-advantages in addition to power-based approaches. They have proven that the dwell time timer value is dependent on the difference between the available data rates for current and destination networks. A handover is activated if a predefined level of RSS threshold network is consistently below and less than the sum of the new RSS and a hysteresis. The proposed scheme seemed to be less sensitive to the increases in the handover delay, but it can affect the performance of real-time applications, which is a dis-advantage of the scheme.

Emmelmenn et al. (Emmelmann et al., 2008) proposes a design seamless handover mechanism for high mobility mobile stations using dynamic dwell timer. This scheme is designed for IEEE 802.11 networks and aims to delay the handover for the transfer of data by telemetry services. The model contains of two proposed cellular coverage areas, namely micro and macro cellular, operating on the same frequency. According to the authors, their proposed method reduces the handover latency by avoiding using conventional handover phases, using a centralized Radio Control Unit (RCU) that adjusts the dwell timer according to the coverage area and speed of the mobile, in addition RCU have had all the handover related information. It is important to mention that RCU has had all the handover related information. As a mobile user enters in macro cell, its handover is estimated by the RCU and transmitted to the neighboring RCU. This helps in reducing packet loss due to advance packet buffering and also, reducing handover delay because of early binding.

Becvaret al. (Becvar, Mach, & Simak, 2011) suggests a handover mechanism in order to maximize the handover prediction efficiency using the RSSI with hysteresis as in (Ylianttila et al., 2005) and (Mohanty & Akyildiz, 2006). They have defined the two different thresholds for this to exploit the best use of it. This scheme involves measurement of the average (mean) value of pre-determined thresholds for the handover initiation. For this purpose, a sufficient number of samples are intended as an aid in RSSI estimation of the number of handovers, which is most likely to happen between the actual and target base stations.

This helps in the assessment of handover probabilities among participating base stations, also discussed the impact of fluctuations in RSSI on the ability of predicting the capacity. The proposed scheme does not need to make a border entry of mobile users or any specific knowledge of the targeted networks. But, the writers need to discuss the question of the interruption of handover in the situations of mobility prediction of vertical handovers.

Using a similar method to (B.-J. Chang & Chen, 2008) (B.-J. Chang et al., 2009), Chang et al. suggested a cross layer according to regression polynomial predictive models RSS scheme with the Markov Decision-making Process (MDP) based network selection for the vertical handover heterogeneous networks wirelessly. The proposed scheme consists of two phases, that is to say: (1) Phase of the decision, to which the measure predictive models of RSS with a value of hysteresis is carried out and (2) Selection of the network phase, in which an optimal goal network to which the handover is intended is calculated. In the first phase, a step backwards polynomial based methodology will be used to determine whether a mobile station moves for the approximation or the return of a network wirelessly. Second phase, the possible candidates have access to a lower cost network with the help of MDP for an optimum network selection for handover. The proposed approach achieves load balancing and unnecessary handovers in the targeted networks while making sure the utilization of higher link and occupying it for a longer time and to avoid unnecessary movements during the routes wireless are busy for a longer period. Another solution is derived based on RSS in (Xia et al., 2008) deals with the adaptation of QoS parameters according to network conditions dynamic heterogeneous networks.

To achieve custom mobility and end-to-end official guarantees for the users in a heterogeneous environment, Kim et al. (M. J. Kim, Son, & Rhee, 2009) proposed a mesh Network based handover decision scheme. They have considered the user movement, RSS and user preferences as mobility decision. Two scenarios have been elaborated by the authors for the possible moments between WLAN and WiMAX Networks, i.e., moving out of the mesh overlay area and moving in the mesh overlay area. There are two domains which are administrated by WLAN and WiMAX, respectively, in each mesh router. When the mobile station notes out of the overlay area, the RSS from the access point in mobile node is used as main metric to initiate the vertical handover. When the mobile station notes into the WLAN coverage area, the mobile station may keep the connection with the WiMAX network or make a decision to trigger the handover to WLAN according to the user preference, The WLAN network condition and the current traffic always in the target network. This scheme reduces the handover delay and packet delivery delay, but it may become the resource consuming for networks as users switch between the two domains very often Ping-Pong effect.

The WLAN-LTE interworking architecture to support 4G networks interoperability is proposed in our publication. The proposed architecture relies on designing a hybrid router with dual radio that can provide seamless handover between LTE and WLAN. The substantial advantages of this architecture are the simplicity and eliminating the need for modifying the existing WLAN functions. The simulation results provided basic verification of router architecture by comparing the performance of the pure LTE (eNodeB and LTE user equipment) and the heterogeneous network (the cell containing the hybrid router and WLAN device). Increasing a network load beyond its capacity degrades the services. Degradations are tolerable for most applications other than real-time or multimedia traffic, which cannot cope with such degradation. Table 2.1 illustrates the advantages and dis-advantages of some handover approaches.

Table 2.1: Transfer between Different Networks

Handover Approaches	**Advantages**	**Disadvantages**
(Emmelmann et al., 2008; Haider et al., 2011; Ylianttila et al., 2005)	-Reduced faulty handovers. -Reduced the impact Ping-Pong effect. -Reduce handover delay.	-Packet loss increased. -High signaling is essential. -Unfit for real-time applications.
(Mohanty & Akyildiz, 2006) (Becvar et al., 2011)	-Limitation of unintended start of the handovers. -Limitation in handover failure.	-Increase in handover failures of data to mobile networks. -The loss of resources to the network.
(B.-J. Chang et al., 2009; Xia et al., 2008; Yan et al., 2008)	-Connection reduces breakdown. -Avoiding of unnecessary handovers. -Load balancing at targeted networks.	-Influence by Ping-Pong effect. -Handover latency increased.

(C. W. Lee et al., 2005) (Bazzi, 2010)	-Low latency. -High level throughput. -Greater good selection of network.	-High loss of packets. -Inefficient calculation of the bandwidth.
(Ayyappan & Kumar, 2010)	-Greater throughput. -Optimal allocation.	-Increase in latency while handover. -Does not compatible with high speed mobility. -Notable Ping-Pong effect.
(M. J. Kim et al., 2009)	-QoS guarantee. -Less value of the packet loss ratio. -Reduced the handover delay.	-Recourse consumption at its peak. -Prone to session instability.
(Bhebhe, 2008)	-Low handover blockade. -High throughput of data.	-High load on the system. -Exponential growth of the handovers latency. -Estimation difficulties of the cost for a specific parameter.
(Tawil, Pujolle, et al., 2008) (Alkhawlani, 2012; Tawil, Salazar, & Pujolle, 2008) (Lahby, Cherkaoui, & Adib, 2012) (Stevens-Navarro & Wong, 2006)	-Low handover blockade. -Noticeable reduction in Ping-Pong effect.	-Degraded in the quality of service. -High latency.

Despite the fact, some of the previous approaches (i.e. RSS and Multi-criteria approach) prove high-efficiency in environments with low interference, but it may not work appropriately in high interference areas. Thus, it must be merged with interference cancellation techniques. In the following section, we will survey the most important frequency reuse techniques.

2.2 FREQUENCY REUSE OVERVIEW

2.2.1 FREQUENCY REUSE FOR LTE NETWORK

Authors in (Porjazoski & Popovski, 2010), analytical contribution to interference cancellation as well as the estimation of the SINR in LTE network. Fractional

Frequency Reuse (FFR) is proposed for the improvement of the cell coverage area. The authors have used analytical method to allow a comparison between the different levels of the reuse, three cell cluster and implemented Inter-Cell Interference Coordination (ICIC) on the basis of FFR headed. Analytical results have shown that, if FFR is used, then the interference is lower than that of Universal Frequency Reuse (UFR) case. With UFR, the improvement of system performance can be determined to 10 dB increases of SINR in uplink. While by the using Fractional Frequency Reus 3 (FFR 3) the interference is less compared to FFR. But the price to the FFR 3 is three times greater spectrum than without FFR. During the use of FFR instead of UFR gives a 10 dB, strengthening of the SINR which results in approximately two times larger cell radius. The authors did not examine the effects of the size of the Cell Center Users (CCUs) and Cell Edge Users (CEUs).

A Soft Frequency Reuse (SFR) has been recently proposed by many researchers in replacing with FFR (L. Chen & Yuan, 2009; Elayoubi, Ben Haddada, & Fourestié, 2008; T. Novlan, Andrews, Sohn, Ganti, & Ghosh, 2010). In SFR the complete bandwidth can be reused in each cell comparing to FFR, the range in each cell is divided into two groups as a major and minor sub-bands. The major sub-bands can be assigned to the user located in the two regions of the cell internal and external regions, which are orthogonal to each other in neighboring cells. On the other hand, the minor sub-bands have a low transmit power compared to major sub-band's one, so it can use only for users in the inner cell area. A power ratio has been introduced to sort out the ratio between the power in major and minor sub-bands (Mao, Maaref, & Teo, 2008). However, in these SFR schemes the distribution of power and spectrum for major and minor sub-carriers are defined. After the simulation (Elayoubi et al., 2008) and (T.

Novlan et al., 2010), The regulatory SFR scheme proves greater spectrum efficiency than FFR technique.

An analytical framework has been proposed for the assessment of the probability of failure user in the cell-edge in FFR schema and SFR scheme in (Bilios, Bouras, Kokkinos, Papazois, & Tseliou, 2013). It has a great influence on the QoS of CEUs and may make a general presentation of cells or network capacity if resources efficiency are combined. In (Mao et al., 2008; Xiang, Luo, & Hartmann, 2007), the SFR scheme has been proposed, adopted in the 3GPP-LTE network. The severe ICI problems can be mitigated from adjacent cells at a cell-edge region in the SFR scheme by emphasizing a part, namely the primary band of the existing radio spectrum and assigning it differently for CEUs. However, only a pre-defined number of CEUs can be accommodated by high-powered primary band and the limited-powered secondary bands are to be allocated to the remaining CEUs, the severer ICI still might incur to some of the CEUs.

The main disadvantages for conventional hard reservation SFR scheme is, if the user is not equally distributed in the cell coverage area, it effects the fair resource distribution and multi-user diversity gain. The authors (Fodor et al., 2009; G. Li & Liu, 2006) proposed the new procedure, it is a soft reservation procedure to overcome the conventional scheme problems due to the common use of the whole region resources between the users. It shows a greater multi-user diversity gain, and more fair resource allocation by a wider region.

The authors (Lu, Tian, Sun, Huang, & Zheng, 2010) proposed a survey that was held on joint design of SFR and the call admission control approach. In this proposed scheme, a new configuration resource policy of the SFR and algorithm of access has been studied.

This leads to a full frequency planning of SFR and the coordination between the different cell regions or adjacent cells. The simulation results show a report of the traditional and proposed algorithm. The proposed mechanism reaches the results improved compared with the traditional admission control mechanism in regard to the use of resources, block-probability, cell throughput, handover failure and the number of users that each cell can facilitate.

The authors in (Yu, Dutkiewicz, Huang, Mueck, & Fang, 2010) discussed the themes of different traffic loads and all sorts of different power ratio and have examined the configurations performance of SFR for LTE-downlink transmission. The total flow cell, CEUs and CCUs are evaluated. The simulation results showed analysis-compares, advantages-disadvantages of SFR comprehensively against the classical frequency reuse of one scheme. An extensive study on the performance the SFR scheme for ICI coordination in LTE has been proposed in (Yu et al., 2010). It examines and evaluates the throughput diversity of flow SFR on average for CCUs, CEUs or taking into account the reports of dynamic force and many workloads. The evaluation of benefits is in the form of system level simulation of the comparison of SFR with conventional frequency reuse. The results have revealed that the SFR system could mitigate the ICI smoothly. This is happening in medium traffic volume and by the improvement of the throughput capacity significantly. The cell-edge throughput improvement is at the charge of dedicating performance of the users in the cell-center if the traffic load is relatively high which may result in limiting the average throughput enhancement. In regards to the transmission power allocation to the CCUs and CEUs, the SFR is sensitive to the allocated power ratio. In detail, the SFR may maximize the throughput of the CEUs but; due to the impact of inter-cell interference the overall cell throughput might be deteriorated.

As an innovative, Load Distribution of Soft Frequency Reuse (LDA-SFR) scheme has been proposed for mitigating the ICI and optimizing the performance for LTE network in (Yu, Dutkiewicz, Huang, & Mueck, 2011). The main goal of that proposed method is to provide a promising solution to mitigate the ICI with high spectrum efficiency to all users in the cell. Two innovative algorithms, named edge bandwidth reuse and center bandwidth compensation have been proposed. The uneven traffic load and user distributions within the cell can be taken by the CEUs by utilizing the edge bandwidth reuse algorithm. On the other hand, a protection mechanism to avoid exhaustive edge bandwidth extension for CCU has been provided by the center bandwidth compensation algorithm. The performance of LTE network after applying the LDA-SFR was superior against that of existing SFR and Adaptive Soft Frequency Reuse (ASFR) schemes due to the achievement of fairness between CEUs and CCUs in terms of average throughput improvement. At first, the improved performance of edge bandwidth reuse algorithm has been achieved by maximizing the bandwidth allocation into the CEUs. Whereas, the good quality communication in terms of higher SINR has been provided by center bandwidth compensation algorithm to project the performance of CCUs.

The authors in (Jiang et al., 2011) have proposed a new technique which is called a Frequency Shifted Frequency Reuse (FSFR) technique to mitigate the control channel interference for LTE network. It was proved as smart and effective frequency planning due to low complexity, low cost and good numerical results. FSFR technique can be helpful for applications which are required neglect control channel inter-cell interference as well low-complexity in terms of operations.

In (Yu, Dutkiewicz, Huang, & Mueck, 2012), a power allocation approach for SFR has been applied in a multi-cell LTE network where, the major ICI was coordinated by SFR.

The mutual interference between cell-edge and cell-center users has been focused on the network. The CEUs' performance is optimized with the condition of keeping the CCUs desirable performance, which is proposed as an optimization problem in this work. The performance of SFR enhanced in multi-cell LTE downlink network based on power allocation solution where the mutual interference between cell-edge and cell-center users are emphasized each eNodeBs. Then the power allocation can be formulated as a constrained optimization problem. The performance of CEUs can be significantly improved by the proposed method where promising performance for CCUs have been achieved compared to conventional SFR with average power allocations.

Due to high demands in terms of improving the performance of railway mobile communication, a SFR has been proposed as an effective frequency planning approach in LTE network by many scholars (Gajewski, 2013; Giambene & Yahiya, 2013; López-Pérez, Claussen, & Ho, 2013; Qian et al., 2012). A comprehensive analysis on inter-cell interference of the SFR scheme in railway communication has been done in (Qin, Zhong, Xu, & Bai, 2012). A brief theoretical analysis on inter-cell interference about SFR has been performed and an investigation on system performance in terms of cell-edge throughput, average cell throughput, carrier frequency, varying power ratio, component carrier load balance have been done in this work. The authors have given some significant conclusions on the performance improvements of SFR scheme with the varying carrier frequency which offers the opportunity to apply Carrier Aggregation (CA) in LTE network. In order to maximize cell edge throughput in SFR the overall cell throughput may be suffered from inter-cell interference. The novel methodology of optimized cell geometry constraints which has given a more inclusive picture of the situation and has clarified the occurring phenomena has been proposed in (Gajewski, 2013). It has focused its study about the comparison between both the SFR and Partial

Frequency Reuse (PFR) and have presented the impact on throughput-coverage features of LTE networks. Firstly, the throughput features of individual user connection has been presented in simulation results to evaluate the stability and availability of achieved bit rate in different cell areas. Secondly, the characteristics of the network capacity have been shown to evaluate the available capacity in different cell regions. The paper results have given a clear view about different ways of cell division by assigning different frequency bands among them. In addition, the paper might be suitable in designing the LTE network in terms of the throughput for individual connection and the capacity of a cell. Moreover, SFR method provided promising results in terms of capacity maximization. However, some advantages have been perceived for the PFR side as well by taking into consideration of the maximum suitable throughput for individual user connection. The effects of the inappropriate selection of the Central Area of a Cell (RCAC) Radius has been clearly shown which contributed the negative results of the inappropriate bandwidth allocation for both SFR and PER. The analysis of a single user connection throughput and the maximum available cell throughput have been shown the stability of the achieved throughput in the cell area and given the information on the overall capacity of a cell, respectively. The maximum available throughput has also provided the information about the capacity for both the CAC and Boundary Area of a Cell (BAC). The optimum value of RCAC radius has been selected with the consideration of network design requirements of the selected area.

Cell capacity issues and cell planning for LTE technology to efficiently utilize the bandwidth have been proposed based on SFR in (Giambene & Yahiya, 2013). The authors divided the cell area into two main parts, namely the central part and the external part and using different reuse schemes for each part. The SINR and the probability of different transmission modes have been characterized in cell area in reference with SFR. The results proved that, the cell capacity optimization has been carried out by means of extensive numerical results in order to select both the radius of the cell center region and the border-to-center power ratio of SFR.

The revolution of utilizing the soft-frequency reuse technique as a way to enhance the Radio Resource Management (RRM) and handover processes in LTE network have been proposed in (Hindia, Reza, & Noordin, 2014; Pramudito & Alsusa, 2014), respectively. The authors based on assigned the available resources in the manner of distribution and centralization to maximize the spectral efficiency across the whole network. As well as, a unique interference mapping technique has been adopted to assist in determining whether a distributed or centralized mode was appropriate per base station. A distributed approach has been established to use the entire spectrum in base station whereby a centralized approach has been executed to utilize the allocated subset of the spectrum. The proposed method has been utilized the full spectrum of proportional fairness scheduler where the centralized approach was used the interference map and a routing strategy to recognize available subcarriers. The proposed algorithm showed an ability to enhance the guaranteed data as well as the same rate for LTE network.

As an extension to FFR Schemes, the horizontal sector offset for LTE network has been proposed. The authors in (López-Pérez et al., 2013) addressed the poor performance problem at the CEUs. The sector offset configuration extension has been proposed to LTE network through a new method by allowing to install offset antennas in eNodeBs without increasing the number of handovers significantly. This extended sector offset configuration has been compatible with channel dependent schedulers as well as offered significant gains. In this proposed method the whole LTE carrier has been divided into two fragments. Every eNodeB has been prepared with configuration of two sectors. It has been shown in the simulation results that the proposed sector offset configuration for LTE increased the average throughput of UE and 5% tile the throughput of UE by up to 22% and 32%. However, the number of handovers increased slightly compared to the traditional sector offset eNodeB configuration. In addition to that, the proposed configuration has significantly been reduced up to 69% handover failure rate by according to the simulation results. The first antenna pattern configuration was offset with respect to the second antenna pattern configuration in a manner that the maximum gain in the first sector configuration points in the sector boundary direction in the second sector configuration. Furthermore, each sector configuration was transmitted over various spectrum fragments, and same CRS was used in every pair of adjacent antennas. Hence, the high interference of cell-edge regions have been significantly reduced as well as the handovers occurred among antennas have also been avoided. Although this new configuration has increased the number of handovers slightly, but the handover failure rate reduced significantly by up to 69%. The concept of this increased number of sectors have been extended more carriers.

Table 2.2: Frequency Reuse Technique for LTE Network

LTE FR Techniques	**Advantages**	**Dis-advantages**
(Porjazoski & Popovski, 2010)	-Analytical study for interference cancelation. -Study the impact of FFR for LOS and N-LOS environments.	-Dose not cover the influence regarding to the change on size of CCU and CEU areas.
(Bilios et al., 2013)	-Dynamic selection for the optimal cell size and operating frequency for each region.	-Complex calculations are required until finding the optimal values. -Cannot integrate efficiently with other algorithms especially handover once since of delay.
(Amer, 2012; Z. Li, Wang, Pan, Liu, & You,	-Significate Improvement for the CEUs in terms of throughput.	-High drop in the overall system performance, system throughput and accommodation capacity especially when the users are

2012)		concentrate in the cell edge.
(Lu et al., 2010)	-Overcome the lack resource configuration for traditional admission control of SFR. -Efficient utilization of ideal resources. -Increase the number of users accommodate per cell.	-Significate increase in admission control procedure information which is required to be exchange between BS and UE.
(Jiang et al., 2011)	-Low cost. -Low complexity.	-More studied supposed to be made especially in high mobility case >120km/h.
(Yu et al., 2012)	-Enhance the CEUs' Performance.	-Up to practical level of cell-center user' number, **Continue…** the performance of the CEUs will be scarified to provide an optimal service for CCUs.
(Giambene & Yahiya, 2013)	-Dynamic adjustment of the transmission mode (MCS) based on the surrounding environment.	-Does not take on its consideration the delay could be added by the transmission delay (queuing delay and re-transmission delay).
(Pramudito & Alsusa, 2014)	-Remarkable improvement for data rate and QoS for guaranteed bit rate data type. -Applicable with different scenarios and environments. -Significate minimizing of the overhead signaling.	- No study for The mix traffic is applied at once (guaranteed and non-guaranteed).

2.2.2 FREQUENCY REUSE FOR WIMAX NETWORK

WiMAX Forum has been proposed based on IEEE standard 802.16. In addition, two types of WiMAX technologies named fixed/nomadic and mobile are available which are classified based on version 802.16-2004 (Maqbool, Coupechoux, & Godlewski, 2008) of the standard and the latter is featured by an amendment, 802.16e (Rappaport, 1996).

Both parameters named SINR and bandwidth of frequency reuse have to be maximized for achieving the promising cell throughput in the network. The cell throughput can be increased by completely utilizing the available bandwidth in each sector with maintaining a minimum SINR level, which is required for connecting with the service.

Whereas, the effect of the frequency repartition scheme has been analyzed based on non-sectored cells in (Tarhini & Chahed, 2007).

Dynamic frequency reuse which cases of sectored cells has been taken into account in (Y. Chen, Wang, Li, Zhang, & Peng, 2008). Two different frequency reuse patters with accentuate on the effect of PermBase have been compared. Here, PermBase is an integer that controls the allocation of subcarriers to a sub-channel in the sector of a cell. The same sub-channel utilizing the same frequency band with different PermBase in two different sectors has been considered. Only one type of frequency reuse approach without fading and shadowing have been simulated for WiMAX network using beam forming and Space Division Multiple Access (SDMA) in (Y.-J. Choi, Kim, & Bahk, 2006). In addition, two frequency reuse approaches using Multiple Input Multiple Output (MIMO) without beam-forming consideration has been compared in (J. Lee & Yanikomeroglu, 2010).

The performance of two frequency reuse schemes for Non Line-of-Sight (NLOS) of beam-forming capable WiMAX network have been analyzed in (Paulraj, Gore, Nabar, & Bolcskei, 2004). Physical representation for SINR computation were not considered in this evaluation process. With the lower resource consumption the proposed interference coordination technique increased SINR.

The usage of FFR in the cellular WiMAX system has been analyzed in (Tomcik, 2005) where frequency resource configurations characteristics of mobile WiMAX networks were defined and FFR system model were presented. The principle of the user partitioning scheme and a FFR combination partition scheme have been proposed according to the system model. The proposed scheme achieved better results compared to the conventional schemes, according to the numerical results. Based on simulations carried out, in contrast to dynamic distance and the dynamic normalized SINR schemes, the proposed combination partition schemes gives better performance results.

A framework to evaluate both DL and the UL coverage performance of the WiMAX (IEEE 802.16e) standard has been presented in (Jalloul & Alex, 2008) under a network system with a number of cells and sectors whereas the spatial region coverage for a FFR1 and FFR3 have been evaluated. The results have shown that, the base station receivers consist of two antennas, a WiMAX could be limited to UL coverage with the tradeoff between the throughputs of the UL sector and UL coverage performance. On the other hand, the coverage performance has been improved significantly with the combination of Segmented Frequency Reuse 3 (SFFR3) and Cyclic Delay Diversity (CDD) on the downlink. Additionally, a comparison between Minimum Mean Square (MMSE) receivers and Maximum Ratio Combining (MRC) of downlink coverage performance at the subscriber mobile station has been shown in the results. It has also been shown that for an adequate performance in the downlink coverage a CDD at the base station transmitter and an MMSE receiver for a single frequency reuse were required. To get a satisfactory downlink coverage, a combination of MMSE processing at receiver and CDD at transmitter were required in low frequency selective channel while utilizing single frequency reuse. It has also been shown that the downlink coverage has been improved by the combination of segmented frequency of 3 and Cyclic Delay Diversity. A two-antenna base station receiver has been used to cover the uplink area by 91% and the CDD and MMSE used to cover the downlink area by more than 96%. Therefore, by utilizing 2-antenna base station receiver the WiMAX network system is limited to the uplink coverage.

Three approaches for the employment of fractional frequency reuse to the downlink of multicellular WiMAX networks are presented in this work (Stiakogiannakis & Kaklamani, 2010). The first approach assigns users to different zones with different frequency reuse factors based on a distance criterion while the second one conducts assignment based on a SINR criterion. The novelty of this work lies on the proposal of a third approach which assigns users to zones considering both user's channel quality and the load of the zones. From its results, it approves a clearly better performance of the proposed algorithm compared to distance-based and SINR-based approaches. It is shown that the employment of FFR with the proposed load-balancing approach improves the performance of WiMAX networks in terms of a variety of metrics, such as blocking probability and achievable bit rate.

A hard FFR pattern was introduced in the IEEE 802.16e standard where the available total bandwidth has been assigned to inner and outer cell users based on time division. The downlink sub-frame has been configured in a way so that users can utilize all available sub-channels close to base station and the users at the cell edge can utilize the fraction of the available sub-channels. The author in (Hamouda, Yeh, Kim, Wooram, & Kwon, 2009) has been proposed a dynamic SINR-based hard FFR to select the size of each region and a frame-by-frame adjustment has been made by allocating the number of symbols per WiMAX sub-frame based on system load. However, this proposed scheme has been effective when the users in the cell distributed in a non-uniform manner. In this scheme, with the non-uniform distribution of the user, the cell edge throughput outage has been reduced by 0.45% and total system throughput has been increased by 1.75% compared to a static FFR scheme.

The cell splits in four overlapping sectors has been proposed in (Sari & Sezginer, 2009) where the users have been served by the MIMO techniques in the overlapped regions.

The full-rate codes and half-rate codes have been introduced for uplink and downlink to analyze the performance of the system. The substantially higher performances have been achieved by the users in the sector overlap regions and benefited from spatial diversity in addition to utilize the full frequency reuse compared to the users located in the sector overlap-free regions. Although there observed some tradeoffs between higher performance and the higher data rate, this proposed frequency reuse technique with cell sectoring mechanism has been increased the cell capacity by a factor higher than 4.

Either Reuse-1 (R-1) or Reuse -3 (R-3) frequency planning pattern has to be utilized in the current WiMAX technology. But both frequency planning have advantages and dis-advantages. In addition, the high spectral efficiency has been achieved by R-1 pattern, but results in high ICI at the CEUs. On the other hand, the ICI has been reduced by using R-3 pattern which ensures good coverage at the CEUs. There is also a limitation that is low CEU's throughput because of the reduction of available bandwidth. Multiple FFR-schemes has been simulated for enhancing the quality of performance of current WiMAX networks in (Darwish, Ibrahim, Badawi, & Elgebaly, 2011). The simulation results proved that the user's throughput was significantly improved by FFR with slight degradation of spectral efficiency than that of the R-1 techniques. The author's considered the multiple FFR algorithms, including adaptive power FFR and two-threshold FFR to characterize the performance of FFR. The user's throughput has been significantly improved by FFR with slight degradation of spectral efficiency than that of the R-1 scenario. The authors considered multiple FFR algorithms, including adaptive power FFR and two-threshold FFR to characterize the network performance based on FFR. In addition, the tradeoff between the spectral efficiency and CEU's throughput by FFR algorithm has been quantified. The two-threshold FFR algorithm achieved 47% better results compared to R-1 in the cell edge throughput compared with R-1 case, where, spectral efficiency degraded up to 17%. On the other hand, the adaptive-power FFR algorithm experienced up to 31% improvement in cell edge throughput than that of R-1 with 11% degradation in spectral efficiency.

The distance based, SINR based and load balancing based reuse schemes have been evaluated in (Stiakogiannakis, Athanasiadou, Tsoulos, & Kaklamani, 2012). The inability of efficiently management of the available resources for both reuse zones is the main drawback for SINR based technique which was recovered by the proposed load balancing approach. A ray-tracing propagation model has been employed for estimating the propagation characteristic to evaluate the different approaches. The authors claimed that the better performance of the proposed algorithm has been achieved than that of the distance-based and SINR-based approaches. Also, the overall performance of WiMAX network has been improved by the proposed method in terms of a variety of metrics, such as blocking ratio and offered bit rate. The distance based approach assigned users to different zones based on a distance criterion, while the SINR based approach conducted assignment based on a SINR criterion. In the proposed method, users have been assigned based on the user’s channel quality and the load of the zones.

The IEEE802.16d/e standardization initiatives for wireless Metropolitan Area Networking (MAN) aims at portable and mobile Broadband Wireless Access (BWA) in cellular deployments offering high data rate and high capacity scenarios for both mobile and fixed wireless access (Ball, 2005). The sub channeling, turbo coding as well as multiple antenna systems (i.e. MIMO) are included in OFDM based WiMAX air interface. The capacity and spectrum efficiency for both the basic SISO and advanced 2x2 MIMO technique have been focused in (Ball, Humburg, Eder, & Lacinak, 2007). The author’s simulated for SISO, MIMO diversity and MIMO spatial multiplexing assuming a pedestrian PedB-3 channel model characterizing slow moving subscriber scenarios. The channel capacity and spectrum efficiency have been evaluated on a semi-analytical technique to estimate the rapid performance in cellular packet data networks. Two generic traffic approaches were utilized to evaluate the spectrum efficiency for the upcoming new broadband OFDM IEEE 802.16 WiMAX system. An Equal Mean Packet-data Call Duration (EMPC-D) was considered in the first traffic model. On the other hand, Equal Mean Packet Call-data Volume (EMPC-V) per subscriber was assumed for the second approach. Promising results up to 40% in terms of spectrum efficiency between both traffic models has been proved in (Ball et al., 2007). The comparison of mobile WiMAX with SISO and MIMO revealed considerable performance advantages for advanced MIMO antenna systems in the order of 120% for EMPC-D and up to 270% for EMPC-V. In addition, the significant advantages of spatial multiplexing massively depended on the applied traffic model.

A multi-cell OFDMA downlink system based radio resource allocation scheme has been proposed and investigated in (Zhou & Ng, 2008). The resources allocated dynamically at both Radio Network Controller (RNC) and base stations in this proposed radio resource allocation scheme. It is a semi-distributed scheme where RNC has been coordinated the ICI of CEUs with the high traffic load distribution. In this scheme, based on real-time traffic load, the channels have been allocated by base stations at the frame level, whereas between the CCUs and CEUs the sub-channel borrowing policy has been adopted in one cell. The hierarchical allocations have been carried out to meet QoS constraints as well as to support multimedia services. The authors in (Wan, Ma, & Guo, 2007) proposed a multi-cell WiMAX network and presented a semi-distributed algorithm based on downlink resource allocation. In regards to scheduling priorities and mechanisms, the resource allocation with efficient QoS has been achieved in this scheme. The ICI has been reduced and frequency reuse ratio has been maximized regardless of the various QoS constraint requirements. The simulation results depicted the better performance compared to the traditional algorithms. Some frequency reuse technique for WiMAX network are illustrated at Table 2.3.

Table 2.3: Frequency Reuse Technique for WiMAX Network

WiMAX FR Techniques	**Advantages**	**Dis-advantages**
(Giuliano, Monti, & Loreti, 2008)	-Provide an extra capacity than the conventional system. -Auto adjusted with the cell-radius as well as the path loss for LOS and N-LOS environments.	-Penalizing the users at cell edge.
(Y. Chen, Wang, Li, Zhang, & Peng, 2008)	-Dynamic distance. -Dynamic normalized SINR schemes.	-Complex calculations are required until finding the optimal values. -Cannot integrate efficiently with other algorithms.
(Qi, Zhong, & Wang, 2008)	-Resource allocation is adoptable between the CCUs and CEUs.	-High delay than existing algorithms.
(Jalloul & Alex, 2008)	-Overcome the coverage issues for existing WiMAX system.	-Slightly increase in admission control information.
(Sari & Sezginer, 2009)	-High degree of Fairness among users. -Significant improvement in terms of the network performance.	-No priority based is into consideration.
(Darwish et al., 2011)	-Enhance the CEUs’ performance.	-Degradation in the spectral efficiency is obvious once the practical level of CCUs’ number is reached.

After deep analyzing and studying of a variety of frequency reuse techniques, the conclusion is demonstrated that the FFR3 technique is the sufficient to be integrated with other handover approaches since it has an ability to enhance the performance of the handover process by maintaining the ICI and CCI interferences at level below than the predefined harmful level for the 4G networks (LTE, WiMAX) along with maintaining low level of the system complexity. By doing so, the high next base station prediction will be more efficient and high accuracy for both horizontal and vertical handovers will be guaranteed, as well as the RSS will be kept at levels higher than the threshold, while maintaining low connection cost and delay within acceptable levels.

2.3 SCHEDULING APPROACHES FOR OFDM/OFDMA NETWORKS

Several algorithms have been proposed to improve the resource allocation performance in terms of throughput and fairness for OFDM networks (i.e., LTE and WiMAX). However, each scheduling algorithm has different methods to determine the users scheduling priority, such as buffer status, delay, expected throughput, channel status and past average throughput. The principal aims of the schedulers should be maximizing the throughput, providing user's QoS demands and providing good fairness to the non-real time (N-RT) users. We elucidate all these along with pros and cons besides it also divides technologically into two types such as wire and wireless and further categorizes in the following three classes.

(1) channel-unaware; (2) channel-aware/QoS-unaware; (3) channel aware/QoS-aware.

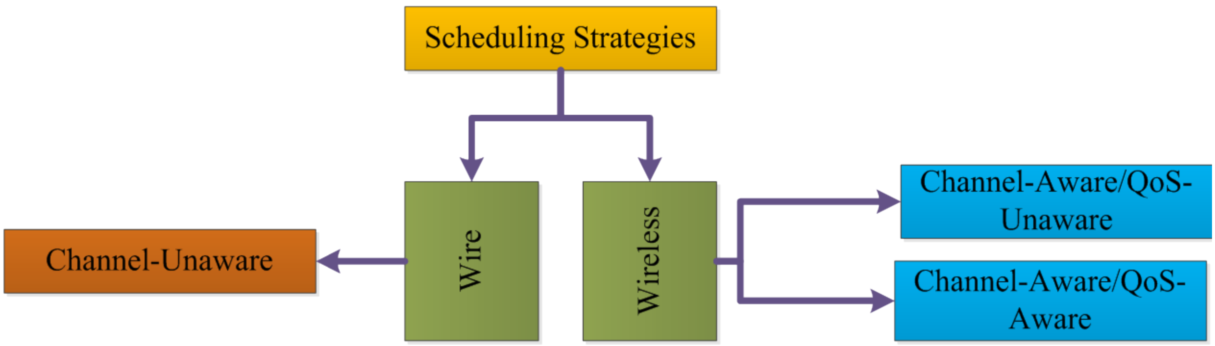

Figure 2.1: Main Types of Scheduling Strategies

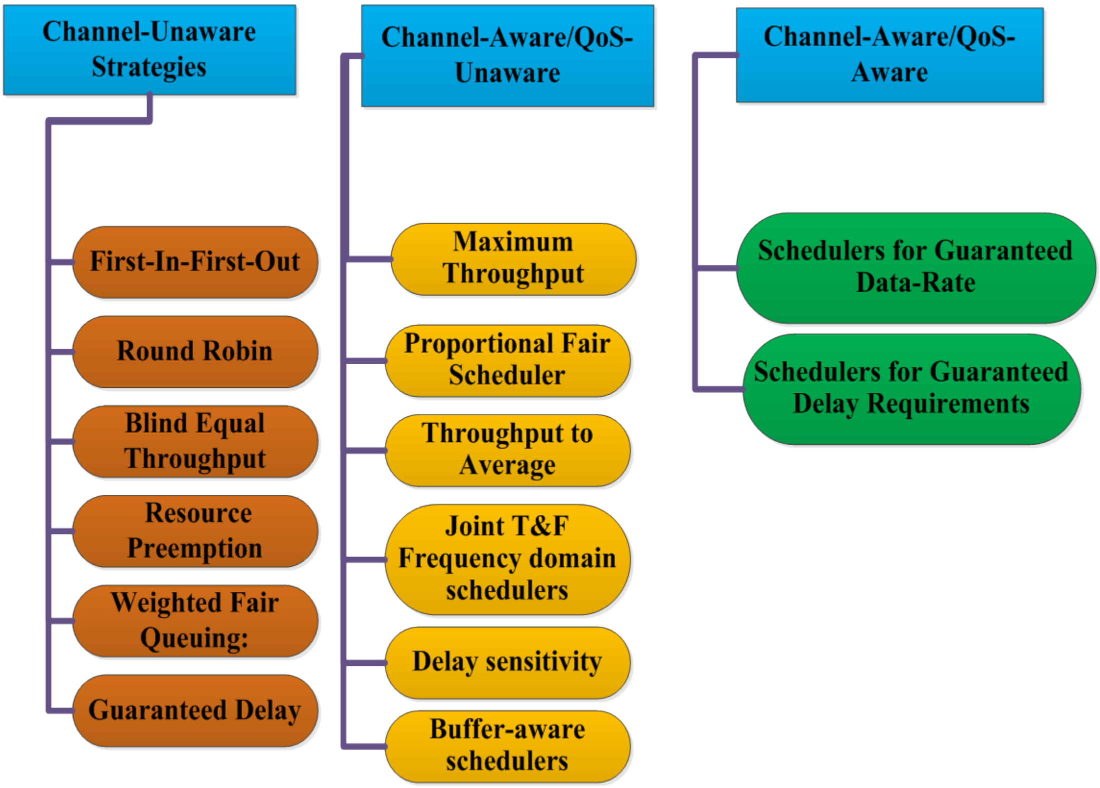

Figure 2.2: Details for the Scheduling Strategies

(a) Channel-Unaware:

This category is based on supposition of time-invariant and error-free transmission media, which is designed for wire used technology while its application is unrealistic in wireless network, instead it can be used in jointly with channel aware methods to improve the system performance. Following are sub strategies types of channel unaware.

(i) First In First Out:

It clears from the name that users serve according to resource request order such as first order performs first and so on, like FIFO queue. FIFO metric is equal to the difference between current time and request issued time (Capozzi, Piro, Grieco, Boggia, & Camarda, 2013).

$$M_{FIFO} = T_{cu} - T_{ri} \tag{2.1}$$

where T_{cu} is the current time and T_{ri} is request issue time. Besides it advantages this policy having some deficiencies in terms of fairness and efficiency, in garner it is inefficient and unfair policy.

(ii) Round Robin:

This type of technique executes fair sharing of time resources among users. Round Robin (RR) metric obtains by substitution request issue time by last served time (Capozzi et al., 2013).

$$M_{RR} = T_{cu} - T_{st} \tag{2.2}$$

where T_{st} is the request issued time, which shows fairness in terms of user occupied channel time, but not in terms of throughput which needs for wireless network because it takes into consideration the experienced channel conditions. Different application-layer bit rates is not efficient for resource allocation to the users having the same amount of time.

(iii) Blind Equal Throughput:

To overcome the limitation of the previously explained allocation policies, Blind Equal Throughput (BET) was introduced which used the past average throughput of every user as metric for throughput fairness, this metric is widely used in most of the state of the art schedulers due to its simplicity and some fascinating properties (Kela et al., 2008). According to this policy, the users which have lower throughput than other will serve until they obtain equivalent throughput. That yields fairness improvement due to the high preference of low throughput user even in bad channel condition and this process perform at every TTI for each user. However the problem concerns about BET is the QoS to priority users for allocation process.

(iv) Resource Preemption:

In fact, all users are not requiring fairness in terms of throughput instead of that their demand for resource priority, therefore the idea of resource pre-emption is developed and many types of priority schemes are defined. The transmission queues are classified into several priority classes in order to high priority class of queues serve first after the completion low priority class towards their service and so on. The main drawback in this strategy is the starvation of low-priority applications. To avoid the problem while handling the differentiation among QoS (high priority) and non-QoS flows, this policy can be fruitfully exploited through scheduling techniques (H Britton-Simmons, 2006).

(v) Weighted Fair Queuing:

Another technique presents for avoiding starvation of low priority application referring to Weighted Fair Queuing priority based policy. In this case, a specific metric for user can be calculated by the collaboration of a specific weight with RR metric. The resource allocation is directly proportional to the user's weight that means the higher weights, the higher allocated resources. The possibility of starvation is zero due to using of RR metric which control the limitlessly growth of waiting time given to a user (Shreedhar & Varghese, 1996).

(vi) Guaranteed Delay:

This policy is defined to avoid packet drops during data transmission through receiving data packet at a specified time. A good result can be achieved by including time specification of packet when it created and also its deadline. There are two policies defined for avoiding the deadline expiration, mostly supporting real time operating system and wired networks these are Earliest Deadline First (EDF) and Largest Weighted Delay First (LWDF) (Fallah, Elfeitori, & Alnuweiri, 2004). EDF policy is used to avoid packet deadline expiration through schedules the packet with the nearest deadline expiration. Similarly LWDF used in terms of weight, i.e., the largest weight will be preferred for allocation first.

(b) Channel-aware/QoS-unaware Strategies:

The schedulers of this category can judge the channel quality for expected maximum throughput though the periodically transmission of CQI using specific control message. The numerical value of achievable throughput for channel-awareness in wireless network can be calculated by using AMC module or Shannon expression for channel capacity. Let us consider *n*th user over all bandwidth and *m*th TTI over the *l*-th RB the maximum achievable throughput (*dnl*) expressed as (Capozzi et al., 2013):

$$dnl(m) = \log[1 + SINRnl(m)] \tag{2.3}$$

There are several techniques describing channel aware/QoS- unaware policies like Maximum Throughput, Proportional Fair Scheduler, Throughput to Average, Joint Time and Frequency domain schedulers, Delay sensitivity and Buffer-aware schedulers.

(i) Maximum Throughput (MT):

According to this policy, the system can achieve maximum throughput in the current TTI through assigning each RB to high achievable user. Mathematically, it can express as follow (Das & Roy, 2013):

$$mMTTA_{i,k} = \frac{d_{i,k}(t)}{d_i(t)} \tag{2.4}$$

Where, $d_{i,k}(t)$ is the spontaneous throughput for user *i* at resource block *k*, and $d_i(t)$ is the overall throughput for user *i* at time *t*.

Although MT provides maximum system throughput, but due to unfair resources allocating procedure, the cell edge user is affected and starvation may occur.

(ii) Proportional Fair Scheduler:

PF scheme is introduced in order to maximize throughput of the system and improve resources fair sharing among users through the combining execution of maximize throughput and blind equal throughput. Mathematically, its matric can be presented as follows:

$$mPF_{i,k} = mMTTA_{i,k} \cdot mBE_{i,k} = \frac{d_{i,k}(t)}{\overline{R}_i(t)} \tag{2.5}$$

Where $\overline{R}_i(t)$ is the past average throughput for user *i* at time *t* and $mBE_{i,k}$ is the blind equal throughput for user *i* at time *t*.

Equation (2.5) shows that, the PF actually explains the fairness and spectral efficiency through BET and MT, respectively. BET using past average throughput as weighting factor in order to give guarantee for fair resource sharing among user like a user even in bad channel condition will be served within a specific period of time.

Different algorithms are used to expend PF in order to fulfil the user's demand of maximum achieved throughput under constraints of OFDM networks. This strategy causes the computational complexity of system, as a result algorithm unsuitable for RT applications.

(iii) Throughput to Average:

Like PF which is intermediate between the MT and BET, similarly, TTA is an intermediate between the MT and PF and its matric which can be obtained from the ratio of achievable throughput on the current RB and in current TTI. And, expressed symbolically represents as follows:

$$mTTA = \frac{d_{i,k}(t)}{d(t)} \tag{2.6}$$

This matric equation of TTA obviously shows that, the achievable throughput of a user is indirectly proportional to RB. The main advantage of TTA scheme is the provision of high degree fairness, that means best resources will be assigned to each active user and guarantees each user will be served in specific time according to this allocation policy.

(iv) Joint Time and Frequency domain schedulers:

The time and frequency schedules cooperatively work for resource allocation, while illustrates in two steps followed by Time Domain Packet Scheduler and Frequency Domain Packet Scheduler.

(1) TDPS.

(2) FDPS.

Both are working in series, TDPS first selects the active users in current TTI among connected users at eNB, after that FDPS assigns RB to each user. The procedure shows that the number of resources allocation to the practical user decreases at TDPS therefore the computational complexity will be decreased at FDPS. The most interesting is the nature of scheme which regarding to support different policy for each phase. For instant, RR can be used to obtain fair sharing of time resource at TDPS while PF on FDPS in order to get better trade-off between spectral efficiency and fairness.

(v) Delay sensitivity :

Delay-sensitive schemes are typically used in RT system, due efficient transmission of network. Every data packet has a limit time by neglecting this expiration limit of packet then average data delivery delay can signify the overall performance. Cross layer algorithm plays an important rule for the better results in order to reduce average delay, transmission power and requirements for BLER. The final decisions procedure of algorithm is obtained through some steps in order to reduce computational complexity of scheme. However, each one is worked independently as an optimizer at given parameters. In delay sensitivity scheme the matric of other schemes can also be used for experienced delay such as the MT and PF matric, referring as utility function for each packet and utility should be variable means decreasing which shows that delay is inversely proportional to utility while higher probability will be allocated first. Furthermore utility function can be used for different allocation schemes and for dynamic packet scheduling as well. This algorithm is used to provide QoS to RT applications while can be directly used in LTE network.

(vi) Buffer-aware schedulers:

Overall system throughput can be increased with low packet dropping probability and some level of fairness by avoid packet losses in OFDM networks through proper buffer management. For this aim Buffer-Aware Traffic-Dependent (BATD) scheme is introduced to dealing with buffer overflow issue. Before transmitting every TTI, user send buffer status information to nearest active eNB while BATD use these information along with traffic statistic to prioritize each MAC queue.

Recently, a new concept for scheduling such as game theory (bankruptcy and shapely value) concept was proposed to enable bandwidth sharing between coalitions of applications, resulting in an improvement in resource allocations. Authors in (Guan, Yuan, Zhang, & Ding, 2013) used cooperative game theory concept to allocate resources over LTE technology. Furthermore, the Nash Bargaining Solutions concept (NBS) is utilized to address the fairness issue by introducing an optimal fair resources allocation. Using game theory concept in this scheme illustrates a high fairness level. The main drawback of the game theory algorithm is that a large number of users add further complexity to the system. To solve such a problem, the users are grouped into 2 users group rather than n-users group. In the same manner, the shapely value algorithm is proposed in (Iturralde, Ali Yahiya, Wei, & Beylot, 2011) to perform resources allocation for real time services. It shows an improved performance and trade-off between throughput gain and fairness index.

A new scheduling algorithm has been proposed for smart grid applications over LTE technology. Moreover, this scheduler is based on mathematical game theory concept to define linear optimization for the resource allocation problem. For doing so, an algorithm is derived and analyzed theoretically. This algorithm concludes that if the new algorithms are used to enhance the latency, LTE could be utilized to support smart grid applications (Shahab, Hussain, & Shoaib, 2013). In (Iturralde, Wei, Ali-Yahiya, & Beylot, 2013), cooperative game theory (bankruptcy and shapely value) is proposed with modified EXP-RULE and M-LWDF algorithms, by introducing virtual token mechanism. The proposed mechanism works by forming coalitions between flow classes to distribute the bandwidth fairly among all users and gives priority to real time flows. Even if this approach is suitable for real time applications, it does not concern about non-real time applications.

(c) Channel-aware/QoS-aware Strategies

(i) Schedulers for Guaranteed Data rate and Delay:

There are many algorithms have been proposed to guarantee the delay and data rate as it is mentioned below.

Exponential Proportional Fairness (EXP/PF) is an extension to the PF algorithm. It distinguishes users based on their packet type. For RT users, it is based on emerging the benefits of the exponential function which guarantees the delay boundaries of RT application and at the same time maximizes the system throughput (2.7) (Afroz, Sandrasegaran, & Ghosal, 2014).

$$K_i = arg \max exp\left(\frac{\alpha_i \times HOL_i(t) - x}{1+\sqrt{x}}\right) \times \frac{r_i(t)}{\overline{R_i}(t)}, \quad \forall i \in RT \tag{2.7}$$

$$\text{where} \quad x = \frac{1}{N_{RT}} \times \sum_{i=1}^{N_{RT}} HOL_i \quad , \tag{2.8}$$

$$\text{and} \quad \alpha_i = \frac{log\, \lambda_i}{\tau_i} \tag{2.9}$$

where $HOL_i\,(t)$ is the head of line packet delay, N_{RT} is the number of active real time downlink flows, α_i is the weighting metric related to acceptable loss rate λ_i and τ_i is the maximum delay budget.

The robustness of this algorithm is based on taking the exponential of the end to end delay of user's packets, thus scheduling metric exponentially grows along with delay metric. Whereas the N-RT users are served as PF but with control degree of service, this degree controlled as proportion to the waiting packets of the RT applications at BS (2.10). The main drawback of this algorithm is the positive probability of drop of the services from N-RT applications as shifting it to RT one.

$$K_i = \arg \ \max\left(\frac{w(t)}{M(t)} \times \frac{r_i(t)}{\overline{R_i}(t)}, \ \forall i \in NRT\right) \tag{2.10}$$

$$\text{where} \quad w(t) = \begin{cases} w(t\text{-}1) - \varepsilon, when \ \ W_{max} > \tau_{max} \\ w(t-1) + \frac{\varepsilon}{j}, when \ \ W_{max} < \tau_{max} \end{cases} \tag{2.11}$$

where, $M(t)$ is the is the average number of RT packets in queue base station buffer at time *t*, ε and j are the constant and $\tau_{\max}$ is the maximum delay constraint of RT users.

In (Ang, Wee, Pang, & Lau, 2014), the M-LWDF used in so many fields for instance streaming video application, it mixes between user channel status quality and the time delay of the packets. It proves to be as a suitable solution for scheduling flows of the high speed downlink packet access (HSDPA). It is based on the head of line packet delay along with the PF metric to ensure the QoS provision fairness and spectral efficiency among users. It takes on its consideration the channel condition, head of line delay and the packet loss ratio as illustrated in (2.12).

$$K_i = \arg\ \max \left(\alpha_i \times HOL_i(t) \times \frac{r_i(t)}{R_i(t)} \right) \tag{2.12}$$

Exponential Rule (EXP-Rule) algorithm (Capozzi et al., 2013) is considered as further modification of above EXP/PF algorithm and the priority metric is calculated as follow:

$$K_i = arg\ \ max \left(b^i \times exp \left(\frac{\alpha_i \times HOL_i(t)}{c + \sqrt{\left(\frac{1}{N^{RT}} \right) \times \sum_j HOL_j}} \right) \times \Gamma_k^i \right) \tag{2.13}$$

where b^i, α_i and c are tunable parameters based on the channel status, $\Gamma_k{}^i$ is representing spectral efficiency. The compression among variety of scheduling techniques are illustrated in Table 2.4.

Table 2.4: Comparison among Variety of Scheduling Techniques

Techniques	Objective	Limitations	Advantages	Result
First-in-First-out	-Serves users according to the order of resource requests, like FIFO queue	-Inefficient and unfair scheme. Practically LTE not their application. -Applicable special in cable network	-Very simple procedure for resource allocation.	-Used jointly with channel-aware approaches to improve system performance along with simplicity.
Round Robin	-Fair sharing of time resource	-Not fair in terms of user throughput, and channel conditions, not efficient, -Does not suitable for wireless network (LTE) due to useless of channel condition.	-Simple like FIFO and fair sharing than FIFO In terms of time Resource.	-The described fairness is only in terms of time but not in terms of channel conditions(throughput).
Blind Equal Throughput	-Throughput Fairness is the objective.	-Fairness are not required always for all users, does not consider priority for strategy for users.	-Fair throughput distribution among users and achieved the Fairness in terms of throughput with guaranteeing some degree of fairness during bad channel users (channel condition).	-All user in the cell have the same throughput implies that user in bad channel condition will be first until all users gain the same position.
Resource Preemption	-Prioritize transmission data in order to different classes.	-Direct application in LTE is not realistic, they are used jointly with channel-aware approaches to improve system performance.	-Simplest method of priority strategies Group users in priority class that way it can be used for distinguish between high	-Scheduler implements some techniques to avoid the starvation of low-priority applications.

			and low priority.	
Weighted Fair Queuing	-Introduce priorities to avoiding the possibility of Starvation.	-To improve system performance use it jointly with channel aware techniques.	-Avoid starvation.	-Higher the Weights, the higher the allocated resources. this approach holds if also the BET metric is taken into account.
Guaranteed Delay	-A specific serve time for packet to avoid packet drop in network.	-Due to not considering channel condition during allocation procedure making it unsuitable in cellular networks.	-Avoid packet drops and deadline expiration.	-Packet can be received in within a specific time to avoid packet drop while EDF and LWDF are used to avoiding deadline expiration.
Maximum Throughput	-Assigning each RB to users to get maximum system throughput	-Performs unfair resource sharing and possibility of starvation particularly for CEUs. -Up to a limit number of users MT is a worst choice for remaining user due to very low throughput.	-Maximize cell throughput to a high level than others schemes. -Satisfying some degrees of fairness	-Always allocate resources to the users experiencing best channel conditions which make it different from other. -A practical scheduler should be intermediate between MT, which maximizes the cell throughput and BET.
Propor-tional Fair Schedule	-To find a trade-off between requirements on fairness and	-Due to increased computational complexity make it hard to realize a	-Users in bad conditions can be surely served within a certain	-PF metric is slightly modified to develop

r	spectral efficiency.	given algorithm in real system	amount of time. Better fairness level.	Generalized Proportional Fair (GPF). -Improve achievable fairness level, depending on the system conditions.
Throughput to Average	-A schedule that can achieve both advantages of MT and PF.	-TTA does not exploit multi-user diversity gain and have no sufficient channel status information for better efficiency. -Users number has opposite effect on TTA strategy.	-Best RBs are allocated to each user. -Guarantee some minimum performance to each flow	-Higher throughput fairness among users.
Joint Time and Frequency domain schedulers	-Technique for radio resources distribution to achieve fairness and spectral efficiency.	-Each phase select a different policy.	-This policy offer to reduce computational complexity, obtain fair sharing of time resources, also achieve a good trade-off between spectral efficiency and fairness	-RR or PF metrics could be used by the TDPS to obtain fair sharing of time resources, and a PF metric could be used by the FDPS to achieve a good trade-off between Spectral efficiency and fairness.
Delay Sensitivity	-Average data delivering delay will be independent of packet deadline expiration while presenting overall	-Cannot apply this method directly in a LTE network	-Changing the shape of the utility function. -Different allocations policies can be implemented.	-Can be used such a system for QoS provisioning to real time flows.

	performance .(typical of real-time flows)			
Buffer-Aware Schedulers	-Avoid packet losses through buffer management in order to improve system throughput and some level of fairness.	-PF scheduling algorithm works well when users experience. -Homogeneous channel conditions and limited fairness when channel value varying.	-Keep dropping probability low, guaranteeing high total system throughput and a certain level of fairness.	-Approach for facing the buffer overflow problem.
Schedulers for Guaranteed Data-Rate	-Prioritize users in both time and frequency domain in order to guarantee data-rate for -QoS-aware solution flows.	-The decision process at the FDPS is QoS-aware.	-Provide high spectral efficiency.	-The first approach aims at high spectral efficiency. -The decision process at the FDPS is QoS-unaware. -Appear to be more Robust in terms of QoS provisioning, due to the strong prioritization applied also in the assignment of radio resources in the frequency domain.
Schedulers for Guaranteed Delay Requirements	-To delivered packet within a certain deadline in order to guarantee bounded delay in QoS aware schemes.	-Having less spectral efficiency, fairness, and QoS provisioning.	-Used For real-time applications as well as for video streaming and VoIP flows.	-Algorithms that make use of delay boundary per-RB metrics.
Modified - LWDF	-M-LWDF provides bounded packet delivering	-Multimedia applications in time multiplexed	-Providing a Higher system throughput,	-MLWDF Is based on the

	delay.	systems is still an issue need to solve. -Mostly used in wire network to supporting real time application.	supporting a more number of users as well as guaranteeing fairness at a satisfactory level. assuring a good balance among spectral efficiency, fairness, and QoS provisioning. -Non-real handling with PF and real-time handling by utilizing weighting metrics flows to treat applications differently. -Provides bounded packet delivering delay if it is not design for OFDMA.	assumption, that a strictly positive probability of discarding packets is acceptable.
Exponential Rule	-To support multimedia applications in time multiplexed systems.		-Give guarantee of good throughput and an acceptable level of fairness Due to PF metric of flow. -Exponential function grows much faster with its argument with respect to the logarithmic function.	-EXP/PF is based on the assumption, that a strictly positive probability of discarding packets are acceptable. -Enhancement of the aforementioned EXP/PF by exploiting the delay-based priorities.

Opportunistic Procedure	-To achieve high bandwidth utilization and very low packet loss rate.	-Expensive computation required. -Many iterations before reaching the allocation outcome.	-Utilize bandwidth in terms of RB allocation to users.	
Delay-Prioritized Scheduler	-To achieve a less complex scheme.		-Less complex	-DPS significantly exploits delay-based priorities, making it similar to EDF.
Cooperative Game-Theory	-To achieved better performance in terms of both packet loss rate and fairness.		-Guarantee, minimum throughput to all flows at same time.	-Significant performance gain over the EXP-Rule is achieved in terms of both packet loss rate and fairness.

2.4 SUMMARY

In this chapter we have overviewed, analyzed and studied the most important related issues to provide Always Best Connection for 4G networks (LTE and WiMAX). We have found that three main issues are needed to be solved, namely handover issues, bandwidth estimation-allocation issues and scheduling issues. So for that, the recent handover algorithms have been deeply studied in terms of the advantages, dis-advantages and limitations. As well as the interference cancelation techniques have studied as a process to guarantee the proper MS connection especially in high attenuation environment. Then for the bandwidth estimation-allocation and scheduling processes, we can accurately determine the required resources for each users only after deep studying of each technology. So the deep studied starting from the basic information, to the frame structure until the layers have proposed. The importance of this chapter is that it urges a serious demand for the proposed approach with providing an optimized solution of each studied issue.

CHAPTER THREE

RESEARCH METHODOLOGY

As it is mentioned in chapter 2, three main issues are needed to be solved. Thus, each mentioned issue has been solved by practical solutions (see Figure 3.1). We are going to illustrate those solutions as follows: (i) Handover issues, it has been divided into two core problems, namely prediction of the target base station and then selection of the best technology; (ii) Bandwidth estimation and allocation issues, which has been designed individually for flat priority applications and specific priority applications; and (iii) Scheduling issues, which have been considered for a generic scheduling priority applications and specific scheduling priority applications.

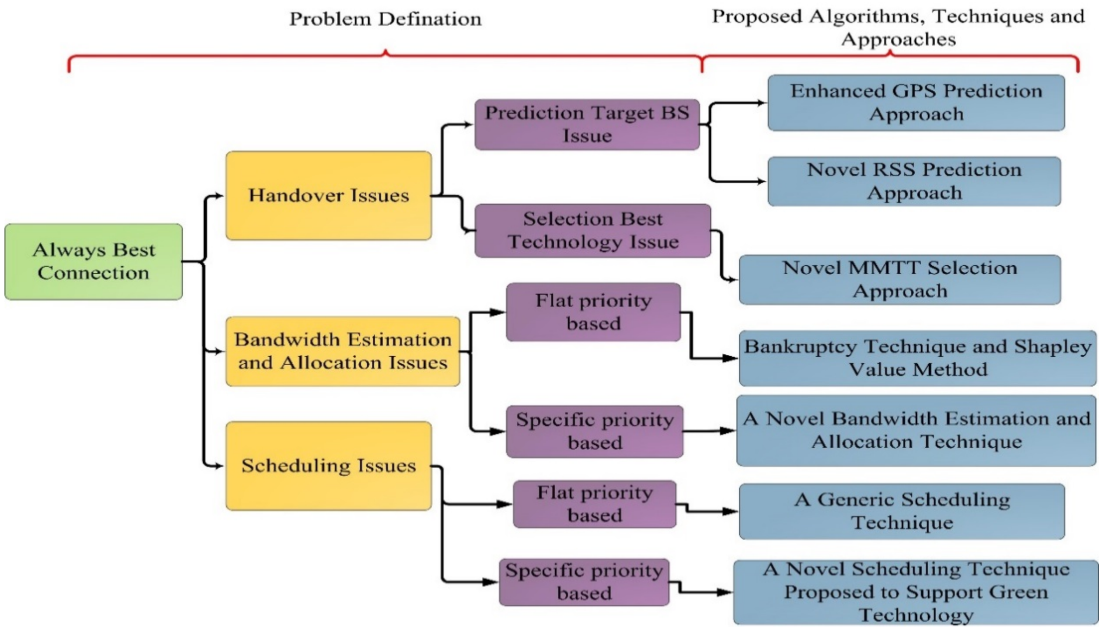

Figure 3.1: Proposed Solutions for Handover, Bandwidth Estimation and Allocation and Scheduling Issues

3.1 HANDOVER ISSUES

As shown in Figure 3.2, the proposed algorithms for solving the handover issues are divided into three stages. First stage, based on the user's preferences either enhanced GPS or novel RSS is selected to predict the target BS. Next stage, Modified Multi Criteria with Two handover Thresholds (MMTT) algorithm selects the most appropriate technology (LTE or WiMAX) which satisfies the user's preferences. Finally, FRR3 technique decreases the ICI and CCI interferences from surrounding BSs.

3.1.1 PREDICTION APPROACHES OF THE TARGET BS

Figure 3.3 illustrates the necessity behind applying the prediction approaches. Due to randomly movement of the MS, its suggestion list combines 6 possible BSs as a target BS. Each BS offers two technologies (LTE and WiMAX), thus the MS should go through 12 options as searching process for the optimal connection as follows: {(1, LTE), (1, WiMAX),…,(6, LTE), (6, WiMAX)}. The introduction of prediction approaches significantly reduces the suggestion list to a maximum of two BSs with four possibilities. Therefore, at least 60% of the search process is reduced out of the calculations. Consequently, a sharp decrease in probability of connection loss, prediction time and system complexity are observed. In the following sub-sections, two efficient prediction approaches are proposed, namely enhanced GPS and novel RSS.

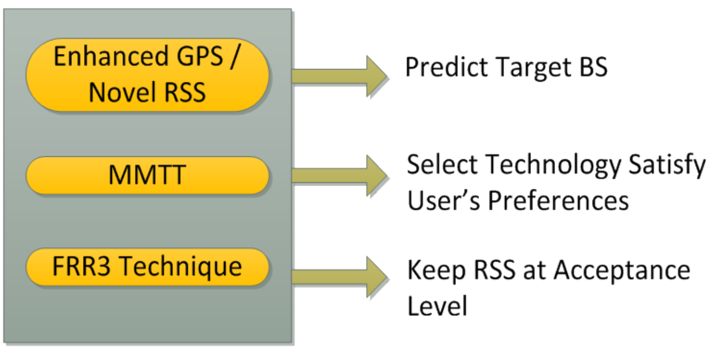

Figure 3.2: The Algorithms to Solve Handover Issues.

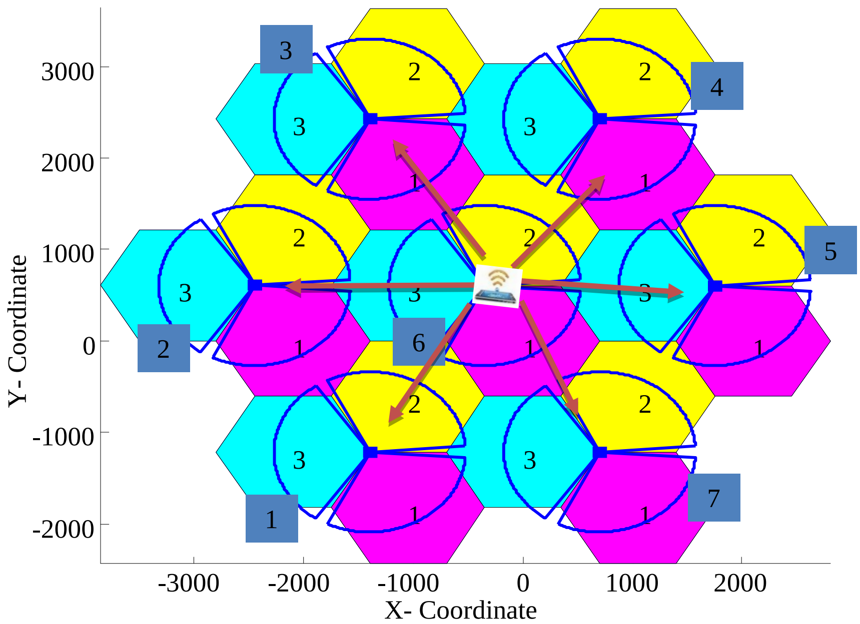

Figure 3.3: Potential Movements of the MS

3.1.1.1 GPS PREDICTION APPROACH

The enhanced GPS prediction approach is subject to MS' behavior, such as angle of movement, cross-distance and velocity. Once the MS' RSS reaches the trigger threshold level (predefined level), the GPS device is activated to determine the current coordination in the layout of three dimensions (latitude (*x*), longitude (*y*) and ellipsoid height (*z*)). Then, the coordination is kept updating up to *n*-time intervals (*n* is the range between the trigger and handover threshold). For each coordination measurement, the crossed distance is calculated as the difference between the current and previous MS' location during one time interval (Equation (3.1)). Also, the angle of movement is determined based on the *x*-axis as 0-degree.

$$D(n)=\sqrt{(x(n)-x(n-1))^2+(y(n)-y(n-1))^2+(z(n)-z(n-1))^2} \tag{3.1}$$

where $D(n)$ is the MS crossed distance, ($x(n$-1), $y(n$-1), $z(n$-1)) is the MS' coordination at n-1 time interval, and ($x(n)$, $y(n)$, $z(n)$) is the MS' coordination at n-time interval.

The MS' velocity (v) is the MS crossed distance divided by the required time to cross it (t) (Equation (3.2)).

$$v = \frac{D(n)}{t} \tag{3.2}$$

By calculating the movement angle, crossed distance and velocity, the next BS is predicted accurately. The main enhancements added to GPS approach are power consumption and prediction cost along with high prediction accuracy, since the GPS device is activated during *n*-time intervals (between the trigger and handover thresholds) instead of keeping the GPS device on all the time.

3.1.1.2 RSS PREDICTION APPROACH

The main objective of the novel RSS approach is to foretell the target BS in lower cost, simpler and faster than the existing algorithms. It does not require any additional information; neither from the BS nor MS. MS' RSS is measured frequently for *n*-time intervals (from trigger to handover thresholds) from all surrounding BSs (Equation (3.3)). Then, the highest RSS accumulative value of practical BS is set as the target BS (Equation (3.4)). The robustness of the approach is that, it takes *n* RSS measurements instead of one as in existing RSS approach, so even if the interferences blur the prediction decision for a while, the target BS keeps maintaining the highest RSS accumulative value which is higher than others. The RSS is calculated as the following:

$$RSS_z(MS) = PT_z + GR + GT_z - PL_z - LT_z - LR \tag{3.3}$$

$$tarBS_z = MAX \sum_{j=1}^{n} \sum_{z=1}^{N} RSS_{z,j}(MS) \tag{3.4}$$

where $RSS_z(MS)$ represents the RSS received at the MS from BS z, the transmission power of BS z (PTz), GR and GTz are the antenna gain of both MS and BS z, respectively, PLz is the path loss between BS z and MS, LR and LTz are the thermal receivers noise in both MS and BS z, respectively, $tarBS_i$ represents the target base station z, n is the interval time between the trigger and handover threshold, j is the interval time index, and N is the total number of BSs.

3.1.2 SELECTION OF THE ACCURATE TARGET TECHNOLOGY

The MMTT approach is proposed to determine the most appropriate target technology (WiMAX or LTE), which can satisfy the user's preferences. This approach is based on evaluating many criteria such as RSS, connection cost, handover process delay, network condition and offered bandwidth. The MMTT guarantees stability of the connection by constantly maintaining the MS' RSS at an acceptable level, and minimizing the number of redundant handovers between technologies due to the network selection, which depends on the user's preferences. The MMTT approach is illustrated as follows:

An algorithm is developed to achieve faster handovers decisions and reductions in the Ping- Pong effect. An enhanced handover algorithm is developed to substantially reduce the redundancy of handovers and enable the selection of the most appropriate target network technology based on users' preferences. The proposed algorithm uses additional criteria such as monetary cost, delay, bandwidth and network conditions. The algorithm consists of six building blocks as shown in Figure 3.4:

(a) Handover RSS threshold and triggered RSS threshold calculation.

(b) The MS user's bandwidth requirements technology selections, i.e., WiMAX and/or LTE.

(c) Evaluation of the network connections cost based on the user's preferences.

(d) Estimation of the WiMAX and LTE conditions.

(e) Building the suggestion List.

(f) Choosing the best target technology.

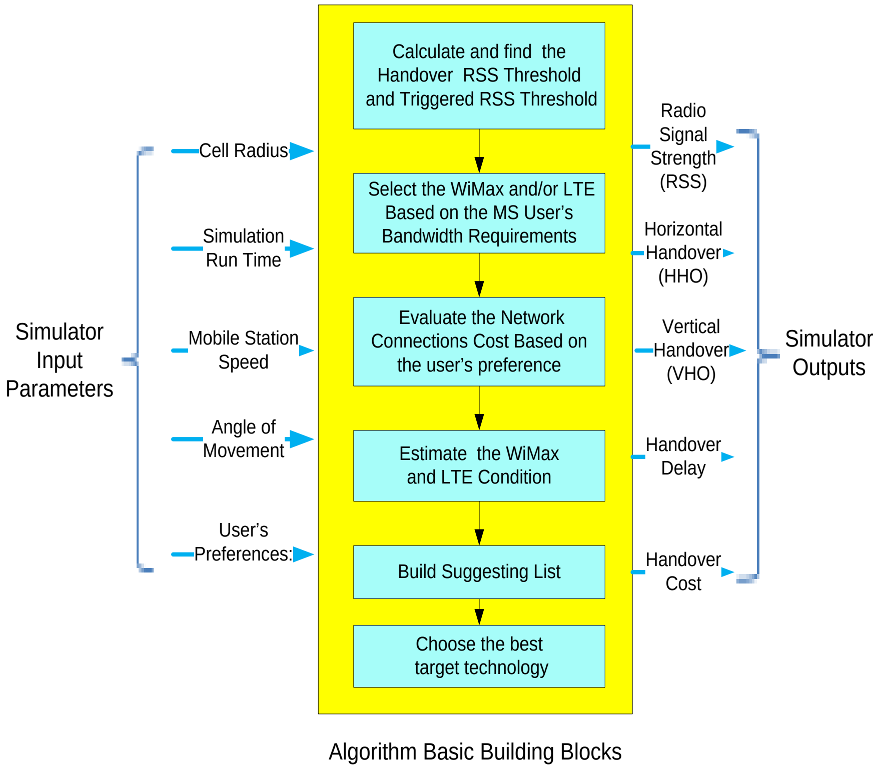

Figure 3.4: MMTT Algorithm Building Blocks

The algorithm inputs are cell radius, simulation run time, mobile station speed, angle of movement and user's preferences. The user's weight preferences parameters are cost weight (w_C), bandwidth weight (w_B), delay weight (w_D), the network performance weight (w_μ) and RSS weight (w_{RSS}). Based on these inputs, the user should be able to calculate and monitors the RSS, HHO-VHO, handover decision delay time and cost.

The expected outcomes from the algorithm display a substantial enhancement in the handover decision and less redundancy, i.e., the Ping-Pong effect is reduced.

The algorithm executes the above blocks sequentially based on the following details:

(a) *Handover RSS threshold and triggered RSS threshold calculations:*

While the MS is moving across cells, it keeps tracking the RSS' serving BS. Once it equals the RSS trigger threshold level, the selection process of the most appropriate target technology starts. If the MS' RSS of technology *k* at serving BS *w* is less than the handover threshold and the MS' RSS of technology k at target BS E is bigger than or equal to the handover threshold, then the RSS condition is satisfied (Equation (3.5)).

$$\begin{aligned} &\left|RSS_{m,k,w} < RSS_{th,w}\right| \, \& \\ &\left|RSS_{m,k,E} \geq RSS_{th,E}\right| \end{aligned} \tag{3.5}$$

where $RSS_{m,k,w}$ is RSS received at the MS m from the technology k at service BS w, and $RSS_{m,k,E}$ is RSS received at the MS m from the technology k at target BS E, while $RSS_{th,w}$ and $RSS_{th,E}$ are the handover threshold for the service BS w and target BS E, respectively. To increase the accuracy of handover and trigger threshold for both serving and target BSs, a self-learning algorithm is developed, as shown in Equations (3.6) and (3.7).

$$RSS_{th,w} = \frac{1}{r} \times \sum_{u=1}^{l} RSS_{m,w,k}^{u} \tag{3.6}$$

$$RSS_{th,E} = \frac{1}{r} \times \sum_{u=1}^{l} RSS_{m,E,k}^{u} \tag{3.7}$$

where r is the number of previous handover processes that occur between the serving BS w and target BS E, u is the index of the handover event, and $RSS_{m,w,k}^{u}$ and $RSS_{m,E,k}^{u}$ are the RSS measurements at the MS m from the serving BS w and target BS E, respectively at handover event.

The self-learning algorithm is triggered after two handover events, then keeps calculating and updating the threshold values of serving and target BSs up to n-time intervals. The main enhancement added by self-learning algorithm is the determination of the most accurate handover and trigger threshold values experimentally, which helps to prevent the sudden disconnections, especially in a high attenuation area, since the threshold values are set to be dynamically adopted with the surrounding area.

(b) Available Bandwidth Calculation:

The available bandwidth of the target technology (B_n) must be calculated in order to select the appropriate target network technology, i.e., LTE or WiMAX. Using (3.8), the available bandwidth is the sum of the *n* mobile stations requirement bandwidth from the set technology bandwidth.

$$B_n = \sum_{m=1}^{n} b_m \tag{3.8}$$

where B_n is the required bandwidth *n* mobile stations connected to technology *k*, and b_m is the required bandwidth for MS *m*.

Based on the calculated B_n, the following conditions are used to select the best proper technology in terms of bandwidth at the target BS as follows:

$$\begin{array}{l} if\, B_n < \left(\left(B_{LTE} \& B_{WiMAX}\right) \& \left(B_{LTE} > B_{WiMAX}\right)\right) \{select \;\; LTE\} \\ \qquad\qquad\qquad\qquad else\ if\ \{select\ WiMAX\} \\ if\ \left(\left(B_{LTE} < B_n < B_{WiMAX}\right) \{select\ WiMAX\}\right) \\ \qquad else\ if\ \left(B_{LTE} > B_n > B_{WiMAX}\right) \{select\ LTE\} \\ else\ drop\ evaluated\ network\ from\ suggetion\ list \end{array}$$

where B_{LTE}, B_{WiMAX} are the available bandwidth at LTE and WiMAX technology, respectively.

(c) Network Cost Calculation:

Each network technology has a different connection cost; thus MS may choose to connect to the lowest or highest connection fee depending on MS preferences and QoS requirements. The cost can be calculated for both LTE and WiMAX based on the cost factor (C_f) (3.9):

$$C_f = \begin{cases} LTE = 1 \\ WiMax = 0.8 \end{cases} \tag{3.9}$$

It is worth mentioning that the cost factors were chosen as fixed values to simplify the calculations. In our proposal, static values are determined as 0.8 and 1 for WiMAX and LTE, respectively.

(d) Network Condition Estimation:

As the MS is moving between cells, the network condition criteria special list values are updated and stored in a matrix. The matrix values are extracted from the previous handover processes. An analysis of these values gives an idea about the expected target technology throughput and how much it is satisfying the user's requirements. The efficiency of the network technology of target BS is measured on a scale between 0-to-1. Zero means the target technology failed to satisfy the minimum user requirements at the previous handover processes and one means the target technology satisfies all mobile station service requirements with the maximum (ideal) efficiency.

(e) Building a Technology Suggestion List:

Each available technology in the target BS should be examined using the above mentioned criteria. If the technology satisfies the minimum MS requirements, it will be added to the suggestion list; otherwise, it will be omitted from the MS suggestion list. A MS adds the examined technology to the suggestion list if all the differences between the technology's offered criteria and MS' minimum requirements criteria are positive; otherwise, it will be dropped. Here, (3.10) is used to qualify such addition.

$$N_a = F(RSS_a - RSS_{th}) \times F(C_a - C_{th}) \times F(D_a - D_{th}) \times F(\mu_a - \mu_{th}) \times F(B_a - B_{th}) \tag{3.10}$$

where N_a is the BS number which is under evaluation, F is a unit function step, RSS_a, C_a, D_a, μ_a, B_a are the radio signal strength, cost, delay for connection setup, network performance, and available bandwidth in BS_a ,respectively. RSS_{th}, C_{th}, D_{th}, μ_{th}, B_{th} are the radio signal strength, cost, delay for connection setup, network performance, and available bandwidth of the minimum MS' requirements respectively.

(f) Choosing the Best Target Technology:

Table 3.1: Evaluation of the BS' Technology

Algorithm: select accurate target technology
input $WC, W^{\mu}, WC, WB, WD, WRSS, RSSth, Cth, dth, \mu_{th}, bth$
Let N be the number of base stations
Let j be the number of available technologies
Let a be the index of base stations
Let k be the index of technologies
for each $a \in N$, $k \in j$ do;
if $RSS_k > RSS_{th}$
and $C_k < C_{th}$
and $d_k < d_{th}$
and $\mu_k > \mu_{th}$
and $b_k > b_{th}$
then $v(a,k) \leftarrow (a,k)$
else, remove it from suggestion list
end if
Calculate (3.11) for all $v(a,k)$
$(a,k) \leftarrow arg\ max\ v(a,k)$
end for

The final step in the proposed algorithm is to choose the best Technology Quality of Service (*TQS*) for the target station using 3.11. The *TQS* is based on parameters which are connection cost (C_k), available bandwidth (B_k), setup connect delay (D_k), network performance (μ_k), radio signal strength (RSS_k) and weight factors.

$$TQS = \frac{wC\left(\frac{1}{C_k}\right)}{\max\left(\frac{1}{C_m}\right)} + \frac{wB(B_k)}{\max(B_m)} + \frac{wD\left(\frac{1}{D_k}\right)}{\max\left(\frac{1}{D_m}\right)} + \frac{w\mu(\mu_k)}{\max(\mu_m)} + \frac{wRSS(RSS_k)}{\max(RSS_m)} \quad (3.11)$$

where wC, wB, wD, $w\mu$, $wRSS$ are the weighting factor of cost are bandwidth, delay, network condition and radio signal strength, respectively. C_m, B_m, D_m, μ_m, RSS_m are the maximum value of the cost, available bandwidth, delay, network performance, and radio signal strength among the BSs in the suggestion list.

Every technology was added to the suggestion list should be validated using the outcome of the *TQS* equation (3.11). The highest *TQS* result will determine the target technology for the base station. It is worth mentioning that the weight factors sum should be 100%. If the calculated *TQS* target base station is more than the *TQS* service base station, a time delay will be inserted to assure signal stability which will reduce the ping-pong effect. The inserted time delay should not exceed the maximum value of the threshold handover delay boundaries. Once all the target station technology criteria are satisfied and stable the handover decision will be made, otherwise the target BS should be changed.

3.1.3 DECREASING THE CCI AND ICI INTERFERENCES

The FRR3 is utilized to decrease the CCI and ICI interferences in order to significantly improve the RSS and the handovers' stability (VHO and HHO). The FRR3 maintains mutual interference between MS and surrounding BSs below a harmful level, especially at a high attenuation area. This guarantees a good performance of the MS-BS connection and the handover process. Moreover, FRR3 is simple, well-established and easy to apply. The FRR3 technique divides WiMAX and LTE BSs into 3 sectors and 3 hexagons, respectively. Each BS' sector and hexagon has its unique operating frequency, with taking into consideration the minimum frequency reuse distance (*dm*). As a result, the ICI and CCI interferences sharply decrease compared to that without applying the FRR3 technique, since the interferences arise only from the adjacent sectors and hexagons in the same propagation angle (using the same frequency operation) instead of from all surrounding BSs, as illustrated in Equation (3.12) (Bilios et al., 2013).

$$SINR_{m,f} = \frac{PL_{a,m} \times T_{a,f} \times h_{a,m,f}}{\sigma_f^2 + \sum_{S=1}^{y} I_{S,X} \times T_{S,f} \times h_{S,X,f}} \tag{3.12}$$

where $SINR_{m,f}$ is the signal-to-interference-plus-noise ratio received at mobile station m from on subcatrries f, $PL_{a,m}$ refers to the path loss associated with the channel between MS m and BS a, $T_{a,f}$ is the transmit power of the BS a on subcarrier f , $h_{a,m,f}$ is the exponentially distributed channel fast-fading power, σ_f^2 is the noise power of the Additive White Gaussian Noise channel on subcarriers f, S is the BS index, and y is the number of co-channel BSs, the sets of all interfering base stations are defined as symbol y and S. More precisely, y is the number of co-channel cell and S is the cell index, $h_{s,x,f}$ is the interference coefficient.

3.2 SCHEDULING FOR FLAT PRIORITY BASED APPLICATIONS

To investigate and study the flat priority based case, three smart grid applications, namely voice, video surveillance and metering data which are proposed and classified into three classes A, B and E, respectively. The model consists of two levels where on the first level, bankruptcy algorithm divides the available resources among a group of classes (bandwidth estimation). Afterwards, shapely value fairly distributes the resources among classes as a proportion according to their demands (bandwidth allocation), which results in serving the low priority classes without starvation. On the second level, TOPSIS algorithm allocates the resources among the users of the class based on the class preferences (scheduling approach). Figure 3.5 illustrates a general diagram of the proposed model.

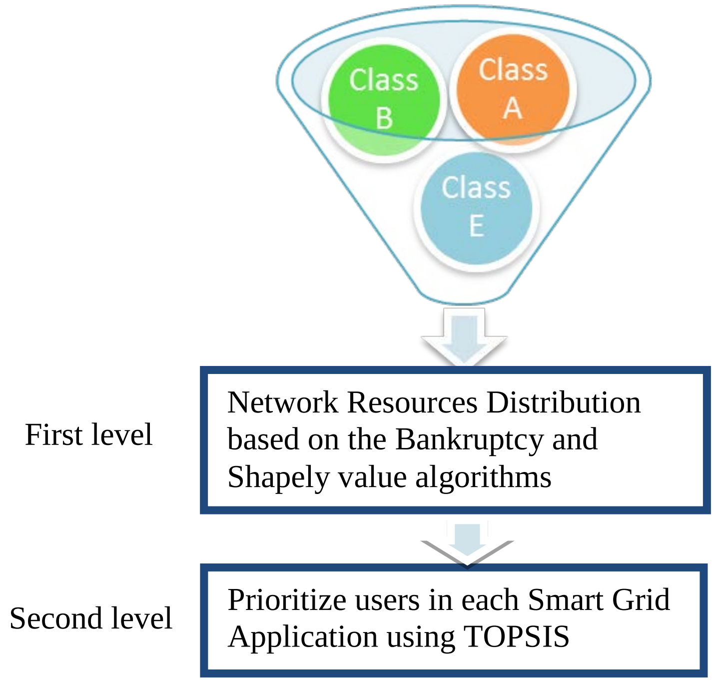

Figure 3.5: Main System Diagram

3.2.1 BANDWIDTH ESTIMATION AND ALLOCATION

Bankruptcy and Shapely Value are used in order to divide the resources perfectly among the classes, bankruptcy forms a coalition between applications (classes), so that the distribution decision is shared among classes rather than individual class. To apply this mechanism, the transferable utility concept (bandwidth in our approach) is used to allow shifting the bandwidth among classes. For instant, if the class A users suddenly increases, more resources are assigned to it from either class B or C. Bankruptcy determines the required data rate of classes based on the O'Neill approach (O'Neill, 1982), as shown in (3.13).

$$U(S) = max\left\{C - \sum_{i \in N \setminus S} P_i \times K_i, 0\right\} \qquad (3.13)$$
$$U(N) = C$$

where $U(S)$ is the utility for the set of coalition S in the game, C is the total available system capacity, N is the set of the smart grid applications ($N = \{1,2,\ldots,n\}$), P_i is the required bandwidth for a smart grid application *i*, and K_i is the quantity of users in a smart grid application *i*.

Once all the potential coalitions among classes are calculated, shapely value factor distributes the resources fairly among them. The fairness distribution property of shapely value is based on the three main parameters (symmetry, additivity and efficiency) (Shapley, 1952) (Sun, Ding, Jiang, Geng, & Chen, 2014), where symmetry means there is no relationship between the player's resource allocation and the order of the players enter into the game. Additivity axiom predicts the relationship between different values of the game and is valid for independent and composite games. Whereas the Pareto efficiency axiom guarantees that no player can earn a better allocation without worsening other players.

The shapely value concept prevents low priority classes from being starved since the resources are distributed as a proportion among classes, as shown in (3.14).

$$\begin{aligned} Sh_{\mathrm{i}}(U) &= \sum_{S \subseteq N} W(S) \times \left(U(S) - U(S \setminus \{i\})\right) \\ where\, W(S) &= \frac{\left(|S|-1\right)! \times \left(n-|S|\right)!}{n!} \end{aligned} \tag{3.14}$$

where $Sh_i(U)$ is the shapely value of smart grid application *i* (the worth of a smart grid application *i* in the game), $U(S \setminus \{i\})$ indicates the coalition utility *S* excluding the smart grid application *i*, *n* is the number of smart grid applications in the game, and $W(S)$ is the probability of entrance for smart grid applications to the game.

3.2.2 SCHEDULING APPROACH

We proposed a new scheduling scheme which is based on TOPSIS method. It is defined as a multi decision maker, which chooses the most appropriate solution from all potential alternatives. This approach has several advantages, such as multiple attribute decision making, guaranteed high satisfaction factor to the smart grid applications' preferences, low complexity and robust scheduling decision. Four criteria are used to make the scheduling decision namely delay, channel status, queue length and past average throughout. Such weighting coefficients increase the scheduling robustness, control and dynamic adjustment. In this work, TOPSIS method is utilized to serve the smart grid application's users based on their criteria values and preferences. The approach procedures are described in the following steps:

Step 1: Criteria value calculation: As the user criteria are the inputs of the TOPSIS algorithm, they are calculated as follows:

i. User *m* delay metric is the difference between the current time and the stamped time of the packet in the buffer queue, and then it is normalized by the delay budget to its related application (3.15).

$$D_m(t) = \frac{t - T_{stamp,m}}{\tau^C} \tag{3.15}$$

where $D_m(t)$ is the delay factor of user m at time t, $T_{stamp,m}$ is the entrance time of user m packets in the buffer queue, t is the real time, and τ^C is the delay budget of application C.

ii. The channel status metric of user m (CS_m) defines the channel quality in terms of the ability of data transmission. It is extracted from the signal to noise ratio, which is received by user m. It is updated periodically at each TTI for each user.

iii. The queue length metric is used as a pointer to give the situation of the user's buffer, and it is calculated as follows:

$$QL_m(t) = \frac{Q_m(t)}{Q} \tag{3.16}$$

where $QL_m(t)$ is the queue length metric of user *m* at time *t*, $Q_m(t)$ is the total packet number of user *m* in the buffer at time *t*, and *Q* is the total accommodation capacity of the buffer.

vi. The past average throughput metric is used as a pointer to determine the data rate, which has been transmitted to user *m* in the previous TTI. It is calculated as a moving average, as shown in (3.17).

$$\overline{TH}_m(t) = \alpha \cdot \overline{TH}(t-1) + (1-\alpha) \cdot r_m(t) \\ where\ 0 \le \alpha \le 1 \quad (3.17)$$

where $\overline{TH}m(t)$ is the past average throughput of user *m*, α is constant related to the window size (the window size widely used is $tc = 0.001$), and $r_m(t)$ is the acquired data rate of user *m* at time *t*. After calculating the evaluation criteria (Step 1, as above) for each user, they will be inserted into Table 3.2.

Table 3.2: TOPSIS Evaluation Criteria

	Delay Factor	Channel Status	Queue Length	Past Average Throughput
User 1	$D_1(t)$	$CS_1(t)$	$QL_1(t)$	$\overline{TH}1(t)$
User 2	$D_2(t)$	$CS_2(t)$	$QL_2(t)$	$\overline{TH}2(t)$
:	:	:	:	:
:	:	:	:	:
User *l*	$D_l(t)$	$CS_l(t)$	$QL_l(t)$	$\overline{TH}_l(t)$

Step 2: Construct the normalized decision matrix: To make a decision over multi-criteria using TOPSIS algorithm, each attribute is transferred from dimensions into dimensionless by finding the normalized value of criteria *j* related to user *m* as it is shown in (3.18). Equation (3.19) contains all users' matrix values after normalizing them.

$$r_{mj} = \frac{x_{mj}}{\sqrt{\sum_{m=1}^{l} x_{mj}^2}} \tag{3.18}$$

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1y} \\ r_{21} & r_{22} & \cdots & r_{2y} \\ \vdots & \vdots & \vdots & \vdots \\ r_{l1} & r_{l2} & \cdots & r_{ly} \end{bmatrix} \tag{3.19}$$

where r_{mj} is the normalizing value of user m metric j, x_{mj} is the value of user m metric j, and R is the normalized decision matrix.

Step 3: Construct the weighted normalized decision matrix: The obtained matrix is calculated by multiplying each attribute from the normalized decision matrix by its associated weight. As we mentioned earlier, each metric has specific weight, which is chosen carefully to be appropriate to the smart grid application demands. For instance, voice application requires higher concentration on the delay factor and queue length rather than past average throughput and channel status. Video surveillance application has a little more tolerance to delay with as much fewer packet loss rate (PLR) as possible. On the other hand, the metering data application requires the highest data rate, to achieve that the higher weights on channel status and past average throughput than other criteria will be given. It is worth to mention that the criteria weights summation is equal to 100%.

Each of previous calculations is updated at each TTI, and the weight related to each criterion is multiplied by criteria values for each smart grid application, as illustrated in (3.20).

$$v(t)=\begin{bmatrix} w_D \times D_1(t) & w_{CS} \times CS_1(t) & w_{QL} \times QL_1(t) & w_{\overline{TH}} \times \overline{TH}_1(t-1) \\ w_D \times D_2(t) & w_{CS} \times CS_2(t) & w_{QL} \times QL_2(t) & w_{\overline{TH}} \times \overline{TH}_2(t-1) \\ \vdots & \vdots & \vdots & \vdots \\ w_D \times D_l(t) & w_{CS} \times CS_l(t) & w_{QL} \times QL_l(t) & w_{\overline{TH}} \times \overline{TH}_l(t-1) \end{bmatrix} \quad (3.20)$$

where $v(t)$ is the decision matrix and w_D, w_{CS}, w_{QL}, $w_{\overline{TH}}$ are the attribute weights for delay, channel status, queue length and past average throughput, respectively.

Step 4: Separation measurement calculation based on the Euclidean distance: TOPSIS utilizes Euclidean distances to measure the separation measurement for users (positive ideal value and negative ideal value). The user who is prioritized to serve supposed to have the shortest distance from the positive ideal value and the farthest distance from the negative ideal value. The positive ideal value is calculated by the summation of Euclidean distance between user criteria values and the highest criteria values among all the users as it is shown in (3.21).

$$S_m^* = \sqrt{\sum_{j=1}^{y}\left(v_{mj}(t)-v_j^*(t)\right)^2} \;,\; j=(1,2,\ldots,y) \quad (3.21)$$

Where S_m^* is the user *m* separation measurement from the ideal value at time *t*, $v_{mj}(t)$ is the metric *j* value for user *m* at time *t*, *j* is the positive ideal value index, *y* is the total number of studied metrics.

Similarly, the negative ideal value is calculated by the summation of Euclidean distance between user criteria values and the lowest criteria values among all the users as it is shown in (3.22).

$$S_m^- = \sqrt{\sum_{j=1}^{y}\left(v_{mj}(t)-v_j^-(t)\right)^2} \;,\; j=(1,2,\ldots,y) \quad (3.22)$$

where S_m^- is the user *m* separation measurement of negative ideal value at time *t*.

At the end of step 4, two values namely, S_m^* and S_m^- for each metric have been counted. These two values represent the distance between each metric and both the ideal and the negative ideal metric values.

Step 5: Closeness to the ideal solution calculation. In the process, the closeness of user *m* to the ideal solution is defined as:

$$C_m^*(t) = \frac{S_m^-(t)}{S_m^*(t) + S_m^-(t)} \;, \quad 0 < C_m^* < 1 \;, (m = 1,2,..., l) \tag{3.23}$$

where $C_x^*(t)$ defines how much the user *x* is close to the ideal solution, and *l* is the total users' number.

Step 6: Prioritize the users in each smart grid application: The set of the users can now be ranked according to the descending order of criteria where the highest value will be the first to be served, and so on.

3.3 SCHEDULING FOR SPECIFIC PRIORITY BASED APPLICATIONS

Due to random variation of radio condition in OFDM network, the obtainable bit rate for the active user is supposed to vary based on SINR which is received at the MS from the BS. Allowing or denying the service for the new user of specific class is based on the admission control procedure. Admission control has two steps, which are classifier and bandwidth estimation and allocation. The first step authenticates whether or not the new user belongs to the classes (applications) (Table 3.3) and the second step decides the acceptance or rejection of new user based on the availability of bandwidth of each class.

Each user will be allocated to related class based on its demands (Table 3.3) by the classifier as follows:

i. Class 1: Urgent to be served which has so strict delay tolerance, such as Distribution Automation (DA) application (priority 1).

ii. Class 2: Requires an RT service which has a tolerance in terms of delay, such as Distributed Energy system and Storage (DER) application (priority 2).

iii. Class 3: Requires N-RT service which has a high tolerance in terms of delay, such as Electrical Vehicle (EV) application (priority 3).

As it is illustrated in Figure 3.6, the system model is divided into two main levels, namely admission control which includes bandwidth estimation and allocation for specific priority based applications. Whereas the second level covers that the scheduling approach for specific priority based applications.

3.3.1 ADMISSION CONTROL

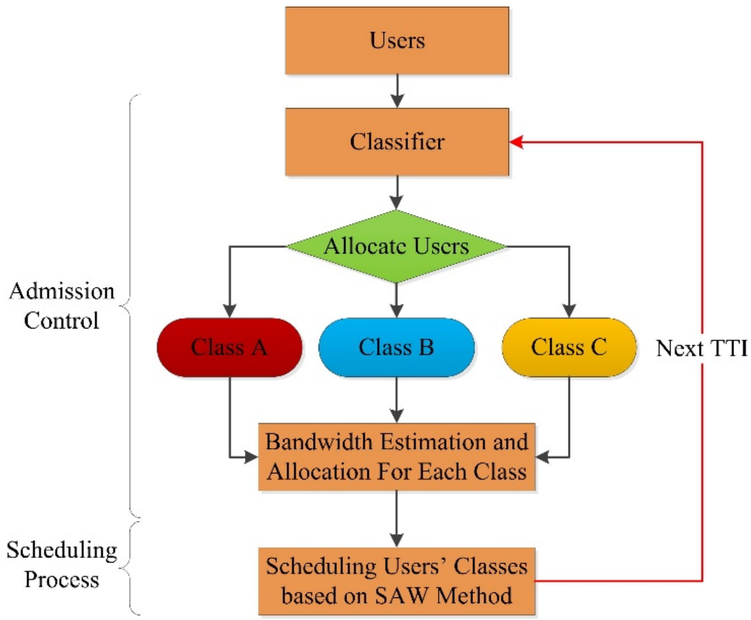

Figure 3.6: Flow Chart of System Model

Table 3.3: The Smart Grid Applications' Demands

Smart Grid Application	Bandwidth Requirement [kpbs]	Delay Budget [ms]
Distribution automation (DA)	100	100
Distributed energy system and storage (DER)	500	300
Electrical vehicle (EV)	64	2000

The classifier determines the user number of each class. Then this information will pass to the bandwidth estimation and allocation level to allocate efficient RBs based on its required data rate.

3.3.2 BANDWIDTH ESTIMATION

Several issues control the data transmission ability of RB, such as distance from the BS, power allocation for each RB and the external and internal noise. In our model, it is assumed that, all users have fixed coordination at the map and the same transmission power is allocated for all sub-carriers. Moreover, two types of noises are defined which are internal and external noise. Thermal noise at the receiver end is internal noise, whereas the interference from neighboring BSs is defined as external noise. The SINR is calculated by multiplying the channel gain of user *m* RB *j* ($C_{gain\,m,j}$) (3.24) with assigned power for the subcarriers ($P_{subcarrier}$) over the noise (3.25) (Jain, Chiu, & Hawe, 1998).

$$C_{gain\,m,j} = 10^{\frac{pathloss}{10} + \frac{multi-fading}{10} + \frac{fading}{10}} \tag{3.24}$$

$$SINR = \frac{C_{gainm,j} \times P_{subcarrier}}{N_0 + I} \tag{3.25}$$

where *pathloss*, *multi-fading* and *fading* are measured in scale of dB, N_0 is the thermal noise and *I* is the interference from surrounding BSs.

At each TTI, MSs report their instantaneous downlink SINR to BS that is used to determine the ability of data transmission for allocate-able RB j of user x at time t ($R_m^j(t)$) as follows:

$$R_m^j(t) = \frac{n-bits}{symbol} \times \frac{n-symbols}{slot} \times \frac{n-slots}{subcarrier} \times \frac{n-subcarriers}{RB} \tag{3.26}$$

where $n-bits$, $n-symbols$, $n-slots$ and $n-subcarrier$ are the number of bits, number of symbols, number of slots and number of subcarriers, respectively (Ali, Zeeshan, & Naveed, 2013).

From (3.26), it can be said that the number of bits per symbol (*n-bits*) has a strong impact on RB's obtainable data rate. Based on the bit per symbol, the data rate will be changed at each TTI along with SINR value. Total number of RBs (n_m^c) required to satisfy the user m of class c can be obtained by the ratio of the demand data rate (r^c) and obtainable data rate for RB ($R_m^j(t)$) with specific Modulation and Coding Scheme (MCS) (3.27). Then the number of required RBs at time t for user m is calculated by (3.28). All sets of RBs, which are assigned to user m at time t must have the same MCS and one RB cannot be assigned to more than one user at time t.

$$n_m^c = \frac{r^c}{R_x^j(t)} \tag{3.27}$$

$$NRB_m{}^c(t) = \frac{n_m^c}{\tau_m} \tag{3.28}$$

where $NRB_m{}^c(t)$ is the number of RBs required for user m of class c at time t and τ_i is the maximum delay budget.

For providing services to the user, scheduler requires to know the exact number of RBs required per user for each class which is calculated by (3.28). After that, in terms of measuring the required bandwidth for class *c* at time *t*, (3.29) is proposed.

$$R^{c}(t) = N^{c}(t) \times b^{c} \tag{3.29}$$

where $R^{c}(t)$ is the required bandwidth for class *c* at time *t*, $N^{c}(t)$ is the number of users allocated to class *c* at time *t* and b^{c} is the required data rate.

3.3.3 BANDWIDTH ALLOCATION

The bandwidth estimation is followed by the bandwidth allocation procedure. The main purpose of bandwidth allocation is to determine whether or not there are enough resources to cover the demand of a particular class. Otherwise, the resources will be shifted from the lower priority class to the higher priority class to cover the shortage and it will be repeated until all network resources have been utilized. For instance, if a new user comes to class 1 and the resources of class 1 are not enough to satisfy that user, then resources from class 3 will be shifted to class 1. High priority class users will be served until all the resources are assigned. This algorithm (Table 3.4) will be updated and calculated at each TTI.

Table 3.4: Proposed Algorithm of Bandwidth Estimation and Allocation

Algorithm 1. *Bandwidth allocation*
1:**procedure** bandwidth allocation for each class
2:insert A, $B^{c}(t)$, mc
3:**for all** c such that $1 \le c \le A$ and $c \in A$ **do**
4:**c**ollect $B^{c}(t)$
5:compute $R^{c}(t)$ from (11)
6:**if** $B^{c}(t) \ge R^{c}(t)$
7:serve user m, $m = [1,2,......,mc]$
8:**else**
9:compute $\delta = \left\| B^{c}(t) - R^{c}(t) \right\|$

if $B^{A}(t) \geq \delta$

$B^{A}(t) = B^{A}(t) - \delta$

$B^{c}(t) = B^{c}(t) + \delta$

else if $B^{A}(t) + B^{A-1}(t) \geq \delta$

$B^{A-1} = B^{A-1} - \left| B^{A} - \delta \right|$

$B^{c}(t) = B^{c}(t) + \delta$

else serve users up to $B^{c}(t)$

end for

end procedure

where $B^{c}(t)$ is the offered data rate from the system to class *c* at time *t*, δ is the difference between the offered and demand data rate, *A* is the total number of classes and *mc* is the set of user belongs to class *c*.

3.3.4 SCHEDULING APPROACH

The proposed scheduling algorithm is based on Simple Additive Weighting (SAW) technique, which is a multi-attribute decision making method to find out the best option from all feasible alternatives. Our proposed scheduling scheme relies on proportional linear transformation of the raw data (criteria values), thus the relative order of magnitude of the standardized scores remains equal. Moreover, it ensures low complexity, dynamic adjusting and good controlling to the scheduling algorithm behavior as well as it satisfies the demand of smart grid application. The dynamic weighting factors, namely delay, past average throughput and instantaneous transmission rate are used to adjust the scheduling decision for each application (class). For instance, some applications require high emphasis on the delay, such as DA, thus the higher weight will be given to delay than others. Whereas, the EV requires more emphasis on throughput than delay, thus the higher weight will be given to past average throughput rather than delay or channel status. The proposed scheduling algorithm is described in Figure 3.7.

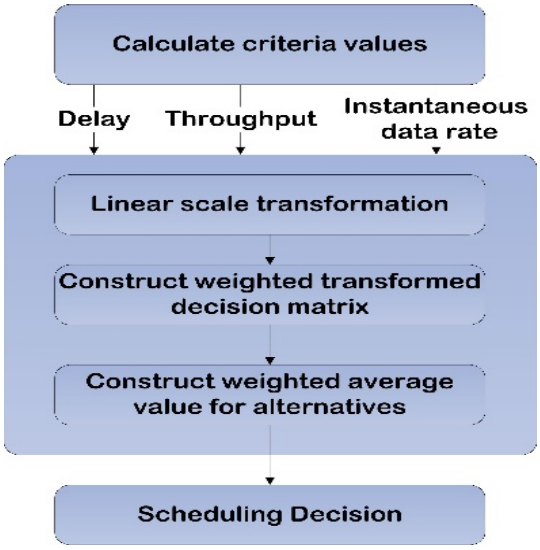

Figure 3.7: Flow Chart of Proposed Scheduling Algorithm

Step1: Calculation of the criteria values: Three criteria values for each user are calculated and inserted as input to the proposed scheduling algorithm as follows:

i. Delay metric of user *m* is calculated as the ratio of the difference between current time and stamped time of packet at the buffer queue to the delay budget of its related class. And, if the delay factor is bigger than one, user *m* 's packets will be dropped from further evaluation (3.30).

$$D_m^c(t) = \frac{t - T_{stamp,m}}{\tau^C} \tag{3.30}$$

where $D_m^c(t)$ is the delay factor of user *m* for class *c* at time *t*, $T_{stamp,m}$ is the entrance time of user *m*'s packets in the buffer queue and τ^C is the delay budget of class *c*.

ii. The instantaneous data rate is the expected data rate, which could be achieved by users *x* from class *c* at time slot *t*.

iii. The past average throughput metric is used as pointer to determine the data rate of user *m* in previous TTI. It calculates as a moving average throughput as follows:

$$\overline{TH}^{c}_{m}(t) = \psi \times \overline{TH}^{c}_{m}(t-1) + (1-\psi) \times r^{c}_{m}(t)$$
$$where\ 0 \le \psi \le 1 \quad (3.31)$$

where $\overline{TH}^{c}_{m}(t)$ is the past average throughput of user *m* of class *c* at time *t*, ψ is constant related to the window size and $r^{c}_{m}(t)$ is the acquired data rate of user *x* from class *c* at time *t.*

Step 2: Linear scale transformation: Data collection is normalized by the maximum value of the criterion for all users as a process to unify all values up to one measurement scale for the specific class. Then, it inserts into the normalized decision matrix at time *t* (*R* (*t*)) as follows:

$$D^{c}_{m1}(t) = \frac{D^{c}_{m}(t)}{D^{*}_{mc}(t)},\ for\ m = 1,2,...,mc$$
$$r^{c}_{m2}(t) = \frac{r^{c}_{m}(t)}{r^{*}_{mc}(t)},\ for\ m = 1,2,...,mc \quad (3.32)$$
$$\overline{TH}^{c}_{m3}(t) = \frac{\overline{TH}^{c}_{m}(t)}{\overline{TH}^{*}_{mc}(t)},\ for\ m = 1,2,...,mc$$

$$R(t) = \begin{bmatrix} D_{11}(t) & r_{12}(t) & \overline{TH}^{c}_{13}(t) \\ D_{21}(t) & r_{22}(t) & \overline{TH}^{c}_{23}(t) \\ \vdots & \vdots & \vdots \\ D_{mc1}(t) & r_{mc2}(t) & \overline{TH}^{c}_{mc3}(t) \end{bmatrix} \quad (3.33)$$

where $D^{*}_{mc}(t)$, $r^{*}_{mc}(t)$ and $\overline{TH}^{*}_{mc}(t)$ are the maximum value of delay, instantaneous data rate and past average throughput, respectively.

Step 3: Construction of the weighted transformed decision matrix: In this step, a set of weight coefficients w^{c}_{D}, w^{c}_{r} and $w^{c}_{\overline{TH}}$ are accommodated to the transformed decision matrix to build the weighted transformed decision matrix *v* (*t*) as follows:

$$v(t)=\begin{bmatrix} w_D^c \times D_{11}(t) & w_r^c \times r_{12}(t) & w_{\overline{TH}}^c \times \overline{TH}_{13}(t) \\ w_D^c \times D_{21}(t) & w_r^c \times r_{22}(t) & w_{\overline{TH}}^c \times \overline{TH}_{23}(t) \\ \vdots & \vdots & \vdots \\ w_D^c \times D_{mc1}(t) & w_r^c \times r_{mc2}(t) & w_{\overline{TH}}^c \times \overline{TH}_{mc3}(t) \end{bmatrix} \tag{3.34}$$

Step 4: Construction of the weighted average value for users: In this process, after summing up the criteria values ($A_m^*(t)$) belong to user *m* in (3.35), the scheduler will serve the user according to the obtained values in descending order.

$$A_m^*(t)=\sum_{g=1}^{A} v_{mg}(t) \tag{3.35}$$

where $A_m^*(t)$ is the descending order of the users at time *t* and $v_{mg}(t)$ is the metric *v* index.

3.4 SUMMARY

Along this chapter, three proposed approaches have been introduced to solve the following issues which are handover, bandwidth estimation-allocation and scheduling issues. The first one aims to provide the seamless and smooth handover process among 4G technologies (i.e., LTE and WiMAX). This mechanism combined two phases, the first one is predicting the next target base station, then select the most appropriate target technology among 4G networks. Whereas at the second issue, the cooperative game theory technique and the new technique have been proposed for estimation and allocation issues for flat priority based and specific priority based applications, respectively. The flat priority based approach is to fairly distribute of the network resources fairly among applications, whereas the specific priority based approach is distributed the resources based on priority. Finally, the scheduling of flat priority based and specific priority based applications are proposed. The scheduling decision for both approaches have focused to fulfill the applications' demands which relies on exploiting the multi-attributes decision making concept by examining multi-criteria such as delay, queue length, past average throughput and instantaneous throughput. To make the scheduling decision is changing dynamically along with the desires, the weight is inserted for each criteria.

CHAPTER FOURE

RESULT AND DISCUSSION

4.1 HANDOVER ISSUES

For the handover issues, NS2 simulator and MATLAB are used to simulate the proposed algorithms, techniques and approaches which were explained in details in Chapter 3 (Section 3.1.2). Here, seven WiMAX and LTE base stations (each of which has three cells) are configured in the simulation. MMTT was implemented and tested for two simulation scenarios, the worst and critical case scenarios as follows:

4.1.1 WORST CASE SCENARIO

In this scenario, it is assumed that the MS is roaming across the coverage area and boundaries of base stations. The MS roaming mobility type is Probabilistic Random Waypoint Mobility Model (PRWM). A case study tracks the mobile station roaming from base station 5 till boundary of 3 through the base station 4 and 1 boundary. Table 4.1 shows the input parameter values for this scenario, and Figure 4.1 shows the simulation area. As shown in Figure 4.1, there are actual threshold (handover threshold) and virtual threshold (trigger threshold).

Table 4.1: Input Parameter Values for Worst and Critical Case Scenario

Input Parameters	Values of Worst Case Scenario	Values of Critical Case Scenario
Mobile speed (km/h)	15	15
Number of cells	7	7
Number MS	1	1
RSS weight **Available bandwidth weight**	40% 10%	45% 5%
Cost weight	30%	10%
Delay weight	5%	30%
Network condition weight	15%	10%
Angle of movement (degree)	90	1
Path loss type	Macro urban path loss PL(dB) =33.81×log10(fc)-79.4+3+35.04×log10(d)	
Simulation time (sec)	100	
MS highest (m)	1	
BS highest (m)	40	

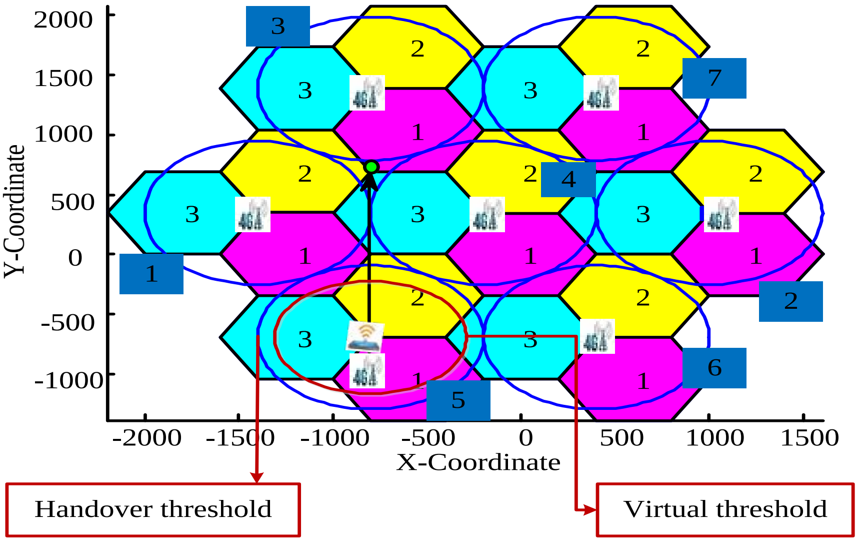

Figure 4.1: The Worst Case Scenario

The results show that the proposed algorithm reduces the missing HHO and VHO redundancy compared to too many in the existing RSS and Modified MC approaches, while they are maintaining a minimum acceptable RSS level (Figure 4.2 and 4.3).

Figures 4.2 and 4.3 show the efficient work of the proposed algorithm even at the cell boundaries. Since the MS faces many difficulties to choose the accurate target BS and technology, many BSs in the suggestion list could be as the target BS. The proposed algorithm shows high accuracy in the handover decision from cell ID 5 to 4 with a few of handover redundancy. Comparing with other two algorithms, the existing RSS and Modified MC approaches preferred connection to the inaccurate target BS 1. Since the existing RSS approach keeps fluctuating, thus they kept Ping-Pong between cells. The Ping-Pong effect is clear between 35 to 100 secs. As a result, the existing RSS and Modified MC approaches cannot be used as a reliable algorithm to provide connection in the critical case scenario. In terms of choosing the target technology (Figure 4.3), the proposed algorithm chooses the WiMAX connection, because it provides higher QoS and satisfaction levels to user preferences than LTE technology, since it offers lower cost and higher RSS than LTE. In addition, the Modified MC shows twice handovers for so short period, which means, they made miss-handover to LTE technology. As soon as it could not provide the minimum user preferences, the MS directly handover to WiMAX again as we can see in 38 and 42 secs. The existing RSS proved to have the worst performance since it kept the Ping-Pong between technologies without getting real benefits from the reserved technology resources during the whole simulation period.

From Figure 4.4 the proposed and existing RSS approaches showed the comparable RSS levels, which are in the acceptable range to maintain the MS connectivity during the simulation period. Furthermore, the Modified MC approach suffers from dis-connectivity between the 82 and 86 sec, leading to data loss and sharply degrades in the QoS of the MS.

Considering the cost factor, the proposed algorithm simulation results showed the lowest cost compared to other two approaches, and satisfied the user's preferences cost factor, which is 30% as shown in Table 4.1 and Figure 4.5. Finally, even though the delay is higher than the other algorithms (Figure 4.6), it can easily satisfy the user preferences (5%) and stay within the acceptable delay boundary.

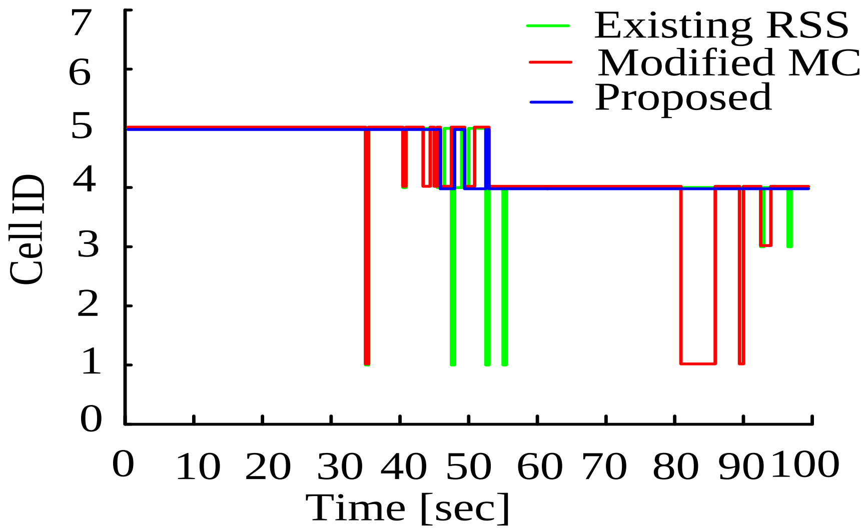

Figure 4.2: Base Stations Handover for the Worst

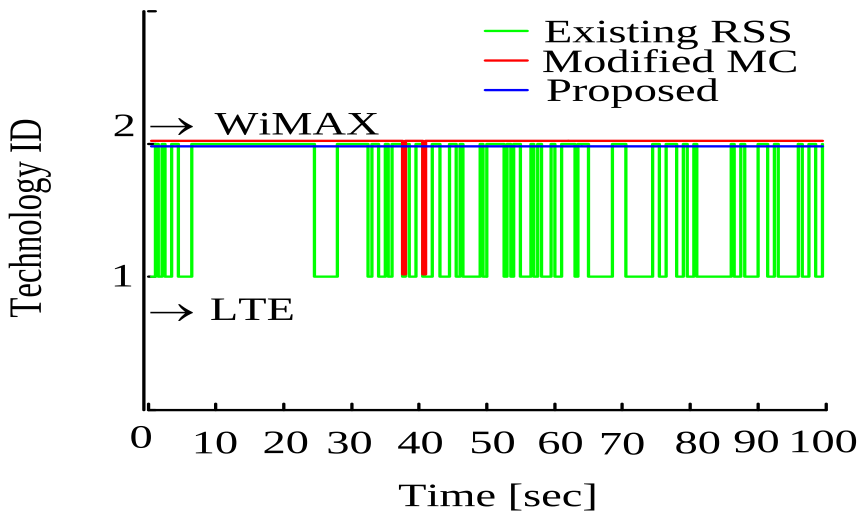

Figure 4.3: Handovers (VHO, HHO) for the Worst Case

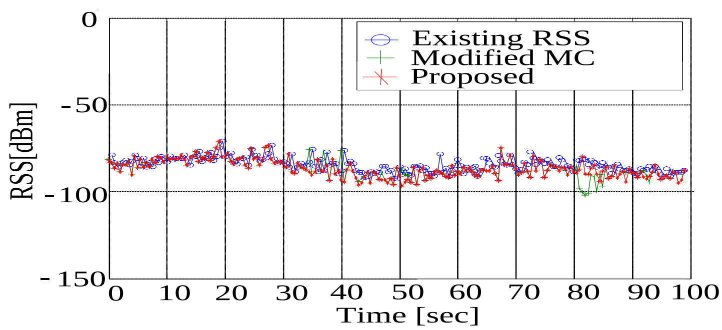

Figure 4.4: The Signal Strength Measurements' Tracking for the Worst Case

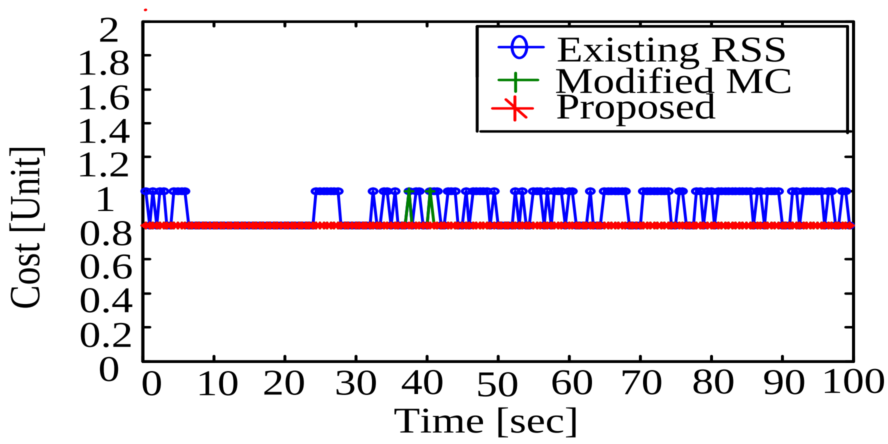

Figure 4.5: Cost Measurements for the Worst Case

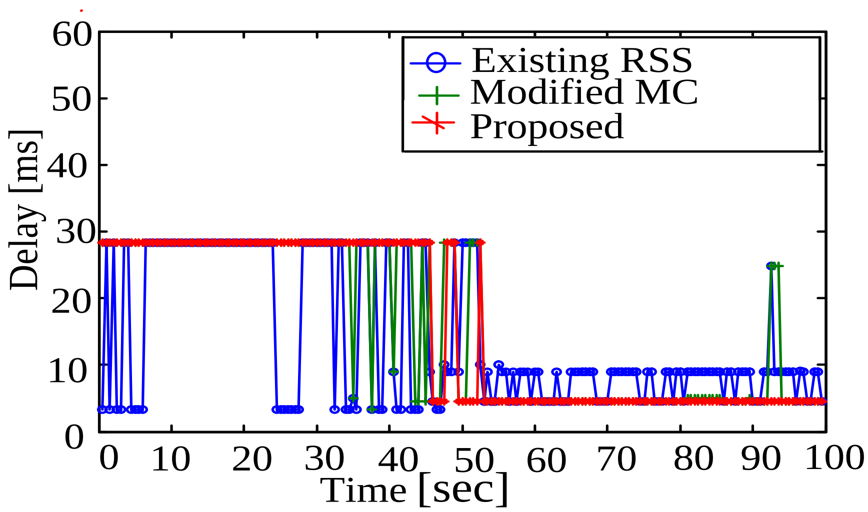

Figure 4.6: Delay in Handover Decision Making Among Algorithms for the Worst Case

4.1.2 CRITICAL CASE SCENARIO

In this case study, it is assumed that the MS is tracked while it is moving between stations, also the mobility type is PRWMM model. Table 4.1 shows the input parameters for this scenario, and Figure 4.7 shows the simulation model.

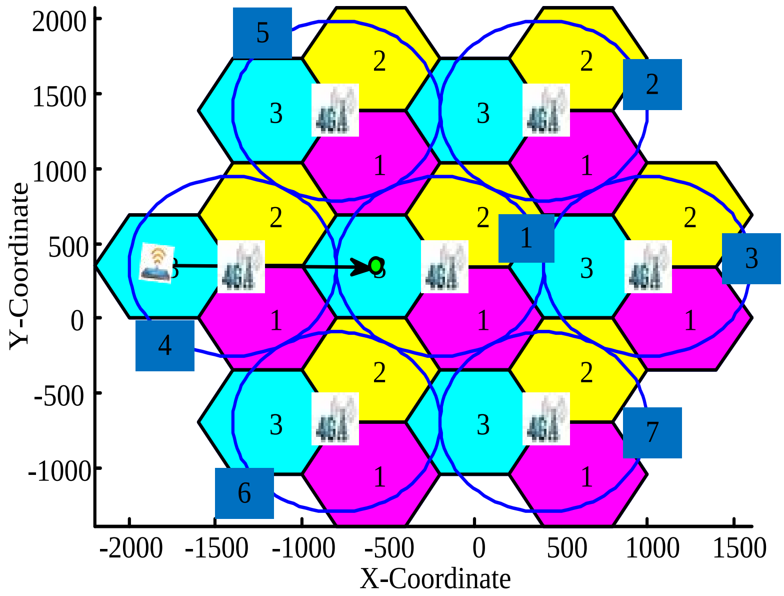

Figure 4.7: The Critical Case Scenario

To validate the performance and accuracy of the proposed algorithm, a comparison with the existing RSS and modified MC approach is presented. The existing RSS is based on the RSS received from the serving and the target BSs (Becvar et al., 2011), whereas the modified multiple criteria approach (Modified MC) (He et al., 2011) is based on the evaluation among multi criteria.

In this scenario, the mobile station is roaming from the BS 4 to 1. As shown in Figure 4.8, the proposed algorithm outperformed the other two algorithms even in most noisy and congested coverage areas. For example, in the simulation period between 70 and 100 secs, the proposed approach has the highest stability rate compared to the other reference algorithms. Meanwhile, in the existing RSS algorithm, the Ping-Pong process occurs between BSs 4 and 1, due to the high fluctuation in the signal strength. Moreover, in the modified MC approach, a Ping-Pong process is taking place between BSs 4 and 1 and a miss-handover to 5 and 6 stations is also spotted. These effects appear due to the fact that the highest weight is given to RSS criteria (45%), which prioritize the BS, offers the highest RSS value.

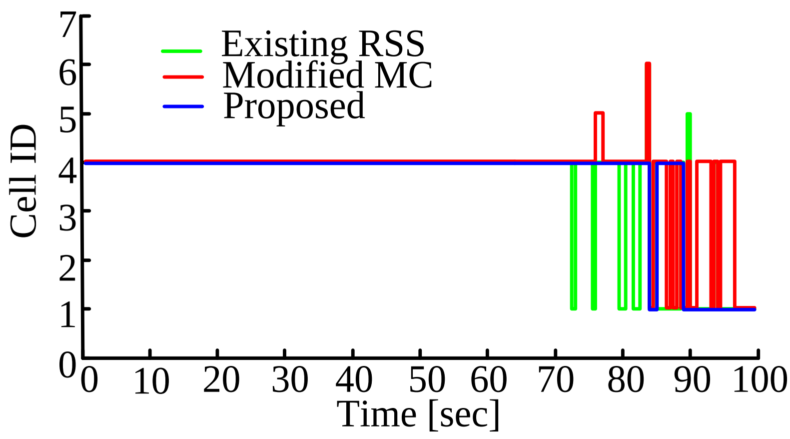

Figure 4.8: Base Stations Handover for the Critical Case

In Figure 4.9, the proposed algorithm also demonstrates higher stability compared to the other two algorithms during the simulation period. In Figure 4.9 at the 90th sec, the proposed algorithm shows its ability to cope up with a large amount of interferences where the MS makes a vertical handover to keep the QoS in the satisfaction level. The existing RSS approach shows high inefficiency to work in the area full of interferences, since from 0 to 15 and from 65 to 100 sec, the MS kept Ping-Pong between the technologies.

From Figure 4.10, even if the huge interferences, MS is inherited from the surrounding cells, the proposed algorithm successes to keep the received signal strength level higher than the minimum level during the simulation period, whereas the modified MC approach is failed in 95th sec. Based on its handover decision method, the existing RSS is the highest RSS value since it is based on selecting the BS with the highest signal strength.

In Figure 4.11, the lowest handover delay for the proposed algorithm occurred, which means that even if the critical case required more time than other scenarios to make an accurate handover decision, the proposed algorithm successes to approve its ability to strict with delay boundaries for making handover process. The observations are clearly depicted in Figure 4.12 where the proposed algorithm shows low connection cost during the simulation period

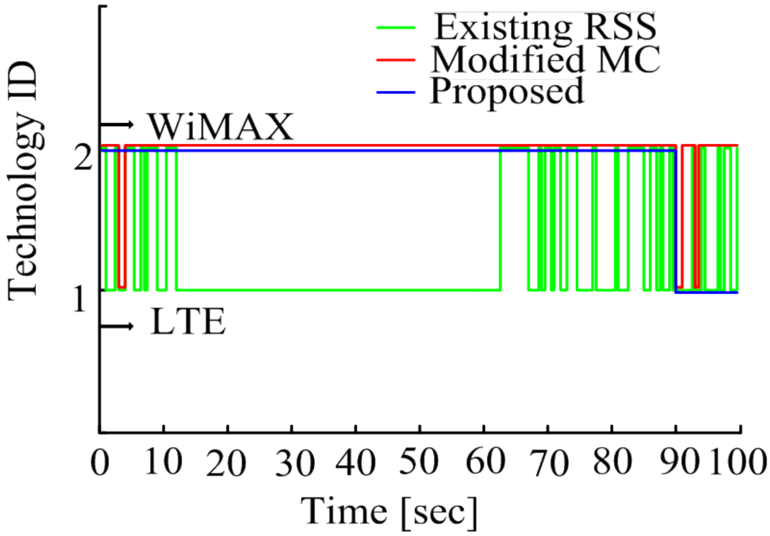

Figure 4.9: Handovers (VHO, HHO) for the Critical Case

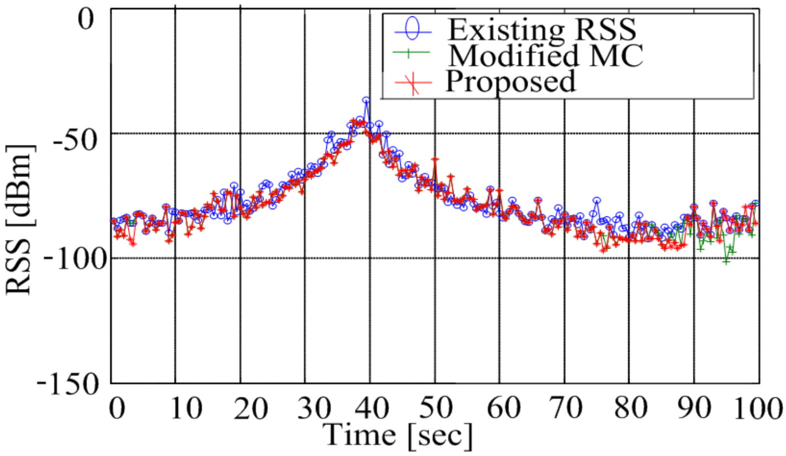

Figure 4.10: The Signal Strength Measurements' Tracking for the Critical Case

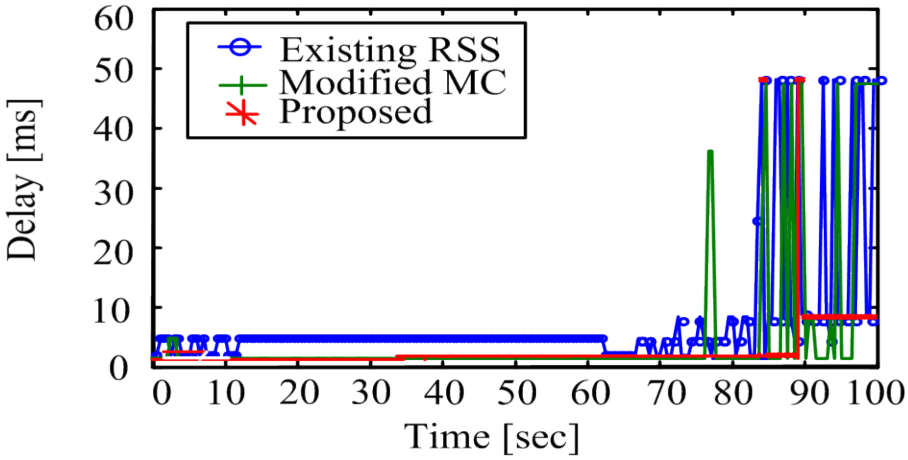

Figure 4.11: Delay Measurements for the Critical Case

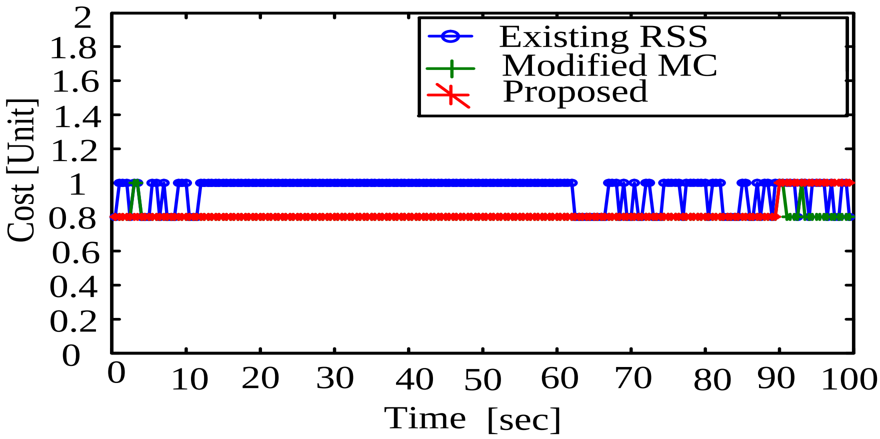

Figure 4.12: Cost Measurements for the Critical Case

4.2 PREDICTION OF TARGET BS

The prediction scenario is validated at the University of Malaya area. The coordination data have been collected from the Google Map database and called to simulate inputs. The predicting target BS using enhanced GPS and novel RSS prediction approaches is presented in chapter three at Sections 3.1.1.1 and 3.1.1.2, respectively, and compared with the existing RSS approach. As shown in Figure 4.13 the MS is assumed to be roaming from point A, located in BS 1, to point B, located in BS 7. These BSs are supported with LTE and WiMAX technologies.

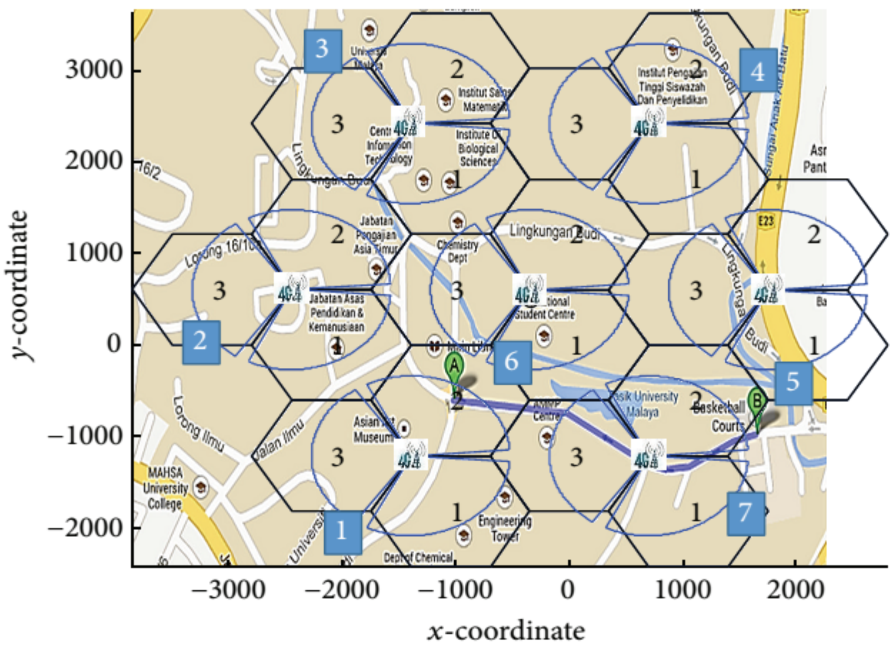

Figure 4.13: MS Movement at the University of Malaya Area

4.2.1 GPS APPROACH

Once the MS reaches the trigger threshold level of the BS 1, the GPS device is activated. The GPS prediction approach determines MS' coordination (*x*, *y* and *z*), and keeps tracking the coordinates up to the handover threshold (during *n*-time intervals). In Figure 4.14, the enhanced GPS prediction approach proves a high prediction quality compared to the existing RSS approach. Between 38 and 52 seconds, the existing RSS approach shows inaccurate and instable determination of the target BS, since high attenuation of BS' edges leads to fluctuation in RSS level, which makes the BS prediction decision unclear, and the MS is continuously shifted between BS 1 and BS 7, which leads to a high ratio of Ping-Pong effects. In terms of the handover accuracy ratio (the proportion of number of accurate handovers over the total number of handovers), the enhanced GPS shows a high level of accuracy comparing to existing RSS, with only two missed handovers for the enhanced GPS.

4.2.2 RSS PREDICTION APPROACH

In order to demonstrate the improvement of the novel RSS prediction approach, it is compared to the existing RSS prediction approach in (Becvar et al., 2011) (Figure 4.15). From 45 to 55 seconds, the novel RSS remarkably reduces the handover failures comparing to the existing RSS. The robustness of the novel RSS is in the way of decision making process which is based on the BS' RSS accumulative values during *n*-time intervals. Whereas the existing RSS is depended on one RSS measurement, which makes it more susceptible to signal fluctuating, at the same time it provides a high accuracy ratio when compared to existing RSS. The novel RSS's missed handovers are considered few, despite being seven, when compared to existing RSS approaches with more than 20 missed handovers.

As a conclusion from Figures 4.14 and 4.15, the enhanced GPS approach has higher accuracy compare with the novel RSS prediction approach. On the contrary, the RSS approach shows less power consumption, no-additional data requirements and lower cost. The reason behind proposing these two prediction approaches is to add flexibility to the prediction process based on the user's preferences. The user tradeoffs are among accuracy, power consumption and cost of prediction.

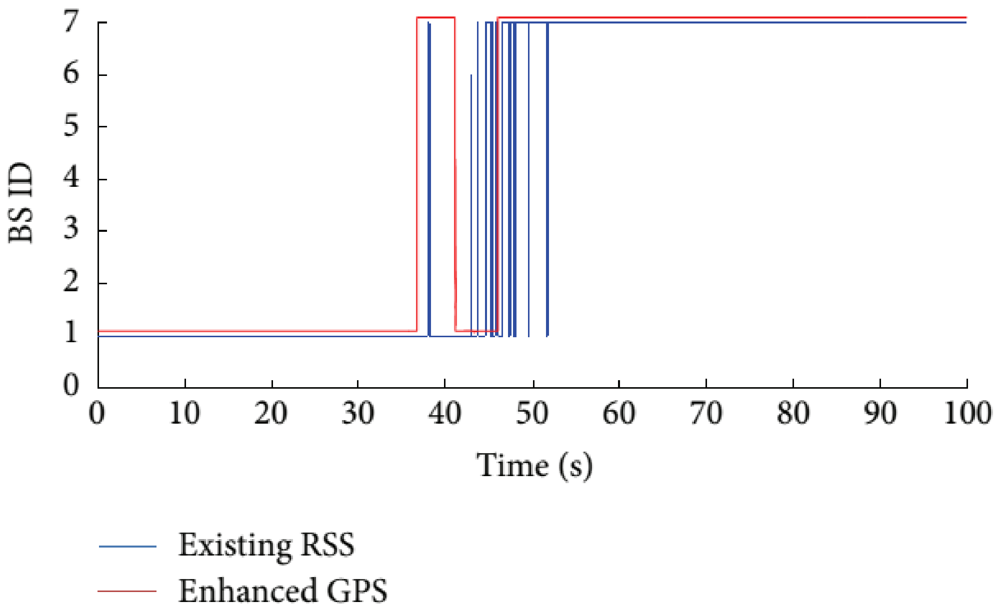

Figure 4.14: BS Prediction Using Enhanced GPS Prediction Approach

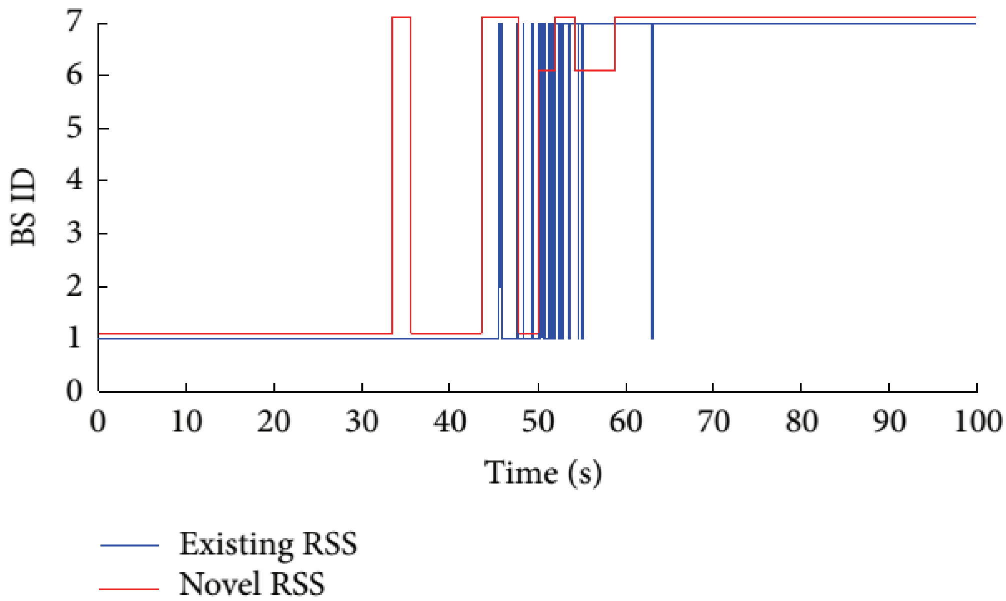

Figure 4.15: BS Prediction Using RSS Prediction Approach

4.3 OVERALL SCENARIO

Figure 4.16 expresses the simulation steps series. The simulation sequence runs as the following steps:

i. Input parameters are set according to Table 4.2.

ii. The existing RSS, multi-criteria (MC) approach and proposed algorithm (modified multi-criteria approach with two handover thresholds) are presented.

iii. FRR3 technique is implemented to all the approaches.

All the above proposed approaches have been simulated, tested and evaluated for BS prediction, HHO and VHO, RSS, delay and cost as simulation outputs. The details result and the decision of each approach are described below:

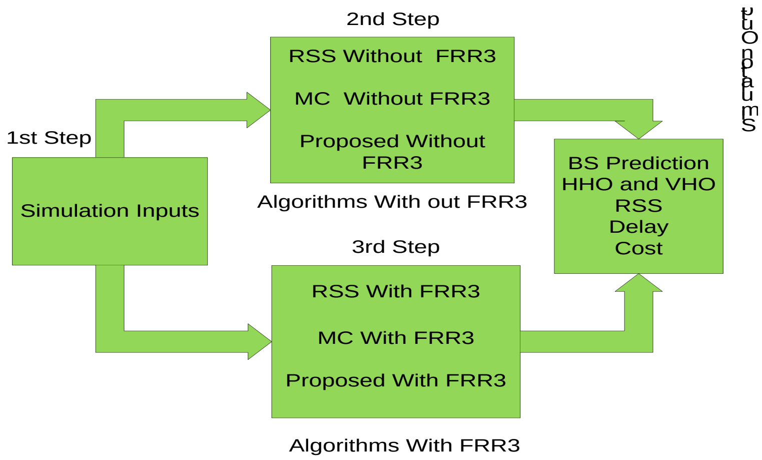

Figure 4.16: The Simulation Steps

4.3.1 PREDICTION OF TARGET BS AND SELECTION APPROPRIATE TECHNOLOGY

In this section, the mechanism's behavior for prediction and selection of the most appropriate target BS and technology is investigated. The topology of Figure 4.17 consists of 7 BSs; each BS supports two technologies (LTE and WiMAX). The results being studied are comprised of three approaches, with and without the FRR3 technique.

The studied approaches are named as: existing RSS approach, MC approach and the MMTT approach. The weighting factors for each criterion (user's preferences) are applied as inputs to the MMTT approach. From Figure 4.17, we assume that the MS is roaming from BS 4 to BS 1. Based on the user preference (Table 4.2), the enhanced GPS prediction approach is chosen as prediction approach since the cost weight is only 5% instead of the novel RSS approach.

Table 4.2: Overall Scenario of Simulation Parameters

Inputs parameters	Units	Values
Number of cell #		7
Number MS #		1
RSS weight #		50%
Bandwidth weight #		20%
Cost weight #		5%
Delay weight #		25%
Angle of movement	degree	0
Mobility type		PRWMM Probabilistic Random Waypoint Mobility Model
Path loss type	dB	Macro urban path loss PL=33.81×log10(fc)- 79.4+3+35.04×log10(d)
Simulation time	second	100
MS highest	Meter	1
BS highest	Meter	40

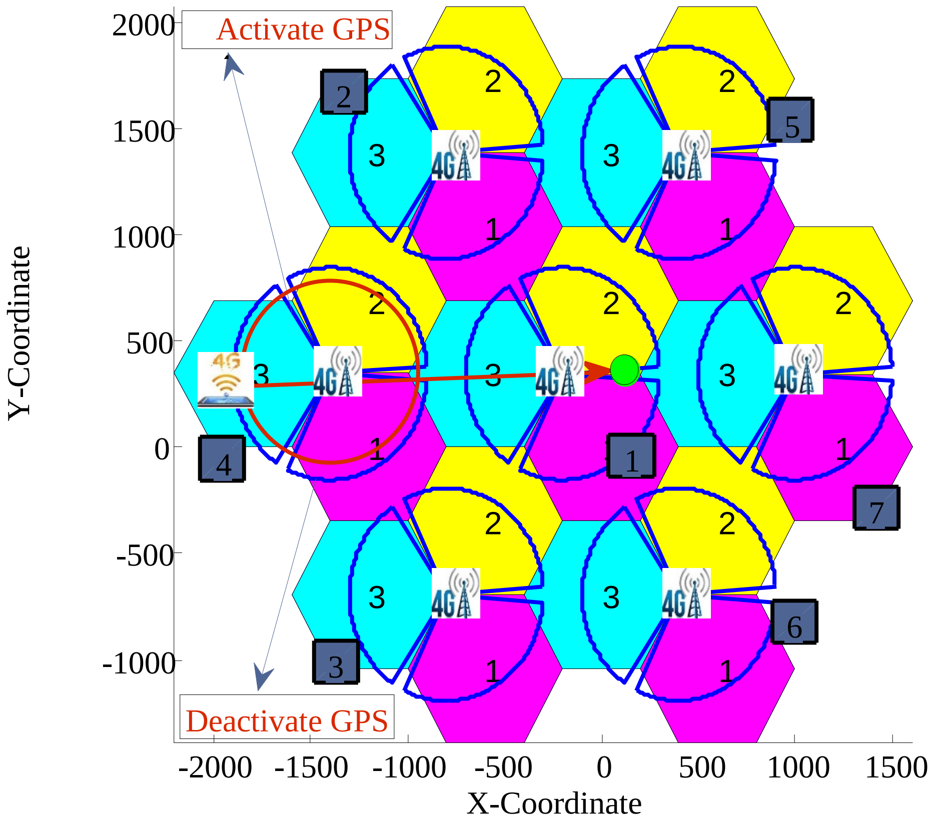

Figure 4.17: MS Movement in the Overall Scenario Simulation

A comparison result of the enhanced GPS approach with other competitive approaches regarding target BS prediction without FRR3 is presented in Figure 4.18. During the simulation period, the enhanced GPS approach proves an accurate BS prediction and high stability compared to the other two approaches. It shows only two handover failures (connection to BS 3 instead of BS 1). Since the MS experiences high ICI and CCI at BS 1 (central BS) and BS 3 seems to be having more acceptable factors than BS 4, the MC approach connects to BS 3 instead of 4 for quite a long time (keep MS without connection between 3 to 43 seconds). Therefore, this kind of prediction is not convenient or practical for utilization in high attenuation areas. The existing RSS approach shows average redundant handovers ratio between the MC and the enhanced GPS approach. The three approaches show a significant enhancement in the prediction process by applying the FRR3, as can be seen clearly from Figure 4.19. Where the enhanced GPS approach provides no redundant handovers, the MC's efficiency has increased remarkably since it is converted to a valid connection with few redundant handovers, i.e., from 0-60 seconds.

High handovers stability leads to more efficiency for exploiting the available resources from both technologies (LTE and WiMAX). That is shown in Figures 4.20 and 4.21, where the MMTT algorithm shows the highest value of the handover quality indicator compared to the other two approaches. The other approaches show many unwanted handovers and waste available resources since they reserve and use a lot of resources from both technologies for a too short period inefficiently. As it can be observed, the degradation of MS' QoS is a conclusion for both of the existing RSS and MC.

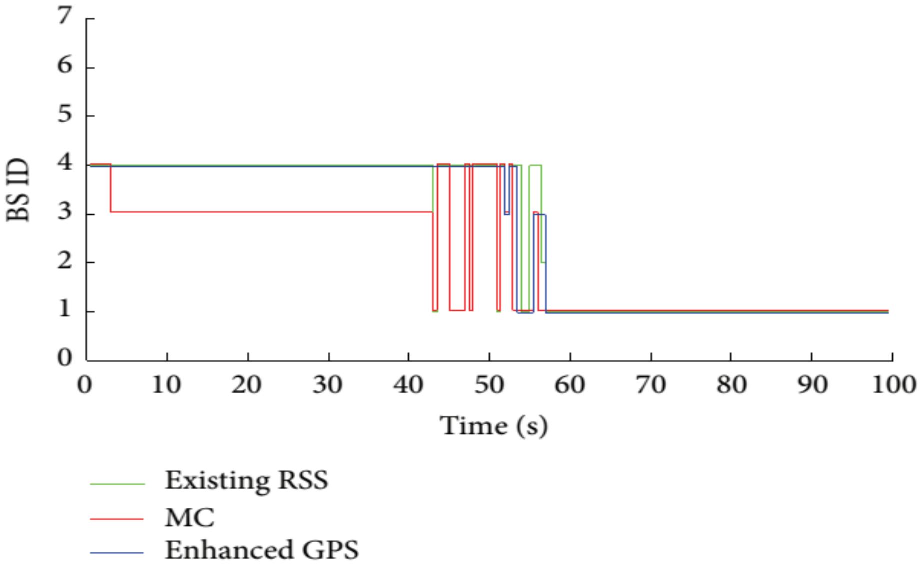

Figure 4.18: BS Prediction without FRR3

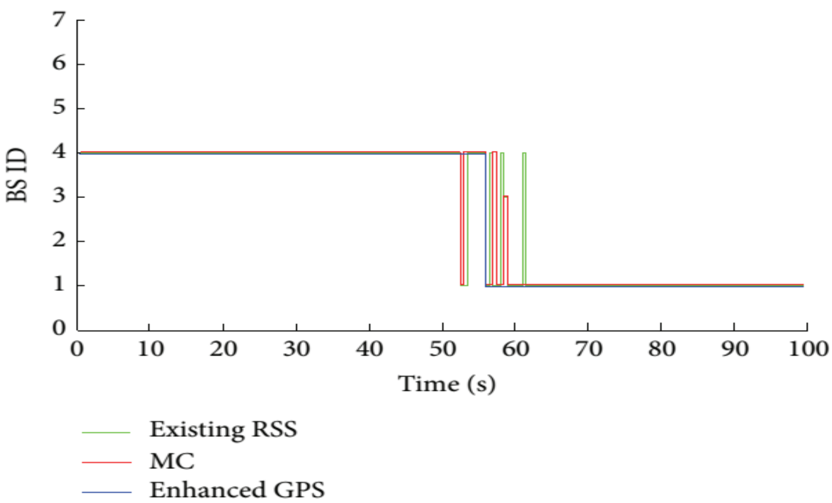

Figure 4.19: BS Prediction with FRR3

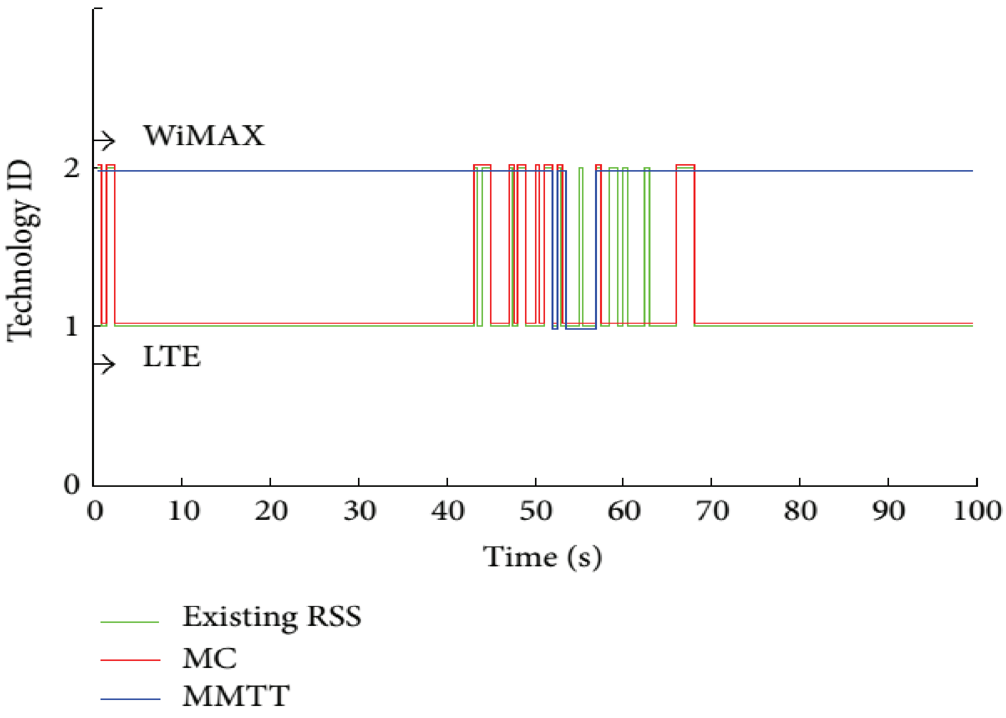

Figure 4.20: HHO and VHO without FRR3

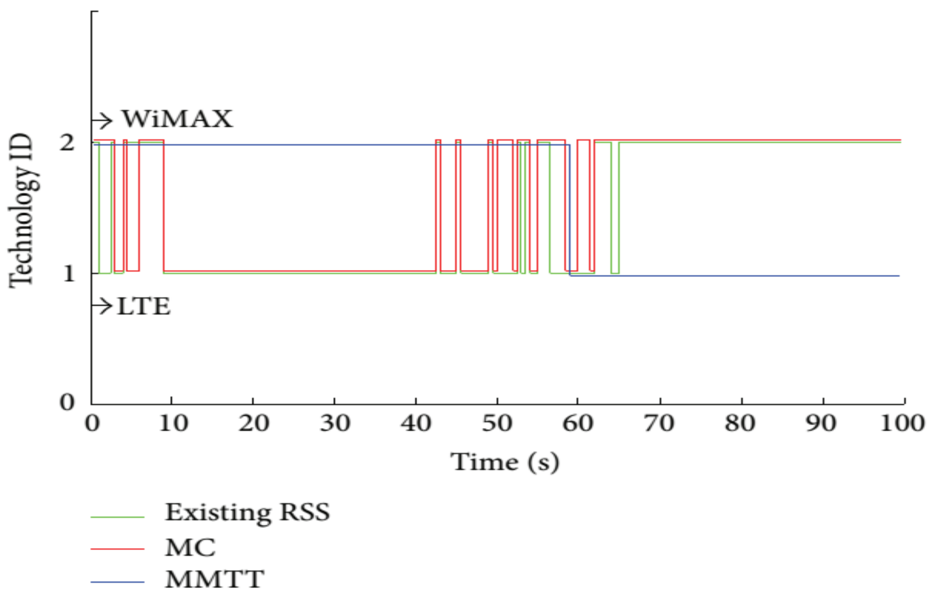

Figure 4.21: HHO and VHO with FRR3

The MMTT approach keeps the signal strength within an acceptable range during the whole simulation period, except at the 57th second (Figure 4.22). As illustrated in Figures 4.22 and 4.23, it is obvious that there is remarkable enhancement between the received signal strength before and after applying the FRR3 technique. At the 57th second, the MMTT algorithm is recovered from degradation in the received signal strength to an acceptable level. At the same time, from 4 to 41 seconds, the MC approach demonstrates a huge enhancement, since it is converted from insufficient to sufficient handover approach.

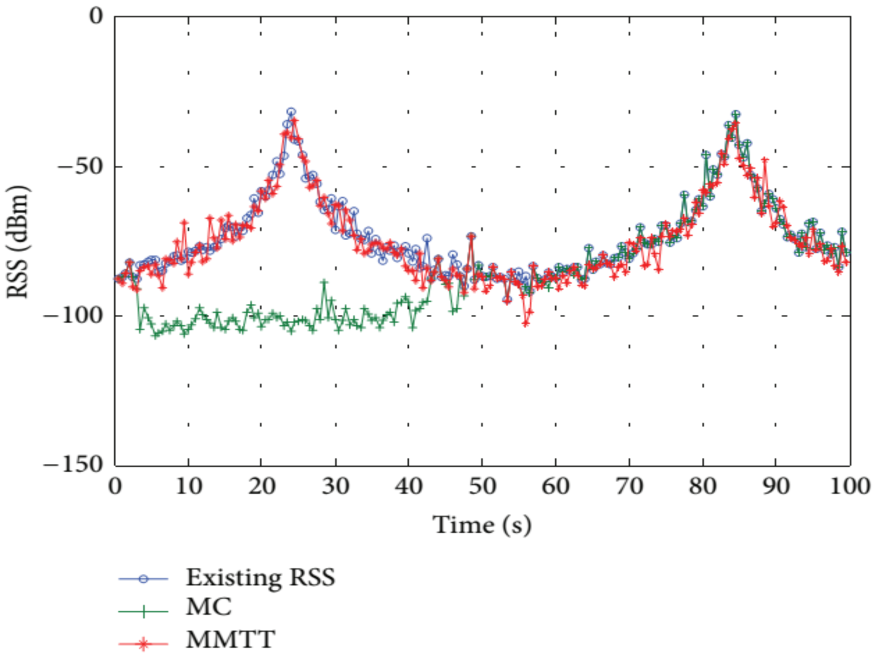

Figure 4.22: Received Signal Strength without Using FRR3

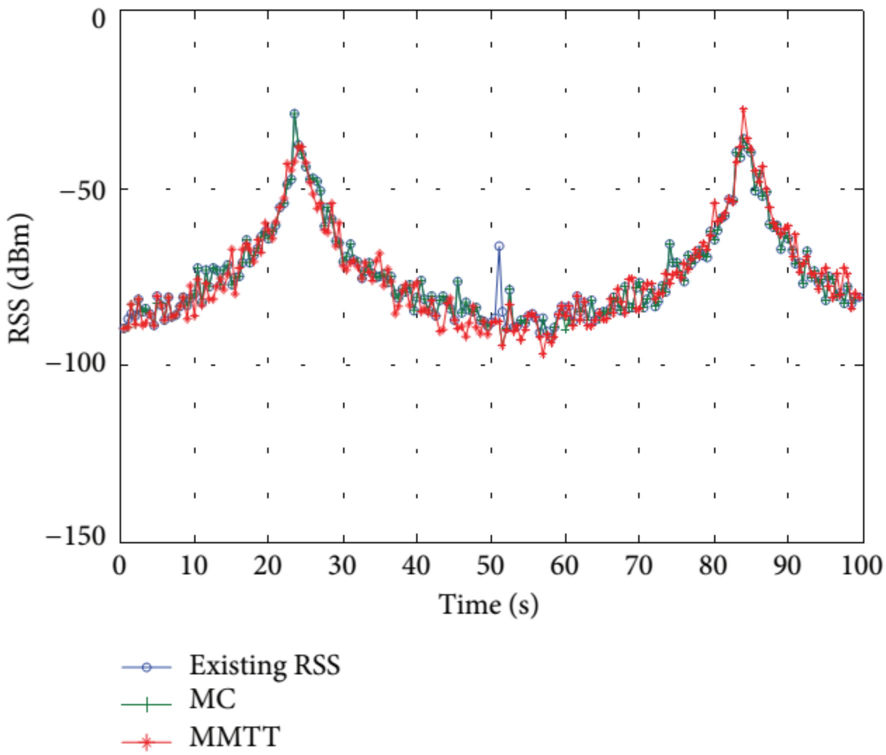

Figure 4.23: Received Signal Strength with FRR3

Even the MMTT approach has the highest handover delay compared to other two approaches, but it still satisfies the user's preferences (Figure 4.24). The FRR3 decreases the handover process delay of the MMTT approach up to roughly 15% in comparison to the scenario with no FRR3. This means that the MMTT algorithm determines the target BS and technology faster than without using the FRR3 technique (Figure 4.25).

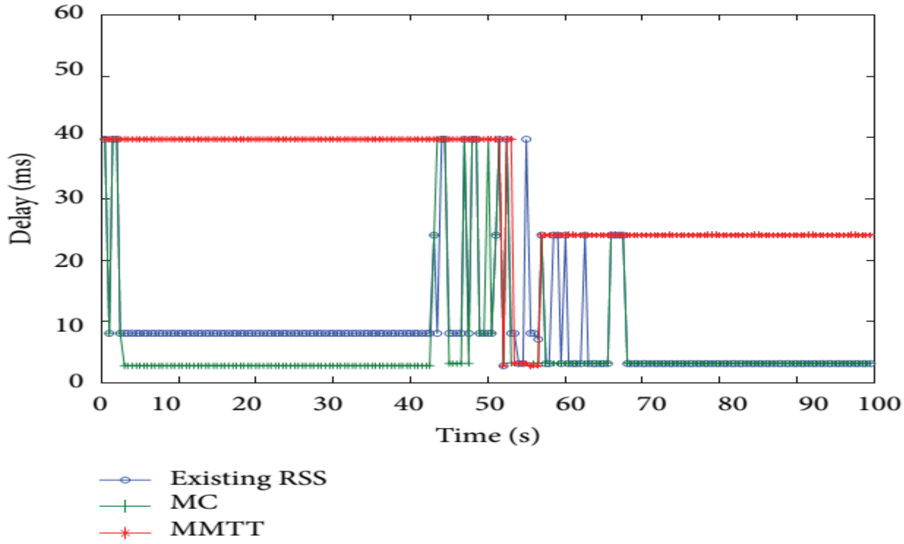

Figure 4.24: Delay without FRR3

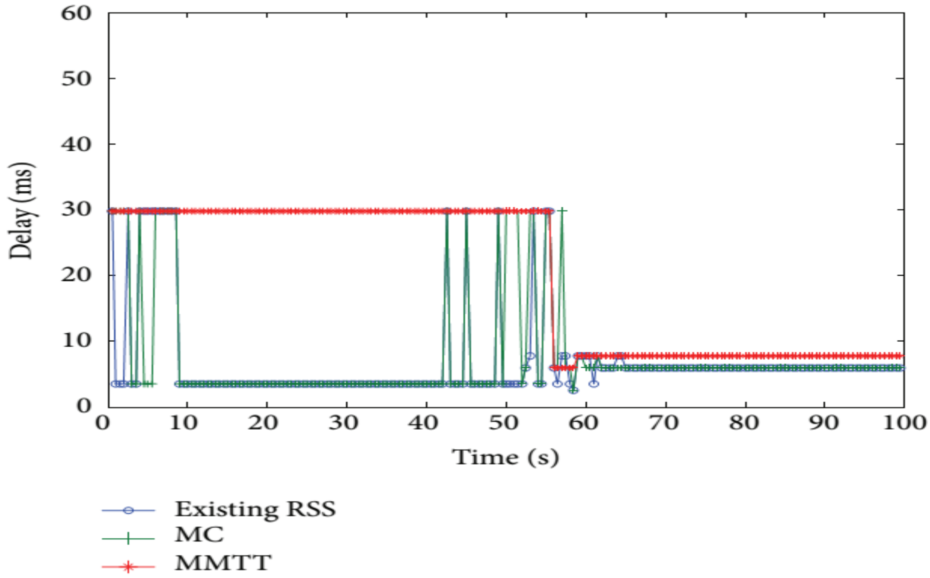

Figure 4.25: Delay with FRR3

From Figure 4.26, it is surmised that the MMTT algorithm achieves the lowest average cost value equal to 0.883, while MC results in 0.8915, and the existing RSS has the highest value of 0.9.

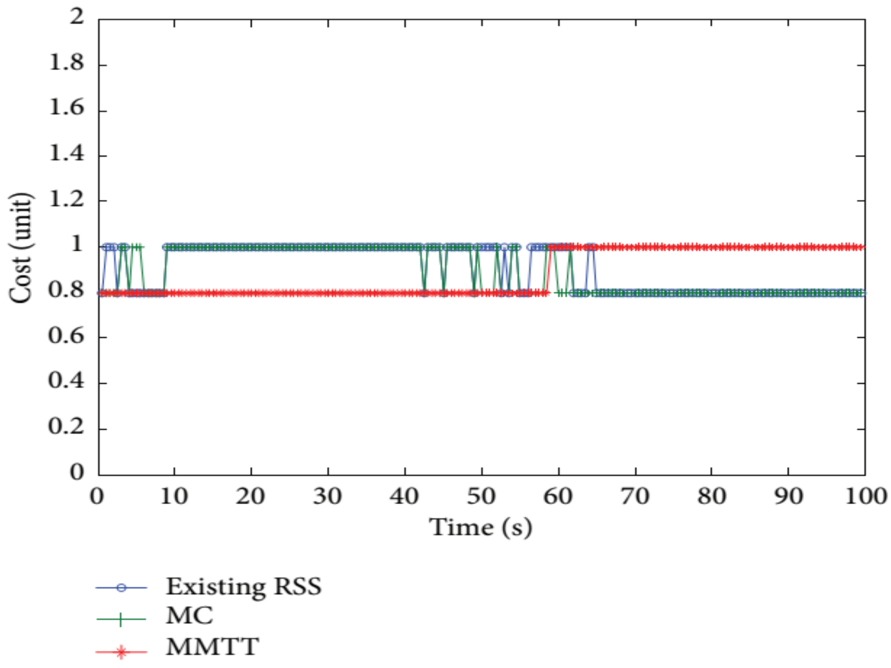

Figure 4.26: Connection Cost

4.4 FLAT PRIORITY BASED APPLICATIONS

The simulation was conducted using LTE-Simulink built on C++ platform. One cell is considered in this scenario which includes noise and interferences. The propagation model, such as simple path loss is based on the distance from the base station and multipath losses are used. Furthermore, shadowing based on log normal distribution (0 dB and 8 dB) and penetration loss with 12 dB is used. The fairness among each user is measured using the Jain's fairness method (Jain et al., 1998). The proposed algorithm is conducted under two scenarios. The first scenario is dedicated to voice and video (RT applications) whereas the second scenario considers all applications including (RT and non-RT applications). The purpose of the two scenarios is to demonstrate the robustness of the proposed algorithm.

Figure 4.27 shows the comparison of the proposed algorithm with PF, EXP/PF and M-LWDF for the first scenario. The proposed algorithm shows the best performance in the overloaded situation by roughly 16% compared to the other algorithms. EXP/PF and M-LWDF show better performance (30 to 50 users) than PF, which shows the worst performance since it does not consider the delay factor. Figure 4.28 illustrates that the proposed scheme shows the lowest delay compared to other schemes.

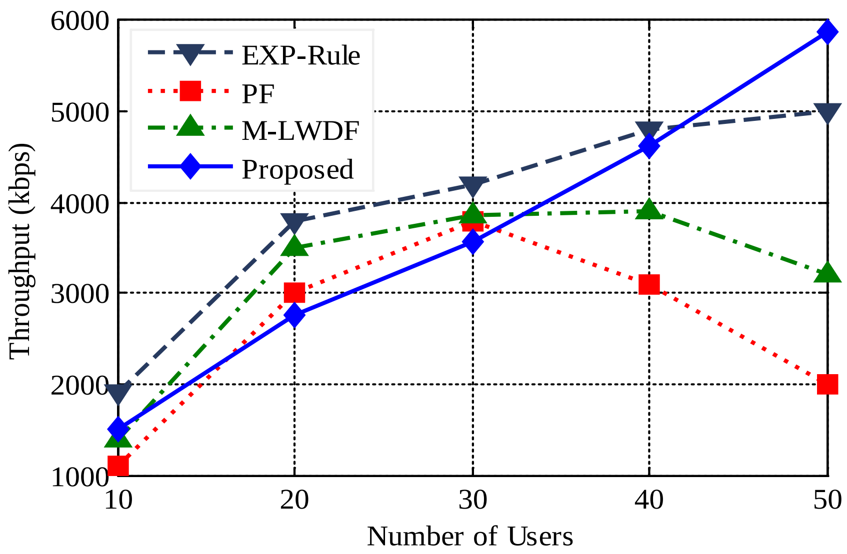

Figure 4.27: Aggregate Throughput of Voice and Video Applications

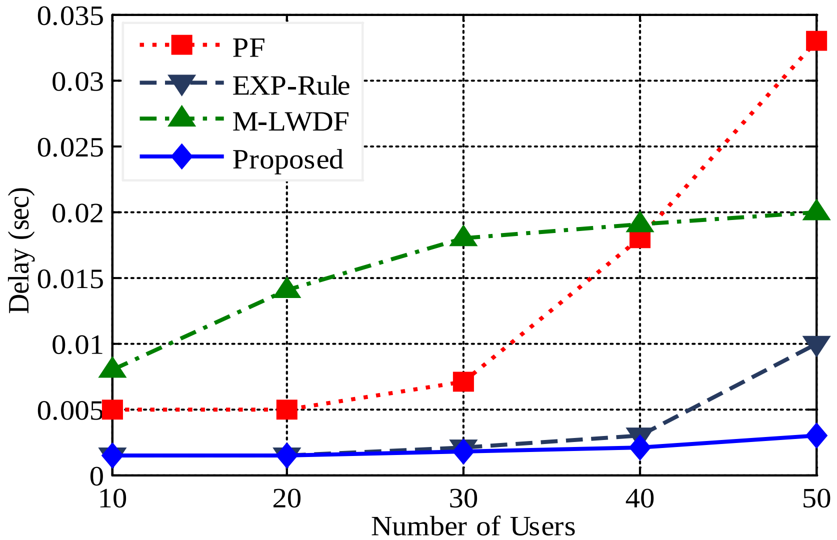

Figure 4.28: Delay of Voice and Video Applications

In the second scenario, all schemes show a good performance for the minimum data rate requirements (32 kbps) of the satisfied voice application, as shown in Figure 4.29 Furthermore, referring to Figure 4.30, all the scheduling schemes met the video surveillance traffic requirements up to 30 users, but they dropped significantly (more than 30 users) except the proposed algorithm, which kept serving the video traffic up to 42 users (overloaded situation). In fact, the reason behind robustness of the proposed algorithm is the dynamic adjustment to smart grid application's requirements. PF showed the worst performance for video surveillance application since it does not concern about the delay factor and it has been designed to serve non-real time applications. The average throughput for metering data flows is illustrated in Figure 4.31 where the proposed algorithm shows a good improvement, approximately 15% higher than the other algorithms (up to 60 users). Moreover, PF shows a good performance in an overloaded situation since its metric is designed to serve users with high data rate and allow high tolerance in terms of delay. Whereas EXP-Rule shows the worst performance since it considers the end-to-end system delay regardless bandwidth requirements.

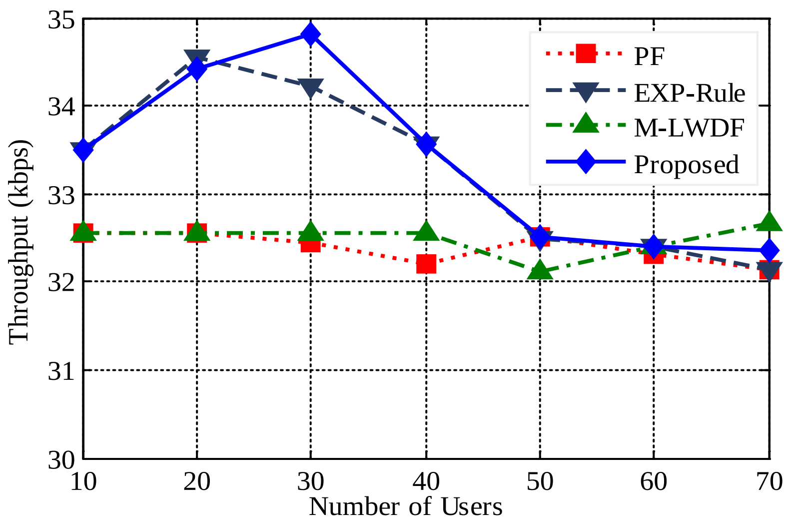

Figure 4.29: Average Throughput of Voice Application

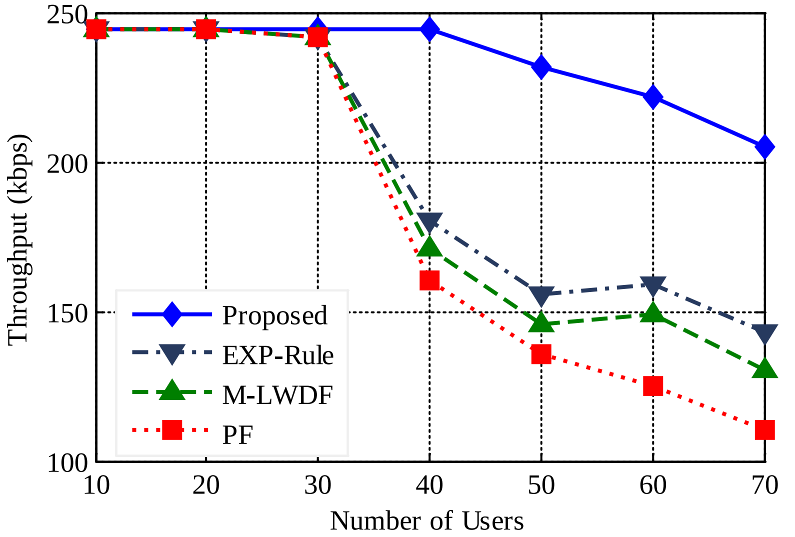

Figure 4.30: Average Throughput for Video Surveillance Application

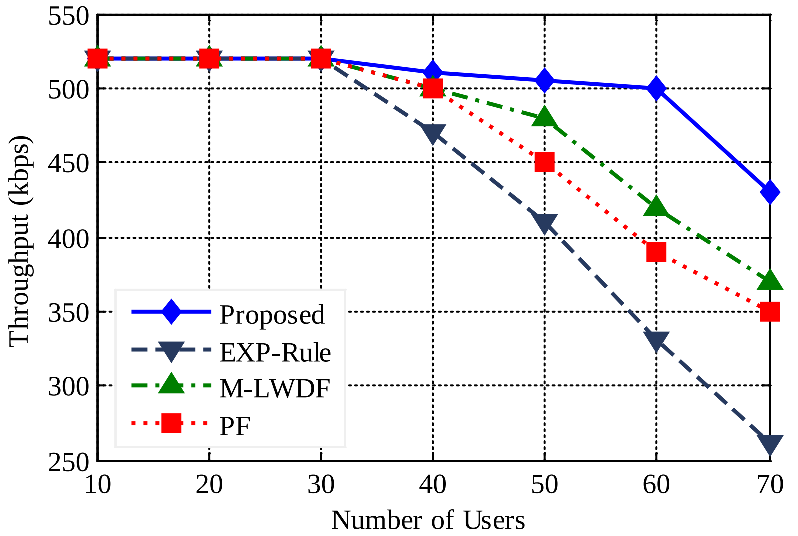

Figure 4.31: Average Throughput for Metering Data Application

The proposed algorithm shows the highest fairness and lowest delay compared to the other schemes (Figures 4.32 and 4.33). In view of the fact that the proposed algorithm assigns higher weights to delay factors for RT applications, as mentioned earlier. In addition, all users (real and non-real time users) had a chance to be served (no starvation for non-real time applications). In contrast, PF shows the lowest fairness index and the highest delay since it does not concern about the delay metric at all, and the probability of packet drop rate increases along with the number of users increases. As a result, PF failed to cover more than 30 users with respect to the traffics delay boundaries.

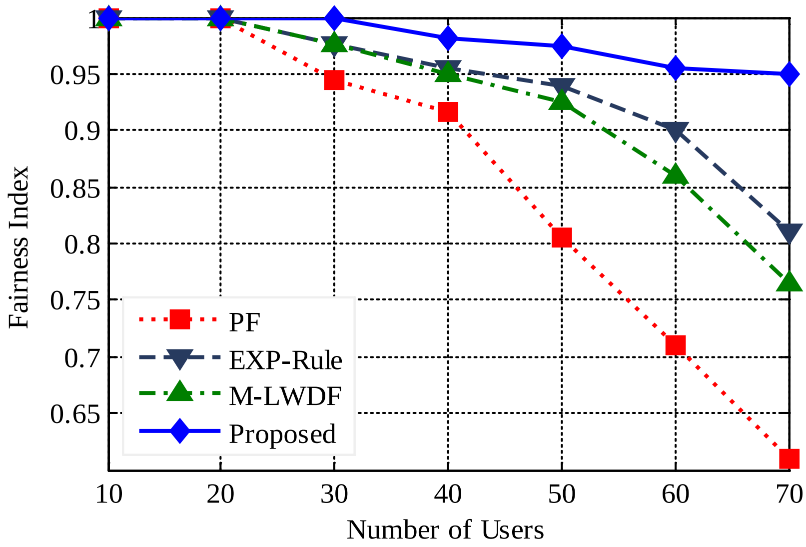

Figure 4.32: Average System Fair Index

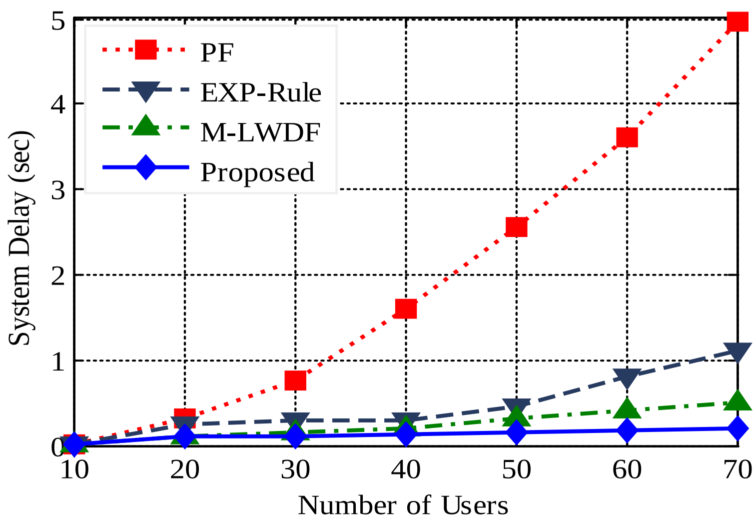

Figure 4.33: Average System Delay

4.5 SPECIFIC PRIORITY BASED APPLICATIONS

The LTE-Sim is used as a simulation tool, which is based on C++. The testing scenario is a single cell with interference and the simulation inputs are illustrated in Table 4.3. All the users have fixed location in the cell and their coordination is well known by the scheduler. As a fairness index, the Jain fairness index method is adopted (Jain et al., 1998). Two types of loss models are utilized in this scenario, which are path loss (it has a direct relation to the distance from the BS) and shadow fading.

Table 4.3: Simulation Parameters

Parameters	**Values**
Cell Radius	1 km
Bandwidth	5 MHz
Number of Cell	1
Number of RBs	25
Bearer Types	From QCI 1- QCI 15
Environment Type	Urban
eNodeB Height	20 m
UE Height	1.5 m
eNodeB Tx power	46 dBm
UE Tx power	23 dBm

Scheduling algorithms, such as EXP-Rule, M-LWDF and EXP/PF have been chosen to compare with the proposed algorithm. The new algorithm focuses on giving high priority to the RT applications and above existing algorithms are popular and well accepted. The throughput performance of the proposed algorithm is illustrated in Figures 4.34 and 4.35. It shows a high ability to serve up to 30 users and then start degrading slowly comparing with other algorithms. Two reasons behind the robustness of the proposed algorithm are the bandwidth estimation-allocation and dynamic scheduling approach. For the bandwidth estimation and allocation, when the number of users increases (after 20 users), some resources shift from EV application as a process to keep serving the users of DA and DER. Another issue is the way of making the scheduling decision for DA and DER guarantees to provide the service based on urgency to serve. At the same time, it needs to satisfy the application's demands (high weight coefficients for delay and instantaneous data rate) that maintains good QoS for DA and DER users along with increasing the user number.

Meanwhile, the EXP-Rule algorithm shows better performance than the M-LWDF and EXP/PF. The EXP-Rule takes the delay metric of the considered user ratio to the sum of the experienced delays of all real time users. That means it exponentially prioritizes the user which has the highest waiting head of line delay along with the higher channel condition of this user. As a result, it offers more resources to the DA and DER users than EV users. After 20 users, M-LWDF and EXP/PF sharply degrade even though M-LWDF considers the delay boundaries and channel status of the DA and DER applications. For that reason, it fails to prioritize their users when packet delay is approaching (clearly after 20 users). From Figures 4.34 and 4.35, it can be said that the proposed algorithm shows noticeable enhancement by 1%, 10% and 15% compared to EXP-Rule, M-LWDF and EXP/PF, respectively.

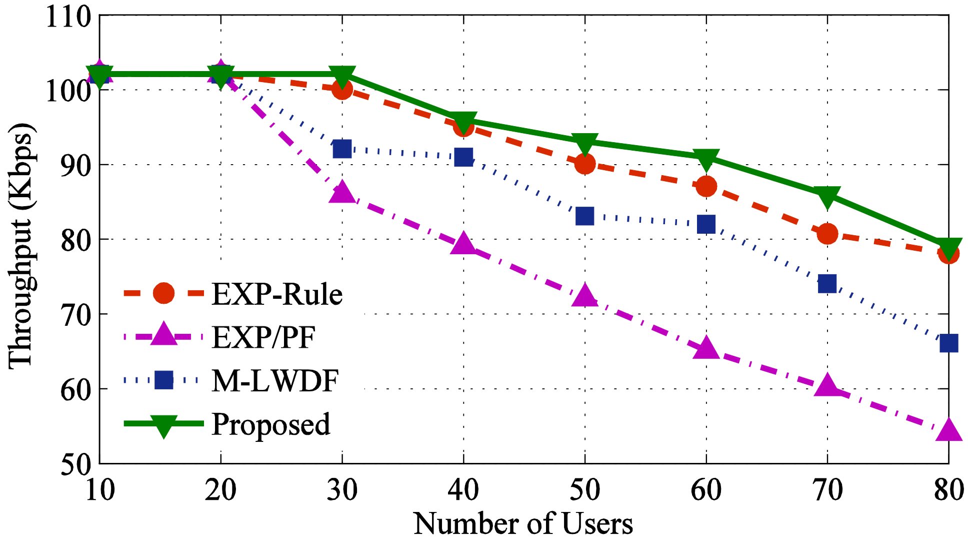

Figure 4.34: Average Throughput for DA Application

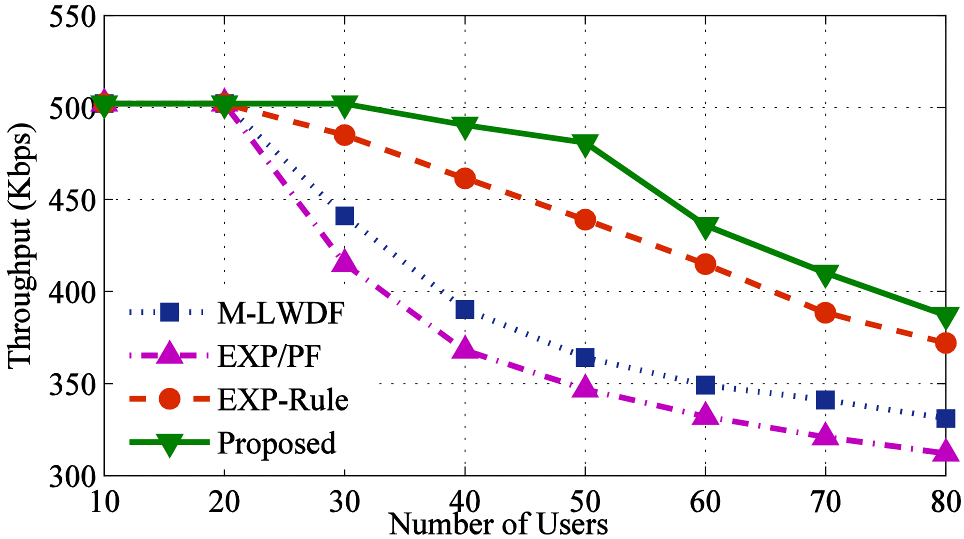

Figure 4.35: Average Throughput for DER Application

For the EV application (Figure 4.36), the proposed algorithm shows slightly better performance than EXP-Rule algorithm. The throughput is stable like other algorithms up to 20 users, but starts decreasing when the amount of the user increases. EXP-Rule shows the lowest performance since the delay boundary of the EV application is 2000 ms. The EXP/PF and M-LWDF show better performance than other algorithms since both of them have the PF metric, which has a direct effect on the scheduling decision. And, even though they are organized to serve the real time applications, they still need to provide the degree of service up to a certain number of users for the EV application.

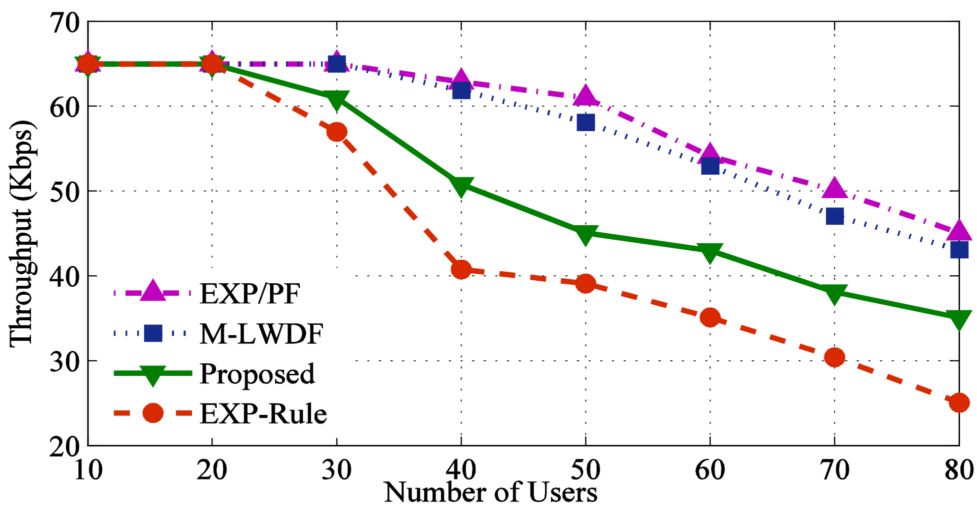

Figure 4.36: Average Throughput for EV Application

Figures 4.37 and 4.38 illustrate that the new algorithm has the lowest serving delay compared to other scheduling algorithms. It gives higher concern to the delay metric than the other metrics. Once the number of RT users increases (after 20 users), the EV application experiences degradation of the servicing level. That leads to add more delay until the higher priority users have been served (as described in Figure 4.39). The EXP-Rule shows an average level of delay since it concerns about maintaining the delay of DA and DER users within the acceptable range even if EV's users do not receive enough services. The M-LWDF and EXP/PF show the higher delay level for DA and DER users as the PF metric at both approaches forces to provide the services for the N-

RT user. As a result, more waiting time for the RT packets will be added as some resources are shifted to serve the EV users.

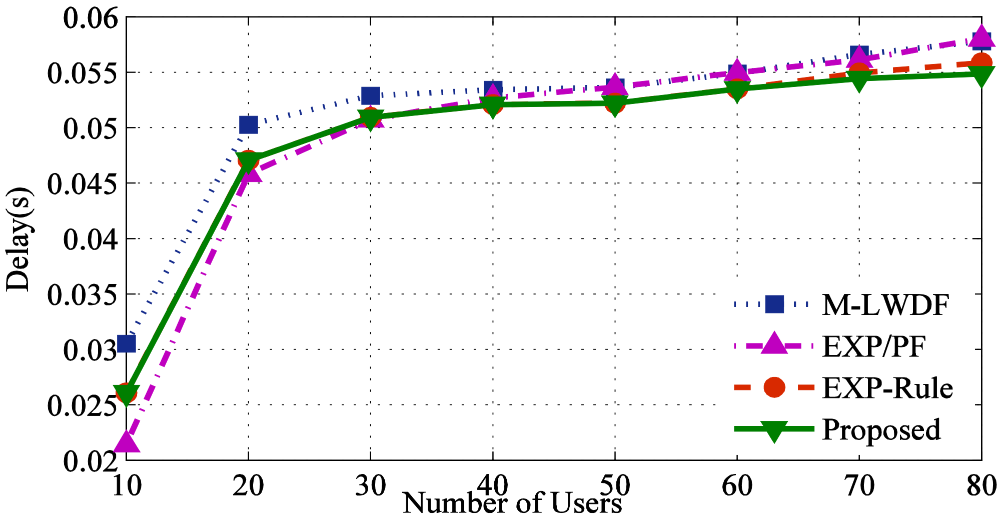

Figure 4.37: Packet Delay of DA Flows

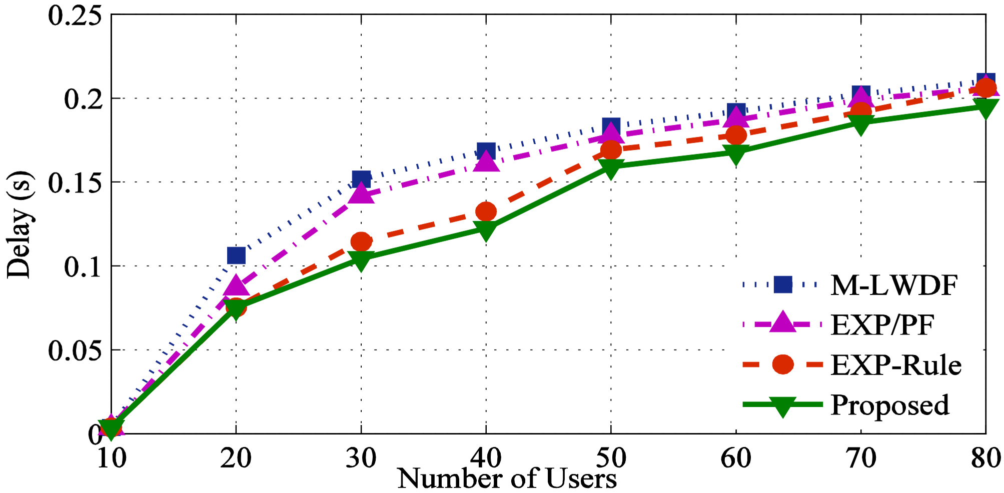

Figure 4.38: Packet Delay of DER Flows

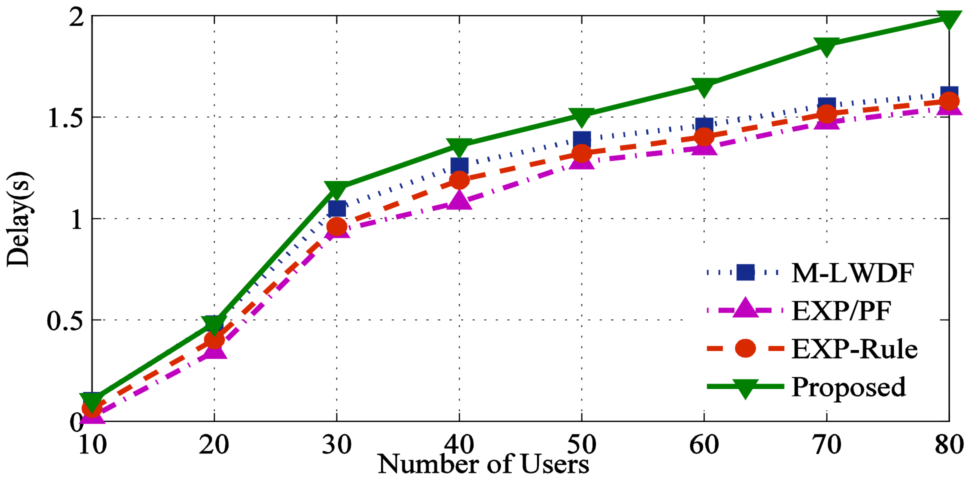

Figure 4.39: Packet Delay of EV Flows

In Figure 4.40, the proposed algorithm shows the lowest packet loss rate (PLR), which proves that new algorithm has the ability to maintain good quality of service for DA user. And, this ratio shows relatively low growth for the proposed algorithm compared to other algorithms. At 80th user, the PLR of the proposed algorithm shows improved performance up to 5%, 10% and 15% compared to EXP-Rule, M-LEDF and EXP/PF, respectively.

For DER flows in Figure 4.41, all scheduling algorithms show almost same level of PLR. Figure 4.42 shows that the proposed algorithm has the highest PLR due to positive probability. EV application drops the packets as a scarifying process to serve the real time user.

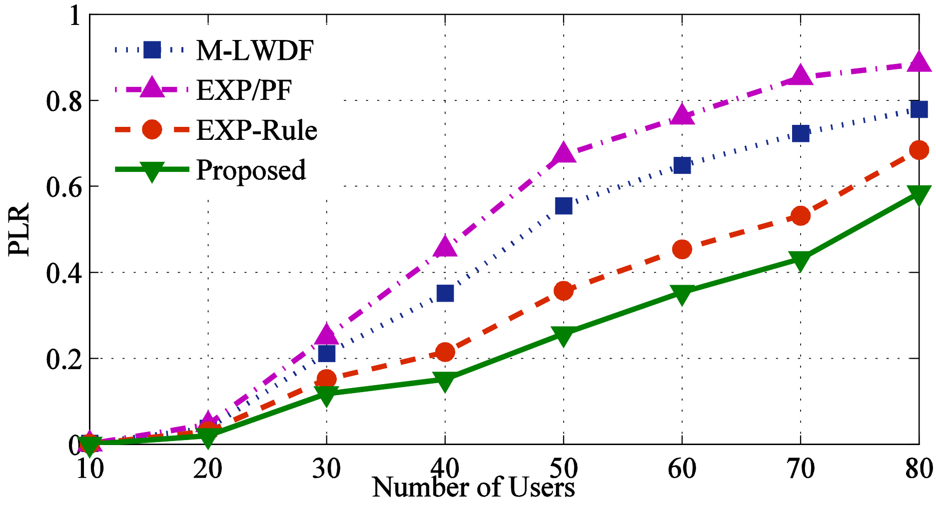

Figure 4.40: Packet Loss Rate of DA Flows

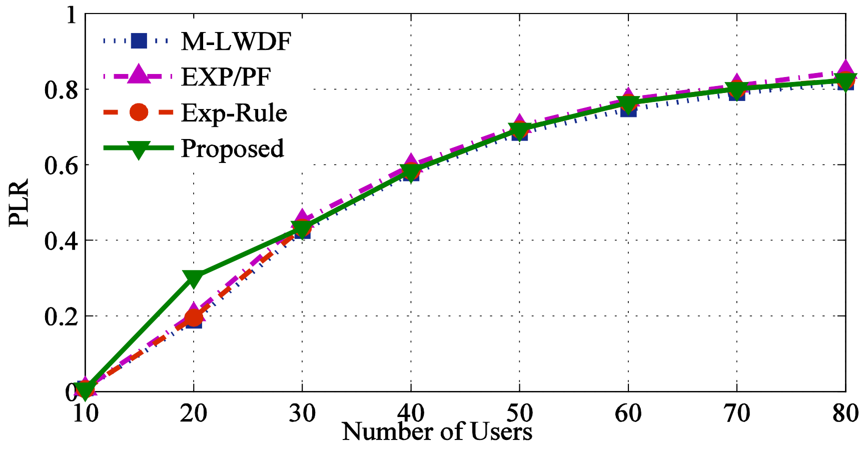

Figure 4.41: Packet Loss Rate of DER Flows

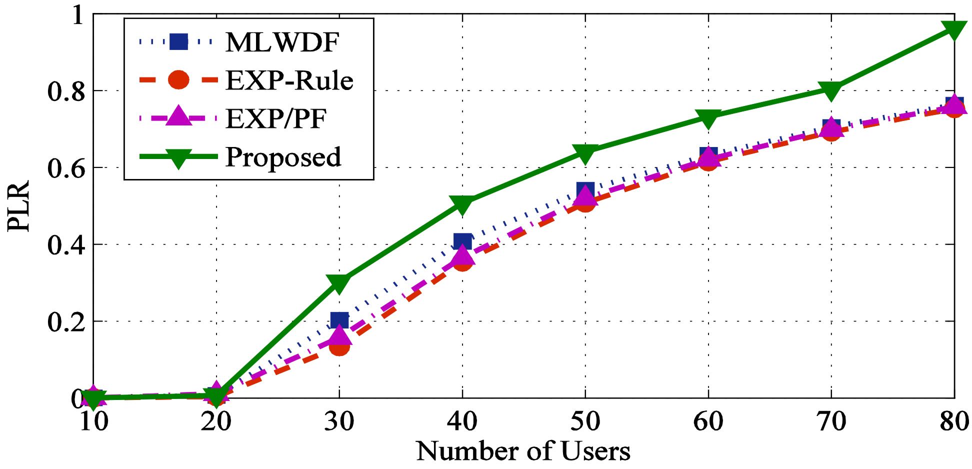

Figure 4.42: Packet Loss Rate of EV Flows

Average Packet Fairness Index among all users is illustrated in Figure 4.43. As the scheduling metric is following the same method for serving the users, the proposed algorithm shows higher performance compared to other algorithms. It reaches to 0.93 even in overloaded situations (up to 80 users), followed by EXP-Rule which is 0.9. Whereas, the M-LWDF and EXP/PF show less contrast by 0.86 and 0.84 fairness index, respectively at the same number of users.

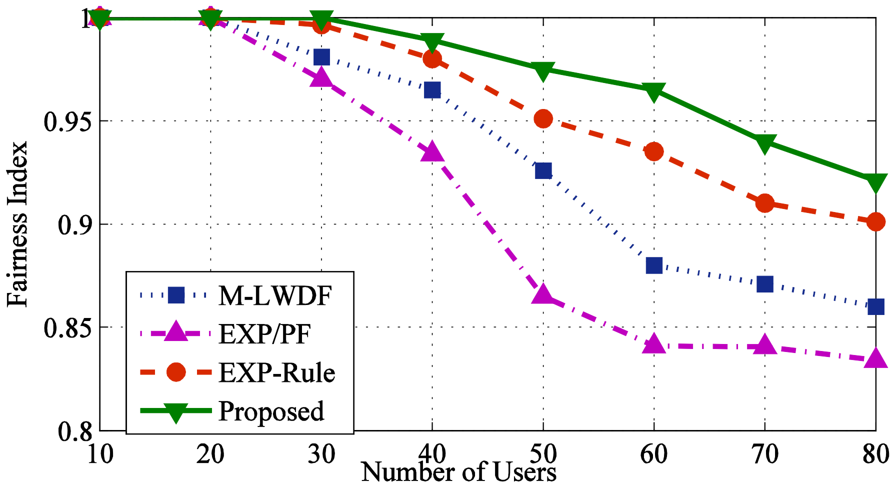

Figure 4.43: Average Packet Fairness Index for All Users

4.6 SUMMARY

Along this chapter, the issues have been tested and simulated as follows:

i. Prediction of the target base station; RSS and GPS approaches demonstrated high performance of next base station prediction comparing with the existing RSS approach.

ii. Selection of the most appropriate available technology (tested for critical and worst case scenarios); by utilizing the MMTT method, it offers higher efficiency of technology selection, along with lower delay, keep the connection with maintaining the RSS level at the acceptable range, especially at the high attenuation area, and guarantee the lower connection cost comparing with existing RSS and MC.

iii. Scheduling for flat priority based; we justify by comparing our method with the well-used algorithms (EXP/PF, EXP-Rule, M-LWDF and PF) that the use of game theory along with TOPSIS technique enhanced the fairness among users, decrease the scheduling delay as well as significantly enhanced in the users' number which can be served by roughly 16% compared to the other algorithms.

iv. Scheduling for specific priority based applications; the proposed algorithm for that served the high priority applications first and demonstrated enhancement by 15% compared with other scheduling approaches. As well as, the PLR improved by up to 5%, 10% and 15% compared to EXP-Rule, M-LEDF and EXP/PF, respectively, finally the fairness index hits the 0.93 in an overloaded situation (up to 80 users).

CHAPTER FIVE

CONCLUSION AND FUTURE WORK

5.1 CONCLUSION

By keeping eyes on providing the best connection for mobile station over 4G networks. We face three main issues, namely handover, bandwidth estimation-allocation and scheduling issues, had been highlighted after keen study of the existing approaches and algorithms for each practical issues (Chapter 2). Then proper solutions have been proposed for these mentioned issues.

Three main obstacles have been solved to overcome the handover issues which are mainly accurate prediction of the next base station, proper selection of the targeted technology and reducing the interferences from nearby base stations.

First of all, the improvement of GPS and RSS algorithms is shown by adding the virtual threshold (trigger threshold) and is presented to solve the prediction issue. In the RSS algorithm, a novel ‘’n’’ number of measurements method is used instead of the standard calculation technology technique. Therefore, the RSS approach results in less affect by the interferences from nearby BSs. While in the GPS algorithm, the improvement level decreases the cost and power consumption, because of the fact that the GPS device is only active among the trigger and handover thresholds instead of all the times. In addition, we show a modified multi criteria with two threshold algorithms resulting an improvement in the efficiency of target network selection. The selection is based on the user choices and setting because it uses the self-learning algorithm to result out the trigger and handover thresholds dynamically.

Finally, by following the FRR3 technique to the system, the sudden and sharp decline in the interferences from surrounding base stations is noted, while efficiency of target base station prediction and selection of target technology are increased, and the delay is decreased by approximately 15%. For the bandwidth estimation-allocation and scheduling issues, we have been through two main types of application: 1) Flat priority based applications (i.e., smart grid applications, namely voice, video surveillance and metering data), 2) Specific priority based applications (i.e., smart grid applications, namely DA, DER and EV). Explaining flat priority based applications, a new bandwidth estimation-allocation technique which is based on game theory approach such as bankruptcy and shapely value are considered, its result improves the efficiency and fairness among different applications while performing the resource allocation, it has been accepted that, the use of coalition concept increases the bandwidth efficiency near about up to 10, 2 and 3 times for voice, video and metering data, respectively, comparing without using the collation concept.

Whereas the TOPSIS mechanism is considered as a flat scheduling technique in LTE network. TOPSIS used Euclidean distances to calculate the separation measurement for users (positive ideal value and negative ideal value). The user who is prioritized to serve supposed to have the shortest distance from the positive ideal value and the farthest distance from the negative ideal value. The positive ideal value is determined by the summing up Euclidean distance between user criteria values and the highest criteria values between all the users. The selected and proposed algorithm (bandwidth estimation-allocation and flat priority based scheduling algorithms) results the best performance by roughly 16% compared to the other algorithms (PF, EXP/PF and M-LWDF), also the least delay and the highest fairness index of approx. 0.98.

Just for the special priority based applications, that is, smart grid applications (DA, DER and EV), the considered bandwidth estimation-allocation technique and the scheduling algorithm for each class are considered as a guarantee for the result oriented usage of available network resources and to meet the application's demands, respectively. The bandwidth estimation is on giving the sufficient amount of resources to each application if there is sufficient bandwidth, otherwise the resources will be distributed according to the priority of each class. While, the scheduling algorithm uses dynamic scheduling technique for three criteria which are delay, past average throughput and instantaneous transmission rate.

It shows the ability to result a robust solution for solving the users' scheduling issues with respect to smart grid application QoS's requirements. Simulation results prove that, the considered technique results higher throughput, lower delay and lower packet loss rate for DA, DER applications also it provides a degree of service for EV application. The proposed algorithm shows marked improvement for DA and DER applications by 1%, 10% and 15% compared to EXP-Rule, M-LWDF and EXP/PF, respectively. Moreover, the fairness index results the higher value that touches to 0.93 even in overloaded situations (up to 80 users).

5.2 FUTURE WORK

Future work on handover issues specifically the smooth seamless handover across various technologies is designed and planned, that can be calculated by considering a generic and extensible MAC Layer for the networks. This extension, will allow the mobile station a smoother transmission and the ability to transmit data among different base stations with different network technologies (i.e., WiMAX, WLAN, LTE and LTE-A). Because the mobile station will be considered with good connectivity and with different technologies, also it does not require any extra equipment, the system is expected to have less delay, low cost and best result.

While, the scheduling approach may be extended by modifying the proposed method so that to result it out in a useful way to serve a variety of applications with different objectives, such as elastic resources and shared services scenario. It will be dependent on migrating the cloud computing system with smart grid applications, which will result high robustness in terms of resistance and privacy protection and hardware failure problems. We will test it in different networks, such as LTE-Advanced.

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