CHAPTER ONE

INTRODUCTION

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1.1 Preface

The number of users of mobile communication networks has increased rapidly. For example, it has been reported that "today, there are billions of mobile phone subscribers, close to five billion people with access to television and tens of millions of new internet users every year" [1]. There is also a growing demand for services over broad band wireless networks due to the diversity of services which can't be provided with a single wireless network anywhere, anytime. This fact means that heterogeneous environment of wireless systems such as Global System for Mobile Communication (GSM), Wireless Fidelity (Wi-Fi), Worldwide Interoperability for Microwave Access (WiMAX), Universal Mobile Telecommunications System (UMTS) and Long Term Evolution (LTE) will coexist providing Mobile Users (MUs) with roaming capability across different networks[2]. These heterogeneous wireless access networks vary widely in terms of multiple attributes such as coverage area, supported data rate for services and cost [3]. This in turn means that each wireless access network has its different characteristics. For example, Third Generation (3G) wireless networks like UMTS can provide a high coverage area, but it supports low data rate which is insufficient to satisfy data intensive applications (e.g., video streaming requires high data rate for better performance) as well as having a very high service cost. In contrast the Wi-Fi wireless network provides a high data rate, low cost but low coverage area [4]. The limitations of these wireless access networks can be overcome by joining these technologies through Vertical Handover (VHO) interworking architectures which is essential to provide ubiquitous wireless access ability with high coverage area, high data rate and low cost to MUs. Therefore, multiple networks 3G (UMTS), WIMAX (Worldwide Interoperability for Microwave Access) and wireless fidelity (wi-fi) are three main things which should be taken into account when considering heterogeneous wireless networks.

1.2 Problem Statement

In 4G ,due to the ubiquity of wireless technologies, users demand are continuous connectivity and guaranteeing the performance required for their communications ,when the performance is decreased the mobile user directly search for high performance connection in other access network. In ubiquity wireless, the unnecessary handover is various deteriorate the performance factor, thus optimum vertical handover is needed.

1.3 Proposed Solution

Based on received signal strength, available Bandwidth, travel time prediction, and the user mobility, a vertical handover algorithm is developed to fulfill the performance requirements for the user. In order to maintain the connectivity among different wireless technologies while the user equipment moves across different networks. The proposed algorithm maintains the user connected to the better network, while reducing the unnecessary handover and handover failure.

1.4 Objectives

The objectives of this research includes

- Design a vertical handover algorithm that uses parameters such as RSS, available bandwidth, travelling time prediction and mobility to make a decision of vertical handover.
- Performance evaluation of the proposed vertical handover through a simulation using MATLAB in terms of:
  - Unnecessary handover probability
  - Handover failure probability
  - Connection break down probability

1.5 Methodology

Vertical handover algorithms have been proposed to trigger handover at the optimal time to the optimal network based on a variety of network parameters.

There are two algorithms, the first algorithm predicts the user's traveling time within a network coverage area, and the averaged Received Signal Strength (RSS) samples and the MT's velocity information are used in the traveling time prediction in a mathematical model. The second algorithm calculates a time threshold based on various network parameters and the handover failure or unnecessary handover probability information. The expression of handover failure or unnecessary handover probability is generated by developing a mathematical model which assumes uniform distribution of entry and exit points of a network coverage area. The predicted traveling time is compared against the time threshold and a handover is necessary only if the traveling time is longer than the threshold.

1.6 Thesis Outlines

The structure of this thesis is organized as follows:

Chapter Two: Is the Literature Review, introduces the evolution of mobile communication system, Different wireless technologies like WLAN, UMTS, and WiMAX, the heterogeneous wireless network and mobility management.

Chapter Three: Simulation Model, is presented the vertical handover decision algorithm and the system model of the research.

Chapter Four: Results and discussion, this chapter is provides the results of work done and discussion the results.

Chapter Five: Conclusion and Recommendation, this chapter concludes the work done in this thesis and gives the recommendation for future work.

CHAPTER TWO

LITERATURE REVIEW

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2.1 Background

2.2.1 Evolution of Mobile Communication System

Today, communication technologies have become an integral part of people's daily life and the wireless communication market has grown rapidly. Driven by the increasing demands of the market, wireless communication technologies have evolved from the first to four generation as illustrated in Figure 2.1

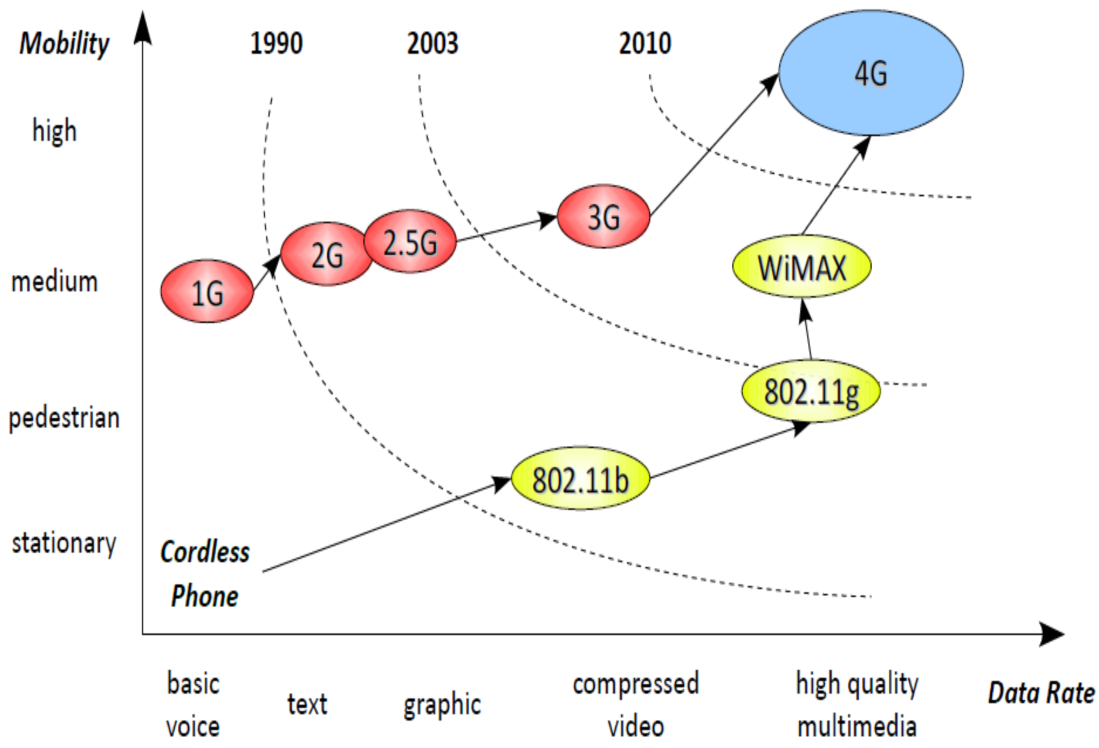

Figure 2.1: Evolution of wireless communications. From 1G to 4G, the data rate and user mobility have both increased [5].

First Generation (1G) mobility systems were analog and proved to be a great advancement in communication mobility. Different 1G standard were deployed in various countries, such as Advanced Mobile Phone System (AMPS), Total Access Communication System (TACS), Japanese Total Access Communication System (JTACS) and Nordic Mobile Telephone (NMT) [6]. 1G was a major innovation in the telecommunication history.

Second Generation (2G) networks introduced digital circuit-switched technology which uses the spectrum in a more efficient way. 2G networks are presently serving the vast majority of mobile users and will remain in the market for a long time. The major 2G cellular standards are GSM, IS-136 and CDMA One [6].

Second and half Generation (2.5G) after 2G and before the 3G, a stepping-stone technology called Two and One-Half Generation (2.5G) was introduced. 2.5G is the realm of enhanced data services. The key 2.5G standards include General Packet Radio Service (GPRS), Enhanced Data rates for GSM Evolution (EDGE), CDMA2000 1xRTT and IS-95B. GPRS is an enhanced mobile data service for users of GSM and IS-136 [7].

Third Generation (3G) networks are characterized by higher data transmission speed, better system capacity and improved spectrum efficiency among other features [8]. There is a range of technologies for 3G, all based around CDMA, including UMTS (with both FDD and TDD variants), CDMA2000 and Time Division-Synchronous Code Division Multiple Access (TD-SCDMA) [8].

Forth Generation (4G) networks are also known as fourth-generation wireless presents broadband mobile communications that supersedes the third generation (3G) of wireless communications. Currently, only few countries in the world have tapped into its use.

The 4G framework was proposed based on the key concept of integration. 4G names such as Long Term Evolution (LTE) and Ultra-Mobile Broadband (UMB) [9].

LTE is designed to provide higher data rates with over 100 Mbps for downlink and over 50 Mbps for uplink for every 20 MHz of spectrum, lower latency and packet-efficient system compared to 3G .LTE also uses Orthogonal Frequency Division Multiple Access (OFDMA) for the downlink and Single Carrier Frequency Division Multiple Access (SC-FDMA) for the uplink and employs Multiple-Input Multiple-Output (MIMO) with up to 4 antennas per station. LTE is designed to be all-IP based system and supports mobility and seamless service between heterogeneous wireless access networks [10].

2.2.2 Mobile broadband wireless technology evolution

The mobile broadband wireless technology like IEEE 802.11-based WiFi or Mobile WiMAX attempts to bring broadband applications to users on the move with the functionality of portability and mobility.

2.2.2.1 Wireless Fidelity (WiFi)

WiFi is a wireless LAN based on the IEEE 802.11 family of standards enhanced to support higher data rates and provide better QoS. It is primarily a LAN technology designed to provide in-

building broadband wireless coverage. This standard operates in the unlicensed 2.4GHz and 5GHz band. The standards include 802.11b, 802.11a, 802.11i, 802.11e, 802.11g, 802.11n. WiFi has become a defector standard for broadband connection in homes, offices, public hot-spots and educational environments [11].
In the past couple of years, a significant number of municipalities and local communities around the world have taken the initiative to get WiFi systems deployed in outdoor to provide broadband access to city centers as well as to rural and underserved areas.

2.2.2.2 WiMAX(Worldwide Interoperability for Microwave Access)

WiMAX is designed to accommodate both fixed and mobile broadband applications. It is based on the IEEE 802.16 standard and focuses on last-mile applications of wireless technology for broadband access [11]. However, WiMAX is different from WLAN and wireless cellular systems like GSM, CDMA and UMTS. It is unique in the sense that it provides broadband access to multiple users in the same geographical area. It uses microwave radios as its fundamental transport medium, making it adaptable to older technologies.
WiMAX systems promise to be very high capacity (up to 134.4 Mbps in a 28MHz channel), and large coverage area 50km or more, not require line of sight and to be work at vehicular speeds under 802.16e extension. [12]

2.2.2.3 Key Features of WiMAX

From technical perspective, the fundamental goal of mobile broadband is to offer higher data rates with reduced latency. The key characteristics of mobile WiMAX system are following [12]:

- Increased data rates: OFDMA based air interface is the key technology to offer higher data rates with higher order modulation schemes such as 64 QAM, and sophisticated FEC (Forward Error Correction) schemes such as convolution coding, turbo coding, and radio techniques like MIMO and beam forming.
- High spectral efficiency: Operators seek to increase the number of customers within their existing spectrum allocations, with reduced cost of per bit.
- Flexible radio planning: Deployment flexibility gives operators to change the cell six depending on the demand.
- All-IP architecture: All-IP based core network will enable PC-like services such as voice, video, data and improves the interworking to other fixed and mobile networks.
- Spectral flexibility: Scalable bandwidths give operators flexibility to reuse their exiting spectrum allocations.

2.2.2.4 Universal Mobile Communication System (UMTS)

The universal mobile communication system is one of the third generation technology .UMTS provide fully integrated digital communication with maximum data throughput up to 2Mb/s .high data transfer and data compression make possible high quality video streaming, and comfortable access to web server. UMTS become perfect tool for providing video conference .UMTS used packet switch connection [13].

- **UMTS system architecture**

UMTS system is divided in to three manly subsystems

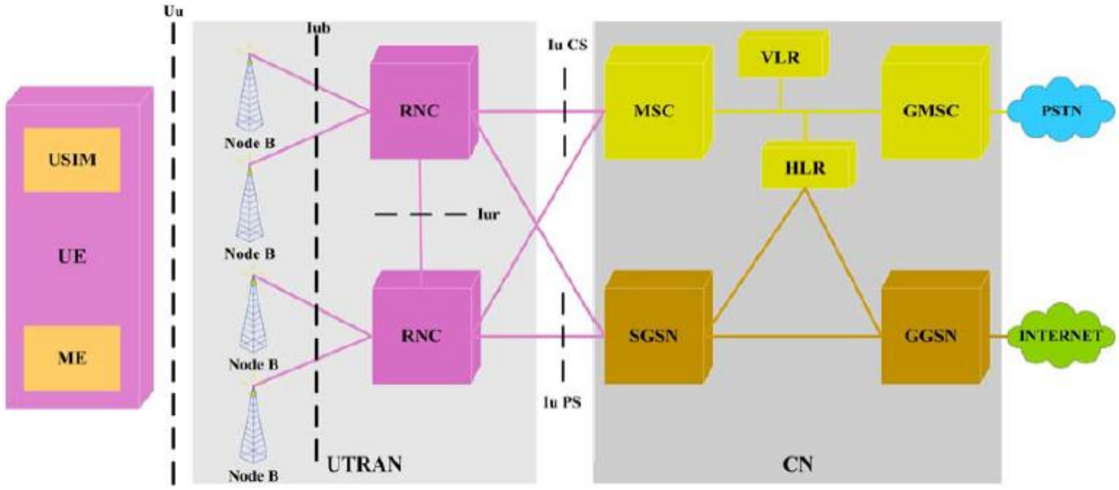

Figure 2:2 architecture of the UMTS

- **User Equipment (UE)**

The UMTS (UE) consist of the mobile equipment and the subscriber identity module(USIM).the ME is the radio terminal used to communication thought Uu interface directly to node B.

- **UTRAN**

Consist of one or more RNSs (Radio Network Sub-system).RNS consists of Node B and RNC. Node-B is a unit for radio transmission and reception. The main task of Node-B is to convert the data traffic between the Uu and IU interface in both direction.

- **Core network**

The core network is divided into two domains, namely, circuited switched (CS) and packet switch (PS). Circuit Switched element include mobile services switch center (MSC) and gateway mobile switch center (GMSC). And packet switch include general packet radio service (GPRS), serving GPRS supporting node (SGSN) and gateway GPRS support node (GGSN) [13].

2.3 Heterogeneous Wireless Networks

One important trend within the area of wireless networking is heterogeneity. No single wireless radio access technology will deliver all required services to all end-users anywhere, anytime. It will rather be the case, a variety of radio access technologies together forming the wireless infrastructure in each geographical area. Overlapping coverage is a typical feature where there is a choice for the end-user to connect to more than one radio access technology, either within the same administrative domain or across administrative borders. This architecture model takes full advantage of existing investments by infrastructure owners. Furthermore, it allows for increased wireless capacity and for backward compatibility. Also, it could offer higher data rates in selected areas at a lower cost. Finally, it allows for enhanced competition and flexibility [14]. Figure 2.3 is the example for heterogeneous network include WiFi, WIMAX, and UMTS.

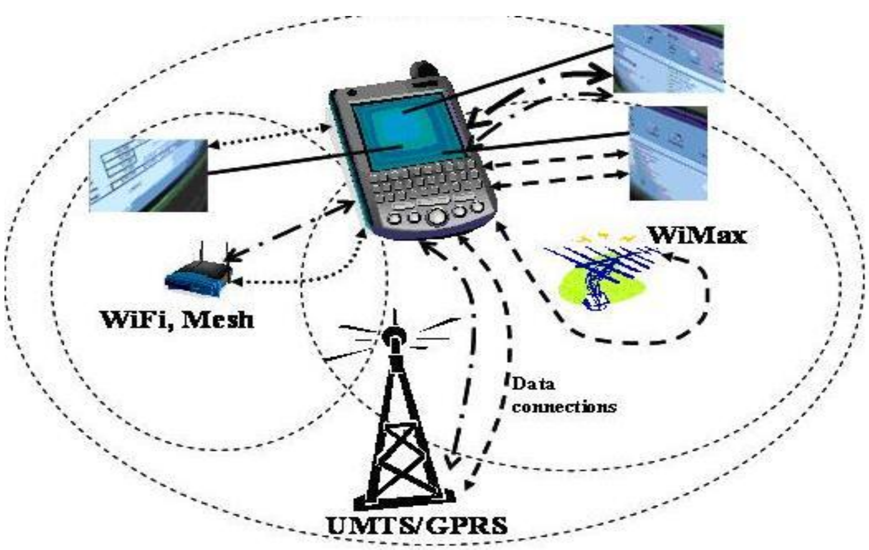

Figure 2.3 Heterogeneous Wireless Networks example.

2.4 Mobility Management in 4G Networks

As one of the most important challenges in 4G, mobility management is discussed in detail in this section. There are two main issues in mobility management: location management and handover management.

Location management allows the network to discover the current Point of Attachment (PoA) of the mobile for call delivery. It involves two stages, location update and call delivery. Location update or registration enables the network to authenticate the user and update the location of the mobile. In this stage, the MT periodically notifies the network of its new access point, allowing the network to authenticate the user and revise the user's location profile. This allows the network to keep track of the MT. Call delivery is responsible for database queries and terminal paging. In this stage, the network is queried for the user location profile and the current position of the MT is found. Current techniques for location management involve database architecture design and the transmission of signaling messages between various components of a signaling network. Since location management deals with database and signaling issues, many of the issues are not protocol dependent and can be applied to various networks [15]. In the 4G wireless environment, a mobile user is able to continue using the mobile device while moving from one point of attachment to another. Such process is called a handover, by which a mobile terminal keeps its connection active when it migrates from the coverage of one network access point to another [16].

Handover is the process of maintaining a user's active sessions when a mobile terminal changes its connection point to the access network (called "point of attachment"), for example, a base station or an access point depending on the access network that each point of attachment belongs to, the handovers can be either horizontal or vertical [17].

2.4.1 Classification of Handovers

Handovers can be classified in various ways. Some of the popular classifications are discussed below.

2.4.1.1 Horizontal Handover

A horizontal handover or intra-system handover takes place between PoA supporting the same network technology. figure 2.4 is example of horizontal handover between two geographically neighboring BSs of a 2G cellular network [18].

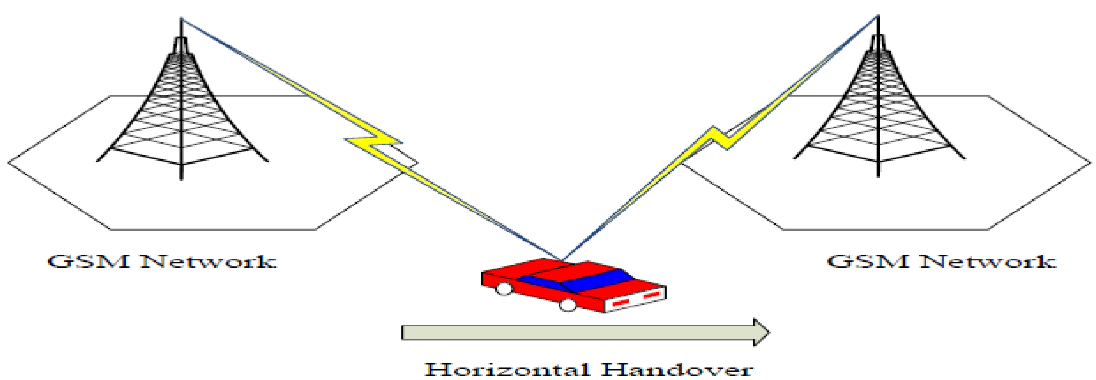

Figure: 2.4 Horizontal Handover descriptions

2.4.1.2 Vertical Handover

Vertical handover or inter-system handover occurs between PoA supporting different network technologies. Figure 2.5 is the examples of vertical handover occur between GSM and UMTS BSs [18].

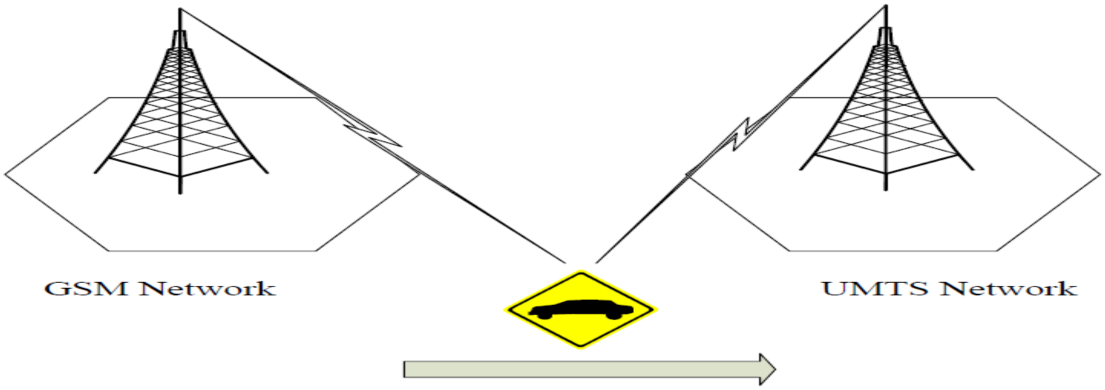

Figure: 2.5 vertical Handover description

2.4.1.3 Hard Handover

The hard handover also called a “break before make” because in the hard handovers the old radio link is released first between the user equipment and the radio network controller, before the new radio link is made between the user equipment and the radio network controller. Thus the source connection is broken first and then the target connection is made. As shown in figure (2.6) the hard handover occur when the mobile station travelling between UMTS (BS1 and BS2) [18].

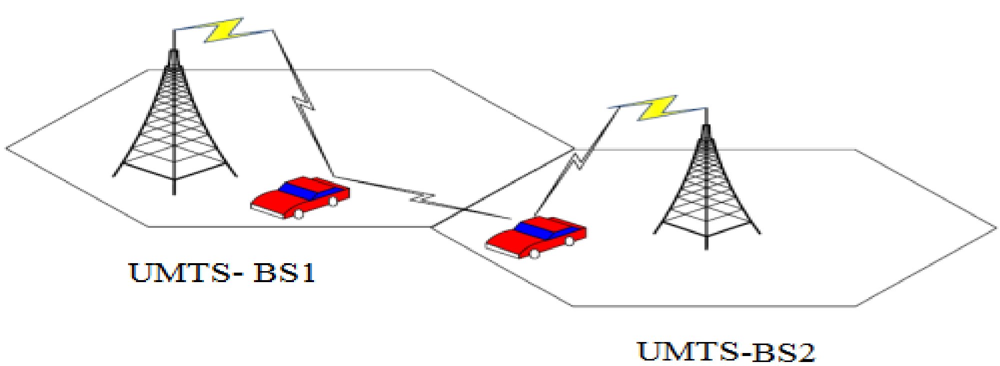

Figure: 2.6 Hard Handover descriptions

2.4.1.4 Soft Handover

Soft handover also called as make-before-break handover in which the mobile node's connection may be created at the target BS before the old BS connection is released [18].figure 2.7 is example of soft handover when the mobile station is make a decision of handover from BS1 to BS2,in this case the mobile station during handover is connected with two signal, signal of the old BS1and signal of the newBS2.

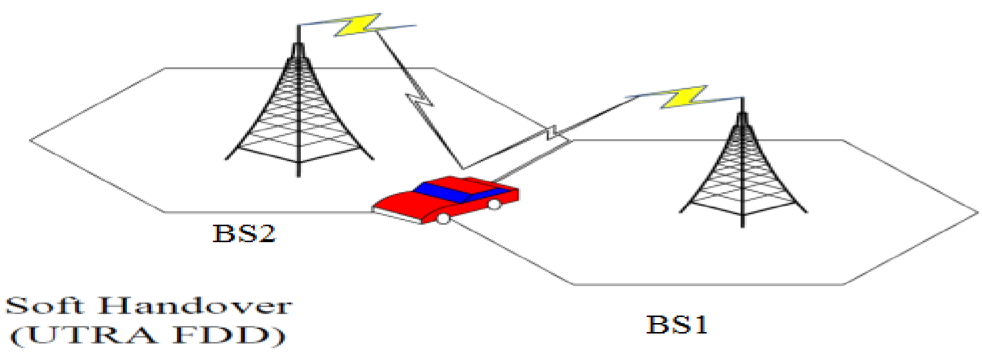

Figure: 2.7 Soft handover descriptions

2.4.1.5 Softer Handovers

It is the special type of the soft handover the communication moves parallel to the same Node-B's having over its different sector [18]. The user equipment and RNC communicates with the two different air interface channels. So two different codes are required for downlink thus the user equipments can know the signal. Rake processing used in the user equipment can receive the two signals. Figure 2.8 show when the mobile user handover from one sector to other in the same BSs.

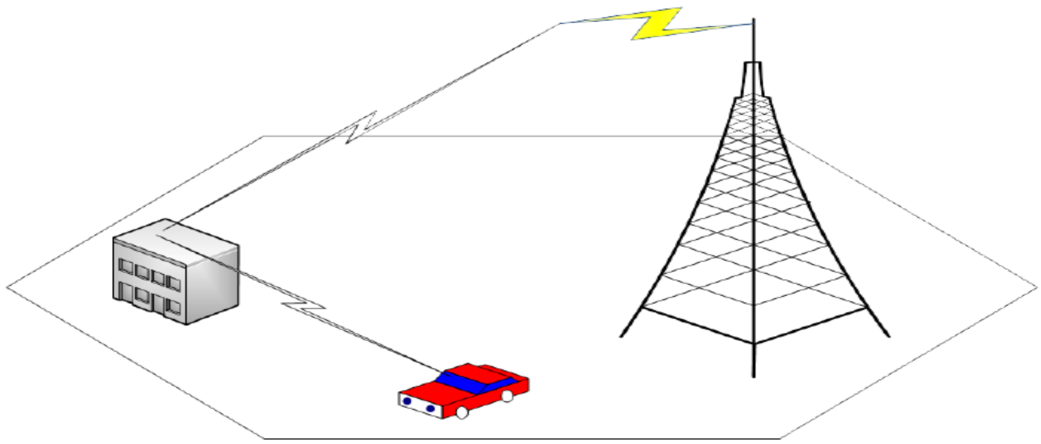

Figure: 2.8 Softer Handover descriptions

2.4.1.6 Mobile-controlled, Network-controlled and Mobile-assisted Handover

Under network-controlled handover, the network makes the decision for handover, while under mobile-controlled handover the mobile node must make the handover decision on its own. Under mobile-assisted handover, the decision to handover is made by the mobile node in cooperation with the network [19].

2.5 Vertical Handover Process

The VHO procedure is divided into three phases: Initiation, Decision and Execution [20] as described below.

2.5.1 Handover Initiation

The handover initiation is a process where the MU, that is equipped with multiple interfaces, searches for an available wireless access networks. In this phase, all required information for the handover decision is gathered, some of this information is related to the user's preferences (e.g., cost and security), network (e.g., latency and coverage) and terminal (e.g., battery and velocity) [20].

2.5.2 Handover Decision

The handover decision (Access Network Selection (ANS)) is responsible for deciding when and where to perform the handover by choosing the best handover access network from the multiple ones available. It then passes the information to handover execution.

2.5.3 Handover execution

In this phase, once a target network is selected and a handover decision is made, the active session for the MU will be maintained and continued on the new wireless access network. The handover execution involves the MU's authentication and the actual transfer of data packets to a new target network in order to reroute the MU's connection path to new Point of Attachment (PoA)[21].

Figure 2.9 is disruption of general handover process, firstly the mobile user is connected with the serving BS. When the link quality is going down directly the mobile station sent handover request to the controller (MSC) . The MSC gathering the information of the networks around the mobile node after that sent handover request accept to mobile node .after that the mobile node determining and calculate the time of handover (there is enough time of handover or not) and directly connected with target BS. Finally The new network make the authentication and authorization for the mobile node and the handover process is done.

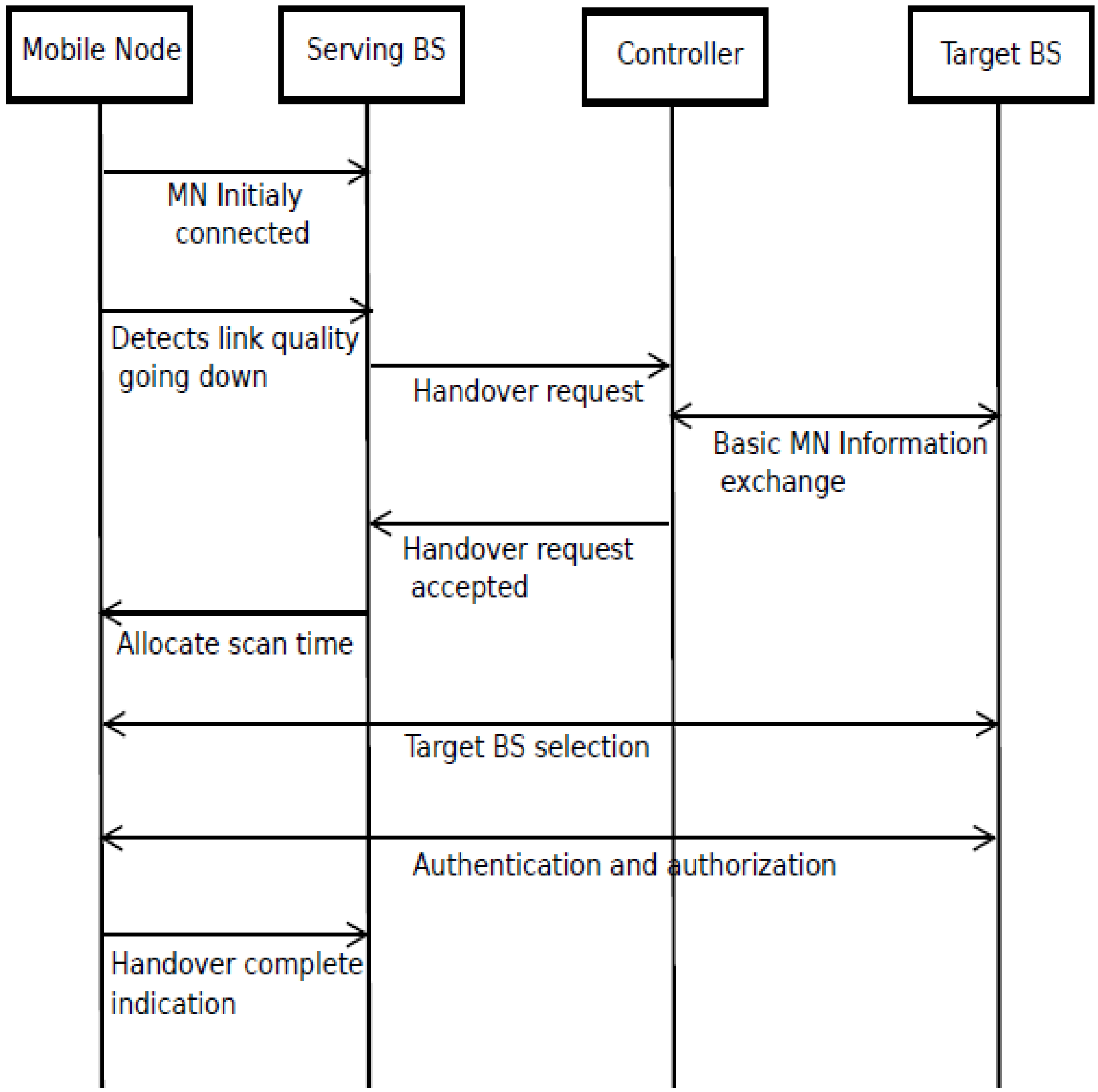

Figure 2.9: General Handover Process.

2.6 Vertical Handover Criteria

There are several parameters used in the VHD algorithms

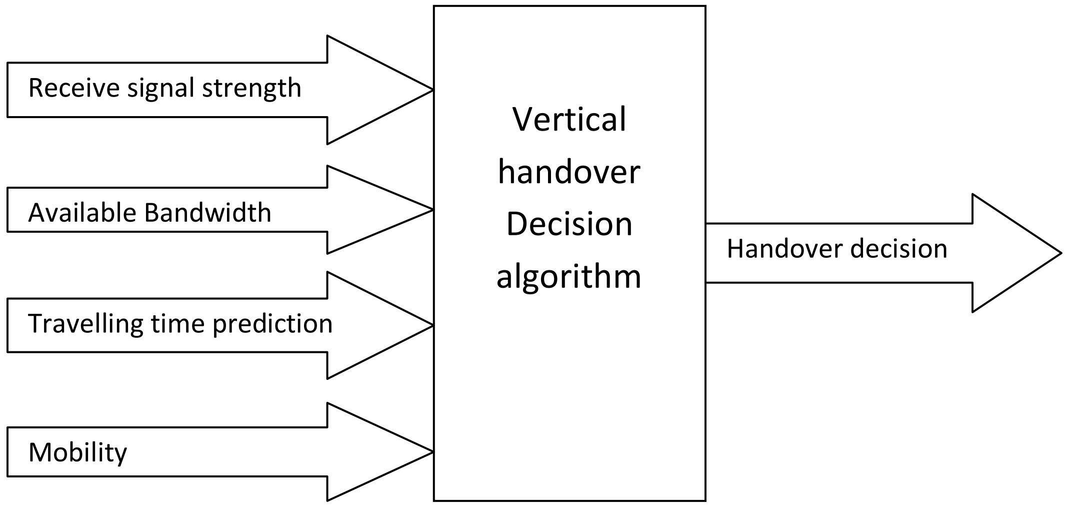

Figure 2.10: Parameters used for making VHD decisions.

- **Received signal strength (RSS)** is the most widely used criterion because it is easy to measure and is directly relevant to the service quality. There is a close relationship between the RSS readings and the distance between the mobile terminal and its point of attachment. The majority of existing horizontal handover algorithms use RSS as the main decision criterion, and RSS is an important criterion for VHD algorithms [22].
- **Available bandwidth** is a measure of available data communication resources expressed in bit/s. It is a good indicator of the traffic conditions in the access network [22].
- **Travelling time prediction** is the prediction of the time when the mobile station travelling inside the WLAN cell.
- **Mobility** is known as the velocity of the mobile terminal and the coverage area of the network.

2.7 Related Works

Different contributions and studies have already been done about the use of vertical handover in HetNets as a way of improving the performance. For instance, In 2010 Qing H. have proposed Cost function based strategy with RSS, network bandwidth, monetary cost and user preference as the vertical handoff decision parameter. Network Selection Function with lower values is selected as target network. This evaluation carried out by considering network resources and decreases the probability of call blocking and call dropping. [23].

In 2011Jun Peng et al. in [24] have proposed judge whether handoff should take place or not. A new comprehensive technique utility evaluation function used to evaluate networks quality and the weights of decision factors are calculated by analytic hierarchy process (AHP). Analysis is carried out in the form of simulation results and it shows that the proposed handoff decision strategy greatly avoid unnecessary handoff.

In 2012 Yutao Ling et al. [25] has analyzed vertical handoff decision strategy which considers the performance of the overall system. This strategy uses parameters like network bandwidth, RSS and variation of RSS. The performance of this strategy has been analyzed and it is observed that it greatly reduces the handoff call dropping probability.

In 2013 the authors in [26] has design an algorithm for vertical handover necessity estimation (HNE), to minimize the number of handover failure and unnecessary handover in heterogeneous wireless network. He take traveling distance and compared it against the RSS based method to make a handover decision in order to minimize the

Probability of handover failures or unnecessary handovers from a cellular network to a WLAN.

In 2014 the authors in [27] has developed an algorithm for vertical handover.Taking the user mobility as important factor in VHO decision in the lower speeds and high speed to reduce the unnecessary handovers.

CHAPTER THREE

SIMULATION MODEL

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This chapter introduce the algorithms that define the method we are proposed to improve vertical handover and the parameters used in the simulation tool.

3.1 Network Model

Consider a heterogeneous network with UMTS, WiMAX and Wi-Fi with one WiMAX BS and one UMTS BS and one Wi-Fi APs and one MU for each network. The number of BS is always selected as one except in the case of highly dense urban environment. The number of user equipment in the particular network is assumed as one. Figure 3.1 is the geometrical representation of the simulation model [29].

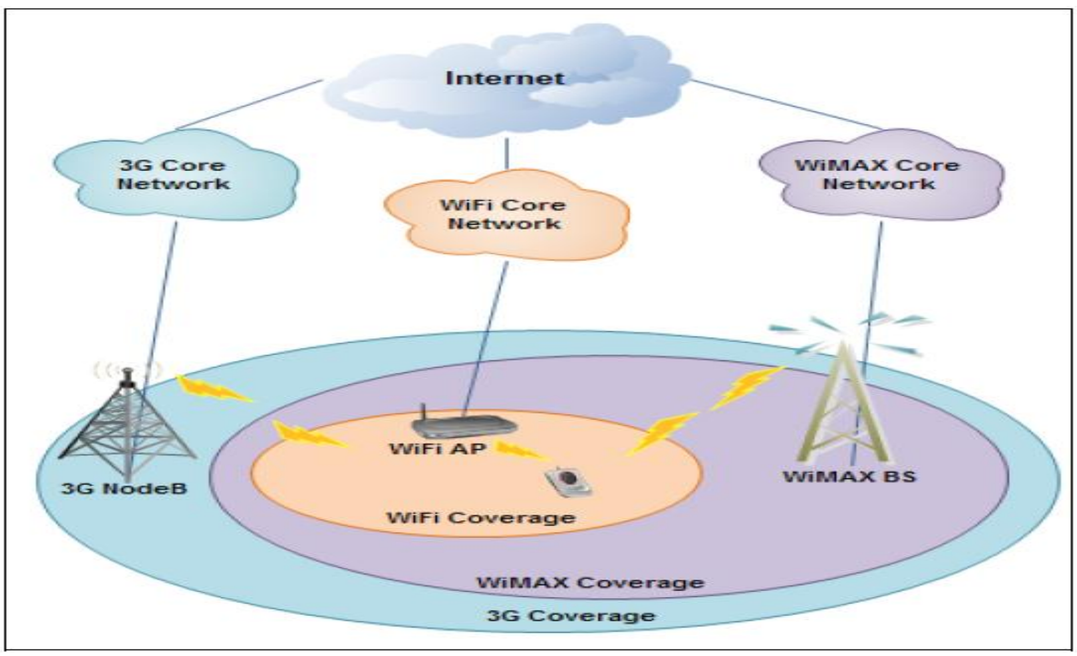


Figure.3.1. Heterogeneous Network System Description

3.2 Vertical Handover decision Algorithm (VHD)

In this chapter new vertical handover decision algorithm will be proposed.

3.2.1 Vertical handover algorithm for user connected to (WIFI)

Figure 3.2 shows the flowchart of vertical handover execution, of one user basically connected to a WiFi network. In order to determine whatever to stay in WiFi or vertically handover to 3G or WiMAX . Number of system parameter should be checked to make this decision. Firstly, RSS of the entire three access network are determined. Secondly, the mobility status of the user is checked. If it is not mobile and there is sufficient bandwidth and the RSS of WIFI is greater than RSS threshold it will stay in WiFi. However, when the user starts to move, it would be not preferable to stay in WiFi, therefore the user should be vertically handover to 3G or WiMAX based on which one has better parameter (RSS, available bandwidth) and if there are sufficient time to make handover process.

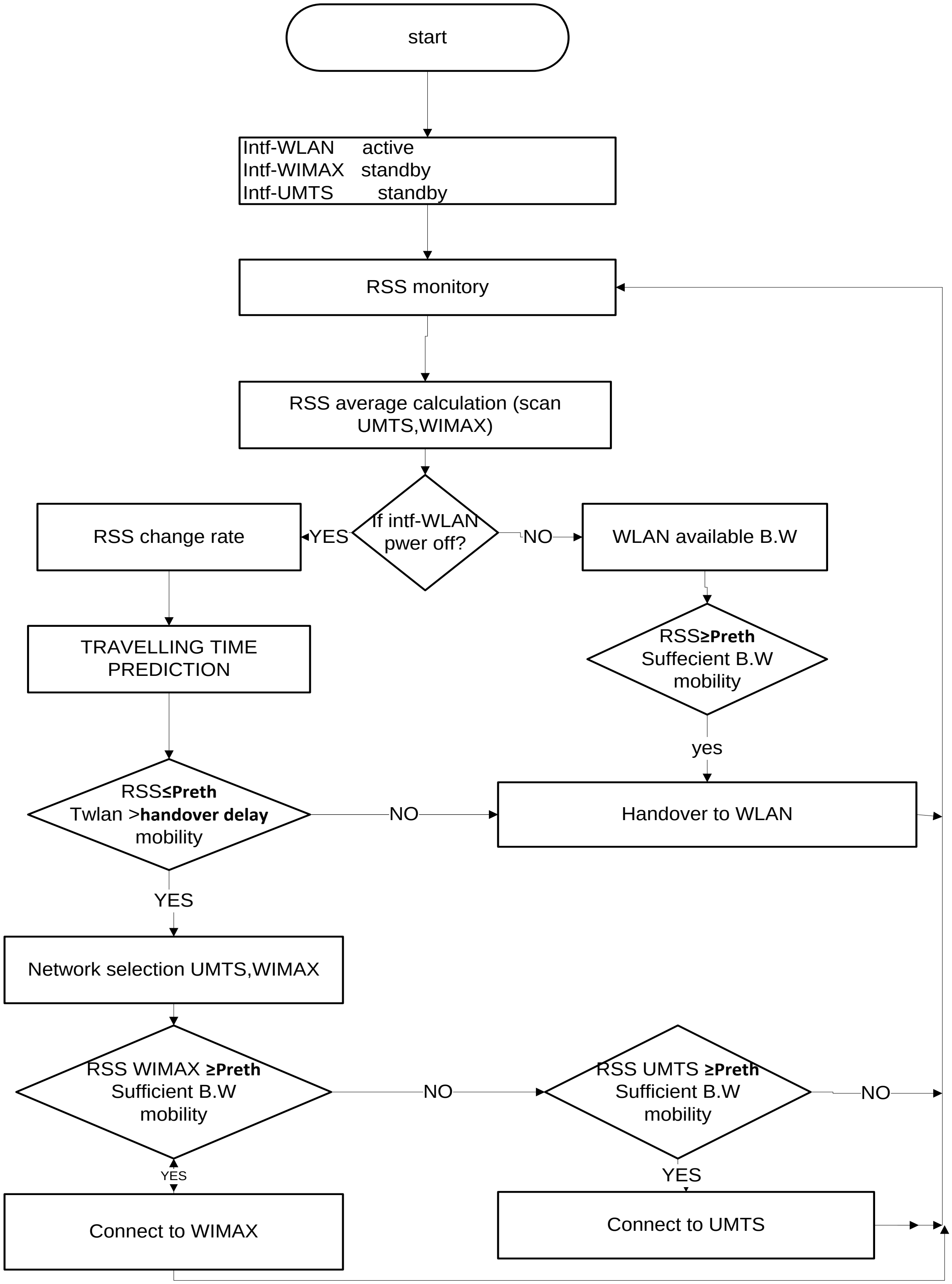


Figure: 3.2 proposed algorithm of vertical handover decision from WLAN to UMTS / WIMAX

3.2.2 Vertical handover algorithm for user connected to 3G

Figure 3.3 shows the flowchart of vertical handover execution, of one user connected to a 3G network. In order to determine whatever to stay in 3G or vertically handover to other networks. Number of system parameter should be checked to make this decision. Firstly, RSS of the entire three access network are determined. Secondly, the mobility status of the user is checked .If it is mobile and there is sufficient bandwidth and the RSS of 3G is greater than RSS threshold it will stay in 3G. However, when the receive signal strength of 3G is be less than RSS threshold , and there is not sufficient bandwidth and the time threshold calculation is greater than handover delay, then the Mobile station directly make a decision of handover to WIMAX or WLAN. Then checked the mobility ,If the mobile station is fixed and the RSS of WLAN is greater than RSS threshold and there are sufficient bandwidth the mobile station is prefer to connect to WLAN ,otherwise connected to WIMAX.

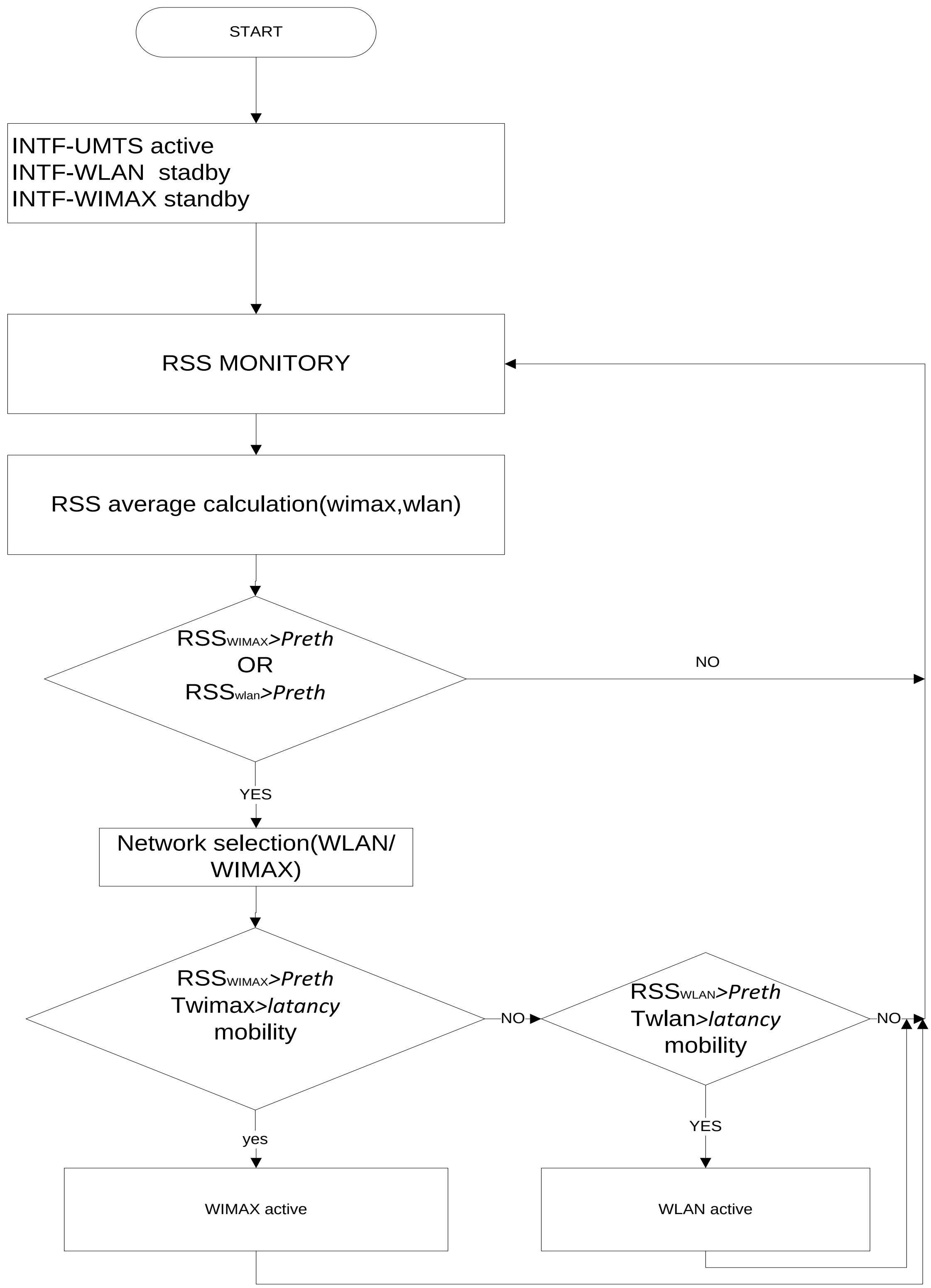


Figure: 3.3 proposed algorithm of vertical handover decision from UMTS to WIMAX /WLAN

3.3 Equation Description and Parameter

3.3.1 Probability of Handover Failure

The handover failure occurs when the traveling time inside the WLAN cell is shorter than the handover latency from the cellular network to the WLAN, τ_i. Time threshold calculation is used to keep the number of handover failures under a desirable threshold. It is calculated using mathematical modeling and probability calculation as explained in Appendix A.

A time threshold parameter T_1 is introduced to make handover decisions. Whenever the estimated traveling time t_{WLAN} is greater than T_1, the MT will initiate the handover procedure. Thus, using Equation ((A-36) in Appendix A) the probability of a handover failure for the method using the threshold T1 is given by [27].

$$Pf = \begin{cases} \frac{2}{\pi}[\sin^{-1}\frac{v\tau_i}{2R} - \sin^{-1}\frac{vT_1}{2R} & 0 \le T_1 \le \tau_i \\ 0 & t_i < T_1 \end{cases} \tag{3-1}$$

The value of T1 for a particular value of Pf when 0 < Pf < 1:

$$T_1 = \frac{2R}{v}\sin(\sin^{-1}(\frac{v\tau_i}{2R}) - \frac{\pi}{2}\text{Pf}) \tag{3-2}$$

Where:

V= velocity of the mobile terminal

R=WLAN radius.

T1 = time threshold parameter for handover failure

- The handover failure probability for Mohanty's [30] methods is given by

$$Pf = \begin{cases} \frac{2}{\pi}[\sin^{-1}(\frac{v\tau_i}{2R})] & 0 \leq vt_i \leq 2R \\ 1 & vt_i < 2R \end{cases} \quad (3-3)$$

Where:

V= velocity of the mobile terminal

R=WLAN radius.

- YAN [31] taken the travelling distance in his methods, the equation of the handover failure is given by

$$Pf = \begin{cases} \frac{2}{\pi}[\sin^{-1}\frac{v\tau_i}{2R} - \sin^{-1}\frac{L}{2R}] & 0 \leq L \leq \tau_i \\ 0 & vt_i < L \end{cases} \quad (3-4)$$

$$L = 2R\sin(\sin^{-1}(\tfrac{v\tau_i}{2R}) - \tfrac{\pi}{2}\mathrm{Pf}) \quad (3\text{-}5)$$

Where:

V= velocity of the mobile terminal

R=WLAN radius

L= distance threshold parameter

$\mathrm{Pf} = $ probability of the handover failure

3.3.2 Probability of Unnecessary Handover

The unnecessary handover occurs if the traveling time inside the WLAN cell is shorter than the sum of the handover time in to (τ_i) and out of (τ_0) the WLAN cell. By using (equation (A-39) in appendix A) the probability of an unnecessary handover is calculated as

$$Pu = \begin{cases} \frac{2}{\pi}[\sin^{-1}\frac{v(\tau_i+\tau o)}{2R} - \sin^{-1}\frac{vT2}{2R} & 0 \le T_2 \le (\tau_i + \tau o) \\ 0 & (t_i + \tau o) < T_2 \end{cases} \quad (3\text{-}6)$$

Thus

$$T_2 = \frac{2R}{v}\sin(\sin^{-1}(\frac{v\tau_i+\tau o}{2R}) - \frac{\pi}{2}\mathrm{Pu}) \quad (3.7)$$

Where:

V= velocity of the mobile terminal

R=WLAN radius.

τ_0= handover latency from WLAN to the cellular network.

τ_i = handover latency from the cellular network to the WLAN.

T_2 = time threshold parameter for unnecessary handover

Pu= unnecessary handover (0 < Pu < 1).

- The unnecessary handover probability for Mohanty's [30] methods is given by

$$\mathrm{Pu} = \begin{cases} \frac{2}{\pi}[\sin^{-1}(\frac{v(\tau_i + \tau_0)}{2R})] & 0 \le v(t_i + \tau_0) \le 2R \\ 1 & v(t_i + \tau_0) > 2R \end{cases} \quad (3.8)$$

Where:

V= velocity of the mobile terminal

R=WLAN radius.

τ_0= handover latency from WLAN to the cellular network.

τ_i = handover latency from the cellular network to the WLAN.

- YAN [31] taken the travelling distance in his methods, the equation of the handover failure is given by

$$Pu = \begin{cases} \frac{2}{\pi}[\sin^{-1}(\frac{v(\tau_i + \tau o)}{2R}) - \sin^{-1}\frac{C}{2R}] & 0 \le C \le v(\tau_i + \tau o) \\ 0 & v(t_i + \tau o) < C \end{cases} \quad (3.9)$$

$$C = 2R\sin(\sin^{-1}(\frac{v(\tau_i+\tau o)}{2R}) - \frac{\pi}{2}\mathrm{Pu}) \quad (3.10)$$

Where:

V= velocity of the mobile terminal

R=WLAN radius

C = parameter used to minimize unnecessary handover

Pf = probability of the handover failure

3.3.3 Number of Handover Failure

The equation (3-11) used to calculate number of handover failure.

$$\text{Number of handover failure} = \mathrm{j} * \mathrm{Pf} \quad (3.11)$$

Where:

j=handover assumption

Pf= probability of handover failure

3.3.4 Number of Unnecessary Handover

The equation (3-12) used to calculate number of unnecessary handover.

$$\text{Number of unnecessary handover} = \mathrm{j} * \mathrm{P}u \quad (3.12)$$

Where:

j=handover assumption

Pf= probability of unnecessary handover

3.3.5 Spectral Efficiency

The spectral efficiency is the result of dividing the data rate by the bandwidth for each network.

$$\text{Spectral efficiency (Bit\textbackslash sec\textbackslash HZ)} = \frac{\text{data rate}}{\text{bandwidth}} \tag{3.13}$$

3.3.6 Throughput

The throughput of the network is the accumulated of data rate with respect of the time

$$\text{Throughput (Bit\textbackslash sec\textbackslash t)} = \frac{\text{data rate}}{\text{simulation time}} \tag{3.14}$$

3.3.7 Probability of Connection Breakdown

A connection breakdown occurs when the traveling time inside the boundary area is less than the handover delay from the WLAN to The cellular network, τ_0. The probability of a connection breakdown Pb is calculated as [36]

$$\mathrm{P}b = G(r) = \begin{cases} 1 & R < r \\ 1 - \frac{1}{\pi}\cos^{-1}\left(\frac{2r}{R} - \frac{R^2 - r^2 - v\ \ {}^2\tau^2 o}{2v\ \ {}^2\tau^2 o R^2} - 1\right), & R - v\tau o \le r \le R \cap c_1 \\ 0 & r < R - v\tau o \le r \le R \cap c^1 \\ \frac{1}{\pi}\cos^{-1}\left(\frac{2v\tau^2 o}{R^2}\right) & c^2 \end{cases} \tag{3.15}$$

Where:

C_1: is the RSS from the WLAN drops below the RSS threshold RSSB when the MT is traveling away from the WLAN AP

C_2: the RSS from the WLAN is below RSSB (and has never been above RSSB) and starts continuously deteriorating, which means the MT travels past the middle point M.

CHAPTER FOUR

RESULTS AND DISCUSSION

CHAPTER FOUR
RESULTS AND DISCUSSION

This work analyzes the performance of vertical handover by simulation code written in MATLAB-M-file. This simulation examines the vertical handover between 3G, WIMAX and WIFI considering the performed metrics such as unnecessary handover, handover failure and connection breakdown. The simulation parameters are stated in table 4.1 and 4.2.

4.1 simulation parameter

Table 4.1: Different Networks Characteristics

Network parameter	WIFI(802.11n)	WIMAX(802.16e)	3G cellular(UMTS)
network radius	150 m	500 m	350 m
RSS	-90 to -10 dBm	-90 to -30 dBm	-90 to -60 dBm
Data rate	600Mbps	70Mbps	2Mbps
Bandwidth	2.4GHZ	3.5 GHZ	2GHZ

Table 4.2: Network Parameters

PARAMETER	SYMBOL	VALUE
WLAN radius	R	150 m
AP transmit power	Pt_x	20dBm
Distance between the AP and the reference point	d_{ref}	1m
Path loss of the reverence point	pL_{ref}	40dB
Path loss exponent	β	3.5
Standard deviation of shadow fading	σ	4.3
Handover delay from cellular to WLAN	τ_i	1s,0.455s
Handover delay from WLAN to cellular	τ_0	1s,0.455s
Tolerable handover failure probability	Pf	0.02
Tolerable unnecessary handover probability	Pu	0.04
Velocity of the mobile user = (10-100) km/h		

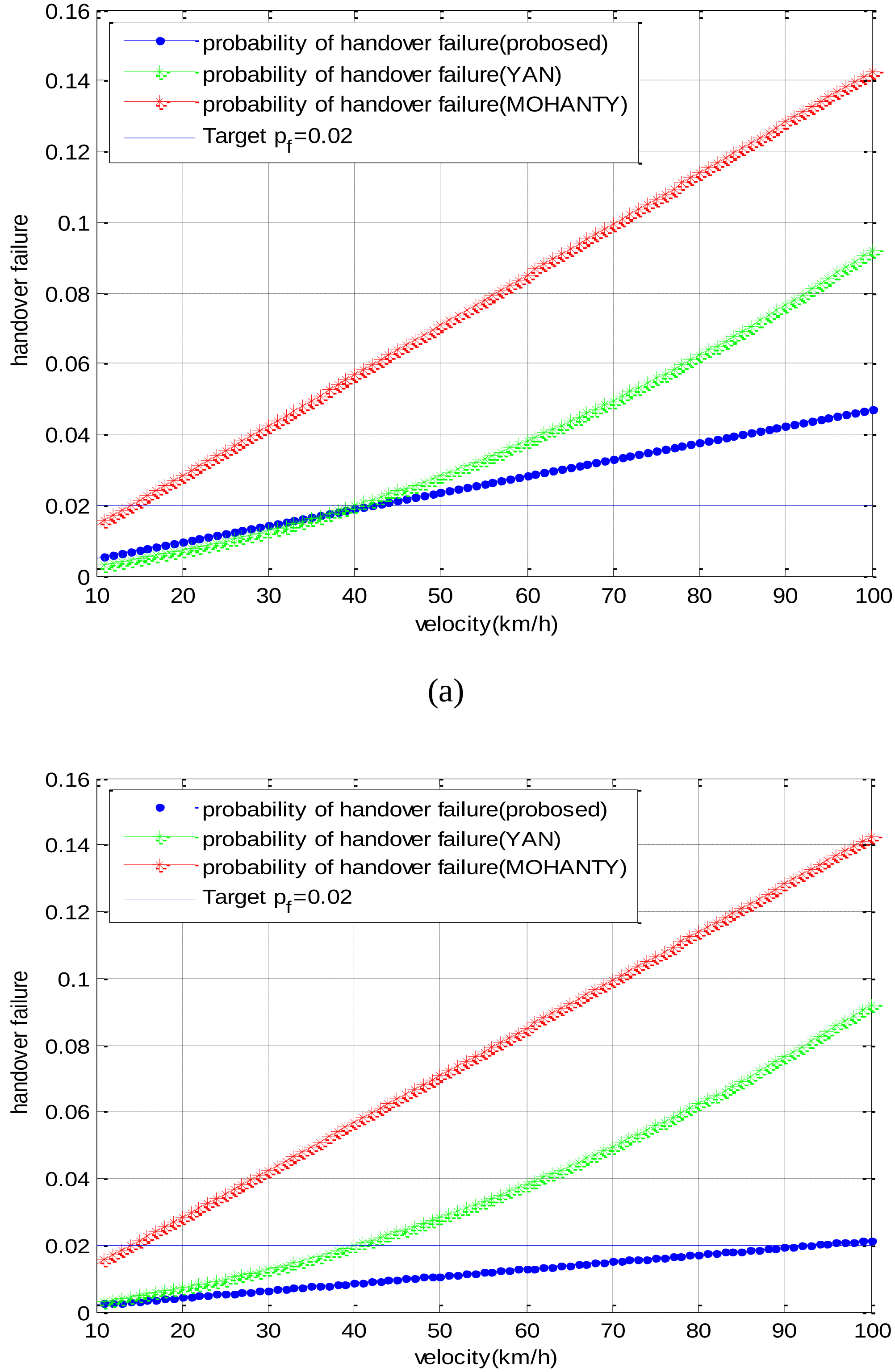
4.2 Simulation Results

Obtained by simulation code written in MATLAB-M-file the results are:

4.2.1 Probability of Handover Failure

Figure (4.1) compare the probability of handover failure with the velocity of the mobile terminal, for different handover decision method. The result shown the probability of handover failure is increase when the velocity of the mobile increase in all handover decision method. But when used the travelling time prediction with mobility, the probability of handover failure is be less than other method. In figure (a), when the handover delay is ($\tau_{\mathrm{i}} = 1s$) and the velocity of mobile user is equal (100Km/h), the probability of handover failure is reduced by 69.28% from MOHANTY and by 50% from YAN. And when the velocity of the mobile user is equal (60Km/h), the probability of handover failure is reduced by 37.5% from YAN and by 63.41% from MOHANTY.

In figure (b), when the handover delay is ($\tau_{\mathrm{i}} = 455ms$) and the velocity of mobile user is equal (100Km/h), the probability of handover failure is reduced by 85.71%from MOHANTY and by 77.78% from YAN and when the velocity of the mobile user is equal to (60Km/h) the probability of handover failure is reduced by 75.75% from YAN and by 79.26% from MOHANTY. From the result shown when the delay increased (1s) and the velocity of the mobile user increased (100km/h) the probability of handover failure is increased .And when the delay increased (1s) and the velocity of the mobile user decreased (60km/h) the probability of handover failure is decreased . And when the delay decreased (455ms) and the velocity of the mobile user decreased (60km/h) the probability of handover failure is decreased.



(a)

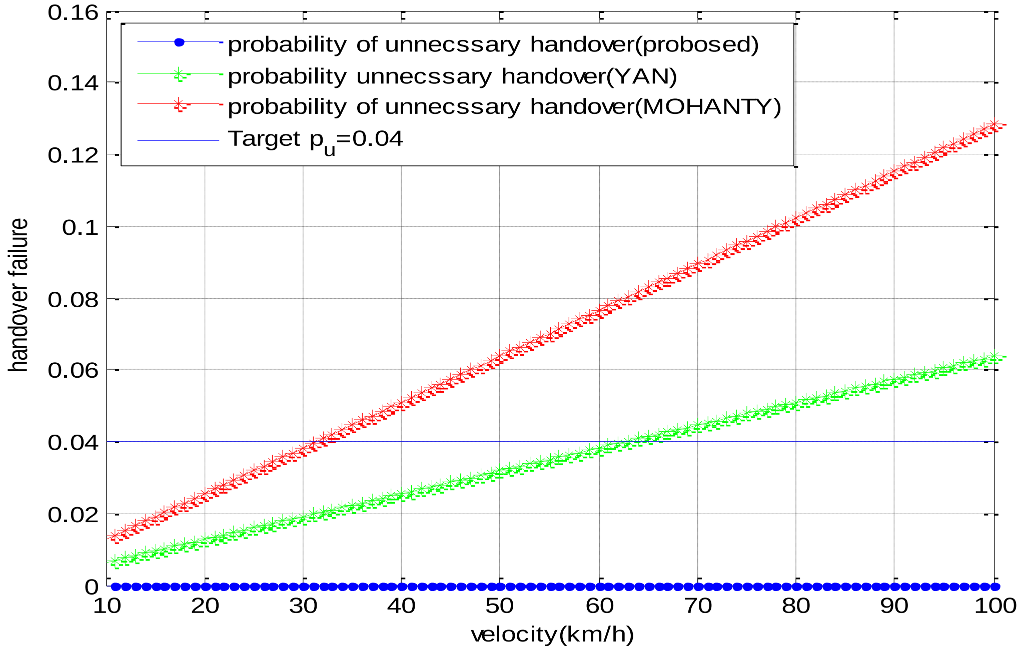
(b)

Figure (4.1): Handover Failure (a) at ($\tau_i = 1s$) and (b) at ($\tau_i = 455ms$)

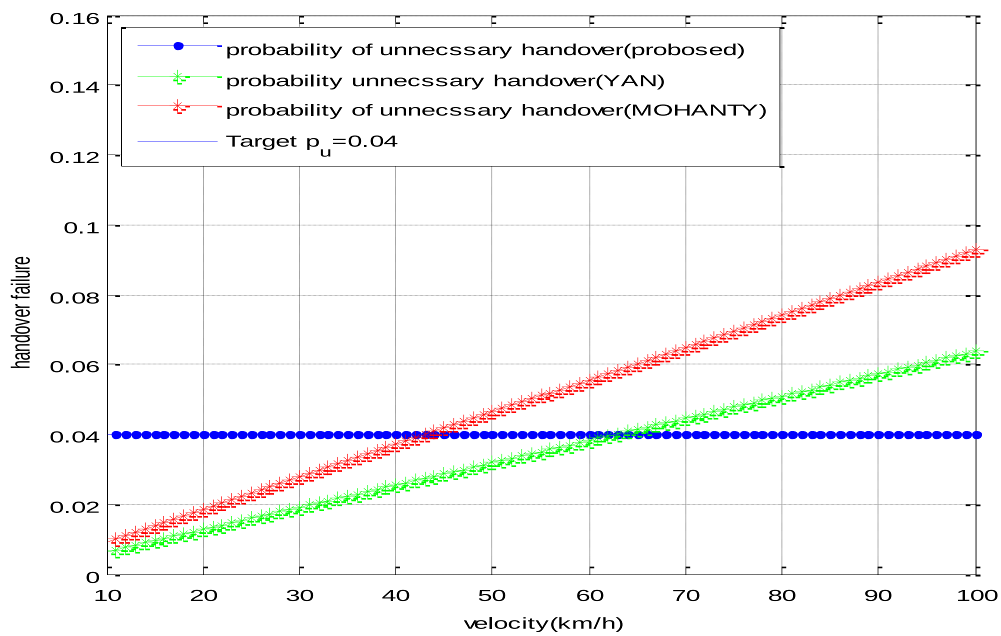
4.2.2 Probability of Unnecessary Handover

Figure (4.2) compare the unnecessary handover with the velocity of the mobile terminal, for different handover decision method. The results show that the probability of unnecessary handover is increased when the velocity of the mobile is increased, in all handover decision method. When the handover delay is ($\tau_{\mathrm{i}} = \tau o = 1s$) and the velocity of the mobile user is equal (100km/h) the probability of unnecessary handover is ZERO, while the probability of unnecessary handover for MOHANTY is 0.13 and for YAN is 0.062. And when the velocity of the mobile user is (60km/h) the probability of unnecessary handover is also remind ZERO, while the probability of unnecessary handover for MOHANTY is 0.079 and for YAN is 0.04.

And when the handover delay ($\tau_{\mathrm{i}} = \tau o = 455ms$) and the velocity of the mobile user equal (100km/h), the probability of unnecessary handover is decreased by 34.4% from YAN and by 55.55% from MOHANTY. And when the velocity of mobile user is equal to (60km/h) the probability of unnecessary handover for our method and for YAN method, both of them is equal 0.04, while probability of unnecessary handover for MOHANTY is equal (0.058) it's increased by 31.03% from our method and YAN method.



(a)

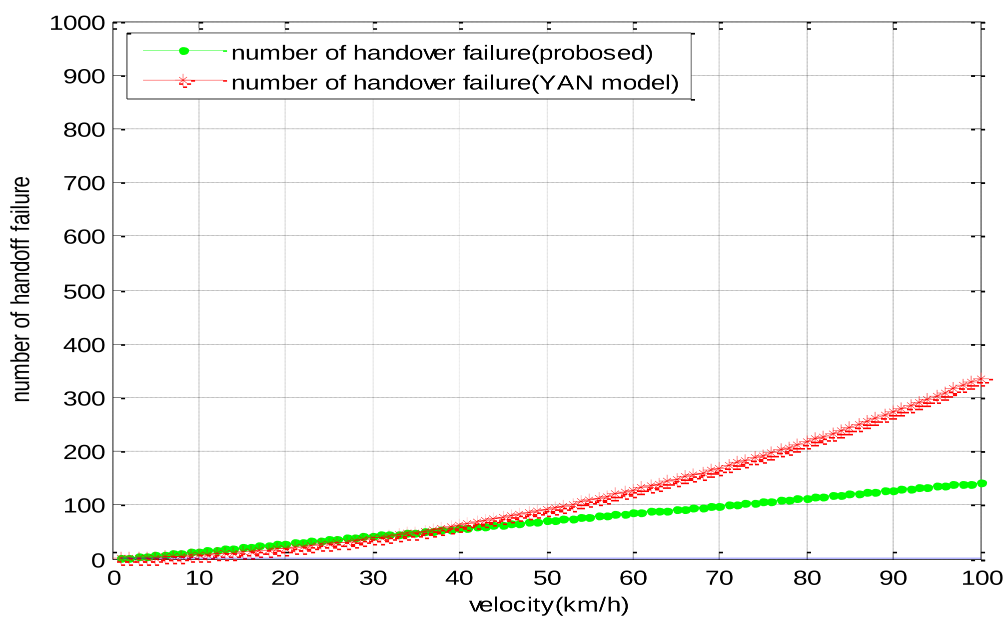


(b)

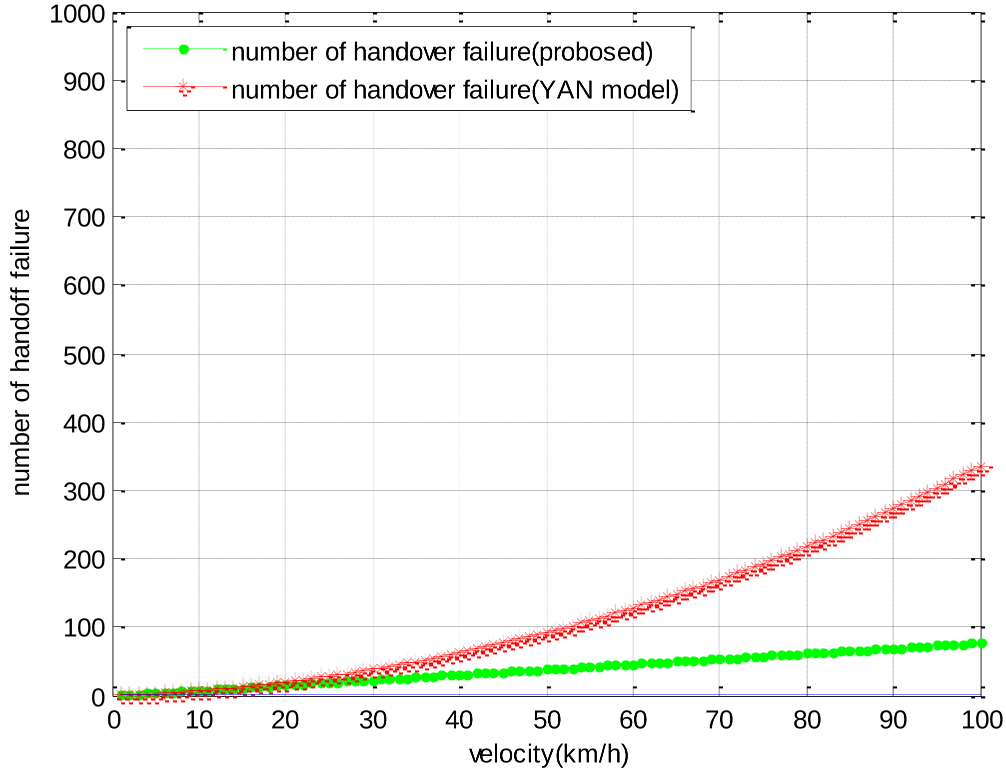
Figure (4.2): Probability of Unnecessary Handover (a) at ($\tau_{\mathrm{i}} = \tau o = 1s$) and $(b) at$ $\tau_{\mathrm{i}} = \tau o = 455ms$)

4.2.3 Number of Handover Failure

Supposed 1000 random user was generated, MT trajectories across the WLAN cell coverage area for speeds from 1 km/h to 100 km/h in 2 km/h increments. Figure (a) shown the number of handover failure compare with the velocity of the mobile terminal. When the handover delay is (τ_i =1s) and the velocity of mobile user is (100km/s) the number of handover failure is reduced by 60.6% and when the velocity of the mobile user is (60km/s) the number of handover failure is reduced by 18.1%. And in Figure (b) when the handover delay is (τ_i =455ms) and velocity of the mobile user is equal (100km/s) the number of handover failure is reduced by 71.87% .And when the velocity of the mobile user is (60km/s) the number of handover failure is reduced by 54.5% .From the result shown when the handover delay decreased and velocity of the mobile user is increased the number of handover failure is increased and vice versa.



(a)

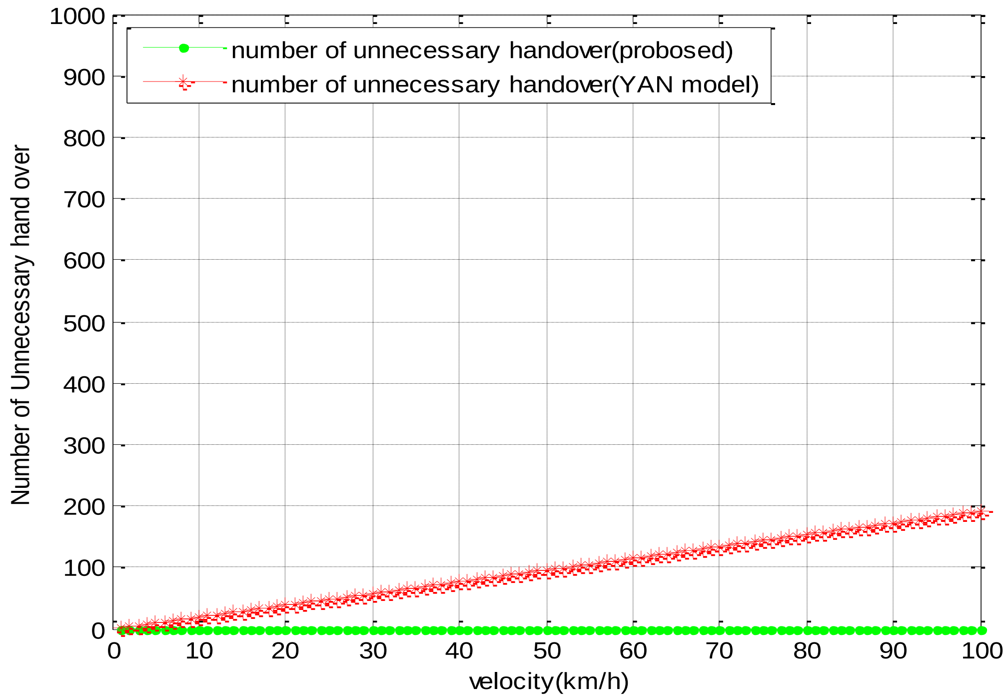


(b)

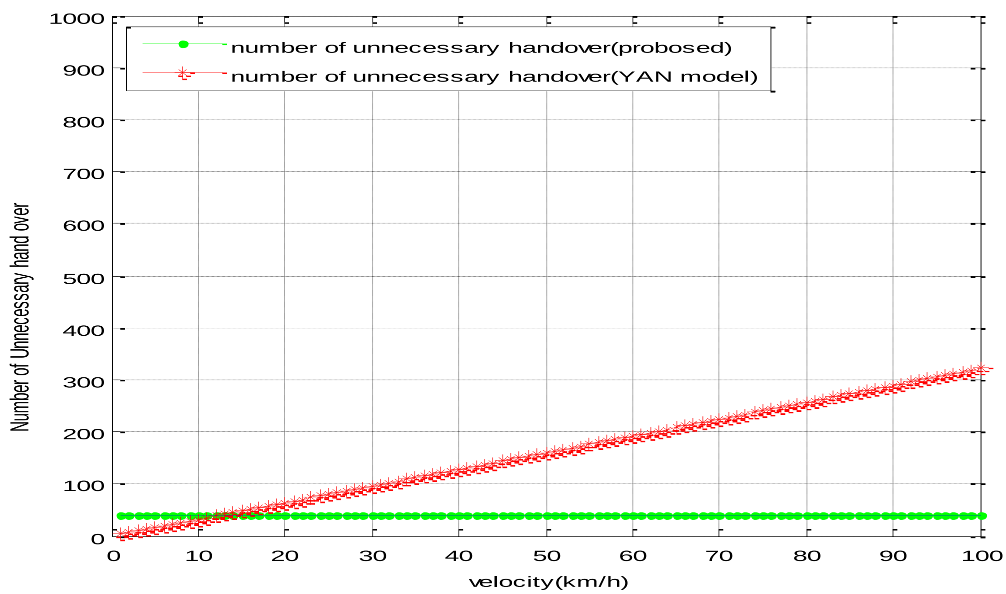
Figure (4.3): Number of Handover Failure (a) at ($\tau_{\mathrm{i}} = 1s$) and (b) at ($\tau_{\mathrm{i}} = 455ms$)

4.2.4 Number of Unnecessary Handover

Figure (4.4) shown the number of unnecessary handover compare with the velocity of the mobile user. When the handover delay is ($\tau_{\mathrm{i}} = \tau o = 1$s) and the velocity of mobile user is (100km/s) the number of unnecessary handover for our method is ZERO and for YAN method [31] is 199.Wherever, when the handover delay is ($\tau_{\mathrm{i}} = \tau o = 455$ms) and the velocity of the mobile user is (100km/s) the number of unnecessary handover for our method is equal 40 and for YAN method is equal 310.



(a)



(b)

Figure (4.4): Number of Unnecessary Handover (a) at ($\tau_{\mathrm{i}} = \tau o = 1s$)

And (b) at ($\tau_{\mathrm{i}} = \tau o = 0.455s$)

4.2.5 Total Number of Failure and Total Number of Unnecessary

Figure (4.5) shown the total number of unnecessary handover and handover failure when used travelling time prediction with the mobility. From the figure (4.5), it is noticed that when the velocity of the mobile terminal is (100km/h) and the handover delay is (1s) the unnecessary handover it is remind ZERO, even when the velocity is increased. And the handover failure is 10% from the total number of vertical handover. And when the velocity of the mobile terminal is (60km/h) and the handover delay is (1s) the unnecessary handover it is remind ZERO, even when the velocity is increased. And the handover failure is 7% from the total number of vertical handover

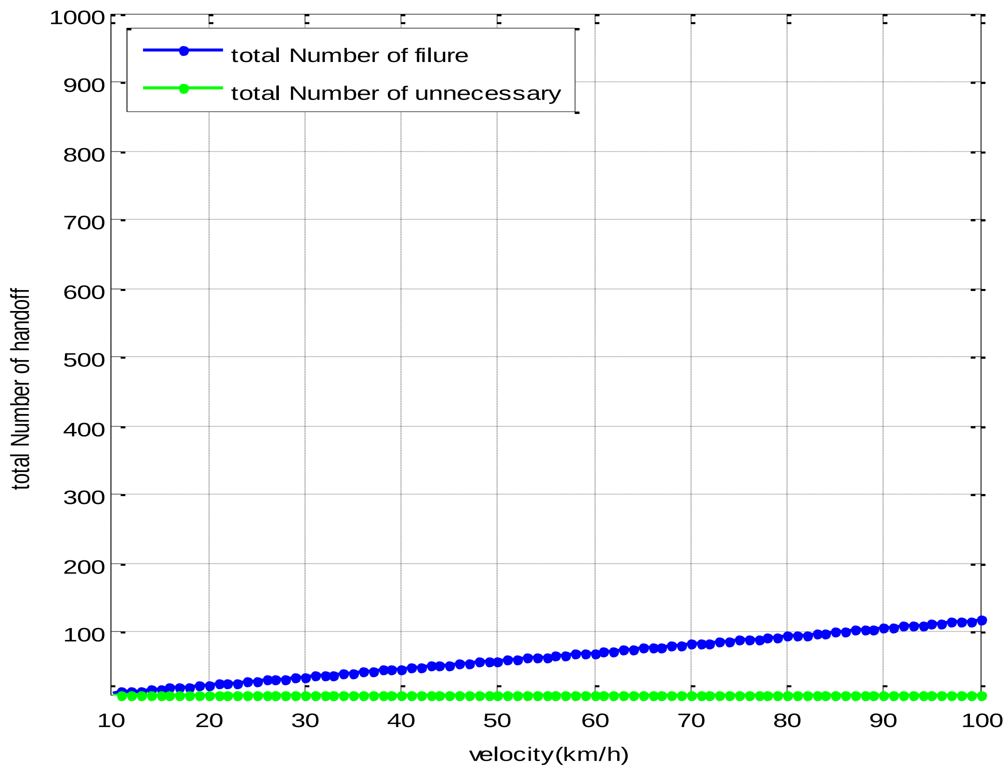


Figure (4.5) Total Number of Handover Failure and Unnecessary Handover.

4.2.6 Probability of Connection Breakdown

Figure (4.6) gives a comparison of the connection breakdown for three values of radius of boundary area. In witch, it is clear that when the radius of boundary area is increased the connection breakdown is decreased. Because the connection breakdown is dependent on the boundary area radius and the velocity of the user. From the figure (4.6), it is noticed that when the velocity is increased for small radius the probability of connection breakdown is increased. But when the velocity is increased for large radius the probability of connection breakdown is remained in the same level even the velocity is increased.

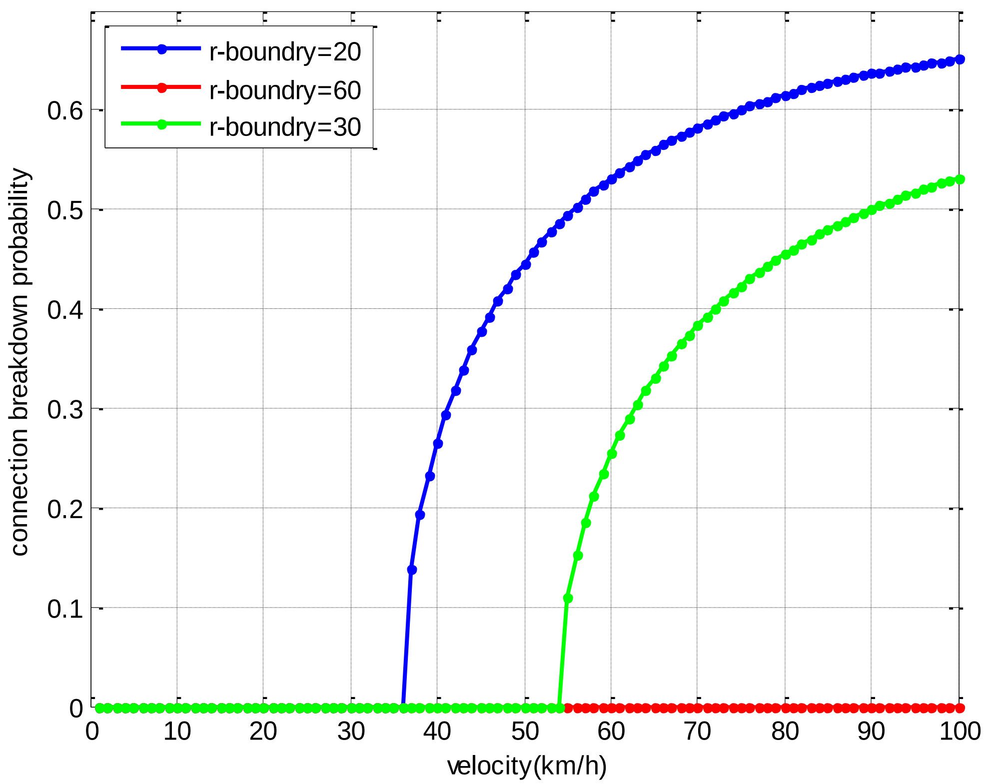
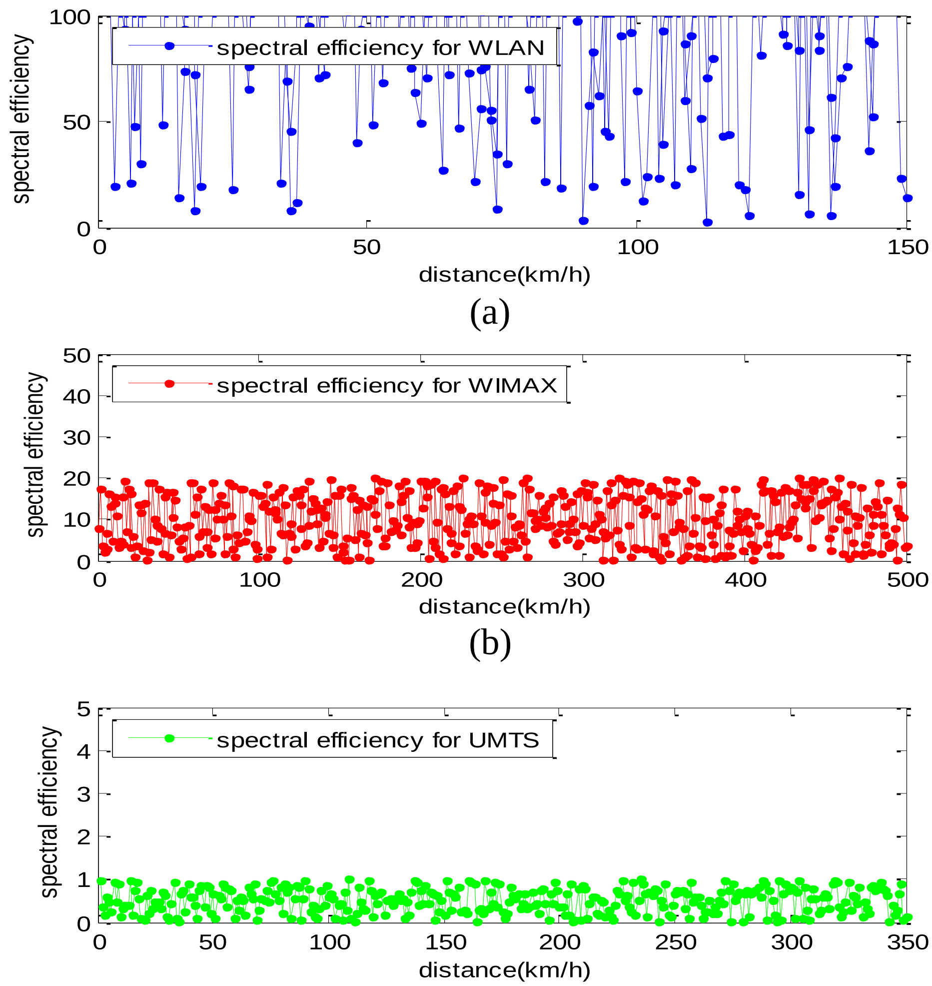


Figure (4.6) Probability of Connection Breakdown

4.2.7 Spectral Efficiency

Figure (4.6) show the spectral efficiency of the WLAN,WIMAX,UMTS compare with the distance radius of each network. The result shown the spectral efficiency of the WLAN is greater by 50% than spectral efficiency of WIMAX ,and WIMAX is greater by 33% than spectral efficiency of UMTS. Because the data rate of WIFI is greater than data rate of WIMAX and UMTS. And data rate of WIMAX is greater than data rate of UMTS.



(a)

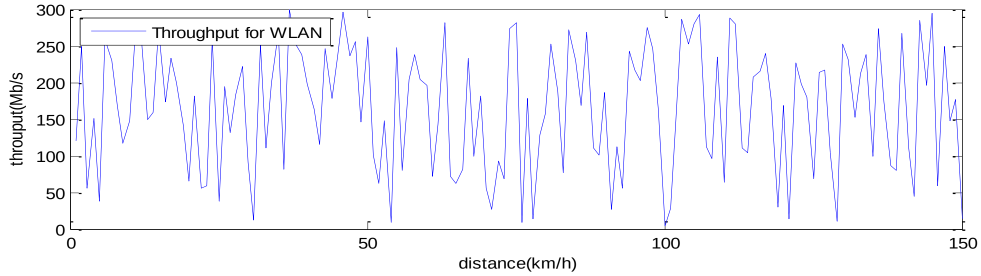
(b)

(c)

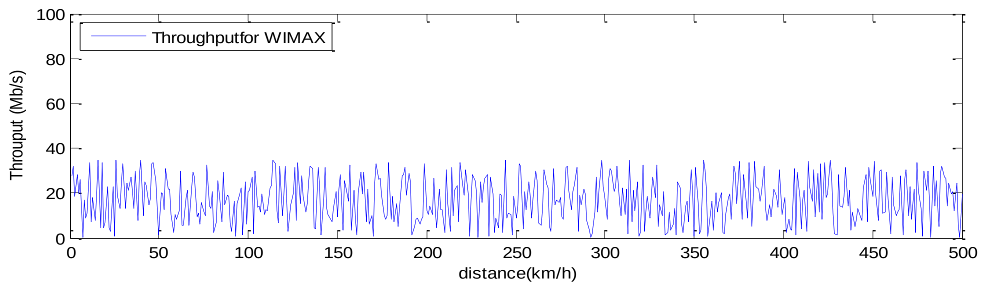
Figure (4.7) Spectral Efficiency for (a) WLAN, (b)WIMAX,and (c)UMTS

4.2.8 Throughput

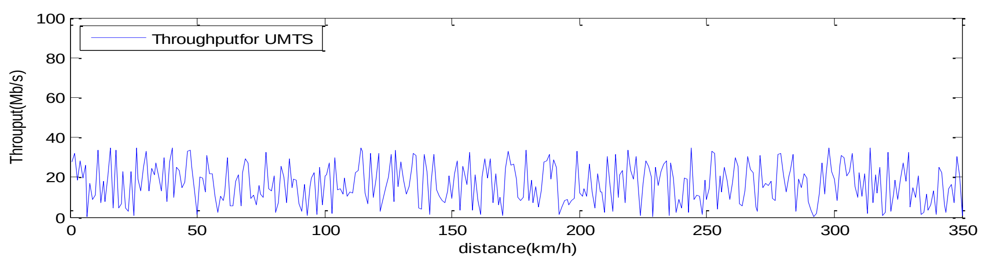
The Figure (4.6) show the throughput of the WLAN,WIMAX,UMTS compare with the distance radius of each network , the result shown the throughput of WLAN is greater by 88.33% than the throughput of WIMAX and UMTS. Because the data rate of WLAN is greater than the data rate of WIMAX and UMTS. And the cell radius of WLAN is smaller than the radius of other networks.



(a)



(b)



(c)

Figure (4.8) Throughput for (a) WLAN,(b)WIMAX,and(c)UMTS

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

The conclusion of the work done is conclude and summarized in this chapter, and some recommendations of the future work is also stated

5.1 Conclusion

In this thesis, the vertical handover have been evaluated, by proposed a new algorithm considering different network parameters such as receive signal strength, available bandwidth, travelling time prediction, and mobility. The proposed vertical handover algorithm aims to minimize the unnecessary handover and handover failure when the user moving between WIFI, WIMAX, and 3G. The MATLAB simulation is used to simulate the effectiveness of the proposed algorithm .It is found that, when the handover delay is (τi =1s), the probability of unnecessary handover is equal ZERO and when the handover delay is (τi =455ms) and the velocity of mobile user is equal to the probability of unnecessary handover is equal 0.04.

Therefore, the probability of handover failure when the handover delay is (τi =1s) and the velocity of mobile user is equal to (100km/h) the probability of handover failure is reduced by 69.28% from MOHANTY and reduced by 50.5% from YAN. And when the handover delay is (τi =455ms) the probability of handover failure is reduced by 85.71%.

5.2 Recommendations

It is recommended for future works to:

- Find new approach to enhance the handover failure and unnecessary handover by using other parameter such as
  - Cost function
  - dynamic RSS threshold
  - Fading effect
  - And prorogation model.
- Also recommended to consider the packet loss during vertical handover execution.

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Appendix A

The handover necessity estimation relies on an algorithm which attempts to predict the traveling time in a WLAN cell coverage area by using successive RSS measurements. The algorithm works under the following assumptions:

- The WLAN cell has a circular geometry.
- The MT travels through the WLAN cell coverage in a straight line with a Constant speed.
- The propagation environment in the WLAN coverage is modeled using the log-distance path loss model [33].

Figure (a) shows the traveling time prediction scenario. The relationship between RSS (in dBm), and the distance between the AP and the MT at any point P inside the WLAN coverage area is obtained by using the log-distance path loss model:

$$Rssp = P_{T_x} - pL_{reF} - 10\beta \; log\left(\frac{L_0 p}{\mathrm{d}_{reF}}\right) + X\sigma \qquad \text{(A-1)}$$

Where:

P_{TX}: is the transmit power of the WLAN AP in dBm

$L_0 p$: is the distance between the AP and point P.

d_{reF}: is the distance between the AP and a reference point.

PLref :is the path loss at the reference point in dB.

β :is the path loss exponent.

$X\sigma$:is a Gaussian distributed random variable with a mean of zero and a standard deviation σ in dB.

Estimation of the traveling time of the MT by using RSS measurements is done in the following way. It is assumed that the MT starts receiving sufficiently strong signals (i.e., it “enters” the WLAN cell) at point P_i and the signal strength drops below the usable level at point P_o, and M is the middle point of the traveling.

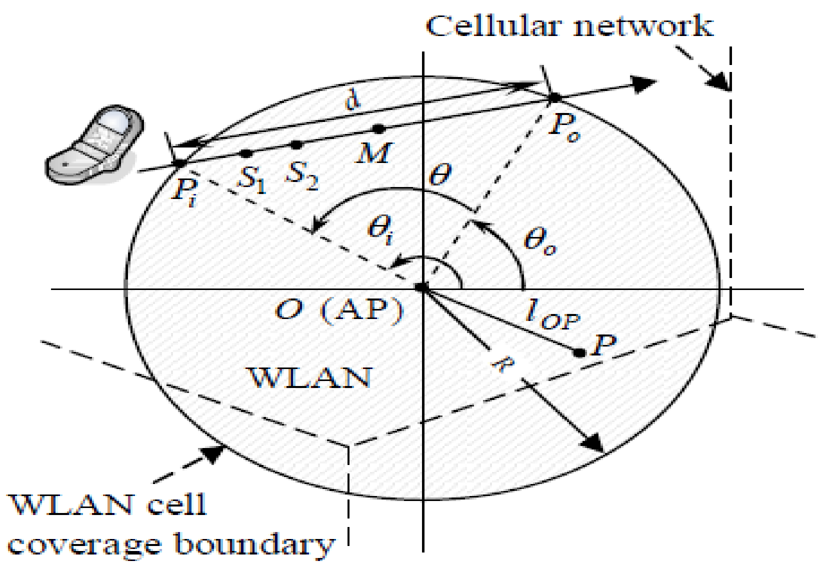

Figure: (a) Prediction of traveling distance in a WLAN cell

Trajectory, as shown in Figure (a), by using (3.1), when the MT enters the WLAN cell coverage area (i.e., the RSS level detected by the MT reaches a pre-determined threshold) at time tp_i , the distance Lop_i(an approximate value for the cell radius (R) can be calculated using

$$R = \sim Lop_i = d_{r\varrho}\mathrm{F}10^{\frac{2(pt_\chi - pL_{r\varrho} - Rssp_i)}{10^\beta}} \qquad (A-2)$$

Where $Rssp_i$ is the RSS at the entry point p_i . To estimate the traveling time t_{WLAN}, the MT takes another RSS sample at point S at time ts. Using Equation (3.1), the distance between O and S, l_{os}, is estimated by

$$l_{os} = d_{ref} 10^{\frac{p_{Tx} - pL_{ref} - RSSs}{10\beta}} \qquad (A-3)$$

Where RSSs is the RSS at the sampling point S.

From the geometric configuration of Figure 3.4, the following equations are obtained:

$$L^2 p_i m + L^2 om = Lop_i^2 = R^2 \qquad (A-4)$$

$$L^2 om + L^2 sm = L^2 os \qquad (A-5)$$

$$Lsm = Lp_i m - Lp_i s \qquad (A-6)$$

where $Lp_i m$, Lom, Lsm , Los and $Lp_i s$ are the distances between the entry point Pi and the middle point M, the AP location O and point M, the sampling point S and point M, points O and S, and points Pi and S, respectively. By substituting Equation (A-5) in Equation (A-6), the following equation is obtained:

$$(Lp_i m - Lp_i s)^2 + L^2 om = L^2 os \qquad (A\text{-}7)$$

Let v be the speed of the MT, which is a constant during the time period when the MT crosses the WLAN cell coverage t. Thus

$$Lp_i m = \frac{vt}{2} \qquad (A\text{-}8)$$

$$Lp_i s = v(ts - tp_i) \qquad (A-9)$$

Where ts and tp_i are times at sampling and entry points S and Pi, respectively. By substituting Equation (A-8, A-9) in Equations (A-4) and (A-7), the following equations are obtained:

$$(\frac{\nu t}{2})^2 + L^2 om = R^2 \qquad \text{(A-10)}$$

$$\left[\frac{\nu t}{2} - \nu(ts - tp_i)\right]^2 + L^2 om = L^2 os \qquad (A-11)$$

Based on Equation (3.10, 3.11) an estimate of traveling time tw_{LAN} is calculated as

$$tw_{LAN} = \frac{R^2 - L^2 os + \nu^2(ts - tp_i)^2}{\nu^2(ts - tp_i)^2} \qquad (A-12)$$

Substituting Equations (A-10) and (A-11) in Equation (A-12), the ultimate Equation of WLAN is

$$tw_{LAN} = \frac{d_{r\varrho} 10^{\frac{2(pt_\chi - pL_{r\varrho} - Rssp_i)}{10^\beta}} - d_{r\varrho} 10^{\frac{2(pt_\chi - pL_{r\varrho} - Rsss)}{10^\beta}} + \nu^{2(ts - tp_i)2}}{\nu^{2(ts - tp_i)2}} \qquad (A-13)$$

The traveling speed of the MT v is measured by an accelerometer embedded in the MT [35]. Accelerometers can be used in handsets for various purposes and one purpose is to accurately estimate the speed of the MT.

From Figure 3.4 the angles Θ_i and Θ_0 are both uniformly distributed in [0; 2π], and $\Theta = |\Theta_i - \Theta_0|$

The first step is to calculate the probability density function (PDF) the PDFs of the locations of Pi and P_0 are given, respectively, by

$$fp_i(\theta_i) = \begin{cases} \frac{1}{2\pi} & 0 \le \theta_i \le 2\pi \\ 0, & otherwise \end{cases} \qquad \text{(A-19)}$$

$$fpo(\theta o) = \begin{cases} \dfrac{1}{2\pi} & 0 \leq \theta o \leq 2\pi \\ 0, & otherwise \end{cases} \qquad (A-20)$$

Since the locations of Pi and Po are independent from each other, their joint PDF is given by

$$f(\theta_{\mathrm{i}}, \theta o) = \begin{cases} \frac{1}{4\pi^2} & 0 \leq \theta_{\mathrm{i}}, \theta o \leq 2\pi, \\ 0, & otherwise \end{cases} \qquad \text{(A-21)}$$

The probability that $\Theta \leq \mathit{\Theta}$, which is also the cumulative distribution function (CDF) of Θ, can be derived using the following integral [31]:

$$F(\Theta) = P(\theta \leq \Theta) = \iint_{\Omega} f(\theta_{\mathrm{i}}, \theta o) d\theta o d\theta_{\mathrm{i}} \qquad (A-22)$$

Where Ω is the space of locations of entry and exit points Pi and Po such that $\Theta \leq \mathit{\Theta}$ and $0 \leq \mathit{\Theta} \leq 2\pi$. $P(\Theta \leq \mathit{\Theta}) = 0$ for $\Theta < 0$ and $P(\Theta \leq \mathit{\Theta}) = 1$ for $\mathit{\Theta} > 2\pi$. From the observation of Figure 4.1 Equation (22) can be rewritten as

$$F(\Theta) =$$

$$P(\theta \leq \Theta) \frac{1}{4\pi^2} \left(\int_0^{\Theta} \int_0^{\Theta+\theta_{\mathrm{i}}} + \int_{\Theta}^{2\pi-\Theta} \int_{\theta_{\mathrm{i}}-\Theta}^{\Theta+\theta_{\mathrm{i}}} + \int_{2\pi-\Theta}^{2\pi} \int_{\theta_{\mathrm{i}}-\Theta}^{2\pi} \right) d\theta o d\theta_{\mathrm{i}}$$

$$= 4\pi\Theta - 4\Theta^2, \quad 0 \leq \Theta \leq 2\pi \qquad \text{(A-23)}$$

The PDF of Θ can be derived by taking the derivative of Equation (A-23) and is given by

$$f(\Theta) = \begin{cases} \frac{1}{\pi}(1 - \frac{\Theta}{2\pi}) & 0 \leq \Theta \leq 2\pi, \\ 0, & otherwise \end{cases} \tag{A-24}$$

The next step is to use the PDF of Θ, and the expression of the traveling time tw_{LAN} as a function of Θ to obtain the PDF oftw_{LN}. From the geometric configuration in Figure 3.1 and by using the cosine formula, the following equation is obtained:

$$(\nu\ tw_{\text{LAN}})^2 = 2\text{R}^2(1 - \cos\theta) \qquad (\text{A}-25)$$

Thus,

$$tw_{\text{LAN}} = g(\theta) = \sqrt{\frac{2\text{R}^2}{\nu^2}(1 - \cos\theta)} \qquad (\text{A}-26)$$

Using the theorem stated in [32], the PDF of tw_{LN} is expressed as

$$f(T) = \sum_1 \text{n}\frac{\text{f}(\theta\text{n})}{\text{g}'(\theta\text{n})} \qquad (\text{A}-27)$$

Where Θ_1-Θn are the roots of function g (Θ), and g\`(.) is the derivative of g(.). In Equation (4.3.7), for g(Θ) there are two roots, Θ1 and Θ2, which are expressed as

$$\theta 1 = \cos^{-1}(1 - \frac{(\nu tw_{\text{LAN}})^{2}}{2\text{R}^2}) \qquad (\text{A}-28)$$

$$\theta 2 = 2\pi - \cos^{-1}(1 - \frac{(\nu tw_{\text{LAN}})^{2}}{2\text{R}^2}) \qquad (\text{A}-29)$$

From (4.3.7), g\`(Θ) is expressed as

$$g'(\theta) = \frac{R\sin\theta}{\nu\sqrt{2(1-\cos\theta)}} \qquad (A-30)$$

So

$$|g'(\theta^1)| = \left| \frac{R\sin(\cos^{-1}(1 - \frac{(vtw\text{LAN})^{\ 2}}{2\mathrm{R}^2}))}{v\sqrt{2\left(1 - \cos\left(\left(\cos^{-1}(1 - \frac{(vtw\text{LAN})^{\ 2}}{2\mathrm{R}^2}\right)\right)}} \right|$$

$$= R\sqrt{1 - \frac{v^2 t^2 w\text{LAN}}{4R^2}} \qquad (A-31)$$

$$|g'(\theta_2)| = \left| \frac{R\sin(\cos^{-1}(1 - \frac{(vtw\text{LAN})^{\ 2}}{2\mathrm{R}^2}))}{v\sqrt{2(1 - \cos((\cos^{-1}(1 - \frac{(vtw\text{LAN})^{\ 2}}{2\mathrm{R}^2}))}} \right|$$

$$= R\sqrt{1 - \frac{v^2 t^2}{4R^2}} \qquad (A-32)$$

And

$$f(\theta_1) = \frac{1}{\pi}\left[1 - \frac{\cos^{-1}(1 - \frac{v^2 t^2 w\text{LAN}}{2R^2})}{2\pi}\right] \qquad (\mathrm{A}-33)$$

$$f(\theta_2) = \frac{1}{\pi}\left[1 - \frac{2\pi - \cos^{-1}(1 - \frac{v^2 t^2 w\text{LAN}}{2R^2})}{2\pi}\right] \qquad (A-34)$$

Thus, using Equations (A-27), (A-31) and (A-33) the PDF of $tw\text{LAN}$ is calculated by

$$f(\mathrm{T}) = \begin{cases} \frac{f(\theta_1)}{|g'(\theta^1)|} + \frac{f(\theta_2)}{|g'(\theta_2)|} & 0 \le \mathrm{T} \le \frac{2R}{v}, \\ 0, & otherwise \end{cases} \qquad (A-35)$$

$$f(\mathrm{T}) = \begin{cases} \frac{2}{\pi\sqrt{4R^2 - v^2 T^2}} & 0 \le \mathrm{T} \le \frac{2R}{v}, \\ 0, & otherwise \end{cases} \qquad (A-35)$$

The third step is to use the PDF of t_{WLAN} to obtain the CDF of t_{WLAN}, which is derived from the integral of Equation (A-35) as

$$F(T) = \Pr[t \leq T] = \int_0^T f(T)dT \qquad (A-36)$$

$$\begin{cases} \frac{2}{\pi}\cos^{-1}\frac{vT}{2R} & 0 \leq T \leq \frac{2R}{v} \\ 1 & \frac{2R}{v} < T \end{cases} \qquad (A-37)$$

A time threshold parameter T_1 is introduced to make handover decisions: whenever the estimated traveling time t_{WLAN} is greater than T_1, the MT will initiate the handover procedure. A handover failure occurs when the traveling time inside the WLAN cell is shorter than the handover latency from the cellular network to the WLAN, τ_i. Thus, using Equation (A-36) the probability of a handover failure for the method using the threshold T_1 is given by

$$Pf = \begin{cases} \frac{2}{\pi}[\sin^{-1}\frac{v\tau_i}{2R} - \sin^{-1}\frac{vT_1}{2R} & 0 \leq T_1 \leq \tau_i \\ 0 & t_i < T_1 \end{cases} \qquad (A-38)$$

By using (37), an equation which can be used by the MT to calculate the value of T1 for a particular value of Pf when 0 < Pf < 1:

$$T_1 = \frac{2R}{v}\sin(\sin^{-1}(\frac{v\tau_i}{2R}) - \frac{\pi}{2}\text{Pf}) \qquad (\text{A}- 39)$$

To calculate T_1, the speed of the MT (v) and the handover latency (τ_i) need to be obtained. In this research, the knowledge of v and τ_i is assumed, and they can be measured by using accelerometers [30] and the technique described in [27], respectively.

Appendix B-1

Probability of Handover Failure

```
R=150;R_M=50;ti=1;tm=1;ty=1;P_f=0.02;P_u=0.04;R_yan=50;
i=[];
v=[];
v0(i)=[];
for i=1:100
    v0(i)=i;v(i)=v0(i)*2/18;
    T1(i)=(2*R/v(i))*sin(asin(v(i)*(ti)/2/R)-pi/2/P_f);
    if T1(i)<=ti
        p_f_fixed(i)=2/pi*(asin(v(i)*(ti)/2/R)-
asin(v(i)*T1(i)/2/R));

        else
         p_f_fixed(i)=0;
    end
end
for i=1:100
    v0(i)=i;v(i)=v0(i)*1/30;
    L(i)=(2*R_yan)*sin(asin(v(i)*(ty)/2/R_yan)-pi/2/P_f);
    if ty>=L(i)
        p_f_YAN(i)=2/pi*(asin(v(i)*(ty)/2/R_yan)-
asin(v(i)*L(i)/2/R_yan));

        else
         p_f_YAN(i)=0;
    end
end
for i=1:100
    v0(i)=i;v(i)=v0(i)*4/18;
    if v(i)*tm>=2*R_M
        p_f_M(i)=1;
        else
      p_f_M(i)=2/pi*(asin(v(i)*(tm)/2/R_M));
    end
end
for i=1:100
    P_f_HNE(i)=P_f;
end
plot(p_f_fixed,'color','b','marker','.','linewidth',1)
hold on
axis([10 100 0 0.16])
plot(p_f_YAN,'color','g','marker','*','linewidth',1)
hold on
axis([10 100 0 0.16])
plot(p_f_M,'color','r','marker','*','linewidth',1)
axis([10 100 0 0.16])
plot(P_f_HNE)
grid on
xlabel(' velocity(km/h)','linewidth',5)
ylabel(' handover failure')
legend( 'probability of handover failure(probosed)','probability of
handover failure(YAN)','probability of handover
failure(MOHANTY)','Target p_f=0.02','location','Northwest');
```

Appendix B-2

Probability of Unnecessary Handover

```
R=150;R_M=50;ti=0.455;tiM=1;t0M=1;P_f=0.02;P_u=0.04;R_yan=50;t0=0.455;t0y=
1;tiy=1;
i=[];
v=[];
v0(i)=[];
for i=1:100
    v0(i)=i;v(i)=v0(i)*4/10;
    T2(i)=(2*R/v(i))*sin(asin(v(i)*(ti+t0)/2/R)-pi/2/P_u);
    if T2(i)>=(ti+t0)
        p_u_fixed(i)=2/pi*(asin(v(i)*(ti+t0)/2/R)-asin(v(i)*T2(i)/2/R));

        else
         p_u_fixed(i)=0;
    end
end
for i=1:100
    v0(i)=i;v(i)=v0(i)*1/20;
    C(i)=(2*R_yan)*sin(asin(v(i)*(tiy)/2/R_yan)-pi/2/P_f);
    if (tiy+t0y)>=C(i)
        p_u_YAN(i)=2/pi*(asin(v(i)*(tiy)/2/R_yan)-asin(C(i)/2/R_yan));

        else
         p_u_YAN(i)=0;
    end
end
for i=1:100
    v0(i)=i;v(i)=v0(i)*2/20;
    if v(i)*(tiM+t0M)>=2*R_M
        p_u_M(i)=1;
        else
      p_u_M(i)=2/pi*(asin(v(i)*(tyM+t0M)/2/R_M));
    end
end
for i=1:100
    P_u_HNE(i)=P_u;
end
plot(p_u_fixed,'color','b','marker','.','linewidth',1)
hold on
axis([10 100 0 0.16])
plot(p_u_YAN,'color','g','marker','*','linewidth',1)
hold on
axis([10 100 0 0.16])
plot(p_u_M,'color','r','marker','*','linewidth',1)
axis([10 100 0 0.16])
plot(P_u_HNE)
grid on
xlabel(' velocity(km/h)','linewidth',5)
ylabel(' handover failure')
legend( 'probability of unnecssary handover(probosed)','probability
unnecssary handover(YAN)','probability of unnecssary
handover(MOHANTY)','Target p_u=0.04','location','Northwest');
```

Appendix B-3

Number of Handoff Failure

```
R=150;R_yan=50;ti=0.544;ty=1;P_f=0.02;P_u=0.04;
j=1000;
i=[];
v=[];
v0(i)=[];
for i=1:100
    v0(i)=i;v(i)=v0(i)*6/18;
    T1(i)=(2*R/v(i))*sin(asin(v(i)*(ti)/2/R)-pi/2/P_f);
    if ti>=T1(i)
        p_f_fixed(i)=2/pi*(asin(v(i)*(ti)/2/R)-
asin(v(i)*T1(i)/2/R));

        else
         p_f_fixed(i)=0;
    end
    no_filure_fixed(i)=j*p_f_fixed(i);
end

for i=1:100
    v0(i)=i;v(i)=v0(i)*2/30;
    L(i)=(2*R_yan)*sin(asin(v(i)*(ty)/2/R_yan)-pi/2/P_f);
    if ty>=L(i)
        p_f_YAN(i)=2/pi*(asin(v(i)*(ty)/2/R_yan)-
asin(v(i)*L(i)/2/R_yan));

        else
         p_f_YAN(i)=0;
    end
    no_filure_yan(i)=j*p_f_YAN(i);
end

for i=1:100
    P_f_HNE(i)=P_f;
    no_filure_HNE(i)=j*P_f;
end
plot(no_filure_fixed,'color','g','marker','.','linewidth',1)
hold on
axis([0 100 0 1000])
plot(no_filure_yan,'color','r','marker','*','linewidth',1)
axis([0 100 0 1000])
plot(P_f_HNE)
grid on
xlabel(' velocity(km/h)','linewidth',1)
ylabel('number of handoff failure')
legend( 'number of handover failure(probosed)','number of handover
failure(YAN model)','location','Northwest');
```

Appendix B-4

Number of Unnecessary Handover

```
R=150;R_yan=50;ti=0.455;t0=0.455;tiy=1;t0y=1;P_u=0.04;
j=1000;
i=[];
v=[];
v0(i)=[];
for i=1:100
    v0(i)=i;v(i)=v0(i)*4/10;
    T2(i)=(2*R/v(i))*sin(asin(v(i)*(ti+t0)/2/R)-pi/2/P_u)
    if T2(i)<=(to+ti)
        p_u_fixed(i)=2/pi*(asin(v(i)*(ti+t0)/2/R)-
asin(v(i)*T2(i)/2/R));

        else
         p_u_fixed(i)=0;
    end
    no_unnecessary_fixed(i)=j*p_u_fixed(i);
end

for i=1:100
    v0(i)=i;v(i)=v0(i)*3/20;
    C(i)=(2*R_yan)*sin(asin(v(i)*(tiy)/2/R_yan)-pi/2/P_f);
    if (tiy+t0y)>=C(i)
        p_u_YAN(i)=2/pi*(asin(v(i)*(tiy)/2/R_yan)-
asin(C(i)/2/R_yan));

        else
         p_u_YAN(i)=0;
    end
    no_unnecessary_yan(i)=j*p_u_YAN(i);
end
for i=1:100
    P_u_HNE(i)=P_u;
    no_unnecessary_HNE(i)=j*P_u_HNE(i);
end
plot(no_unnecessary_fixed,'color','g','marker','.','linewidth',1)
hold on
axis([0 100  0 1000])
plot(no_unnecessary_yan,'color','r','marker','*','linewidth',1)
axis([0 100 0 1000])
%plot(no_filure_HNE)
grid on
xlabel(' velocity(km/h)')
ylabel('Number of Unnecessary hand over ')
legend( 'number of unnecessary handover(probosed)','number of
unnecessary handover(YAN model)','location','Northwest');
```

Appendix B-5

Total Number of Handover

```
R=150;R_M=50;ti=1;tm=1;ty=1;P_f=0.02;P_u=0.04;R_yan=50;
i=[];
j=1000;
v=[];
v0(i)=[];
for i=1:100
    v0(i)=i;v(i)=v0(i)*2/18;
    T1(i)=(2*R/v(i))*sin(asin(v(i)*(ti)/2/R)-pi/2/P_f);
    if T1(i)<=ti
        p_f_fixed(i)=2/pi*(asin(v(i)*(ti)/2/R)-
asin(v(i)*T1(i)/2/R));

        else
         p_f_fixed(i)=0;
    end
    no_of_handoverfailure(i)=j*p_f_fixed(i);
end

for i=1:100
    v0(i)=i;v(i)=v0(i)*4/10;
    T2(i)=(2*R/v(i))*sin(asin(v(i)*(ti+t0)/2/R)-pi/2/P_u);
    if T2(i)>=(ti+t0)
        p_u_fixed(i)=2/pi*(asin(v(i)*(ti+t0)/2/R)-
asin(v(i)*T2(i)/2/R));

        else
         p_u_fixed(i)=0;
    end
     no_ofunnecessary(i)=j*p_u_fixed(i);
end
plot(no_of_handoverfailure,'color','r','marker','.','linewidth',1)
hold on
 plot(no_ofunnecessary,'color','Y','marker','.','linewidth',1)
grid on
axis([0 100 0 1000])
xlabel(' velocity(km/h)','linewidth',1)
ylabel('total Number of handoff')
legend( 'total Number of filure','total Number of
unecessary','location','Northwest');
```

Appendix B-6

Connection Breakdown

```
R=150;R_fixed=130;R_pro=120;R_hyst=90;tau_i=2;tau_o=2;P_b=0;
for i=1:100
 v0(i)=i;v(i)=v0(i)*5/18;
 if v(i)*tau_o<=(R-R_fixed)
 P_b_fixed(i)=0;
 elseif v(i)*tau_o>=(sqrt(R^2-R_fixed^2))
 P_b_fixed(i)=1;
 else P_b_fixed(i)=1-1/pi*(acos(2*R_fixed^2/R^2-(R^2-R_fixed^2-
(v(i)*tau_o).^2).^2/2./(v(i)*tau_o).^2/R^2-1));
 end
end
    for i=1:100
 v0(i)=i;v(i)=v0(i)*5/18;
 if v(i)*tau_o<=(R-R_hyst)
 P_b_hyst(i)=0;
 elseif v(i)*tau_o>=(sqrt(R^2-R_hyst^2))
 P_b_hyst(i)=1;
 else P_b_hyst(i)=1-1/pi*(acos(2*R_hyst^2/R^2-(R^2-R_hyst^2-
(v(i)*tau_o).^2).^2/2./(v(i)*tau_o).^2/R^2-1));
 end
    end
  for i=1:100
 v0(i)=i;v(i)=v0(i)*5/18;
 if v(i)*tau_o<=(R-R_pro)
 P_b_pro(i)=0;
 elseif v(i)*tau_o>=(sqrt(R^2-R_pro^2))
 P_b_pro(i)=1;
 else P_b_pro(i)=1-1/pi*(acos(2*R_pro^2/R^2-(R^2-R_pro^2-
(v(i)*tau_o).^2).^2/2./(v(i)*tau_o).^2/R^2-1));
 end
end

plot(P_b_fixed,'color','b','marker','.','linewidth',2)
hold on
axis([0 100 0 0.7])
plot(P_b_hyst,'color','r','marker','.','linewidth',2)
hold on
plot(P_b_pro,'color','g','marker','.','linewidth',2)
xlabel(' velocity(km/h)','linewidth',5)
ylabel('connection breakdown probability')
grid on
 legend( 'r-boundary=20','r-boundary=60','r-
boundary=30','location', 'Northwest');
```

Appendix B-7

Spectral Efficiency

```
r=[];d=600;b=2.4;
dm=70;bm=3.5;
xm=rand(1,500)
wm=[xm]
du=2;bu=2;
xu=rand(1,350)
wu=[xu]
x=rand(1,150)
w=[x]
for r=1:150
    th=d/b;
    fth=th*w;

end
plot(fth,'color','b','marker','.','linewidth',1)
axis([0 150 0 5])
hold on
xlabel(' distance(km/h)','linewidth',5)
ylabel(' spectral efficiency')
legend( 'spectral efficiency for WLAN','location','Northwest');
for r=1:500
    thm=dm/bm;
    fthm=thm*wm;
end
%plot(fthm,'color','r','marker','.','linewidth',1)
axis([0 500 0 15])
hold on
xlabel(' distance(km/h)','linewidth',5)
ylabel(' spectral efficiency')
legend( 'spectral efficiency for WIMAX','location','Northwest');
for r=1:350
    thu=du/bu;
    fthu=thu*wu;
end
%plot(fthu,'color','g','marker','.','linewidth',1)
axis([0 350 0 2])
hold on
xlabel(' distance(km/h)','linewidth',5)
ylabel(' spectral efficiency')
legend( 'spectral efficiency for UMTS','location','Northwest');
```

Appendix B-8

Throughput

```
r=[];d=53;t=2;dm=70;du=2;
xu=rand(1,350)
wu=[xu]
xm=rand(1,500)
wm=[xm]
x=rand(1,150)
w=[x]
for r=1:150
    th=d/t
    fth=th*w
end
%plot(fth)
axis([0 150 0 25])
xlabel(' distance(km/h)','linewidth',5)
ylabel(' throuput')
legend( 'throughputfor WLAN','location','Northwest');
for r=1:500
    thm=dm/t
    fthm=thm*wm
end
plot(fthm)
axis([0 500 0 25])
xlabel(' distance(km/h)','linewidth',5)
ylabel(' Throuput')
legend( 'Throughputfor WIMAX','location','Northwest');
for r=1:350
    thm=dm/t
    fthm=thm*wm
end
plot(fthm)
axis([0 350 0 25])
xlabel(' distance(km/h)','linewidth',5)
ylabel(' Throuput')
legend( 'Throughputfor UMTS','location','Northwest');
```