Improved Vertical Handoff Schemes for K-Tier Heterogeneous Wireless Network

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Dedicated to my Late Grandfather, Parents and Wife with love...

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Certificate

This is to certify that the work in the thesis titled ***Improved Vertical Handoff Scheme for K-Tier Heterogeneous Wireless Network*** by ***Amitav Panda*** is a record of an original research work carried out under our supervision and guidance in partial fulfilment of the requirements for the award of the degree of Master of Technology (Research) in Electronics and Communication Engineering. To the best of our knowledge the work embodied in this thesis has not been submitted for any degree or academic award elsewhere.

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Abstract

The vertical handoff schemes for heterogeneous wireless networks are presented in the thesis. A heterogeneous network consists of multiple tiers of available wireless networks, framed as K-tier heterogeneous wireless network (KHWN). A typical KHWN adopted in the thesis consists of Global System for Mobile communication (GSM), Universal Mobile Telecommunications System (UMTS), Wireless Local Area Network (WLAN) and Long Term Evolution (LTE). The handoff scheme considers the Receiving Signal Strength (RSS)and Signal to Interference and Noise Ratio (SINR) with the traffic cost as the key parameters for vertical handoff decision making process. The key parameter RSS is estimated through a proposed path loss model based on local terrain and is observed to be better as compared to the earlier empirical models. With the local terrain input, the path loss model and RSS has been estimated for GSM, UMTS, WLAN and LTE networks. Following this a VHO scheme is proposed for voice and data communication. Subsequently this SINR and a KHWN consisting of multi-tier with the four types of services viz. voice call, video streaming, web browsing and telemetry are considered. In this multi-hierarchy decision making process the best suited Analytical and Hierarchical Process (AHP) is applied, for the decision making process in VHO. The proposed scheme of vertical handoff provides higher QoS than the earlier algorithms of Combined SINR based Vertical Handoff (CSVH) and Multi-dimensional SINR based vertical handoff (MSVH). Also the unnecessary VHO are controlled by the proposed scheme. The result shows that the proposed scheme provides low cost traffic and overall system throughput with a control of unnecessary handoffs for all kinds of services within the KHWN.
***Keywords*:** Vertical handoff scheme, k-tier heterogeneous wireless network, receiving signal strength, signal to noise and interference ratio, throughput.

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List of Abbreviations

1G	First Generation
2G	Second-Generation
3G	Third-Generation
3GPP	3rd Generation Partnership Project
4G	Fourth-Generation
5G	Fifth-Generation
AHP	Analytical and Hirachical Process
AP	Access Point
BCCH	Broadcast Control Channel
BS	Base Station
CS	Circuit Switching
CR	Consitency Ratio
DE	Decision epochs
DL	Downlink
E-UTRA	Evolved Universal Terrestrial Radio Access
EDGE	Enhanced Data Rate for GSM Evolution
EIRP	Effective Isotropic Radiated Power
eNodeB	Evolved Node-B
FDD	Frequency Division Duplex
GSM	Global System for Mobile Communications
GRA	Grey Relational Analysis
HSDPA	High Speed Downlink Packet Access
HSPA	High Speed Packet Access
HWN	Heterogeneous Wireless Network
KHWN	K-Tier Heterogeneous Wireless Network
IMS	IP Multimedia Sub-system
IP	Internet Protocol
ITU	International Telecommunication Union

LoS	Line of Sight
LTE	Long Term Evolution
LTE Adv	LTE-Advanced
MDP	Markov Decision Process
MADM	Multi Attribute Decision Making
MIMO	Multiple-Input Multiple-Output
MM	Mobility Management
MME	Mobility Management Entity
MS	Mobile Station
NGWN	Next Generation Wireless Network
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiple Access
PS	Packet Switching
RF	Radio Frequency
RSS	Received Signal Strength
RSST	Received Signal Strength Threshold
SAW	Simple Additive Weighting
SC-VHOS	SINR and Cost based Vertical Handoff Scheme
SINR	Signal-to-Interference plus Noise Ratio
SNR	Signal to Noise Ratio
SONET	Synchronous Optical Networking
TDD	Time Division Duplex
TDMA	Time Division Multiple Access
T-DVHD	Trusted Distributed Vertical Handover Decision
TN	Transceiver's Node
TOPSIS	Technique for Order Preference by Similarity to an Ideal Solution
UE	User Equipment
UL	Uplink
UMTS	Universal Mobile Telecommunications System

VHO Vertical Handoff

VHOS Vertical Handoff Scheme

VoIP Voice-over-IP

WiFi Wireless Fidelity

WiMAX Wireless Interoperability for Microwave Access

WLAN Wireless Local Area Network

Chapter 1

Introduction

1.1 Introduction

The swift growth in wireless communication technology has changed human living standards. This effect is visible with the exponential increase in mobile users. To match with the rising demand, there is a very fast evolution in communication standards. This results in rapid movement of standards from one generation to other.

The evolution of wireless communication technologies are represented by their generations. The mobile wireless industry started way back in 1970's with the first generation of mobile communication technology called 1G [1]. The mobile 1G, was Nordic Mobile Communication (NMT) and Total Access Communication Systems (TACS) operates on analog technology [2]. The technology was primarily designed to provide voice services. Large size phone, frequent call drops and a limited mobility were the main drawbacks of this generation systems [3].

In early 90's the popular Global System for Mobile Communication (GSM) designated as second generation (2G) was introduced. This had the innovative evolution in the digital technology. The second generation supported data and voice mobility. Later the General Packet Radio Service (GPRS)(2.5G) and Enhanced Data Rates for Global Evolution (EDGE)(2.75G) came into the scenario for better data support and mobility across the network.

Due to higher demand for data services on wireless communication, the evolution led to third generation (3G) wireless communication technologies, Universal Mobile Telecommunications System (UMTS) and Wideband Code Division Multiple Access (WCDMA). These technologies provide integrated packet high quality audio video and data services with mobility support.

The fourth generation (4G) Long Term Evolution (LTE) is the advancement of 3G technology. In addition to the usual voice and other services of 3G, 4G provides mobile broadband internet access, through smart phones, and other mobile devices [4]. Potential and current applications of 4G include amended mobile web access, IP telephony, gaming services, high-definition mobile TV, video conferencing, 3D television and cloud computing. Table 1 presents a comparative overview of the major wireless communication evolutions with their technology features [4].

The change of technology from the end user's perspective is deliberate and the new generation technology overlaps with the existing technology [5]. Hence for certain period of time both the technologies co-exist and hence forms heterogeneous wireless networks. Table 1.1 also compares differences in different generations [6].

1.2 Heterogeneous wireless networks

New generation of technology in mobile brings more appealing applications for the end-users. It is very natural for the new technology to demand for the co-existence of the new applications along with existing applications. The heterogeneous wireless networks constitute technologies ranging from 2.75G to 4G [7] and is expected to go beyond. A Heterogeneous Wireless Network (HWN) consists of multi-tier networks with different capabilities in terms of operating systems, hardware, protocols and applications with mobility. So, the HWN has the ability to meet the expectations of the end user for better connectivity and mobility with all possible applications [1].

This reiterates the importance of mobility of the end users. With the focus to achieve better mobility, heterogeneous multi-tier network is mapped in a typical urban environment and the multi-tier constitutes standards like GSM, EDGE, UMTS, Wireless Local Area Network(WLAN), LTE etc. A prediction of use and demand for mobility in an Indian scenario is represented in Figure 1.1. This brings about the challenges in divergent activities of the network management [8]. It is highly essential for the end user to seamlessly avail the services without disruption while travelling.

1.2.1 Handoff: An oversight

The process of transfer of an ongoing connection from the serving base station to the adjacent base station without interruption is known as handoff. The handoff is demonstrated in Figure 1.2, where the handoff takes place while the user moves from one cell coverage area to adjacent coverage area.

There are two basic handoff techniques, Network Controlled Handoff (NCHO) and

Technology/ Features	**1G**	**2G**	**2.5/ 2.75G**	**3/ 3.5G**	**4G**
Deployment Start	1970-1984	1980-1991	1991-1999	2001-2006	2007-2012 onwards
Data Bandwidth	1.9 Kbps	14.4 Kbps	384 Kbps	2M̃bps	200 Mbps - 1Gbps
Standards	AMPS	TDMA, CDMA, GSM	GPRS, EDGE, 1xRTT	CDMA200, WCDMA, UMTS	HSSPA, LTE, LTE-A
Technology	Analog Cellular Technology	Digital Cellular Technology	Digital Cellular Technology	Broadband with HSPA, HSDPA, WCDMA	Unified IP, Broadband WiMAX, LTE, WLAN and LTE Adv.
Service provided	Mobile Telephony (Voice)	Digital voice with Short message service	Packet data with High Capacity	Integrated High quality audio, video and data	Dynamic information access, wearable devices
Multiplexing	FDMA	TDMA, FDMA, CDMA	TDMA, CDMA	CDMA, MIMO	OFDMA with MIMO
Switching	Circuit	Circuit	Circuit & Packet switching	Packet switch	All IP
Core Network	PSTN	PSTN	Circuit & Packet switch	Packet Network	Internet
Handoff	Horizontal Handoff	Horizontal Handoff	Horizontal Handoff	Horizontal Handoff	Horizontal Handoff and Vertical Handoff

Table 1.1: Comparative overview of wireless communication evolution

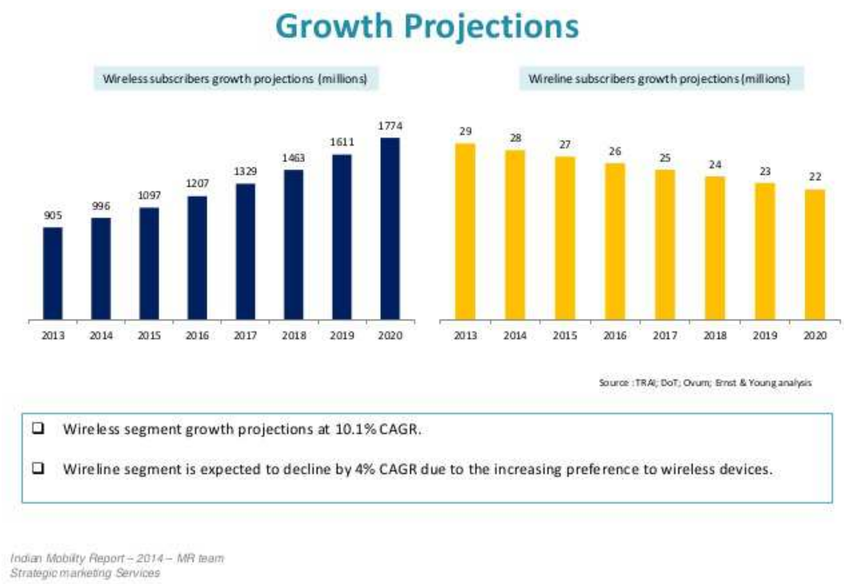

Figure 1.1: Mobility growth prediction in India Source:TRAI and DoT

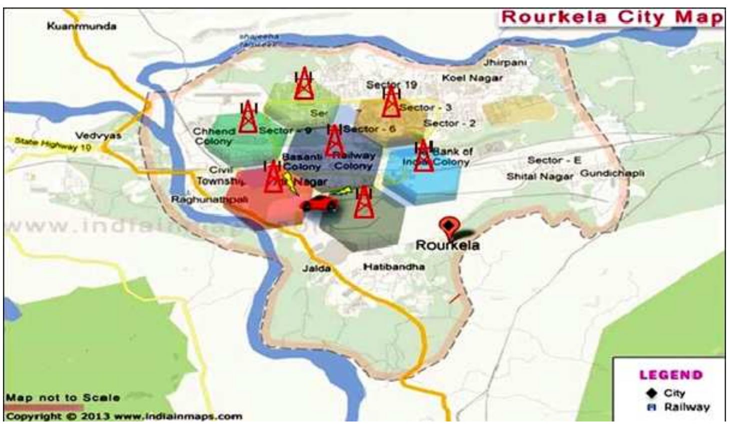

Figure 1.2: Handoff

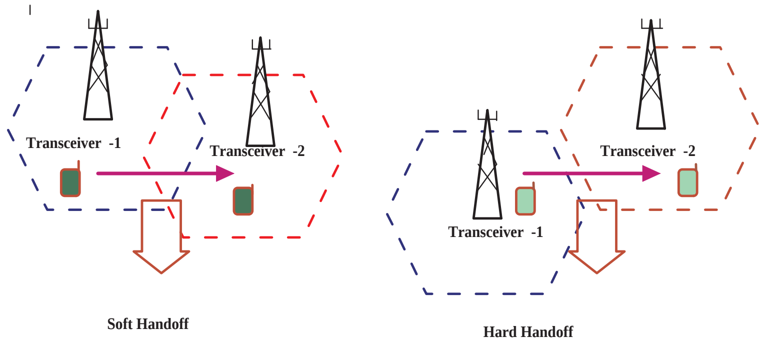

Figure 1.3: Hard handoff and soft handoff

Mobile Controlled Handoff (MCHO). In NCHO, the network makes handoff decision based on measurements of the signal quality at mobile station (MS) at a number of candidate base stations (BS). Specifically, if the MS is measured to have a weaker signal in its existing cell, while a stronger signal is available in the neighbouring cell, a handoff decision can be made by the network to switch the user to new BS from the old cell. Such type of handoff general takes 100-200ms and often produces a noticeable interruption in the conversation. However, overall delay of such a type of handoff in general is in the range of 5-10ms [1]. Thus, this type of handoff is not suitable to a rapid changing environment and a high density of users. NCHO was used in the first-generation analogue systems such as AMPS [2, 9].

In contrast to NCHO, it is the MS that totally control the decision process of handoff in MCHO approach. A MS measures signal strength from all the surround base stations (BS). If the MS find that there is a new BS which has a higher Receiving Signal Strength (RSS) than the existing BS then it may consider to handoff from the old BS to the new BS given a certain signal threshold is reached [1]. MCHO is the highest degree of handoff decentralization, thereby enabling very fast handoff, typically on the order of 0.1ms as used in higher generations of networks. There are two common types of handoff in each network type.

1. Hard handoff

2. Soft hand off

A hard handoff is one in which the channel in the serving cell is first released and only then the channel in the target cell is engaged. Thus the connection to the source is broken before, the connection to the target is made. Such handoff process is also known as break-before-make. Hard handoff are intended to be instantaneous in order to minimize the disruption to the call. A hard handoff is perceived by network engineers as an event during the call [10]. It requires least processing by the network providing service. When mobile is between base stations, then mobile can switch to any of base stations. So, base station bounces the link with mobile device back and forth. This is the ping-pong effect.

A soft handoff is one in which the channel in the source cell is retained and used for a while in parallel with the channel in the target cell. In each case the connection to the target is established before the connection from the source is broken, hence this handoff is also called make-before-break. The interval, during which the two connections exist, may be brief or substantial. For this reason the soft handoff is perceived by network engineers as a state of the call, rather than a brief event. Soft handoff may involve using connections to more than two cells, e.g. connections to three, four or more cells can be maintained by one mobile unit at the same time. When a call is in a state of soft handoff the signal of the best of all used channels can be utilized for the call at a given moment or all the signals can be combined to produce a clearer copy of the signal. The later is more advantageous, and when such combining is performed both in the downlink (forward link) and in the uplink (reverse link), the handoff is termed as softer. Softer handoffs are possible when the cells involved in the handoff have a single cell site [7, 10, 11].

In the HWN scenario the handoff is defined as

1. Horizontal handoff: Handoff occurring within the same network is known as horizontal handoff. The concern of horizontal handoff is to maintain the on-going call, with the change of connectivity due to the movement of a mobile node. Maintaining the on-going call is done by dynamically updating the changed connectivity address. The majority of proposed handoff mechanism might be included the horizontal handoff option because it focuses on to maintain on-going call even though the location is changed within the same wireless network

Technology	Horizontal handoff	Vertical handoff
Access technology	Single technology	Heterogeneous technology
Network interface	Single interface	Multiple interface
Actually used IP address at a time	Single IP address	Multiple IP address
QoS parameter	Single value	Multiple values
Network connection	Single connection	Multiple connections

Table 1.2: Comparison of vertical handoff and horizontal handoff

technology [12].

2. Vertical handoff: Handoff occurring within heterogeneous networks is known as vertical handoff. Vertical handoff is different from horizontal handoff. The access technology used is also changed along with the IP address, because the mobile nodes move different access network which uses different access technology. In this scenario, the main concern of vertical handoff is to maintain on-going call with the change of network interfaces, QoS characteristics, RSS [13].

The difference between the vertical handoff and horizontal handoff is demonstrated in the Table 1.2

1.3 Motivation

The wireless telephony system has changed with advancement of the technology according to the demand of end users. The first such impact was voice telephony system in 1G. The need of the end user was shifted to avail the voice communication mobility. After this the wireless technology evolved as GSM, 2G in which the data service was embedded with mobility. Due to increase in demand of data services the evolution of wireless technologies from 3G to 4G and 5G developed. The evolution of wireless technologies can meet the demand of the end users to provide services which can be applicable for health, education, science and technology, telemetry, business, social media etc. The growth prediction depicts the exponential increase of mobile services in Figure 1.4. So the trend of mobile application goes on increasing across all spheres of human life. These technologies are expected to provide services like voice, data, web browsing, video streaming and telemetry with mobility of the end users. The

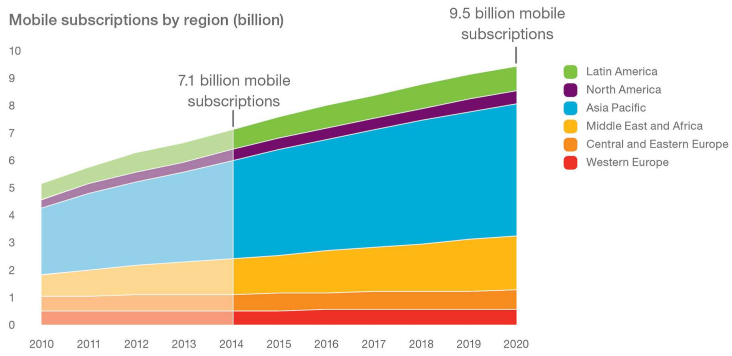

Figure 1.4: Mobile user's growth prediction. Ref. Ericsson mobility report

feature of horizontal handoff is available in 2G, 3G, 4G and 5G to provide mobility for all kinds of services. In today's scenario, all the technologies are embedded to form a heterogeneous wireless network. So in order to provide mobility within such heterogeneous network the vertical handoff is essential to avail uninterrupted services. Though 2G and 3G wireless services co-exist, they don't posses the feature of vertical handoff. 4G has the vertical handoff feature but this is not extended to all kinds of wireless networks. Hence it becomes essential to improve the performance of mobility in a heterogeneous wireless network through the improvement of vertical handoff.

1.4 Objective of the thesis

Every mobile user in the world is keen in accessing information while maintaining the mobility. So the role of mobile hand-held devices to perform all kind of tasks in various fields for better communication, improved productivity in business and reduced operating costs, making the process faster and efficient. Telecommunications service providers and other companies providing various services are looking for ways to streamline and optimise the operations.

The top priorities of all service providers is to deliver seamless mobility in next generation heterogeneous wireless networks, which can provide seamless communications with a diversity of services for all preferred locations comprehensively.

The problem associated with the wireless mobile hand held devices is now transforming the ability to do remote management in the field of education, health, security, business and social relations. For these requirements novel handoff techniques are based on following parameters like bandwidth, Signal to Noise Interference Ratio (SINR), handoff latency, power consumption, network cost, user preferences, network throughput, network load balancing, network security, RSS and velocity of the User Equipment(UE) [9]. Several investigations have been made on VHO, taking individual parameters for GSM, WLAN and UMTS networks under consideration. However majority of these find a scope for having an integrated solution for VHOS in heterogeneous networks including LTE (4G) taking into account all the parameters [14, 15].

This study has the following objectives

1. Carry out an extensive investigation to the research work done in the VHO.

2. Propose new techniques for VHOS considering the local terrain, path loss model and RSS for all tiers of wireless networks in a K-tier Heterogeneous Wireless Network (KHWN).

3. Analyse the proposed VHOS performance considering different constraints of the environment reported in standard literature.

1.5 VHOS techniques available

The present vertical handoff decision algorithm of the heterogeneous network is summarized, and existing problems and the future research direction are discussed [4,8,16]. It is seen that the traditional handoff algorithm based on pre-defined path loss model with RSS is not suitable for heterogeneous wireless network with different kinds of user services at different terrain across all locations [13, 17–19]. The decision algorithms which take into consideration, the comprehensive network and decision factors, appeared to provide better handoff performance and improved user satisfaction index with better QoS [20, 21]. On the other hand, Next Generation Wireless Network (NGWN) is of complex structure resulted from the integration of heterogeneous wireless networks. In these networks, the design of an effective vertical handoff balancing algorithm to improve the comprehensive performance of the whole system is a very important issue [12, 22–24].

1.6 Contributions of the thesis

1.6.1 RSS based VHOS in k-tier heterogeneous wireless network

In this chapter we propose the VHOS between each tier of the network, after getting the proficiency and accuracy in the RSS measurement in each network of the KHWN domain. In the literature study we found most of the RSS estimations are based on selected empirical and statistical model with the local terrain data of Indian urban as well as sub-urban environments [5, 25]. The proposed statistical model aligns in accordance to the pre-set data, considering roof height, road width as normal random variables, by taking the real data of Indian urban and sub-urban terrain. The five parameters are modelled statistically, with the terrain information on, road width and roof top height, with height of base station, distance from base station. The model is validated by comparing the simulated results with the measurement campaigns carried out in urban and suburban regions [26]. From the path loss model the RSS has been estimated which gives a better performance [8]. The results of RSS for all networks considered are quit exciting and demonstrated in the simulation results of chapter-3. The new integrated KHWN concept is incorporated to achieve mobility within different tiers of networks using a VHOS based on the results of the RSS.

1.6.2 SINR and cost based vertical handoff in k-tier heterogeneous wireless network

The previous studies for vertical handoff in heterogeneous wireless networks such as combined SINR based vertical handoff (CSVH), multi-dimensional adaptive SINR based VHO algorithms (MASVHO) and multi-attribute vertical handoff algorithm with predictive SINR using grey model GM (1,1) use SINR, user required bandwidth, user traffic cost, utilization of each access network, and user preference [27–30]. However, all these techniques are applied to WLAN and WCDMA networks. Applying these methods for VHOS in KHWN and considering all types of traffics independently, it is found that the results provide less throughput with no remarkable reduction in traffic cost [14, 31, 32]. Hence we are motivated to propose VHOS for KHWN to provide seamless vertical handoff with multi attribute QoS [18]. The proposed method is superior to the existing methods in following performance indices.

1. SINR,
2. Bandwidth,
3. User traffic cost from k-tier access networks,
4. User preference criterion to make hand off decision,
5. Hysteresis buffer time.

The proposed VHOS deals with different traffic types, provides high system level throughput, as achieves low cost traffic. In this method the handoff is fired when the predicted value of SINR is less than a pre-established threshold value determined based on user's application or QoS restrictions [13, 21, 29, 31, 33]. The result of the proposed SINR and cost based VHOS (SCVHOS) with the previous methods CSVH and MASVHO. The simulation results demonstrate the most optimal performance of the proposed scheme.

1.7 Thesis Organisation

Chapter-1

The development of generations of wireless communication technology is discussed. The various architecture of the each generation of the networks are also presented [1, 34].

Chapter-2

An overview of handoff and mobility among heterogeneous networks called vertical handoff and mobility is presented in this chapter. Recent developments of the vertical handoff decision algorithms in heterogeneous network is reviewed, the existing problems and the future research direction are discussed. It is inferred from the discussion and the analysis that the traditional handoff algorithm based on RSS is no longer suitable for heterogeneous wireless network with various user services. The decision algorithms which take comprehensive network and DE factors into consideration is expected to offer better handoff performance, better user satisfaction and QoS. On the other hand, Next Generation Wireless Networks (NGWN) is complex in structure resulting form the integration of heterogeneous wireless networks. In such a scenario the design of an effective vertical handoff balancing algorithm to improve the comprehensive performance of the overall system is a vital issue [8, 18, 25].

Chapter-3

The estimated the path loss and RSS for all the KHWN are discussed separately, considering the Indian terrain conditions for urban and sub urban environments. An algorithm for vertical handoff which integrates the network types like GSM, UMTS, WLAN and LTE in the KHWN is proposed. The importance of VHOS lies in dealing with the mobility between old technologies like GSM, as well as the for-coming new technologies. In this proposed VHOS, the interoperability is possible within KHWN considering the real time data for each tier of the network [9, 33]. From the estimated RSS parameter based on statistical and empirical models, the algorithm for VHOS is proposed. The proposed of VHOS algorithm is robust and noncomplex as the real-time parameters for estimating RSS as pre-set according to Indian terrain and can also be modified to other known environments [14].

Chapter-4

The VHOS is proposed based on SINR, Cost and Bandwidth as the key parameters for handoff decision making, in KHWN. The LTE(4G) and WLAN are considered as the two layers for executing the VHO. As the parameters SINR and Cost are directly dictate the QoS of the network, the VHOS can be considered as the QoS based handoff in KHWN. The same consideration can be validated for multiple tiers of the next generation heterogeneous wireless networks [12, 20, 22]. As per the simulation results, the proposed scheme of VHO achieves QoS, better than the earlier algorithms of CSVH and MSVH and also the data throughputs are reported to be superior. The control of unnecessary handoffs is incorporated by setting the adaptive hysteresis time. The simulation results are validated for four types of traffics in the KHWN [8, 21, 29].

The work other than Analytical and Hirarchical Process (AHP) method can be applied for determining the score of the target network during the VHO [35]. The execution part of the VHOS can also be optimized [5, 10, 19].

Chapter-5

The conclusion, limitation and future scope of implementation of the research work is presented in this chapter. The VHOS is proposed through building a stimulating approach. Most of the work carried out in the literature surveyed regarding the VHOS design focuses on the challenge as the quality and multitier network support based VHOS. The proposed local terrain based RSS method for KHWN improves the quality of receiving signals and handoff. The essential parameters of RSS, SINR, cost, bandwidth and hysteresis time is considered while proposing the VHOS for KHWN. Based on these parameters the VHOS is proposed with the best suited analytical hierarchical process AHP for vertical handoff within the KHWN environment. The results found are with better quality of throughput, cost effective traffic, and lower ping pong handoffs and of multi-tier supported.

Perceiving the proposed VHOS in comparison to the existing algorithms, several ideas and improvements have been devised that may help to form the basis of future work to be carried out in this research area. The research can be put in the existing VHO algorithms and can be modified and tested for real time application by various telecom service providers [2]. The limitation of the work is presented and the scope of implementation of the VHOS work is also elaborated.

Chapter 2

Vertical handoff in heterogeneous wireless network: A Review

2.1 Introduction

Since the beginning of wireless communication evolution, the wireless network always emerged with mess of current and next generation of wireless communication archetypes. Different network archetypes envisioned to provide different kinds of services like voice, video streaming, web browsing, telemetry and the like. The network archetypes also aim to provide ubiquitous network coverage with mobility. So there is a requirement of inter and intra network mobility for all kinds of services through VHO. So the VHO plays the key role for providing mobility across multiple network archetypes. Several approaches were proposed by different authors to get the optimum solution for finding out the VHO algorithms for multi-tier,multiple service environments.

In this chapter an extensive study of earlier reported VHO's by different heterogeneous network is carried out. The algorithms and the proposals are analysed for finding out the optimum solutions for the desired multiple networks. The review also comes up with the key parameters responsible for the VHO. In the last section, the applicability and limitations are discussed and the future direction of research is presented.

2.2 Vertical handoff in heterogeneous wireless network

The prime objective of VHO is to achieve mobility within heterogeneous wireless networks. The heterogeneous wireless network consists of multiple wireless technologies to provide diversified services to the mobile users. Mobility management addresses the key issues of location management and handoff management. Location management tracks the UE for successful information delivery. Handoff management maintains the active connections to provide seamless connectivity with the UE, as they change their point of attachment to the network. In the converged HWN's, both intra-technology handoff and inter-technology handoff co-exist. Intra-technology handoff

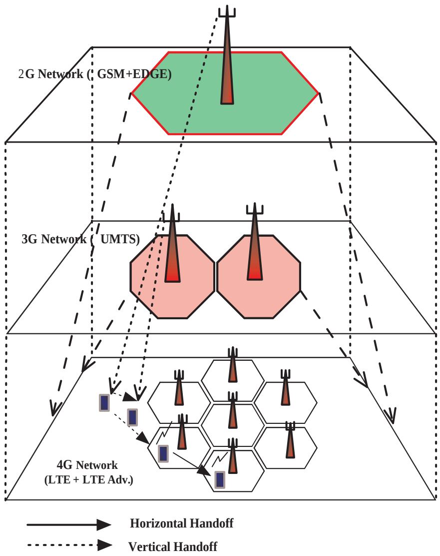

Figure 2.1: Vertical handoff in K-tier heterogeneous wireless network

is the traditional horizontal handoff process in which the UE handoff between two Access Points (AP) or base stations using the same access technology. On the other hand, inter-technology handoff, or vertical handoff, occurs when the UE roams between different access technologies, Figure 2.1 represents a case of HHO and VHO.

The main distinction between VHO and HHO lies in symmetry. While HHO is a symmetric process, VHO is an asymmetric process in which the UE moves between two different networks with different characteristics. This introduces the concept of a preferred network, which is usually the underlay in the desired HWNs, which provides better throughput performance, lower latency and error free at lower cost for the users. This is indeed noticeable that the advent of HWN allow for the deployment of non-homogeneous transceivers, with the advantage of improved spectral efficiency per unit area. One of the most important features of HWN is the possibility to access each tier of the HWN to the end users for availing all kinds of services available. Emerging archetypes for heterogeneous network architectures revolve around the notion of the heterogeneous wireless Network to provide 'Multiple tier', 'Multi-technology' and 'Multiple services'.

2.2.1 Multiple services

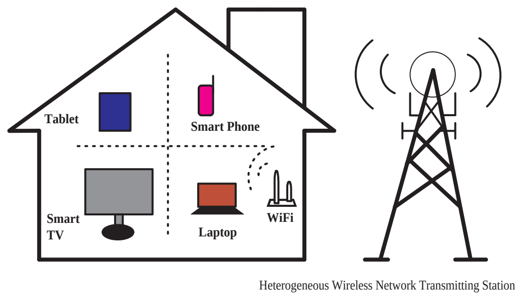

Figure 2.2: Multiple services provided by HWN

This term refers to the client experience when connecting to the edge of a network. Since there are often multiple service options, their associated service definitions can be varied based on the underlying network implementations [17]. As demonstrated in the fig 2.2 the smart home is presented with all types of connectivity through HWNs with the multiple applications.

2.2.2 Multiple technology

The discussed services are based on multiple technologies like time division multiple access (TDMA), frequency division multiplexing (FDMA), orthogonal frequency division multiple access (OFDMA) and IP-routed services as well. From lower layers based on technologies such as multi-protocol label switching (MPLS), wavelength-division multiplexing (WDM). Multiple technologies are implemented in HWNs to facilitate the operators to provide technologies such as IP, Ethernet, MPLS, T-MPLS, Synchronous Optical Networking (SONET), next- generation SONET, Asynchronous Transfer Mode (ATM) [36]. Through this technology the end users are availing the applications such as voice, data, multi-media, internet browsing, video streaming, telemetry etc [37].

2.2.3 Multi-tier heterogeneous network

A multi-tier wireless system integrates the high-tier wireless systems and the low-tier wireless systems into a single system to provide the advantages of both tiers. Such a system is expected to provide better service (more service availability and

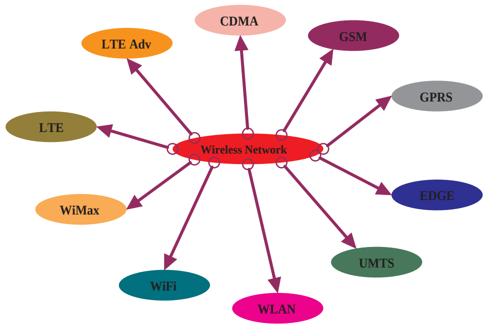

Figure 2.3: Multiple wireless networks available are demonstrated

more cost effectiveness to the users) at the expense of the extra tier- switching management. Examples of multi-tier systems include the interconnection network of a satellite communication network and a terrestrial cellular network, the integration of low-power systems such as wireless personal area networks and cellular systems, and the integration of higher mobility of cellular systems with low- mobility wireless local area networks as represented un the Figure 2.3.

In such a system, mobility management is critical, because only when the location of a mobile user is known or tracked, can the service quality for the user be guaranteed [38].

A mobile user who is streaming a music video on their smart phone while taking the bus to work will most likely leave the coverage area managed by one of its network providers base stations and move into the next closest one. Although the user does not realize it, there is a handshake that occurs and the users video streaming session is transferred from one base station to the other, seamlessly. In this scenario, because the networks consist of the exact same technology, it is considered to be homogeneous. In the heterogeneous case, the consideration is to move from one type of network technology to another one. The main difficulty here is that each technology behaves based on its own set of rules and languages, as a result, facilitating a common process across all these disparate technologies is no easy feat. The three main technologies leveraged in the experiments related to this thesis are Wireless Interoperability for Microwave Access (WiMAX), Wi-Fi, and UMTS [39].

2.3 Vertical handoff algorithms

Earlier studies on vertical handoff were based on various parameters and applicable for different network archetypes as per the attributes of the consideration. The factors considered for vertical handoff algorithms are, RSS, SINR, QoS, BER, security, type of networks, traffic model, area of operation etc. The quality of handoff depends upon the QoS of the service, quality of experience, latency, handoff failure rate, decreased handoff ping pong and the number of service with inter-technology support.

The basic type of handoff discussed in Fang and Imrich Chlamtac [40] introduced generalized analytical results for handoff probability, to reflect the realistic cases of emerging wireless systems.

Tariq Al, Mohammad Saquib and Chaitali [41] reported a realistic performance analysis by considering the sample RSS within the heterogeneous wireless network for the voice application within focused on WLAN only. However cases for other wireless networks while proposing the VHO are not considered here.

Ben Jye Chang and Jun Fu Chen [42] proposed a cross-layer-based adaptive vertical handoff algorithm with predictive RSS to reduce the unnecessary handoff while significantly increasing utilization and decreasing connection dropping. This approach determines the optimal target network in two phases. One is polynomial regression RSS prediction and another is Markov decision process analysis [43–45]. The result shows that the proposed scheme significantly decreases the VoIP packet loss probability, while the resulting increased total time required for the vertical handoff procedure was reasonable in the context of the 3G and WLAN handoff. A realistic performance analysis by considering the sample RSS within the heterogeneous wireless network for the voice application focused on WLAN only [41] by considering statistical properties of RSS the handoff algorithm was proposed. Here the authors only consider the RSS with the WLAN.

Celal eken,Serhan Yarkan and Hseyin Arslan [31] proposed an adaptive fuzzy-based handoff decision system which combines data and interference rate, RSS Index (RSSI) and speed parameters, in order to satisfy both user and network requirements for next generation wireless heterogeneous networks and the study reveals that interference plays a crucial role in making vertical handoff for next generation wireless networks.The work is silent about the QoS [41, 46, 47].

Foong Kwong, Chuah and Lee [48] proposed a similar approach to fulfil the different requirements of different segments especially in the hybrid satellite and terrestrial scenario. Using Adaptive Network Fuzzy Inference System (ANFIS) where the training element is incorporated into the existing the approach was newer but it was relevant to only two networks satellite and terrestrial type network type.

Kaveh Shafiee, Alireza Attar and Victor C. M. Leung [49] addressed the problem of optimal vertical handoff in a vehicular network setting, to investigate the VHO strategies in a random inter-distance scenario with both V2I and Vehicle-to- Vehicle (V2V) communication capabilities. The combination of WLAN plus cellular plus inter networking was considered.

Liu Xia and Jang Ling [50–52] proposed intelligent vertical handoff algorithms for 4G communication system, which mainly deals with a novel vertical handoff decision algorithm based on fuzzy logic with the aid of grey theory and dynamic weights adaptation. The approach predicted received signal strength in order to reduce the call dropping probability [46, 53]. The fuzzy logic theory based quantitative decision algorithm takes three quality of service (QoS) metrics, received signal strength (RSS), available bandwidth (BW), and monetary cost (MC) of networks. The authors limited their work to only to UMTS and WiFi.

Dongyeon Lee, Youngnam Han and Jinyup Hwang [54] proposed a vertical handoff decision algorithm based on the utility function to satisfy wireless QoS. The trade-off between handoff rate and throughput was done based on user's mobility.The network selection process in a heterogeneous wireless environment was not considered [55].

SINR as the key parameters for the VHO algorithms was focused in [18, 47, 55–57]. Sudipta, Sarma,Satapathy [58] proposed an algorithm based on the received signal to inference plus noise ratio (SINR) for handoff between GPRS and Wi-Fi networks. Ahmad Jabban, Youssef Nasser, Maryline Hlard [59]considered a new network selection strategy based on the estimated Signal to Interference-plus-Noise Ratio (SINR) value in an integrated heterogeneous wireless network, allowing users to select the network that has a higher SINR value from all the available networks during its communication [60].

Kemeng Yang, Iqbal Gondal and Bin Qiu, [61] proposed a multi-dimensional adaptive SINR based vertical handoff algorithm (MASVH) which used the combined effects of SINR, user required bandwidth, user traffic cost and utilization from participating access networks to make handoff decisions for multi-attribute QoS consideration.The consideration was for WLAN and UMTS networks. Yu Zhang,Zheng [47, 62] later proposed the extended version which provide seamless mobility and transmission in heterogeneous wireless networks with a vertical handoff technique to guarantee an always best connected and presented a cost-based vertical handoff algorithm with combination prediction of SINR (CPSVH) in heterogeneous wireless networks to make handoff decision. Their approach involves two steps, first SINR is predicted by combining GM (1,1) and BP neural network for accurate timing to trigger handoff, and then a handoff decision on the optimal network is made by way of a cost function.

Shengmei Liu, Zhongjiu Zheng and Su Pan [13, 63] proposed Preference Ranking Organization Method by Similarity to Ideal Solution (PROMSIS) vertical handoff algorithms for heterogeneous wireless networks, four 3GPP defined traffic classes are considered in performance evaluation [64–66]. An attribute matrix is constructed considering some major attributes. Handoff decision meeting multi attribute QoS requirement is made according to the traffic features [61].

Ardian Ulvan, Robert Bestak and Melvi Ulvan [26] [9] proposed the handoff procedure for LTE-based, femto-cell where the signalling flows in both horizontal and vertical handoffs, was analysed. Only the hand-in scenario was evaluated. The reactive handoff mechanism introduced to mitigate the unnecessary handoff. Though it was proved that the performance of reactive handoff is better, the further study is still needed when this algorithm is integrated with the RF and traffic criteria that have been assigned as the handoff initiation for all kind of 3GPP standards.

Anupama, Gowri, S Sri, B Prabakara and Murali, T Satya [67] presented an intelligent vertical handoff decision algorithm that selects the target network based on the traffic class of the mobile user. They used Fuzzy Logic and Genetic algorithm to make an intelligent vertical handoff decision. The algorithm uses only two modules, to estimate the handoff requirement to select the optimal network. Multiple network modules were not considered.

Tong, Dan Jia, Zhenhong and Qin, Xizhong and Cao Chuanling and Chang Chun [68] An optimal Savitzky-Golay filtering based vertical handoff algorithm is adopted, which equips the MS to decide network coverage boundaries accurately. The author applied the method for VHO in WLAN and LTE networks only.

Christopher, A Ferdinand and Jeyakumar [69] proposed a deployment of social context incorporated with vertical handoff and admission control algorithms called VHO-AC for the 4G-HWN environment only. The next genearation heterogeneous wireless networks are not considered.

Sun, Yong and Liu, Chao and Yang, Peng and Wen, Xiangming [70] the authors proposed a smart vertical handoff decision algorithm based on queuing theory. This algorithm formulates the whole heterogeneous wireless area and handoff procedure using queuing theory evaluated blocking probability of the network. Other performance parameters of VHO were not considered.

Kehal, Nimrat Kaur and Singh, Maninder [71] considered heterogeneous networks, sub networks (WLAN and WiMAX) to analyse vertical handoff and have discussed an approach to improve service quality in network. Used ASN (Access Service Network) anchored mobility for performance evaluation VoIP application, other applications were not considered in a heterogeneous wireless network environment.

Omheni, Nouri and Zarai, Faouzi and Obaidat, Mohammad S and Hsiao, Kuei-Fang [72] presented a novel approach for handoff decision making the context of heterogeneous wireless network. Proposed scheme was the selection of the most suitable radio access network for each application.

Du, Zhiyong and Wu, Qihui and Yang, Panlong [73] compared the mobile terminal signal strength ratio with the average signal strength ratio for proposing the handoff. They also added the hysteresis time while proposing VHO.

El Idrissi, Younes El Hajjaji and Zahid, Noureddine and Jedra, Mohamed [74] proposed the interworking of the 3G and the WLAN technique which can provide a perfect connectivity solution in terms of data rate, service cost and area coverage. A new simplified authentication method and key agreement for vertical and horizontal handoffs based on security was described. But the authors have not considered the cases of 4G and other heterogeneous networks.

Bo, Sui and Lin, Li and Feng, Dan [75] proposed multi-attribute based vertical handoff algorithm on node mobility model characteristics. The access point pre-switch to the adjacent access points, and when the signal coverage rate of the access point is below a pre-set threshold, handoff is triggered. The method considers only for WLAN and WiFi networks.

Phyu Sin Nein, Hla Myo Tun and Win Zaw Hein [76] demonstrated the performance of vertical handoff using the integration of 4G cellular and wireless local area networks as an illustration. They presented an analytical framework to evaluate the converged system performance, which is validated by computer simulation.

Bo, Sui and Lin, Li and Feng, Dan [75] proposed Multi-attribute based vertical handoff algorithm on node mobility model characteristics. The access point pre-switch to the adjacent access points, and when the signal coverage rate of the access point is below a pre-set threshold, handoff is triggered. The method considers only for WLAN and WiFi networks.

Shangguang Wang,Cunqun Fan, Ching-Hsien Hsu and Qibo Sun Fangchun Yang [77–80] proposed method support the VHO among wireless access in vehicular environments, WiMAX and introduced a VHO method based on a self selection decision tree, which can support the VHO among WAVE, WiMAX, and 3G cellular. The other network attributes and user preferences were not taken into account. Hence the further work focuses on how to optimize the proposed method by improving user preferences within heterogeneous wireless networks.

2.3.1 Classification of VHO Algorithms

There are various ways to classify VHO algorithms. Various vertical handoff algorithms are presented in the Table 2.3.1 with their area of applications and constraints.

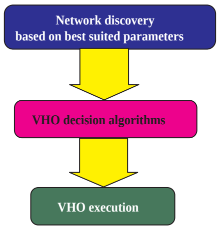

Figure 2.4: VHO phases

In this dissertation, VHO algorithms are divided into four groups based on the handoff decision criteria used and the methods used to process them.

2.4 Phases of VHO

The VHO process can be split into three stages as shown in Figure 2.4.

(i) During Network discovery phase, the UE determines which networks can be used and what services are available in each network. These networks may also advertise the supported data rates and quality-of-service (QoS) parameters for different services. Because the users are mobile, the available collocated networks depend on the location of the user. The traffic load in each network may also change with time. Thus, this phase may be periodically invoked.

(ii) In the VHO decision phase, the UE determines whether the connections should continue using the existing selected network or be switched to another network. The decision may depend on various parameters including the type of the application (e.g., conversational, streaming, inter- active, background), minimum bandwidth, and delay required by the application, access cost, receiving power RSS, latency of switching process, and the user's preferences.

(iii) During the VHO execution phase, the connections are rerouted from the existing network to another one in a seamless manner. This phase also includes the authentication, authorization, and the transfer of context information. Because the UE may still be communicating via the existing network while VHO execution is taking place. this provides enough time for the network to perform the necessary functions while minimizing any service disruptions. Today the diversified HWN consists of the wireless networks as shown in the Figure 2.4

Name	Method	Parameters Used	Suitable area of application	Constraints
RSS Measurement	Traditional	RSS with Threshold, Dwell Time	Reduces the handoff blocking	Low throughput and user preferences are not considered
Policy-enabled	Function	Cost function	Simplify handoff process, Speed up handoff decision	Increases the complexity, ambiguous handoff decision
Constraint MDP	User Centric	Connection duration, delay, bandwidth, cost, velocity	Reduce call dropping, monetary budget for connection	When user's velocity increased call dropping also increased
Cross-layer	User Centric	User preferences	Works well for both QoS and non QoS applications, reduces handoff delay	Many input from different layers and user for handoff trigger
Dynamic Decision model	User Centric	RSS, RSST, bandwidth, power	Simple and efficient, number of handoffs reduced	Suitable for soft vertical handoffs only
Quality Dependent	User Centric	Bandwidth, Power, Cost	Maximize the user's satisfaction level	Not considered the network parameters
SAW	MADM	Bandwidth, Delay, Jitter, Packet loss	Reduce processing delay and trusted handoff	Minimum number of parameters are considered
WPM/MEW	MADM	Bandwidth, jitter, delay, cost	Reduce processing delay and trusted handoff	Minimum number of parameters are considered
TOPSIS	MADM	SINR, data rate, bandwidth, cost	Excellent performance against requirement of traffic and user	QoS parameters are not considered
GRA	MADM	Bandwidth, jitter, delay, cost	T-DVHD reduces processing delay	handoff dropping rate is high
QoS Aware	Fuzzy	Bandwidth, jitter, delay, error rate	Good performance for delay sensitive applications	Bandwidth performance is moderate
Minimizing handoff using Genetic algorithm	Context aware	User, networks, and user device information	Fast handoff, less delay, minimum handoff, simple	Multimedia traffic is not considered
Congestion-aware	Game theory	Congestion on network traffic	Reduce congestion, service time and delay	Traffic type is not considered

Table 2.1: Different algorithms for vertical handoff

- RSS based vertical handoff algorithms
- Signal to Noise and Interference Ratio based VHOS
- Bandwidth based algorithms
- Latency and Cost based VHO algorithms
- Combination algorithms

RSS based algorithms:

RSS is used as the main handoff decision criterion in this group. Various strategies have been developed to compare the RSS of the current point of attachment with that of the candidate point of attachment. In RSS based horizontal handoff decision strategies are classified into the following six subcategories: relative RSS, relative RSS with threshold, relative RSS with hysteresis, relative RSS with hysteresis and threshold, and prediction techniques [41, 46, 81]. For VHD, relative RSS is not applicable, since the RSS from different types of networks can't be compared directly due to the disparity of the technologies involved. For example, separate thresholds for each network. Furthermore, other network parameters such as bandwidth are usually combined with RSS in the VHD process.

Signal to Noise and Interference Ratio based VHOS:

SINR is the key parameter for maintaining the QoS and throughput of the networks. So the SINR can be considered as the key parameter for vertical handoffs. So several vertical handoff algorithms are proposed based on SINR [13].

Bandwidth based algorithms:

Available bandwidth for a mobile terminal is the main criterion in this group of algorithms. In some algorithms, both bandwidth and RSS information are used in the decision process [47, 82, 83] . Depending on whether RSS or bandwidth is the main criterion considered in the algorithm.

Latency and Cost based VHO algorithms:

Using lower latency technique the fast Mobile handoffs can be achieved over different wireless technologies (e.g., WLAN, Cellular, WiMAX etc.). In each wireless technology has different layer 2 handoff procedures, and the best low-latency technique for each should be used to optimize the handoff performance. Further deployment and experimentation are required to determine which technique is best suited for heterogeneous wireless networks. Further the performance measurements and work on low-latency-over the specifications in collaboration with the appropriate wireless technology is required [83,84]. This class of algorithms combine metrics such as monetary cost, security, bandwidth and power consumption in a cost function, and the handoff decision is made by comparing the result of this function for the candidate networks [84]. Different 34 weights are assigned to different input metrics depending on the network conditions and user preferences.

Combination algorithms:

The main purpose of integrated UMTS/WLAN networks is to satisfy users requirements and improve utilization efficiency of radio resources. It is known that the disproportional distribution of mobile users and services occur in time and space domain in hotspots, as well as radio resource waste in other districts. Based on these facts, many worldwide organizations and projects have paid more and more attention to the cooperative UMTS/WLAN networks, including UMTSPP-LTE, E2R, WINNER, ETP of FP7, etc. Under the discussion above, it is necessary to provide seamless vertical handoffs between WLAN and UMTS cellular network in heterogeneous wireless networks. With regard to vertical handoff performance, there is a critical need for developing algorithms for connection management and optimal resource allocation for seamless mobility [85].

2.5 Performance evaluation of VHOS

The roaming of users in an multi-technology heterogeneous network parameters magnifies the mobility impact on the networks performance. The end user perceived service quality, necessitating novel mobility modelling and analysis approaches for performance evaluation. Ahmed H. Zahran, Ben Liang and Aladdin Saleh [86] presented and compared three mobility models in two-tier integrated heterogeneous wireless systems and proposed a general stochastic performance analysis framework based on application session models derived from these mobility models, applying it to a 3G-WLAN integrated system as an example [87]. Using the proposed modelling and analysis methods, the investigation done to find the impact of different parameters, including ubiquitous mobility with coverage, data throughput, probability of handoff failure, handoff delay and combination of these parameters.

2.5.1 Ubiquitous Mobility

The rate of enhanced heterogeneous wireless technology infrastructure facilities to the end users to be always connected is always in increasing trend. The handoff of an ongoing call among the networks present like home WiFi to the 2G/3G/4G or connected devices (mobile phone, tablet), to the workplace (company network and mobile devices), and everywhere in between through the ubiquitous mobility is a challenge. The user demands are becoming more to access any of the network to full fill the requirement. The ubiquitous mobility is so demanding today, hence finding a public telephone now a days is something like a treasure hunt. This perception of perpetually having access to the internet and its supporting telecommunication infrastructure is reinforced by numerous studies such as the, visual networking index, global mobile data traffic forecast update $(2011 - 2016)$. In 2011 the average connection speed increased by approximately sixty-six percent, where the downstream speed was calculated as 315 kbps. By 2016 an average consumer mobile connection will have a speed that surpasses 1 Mbps [88] . Given these measures, it is evident that society is moving in a direction of constant and complete connectivity. In order to meet this ever growing demand, it is important that network providers and device manufacturers effectively manage the heterogeneous network resources that are appearing within the environment. In doing so, not only will the customer be satisfied but it will lead to larger adoption and acceptance of the always connected mentality, driving more business.

2.5.2 Throughput

The throughput refers to the data rate delivered to the mobile terminals on the network. Handover to a network candidate with higher throughput is usually desirable.

2.5.3 Probability of handoff failure

A handoff failure occurs when the handoff is initiated but the target network does not have sufficient resources to complete it, or when the mobile terminal moves out of the coverage of the target network before the process is finalized. In the former case, the handoff failure probability is related to the channel availability of the target network while in the latter case it is related to the mobility of the user.

2.5.4 Handoff delay

Handoff delay is the duration between the initiation and completion of the handoff process, and is related to the complexity of the Vertical Handoff Decision making (VHD) process. Reduction of the handoff delay is especially important for delay sensitive voice or multimedia applications.

2.5.5 Combinational approach for VHO

These VHD algorithms attempt to use a richer set of inputs than the others for making handoff decisions. When a large number of inputs are used, it is usually very difficult or impossible to develop explicit analytical formulations of handoff decision processes. Due to this reason, researchers apply machine learning techniques to formulate the processes. The literature survey reveals that fuzzy logic and artificial neural networks based techniques are popular choices. Fuzzy logic systems allow human experts qualitative thinking to be encoded as algorithms to improve the overall efficiency [83]. If there is a comprehensive set of input-desired output patterns available, artificial neural networks can be trained to create handoff decision algorithms [57] . It is also possible to create adaptive versions of these algorithms which, through continuous and real time learning process, the systems can monitor their performance and modify their own structure to create highly effective handoff decision algorithms.

2.6 Evaluation of VHO schemes

VHO algorithms can be quantitatively compared under various usage scenarios by measuring the received signal strength of the UE, minimum and maximum handoff delays, the number of handoff,the number of failed handoffs due to incorrect decisions, and the overall throughput of a session maintained over a typical mobility pattern. These metrics are responsible for VHOS [31, 43].

2.7 Summary

A comprehensive overview of VHO and VHO algorithms are presented. These algorithms are categorized into four groups: RSS, bandwidth, cost function and combination based. VHO algorithms in the published research literature lack a comprehensive consideration of various network parameters, user mobility and user preferences. The research project presented in this thesis attempts to address this issue, and provides an integrated solution to the optimization of the VHO process. Hence, the framework for VHO is provided considering the most robust method of calculating the path loss through local terrain in the following chapters.

Chapter 3

Received Signal Strength Based Vertical Hand Off Scheme for K-Tier Heterogeneous Wireless Network

3.1 Introduction

A new VHO scheme by considering the local terrain as the pre-condition for estimating the path loss, which determines the RSS of the mobile receivers and based on the RSS the VHOS is proposed here. From the extensive review of the recent development in the wireless communication technologies, which spread with the advancement of multiple technologies such as GSM, UMTS, WLAN and LTE to form a heterogeneous wireless network. The heterogeneous wireless network intend to provide the end user an un-interrupted service for voice, data, multimedia, video streaming, telemetry etc.

The demand of such services are universally present at all locations. So the heterogeneous wireless network needs to provide ubiquitous coverage at all locations. Figure 3.1 represents a heterogeneous wireless network consisting of all generations of wireless technology, to provide coverage to an Indian environment. This integrated heterogeneous network is multi-tier and with multi-technology in nature. In this study the k-tier heterogeneous wireless network (KHWN) is considered to be the integration of all available wireless networks like GSM, UMTS, WLAN and LTE. The challenge is the interoperability with vertical handoff in KHWN. The co-existence of wireless communication technologies such as GSM, UMTS, LTE are represented as per the Figure 3.1 in a local terrain context.

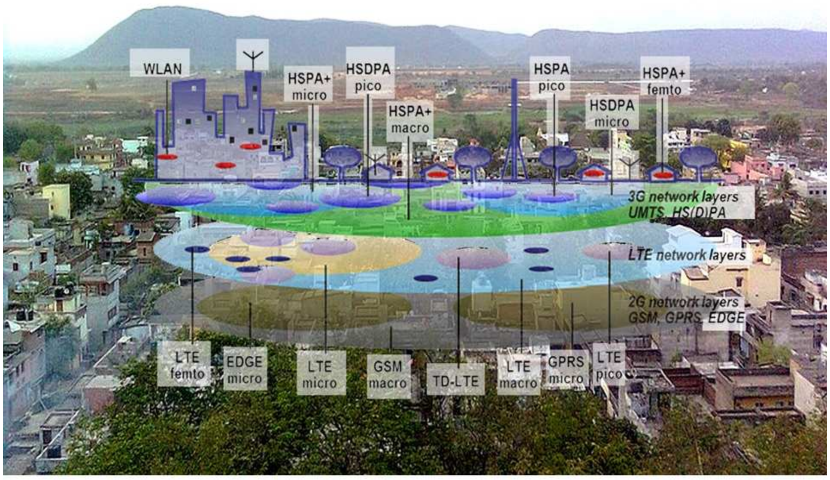

Figure 3.1: Heterogeneous wireless networks of local terrain

Each technology has its importance in terms of the bandwidth, signalling load, access speed and cost effectiveness which are dependant of the environment. So the terrain parameters directly influences the performance of the KHWN. Hence the priorities must be set to make a trade-off between QoS and cost to satisfy the need of the customer while providing better services. So without proper VHOS in KHWN, it is not possible to access the KHWN ubiquitously. In this scenario the end users UE is considered to be capable of accessing to the KHWN for subscribing all kinds of services. The user equipment(UE) periodically sends the signal strength measurement report based on the RSS through a common broadcast control channel which is common to the physical layer of each tier of the KHWN.

The RSS is estimated through various empirical and statistical models. The common terrain with certain model based RF signal loss reflected in the environment, Like Okumara-Hata model, which is widely-used. In KHWN environment, we are certainly using different frequency bands with different technologies coexist and work together [89]. So there should be certain robust model considering more local terrain and environmental conditions.

Estimating the RSS in KHWN some standard methods like Okumara Hata and followed Walfisch-Ikegami models were followed [90]. The limitations of such propagation models are; these are not suited for each and every type of environment conditions for estimating the path loss [91]. The RSS depends on the proper estimation of path loss for which a proper path loss model is needed to adopt. Hence the RSS is not independent of the pre-set environmental condition. The horizontal handoffs for various wireless technologies like GSM, UMTS are based on the RSS with a threshold, But in a scenario like KHWN, where multiple technologies and multiple applications are embedded, the traditional RSS based handoff will have the limitations. In the recent times the handoff in wireless communications are proposed mainly based on the parameters of RSS, signal to noise ratio (SNR), interference and bit error rate etc [31].

A number of VHOS are studied where the scheme proposes VHOS between either of two networks [92] taking various complex methods. From the literature study in chapter-2, it is well understood that no optimum path loss propagation models are proposed considering the local terrain. Once the local terrain based path loss model will be proposed the same path loss model can be applicable to other local terrains.

In this work the RSS is estimated from the proposed path loss model based on local terrain, considering all types of environments such as lower dense, moderately dense, higher dense, industrial area and market areas as environment conditions with the KHWN. From the proposed path loss model the RSS is estimated through empirical methods.

The proposed VHOS occurs between each tier of the network, after getting the proficiency and accuracy in the RSS measurement through the BCCH channel of the KHWN. The best suited empirical and statistical model is selected with the prior information of Indian terrain considering lower dense, moderately dense, higher dense, industrial area and market areas. The proposed empirical model aligns in accordance to the pre-set data, considering roof height, road width as normal random variables. These five parameters are modelled statistically, with the terrain information on, road width and roof top height, with height of base station, distance from base station. The model is validated by comparing the simulated results with the measurement campaigns carried out for the described Indian terrain. The new integrated KHWN concept is incorporated to achieve mobility within different tiers of networks using a VHOS based on the results of the RSS [93].

3.2 RSS measurement using empirical propagation models

The RSS is the measure of receiving power of a radio link. The measurement of signal strength at a receiving antenna is the method of determining the quality of services. Thus the RSS is a common factor to every kind of wireless communication methods. The RSS is based on certain factors like the transmitting power, receiver sensitivity, antenna gain, connector loss, antenna height and path loss. Among these factors the path loss is dynamic and complicated to estimate because it directly depends upon the environment of different terrain, varies location to location. For this the path loss models were proposed earlier [25].

3.3 Path loss propagation models

The path loss prediction in micro cell, pico cell, fem too cell are confined through the propagation models. The various path loss models in the literature comprehensibly presented and discussed. The below mentioned empirical path loss models are analysed and simulated. The results are compared with the proposed local terrain based path loss models. Below mentioned available path loss models are discussed.

1. Free space path loss model
2. Okumara-Hata model
3. Walfisch Ikegami Model
4. Dual slope model
5. Berg model

3.3.1 Free space propagation model

The field strength of an emf-wave decreases with an propagation to the distance. considering on ideal some of omni directional transmitter $T_1 \rightarrow$ transmitting power P_1

Uniformity in all direction with a radius of $d_1 \rightarrow$ of the area The power density will be

$$\gamma = \frac{P_1}{4\pi^2 d_1^2} {}^{w}\!/_{m^2} \tag{3.1}$$

In the ideal case the antennas transmit the main part of the transmitted power in a preferred direction. The relation of antenna gain G_T is with respect to the isotropic radiation. So the effective isotropically radiated power.

$$EIRP = P_T G_T = P_1 \tag{3.2}$$

An antenna with gain G_T which transmits the power P_1 on to uni-direction. The power density will be

$$P_d = \frac{4\pi}{P_1 GT} \tag{3.3}$$

So the power density flow (Power par unit area) through spherical plain with radius d will be

$$P = \frac{P_T G_T}{4\pi d^2} \tag{3.4}$$

The power received R_p will be the product of power density, the effective antenna area. The wave length λ and gain of the receiving antenna.

$$R_P = P_T G_T G_R \left(\frac{\lambda}{4\pi d^2}\right)^2 \tag{3.5}$$

The term $\left(\frac{\lambda}{4\pi d^2}\right)$ is referred as the Free space path loss

Representing above in logarithmic from, the difference$T_p - R_p$ is expressed as $-10\log\left(\frac{R_p}{T_p}\right)$

The free space path loss F_L results can be derived as

$$F_L = -10\log(G_T) - 10\log(G_R) + 20\log(f) + 20\log(d) - 20\log\left(\frac{C}{4\pi}\right) \tag{3.6}$$

where $C = \lambda f$ The expression can be reduced as

$$F_L = -20\log\left(\frac{\lambda}{4\pi d_1}\right) \tag{3.7}$$

$$F_L = -20\log\left(\frac{R_P}{T_P}\right) \tag{3.8}$$

The model of path loss is estimated is estimated through the logarithmic distance P_{d_i} and the d_i power decaying index from equation 3.7 and equation 3.8.

This model is fixed for one type of scenario and can be expressed as -

$$pathloss = L_f + 10P_{d_i} log_{10}\left(\frac{d}{m}\right)$$

3.3.2 Dual slope model

The model intended to find out the path lan behaved differently at c loss distance ranges

$$L_1\left(d\right) = 10r_1 \log_{10}\left(\frac{4\pi d}{\lambda}\right), \quad a_0 \quad for \quad d < d_{Bx} \tag{3.9}$$

$$L_2\left(d\right) = L_1\left(d_{bx}\right) + 10r_2 10 \log_{10}\left(\frac{d}{d_{bx}}\right) ford \geq d_{br} \tag{3.10}$$

$\lambda =$ signal wave length $d_{bx} =$ break point distance $r_1 =$ power decaying index before d_{br} r_2 =Power decaying index before d_{bx} $a_0 =$ differ bet real loss

Free space loss a_0 varies from $0db$ to $5db$ as a effect of wave guiding.

3.3.3 Okumara and Hata model

After doing various measurements within different environments, the correction to free space model has been model introduced in Okumara Hata model for the frequency band of 400mhz to 900mhz. The Okumara and Hata model was claimed to be best suited for urban and sub-urban environments, the path loss model is represented in equation 3.12

$$\begin{aligned} pathloss \quad L = {} & 69.55 + 26.16 \log_{10}\left(\frac{f}{MHz}\right) - 13.82 \log_{10}\left(\frac{b_m}{m}\right) - acf \\ & + \left(49.9 - 6.55 \log_{10}\left(\frac{h_b}{m}\right)\right) \log_{10}\left(\frac{d}{km}\right) \end{aligned} \tag{3.11}$$

F carrier frequency $H_b =$ base station antenna height $A(cf) =$ correlation function $d =$ distance between transmitter and receiver

3.3.4 Walfisch Ikegami model

Considering the microwave propagation above the roof top, the Walfosh Ikegmi(or cost 231) model was proposed. This model is based on theoretical analysis of Walfisch Britoni model developed by Walfish and Britoni in 1988 to get the multiple diffraction loss for the BS antennas of more hight. The model takes into account free space loss and loss due to diffraction down to the street and buildings etc so the path loss loss was expressed as

$$L = L_F - 16.9 + 10\log_{10}\left(\frac{w}{m}\right) + 10\log_{10}\left(\frac{f}{MHz}\right) + 20\log_{10}\left(\frac{\Delta hm}{m}\right) + L\left(\phi\right) + Lms \tag{3.12}$$

W = with of the street L_t = free space loss f = Career frequency Ahm = height of mobile antenna Lms = diffraction loss

$$L\left(\phi\right) = \begin{cases} -9.646 & for\ 0^0 \leq \phi < 3\pi \\ 2.5 + 0.075\left(\phi - 35\right) & for \quad 35^0 \leq \phi < 55^0 \\ 4 - 0.114\left(\phi - 55\right) & for \quad 55^0 \leq \phi \leq 90^0 \end{cases} \tag{3.13}$$

The Walfisch Ikamy model performance is limited when the BS is lower than the roof top, So in the area where high rise buildings are located the W.I model is not applicable.

3.3.5 Berg model

This model is introduced in 1995 by Berg, which was focused on the outdoor path loss, in a environment where the street surrounds with the high rising buildings and the BS antenna heights taller then the buildings. If the signal originated form the BS is S_bs, the RSS behaves as if the signal originates form a virtual transmitter located in the proximity to the street crossing.

So the Berg model introduced a continuous path loss as a form of the angle Θ of the road turning. So the path loss is represented as

$$L = 20log_10(4\pi * d_f/\lambda) \tag{3.14}$$

d_l= 'illusory' distance, defined by the recursive expression. considering 3 segments of the $d_0 = 0$ $d_m = KM$

3.4 The Proposed Path Loss Model

The proposed path loss model is based on the collection of Indian local terrain information and the multiple wireless technologies in the KHWN. In this work the scenarios of KHWN from femto cell to macro cell is considered, where access point (AP) of each tier has the different receiving power throughout the entire network coverage area. The 1st and 2nd tiers considered are GSM, UMTS micro cell and LTE, Pico cell respectively. The third tier is WLAN for femto cell. The entire coverage is assumed to be k-tier providing uniform coverage with different transmitting and receiving powers. Several statistical and empirical propagation loss models for estimating RSS are provided in the literature [93]. These propagation models are based on extensive experimental and statistical data considering various Indian terrain environments represented below.

1. Low dense populated area
2. Moderate dense populated area
3. High dense populated area
4. Industrial area
5. Congested Market area

The model also proposes the path loss model for all the networks of the KHWN such as GSM, UMTS, WALAN and LTE.

3.4.1 GSM and UMTS network

Considering the above defined Indian terrain condition the path loss model proposed are extension of the COST 231 Walfisch-Ikegami propagation model and the Hata-Okumura models [94]. These are considered as the correction for environment based path loss models and are the combination of path loss models from J. Walfisch and F.Ikegami model, based on numerous site tests and analysis. Considering the GSM and UMTS cellular networks are deployed as micro cells within the 0.5 kilometre. The licensed frequency bands for GSM/UMTS in the Indian sub-urban environment are 900 MHz, 1800 MHz and 1900 MHz band. So considering the micro cell as first of the k-tier of wireless network spread for It is appropriate for flat suburban and urban areas that have consistent building heights, and large population areas with densely locate buildings such that the cell radius can be less than 1 km. It calculates the multiple screen forward diffraction loss of base station antenna. This gives a better path loss prediction can be presented as 3.26.

$$\begin{aligned} P_L = 59.86 + 20\log(f) - 10\log(w) + 10\log(f) + 20\log(h\_roof - h\_UE) \\ - 18(1 + (h\_TX - h\_roof)) + (h\_TX - h\_roof) + 18\log(d) \\ - [4 + 0.7(f \div 925 - 1)]\log(f) - 9\log(b) \end{aligned} \tag{3.15}$$

where P_L is the path loss in dB, d is the distance between UE and the Transceiver in Km, f is the frequency in MHz, w is the mean value for width of the street in meters, h_roof is the mean value of height of the buildings in meters, h_UE is the height of the UE in meters, h_TX is the height of the transceiver in meters, b is the mean value of building separation in meters.

3.4.2 Wireless Local Area Network

In the KHWN, WLAN has an important application for in-building solutions by deploying as femto cells. Integration of femto cells in a KHWN like WLAN system possess the biggest design challenges, As its difficult to predict the propagation of radio wave in an indoor environment. In the 802.11 WLAN work group with the

2.5 GHz frequency band, characterization of the indoor radio propagation channel is essential. The empirical model helps to reduce the computational complexity. So we have taken Log Normal path loss model, which is best, suited for femto cell range with 2.5 GHz frequency range [13].

The path loss for WLAN (PL_{WLAN}) in dB can be expressed as

$$PL_{WLAN} = PL(d_0) + 10n\log(\frac{d}{d_0}) + X_\sigma \tag{3.16}$$

Where $PL(d_0)$ is the path loss w.r.t the reference distance d_0, n is the path loss exponent, d is the separation between transceiver and UEs in meter. X is a zero mean Gaussian distributed random variable with standard deviation . The reference distance d_0, the path loss exponent n and the standard deviation σ, statistically describes the path loss for an arbitrary distance between transceiver and UE.

3.4.3 LTE advanced network

LTE Advanced is a mobile communication standard, formally submitted as a candidate of 4G system to International Telecom Union(ITU) in 2009 and accepted in march 2011. This is standardized by the 3rd generation partnership project (3GPP). One of the important advantages of LTE Advanced is the ability of advanced network optimization for KHWN with a mix of macro cells with low power Pico and femto cells. The Pico cell range varies up to 200 meters and the femto cell coverage range extends up to 12 meters. The path loss in dB is estimated by the proposed used Advanced empirical model considering the local terrain data inputs.

$$PL_{LTE} = 69.55 + 26.16\log(f) - 13.82\log(h_{TX}) - C_H + [44.9 - 6.55\log(h_{UE})]\log(d) \tag{3.17}$$

For sub urban and urban areas in India, taken data from Municipality Corporation

$$C_H = 0.8 + (1.1\log(f) - 0.7)h_{UE} - 1.56\log(f) \tag{3.18}$$

C_H is the antenna height correction factor in dB.

3.5 RSS estimation based on proposed path loss model

As described above from the proposed path loss models the RSS can be estimated through the empirical methods. The empirical method is applicable to all tiers of networks in KHWN.

3.5.1 GSM and UMTS

The RSS for GSM micro cell in the KHWN is expressed in dBm as

$$RSS_{GSM/UMTS} = P_{TX} + \sum G_T - \sum A - P_L \tag{3.19}$$

Here RSS of GSM/UMTS is expressed and the transmitted power of the transceiver is expressed in dBm. G_T is the antenna gain in dB, A is the loss of RF connectors at the transceiver end.

3.5.2 Wireless local area network

The received signal strength (RSS_{WLAN}) in dBm, according to the path loss can be estimated.

$$RSS_{WLAN} = P_{TR} - PL_{WLAN} \tag{3.20}$$

The $P_T R$ is the actual transmitted power by the transceiver station, in dBm. The VHO takes place when the RSS obtains above a certain threshold interference sensitivity level.

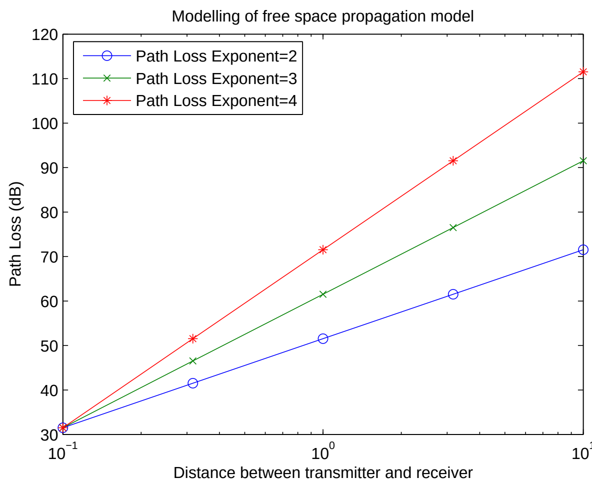

Figure 3.2: Free Space Path loss model: Represents the free space path loss model, the plot seems is straight as there is no loss in a free space model

3.5.3 LTE advanced network

The RSS for advanced LTE is evaluated in dBm as

$$RSS_{LTE} = P_{TX} + G_T + G_{RX} - PL_{LTE} - A \tag{3.21}$$

where $G_{RX}$is the gain of the receiver in dB.

3.6 Performance based analysis of RSS in a K-tier heterogeneous wireless network

The performance of RSS is analysed based on existing empirical path loss models with the proposed local terrain based path loss model. With the local terrain data the path loss for different networks are having better values. The details are demonstrated in the simulation results.

3.7 Simulation Result and Performance Analysis

The free space path loss model simulation is represented as in Figure 3.2

The Okumara and Hata model are simulated for the analysis of path loss for

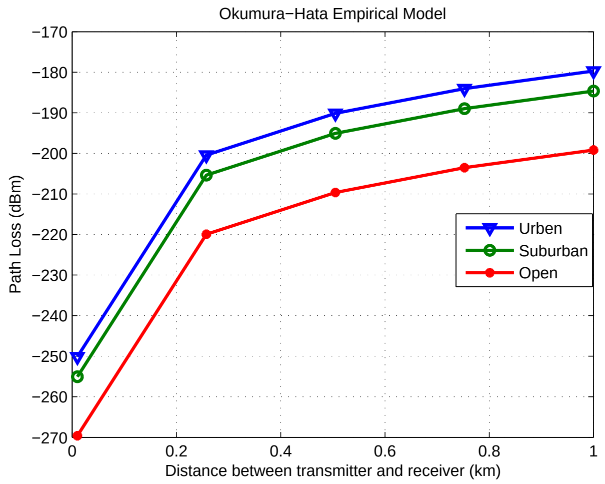

Figure 3.3: Okumara and Hata model: The path loss is simulated using Okumara and Hata model considering the estimated data inputs

estimated data inputs represented in Figure 3.3

The two ray model path loss model is represented in Figure 3.4

Walfish 1 Ikegmi path loss model is demonstrated in the Figure 3.5.

Considering the Berg Model the path loss simulation is demonstrated in the Figure 3.6. The comparison of the existing path loss models are represented in the Figure 3.7. From the comparison result the W.I model has the better performance which is best suited for urban environment. From the Figures of proposed model it is found that the proposed model has the better performance than the existing empirical models. The proposed scheme is evaluated with the parameters for simulations are presented, considering the urban and sub urban terrain of India. In table 3.7 presents the network parameter considers for the different networks are presented accordingly simulation has been done.

The GSM and UMTS path loss models are presented in fig 3.8.

For LTE the path loss and RSS simulation is shown below in fig 3.10 and Figure 3.24.

The performance of path loss and RSS of KHWN is calculated from the simulation result. The RSS threshold for different Networks in each tier is estimated in Table-1

Table 3.2 shows the environmental and path loss parameters of KHWN based on the Indian terrain data, collected from Municipality Corporation, Rourkela. The

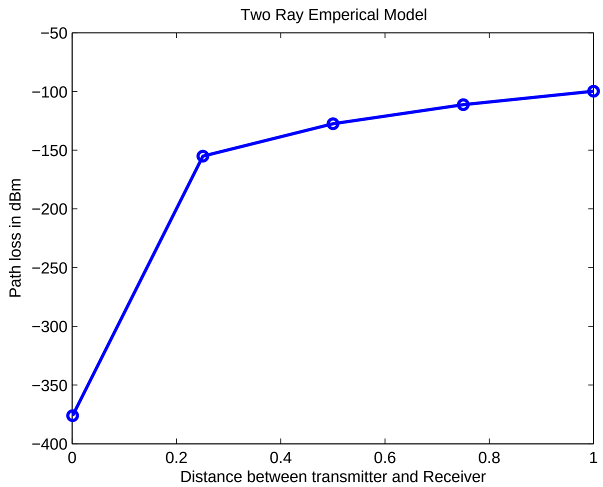

Figure 3.4: Path loss using Two Ray model

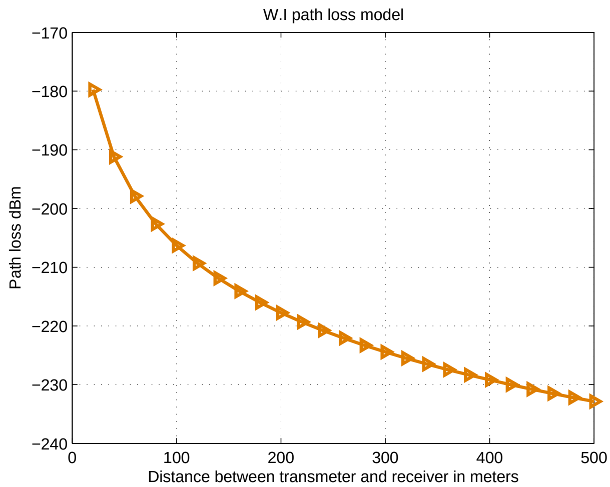

Figure 3.5: W.I path loss model

Network Type	Transceiver output Power	Frequency Band	Gain of the TX Antenna	Gain of UE's Antenna	Duplex-er RF connector loss	RSS Thres-hold
GSM	-45dBm	900 MHz	15dB	1 dB	2 dB	-115dBm
UMTS	-43dBm	1900 MHz	17dB	2 dB	1.5 dB	-100dBm
WLAN	-47dBm	2500 MHz	18dB	4 dB	0.55 dB	-90dBm
LTE	-23dBm	2400 MHz	14dB	3 dB	0.45 dB	-80dBm

Table 3.1: The KHWN parameter details are represented

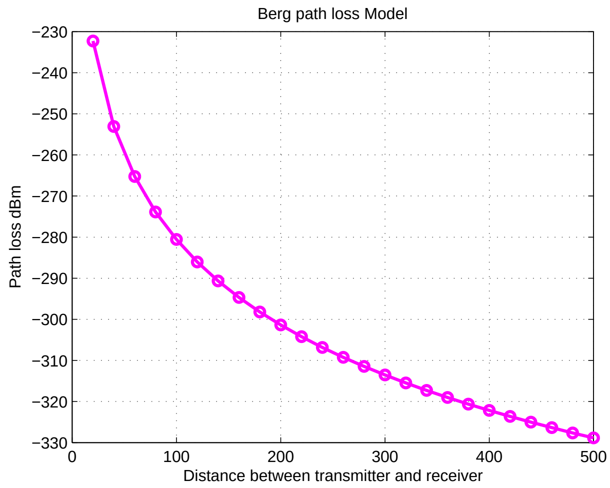

Figure 3.6: Path loss using Berg Model

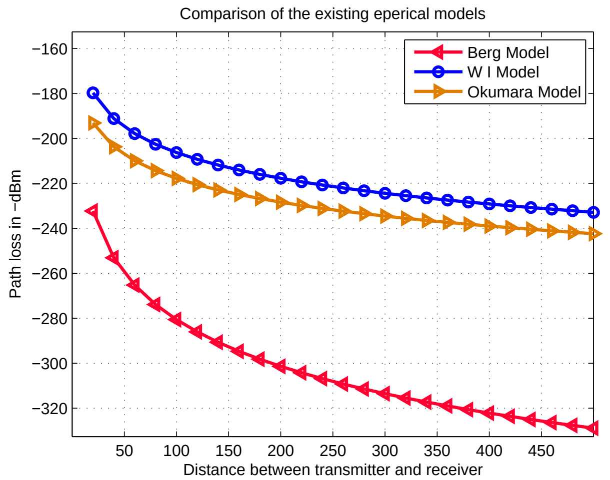

Figure 3.7: Comparison of existing path loss models

Parameters	Values
Average Height of the Transceivers GSM, UMTS,WLAN, LTE Networks	45,40, 25, 30Mtrs respectively
Average height of the Receiver UE	2.5Mtrs
Mean Height of the Buildings	12Mtrs
Mean width of the Road	6Mtrs
Mean Separation of Buildings	8Mtrs
Duplexer and connector loss	2dB
Path loss exponent for highly dense populated area	1.92
WLAN reference distance (30mtrs) mean path loss	49.76dB

Table 3.2: Indian terrain highly dense populated environmental data are represented

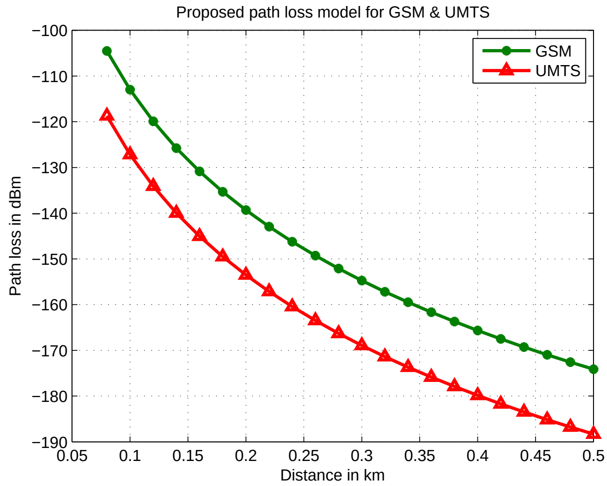

Figure 3.8: Proposed path loss estimation with respect to the distance between transmitter and receiver for GSM and UMTS networks

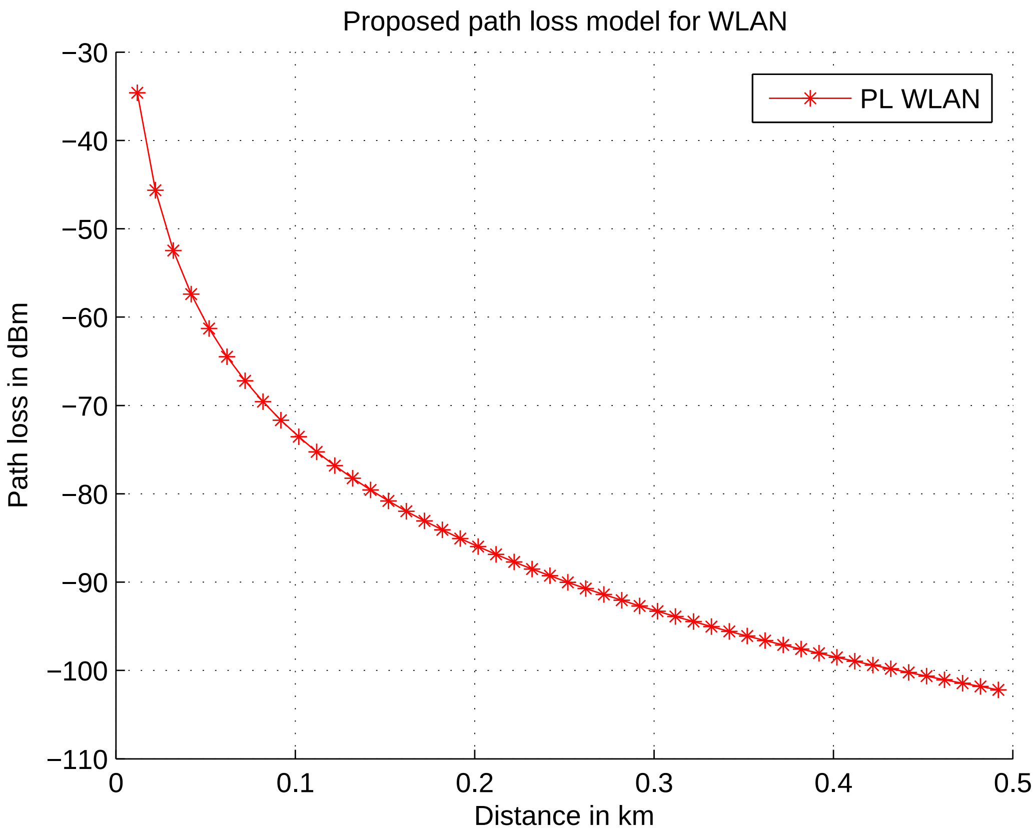

Figure 3.9: Proposed path loss estimation with respect to the distance between transmitter and receiver for WLAN

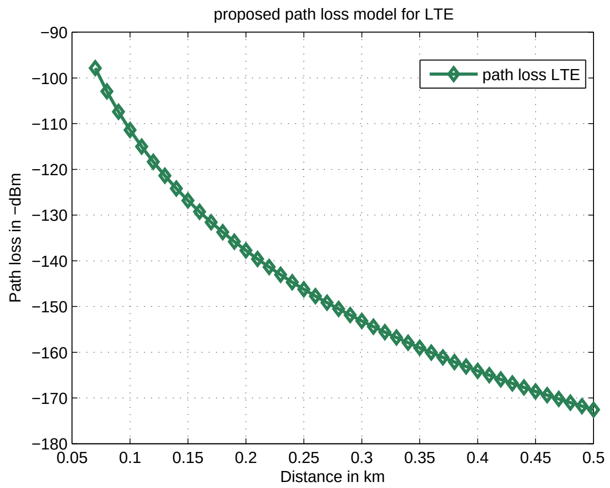

Figure 3.10: Proposed path loss estimation with respect to the distance between transmitter and receiver for LTE network

Parameters	Values
Average height of the transceiver of GSM, UMTS, WLAN, LTE	50, 40, 25, 20 in meters
Average height of the receiver	1.5 Mtrs
Mean height of the buildings	4 Mtrs
Mean width of the road	4 Mtrs
Mean separation of the building	6 Mtrs
Path loss exponent	1.8
Reference distance, mean path loss	40.8 dB

Table 3.3: Lower dense populated area environmental data

simulation results given in Figs.1, 3, and 5 shows for the path loss of GSM, UMTS, WLAN and LTE networks. The path loss for GSM varies from 105 to 165 dBm with a distance of 0.5 Km with the terrain data collected and estimated, while for UMTS it varies from 120 to 180 dBm.

In the Table 3.3 the low dense populated area environmental data are represented based on this the path loss and RSS are estimated the RSS for low dense populated area in a KHWN environment are represented in the simulations

From the data represented in the Table 3.6, the RSS can be estimated for the KHWN, The RSS is estimated for each network located in the market dense area. The simulation results are represented in Figure

From the path loss model the RSS is estimated and simulated from the same

Parameters	Values
Average height of the transceiver of GSM, UMTS, WLAN, LTE	40, 30, 20, 18 in meters
Average height of the receiver	2.0 Mtrs
Mean height of the buildings	6 Mtrs
Mean width of the road	5 Mtrs
Mean separation of the building	8 Mtrs
Path loss exponent	1.7
Reference distance, mean path loss	40.8 dB

Table 3.4: Moderate populated area environmental data are presented

Parameters	Values
Average height of the transceiver of GSM, UMTS, WLAN, LTE	40, 30, 10, 10 in meters
Average height of the receiver	1.0 Mtrs
Mean height of the buildings	15 Mtrs
Mean width of the road	6 Mtrs
Mean separation of the building	7 Mtrs
Path loss exponent	1.9
Reference distance, mean path loss	39.8 dB

Table 3.5: Industrial and environmental data are presented

Parameters	Values
Average height of the transceiver of GSM, UMTS, WLAN, LTE	30, 25, 18, 15 in meters
Average height of the receiver	1.0 Mtrs
Mean height of the buildings	2.5 Mtrs
Mean width of the road	2.8 Mtrs
Mean separation of the building	2 Mtrs
Path loss exponent	1.92
Reference distance, mean path loss	42.8 dB

Table 3.6: Market area with the environmental data are represented

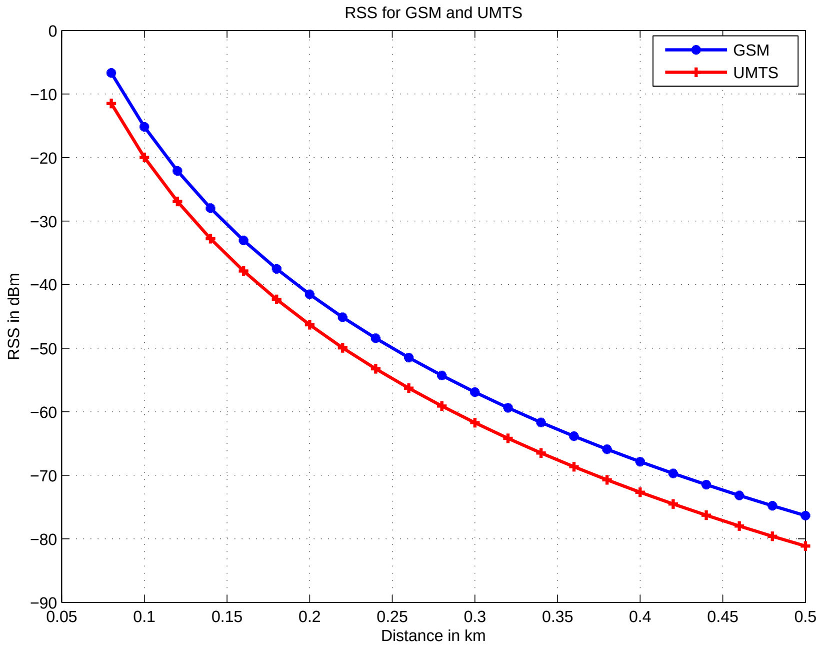

Figure 3.11: RSS of GSM and UMTS networks: Considering the highly dense populated area

statistical data based on the path loss model as discussed earlier. From the simulation the RSS for GSM varies from -35dBm to 95dBm for a distance of 0.5 Km and for UMTS the RSS varies from -20 to -95 dBm. As shown in simulation plot in Figure 3.11. Based on the local terrain the RSS is estimated in the simulation results in Figures 3.14, 3.11, 3.13, 3.15, 3.12.

Similarly the path loss plot for WLAN is simulated from the data provided in Table 3.2 and 3.7. The simulation is based on equation. The path loss varies from 30 to 105 dB and the RSS is estimated from the statistical and empirical model and data as discussed earlier. From the simulation result it shows the RSS varies from -20 to 85 dBm for a distance of 0.5 Km in the terrain of Indian urban and sub urban areas. The simulation plot is shown in Figures 3.19, 3.20, 3.18, 3.17.

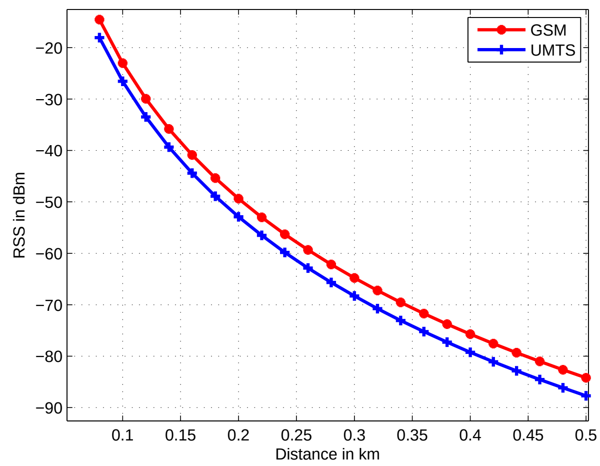

Figure 3.12: RSS estimation for GSM/UMTS network considering the moderately dense area

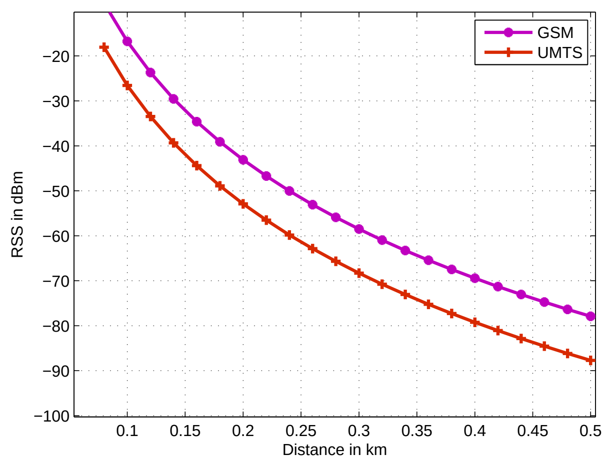

Figure 3.13: RSS estimation for GSM/UMTS network considering the industrial area

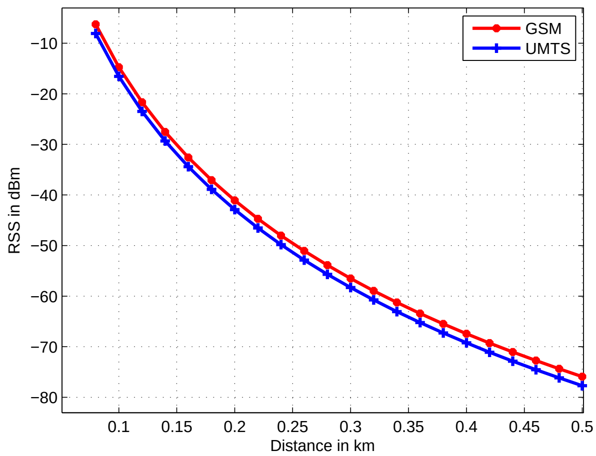

Figure 3.14: RSS estimation for GSM/UMTS network considering the low dense area

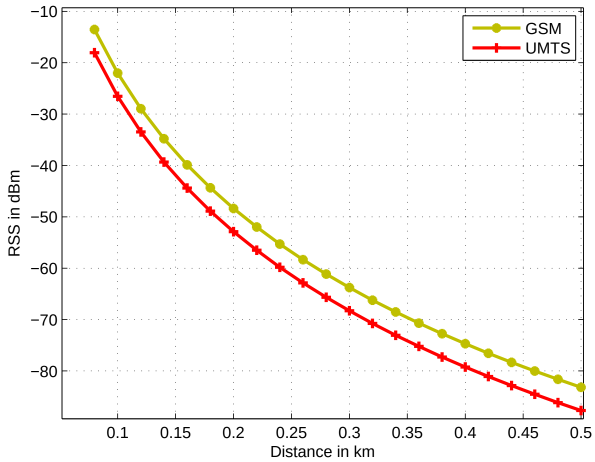

Figure 3.15: RSS estimation for GSM/UMTS network considering the dense market area

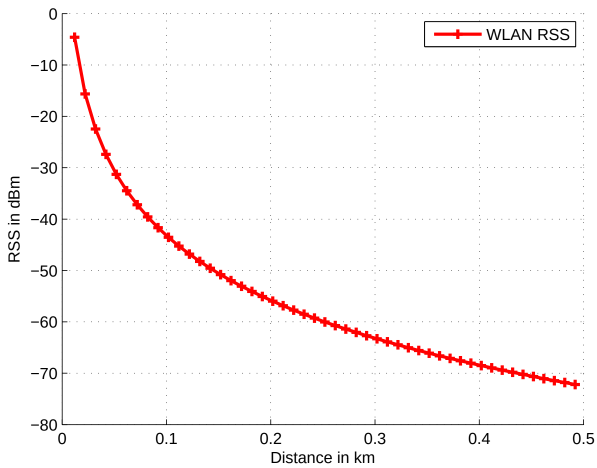

Figure 3.16: WLAN RSS(Lower populated area): Through the proposed path loss model considering the lower dense populated areas

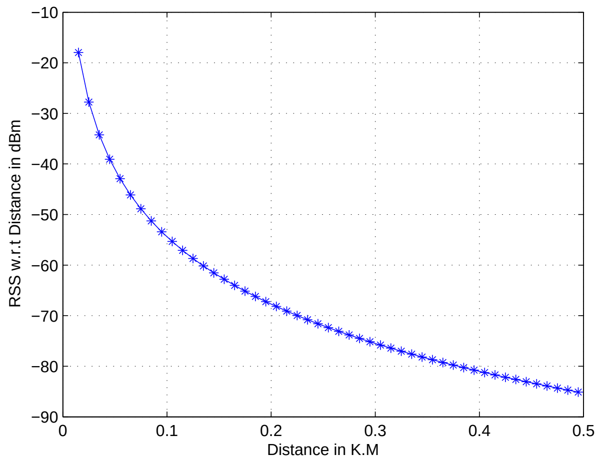

Figure 3.17: RSS estimation for WLAN in low dense area

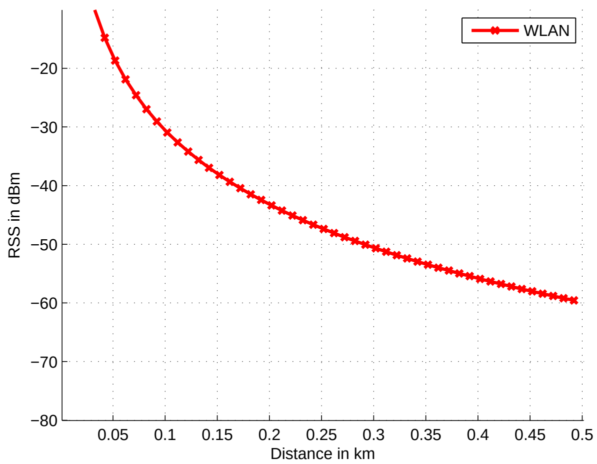

Figure 3.18: RSS estimation for LTE network considering the moderately dense area

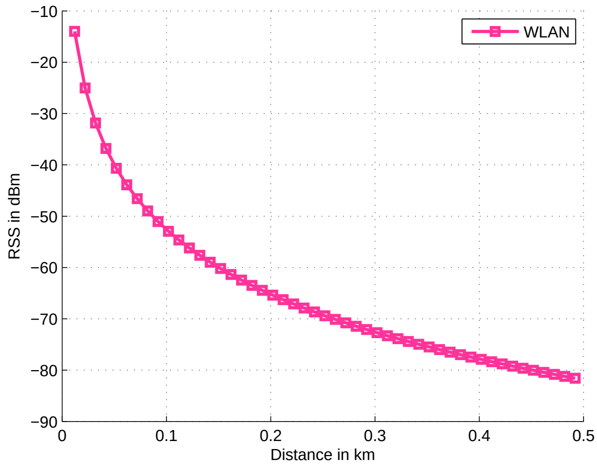

Figure 3.19: RSS estimation for WLAN network considering the dense market area

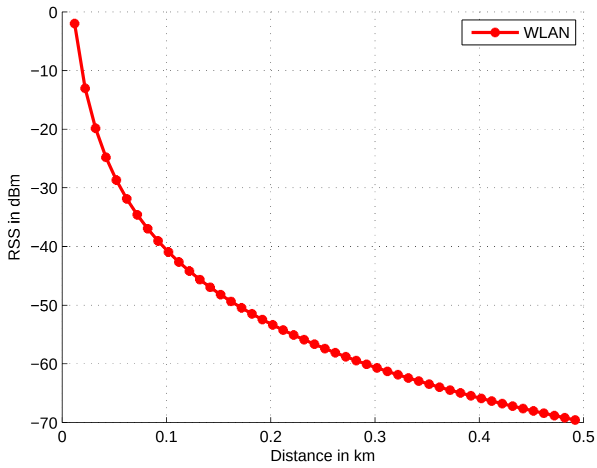

Figure 3.20: RSS estimation for WLAN network considering the industrial area

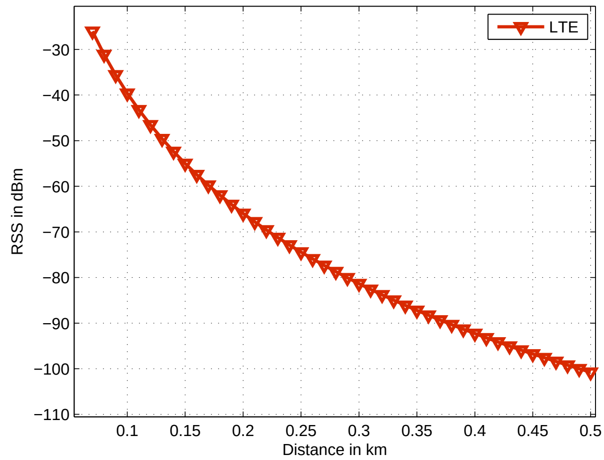

Figure 3.21: RSS estimation for LTE network considering the dense moderately dense area

For the LTE network the RSS estimated in the simulation represented in Figures 3.24, 3.21, 3.22, 3.25, 3.23.

The comparison of the RSS for each tier of the Network simulation is as shown in Figures 3.26, The handoff region are marked accordingly.

3.8 RSS based VHO Scheme

In the KHWN, the accessibility of the UEs can be dedicated for voice and data. The voice call is preferred in circuit switched (CS) domain of networks, GSM and UMTS and the packet switched (PS) networks, LTE and WLAN bandwidth and signalling cost are taken into account. The UEs send measurement reports of RSS for all the adjacent Transceivers in the k-tier heterogeneous network through the broadcast control channels (BCCH) [95]. When a call is initiated the UE measures the current RSS of the networks. The VHO scheme for voice and data call are proposed below:

VHOS for voice call

- If $R_G < R_{thGSM} + h_V$ and $R_U \geq R_{thUMTS} + h_V$ then the handoff is done from GSM to UMTS.

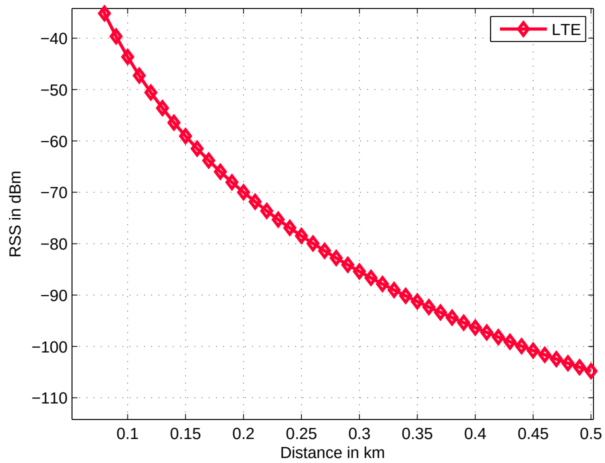

Figure 3.22: RSS estimation for LTE network considering the highly dense area

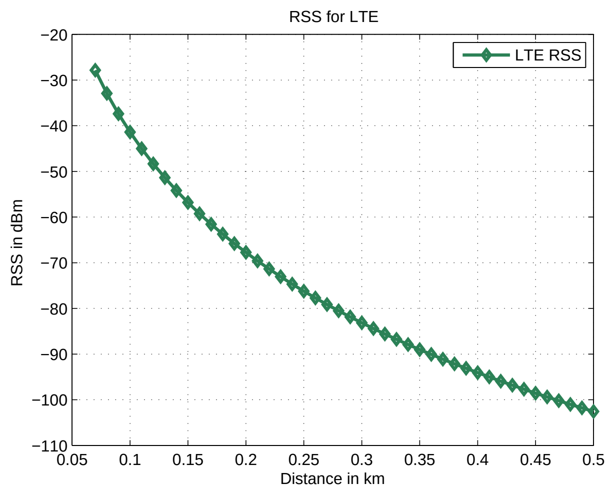

Figure 3.23: for LTE network considering the industrial area

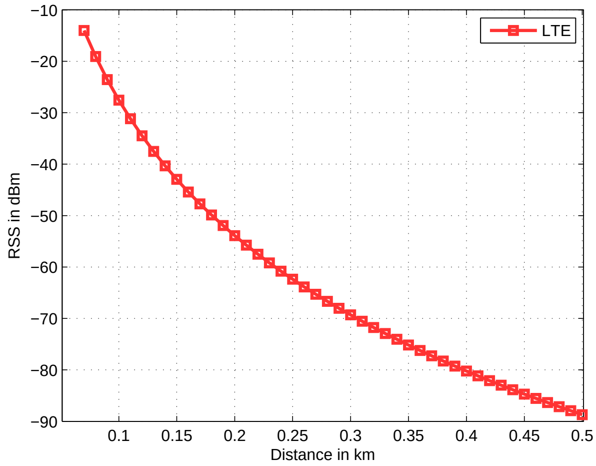

Figure 3.24: RSS estimation for LTE network considering the lower dense population area

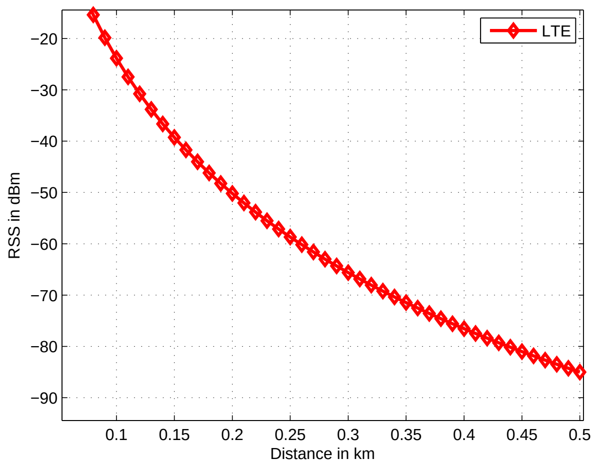

Figure 3.25: RSS estimation for LTE network considering the dense market area

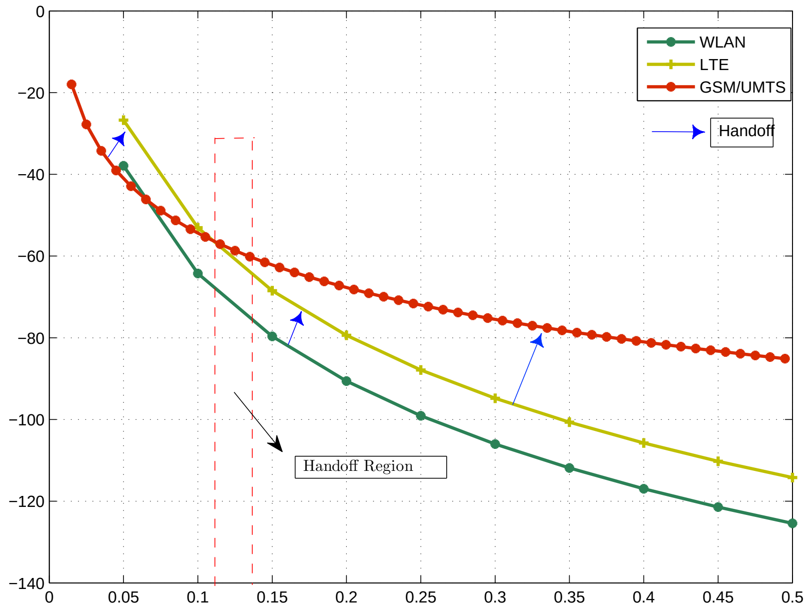

Figure 3.26: Combined RSS for KHWN: The handoff regions are marked

- If $R_U \leq R_{thUMTS} + h_V$ and $R_G > R_{thGSM} + h_V$ Then the Handoff is done from UMTS to GSM.

- If $R_G < R_{thGSM} + h_V$ and $R_U \geq R_{thLTE} + h_V$ Then the handoff is done from GSM to LTE.

- If $R_U \leq R_{thLTE} + h_V$ and $R_G > R_{thGSM} + h_V$ Then the Handoff is done from LTE to GSM.

VHOS for Data call

- If $R_W < R_{thWLAN} + h_D$ and $R_L \geq R_{thLTE} + h_D$ Then the handoff is done from GSM to UMTS.

- If $R_L R_{thLTE} + h_D$ and $R_W > R_{thWLAN} + h_D$

- If $R_U < R_{thUMTS} + h_D$ and $R_L \geq R_{thLTE} + h_D$ Then the handoff is done from UMTS to LTE.

- If $R_L R_{thLTE} + h_D$ and $R_U > R_{thUMTS} + h_D$

The R_{GSM}, R_{UMTS}, R_{LTE} and R_{WLAN} are the current RSS of the GSM, UMTS, LTE and WLAN networks at a reference point 'p' respectively. The threshold set for GSM, UMTS, LTE, WLAN are R_{thGSM}, R_{thUMTS}, R_{thLTE} and R_{thWLAN} respectively. These are the threshold RSS values set for each network, beyond this the call gets transfer to another network or the same network considering the measurement report and type of access, voice and data, But considering only the threshold values cause ping pong handoff and that increases the signalling load of the entire network. So the hysteresis values set to avoid the problem. The hysteresis for voice call is h_V and for data is h_D typically in the order of +3dB and +6dB respectively.

3.9 Summary

In this chapter the path loss and RSS for all the KHWN are estimated separately, considering the Indian terrain conditions for the environments such as low dense populated area moderate dense populated area, high dense populated area industrial area, congested Market area, which give the best RSS results. It also propose algorithm for vertical handoff techniques which integrates the network types like GSM, UMTS, LTE, and WLAN in the KHWN. The importance of VHOS lies in dealing with the mobility between old technologies like GSM, as well as the upcoming new technologies. In this proposed VHOS the interoperability can be possible within KHWN. This chapter mainly drives the idea of estimating the RSS parameters based on Indian urban and sub-urban terrains real time data for each tier of KHWN. From these novel statistical and empirical models, the algorithm for VHOS has been proposed. The proposed of VHOS algorithm is robust and non complex as the real-time parameters for estimating RSS is estimated according to Indian terrain. This can also be modified to other known terrain. Further the RSS based VHOS can be extended and compared with the signal to noise and interference based VHOS.

Chapter 4

SINR and Cost Based Vertical Handoff Scheme for K-Tier Heterogeneous Wireless Network

4.1 Introduction

The method finding of path loss for the local terrain with the estimation of RSS for all tiers of networks and proposing VHOS is discussed in the present chapter. Considering the same heterogeneous k-tier wireless network it is very much interesting to extended for SINR and cost based VHOS.

As the demand in next generation wireless networks in accessing all types of uninterrupted services like voice, video streaming, web browsing and telemetry with mobility for end user equipments(UEs) is increasing. Where the different types of networks provide varying quality of services. Hence, integration of such heterogeneous networks necessitates to provide all kind of services to the end user's demand. The k-tier heterogeneous wireless network (KHWN) is one of the above stated heterogeneous networks [35]. The KHWN is architect by integrating the cellular networks, long term evolution(LTE) and wireless local area network (WLAN). The vertical handoff within KHWN allows UEs to get continuous seamless connectivity with the required Quality of service (QoS) along each tier of the network. Practically coverage geometry of wireless networks is complex and challenging to estimate the QoS for vertical hand off scheme.

In the literature studies, vertical handoff was originally based on received signal strength (RSS) criterion. Here, the vertical handoff decisions are made by comparing the RSS between the reset threshold and hysteresis values. Today users have the demand for different kinds of services with mobility for which, QoS have important role for providing services which include voice, video streaming, web browsing, and telemetry etc, with mobility. The QoS directly depends upon the SINR. So, the performance of the system based on RSS is far from desired [25]. The VHOS in KHWN follows a hierarchal process which is based on pairwise comparison of QoS among each tier of the networks. We propose the Saaty's analytic and hierarchical process (AHP) for VHOS in KHWN [96]. This process reveals the parameters as well as the various alternatives to be considered in the VHOS determination. It is followed by number of pairwise comparisons for determining factor weights and factor

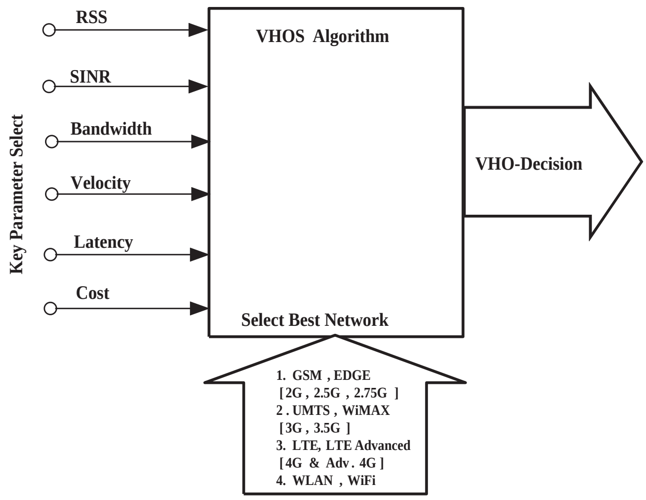

Figure 4.1: Key parameters for VHOS

evaluations. [6, 83, 84].

The previous studies for vertical handoff in heterogeneous wireless networks such as combined SINR based vertical handoff (CSVH) [63], multi dimensional adaptive SINR based VHO algorithms (MASVHO) [66] and multi-attribute vertical handoff algorithm with predictive SINR using GM (1,1) use SINR, [97] user required bandwidth, user traffic cost, utilization of each access network, and user preference [98]. However, all these techniques are applied to WLAN and WCDMA networks. While applying these methods for VHOS in KHWN considering all types of traffics independently it is found that the results provide less throughput and reduction in traffic cost is not optimum. Hence we were motivate to propose VHOS for KHWN to provide seamless vertical handoff with multi-attribute QoS. The proposed method is superior to the existing methods for three factors:

1. The proposed method deals with different traffic types;

2. The proposed method provides high system level throughput;

3. The proposed method achieves low cost traffic.

The VHOS key parameters are presented in Figure 4.1. From the figure it can be seen that the key parameters for VHO scheme depends upon the SINR, RSS, Cost, Bandwidth etc.

The proposed VHOS uses (i) SINR, (ii) user required bandwidth, (iii) user traffic cost from k-tier access networks and (iv) user preference criterion to make hand off decision. In this method the handoff is fired when the predicted value of SINR is less than a pre-established threshold value determined by user's application or QoS restrictions [70].

The attributes and parameters are taken as per the third generation partnership project (3GPP) standard. The types of traffic considered are voice, streaming video, web browsing and telemetry. All the attributes for each type of services are also considered. In this proposed method the analytical and hierarchical structure model, which includes goal level, criterion level, alternative level, is applied over the collected input data by pairwise comparisons of attributes. Every compared attributes on each level is again compared with adjacent attributes in order to construct the comparison decision matrix M based on 9 point AHP methods [99, 100]. For KHWN, we consider the downlink path with an arbitrary number of cellular network, broadly LTE and WLAN. Appropriate weight factors are assigned to the attributes like SINR, COST and bandwidth. These weight factors are derived from eigenvalue of the AHP. The VHOS decision is set up by breaking the decision into a hierarchy of interrelated decisions. The decision matrix is constructed comparing the adjacent of each attributes with respect to its importance. The consistency ratio (CR) of 0.1 value is acceptable [74]. Vertical handoff triggering require $CR \geq 0.1$ [46]. The VHOS is established according to the attribute matrix and weight vector.

4.2 Heterogeneous network scenario

The LTE and WLAN networks are modelled considering the transceivers as per 3GPP standard. The UE's represents the end user's receiver and the e_{NB_i} and e_{AP_i}, represents the transceivers of LTE and WLAN respectively. The coverage of both the networks are taken as ubiquitous for all the UEs. Considering n and m number of transceivers for the LTE and WLAN respectively are present in the networks and collecting all these transceivers into a matrix B, the transceivers can be represented as

$$B = [e_{NB}; e_{AP}] \tag{4.1}$$

where $e_{NB} = [e_{NB_1}, e_{NB_2}...e_{NB_n}]^T$
and $e_{AP} = [e_{AP_1}, e_{AP_2}, ...e_{AP_m}]^T$.
Thus, there are $m+n$ transceivers where e_{NB_i} is the i_{th} transceiver of LTE and e_{AP_j} is the j_{th} transceiver of WLAN. The indexing has been done from 1 to $m+n$ in the set of B. The best possible transceiver channel, which is having best SINR, is assigned to the user equipment UE by the KHWN with the help of an algorithm.

4.2.1 Signal to Interference and Noise Ratio

In heterogeneous wireless networks, signal propagation and the positioning of network transmitters and receivers are the key parameters which contributes to estimate the SINR. The availability and quality of the throughput of a transceiver depend upon the SINR value of the KHWN. The Shannon's Theorem provides an upper bound to the capacity of a link, in bits per second (bps) [101]. The theorem is stated as

$$R_i^k = Wlog_2(1 + \frac{\gamma_i^k}{\Gamma}) \tag{4.2}$$

where, R_i^k is the maximum achievable data rate , W is the bandwidth, γ_i^k is the SINR received at the UE k when associated with the transceiver B_i and Γ is the dB gap between the uncoded M-QAM and $[capacity - coding'gain]$ [102]. Thus, the maximum achievable data rate for any LTE and WLAN link can be represented as $(R^k_{e_{NB,i}})$ and $(R^k_{e_{AP,i}})$ respectively. Since there is a relation between the data rate and SINR, hence SINR can be used to choose the transceiver from the KHWN. Similar to Equation 4.2 relation between SINR and data rate for individual LTE and WLAN in KHWN can be given as

$$R^k_{e_{NB_i}} = W^k_{e_{NB}} log_2(1 + \frac{\gamma^k_{e_{NB}}}{\Gamma^k_{e_{NB}}}) \tag{4.3}$$

$$R^k_{e_{AP_i}} = W^k_{e_{AP}} log_2(1 + \frac{\gamma^k_{e_{AP}}}{\Gamma_{e_{AP}}{}^k}) \tag{4.4}$$

The $\gamma^k_{e_{NB}}$ and $\gamma^k_{e_{AP}}$ are the receiving SINR. Assuming the same down link data rate for all co-existed networks and using (4.3) and (4.4), the relationship between $\gamma^k_{e_{NB_i}}$ and $\gamma^k_{e_{AP_i}}$ is given as

$$\gamma^k_{e_{NB_i}} = \Gamma((1 + \frac{\gamma^k_{e_{AP_i}}}{\Gamma^k_{e_{AP_i}}}^{\left(\frac{W^k_{e_{AP_i}}}{W^k_{e_{NB_i}}}\right)} - 1) \tag{4.5}$$

similarly $\gamma^k_{e_{AP_i}}$ can be evaluated from $\gamma^k_{e_{NB_i}}$.

The received SINR from $e_{NB_i}{}^k$ for $i(\gamma_{e_{NB}})$ no of UEs is converted to equivalent SINR of $(\gamma^{'}_{AP})$ to get the same received data rate.

4.2.2 Cost and Bandwidth

Considering the set of SINR values S for all e_{NB}s and e_{AP}s , can be represented as

$$S = (S_{e_{NB},i} \cup S^{'}_{AP,i}) \tag{4.6}$$

For a required bandwidth R_i for a user i, the minimum receiving SINR from e_{NB} and $\gamma_{min,i}$ can be calculated from the relationship 4.6. Let C be the system cost vector. in order to directly associate the cost value with the SINR value, the cost per bit is converted to cost per SINR (C_{SINR}).

Let W be the network available bandwidth vector.

So the attribute matrix is as following:

$$R_a = \begin{bmatrix} S - \gamma_{min} 1/C_{SINR} \\ U \end{bmatrix} \tag{4.7}$$

4.3 Vertical hand-Off scheme

Considering the findings of SINR and cost from the above discussion, the parameters can be set for VHOS in the KHWN. In this assumption we have considered the LTE and WLAN as the two tires of the networks as a part. So the VHOS decision making process can be set for the above assumption. We have also considered the four types of traffics in the decision making process.

- Voice
- Video Streaming
- Web browsing
- Telemetry

To rank the important decision parameters the the decision making process made hierarchical, as shown is the figure 4.7 . The previous study suggests that the AHP method is best suited for such decision making process. [102, 103]

Following this method we have taken the overall score of a target network among KHWN, determined by the weighted sum of all the absolute values obtained from the hierarchy of the network SINR, cost and bandwidth.

In AHP the Saaty's 9 point method deals with the pairwise comparison matrix.

The selected network

$$A^* = \arg\max_{i \epsilon m} \sum_{j=1}^{N}, W_{f_j} r_{ij} \tag{4.8}$$

where,

- A^* is the comparison matrix
- N - is the number of parameters
- m - denotes the number of candidate networks is KHWN
- r_{ij} value of the attributes

- j - the element of the attribute matrixm_a
- W_{fj} denotes the weight factor
  which indicates the importance of each attribute.

By applying the AHP method we use the eigenvalue method evaluate the relative weights of decision elements. considering the high priority elements x_0 as the criteria and its dominant level below (D_L) have the elements,

$$x_1, x_2, x_3, \ldots, x_l$$

The relative magnitude factors in D_L are estimated through AHP pairwise comparison based on the judgements which is ranked on a Saaty 9-point scale [46]. The results of the comparison are reciprocal of the numbers. The AHP comparison matrix M_{AHP} is consider, Which is a square matrix . Now we can calculate the eigenvector vector of the matrix M_C with the maximum eigenvalue value λ_{max}.

According to the demand of traffic within KHWN between LTE and WLAN, the four types of traffic access classes of voice, video streaming, web browsing and telemetry .These four types of traffic access techniques can be represented by Matrix in AHP model as matrix M_{c1}, M_{c2} M_{c3} and M_{c4} respectively. For all classes the attributes are set according to the requirement and the AHP 9 point scale.

$$M_{c1} = \begin{array}{c} \\ c_1 \\ c_2 \\ c_3 \end{array} \begin{array}{c} \begin{array}{ccc} c_1 & c_2 & c_3 \end{array} \\ \begin{pmatrix} 1 & 1/9 & 1 \\ 9 & 1 & 9 \\ 1 & 1/9 & 1 \end{pmatrix} \end{array} \tag{4.9}$$

The M_{c1} is the comparison matrix for conversational traffic of the KHWN. Similarly for video streaming M_{c2}, for web browsing M_{c3} and for telemetry M_{c4} are represented as follow:

Table 4.1: Represented consistency ratio

Traffic Type	SINR	COST	Bandwidth	CR
Voice	0.0909	0.8082	0.0909	0
Video Streaming	0.0704	0.1782	0.7514	0.0158
Web browsing	0.7143	0.1429	0.1428	0
Telemetry	0.7085	0.0603	0.2311	0

$$M_{c2} = \begin{pmatrix} 1 & 1/3 & 1/9 \\ 3 & 1 & 1/5 \\ 9 & 5 & 1 \end{pmatrix} \tag{4.10}$$

$$M_{c3} = \begin{pmatrix} 1 & 9 & 5 \\ 1/9 & 1 & 1/5 \\ 1/5 & 5 & 1 \end{pmatrix} \tag{4.11}$$

$$M_{c4} = \begin{pmatrix} 1 & 5 & 5 \\ 1/5 & 1 & 1 \\ 1/5 & 1 & 1 \end{pmatrix} \tag{4.12}$$

Given in the above the decisions for each types of traffic specified through each type of networks, now we need to take decision for which is the best alternative for VHOS. So the pair wise comparison method of multi criteria decision making process using AHP has been adopted [98]. Here we attempted to determine the relative importance of each attributes. Applying the right principal eigenvector of matrix given the judgement with pairwise comparison and the approximation of the eigenvalue denoted by λ_x The consistency index can be calculated as

$CI = \frac{(\lambda_x - n)}{n-1}$, so the consistency ratio CR can be evaluated $CR = CI/RCI$ where random consistency index (RCI) is the average value of CI according to Saaty scale [98]. The well acceptance scale value for CR is $CR < 0.1$ for which the matrix are consistence as shown in table 4.1.

The decision matrix are considered to be consistence as we get the CR value less than 0.1. We have considered 4 types of traffic classes and the SINR, cost and bandwidth as the basic parameters for VHOS decision making process, which we got to be consistence as presented in the table 4.3.

4.4 VHO decision process

The proposed VHOS is considered with three parameters

1. QoS for each types of access
2. Available number of choices of Networks from the KHWN
3. Considered Hysteresis time buffer to avoid unnecessary handoff s

Hysteresis time defined as H_t is the buffer time for an VHO to trigger. The VHO triggers when the following condition satisfies.

$$\begin{cases} SINR_{currentnetwork} > SINR_{predefinedthreshold} \\ and\, if \\ cost\, function\, value, of target\, network < cost\;\, value\, of\; current\, network \end{cases}$$

The buffer hysteresis time included for determining the VHOS process H_t if the above criteria satisfies then the VHO can be triggered, considering the H_t If the handoff latency is h_l and the number of evaluations N then the VHOS triggering time can be represented as

$$VHOS_t = \frac{h_l}{e^{N_{target} - N_{current}} - 1} \tag{4.13}$$

The N_{target} and $N_{current}$ are the cost function values of the current and target network. Which can change dynamically over short period of time. So the H_t is modified as below, to achieve an adaptive VHO, which can deal with the dynamic KHWN

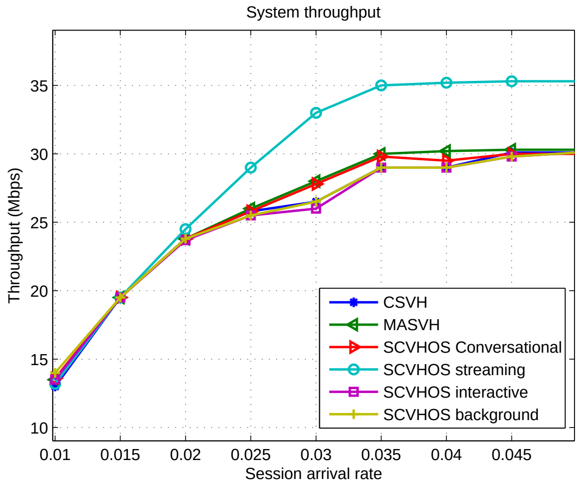

Figure 4.2: The simulation result based on traffic throughput, with the services like voice, video streaming web browsing and telemetry are demonstrated in this plot, also the results are compared with the CSVH and MASVH type schemes

environment. Considering the total evaluation count as $'n'$ and current evaluation is k. So the process will execute the same till $k= N$. So considering $k = 0, h_l = 0$

$$\phi = e^{N_{current}} - e^{N_{target}} \tag{4.14}$$

$$\phi_k = \frac{h_l}{n} + \frac{h_l}{n(\phi_k - 1)} \tag{4.15}$$

$$H_{t_k} = h_l(\frac{\phi_k}{n(\phi_k - 1)}) \tag{4.16}$$

The process executed until $k = N$

for $\phi_k > 1$ evaluating equation (15)we get

$$H_t = \sum_{k=0}^{N}[\frac{h_l}{N} + \frac{h_l}{N(\phi_k - 1)}] \tag{4.17}$$

The simulation studies were conducted to get the best suited overall system throughput and lowest traffic cost for access of voice, video streaming, web browsing and telemetry within KHWN for LTE and WLAN networks. Figure 4.2 shows the overall system throughput from which it is seen that system throughput is balanced in each type of traffic considering the attributes of bandwidth.

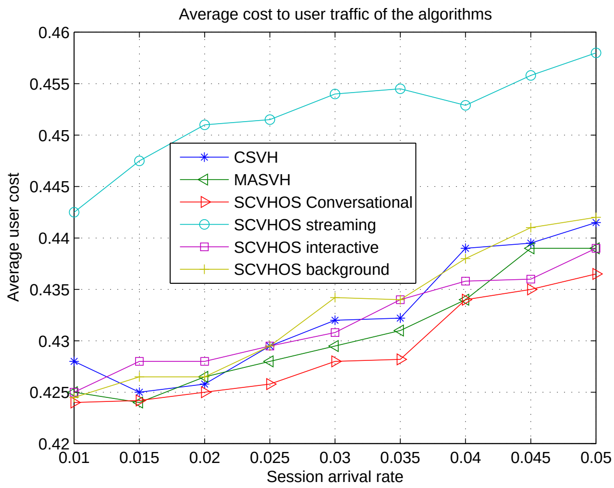

Figure 4.3: The simulation result based on traffic cost, with the services like voice, video streaming web browsing and telemetry are demonstrated in this plot, also the results are compared with the CSVH and MASVH type schemes

The highest throughput was seen for streaming videos as the throughput requirement is more. The cost for each access technique has been represented in the Figure 4.3 where, the cost is seen to be lower than the earlier schemes of CSVH and MASVH algorithms.

The SCVHOS flow is demonstrated in the flow chart below Figure .

4.5 Results and Discussion

The performance of SINR and Cost based Vertical Handoff Scheme (SCVHOS) was evaluated concentrating on the download traffic, as the download traffic normally require higher bandwidth in case of video streaming, web browsing and telemetry. The SCVHOS performance is simulated with respect to cost and the over all system throughput as demonstrated in Figure 4.2. The performance is compared to the combined SINR based vertical handoff (CSVH) and multi-dimensional adaptive SINR based vertical handoff (MASVH) ($k = 4$) algorithms [104] shown in Figure 4.3. In addition to that, here modified hysteresis time is applied in order to reduce the ping pong VHO. From the simulation studies it is seen that the result achieved here is better than that of earlier methods. The number of VHO's considerably reduce as

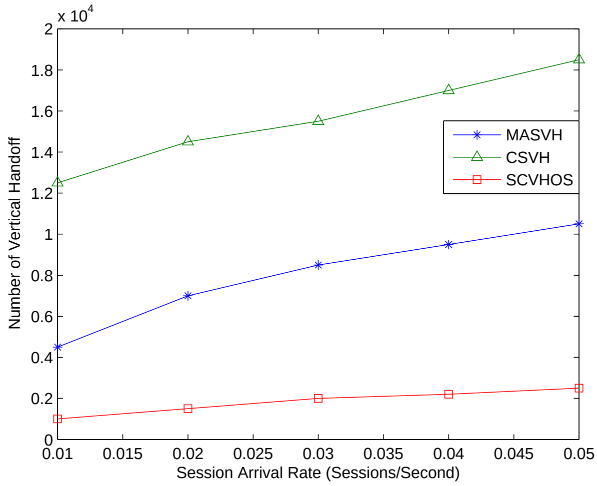

Figure 4.4: Number of VHO for Voice

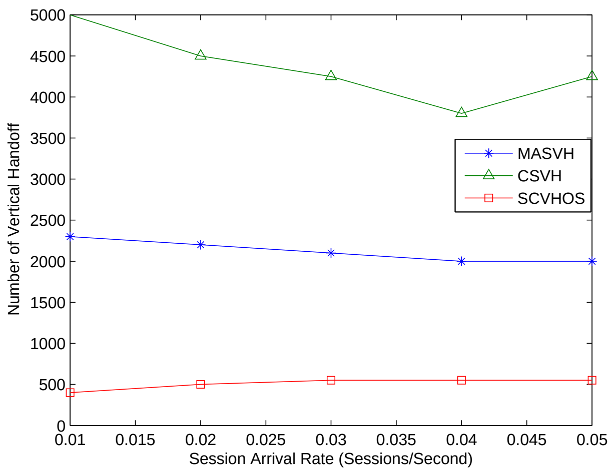

Figure 4.5: Number of VHO for Video Streaming

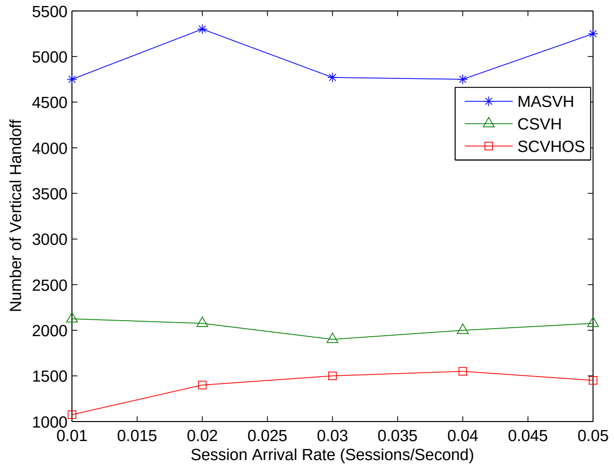

Figure 4.6: Number of VHO for web browsing

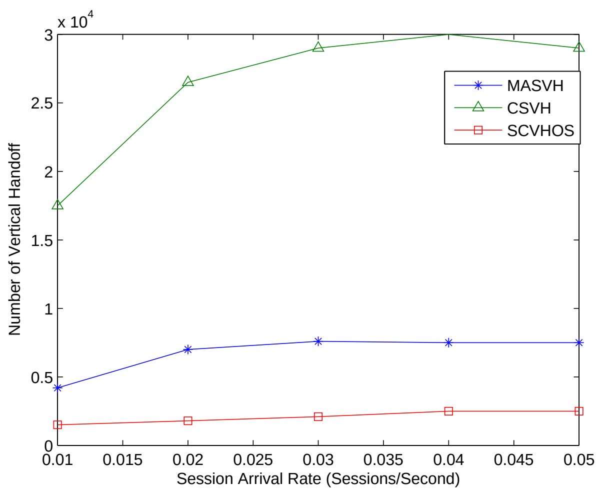

Figure 4.7: Number of VHO for Telemetry

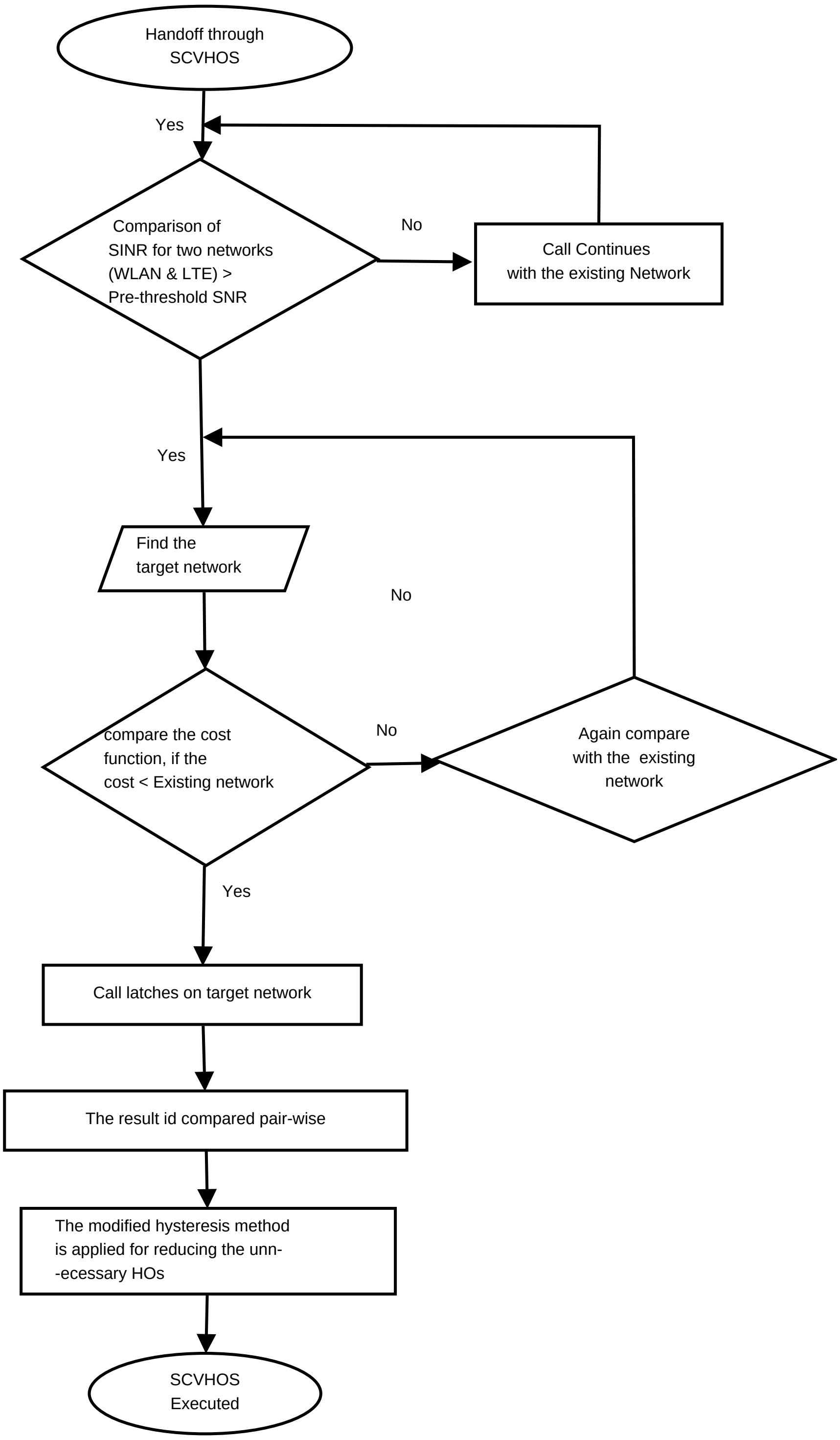

Figure 4.8: The VHOS flow

shown in the Figure 4.4, for voice calls, Figure 4.5, for video browsing, Figure 4.6, for web browsing and for telemetry Figure 4.7. The comparison with earlier processes are displayed and the numeric results demonstrates this method to offer a near optimal performance.

4.6 Summary

The VHOS for KHWN remains a challenging problem in order to provide voice, data and multimedia services seamlessly in each tier of the network. The proposed VHOS using SINR, Cost and Bandwidth are taken as QoS criterion for VHOS in next generation cellular networks LTE and WLAN. The proposed VHOS is observed to achieve superior QoS compared to the earlier algorithms of CSVH and MSVH. Also the unnecessary VHOS are greatly controlled for the voice, video streaming, web browsing and telemetry services. The result shows that the proposed scheme is consistent and the simulation result also establishes that this VHOS provides low cost traffic and over all system throughput with a control of unnecessary handoffs for above mentioned services within the KHWN.

Chapter 5

Conclusion and scope for future work

5.1 Conclusion

The vertical handoff schemes for heterogeneous networks were proposed based on some estimated RSS and SINR earlier, which did not take into account the inputs of local terrain with multiple tiers of heterogeneous wireless networks and the quality of service. In order to improve the vertical handoff schemes for k-tier heterogeneous wireless networks, the present work proposes some novel VHOS techniques.

A comprehensive study of VHO and VHO algorithms is presented in this report. These algorithms are categorized into four groups as RSS, bandwidth, cost function and combination based algorithms. VHO algorithms reported in standard literature lack a comprehensive consideration of various network parameters, like user mobility and user preferences. The research project presented in this thesis add these issues and provides an integrated solution to the VHO process for near optimal performance. The framework for VHO is provided considering the most robust method of calculating the path loss through local terrain.

Proposed local terrain based RSS method for KHWN improves the quality of receiving signals and handoff. The basic parameters of SINR and traffic cost are then considered as the key parameters for VHOS. Based on these parameters, the VHOS is proposed with the best suited analytical hierarchical process AHP for vertical handoff within the KHWN environment. The results found are observed to offer better quality of throughput, cost effective traffic, and lower ping pong handoffs and also multi-tier supported.

The VHOS for KHWN remains a challenging problem in order to provide voice, data, multimedia seamlessly in each tier of the network. The proposed VHOS using SINR, Cost and Bandwidth are taken as QoS criterion for VHOS in next generation cellular networks LTE and WLAN. The proposed scheme of VHOS achieved QoS better than the earlier algorithms of CSVH and MSVH.

Also the unnecessary VHO are significantly controlled. The result shows that the proposed scheme is consistent and the result confirms that this VHOS provides low cost traffic and over all system throughput with a control of unnecessary handoffs for all kind of services within the KHWN.

5.2 Scope for future research

Perceiving the proposed VHOS in comparison to the existing algorithms, several ideas and improvements have been devised that may help form the basis of future work to be carried out in this research area. The work presented here is carried out in the analytical and simulation environment. So the work has a scope to be extended for an environment, with more real time constraints. Further similar schemes have a scope for being proposed for fifth generation or beyond networks. If the Light Fidelity (LiFi) network is implemented then the handoff will be essential for mobility. The handoff is really an ever challenging process with the evolution of wireless communication standards.

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