AHMED AREBI KAROUD

INVESTIGATION OF WEIGHTS EFFECT ON HANDOVER DECISION ALGORITHMS IN NETWORK SELECTION

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A THESIS SUBMITTED TO THE GRADUATE SCHOOL OF APPLIED SCIENCES OF NEAR EAST UNIVERSITY

By
AHMED AREBI KAROUD

In Partial Fulfilment of the Requirements for the Degree of Master of Science in Electrical and Electronic Engineering

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Approval of Director of Graduate School of Applied Sciences

Prof. Dr. Nadire ÇAVUŞ

We certify this thesis is satisfactory for the award of the degree of Masters of Science in Electrical and Electronic Engineering

Examining Committee in Charge:

Prof.Dr. Bülent Bilgehan	Chairperson, Department of Electrical and Electronic Engineering, NEU
Assoc.Prof.Dr. Kamil Dimililer	Department of Automotive Engineering, NEU
Assist.Prof.Dr. Sertan Serte	Supervisor, Department of Electrical and Electronic Engineering, NEU

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name: AHMED KAROUD
Signature:
Date:

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To my family...

ABSTRACT

The new generation of networks that based on wireless technologies witnessed a kind of technology called a heterogeneous to a mobile user, in which the user can move and get access to different terminal services. A user connected to one network can change its connection at any time to any other network that provides a better service. And the target of this technology is how to offer always the best connection.

Vertical handover provides a quite good roaming without much distortion in their services and the ability to choose the best network to meet the requirement of applications. So far many different techniques have been deployed for Vertical Handover process, among all of these approaches for ranking available networks before making decision of handover, one of the approaches called Multiple Attribute Decision Making and known MADM, is considered for solving such types of vertical Handover problems.

This thesis introduces a vertical handover process that depends on three different algorithms SAW, MEW and TOPSIS, named MADM. Among three different networks, namely, HSDPA2, LTE and WiFi, an algorithm will decide which network will be selected.

This study has shown that there is a high agreement of selection the same network by the three algorithms for four different traffic classes named; conversational, streaming, interactive and background. The agreement through the three algorithms reaches 94% and the agreement between by SAW and TOPSIS reaches 99%.

With regard to network selection, only two networks, LTE, WiFi, among three different networks have been selected with the following percentages 48% for LTE and 52% for WiFi, while HSDPA2 has not been selected. The selected network is the network that gets the highest values, so that it is the first candidate in the networks.

Network selection does not depend only on network parameters as such but also on parameter weights. In another words, network selection does not depend only on network specifications but also on application requirements.

The thesis will help the scientists or humans in the decision of network considering their mobiles in order to have better communication with each other.

***Keywords**:* Vertical Handover (VH); VH algorithm; MADM

ÖZET

Kablosuz teknolojilere dayanan yeni nesil ağlar, kullanıcının farklı terminal hizmetlerine erişebileceği ve erişebileceği bir mobil kullanıcı için türdeş olmayan bir tür teknolojiye tanık oldu. Bir ağa bağlı bir kullanıcı, bağlantısını istediği zaman daha iyi bir servis sağlayan başka bir ağla değiştirebilir. Ve bu teknolojinin hedefi, her zaman en iyi bağlantıyı nasıl sunacağımızdır.

Dikey aktarma, hizmetlerinde çok fazla bozulma olmadan ve uygulamaların gereksinimlerini karşılayacak en iyi ağı seçme becerisi olmadan oldukça iyi bir dolaşım sağlar. Dikey Aktarma işlemi için şimdiye kadar birçok farklı teknik uygulanmıştır, aktarma kararını vermeden önce mevcut ağların sıralanmasına yönelik tüm bu yaklaşımların arasında (Çoklu Özellik Kararı Alma) MADM olarak bilinen yaklaşımlardan biri olan bu tür dikey Aktarma türleri sorunlarını çözmek için düşünülmektedir.

Bu tez, MADM adlı üç farklı algoritmaya (SAW, MEW ve TOPSIS) bağlı olan bir dikey devir işlemi sunar. HSDPA2, LTE ve WiFi olmak üzere üç farklı ağ arasında, hangi ağın seçileceğine bir algoritma karar verecektir.

Bu çalışma, aynı ağın, seçilen dört farklı trafik sınıfı için üç algoritma ile seçilmesinde yüksek bir anlaşma olduğunu göstermiştir; konuşma, akış, etkileşimli ve arkaplan.

Üç algoritma ile yapılan anlaşma% 94'e, SAW ile TOPSİS arasındaki anlaşma% 99'a ulaştı.

Üç farklı şebekeden, HASDPA2 seçilmemiş iken, seçilen yalnızca iki şebeke; LTE için %48 ve Wifi için %52 elde edilir. Şebeke seçimi ile ilgili olarak seçilen ağ, en yüksek değerleri alan ilk adaydır.

Ağ seçimi yalnızca olduğu gibi ağ parametrelerine değil, aynı zamanda parametre ağırlıklarına da bağlıdır. Başka bir deyişle, ağ seçimi yalnızca ağ özelliklerine değil, aynı zamanda uygulama gereksinimlerine de bağlıdır.

Bu tez, Bilim adamları ve insanlara, birbirleriyle daha iyi iletişim kurabilmek için cep telefonlarını göz önünde bulundurarak ağ seçme ve karar vermede yardımcı olacaktır.

Anahtar Kelimeler: Dikey Aktarma (VH); VH algoritması; MADM

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LIST OF ABBREVIATIONS

1G:	First Generation
2G:	Second Generation
3G:	Third Generation
3GPP:	3rd Generation Partnership Project
4G:	Forth Generation
5G:	Fifth Generation
ABC:	Always Best Connected
AHP:	Analytic Hierarchy Process
B3G:	Beyond Third Generation
BER:	Bit Error Rate
BW:	Bandwidth
CDMA:	Code Division Multiple Access
D-AMPS:	Digital Advanced Mobile Phone System
EDGE:	Enhanced Data rates for GSM Evolution
EV-DO:	Evolution Data Optimized
FDD:	Frequency Division Duplex
FL:	Fuzzy Logic
GPRS:	General Packet Radio System
GSM:	Global System for Mobile
HSPA:	High Speed Packet Access
HSDPA2:	High Speed Data Packet Access 2
IEEE:	Institute of Electrical and Electronics Engineers
IP:	Internet Protocol
Kbps:	Kilo Bits Per Second
LTE:	Long Term Evolution
MADM:	Multiple Attribute Decision Making
Mbps:	Mega Bits Per Second
MEW:	Multiplicative Exponent Weighting
MICS:	Media Independent Command Service
MIES:	Media Independent Event Services

MIH: Media Independent Handover

MIH_LINK_SAP: Media Independent Handover Link Service Access Point

MIH_NET_SAP: Media Independent Handover Network Service Access Point

MIH_SAP: Media Independent Handover Service Access Point

MIHF: Media Independent Handover Function

MIIS: Media Independent Information Service

MIMO: Multiple Input and Multiple Output

MN: Mobile Node

NGN: Next Generation Network

NNs: Neural Networks

OFDMA: Orthogonal Frequency Division Multiple Access

QoS: Quality of Service

RSS: Received Signal Strength

SAW: Simple Additive Weighting

SC-FDMA: Single Carrier Frequency Division Multiple Access

TDD: Time Division Duplex

TDMA: Time Division Multiple Access

TD-SCDMA: Time Division-Synchronous Code Division Multiple Access

TOPSIS: Technique for Order Preference by Similarity to Ideal Solution

UMB: Ultra Mobile Broadband

UMTS: Universal Mobile Telecommunication System

VH: Vertical Handover

WAN: Wide Area Network

WiFi: Wireless Fi

WiMAX: Worldwide Interoperability for Microwave Access

WLAN: Wireless Local Area Network

WPM: Weighted Product Method

CHAPTER 1
INTRODUCTION

1.1 Overview

Telecom Networks are a mix of many technologies, wired and wireless. In recent years, the world witnessed a tremendous growth in mobile telecommunications traffic, with enormous spread of smart phone devices. However, wireless networks are more popular and are becoming something very important in our lives. Industries and academics are working on wireless technologies, to always provide better wireless services for users of these networks. Continued connectivity, when the users move and across different wireless networks, maintaining an reasonable QoS is one of the most challenges.

Heterogeneous network is a new term used to indicate that networks have different technologies that users should roam seamlessly within their coverage area. Group of networks where different technologies work as one and users traverse their boundaries of coverage or even able to choose which is better and satisfy more the current application requirements in case of no movement without falling down of calls, called as a next generation network (NGN) (Hossain, 2008).

NGN is a definition of how much progressing in Telecom networks and its evolution. The target of developing like these technique that making one network able to provide users with services and information (video, voice, data, ...) similar to those used on the Internet. Those mobile users always ask increasing for internet services from anywhere. (Hu and Qian, 2013).

As a handover within the same technology occurs seamlessly, a heterogeneous network must also be as seamless as possible in allowing communication amongst various network technologies. This is called Vertical Handover. Vertical Handover is therefore very important in the next mobile communications scenario (Hossain, 2008).

(The words Vertical Handover and Vertical Handoff are synonymous (Hossain, 2008)). Vertical Handover is standardized under IEEE 802.21, and since it occurs amongst various different network technologies, this kind of handover is called Media-Independent Handover (MIH) (Committee, 2009).

1.2 Literature Review

This literature review of vertical handover in NGN introduces the followed approaches in field of vertical handover decision mechanism, and introduces some details overview of its studies. All these researches and studies promise to offer better services compared to that offered by other networks in mobile communication. During mobile roaming among many access network technologies, like a 4G, WAN, WiMAX and satellite networks, create changes in heterogeneous networks. All NGN based on idea of an IP-based network, the necessity of handover process is to provide a good connection, is seamlessly with the available networks regardless of services, location and time. Usually, a mobile occur a decision of handover, and a network may initiate this decision as well. (Malathy and Muthuswamy, 2018).

In (Ismail and Nordin, 2014), by various parameters mobility management schemes initiate handover, handover takes in account a single parameter or two or more. Vertical handover parameters play a significant role in making of decision, and have an effect on process and performance of system

Figure 1.1 presents several parameters that can affect on decision of vertical handover, in a environment of heterogeneous, some of them are static parameters and some other are dynamic, as follow (Ismail and Nordin, 2014; Nasser et al., 2006).

- Parameters related to network: BW, RSS, BER, cost, etc.
- Parameters related to mobile node: velocity, location, power of battery, etc.
- Parameters related to user: preferences.

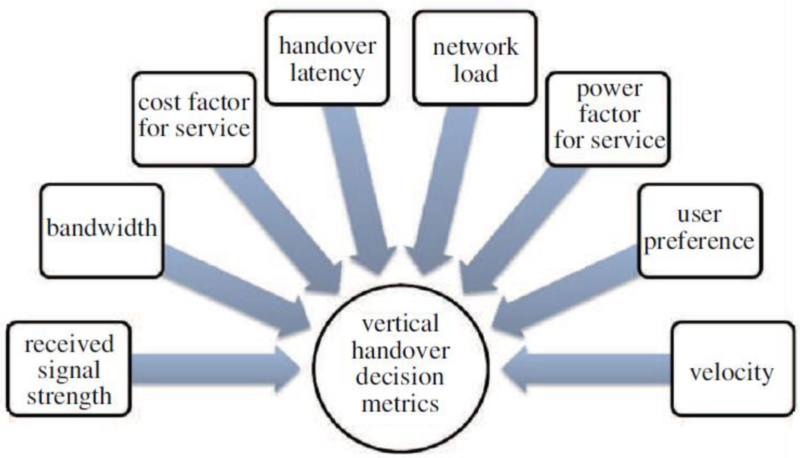

Figure 1.1: Vertical handover decision parameters (Malathy and Muthuswamy, 2018)

Figure 1.2 provides a comprehensive survey of the plans for implementing handover to a heterogeneous network (Mohanty and Akyildiz, 2006).

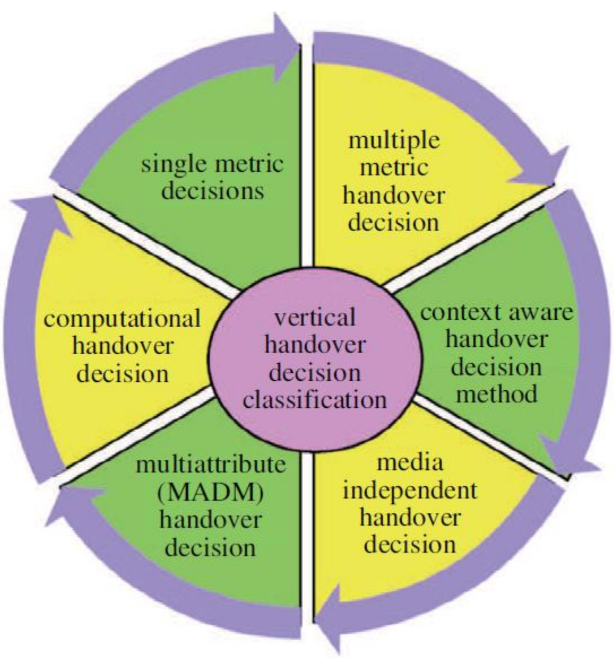

Figure 1.2: Vertical handover decision classification (Malathy and Muthuswamy, 2018)

The next is approaches introduce a general review of the latterly enhanced algorithms by using one parameter or more.

1.2.1 Decision of Handover Based On Single Parameter

- RSS-Based Handover Decision

  This scheme considers the signal strength as the main parameter for selecting a certain network. Switch-over starts occur when the RSS measured falls below the certain level called threshold value, similar to Horizontal handover. A quite support for management technique of handover is available with regard to the link layers and network layers (Mohanty and Akyildiz, 2006). Moreover, such these handover depends on RSS very suitable with horizontal handover only (Yan et al., 2010).

- Bandwidth-Based Vertical Handover

  This scheme considers the difference in Bandwidth as the main parameter for deciding which network to switch to. The paper by (Ma and Ma, 2012), presented scenario of vertical handover between WiMAX and WLAN based on bandwidth. The advantages of these schemes high throughput, but high handover delay witnessed, usually results calls drop in many times (Malathy and Muthuswamy, 2018).

- Cost-Based Vertical Handover

  This scheme considers the cost parameter as the main parameter for comparing networks before selection. The cost parameter represented as a function that contains monetary cost, BW and power consumption, and these forming together a one parameter, to select the best network regarding to the cost. This technique results many unnecessary handovers and that leads to many failure in handover as well (Lee et al., 2010; Malathy and Muthuswamy, 2018).

1.2.2 Decision of Handover Based On Multi Parameter

In this approach, the decision function is calculated by multiple parameters like RSS, BW, how many users, power consumption and network cost. The complexity increases when number of network parameters increases, because the analysis becomes complex specially with adding the cost parameter. In (Takagi and Rodrıguez, 2010), introduced analysis of mobility management, and added network cost along with that multiple parameters. Usually a low-cost network is chosen by users which leads to failure in handover many times (Liang et al., 2017).

1.2.3 Decision of Handover Based On Context-Aware

Context-aware technique is done by following and studding all the information that come from movement of user, ability of mobile device and mobile station as well, battery level, location and velocity of mobile. In (Choi, 2010; Bellavista et al., 2007), said that to guarantee efficient service continuity in heterogeneous environment network should know about handover-related context information. Context-aware is designed to offer best handover deciosion to user, although, failure still happends (Malathy and Muthuswamy, 2018).

1.2.4 Media-Independent Handover Decision

The client and server offer information, these information acts together as a significant role in handover decisions. MIH profits this information at link layer (Khattab and Alani, 2013). Media independent handover introduces to user a quite good handover with reasonable QoS in heterogeneous network, which maintain a very good resource management in the network (Kim et al., 2011). As link layer receives information of location, the mobile node may change the location, so information of mobile nodes should provide by designing architecture based on area. Although, no proper direction of gathering information (Malathy and Muthuswamy, 2018).

1.2.5 Multi-parameter Handover Decision

Selecting of the best network within multiple attribute measured from all available interconnected networks is the main target of multi-criteria-based algorithm. The best candidate network is determined by calculation of score function [35]. During ranking networks by computing multiple parameters, the network with highest score is used as the preferable network for making decision of switch-over in the vertical handover process. The approaches that work with multi-criteria using techniques like SAW,TOPSES, MEW, AHP, WPM and VIKOR. (Malathy and Muthuswamy, 2018).

1.2.6 Computational Handover Decision

Handover decision algorithm based on fuzzy logic are widely available. Wireless network movable conditions necessitate computational intelligence techniques. these techniques include FL, fuzzy-MADM, and NNs neural network for decision of VH (Yan et al., 2010; Yuan et al., 2017). This smart techniques not like traditional techniques, these approaches enable FL to make a better decision when there are no precise information and deal with them more difficult. In (Ben-Mubarak et al., 2013), a VH algorithm presented by FL between WWAN and WLAN networks. After all, still complexity exist, the decision that based on mobile node makes the handover policy not good enough in heterogeneous networks (Malathy and Muthuswamy, 2018).

From the brief review that presented, still the decision of switch-over that comes from mobile node creates an inefficient handover , because of complex design and the limited memory storage of mobile device. So, an optimized design that comes from network server side still an open challenge (Malathy and Muthuswamy, 2018).

Table 1.1: Comparison of various methods for vertical handover(Malathy and Muthuswamy, 2018)

Existing vertical handover schemes		Advantage(s)	Disadvantage(s)
Single metric	RSS-based schemes	Simple design	Increased unnecessary handovers Increased ping-pong effect
	bandwidth-based schemes	Good throughput performance Good network selection	Inefficient bandwidth computation
	Cost function	Less call drop probability Reduced ping-pong effect	Increased system overload
Multiple metric	Context-aware schemes	Very less call drop blocking Good context collection	Complex design leads to implementation issues
	MIH	Good network selection Reduced latency	High-signaling overheads Increased resources consumption
	MADM schemes	Better decision on dynamic parameters	Performance dependence on traffic class
Computation	FL	User-satisfied handovers Reduced handover delay	Heavy complex design Higher processing time
	NNs	Successful handovers Reduced handover delay	Heavy complex design Centralized control
Multi-attribute + Computation	MADM-AI	Reduced handover decision delay Precise data for handover decision	Heavy complex design Terminal-based decision Huge training process
	MADM-context-aware schemes	Improved QoS for user	Unreliable handover decision at high speed Terminal-based decision

1.3 Goals and Objectives of the Thesis

Handover procedure is one of the most important functions in a mobile technique in a environment of heterogeneous network which always keep a user connected to the best network, such that quality of service of the ongoing session is met. Handover process used to depends on RSS, but Vertical Handover is more complicated in selecting network within available networks, generally known as multiple attribute decision making and called MADM. This selecting of network depends on many parameters and algorithms are used for handover decision. This thesis introduces MADM and the study will be about network selection and comparison between the famous available algorithms that are used in network selection.

1.4 Structure of the Thesis

This thesis consists of six chapters sorted as follow:

Chapter 2, explained briefly evolution of mobile communication systems, by giving an overview of cellular technology evolution from 1G to 4G, defines the technologies of mobile broadband (WiFi, WiMAX) and finally describes the new technology, Next Generation Networks (NGN).

Chapter 3, Presents the Vertical Handover standard, IEEE 802.21 or MIH (Media-independent handover). It introduces MIH model, explains the software components of MIH with some detail about their functionalities, the handover process and its parameters.

Chapter 4, This chapter introduces MADM how it is involved in the handover process, network selection, and weight evaluation.

Chapter 5, the results of the comparison between MADM's technique have been introduced and analyzed.

Chapter 6, this chapter concludes the thesis.

CHAPTER 2
HISTORY OF MOBILE SYSTEM

2.1 Mobile Technology

Last 40 years, the world witnessed development in telecommunication systems and very growth in internet, that have made a very big change on lifestyles, everywhere in this world. With more wireless services needs from users, the growth in 2002 was so fast, it witnessed for the first time in the telecommunications history that, number of subscribers of mobiles became more than number of fixed lines. International Telecommunication Union (ITU), in September 2005 announced that registration number of mobile subscriber was exceeded 2 billion. In 2007, it is registered by Global mobile Supplier Association (GSA), number of subscribers in the world for mobile was almost 3 billion (Thinh and Vuong, 2008).

In mobile communication systems, there is new generation emerges into the world every 10 years. In 1980s, the world witnessed 1G, the original analog mobile voice network, called first generation. In 1990s, the world witnessed 2G, the technology that based on digital for a first time, for data traffic and mobile voice network, called second generation.. In 2000s, the world witnessed 3G, the technology of digital mobile with high speed, multimedia and additional to data service, called third generation. In 2010s, the world witnessed 4G, the technology that based on IP and very high throughput, called fourth generation.

2.1.1 First Generation (1G)

First generation system started in the end of seventies, where it was analog transmission system with throughput almost 14.4 Kbps (peak). The key 1G standards included for examples, Japanese Total Communication System (JTACS), and Advanced Mobile Phone System (AMPS). 1G was indeed most innovation in history of telecommunication. However, 1G was faced many problems like the quality was not very good for transmissions, utilization of the spectrum was not good enough, and the same for capacity of available frequencies and security (Yan, 2010).

2.1.2 Second Generation (2G)

Second generation networks introduced digital technology. Its networks have been serving a lot of mobile subscribers. 2G cellular standards like GSM, CDMA1 and IS-136. Global System for Mobile (GSM) uses technology of TDMA and technology of FDD. GSM is the fastest communication technology growing in the world of all time. CDMA1 uses technology of CDMA, Code Division Multiple Access, CDMA1 known as the original ITU IS-95. IS-136 is called Digital Advanced Mobile Phone System (D-AMPS), uses technology of TDMA and known more in America, particularly in Canada and United States (Yan, 2010).

2.1.3 Second and Half Generation (2.5G)

The 2.5G standards consist technologies of General Packet Radio Services (GPRS) and IS-95B. GPRS is an Enhanced mobile data service for users of GSM and IS-136. GPRS is enhancement of GSM, with transmission speed is up to 172.2kbps. It supports a packet-switch solution. Another technology called Enhanced Data rates for GSM Evolution (EDGE), known as an enhancement for GPRS, provides data rate up to 384kbps. The operators after using EDGE could handle more subscribers, about three times than with GPRS (Yan, 2010).

2.1.4 Third Generation (3G)

Third generation networks are distinguished by a very high data rates, high capacity and greater spectrum efficiency are improved as well. Technology of 3G are all based on CDMA, like UMTS, CDMA2000 and TD-SCDMA (Thinh and Vuong, 2008).

- UMTS: uses the technique of WCDMA called Wideband Code Division Multiple Access, has been standardized by 3GPP. The maximum user data rate is 1,920Kbps.The enhancement of UMTS is HSPA, called High Speed Packet Access, HSPA referred to as a 3.5G technology, introduced peak rate up to 14.4Mbps.
- CDMA2000: is the enhancement of 2G CDMA1. CDMA2000 represents these technologies like CDMA2000 1xRTT, CDMA2000 EV-DO and CDMA2000 EV-DV. All of them called as a family of CDMA2000.
    - CDMA2000 1xRTT (Radio Transmission Technology), this technology has data rate up to 307kbps.

- CDMA2000 EV-DO (Evolution-Data Optimized), has data rate up to 24Mbps downstream and 153kbps upstream.
- CDMA2000 (Evolution-data and voice), is 3GPP2 standard, has data rate up to 4.8Mbps downstream and 307kbps upstream.

- TD-SCDMA: called Time Division-Synchronous Code Division Multiple Access, uses TDD technology, data rate up to 2-6Mbps.

2.1.5 Fourth Generation (4G)

After deployment of 3G, its enhancement have been introduced as 3.5G or 4G, known as UMB called Ultra Mobile Broadband and LTE called Long Term Evolution (Hossain, 2008; Acharya et al., 2014).

- UMB: is the next version of the 3GPP2, is the enhancement of CDMA2000EV-DO. UMB also incorporates OFDMA, MIMO and peak download up to 280 Mbps, and 75 Mbps for upstream transmission (Hossain, 2008; Acharya et al., 2014).

- LTE: is the next version of the 3GPP. LTE technology has data rate up to 100Mbps downstream and up to 50Mbps upstream. For downlink, LTE uses OFDMA which called orthogonal frequency division multiple access, for uplink uses SC-FDMA which called single carrier frequency division multiple access. MIMO technique has been employed in LTE with up to four antennas per station, MIMO technique means multiple input and multiple output. LTE is based on IP in design and supports heterogeneous network (Hossain, 2008; Acharya et al., 2014).

2.1.6 Fifth Generation (5G)

Fifth generation called technique of 2020, it will support IPv6 technology, 5G technologies start to spread worldwide cellular phones, because of switch and router technology, 5G will provide high connectivity. 5G offered priceless handset to its customers approximately and in soon future will dominant all markets of this world. 5G characterized by excellent support both software and consultancy. If any comparison have made between 5G and the generation of mobiles before, it is obvious that 5G distinguish with incredible features and advantages like coverage, high data rate, even at edge of cell, low consumption in power of battery, multiple data transfer, data rate up to 1Gbps and more security. (Agarwal et al., 2015).

2.2 Wireless Mobile Broadband

The broadband accesses over twisted-pair, coaxial cable, fiber or digital subscriber line. The services of broadband wireless can be divided into WiMAX (IEEE 802.16) known as fixed broadband wireless technology and WiFi (IEEE 802.11) known as mobile broadband wireless technology. Mobile broadband wireless technology includes mobile WiMAX as well. In addition, mobile broadband applications have been supported by 3G cellular and beyond 3G cellular systems.

- WiFi, IEEE 802.11 standards family called WiF, started as a WLAN technology. WiFi could coverage a broadband in the buildings. IEEE 802.11 specifications were introduced in 1997 as first time in history of telecommunications. The data rate is up to 540Mbps (Thinh and Vuong, 2008).

- WiMAX, IEEE 802.16 standard called WiMAX, designed to avail both fixed broadband and mobile broadband applications. Fixed broadband applications data rate is up to 1Gbps and mobile broadband applications data rate is up to 100Mbps. The term WiMAX was created in 2001 (Thinh and Vuong, 2008).

2.3 Next Generation Network (NGN)

Next generation network is a term to describe generation that came after third genration, some call them beyond third generation (B3G), or rourth generation (4G), when they comprise multiple mobile and wireless technologies that have been mentioned before and work together to complement each other. Heterogeneous network is next generation network, which means all available networks can be a part of heterogeneous wireless access environment, offers high data rate services by using technique of IP. The integration of different wireless network technologies is the main concern on NGN.

This complementary work results many challenges that should face and to be solved in the researches. like mobility management, handover decision in these environment of heterogeneous technologies. Also, because of the convergence in networks there are many problems to overcome. The objective of convergence is to provide more service from both cellular technology and broadband wireless technology. For example, WiFi can be used to provide higher data rates, while 3G data service provides greater roaming and voice service on a global basis.

In the event of a weakness in the signal, when link quality goes down, reaching the minimum permissible or finding another better network, the vertical handover function switch over mobile user (MN) into the best possible access network, by searching for it in advance, and then making the transfer decision.

Many advantages can come from next generation network like, reducing cost, one billing, improved services to subscribers, more available, and always best connected (ABC) features, cause the services always delivered through the best available network (Hu and Qian, 2013).

In Figures 2.1 and 2.2 present evolution of mobile communication systems illustrated in brief way and number of mobile telephone subscriptions and their prediction until 2024.

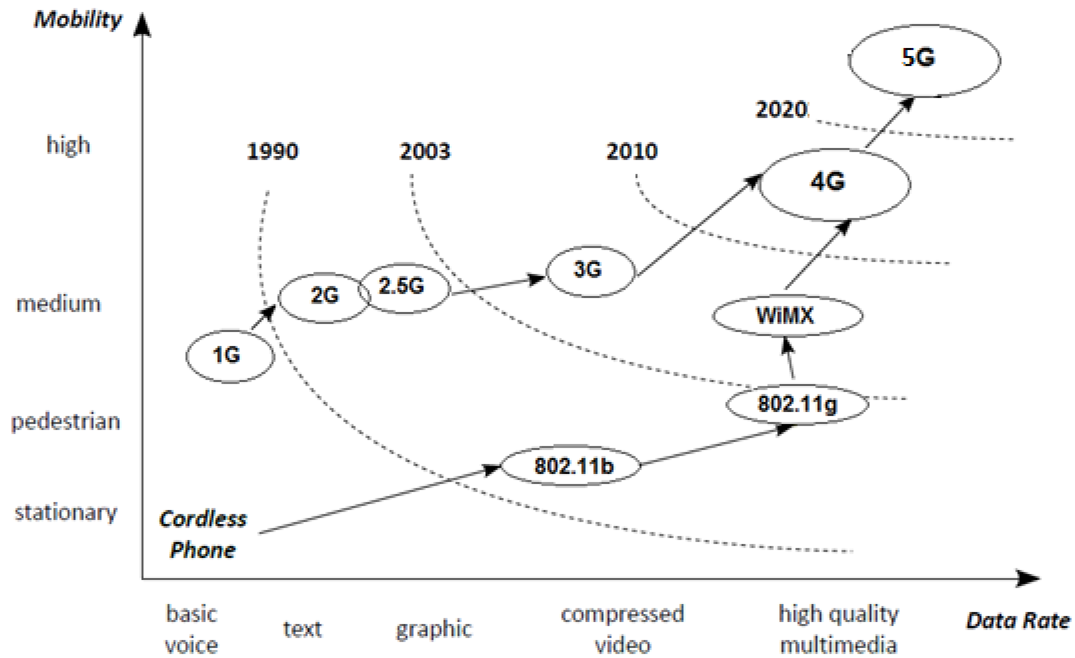

Figure 2.1: Development of mobile communication systems

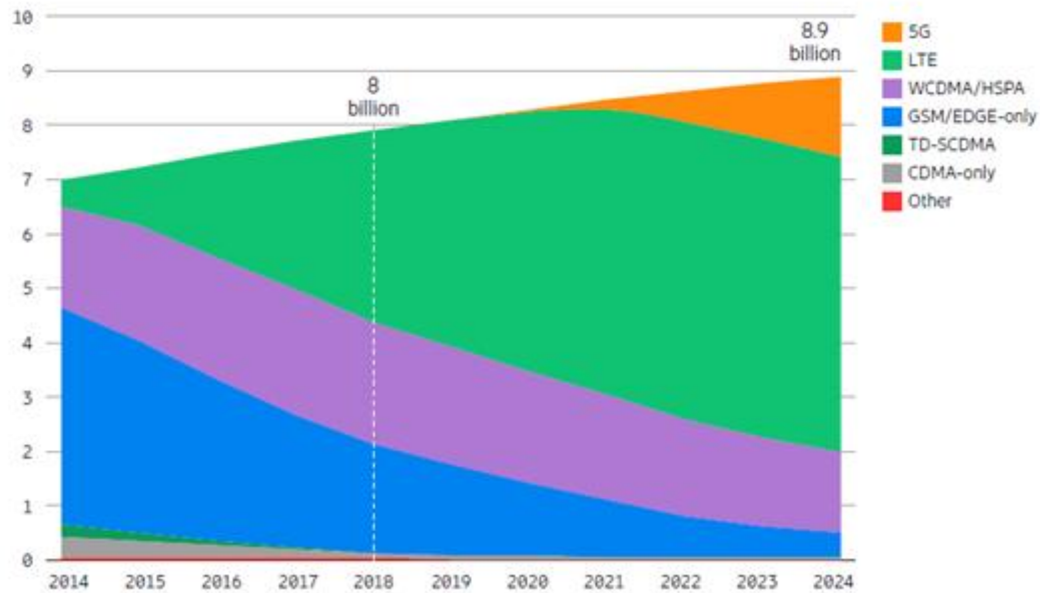

Figure 2.2: The number of mobile telephone subscriptions and their prediction until 2024 (Jejdling, 2018)

2.4 Horizontal and Vertical Handover

the movement of mobile user from a cell to another cell, or movement of mobile user from any coverage area to another coverage area during mobile calling in heterogeneous network, this movement pushes to transfer a call to a new cell or a new coverage area that comes from a new base station where the user exist. If the user crossed the boundary of coverage and could not find a nay other coverage, the call will fall down. When a mobile user reach to the boundary of coverage, the current base station link becomes too weak or even disconnect. This mechanism of change is a very important issue in a wireless network systems and is called handover. In heterogeneous network as shown in Figure 2.2 this handover could be one of these two types (Hossain, 2008):

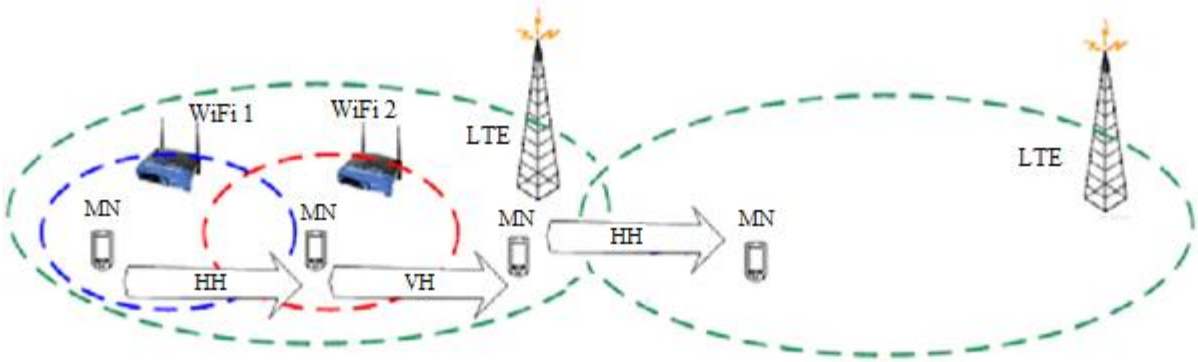

Figure 2.3: Horizontal and Vertical Handover

2.4.1 Horizontal Handover

This kind of handover happens when the mobile user moves across different networks access points and it gets switch over among them, and these networks belong to the same technology. Horizontal Handover only depends on received signal strength parameter RSS..

2.4.2 Vertical Handover

This kind of handover happens when the mobile user moves across different networks access points switches between different network access-points and these network access-points and it gets switch over among them, and these networks belong to different technologies. Vertical depends on many parameters not just only RSS.

Figure 2.3 shows the scope of operation between horizontal and vertical handovers.

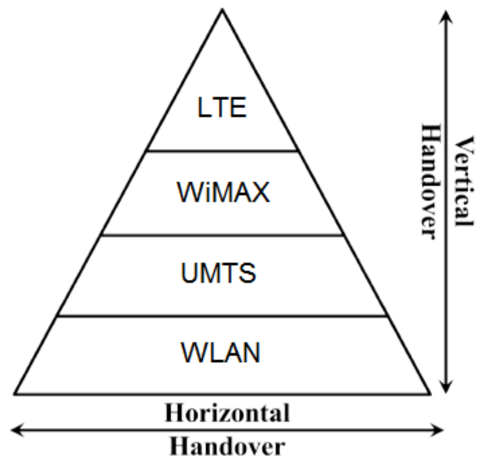

Figure 2.4: Horizontal and Vertical Handover in general

Handover could be also classified as:

- Soft Handover, if the mobile user (MN) can connect to more than one access point during handover, or the connection to the new access point happens before disconnecting with the link of the previous access point.

- Hard Handover, the connection to the new access point happens after disconnecting with the link of the previous access point, the mobile user (MN) can't connect to more than one access point during handover.

CHAPTER 3

MEDIA INDEPENDENT HANDOVER (IEEE 802.21)

3.1 Overview

IEEE 802.21 defines Vertical Handover or as known a media independent handover (MIH). MIH can implement seamless handover among homogeneous networks that have the same technology, and seamless handover between heterogeneous networks that have different technologies as well. IEEE 802.21 is a very special standard within IEEE standards family, it is interworking between IEEE 802 standard and non-IEEE 802. The standard IEEE 802.21 defines the tools required to discover networks surrounding mobile users. IEEE 802.21 facilitates handover initiation and preparation by exchanging information, events, and commands, and then to execute intelligent heterogeneous handovers. The actual handover execution mechanism does not standardized by IEEE 802.21, IEEE 802.21 is just responsible for initiation and preparation. The idea behind IEEE 802.21 is that improving the experience of users, this comes by providing some functionalities known as MIH functionality, both of handovers that initiated by mobile or by network are assisted by MIH functionality. IEEE 802.21 enables handovers for mobile users and fixed users. During users' movement, wireless link conditions change and can occur handovers for mobile users. Also, changing in surrounding network environment for any reason can occur handover for the stationary users as well, making one network for users better than another (Taniuchi et al., 2009; Committee, 2009).

3.2 Handover Procedures

There are many techniques of handover decision algorithms which have been studied , and many different approaches have been adopted. They could be listed in general in two categories (Rajinikanth and Jayashri, 2015; Hossain, 2008):

- Multiple attribute decision making, and known as MADM.
- Knowledge based systems which includes fuzzy logic (FL) and neural networks (NNs).

Some approaches combine two procedures together (Fussy with Neural, Fussy with MADM...).

In this thesis, MADM technique will be followed.

3.3 Vertical Handover Process

There are four steps that should be followed, for Vertical Handover process (Sharma et al., 2011):

- System discovery, this process starts when the MT interfaces turned on for searching any signals or by turn on the interfaces periodically. Discovering the surrounding networks is by measuring RSS that mobile can reach and connect with.

- Score function calculation, this process evaluates the score function for every available network, that is evaluated by using (multiple attribute decision making technique) (MADM), for example (SAW, MEW or TOPSIS). In the next chapter, these techniques will be explained in detail.

- Network selection, all available/candidate networks are put in a list started from the best on the top of a candidate list until the worst one, and that depends on their score values, that calculated by score functions for each.

- Handover execution after networks are sorted, handover is executed by switching mobile to network that on the top of the list, if it is needed. Otherwise, staying at the same network which satisfied the user or application requirements. For any reason the first network that in the candidate list is not available, the second one in the list would be the next choice.

3.4 Parameters

As mentioned before in types of handover, vertical handover depends on many parameters not only RSS, those parameters are introduced (Payaswini and Manjaiah, 2014):

- RSS
- Cost of Service
- User preferences
- Speed
- Bandwidth
- Battery level of node

- RSS, a received signal strength is a very important parameter in wireless network connection, RSS is a parameter indicates to a coverage of network is exist or not. If RSS of the current network is a weak and starts in degradation, then the handover is desired.

- Bandwidth, (UMTS, WLAN, WiMAX ...etc) all these networks offer a different bandwidth values. Since the transfer of data depends on available bandwidth, it is normal the higher bandwidth is more attractive for selection.

- Preferred network, a preferred cost and a preferred technology all of them are considered as user preferences in vertical handover decision. Although, users would like to avoid unnecessary handover that occurs when there is a varying in cost in different technologies. The chosen of network could be either depend on a best performance of network or an effective network regardless cost, which usually has the best specification, even it has higher in cost, because the connectivity and satisfy the user and application requirements are more important.

- Battery level of node, a power of battery is consumed as a mobile access to different networks, because of required energy for transmitting and receiving of packets during handover process. In case of limited battery power, the battery power could be a very important for handover. If the energy level of the mobile is lower than threshold, handover will be switched to network which needs less energy.

- Cost of service, as different networks have a different billing plans that may affect on choice of the user, consequently affect on decision of handover.
- Mobile node speed, a speed of the user is very important specially during moving with a very high speed and relatively small coverage, so it should be taken in account of handover decision. This speed causes what is called hysteresis phenomena, after the user passes across the coverage with high speed, and shortly handover back to a previous network.

3.5 MIH Software Components

For improving the user experience, IEEE 802.21 offers functionalities that helps in both of mobile and network initiated handover. The MIH model shown in Figure 3.1 consists of three elements named; MIH user, MIH function and service access points (SAPs) (Committee, 2009):

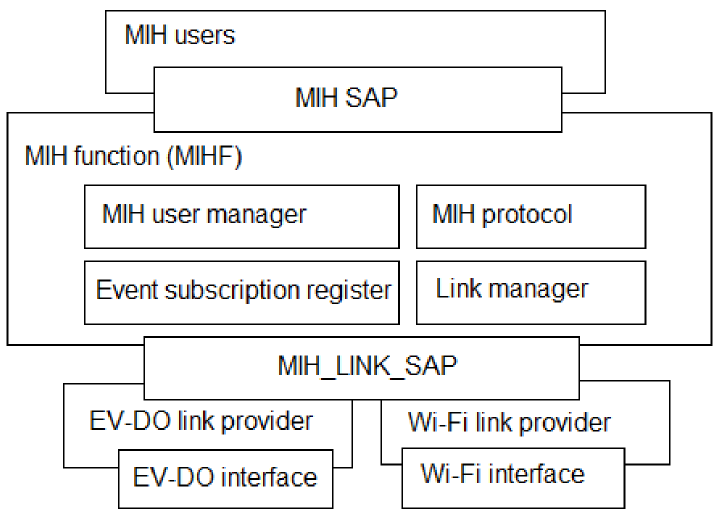

Figure 3.1: Model of MIH (Committee, 2009)

- MIH user, the logical component that uses MIH services.
- MIH function, MIHF is a logical component introduces services through an interfaces to higher layers, and MIHF receives these information from the lower layers, through specific interfaces. MIHF consists of four components named; MIH user manager, Event subscription registrar, MIH protocol and Link Manager, are explained in brief as follow:
    - MIH user manager, is an administrator of the MIH users, uses MIHF to manage MIH users.
    - Event subscription registrar, maintains local users event subscriptions to both of local and remote events, and maintains remote users event subscriptions also to local events.
    - MIH protocol, provides process that send messages to component of MIHF at remote side.
    - Link Manager, is a component manages local links by commands and events.

  These four logical components cooperates together to offer MIH user with both of media independent command and event services.
- MIH SAPs, in IEEE 802.21 specification, the MIH SAPs are defined as primitives. MIH SAPs introduce information about their functionality and parameters. MIH SAPs as shown in Figure 3.2 consist three elements:

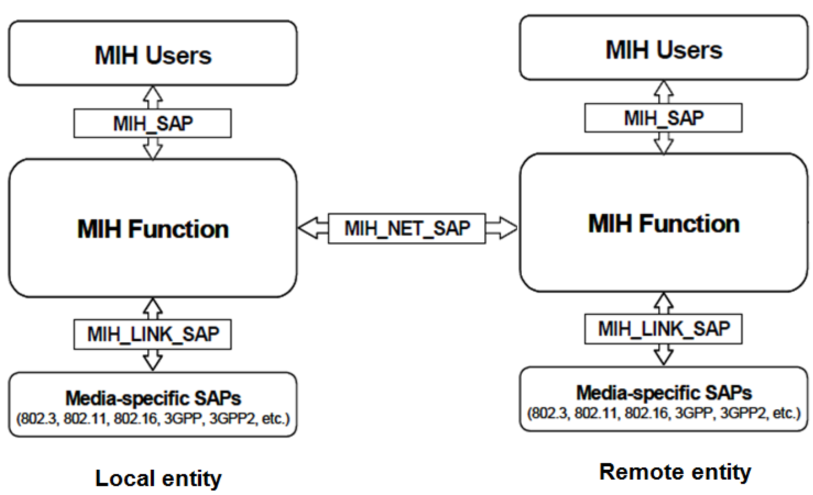

Figure 3.2: Different MIHF SAPs (Committee, 2009)

- MIH_SAP, it is an interface connect the upper layers with MIHF, and it's function to monitor and control different links.
- MIH_LINK_SAP, it is an interface connect the lower layers with MIHF, and it's function to monitor and control media specific links.
- MIH_NET_SAP, it is a specific interface that supports changing information and messages between different MIHFs.

3.6 MIH Services

IEEE 802.21 has defined three services that help in vertical handover among heterogeneous networks as shown in Figure 3.3, and are explained briefly as follow:

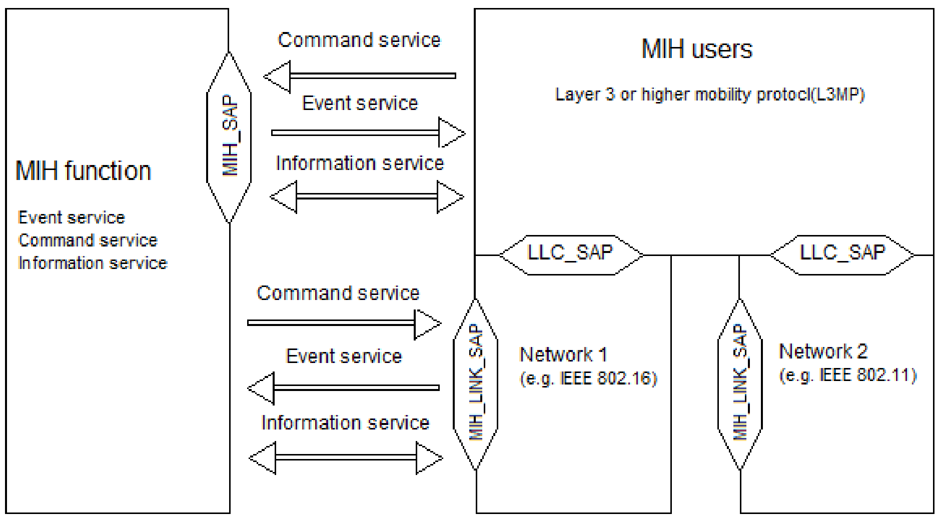

Figure 3.3: Different MIH services (Committee, 2009)

3.6.1 MI Event Services (MIES)

It expresses the events that indicate changes in the link characteristics, like changing in link status and link quality (e.g., Link_Down, Link_Up). As shown in Figure 3.4 two kinds of events were clarified, link events that is received at upper layer and come from lower layers, and MIH events that originate from the MIHF and can be remote events or even local events.

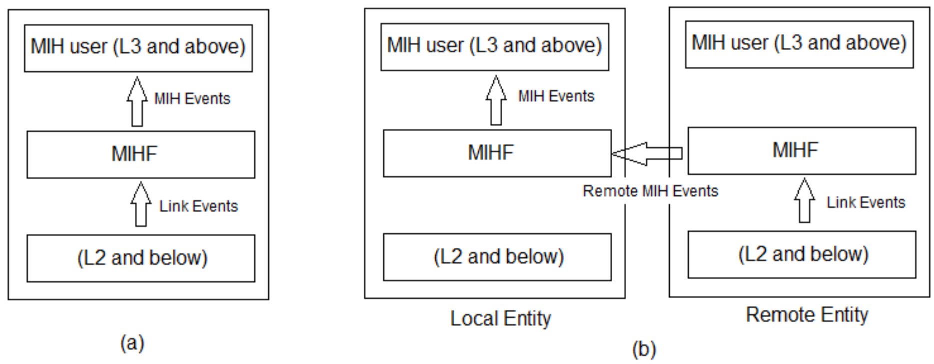

Figure 3.4: Media Independent Handover Events (Committee, 2009)

3.6.2 MI Command Services (MICS)

Introduces commands to control and manage the state of link. MIH user commands for example (Link_Get_parameters), the command can be received in local component that originates the command, or located in remote component. So, there are two kinds of commands, local commands and remote commands as shown in Figure 3.5.

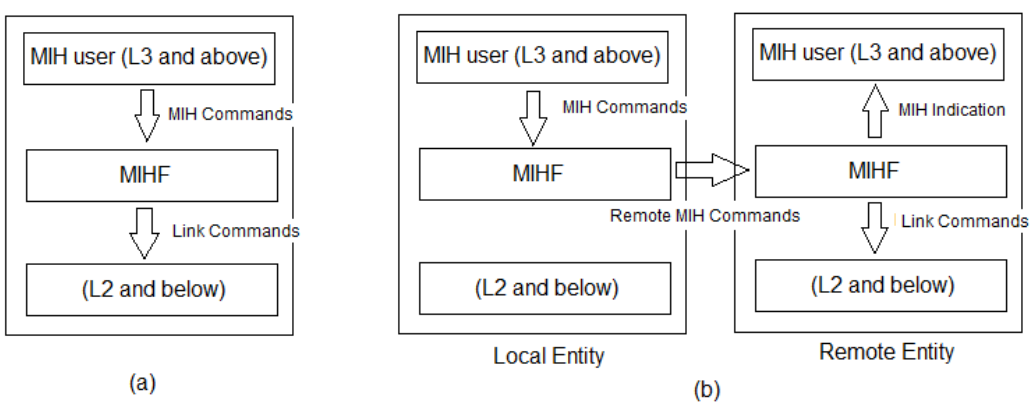

Figure 3.5: Media Independent Handover Commands (Committee, 2009)

3.6.3 MI Information Services (MIIS)

Introduces a framework for MIH components, which discover the surrounding area and gather all the available information that facilitate later in making an effective handover decision.

CHAPTER 4
MULTIPLE ATTRIBUTE DECISION MAKING (MADM)

4.1 Overview

Various mathematical models have being developed for studding the selection of which wireless networks, should be chosen or to be the best, within heterogeneous environment, and MADM is one of these models. MADM is considered as one of the approaches for solving such these problems, different types of a few famous MADM algorithms introduced here, namely, SAW, MEW, TOPSIS and AHP. This chapter introduces the steps and mathematical equations for these algorithms. The results that come from every algorithm will be presented, and then analyzing of effect their response on the decision ranking will be done.

Here the types of MADM algorithms based Vertical Handover:

- Simple Additive Weighting and called SAW
- Multiplicative Exponent Weighting and called WEW
- Technique for Order Preference by Similarity to Ideal Solution and called TOPSIP
- Analytic Hierarchy Process and called AHP

4.2 Simple Additive Weighting (SAW)

SAW is one of the classical methods of MADM, it is a very simple method. SAW can do a ranking for different candidate networks by determining of score function of each existing network in the surrounding area of mobile user. The score function for each network is determined by summing the normalized contribution from each parameter that multiplied by its assigned weight as follows (Lahby et al., 2013; Vine, 2010):

$$S_i = \sum_{j=1}^{m} v_{ij} \qquad (4.1)$$

and $$v_{ij} = r_{ij} w_j \qquad (4.2)$$

Where

r_{ij} : is the normalized contribution from each parameter

w_j : is the weight that is assigned for every parameter

S_i : is the score of each network,

$i = 1, \dots n$, n : number of networks

$j = 1, \dots m$, m : number of parameters

(r_{ij}) is the normalized value of each parameter, it is calculated depending on kind of parameter, and there are two kinds of parameters:

For benefit parameters, value of (r_{ij}) is calculated by this formula:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^2}} \qquad (4.3)$$

Where

x_{ij} : is the parameter.

For cost parameters, value of (r_{ij}) is calculated by this formula:

$$r_{ij} = 1 - \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^2}} \qquad (4.4)$$

The selected network in SAW is chosen by this formula:

$$SAW = \max (S_i), \quad \text{and} \quad i = 1, \dots n \qquad (4.5)$$

(n) is the number of available candidate networks.

The selected network is that gets the highest score value among different available networks, which places at the top of a candidate list.

4.3 Multiplicative Exponent Weighing (MEW)

MEW is one of the classical methods of MADM, MEW can do a ranking for different candidate networks as well, MEW is a bit similar to SAW method, the difference between the two techniques is that, instead of using addition in SAW, the MEW uses the multiplication. The score function for each network is the result of multiplication of the normalized contribution from each parameter to the power of its assigned weight as follows (Lahby et al., 2013; Vine, 2010):

$$P_i = \prod_{j=1}^{m} (v_{ij}) \qquad (4.6)$$

Depending on kind of parameter, benefit or cost parameter, (v_{ij}) will be calculated:

$$v_{ij} = r_{ij}^{w_j} \quad \text{for benefit parameter} \qquad (4.7)$$

$$v_{ij} = r_{ij}^{-w_j} \quad \text{for cost parameter} \qquad (4.8)$$

For cost parameter, the value of (w_j) will be considered negative.

The normalized value of (r_{ij}) is calculated as in equation (4.3)

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^2}}$$

Where

r_{ij} : is the normalized contribution from each parameter

w_j : is the weight that is assigned for every parameter

P_i : is the score of each network

x_{ij} : is the parameter

$i = 1, \ldots n$, n : number of networks

$j = 1, \ldots m$, m : number of parameters

The selected network in MEW is similar to SAW and chosen by this formula:

$$MEW = \max (P_i) , \quad \text{for } i = 1, \ldots n \qquad (4.9)$$

(n) is the number of available candidate networks.

The selected network is that gets the highest score value among different available networks, which places at the top of a candidate list.

4.4 Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)

TOPSIS is one of the classical methods of MADM, was invented in the beginning of eighties of the last century. TOPSIS idea to choose the optimal network comes from that, start to choose the closest network to the best ideal network, in the same time, this network should be farthest from the worst ideal network. The technique steps are explained in detail as follows (Lahby et al., 2013; Vine, 2010):

Make the decision matrix as shown:

$$\begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & & x_{2m} \\ \vdots & & \ddots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{nm} \end{bmatrix}$$

Where

x_{ij} : is the parameters of any candidate network

$i = 1, \dots n$, n : number of networks

$j = 1, \dots m$, m : number of parameters

Make the normalized matrix as shown:

$$\begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & & r_{2m} \\ \vdots & & \ddots & \vdots \\ r_{n1} & r_{n2} & \cdots & r_{nm} \end{bmatrix}$$

Each normalized element (r_{ij}) is obtained as in equation (4.3) as follows

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^2}}$$

$i = 1, \dots n$, n : number of networks

$j = 1, \dots m$, m : number of parameters

Make the weighted matrix as shown:

$$\begin{bmatrix} v_{11} & v_{12} & \cdots & v_{1m} \\ v_{21} & v_{22} & & v_{2m} \\ \vdots & & \ddots & \vdots \\ v_{n1} & v_{n2} & \cdots & v_{nm} \end{bmatrix}$$

Where

$$v_{ij} = r_{ij}\, w_j \qquad (4.10)$$

(w_j) is the assigned weight for every parameter

And

$$\sum_{j=1}^{m} w_j = 1 \qquad (4.11)$$

Determine the ideal and negative ideal solution (A^+) and (A^-) as follows:

$$A^+ = [A_1^+ \quad A_2^+ \quad \dots \quad A_m^+] \qquad (4.12)$$

$$A^- = [A_1^- \quad A_2^- \quad \dots \quad A_m^-] \qquad (4.13)$$

For benefit attributes,

$A_j^+ = \max\ (v_{ij})$ And $A_j^- = \min\ (v_{ij})$

For cost attributes

$A_j^+ = \min\ (v_{ij})$ And $A_j^- = \max\ (v_{ij})$

Calculate the similarity distance using

$$S_i^+ = \sqrt{\sum_{j=1}^{m} (A_j^+ - v_{ij})^2} \quad , \text{for } i = 1, \dots, n \qquad (4.14)$$

$$S_i^- = \sqrt{\sum_{j=1}^{m} (v_{ij} - A_j^-)^2} \quad , \text{for } i = 1, \dots, n \qquad (4.15)$$

Calculate the network that closest to the ideal network by this formula:

$$C_i = \frac{S_i^-}{S_i^+ + S_i^-} \ , (i = 1, \dots\dots, n). \qquad (4.16)$$

Ranking the candidate networks according to its values which determined in C.

4.5 Analytic Hierarchy Process (AHP)

AHP is one of the classical methods of MADM, it was developed at the end of seventies by Prof T. Saaty at Wharton School of Business. AHP is distinguished with ability to evaluate the weighs of different parameters of a candidate networks. The steps of AHP hierarchal structure are as follows (Saaty, 1987; Mohamed et al., 2012):

Make the pair-wise matrix as shown:

$$\begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & & x_{2n} \\ \vdots & & \ddots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{nn} \end{bmatrix}$$

Where

$x_{ii} = 1$

(x_{ij}) elements are obtained from table (4.1), called Saaty table.

Note that $(x_{ji} = \frac{1}{x_{ij}})$

Table 4.1: Saaty table

Saaty's scale	The relative importance of the two sub-elements
1	Equally important
3	Moderately important with one over another
5	Strongly important
7	Very Strongly important
9	Extremely important
2,4,6,8	Intermediate values

Make the normalized matrix as shown:

$$\begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & & r_{2n} \\ \vdots & & \ddots & \vdots \\ r_{n1} & r_{n2} & \cdots & r_{nn} \end{bmatrix}$$

Where

$$r_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}} \quad (4.17)$$

The weights can be calculated by

$$w_i = \frac{\sum_{j=1}^{n} r_{ij}}{n} \quad (4.18)$$

(w_i) the assigned weight for every parameter

And keeping in mind that

$$\sum_{i=1}^{n} w_i = 1 \quad (4.19)$$

4.6 Network Selection and Comparison

In this section, selections of different networks from three different algorithms SAW, MEW and TOPSIS are compared. AHP is used for the evaluation of weights. Three networks, where the selection comparison will be done, are HSDPA2, LTE, and WiFi.

For the selections, four different traffic classes are considered. These are conversational, streaming, interactive, and background traffic classes. Each selection comparison depends on four different parameters namely; BER, delay, jitter and BW. The network parameters or specifications of HSDPA, LTE, and WiFi that have been received at the end user are listed in Table 4.2 (Navarro and Wong, 2006).

Table 4.2: Network specifications (Huang et al., 2012; Navarro and Wong, 2006)

	BER	**Delay (ms)**	**Jitter (ms)**	**BW (Mbps)**
Net-1 HSDPA2	0.0001	78	10	13
Net-2 LTE	0.001	69.5	5.6	100
Net-3 WiFi	0.00001	64.5	7.9	6

Each traffic class has a different quality of service requirement, and for this, different weights have been assigned for the same parameter within different classes of traffic. Tables 4.3 shows that, the AHP pair-wise matrices for the different traffic classes (Navarro and Wong, 2006).

Table 4.3: AHP pair-wise matrices (Navarro and Wong, 2006)

(a) Conversational

Conversational	**BER**	**Delay**	**Jitter**	**BW**
BER	1	0.111111	0.111111	1
Delay	9	1	1	9
Jitter	9	1	1	9
BW	1	0.111111	0.111111	1

(b) Streaming

Streaming	**BER**	**Delay**	**Jitter**	**BW**
BER	1	0.2	0.111111	0.111111
Delay	5	1	0.2	0.2
Jitter	9	5	1	1
BW	9	5	1	1

(c) Interactive

Interactive	**BER**	**Delay**	**Jitter**	**BW**
BER	1	5	9	5
Delay	0.2	1	5	1
Jitter	0.111111	0.2	1	0.2
BW	0.2	1	5	1

(d) Background

Background	**BER**	**Delay**	**Jitter**	**BW**
BER	1	9	9	5
Delay	0.111111	1	1	0.2
Jitter	0.111111	1	1	0.2
BW	0.2	5	5	1

By using those pair-wise matrices shown in Table 4.3, and following the rest steps (2 and 3) of Analytic Hierarchy Process (AHP) presented in section 4.5, the weights have been calculated and tabulated as shown in Table 4.4.

Table 4.4: The weights

Traffic class	BER	Delay	Jitter	BW	Sum
conversational	0.05	0.45	0.45	0.05	1
streaming	0.0389	0.1176	0.4217	0.4217	1
interactive	0.6251	0.1650	0.0447	0.1650	1
background	0.6523	0.0585	0.0585	0.2304	1

Now the sensitivity/effect of the assigned weights on selection of the network will be investigated, for the four different traffic classes, the weights of the BER, delay, jitter and BW are varied separately from 0 to 1 in steps of 0.2. The weights for others parameters are calculated in proportion to the values that specified in Table 4.4. For all four traffic classes, the calculated values are listed in Table 4.5.

Table 4.5: Tables of weights of each attribute being incremented at a constant step of 0.2

(a) Conversational traffic class

BER	Delay	Jitter	BW	Sum
0	0.473684	0.473684	0.052632	1
0.2	0.378947	0.378947	0.042105	1
0.4	0.284211	0.284211	0.031579	1
0.6	0.189474	0.189474	0.021053	1
0.8	0.094737	0.094737	0.010526	1
1	0	0	0	1

Delay	BER	Jitter	BW	Sum
0	0.090909	0.818182	0.090909	1
0.2	0.072727	0.654545	0.072727	1
0.4	0.054545	0.490909	0.054545	1
0.6	0.036364	0.327273	0.036364	1
0.8	0.018182	0.163636	0.018182	1
1	0	0	0	1

Jitter	BER	Delay	BW	Sum
0	0.090909	0.818182	0.090909	1
0.2	0.072727	0.654545	0.072727	1
0.4	0.054545	0.490909	0.054545	1
0.6	0.036364	0.327273	0.036364	1
0.8	0.018182	0.163636	0.018182	1
1	0	0	0	1

BW	BER	Delay	Jitter	Sum
0	0.052632	0.473684	0.473684	1
0.2	0.042105	0.378947	0.378947	1
0.4	0.031579	0.284211	0.284211	1
0.6	0.021053	0.189474	0.189474	1
0.8	0.010526	0.094737	0.094737	1
1	0	0	0	1

(b) Streaming traffic class

BER	**Delay**	**Jitter**	**BW**	**Sum**
0	0.122439	0.43878	0.43878	1
0.2	0.097951	0.351024	0.351024	1
0.4	0.073464	0.263268	0.263268	1
0.6	0.048976	0.175512	0.175512	1
0.8	0.024488	0.087756	0.087756	1
1	0	0	0	1

Delay	**BER**	**Jitter**	**BW**	**Sum**
0	0.04411	0.477945	0.477945	1
0.2	0.035288	0.382356	0.382356	1
0.4	0.026466	0.286767	0.286767	1
0.6	0.017644	0.191178	0.191178	1
0.8	0.008822	0.095589	0.095589	1
1	0	0	0	1

Jitter	**BER**	**Delay**	**BW**	**Sum**
0	0.067299	0.203484	0.729217	1
0.2	0.05384	0.162787	0.583373	1
0.4	0.04038	0.12209	0.43753	1
0.6	0.02692	0.081394	0.291687	1
0.8	0.01346	0.040697	0.145843	1
1	0	0	0	1

BW	**BER**	**Delay**	**Jitter**	**Sum**
0	0.067299	0.203484	0.729217	1
0.2	0.05384	0.162787	0.583373	1
0.4	0.04038	0.12209	0.43753	1
0.6	0.02692	0.081394	0.291687	1
0.8	0.01346	0.040697	0.145843	1
1	0	0	0	1

(c) Interactive traffic class

BER	Delay	Jitter	BW	Sum
0	0.440279	0.119441	0.440279	1
0.2	0.352223	0.095553	0.352223	1
0.4	0.264168	0.071665	0.264168	1
0.6	0.176112	0.047777	0.176112	1
0.8	0.088056	0.023888	0.088056	1
1	0	0	0	1

Delay	BER	Jitter	BW	Sum
0	0.748728	0.05362	0.197652	1
0.2	0.598982	0.042896	0.158122	1
0.4	0.449237	0.032172	0.118591	1
0.6	0.299491	0.021448	0.079061	1
0.8	0.149746	0.010724	0.03953	1
1	0	0	0	1

Jitter	BER	Delay	BW	Sum
0	0.654464	0.172768	0.172768	1
0.2	0.523571	0.138214	0.138214	1
0.4	0.392678	0.103661	0.103661	1
0.6	0.261786	0.069107	0.069107	1
0.8	0.130893	0.034554	0.034554	1
1	0	0	0	1

BW	BER	Delay	Jitter	Sum
0	0.748728	0.197652	0.05362	1
0.2	0.598982	0.158122	0.042896	1
0.4	0.449237	0.118591	0.032172	1
0.6	0.299491	0.079061	0.021448	1
0.8	0.149746	0.03953	0.010724	1
1	0	0	0	1

(d) Background traffic class

BER	Delay	Jitter	BW	Sum
0	0.16854	0.16854	0.662921	1
0.2	0.134832	0.134832	0.530337	1
0.4	0.101124	0.101124	0.397752	1
0.6	0.067416	0.067416	0.265168	1
0.8	0.033708	0.033708	0.132584	1
1	0	0	0	1

Delay	BER	Jitter	BW	Sum
0	0.692946	0.062241	0.244813	1
0.2	0.554357	0.049793	0.195851	1
0.4	0.415767	0.037345	0.146888	1
0.6	0.277178	0.024896	0.097925	1
0.8	0.138589	0.012448	0.048963	1
1	0	0	0	1

Jitter	BER	Delay	BW	Sum
0	0.692946	0.062241	0.244813	1
0.2	0.554357	0.049793	0.195851	1
0.4	0.415767	0.037345	0.146888	1
0.6	0.277178	0.024896	0.097925	1
0.8	0.138589	0.012448	0.048963	1
1	0	0	0	1

BW	BER	Delay	Jitter	Sum
0	0.847715	0.076142	0.076142	1
0.2	0.678172	0.060914	0.060914	1
0.4	0.508629	0.045685	0.045685	1
0.6	0.339086	0.030457	0.030457	1
0.8	0.169543	0.015228	0.015228	1
1	0	0	0	1

By using the data in Table 4.5, the next chapter analyzes the relationship between parameter weights and network selection by using three different algorithms; SAW, MEW and TOPSIS.

CHAPTER 5

RESULTS AND ANALYSIS

This chapter investigates how parameter weights affect the network selection. By using three different networks shown in Table 4.2, the networks are HSDPA2, LTE and WiFi which are named as Network 1, 2 and 3 respectively.

- HSDPA2 is called Net-1.
- LTE is called Net-2.
- WiFi is called Net-3.

Network selection process uses three different algorithms, as explained in chapter 4.

- SAW.
- MEW.
- TOPSIS.

The user selects the best network among those three different networks depending on the following parameters; BER, Delay, Jitter and BW as shown in Table 4.2, and the weight of each parameter is varied as presented in Table 4.5 to see how it affects the selection results. The selection process is repeated for four traffic classes indicated below.

- Conversational.
- Streaming.
- Interactive.
- Background.

5.1 Conversational Traffic Class

Tables 5.1-5.4 and Figures 5.1-5.4 show the best selected network from user during variation of each parameter weight (BER, delay, jitter and BW) for conversational traffic class. Each parameter weight is incremented by 0.2 and varied between 0 and 1.

Figures 5.1-5.4 graphically present results shown in tables 5.1-5.4 respectively.

Table 5.1: Network Selection based on Variation of BER Weight for conversational traffic class

BER	SAW	TOPSIS	MEW
0	2	2	2
0.2	3	3	3
0.4	3	3	3
0.6	3	3	3
0.8	3	3	3
1	3	3	3

This table shows the selection of network 2 LTE when parameter weigh of BER = 0 , then selection of network 3 WiFi are dominant from three different algorithms.

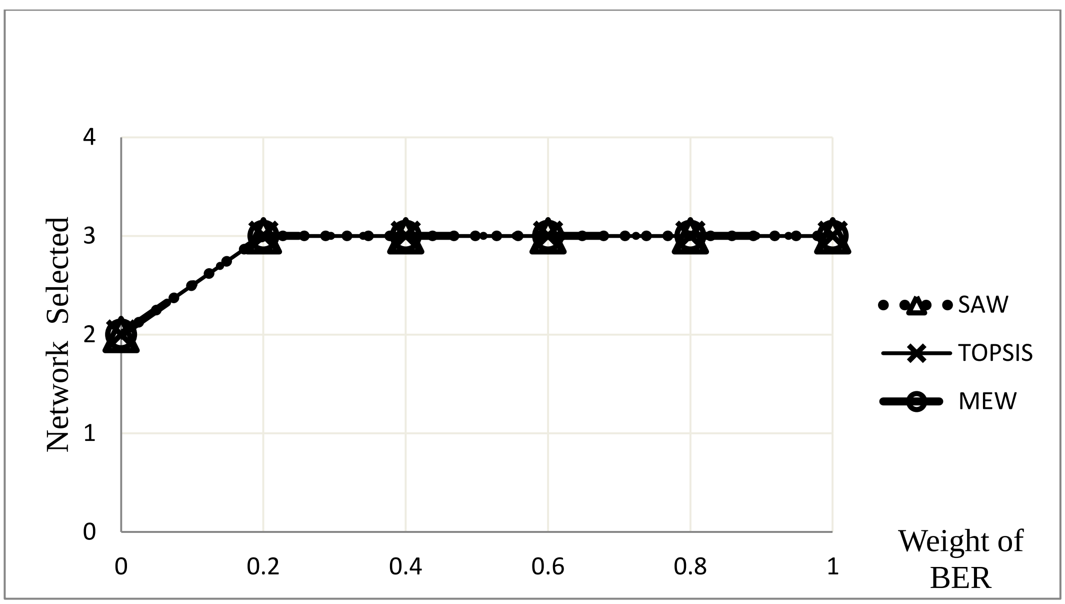

Figure 5.1: Network selected vs weight of BER for conversational traffic class

Table 5.2: Network Selection based on Variation of Delay Weight for conversational traffic class

Delay	SAW	TOPSIS	MEW
0	2	2	2
0.2	2	2	2
0.4	2	2	2
0.6	2	2	2
0.8	3	3	3
1	3	3	3

this table shows the selection of network 2 LTE when parameter weigh is incremented to 0.6, then selection of network 3 WiFi started at 0.8 from three different algorithms.

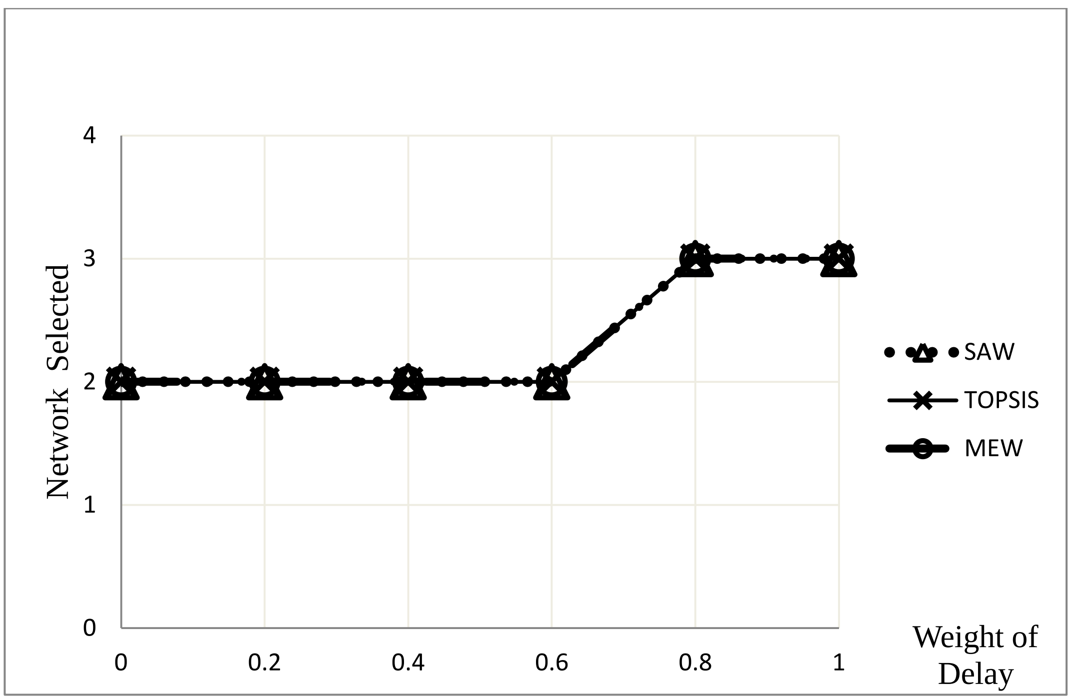

Figure 5.2: Network selected vs. weight of delay for conversational traffic class

Table 5.3: Network Selection based on Variation of Jitter Weight for conversational traffic class

Jitter	SAW	TOPSIS	MEW
0	3	3	3
0.2	2	3	3
0.4	2	2	2
0.6	2	2	2
0.8	2	2	2
1	2	2	2

This table shows the selection of network 3 WiFi when parameter weigh = 0, then selection of network 2 (LTE) started at 0.4 to 1 from three different algorithms. when parameter weigh = 0.2 SAW selected network 2 (LTE) but both TOPSIS and MEW selected network 3 WiF.

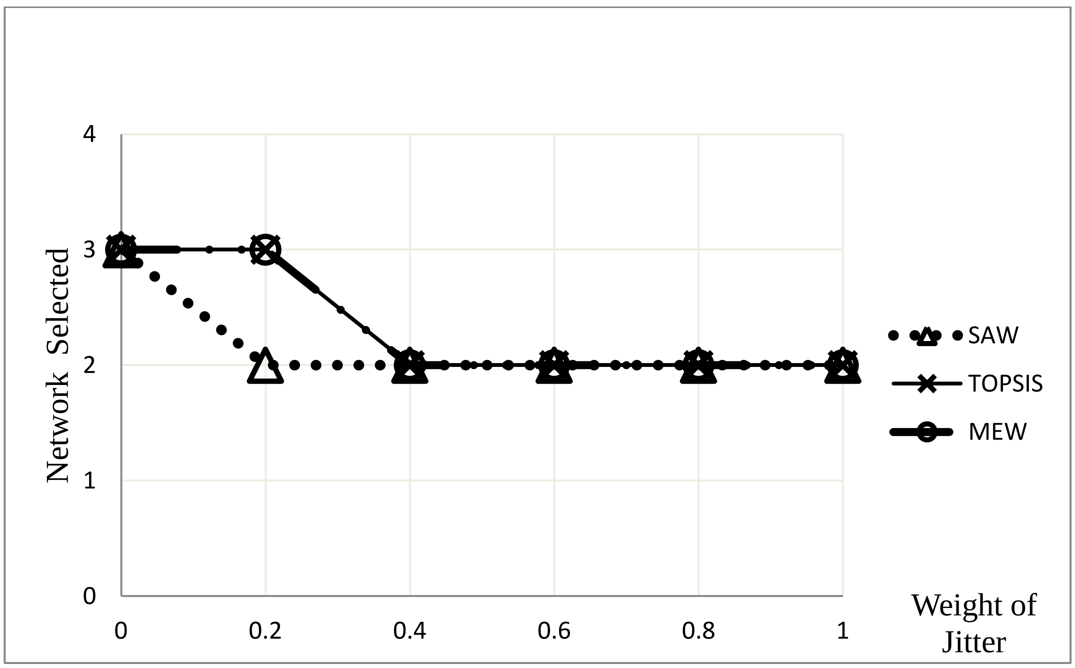

Figure 5.3: Network selected vs weight of jitter for conversational traffic class

Table 5.4: Network Selection based on Variation of BW Weight for conversational traffic class

BW	SAW	TOPSIS	MEW
0	2	2	3
0.2	2	2	2
0.4	2	2	2
0.6	2	2	2
0.8	2	2	2
1	2	2	2

This table shows the selection of network 2 LTE started from 0.2 to 1 by three different algorithms. When parameter weigh = 0 SAW and TOPSIS selected network 2 LTE but MEW selected network 3 WiF.

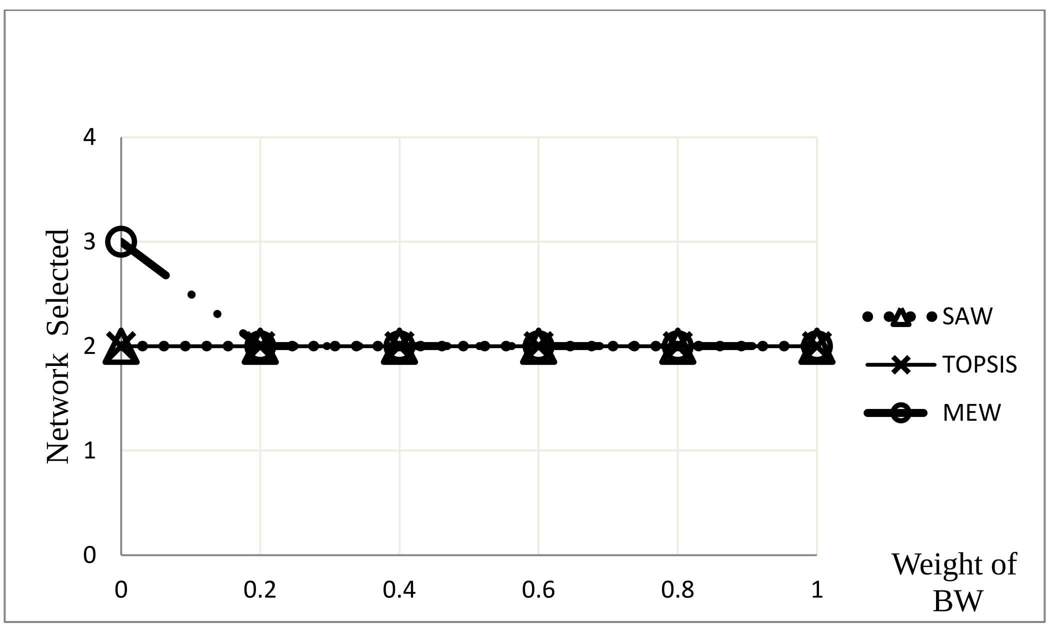

Figure 5.4: Network selected vs. weight of BW for conversational traffic class

The results from the above graphs, 5.1 to 5.4 are presented in Figures 5.5-5.7 present histogram plots that show the network selection agreement of different algorithms in conversational traffic class. Figure 5.5 shows the total percentages of selecting the same network by two or three algorithms. Figure 5.6 shows the total selection percentage of each network by all algorithms. Finally, Figure 5.7 shows the total selection percentage of each network by each algorithm.

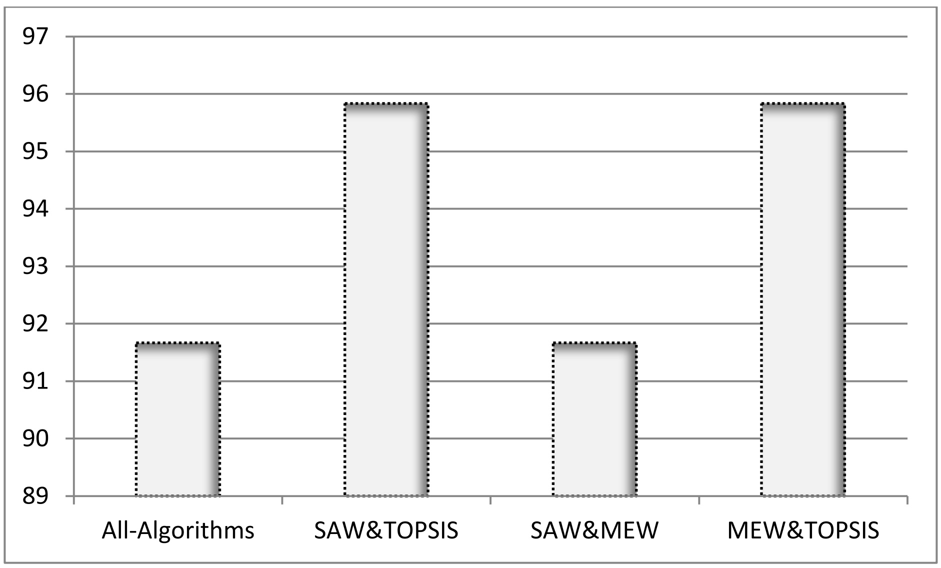

Figure 5.5: Total percentages of selecting the same network by two or three algorithms for conversational traffic class

This above histogram shows that the agreement of different algorithms in selection of the same network is higher that 91% in conversational traffic class. The agreement reaches almost 96% between SAW and TOPSIS also between MEW and TOPSIS.

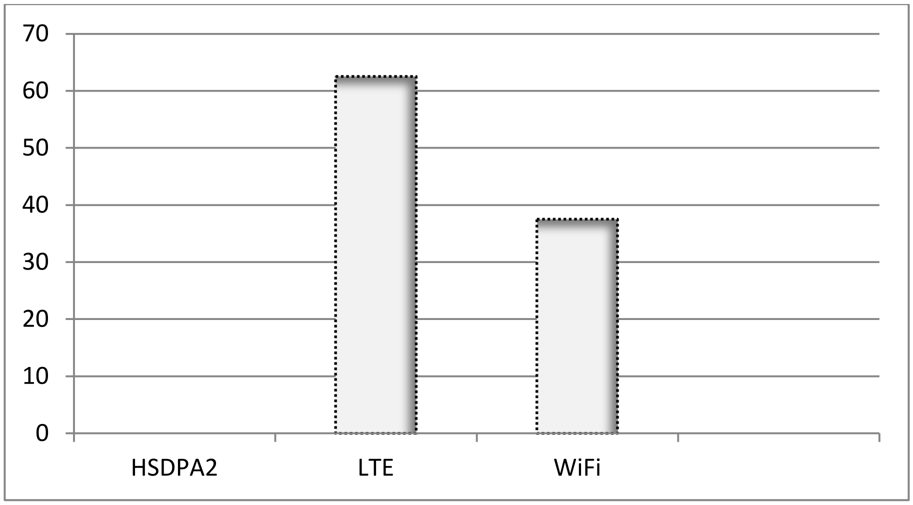

Figure 5.6: Total percentages of selecting each network for conversational traffic class

This above histogram shows that the selection of network 2 LTE reaches 62% among of different algorithms and during variation of four weights, and selection of network 3 WiFi reaches 38%, but no any selection for network 1 HSDPA2.

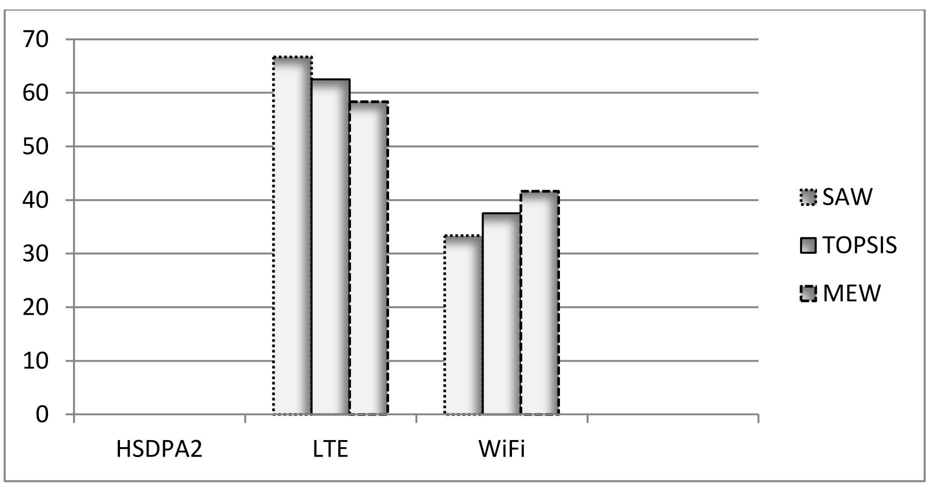

Figure 5.7: Percentages of selecting each network by individual algorithms for conversational traffic class

This above histogram shows that the most selection of network 2 LTE comes from algorithm SAW and the least selection comes from MEW, and for network 3 WiFi on the contrary.

It can be concluded from Figures 5.1-5.7 for conversational traffic class that:

Network selection is between network 2 LTE and network 3 WiFi, while network 1 HSDPA2 has not been selected. This selection comes from effect of parameters in Table 4.2 and weights in Table 4.4.

To understand the effect of parameters; from Table 4.2, the network 2 LTE has the two best values of Jitter and BW parameters, the network 3 WiFi also has the two best values of BER and Delay parameters, and those best parameters support selection of their networks specially when those parameters have high values of weights, while the network HSDPA2 has no best values of any parameter, the network HSDPA2 has only the two worst values of delay and jitter parameters.

To understand the effect of weights; from table 4.4, the effect of Delay and Jitter weights 0.45, 0.45 for each are the highest in network selection in conversational traffic class. The network LTE has the best value of Jitter parameter, the network WiFi has the best value of Delay parameter as shown in Table 4.2, so the network selection in conversational traffic class is between LTE and WiFi, 45, 27 times network selected for each respectively. and no any selection for HSDPA2.

It can be also concluded that total percentages of selecting the same network by two or three algorithms for conversational traffic class are not the same but higher than 91% for all.

5.2 Streaming Traffic Class

Tables 5.5-5.8 and Figures 5.8-5.11 show the best selected network from user during variation of each parameter weight (BER, delay, jitter and BW) for streaming traffic class. Each parameter weight is incremented by 0.2 and varied between 0 and 1.

Figures 5.8-5.11 graphically present results shown in tables 5.5-5.8 respectively.

Table 5.5: Network Selection based on Variation of BER Weight for streaming traffic class

BER	SAW	TOPSIS	MEW
0	2	2	2
0.2	2	2	2
0.4	3	3	3
0.6	3	3	3
0.8	3	3	3
1	3	3	3

This table shows the selection of network 2 LTE when parameter weigh is incremented to 0.2, then selection of network 3 WiFi started at 0.4 from three different algorithms.

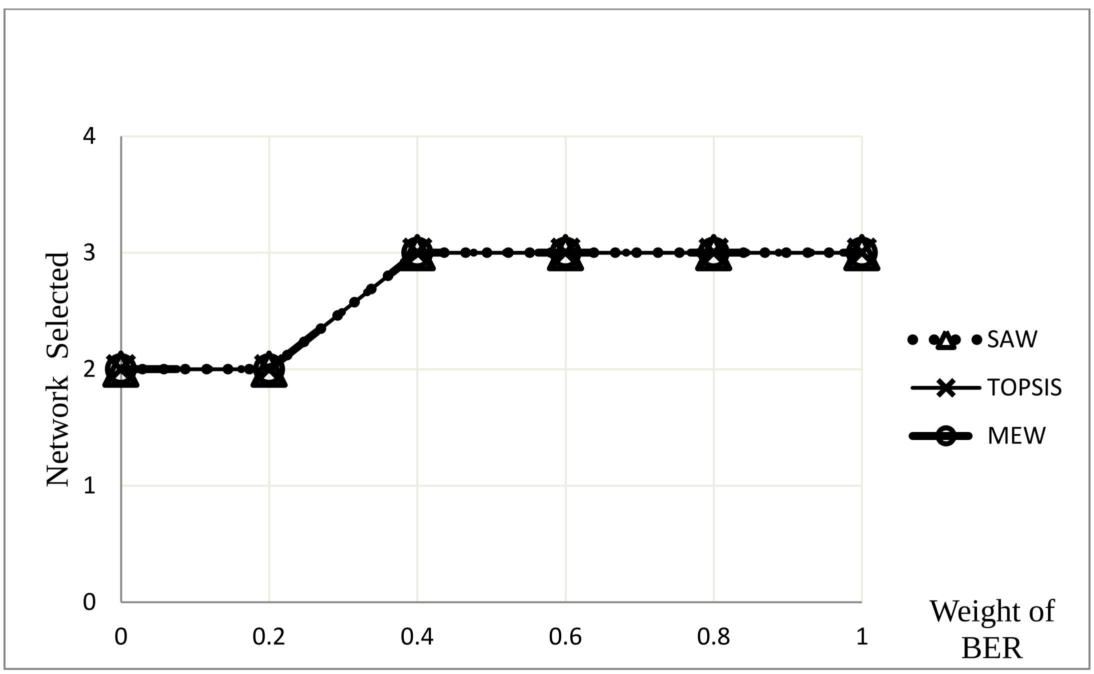

Figure 5.8: Network selected vs weight of BER for streaming traffic class

Table 5.6: Network Selection based on Variation of Delay Weight for streaming traffic class

Delay	SAW	TOPSIS	MEW
0	2	2	2
0.2	2	2	2
0.4	2	2	2
0.6	2	2	2
0.8	2	2	2
1	3	3	3

This table shows the selection of network 2 LTE when parameter weigh is incremented to 0.8, then selection of network 3 WiFi only at 1 from three different algorithms.

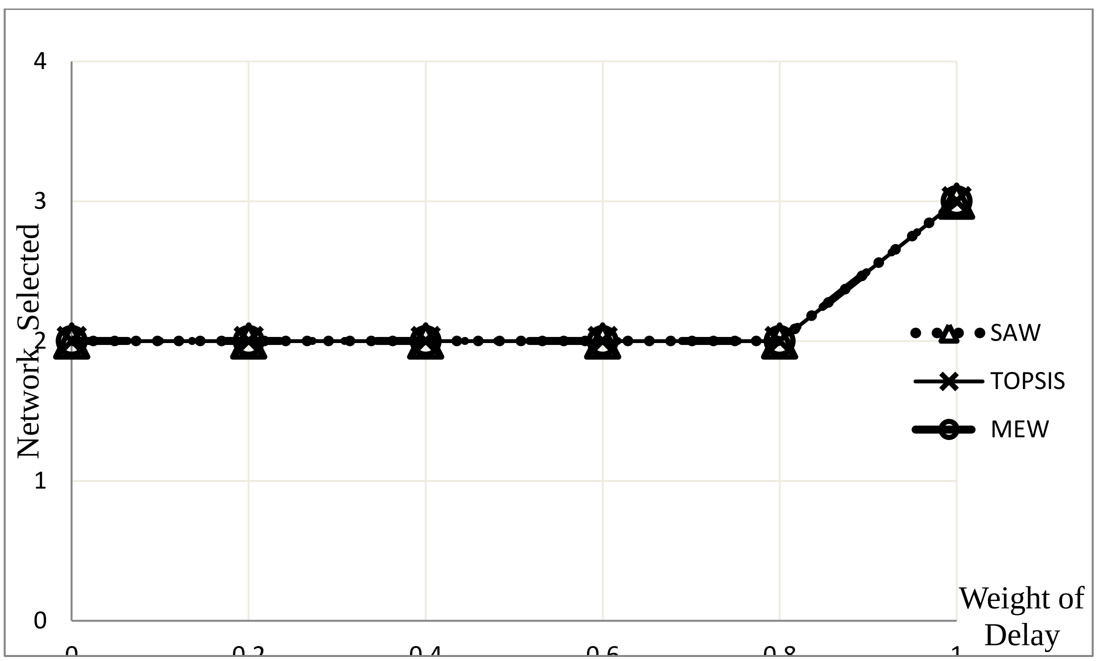

Figure 5.9: Network selected vs weight of delay for streaming traffic class

Table 5.7: Network Selection based on Variation of Jitter Weight for streaming traffic class

Jitter	SAW	TOPSIS	MEW
0	2	2	2
0.2	2	2	2
0.4	2	2	2
0.6	2	2	2
0.8	2	2	2
1	2	2	2

This table shows the selection of network 2 LTE is dominant by three different algorithms. Variation of jitter weight has no effect on selecting networks.

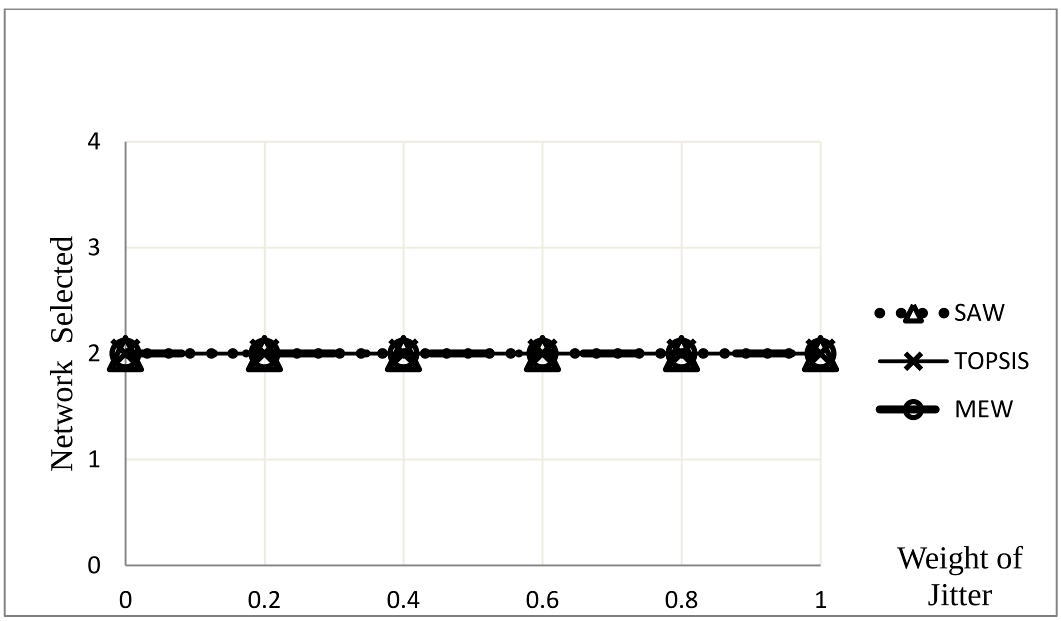

Figure 5.10: Network selected vs weight of jitter for streaming traffic class

Table 5.8: Network Selection based on Variation of BW Weight for streaming traffic class

BW	SAW	TOPSIS	MEW
0	2	2	3
0.2	2	2	2
0.4	2	2	2
0.6	2	2	2
0.8	2	2	2
1	2	2	2

This table shows the selection of network 2 LTE is dominant by three different algorithms, except at weigh = 0 and only by MEW.

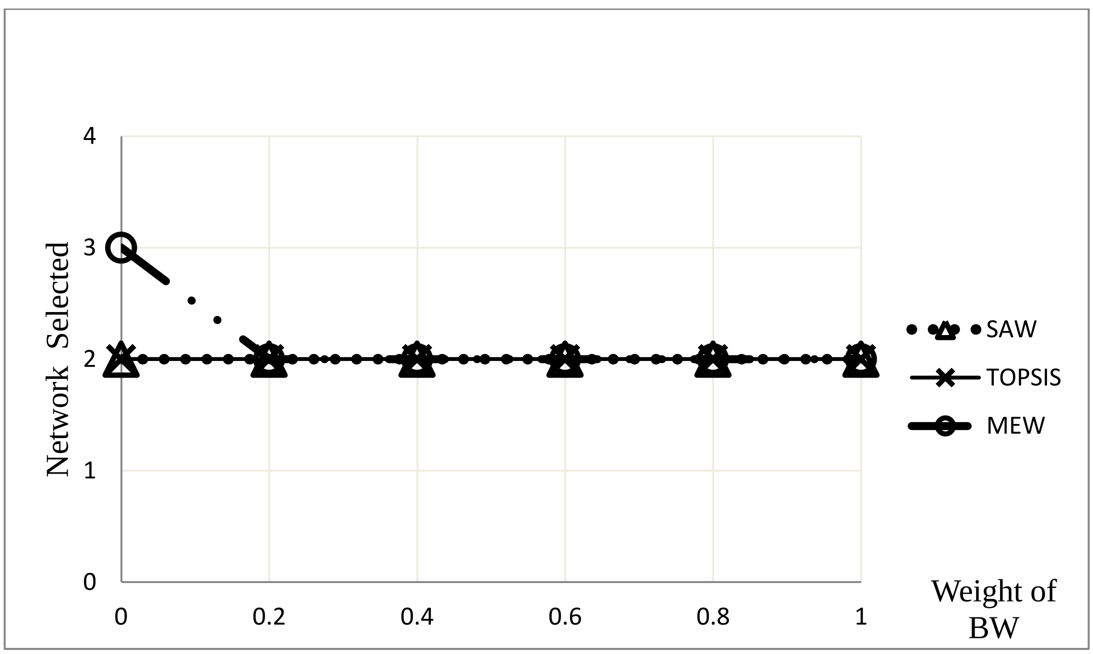

Figure 5.11: Network selected vs weight of BW for streaming traffic class

The results from the above graphs, 5.8 to 5.11 are presented in Figures 5.12-5.14 present histogram plots that show the network selection agreement of different algorithms in streaming traffic class. Figure 5.12 shows the total percentages of selecting the same network by two or three algorithms. Figure 5.13 shows the total selection percentage of each network by all algorithms. Finally, Figure 5.14 shows the total selection percentage of each network by each algorithm.

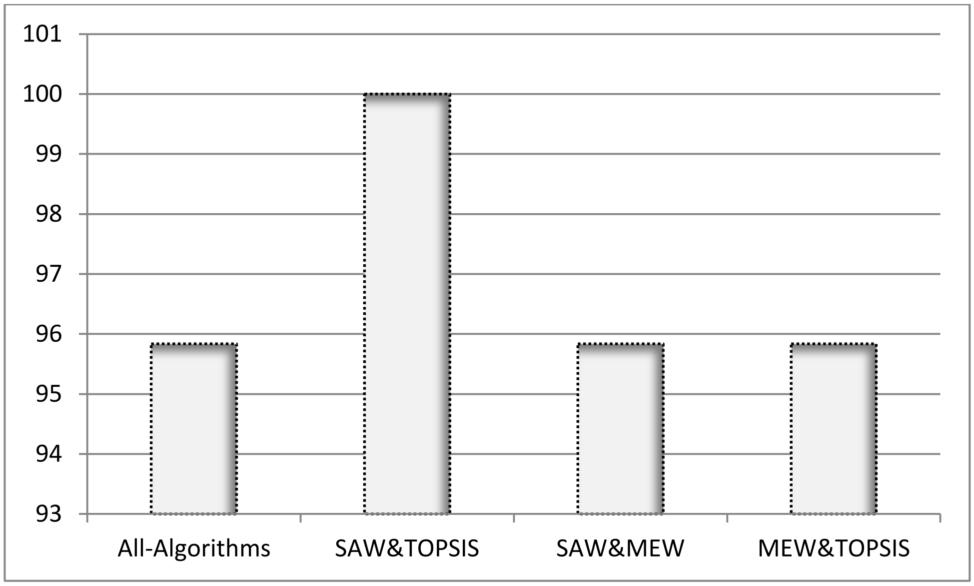

Figure 5.12: Total percentages of selecting the same network by two or three algorithms for streaming traffic class

This above histogram shows that the agreement of different algorithms in selection of the same network is higher than 95% by streaming traffic class. The agreement reaches 100% between SAW and TOPSIS.

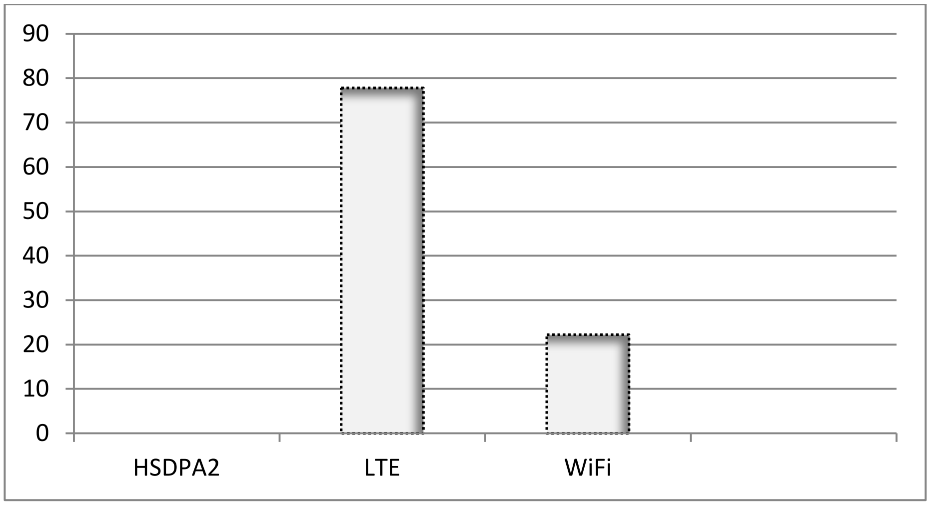

Figure 5.13: Total percentages of selecting each network for streaming traffic class

This above histogram shows that the selection of network 2 LTE reaches 78% among of different algorithms and during variation of four weights, and selection of network 3 WiFi reaches 22%, but no any selection for network 1 HSDPA2.

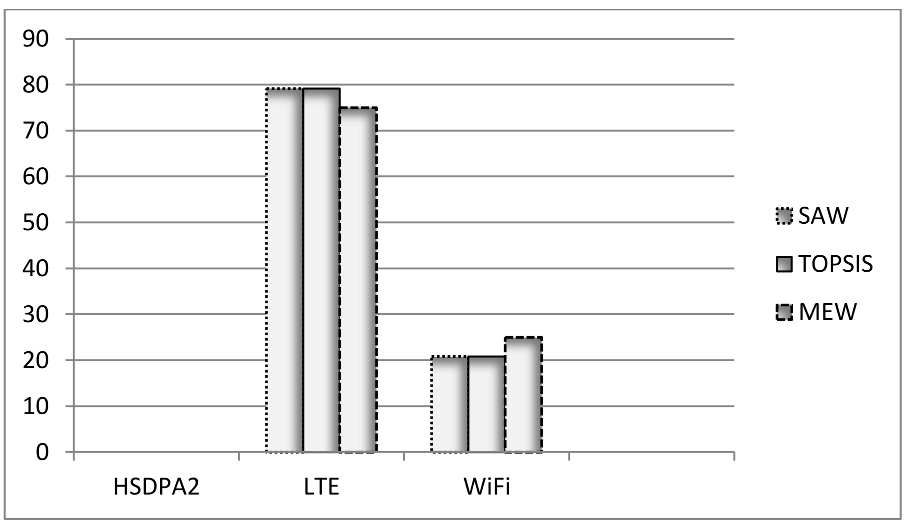

Figure 5.14: Percentages of selecting each network by individual algorithms for streaming traffic class

This above histogram shows that the most selection of network 2 LTE comes from algorithms SAW and TOPSIS, the least selection comes from MEW, and for network 3 WiFi on the contrary.

It can be concluded from Figures 5.8-5.14 that for streaming traffic class:

Network selection is between network 2 LTE and network 3 WiFi, while network 1 HSDPA2 has not been selected. This is like conversational traffic class scenario, the only difference is times of network selecting which is in this streaming traffic class, 56, 16 times network selected for LTE and WiFi respectively.

Network selection in streaming traffic class depends as conversational traffic class on effect of parameters in Table 4.2 and weights in Table 4.4. The difference in times of network selection which is higher in LTE in streaming than conversational and less than in WiFi comes from the high values of Jitter, BW weights in streaming traffic class as shown in Table 4.4 and also network 2 LTE has the best values of Jitter, BW parameters among three networks as shown in Table 4.2.

It can be also concluded that total percentages of selecting the same network by two or three algorithms for streaming traffic class is higher than 95% for all.

5.3 Interactive Traffic Class

Tables 5.9-5.12 and Figures 5.15-5.18 show the best selected network from user during variation of each parameter weight (BER, delay, jitter and BW) for interactive traffic class. Each parameter weight is incremented by 0.2 and varied between 0 and 1.

Figures 5.15-5.18 graphically present results shown in tables 5.9-5.12 respectively.

Table 5.9: Network Selection based on Variation of BER Weight for interactive traffic class

BER	SAW	TOPSIS	MEW
0	2	2	2
0.2	2	2	2
0.4	3	3	3
0.6	3	3	3
0.8	3	3	3
1	3	3	3

This table shows the selection of network 2 LTE when parameter weigh is incremented to 0.2, then selection of network 3 WiFi started at 0.4 to 1 from three different algorithms.

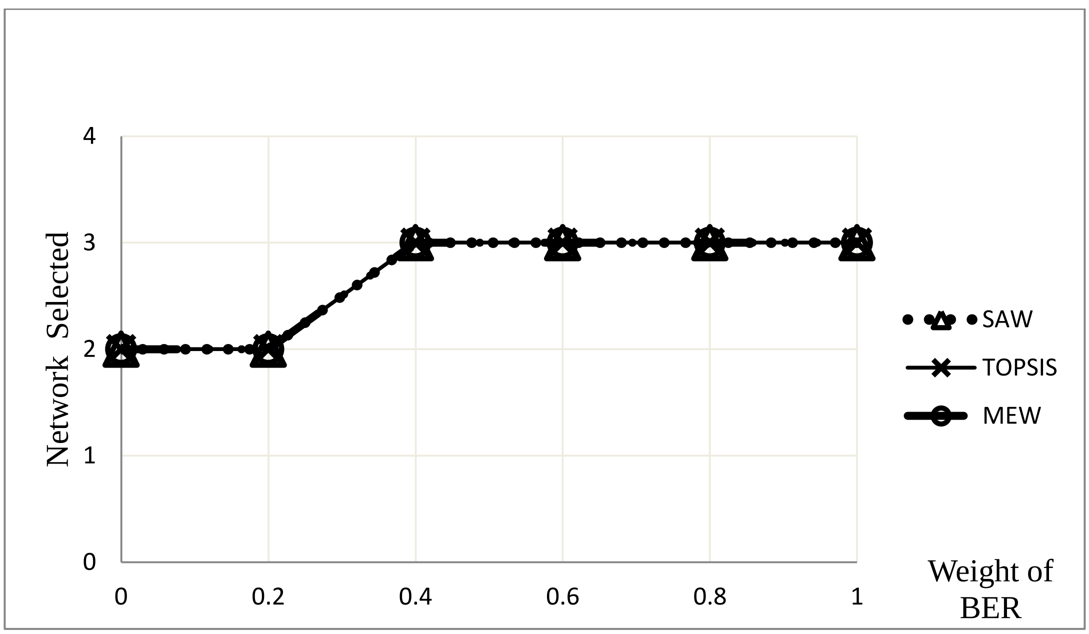

Figure 5.15: Network selected vs weight of BER for interactive traffic class

Table 5.10: Network Selection based on Variation of Delay Weight for interactive traffic class

Delay	SAW	TOPSIS	MEW
0	3	3	3
0.2	3	3	3
0.4	3	3	3
0.6	3	3	3
0.8	3	3	3
1	3	3	3

This table shows the selection of network 3 WiFi is dominant by three different algorithms.

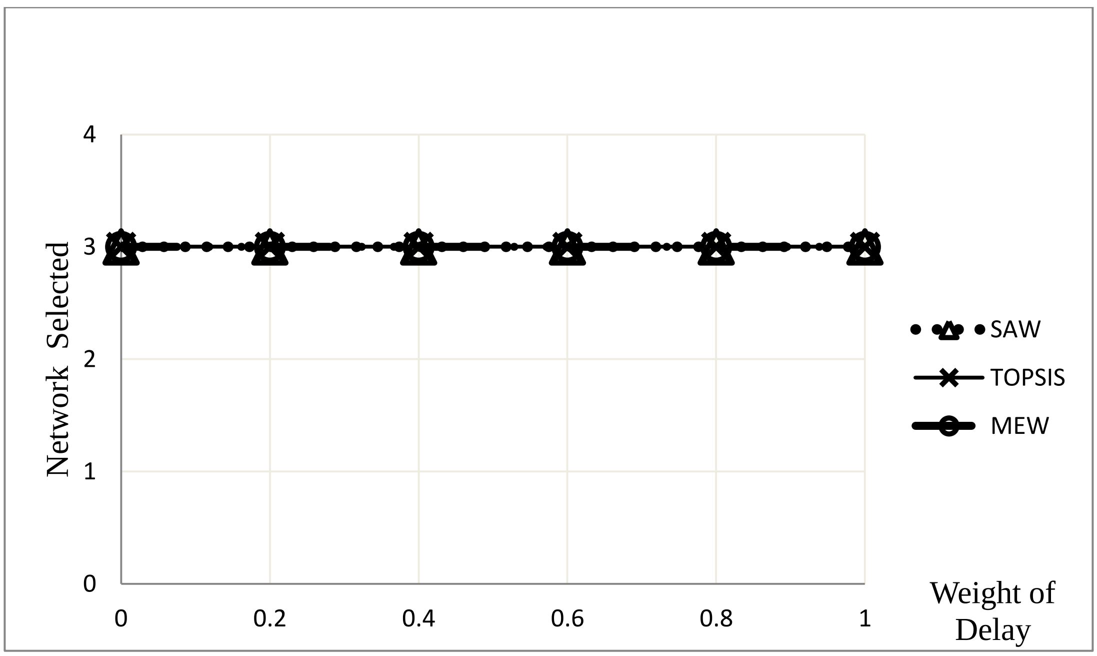

Figure 5.16: Network selected vs weight of delay for interactive traffic class

Table 5.11: Network Selection based on Variation of Jitter Weight for interactive traffic class

Jitter	SAW	TOPSIS	MEW
0	3	3	3
0.2	3	3	3
0.4	3	3	3
0.6	3	3	3
0.8	2	2	3
1	2	2	2

This table shows the selection of network 3 WiFi when parameter weigh is incremented to 0.6, and selection of network 2 LTE when parameter weigh = 1 by three different algorithms. When parameter weigh = 0.8 the three algorithms selected not the same network.

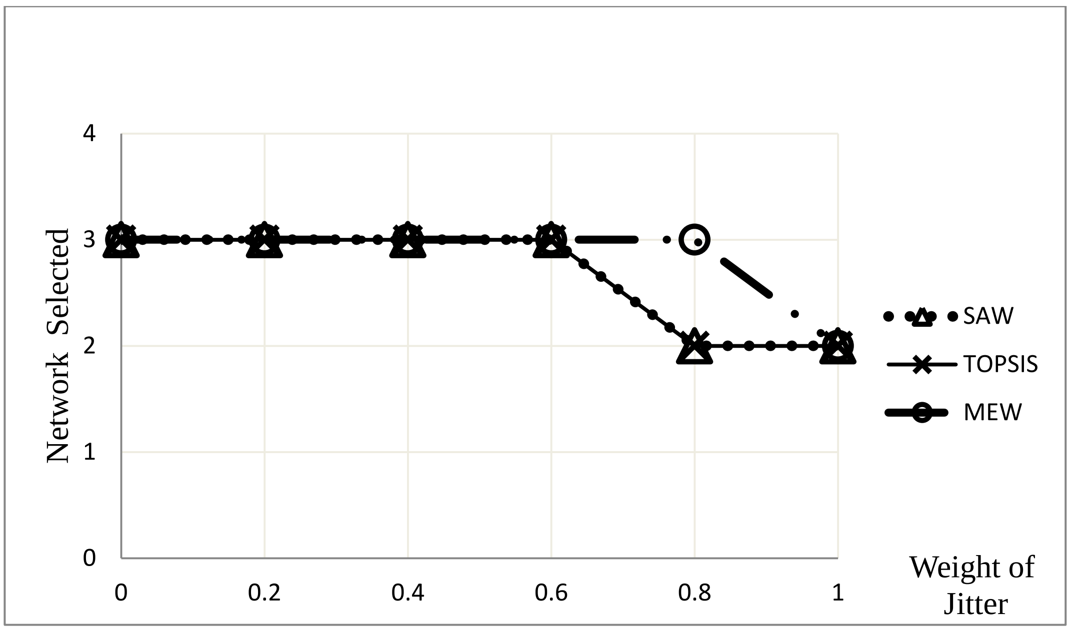

Figure 5.17: Network selected vs weight of jitter for interactive traffic class

Table 5.12: Network Selection based on Variation of BW Weight for interactive traffic class

BW	SAW	TOPSIS	MEW
0	3	3	3
0.2	3	3	3
0.4	3	3	3
0.6	2	2	2
0.8	2	2	2
1	2	2	2

This table shows the selection of network 3 WiFi when parameter weigh is incremented to 0.4, then selection of network 2 LTE started at 0.6 to 1 by three different algorithms.

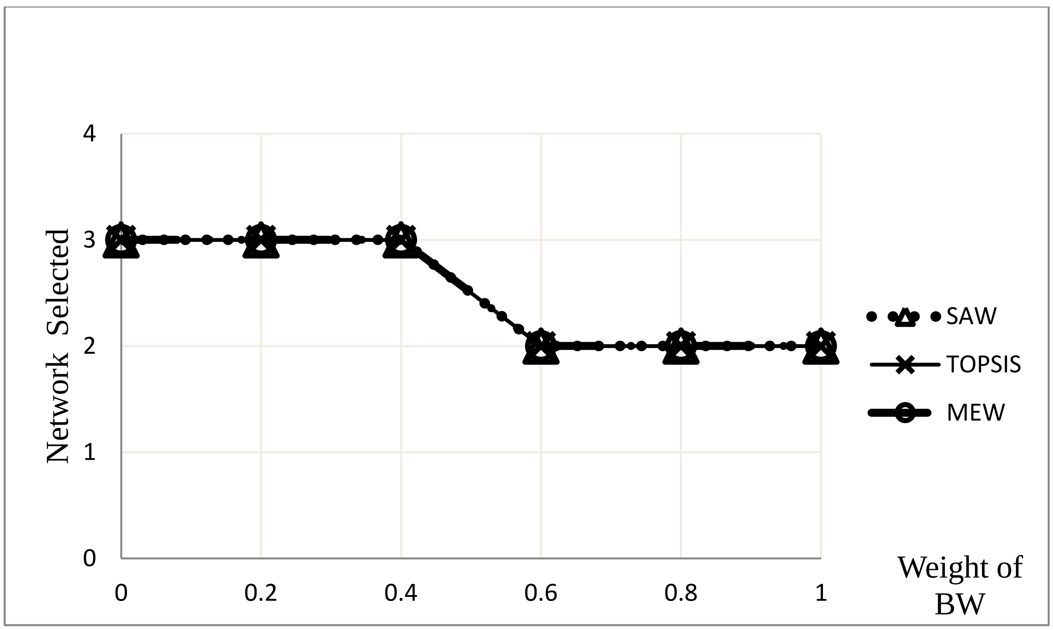

Figure 5.18: Network selected vs weight of BW for interactive traffic class

The results from the above graphs, 5.15 to 5.18 are presented in Figures 5.19-5.21 present histogram plots that show the network selection agreement of different algorithms in streaming traffic class. Figure 5.19 shows the total percentages of selecting the same network by two or three algorithms. Figure 5.20 shows the total selection percentage of each network by all algorithms. Finally, Figure 5.21 shows the total selection percentage of each network by each algorithm.

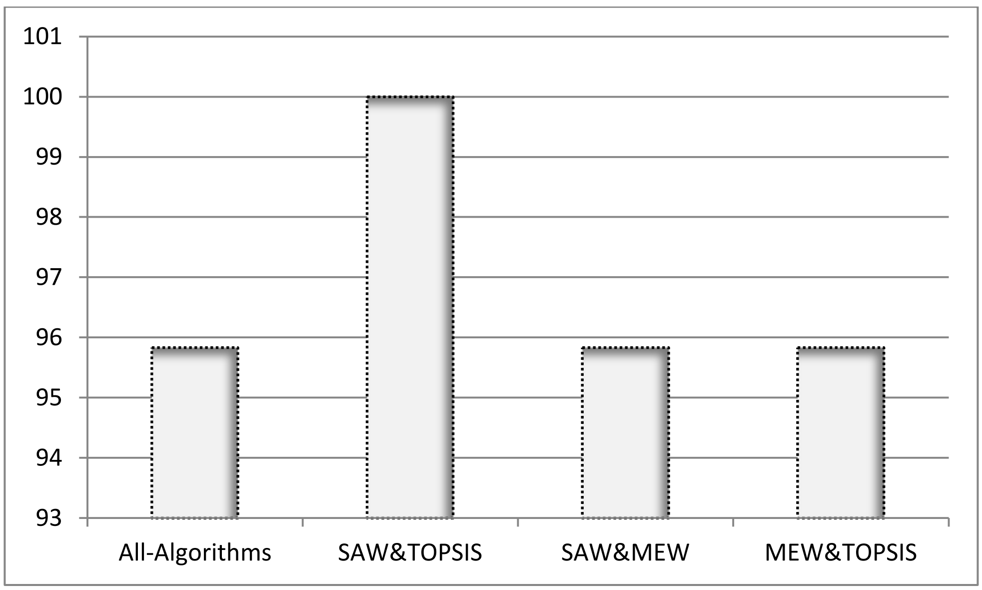

Figure 5.19: Total percentages of selecting the same network by two or three algorithms for interactive traffic class

This above histogram shows that the agreement of different algorithms in selection of the same network is higher than 95% by streaming traffic class. The agreement reaches 100% between SAW and TOPSIS.

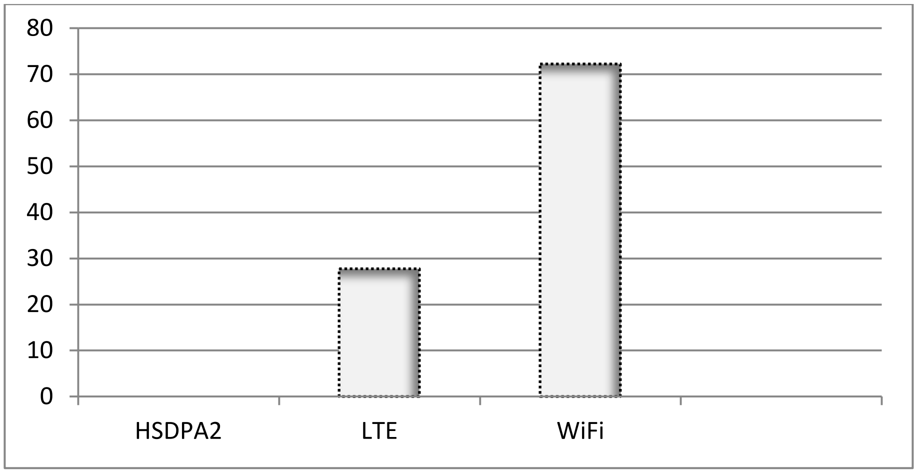

Figure 5.20: Total percentages of selecting each network for interactive traffic class

This above histogram shows that the selection of network 2 LTE reaches 28% among of different algorithms and during variation of four weights, and selection of network 3 WiFi reaches 72%, but no any selection for network 1 HSDPA2.

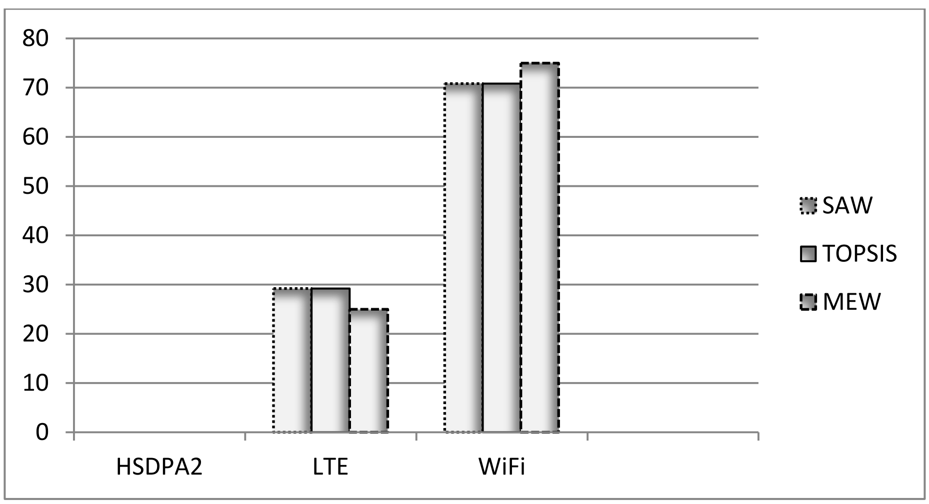

Figure 5.21: Percentages of selecting each network by individual algorithms for interactive traffic class

This above histogram shows that the most selection of network 2 LTE comes from algorithms SAW and TOPSIS, the least selection comes from MEW, and for network 3 WiFi on the contrary.

It can be concluded from Figures 5.15-5.21 that for interactive traffic class:

Network selection is between network 2 LTE and network 3 WiFi, while network 1 HSDPA2 has not been selected. This is like both last traffic classes scenarios, but the difference is times of network selecting which is in this interactive traffic class, 20, 52 times network selected for LTE and WiFi respectively.

It can be seen that times of network selecting of WiFi is higher than LTE, network selection in interactive traffic class depends also on effect of parameters in Table 4.2 and weights in Table 4.4. The dominance of selecting WiFi in interactive traffic class comes from the high value of BER weight as shown in Table 4.4, and WiFi has the best values of BER parameter as well, as shown in Table 4.2.

It can be also concluded that total percentages of selecting the same network by two or three algorithms for interactive traffic class is higher than 95% for all.

5.4 Background Traffic Class

Tables 5.13-5.16 and Figures 5.22-5.25 show the best selected network from user during variation of each parameter weight (BER, delay, jitter and BW) for background traffic class. Each parameter weight is incremented by 0.2 and varied between 0 and 1.

Figures 5.22-5.25 graphically present results shown in tables 5.13-5.16 respectively.

Table 5.13: Network Selection based on Variation of BER Weight for background traffic class

BER	SAW	TOPSIS	MEW
0	2	2	2
0.2	2	2	2
0.4	3	3	3
0.6	3	3	3
0.8	3	3	3
1	3	3	3

This table shows the selection of network 2 LTE when parameter weigh is incremented to 0.2, then selection of network 3 WiFi started at 0.4 to 1 by three different algorithms.

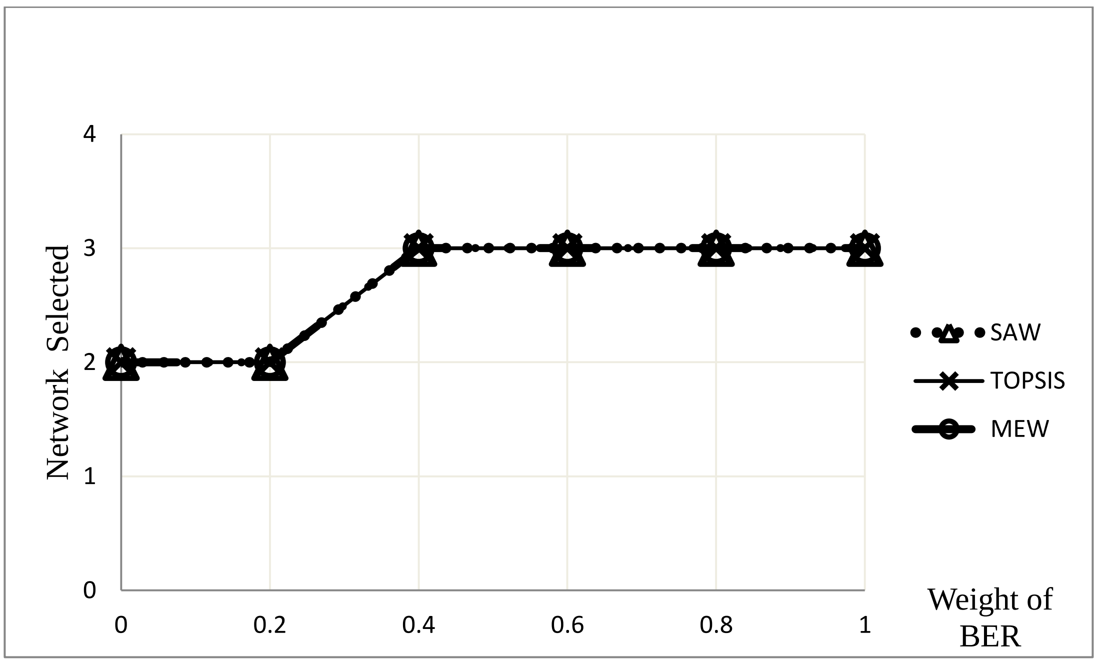

Figure 5.22: Network selected vs weight of BER for background traffic class

Table 5.14: Network Selection based on Variation of Delay Weight for background traffic class

Delay	SAW	TOPSIS	MEW
0	3	3	3
0.2	3	3	3
0.4	3	3	3
0.6	3	3	3
0.8	3	3	3
1	3	3	3

This table shows the selection of network 3 WiFi is dominant by three different algorithms.

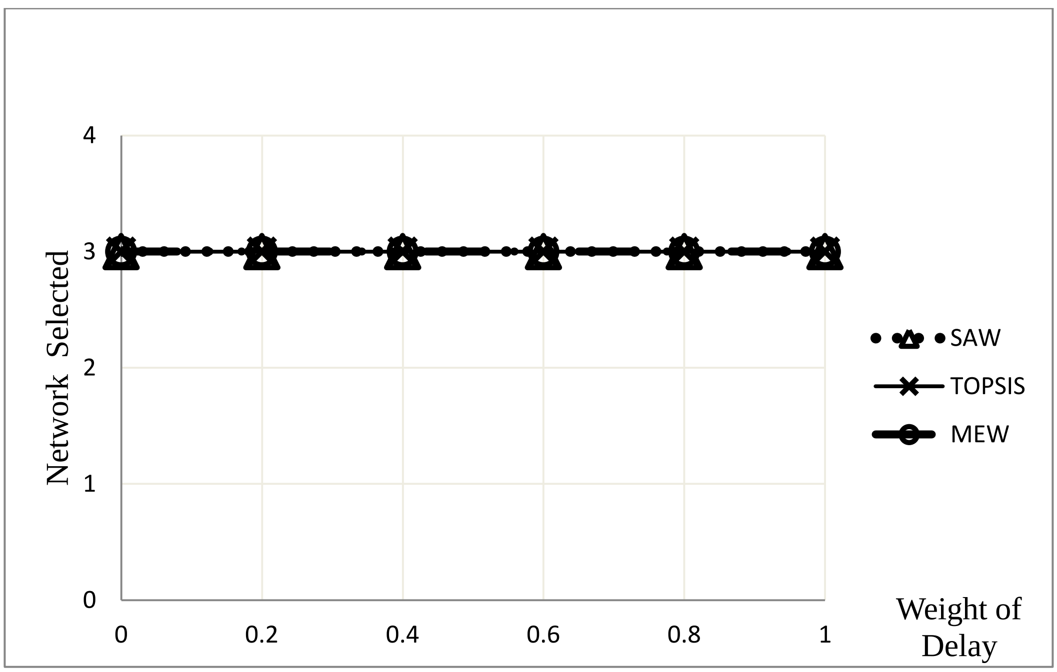

Figure 5.23: Network selected vs weight of delay for background traffic class

Table 5.15: Network Selection based on Variation of Jitter Weight for background traffic class

Jitter	SAW	TOPSIS	MEW
0	3	3	3
0.2	3	3	3
0.4	3	3	3
0.6	3	3	3
0.8	2	2	3
1	2	2	2

This table shows the selection of network 3 WiFi when parameter weigh is incremented to 0.6, and selection of network 2 LTE when parameter weigh = 1 by three different algorithms. When parameter weigh = 0.8 the three algorithms selected not the same network.

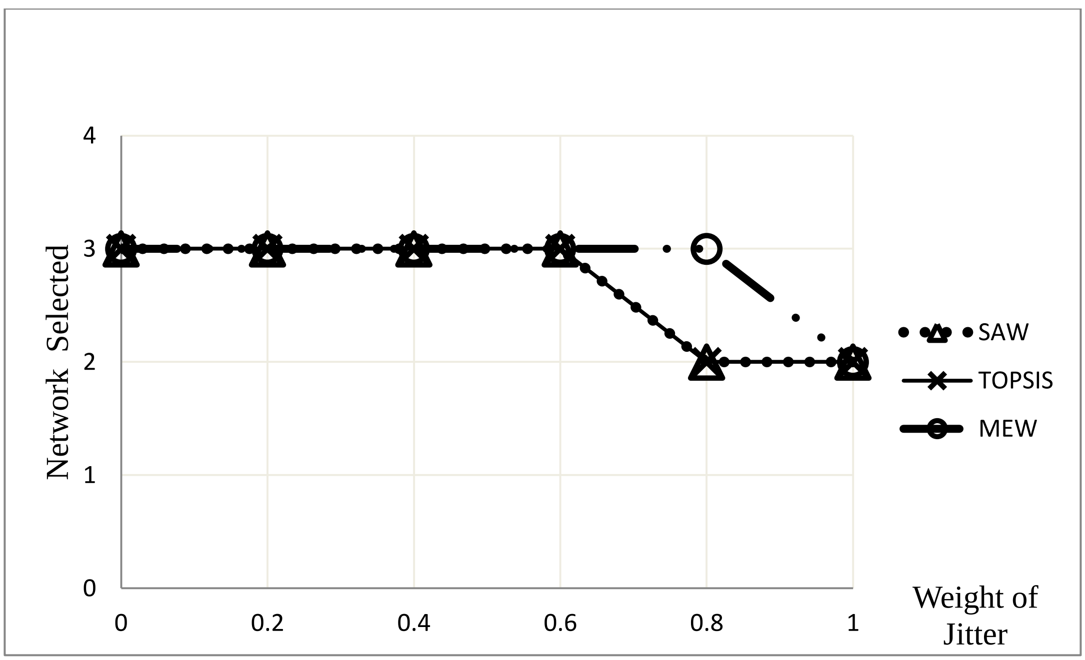

Figure 5.24: Network selected vs weight of jitter for background traffic class

Table 5.16: Network Selection based on Variation of BW Weight for background traffic class

BW	SAW	TOPSIS	MEW
0	3	3	3
0.2	3	3	3
0.4	3	3	3
0.6	2	2	2
0.8	2	2	2
1	2	2	2

This table shows the selection of network 3 WiFi when parameter weigh is incremented to 0.4, then selection of network 2 LTE started at 0.6 to 1 by three different algorithms.

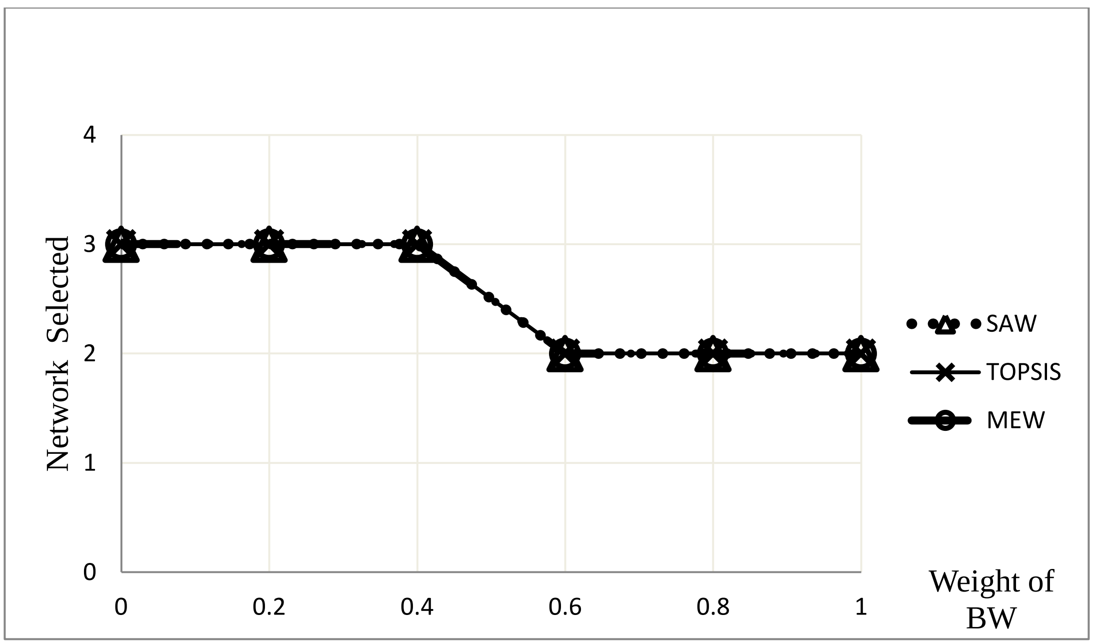

Figure 5.25: Network selected vs weight of BW for background traffic class

The results from the above graphs, 5.22 to 5.25 are presented in Figures 5.26-5.28 present histogram plots that show the network selection agreement of different algorithms in streaming traffic class. Figure 5.26 shows the total percentages of selecting the same network by two or three algorithms. Figure 5.27 shows the total selection percentage of each network by all algorithms. Finally, Figure 5.28 shows the total selection percentage of each network by each algorithm.

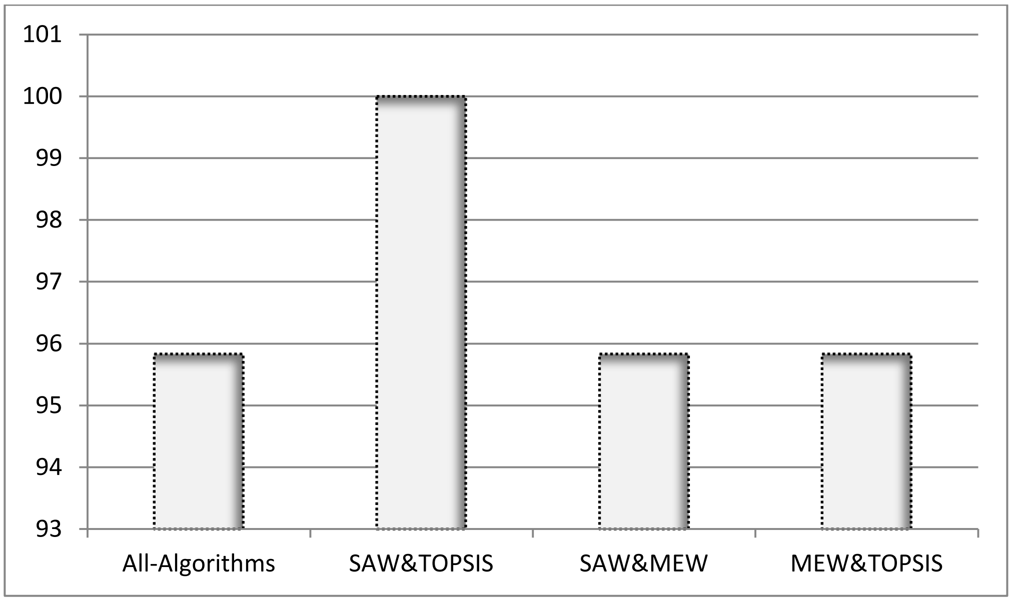

Figure 5.26: Total percentages of selecting the same network by two or three algorithms for background traffic class

This above histogram shows that the agreement of different algorithms in selection of the same network is higher than 95% by streaming traffic class. The agreement reaches 100% between SAW and TOPSIS.

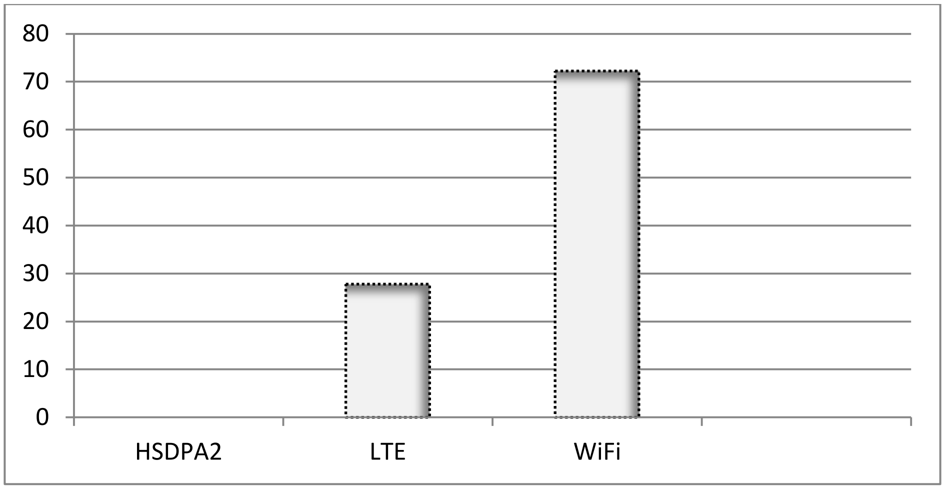

Figure 5.27: Total percentages of selecting each network for background traffic class

This above histogram shows that the selection of network 2 LTE reaches 28% among of different algorithms and during variation of four weights, and selection of network 3 WiFi reaches 72%, but no any selection for network 1 HSDPA2.

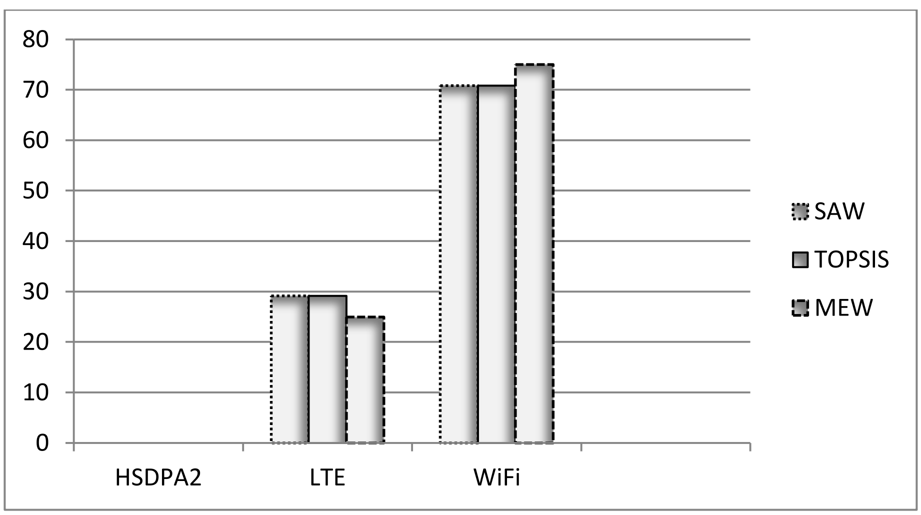

Figure 5.28: Percentages of selecting each network by individual algorithms for background traffic class

This above histogram shows that the most selection of network 2 LTE comes from algorithms SAW and TOPSIS, the least selection comes from MEW, and for network 3 WiFi on the contrary.

It can be concluded from Figures 5.22-5.28 that for background traffic class:

Network selection is between network 2 LTE and network 3 WiFi, while network 1 HSDPA2 has not been selected. This is similar to all last traffic classeses scenarios.

Network selection times of background traffic class is 20, 52 times network selected for LTE and WiFi respectively, and this is very similar to interactive traffic class.

This similarity comes from similarity between parameter weights in background traffic class and parameter weights in interactive traffic class.

WiFi has the best values of BER parameter and high value of BER weight as well, as shown in Tables 4.2, 44 respectively.

It can be also concluded that total percentages of selecting the same network by two or three algorithms for background traffic class is higher than 95% for all.

5.5 All Traffic Classes

Figures 5.29-5.31 present histogram plots that show the network selection agreement of different algorithms in all traffic classes. Figure 5.29 shows the total percentages of selecting the same network by two or three algorithms. Figure 5.30 shows the total selection percentage of each network by all algorithms. Finally, Figure 5.31 shows the total selection percentage of each network by each algorithm.

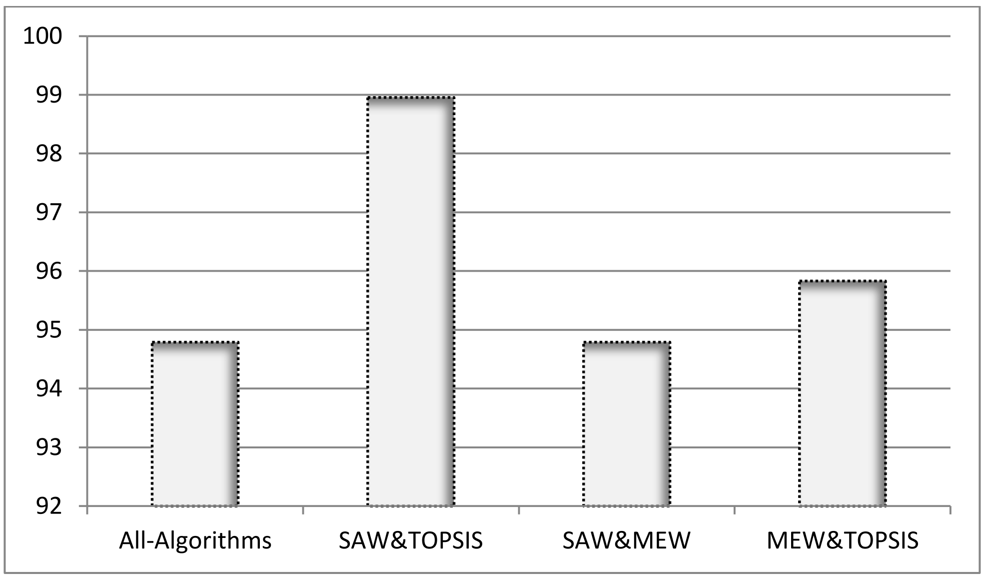

Figure 5.29: Total percentages of selecting the same network by two or three algorithms for all traffic classes

This above histogram shows that the agreement of different algorithms in selection of the same network is higher than 94% by all traffic classes. The agreement reaches 99% between SAW and TOPSIS.

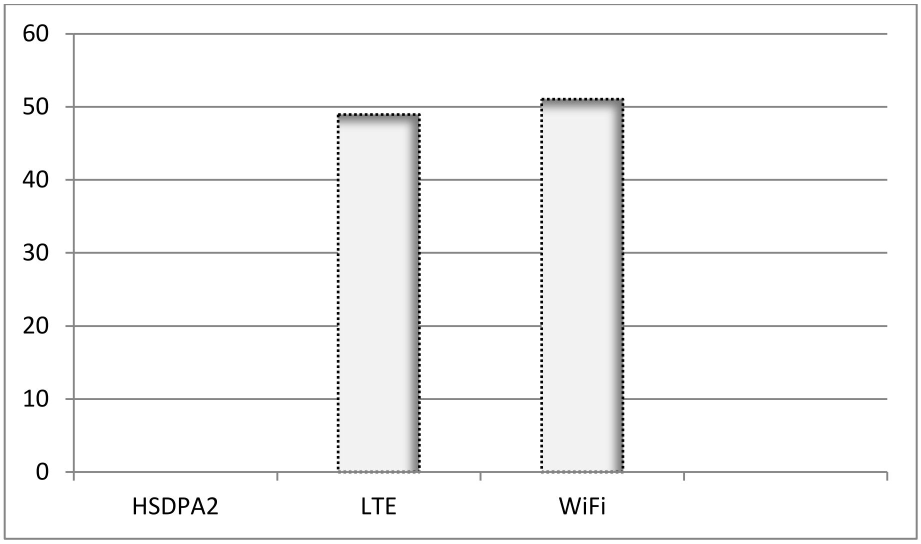

Figure 5.30: Total percentages of selecting each network for all traffic classes

This above histogram shows that the selection of network 2 LTE and network 3 WiFi reached 48%, 52% respectively during variation of four weights and by different algorithms SAW, MEW and TOPSIS. But no any selection for network 1 HSDPA2.

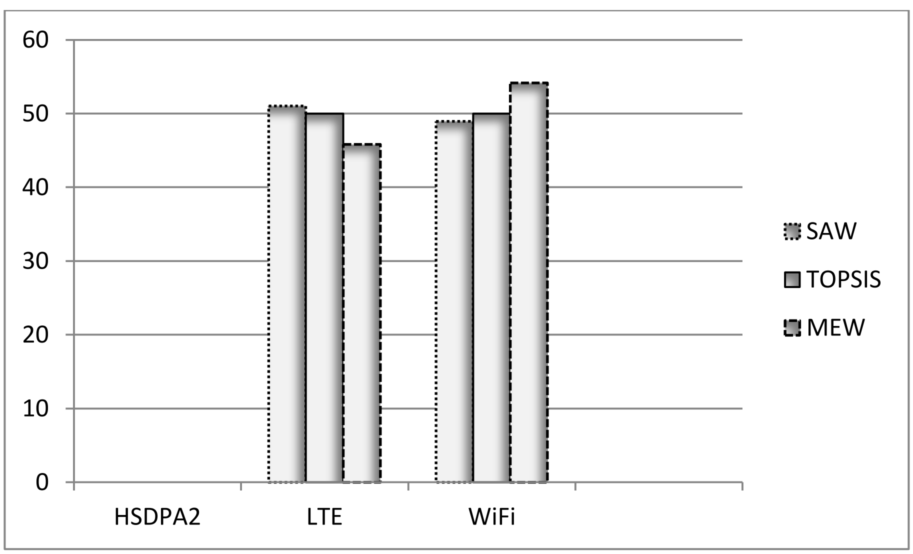

Figure 5.31: Percentages of selecting each network by individual algorithms for all traffic classes

This above histogram shows that the most selection of network 2 LTE comes from algorithm SAW, the least selection comes from MEW, and for network 3 WiFi on the contrary.

It can be concluded from Figures 5.29-5.31 that for all traffic classes:

Network selection is between network 2 LTE and network 3 WiFi, 141, 147 times network selected for each respectively, while network 1 HSDPA2 has not been selected.

It can be also concluded that total percentages of selecting the same network by two or three algorithms for all traffic classes is not the same but higher than 94% for all.

5.6 Summary of Results and Analysis

First, two networks LTE, WiFi among three different networks LTE, WiFi and HSDPA2 only have been selected in different percentages 48% for LTE, 52% for WiFi. The selection of these networks depended on two important things, the parameters values and parameter weights. In other words, depended on network specifications and application requirements.

Second, the network 3 (WiFi) is the most selected network as the best one among the three networks because WiFi has the best two parameters, BER and Delay. Also these parameters supported by the highest weight values, the highest value of delay weight in conversational and the highest value of BER weight in interactive and background.

Third, the network 2 (LTE) is selected as the second network. LTE has the best two parameters; Jitter and BW among these networks. Also these parameters are supported by the highest weight values, the highest value of BW weight in streaming and the highest value of Jitter weight in conversational and streaming.

Fourth, the network 1 (HSDPA2) has not been selected, because it has no favorable parameters, in addition, to having two worst parameters, namely, delay and jitter. While, LTE and WiFi each of them has two favorable parameters

Fifth, when a specific weight values become equal to one, which means all other weights are zero, all the algorithms, SAW, TOPSIS and MEW, select the same network. Which means that selections are affected by just one parameter. The selected network is the network that has the best value of that parameter which weighted by one.

Sixth, the agreement of selection the same network by all of the three algorithms for all traffic classes is 94% . SAW and TOPSIS agree on a specific network 99%, because the SAW technique is implicitly included in the TOPSIS technique, however, the MEW technique is completely different.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

The main purpose of this thesis is that, investigating how the weight of network parameters affect the priority of a network being selected. The networks that have been used are; HSDPA2, LTE and WiFi. The parameters that are taken into consideration for each network are; BER, delay, jitter and bandwidth. The method of multiple attribute decision making which known MADM is used to decide which network should be chosen according to the weight of parameter. Three algorithms are used within the MADM named; SAW, MEW and TOPSES. The process is repeated for four different traffic classes named; conversational, streaming, interactive and background. The results that have been observed are:

There agreement among all three algorithms in selecting the same network for all traffic classes is about 94% .

The agreement by SAW and TOPSIS reaches 99%, because the SAW technique is implicitly included in the TOPSIS, on the other hand the MEW technique is completely different.

Only two networks LTE, WiFi among three different networks have been selected with the following percentages 48% for LTE, 52% for WiFi, while HSDPA2 has not been selected. The network that have being selected is the network that obtains the highest score, which has the priority to be chosen for switch over, as a best candidate network.
This study has also proved that there is a wider choice of selecting a specific network when the network parameters are given different weights.

For future work, it could be suggested to investigate other techniques beside AHP to evaluate weights and include more parameters such battery level of the mobile, RSS, cost etc. Methods such as NNs, Fuzzy logic and genetic algorithms could be investigated instead of MADM, the important numerical parameters will be chosen that affects a machine learning system to decide suitable network for mobile user.

REFERENCES

Acharya, J., Gao, L., and Gaur, S. (2014). Heterogeneous Network In LTE-Advanced. West Sussex: John Wiley & Sons.

Agarwal, A., Misra, G., and Agarwal, K. (2015). The 5th Generation Mobile Wireless Networks- Key Concepts, Network Architecture and Challenges. From http://pubs.sciepub.com/ajeee/3/2/1/ (American Journal of Electrical and Electronic Engineering)

Babatunji, O. (2014). Considering Fading Effects for Vertical Handover in Heterogenous Wireless Networks. *Master Thesis, COMSATS Institute of Information Technology,*Islamabad, Pakistan.

Becvar, Z. (2009). Reduction of Handover Interruption In Mobile Networks. *Doctor Thesis, Czech Technical University in Prague, Faculty of Electrical Engineering, Department of Telecommunication Engineering*, Prague, Czech.

Bellavista, P., Corradi, A., and Foschini, L. (2007). Context-Aware Handoff Middleware for Transparent Service Continuity in Wireless Networks. *Pervasive and Mobile Computing, 3(4): 439-466.*

Ben-Mubarak, M.A., Ali, B.M., and Noordin, N.K. (2013). Fuzzy Logic Based Self-Adaptive Handover Algorithm for Mobile WiMAX. *Wireless Personal Communications, 71(2): 1421-1442.*

Chen, J.C., and Zhang, T. (2004). IP-Based Next-Generation Wireless Networks. New Jersey : John Wiley & Sons.

Chen, W., and Shu, Y. (2005). Active Application Oriented Vertical Handoff in Next Generation Wireless Networks. in *Proc. IEEE WCNC'05*, New Orleans, LA.

Choi, H.H. (2010). An Optimal Handover Decision for Throughput Enhancement. *IEEE Communications Letters, 14(9): 851-853.*

Committee, L.M.S. (2009). IEEE Standard for Local and metropolitan area networks-Part 21: Media Independent Handover Services. New York : IEEE Computer Society

Hossain, E. (2008). Heterogeneous Wireless Access Networks Architectures and Protocols. New York : Springer Science+Business Media, LLC.

Hu, R.Q., and Qian, Y. (2013). Heterogeneous Cellular Networks. West Sussex : John Wiley & Sons.

Huang, J., Qian, F., Gerber, A., Mao, Z.M., Sen, S., and Spatscheck, O. (2012). A Close Examination of Performance and Power Characteristics of 4G LTE Networks. *AT&T Labs-Research, University of Michigan.*

Ismail, M. and Nordin, R. (2014). Vertical Handover Solutions Over LTE-Advanced Wireless Networks. *Wireless Personal Communications, 77(4): 3051-3079.*

Jejdling, F. (2018). Ericsson Mobility Report*: Executive Vice President and Head of Business Area Networks.*

Khattab, O., and Alani, O. (2013). A Survey on Media Independent Handover (MIH) and IP Multimedia Subsystem (IMS) in Heterogeneous Wireless Networks. *International Journal of Wireless Information Networks, 20(3): 215-228.*

Kim, Y., Pack, S., and Kang, C.G. (2011). An Enhanced Information Server for Seamless Vertical Handover in IEEE 802.21 MIH Networks. *Computer Networks, 55(1): 147-158.*

Lahby, M., Cherkaoui, L., and Adib, A. (2013). An Enhanced-TOPSIS Based Network Selection Technique for Next Generation Wireless Networks. *Department of Computer Science, LIM Lab. Faculty of Sciences and Technology of Mohammedia B.P. 146 Mohammedia, Morocco.*

Lee, D.W., Gil, G.T., and Kim, D.H. (2010). A Cost-Based Adaptive Handover Hysteresis Scheme to Minimize The Handover Failure Rate in 3GPP LTE System. *EURASIP Journal on Wireless Communications and Networking, 2010(1): 750173.*

Liang, S., Zhang, Y., and Fan, B. (2017). Multi-Attribute Vertical Handover Decision-Making Algorithm in A Hybrid VLC-femto System. *IEEE Communications Letters, 21(7): 1521-1524.*

Ma, D., and Ma, M. (2012). A QoS Oriented Vertical Handoff Scheme for WiMAX/WLAN Overlay Networks. *IEEE Transactions on Parallel and Distributed Systems, 23(4): 598-606.*

Malathy, E.M., and Muthuswamy, V. (2018). Vertical Handover Decision Schemes in Next-Generation Wireless Network. *Journal of Communications and Information Networks, Vol.3, No.1.*

Malathy, E.M., and Vijayalakshmi, M. (2015). Knapsack-TOPSIS Technique for Vertical Handover in Heterogeneous Wireless Network. *PloS One, 10(8): 1-16.*

Mathias, C. (2010). 1g 2g 2.5g 3g 3.5g 4g comparisons, peak speed, real speed, carriers in a classroom in 5 minutes. From https://www.youtube.com/watch?v=_3k5Iic4pWI

McNair, J., and Zhu, F. (2004). Vertical Handoffs in Fourth-Generation Multinetwork Environments. *IEEE Wireless Comm.*, vol. 11, no. 3.

Milena, S., and Mahonen, P. (2007). Algorithmic Approaches for Vertical Handoff in Heterogeneous Wireless Environment. Wireless Communications and Networking Conference.

Miyim, A.M., Mahamod, I., and Rosdiadee, N. (2012). Prioritized Network-Based Vertical Handover Decision in Multi-Access Wireless Networks. *Communications (APCC), 2012 18th Asia-Pacific Conference on. IEEE, 2012.*

Mohamed, L., Leghris, C., and Abdellah, A. (2012). An Intelligent Network Selection Strategy Based on MADM Methods in Heterogeneous Networks. *International Journal of Wireless & Mobile Networks (IJWMN) Vol. 4, No. 1.*

Mohanty, S., and Akyildiz, I.F. (2006). A Cross-Layer (layer 2 + 3) Handoff Management Protocol for Next-Generation Wireless Systems. *IEEE Transactions on Mobile Computing, 5(10): 1347-1360.*

Nasser, N., Hasswa, A., and Hassanein, H. (2006). Handoffs in Fourth Generation Heterogeneous Networks. *IEEE Communications Magazine, 44(10): 96-103.*

Navarro, E.S., and Wong, V.W.S. (2006). Comparison Between Vertical Handoff Decision Algorithms for Heterogeneous Wireless Networks. *Department of Electrical and Computer Engineering, The University of British Columbia, Vancouver, Canada*

Pangalos, P.A. (2003). Vertical Handover Techniques Over Heterogeneous Networks. *Doctor Thesis, Centre for Telecommunications Research, King's College London,* London, UK.

Payaswini, P., and Manjaiah, D.H. (2014). Improved Vertical Handoff module for NS2 Using IEEE 802.21 MIH for Heterogeneous Networks. *Dept. Of Computer Science, Mangalore University, Karnataka 574 199*.

Rajinikanth , E., and Jayashri, S. (2015). Identification of Suitable Parameters for Predicting Handoff in Heterogeneous Wireless Networks. *International Conference on Circuit, Power and Computing Technologies [ICCPCT]*.

Rajule, N., and Ambudkar, B. (2015). Seamless and Optimised Vertical Handover Algorithm. *International Conference on Computing Communication Control and Automation*.

Saaty, R.W. (1987). The Analytic Hierarchy Process – What It Is and How It Is Used. *4922 Ellsworth Avenue, Pittsburgh, PA 15213, U.S.A.*

Sharma, M., and Khola, R.K. (2012). Fuzzy Logic Based Handover Decision System. *International Journal of Ad hoc, Sensor & Ubiquitous Computing (IJASUC) Vol.3, No.4.*

Sharma, V., Agarwal, A., and Qadeer, M.A. (2011). Media Independent Handover (IEEE 802.21): Framework for Next Generation Vertical Handover. *International Conference on Computational Intelligence and Communication Systems*.

Takagi, H., and Rodrıguez-Dagnino, R.M. (2010). Application of Renewal Theory to Call Handover Counting and Dynamic Location Management in Cellular Mobile Networks. *European Journal of Operational Research, 204(1): 1-13.*

Taniuchi, K., Ohba, Y., Fajardo, V., Das, S., Tauil, M., Cheng, Y.H., Dutta, A., Baker, D., Yajnik, M., and Famolari, D. (2009). IEEE 802.21: Media Independent Handover: Features, Applicability, and Realization. *IEEE Communications Magazine.*

Thinh, Q., and Vuong, N. (2008). Mobility Management in 4G Wireless Heterogeneous Networks. *Doctor Thesis, l'Université d'Evry Val-d'Essonne*, Paris, France.

Vegni, A. (2009). A Combined Vertical Handover Decision Metric for QoS Enhancement in Next Generation Networks. Wireless and Mobile Computing, Networking and Communications, 2009. WIMOB 2009. IEEE International Conference.

Vine, H.A. (2010). Comparison Between MADM Algorithms for Vertical Handoff Decision. *Technical Journal, University of Engineering and Technology Taxila, 2010*

Yan, X. (2010). Optimization of Vertical Handover Decision Processes for Fourth Generation Heterogeneous Wireless Networks. *Doctor Thesis, Department of Electrical and Computer Systems Engineering, Monash University*, Australia.

Yan, X., Sekercioglu, Y.A., and Narayanan, S. (2010). A survey of Vertical Handover Decision Algorithms in Fourth Generation Heterogeneous Wireless Networks. *Computer Networks, 54(11): 1848-1863.*

Yuan, X., Elhoseny, M., and El-Minir, H.K. (2017). A Genetic Algorithm Based. *Dynamic clustering method towards improved WSN longevity*. *Journal of Network and Systems Management, 25(1): 21-46.*

Zekri, M. (2012). Mobility Management and Vertical Handover Decision Making in Heterogeneous Wireless Networks. *Doctor Thesis, Economies and finances. Institut National des Telecommunications,* Paris, France.

Zhu, F., and McNair, J. (2004). Optimizations for Vertical Handoff Decision Algorithms. in *Proc. IEEE WCNC'04*, Atlanta, GA.