Optimization Of Coverage And Handover For Heterogeneous Networks

Rima Almosbahi, Mohamed Elalem

Author University, Elmergib University, Alkhoms Libya
rima.almosbahi@gmail.com

Mohamed Elalem, Electric and Computer Department, Elmergib, Alkhoms Libya
moh.elalem@gmail.com

Abstract: The wide increase of wireless systems and the use of software radio technologies enable the employment of a heterogeneous network. In this concept services are delivered via the network that is most efficient for that service. The solution is based on a common core network that interconnects access points of various wireless access points. A mobile host can apply multiple different access networks simultaneously to increase capacity or efficiency. The signal coverage starts within the cell, by predicting the affecting parameters on the signal power level in the uplink and downlink at the practical cases. In this paper, the concentration is completely on preprocess of network planning i.e. link budgeting of LTE and WiMAX cellular systems. This investigation can also lead the radio planner to a thorough understanding of radio wave propagation for designing mobile communication system. The mathematical model calculation mainly includes path loss, link budgets etc. Radio propagation is site specific and it varies substantially depending on geography, frequency at which system will operate mobile terminal speed, interface sources and other dynamic factors. The coverage planning used to obtain the LTE cell range is based on the required receiver sensitivity, and link budget calculations to estimate maximum allowable path loss, then the proposed approach to enhance the coverage is implemented by measuring the received signal along path from the cell center and its edge, and installing a WiMax base station on the edge. The importance of using heterogeneous technology is by estimating the change of received power in the cell edge.

Keywords: Heterogeneous network , LTE worldwide, link budget, coverage, vertical handover, handover necessity estimation

1. Introduction

Starting from the first generation of cellular network, which is analog communication to the ones that are being developed now like long tem evolution (LTE), LTE advance and WIMAX 802.16m, the technology is expanding in higher quality and accessibility, so it requires a new emerging system architectures and management with issues related to quality of service, capacity and coverage. For this reason, the 3rd Generation Partnership Project (3GPP), which is currently the dominant specifications development group for mobile radio systems in the world, started to work on the standard of LTE [1]. LTE is the evolution of the third generation of mobile communications to the fourth-generation technology that is essentially an all IP broadband internet system with voice and other services built to ensure 3GPP"s competitive edge over other cellular technologies. The goal of LTE is to provide a high data rate, low latency and packet optimized radio access technology supporting flexible bandwidth deployments. In parallel, new network architecture is designed with the goal to support packet-switched traffic with seamless mobility, quality of service and minimal latency. Like other cellular technologies LTE uses OFDM as multiplexing technique, and uses wider spectrum, up to 20 MHz, to provide compatibility with existing cellular technologies, and increases the capacity of the system [2]. After years of development and uncertainty, a standard based interoperable solution is emerging for wireless broadband. A broad industry consortium, the Worldwide Interoperability for Microwave Access (WiMAX) Forum has begun certifying broadband wireless products for interoperability and compliance with a standard. WiMAX is based on wireless metropolitan area networking (WMAN) standards developed by the IEEE 802.16 group and adopted by both IEEE and the ETSI HIPERMAN group. In this paper, a concise technical overview of the emerging WiMAX solution for broadband wireless is predented. Unlike WLAN, WiMAX provides a media access control (MAC) layer that uses a grant-request mechanism to authorize the exchange of data. This feature allows better exploitation of the radio resources, in particular with smart antennas, and independent management of the traffic of every user. This simplifies the support of real-time and voice applications. One of the inhibitors to widespread deployment of WLAN was the poor security feature of the first releases. For a WiMAX system, the downlink coverage is easier to plan than uplink. This is due to the fact that in the downlink, the interference originates from the same location, that is, from a neighbouring base station transmitting on the same channel. The WiMAX base station connects the core service network to the end user, and therefore it is an important metric in determining the coverage of the network and end-users experience. Network coverage is calculated based on the path-loss data between the base stations and users as well as using antenna configuration parameters such as antenna type, power, radiation characteristics, tilt and azimuth [5].

2. Heterogeneous Networks

Small cells are primarily added to increase capacity in hot spots with high user demand and to fill in areas not covered by the macro network – both outdoors and indoors. They also improve network performance and service quality by offloading from the large macro-cells. The result is a heterogeneous network (HetNets) with large macro-cells in combination with small cells providing increased bitrates per unit area. Figure 1 illustrates the heterogeneous network structure.

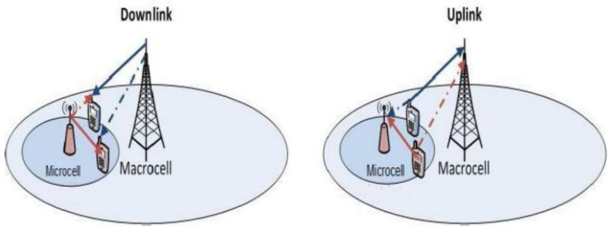

***Figure 1:** The heterogeneous network structure*

HetNets improve the overall capacity as well as provide a cost-effective coverage extension and higher data rates to hot spots such as airports and shopping malls by deploying additional network nodes within the local-area range. In addition, HetNets also increase overall cell-site performance and cell-edge data rates by bringing the network closer to end users. In that way, radio link quality can be enhanced due to the reduced distance between transmitter and receiver, and the larger number of eNode Bs allows for more efficient spectrum reuse and therefore larger data rates [6]. A major issue in heterogeneous network planning is to ensure that the small cells actually serve enough users. One way to do that is to increase the area served by the small cell, which can be done through the use of a positive cell selection offset to the Strongest Signal Down Link (SSDL) of the small cell. This is called Cell Range Extension (CRE). As shown in Figure 2, a negative effect of this is the increased interference on the DL experienced by the user Equipment (UE) located in the CRE region and served by the base station in the small cell. This may impact the reception of the Down Link (DL) control channels in particular [7].

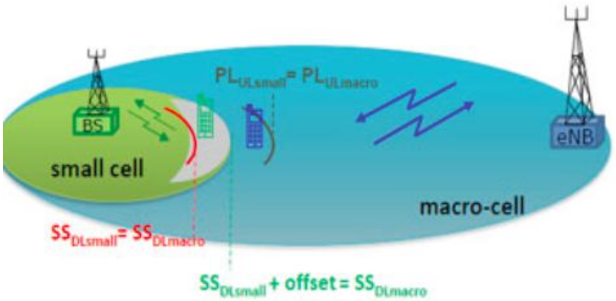

***Figure 2** The cell range extension using HetNet*

3. LTE and WiMax Coverage Calculation

The coverage calculations are based on the link budget, which is used to estimate the maximum allowed signal attenuation called path loss between the mobile and the base station antenna. The maximum path loss allows the aximum cell range to be estimated with a suitable propagation model, such as COST231 Hata and Walfish-Ikegami Model. The cell range gives the number of base station sites required to cover the target geographical area. The link budget calculation can also be used to compare the relative coverage of the different systems [8]. Link budget is considered to evaluate the losses and gains between the two communication ends; base station and end user to produce the maximum allowable loss in signal strength that can be tolerated between the transmitter and receiver. Link budget traces power expenditures along path from transmitter to receiver to identify or determine the maximum allowable path loss and to determine the maximum feasible cell radius using propagation model. Also the link budget is purposed to determine the radius of the cells, and finally to determine the locations of cell sites as well as the spacing between them to ensure reliable and uninterrupted communication as mobile stations move through the coverage area of interest [9].

3.1 LTE Coverage Planning

The main steps of coverage planning of any mobile network is link budget calculation. The aim of link budget calculation is calculating the cell radius of the base station to calculate the required ranges of the base stations to cover the target geographical area. The cells BS and end user parameters used in the calculation of coverage radius are given in Table 1

***Table 1**. The LTE cell BTS and end user parameters*

Parameter	Value
Transmitted power of BTS antenna (P_{TX})	30 dB
Single RB (Resource Block) Bandwidth	15 kHz
Receiver Bandwidth	12 MHz
Number of Physical Resource Blocks	100
SINR Required at Cell Edge	-6.86 dB
Noise Figure	7 dB
BS Antenna gain (G_{TX})	18 Dbi
Feeder Loss (L_{feeder})	0.4
TMA Insertion Loss	0
Total Power Increase (P_{Ti})	3
UE Antenna Gain	0
Body Loss	0
Interference Margin	3
Additional Gain	0
Average Penetration Loss	12
Log Normal Fading Margin	7.9
Gain Against Shadowing	2.4
BS Antenna Height	30 m
Operating Frequency	2.6 GHz

Effective Isotropic Radiated Power (EIRP)

EIRP is the amount of power that would have to be emitted by an isotropic antenna (that evenly distributes power in all directions and is a theoretical construct) to produce the peak power density observed in the direction of maximum antenna EIRP is defined as:

$$\mathbf{EIRP} = \mathbf{P_{TX}} + \mathbf{G_{TX}} - \mathbf{L_{Feeder}} - \mathbf{TMA\ Ins.\ loss} + P_{Ti} \quad (1)$$

Receiver Sensitivity

The receiver sensitivity indicates the minimum signal strength required to enable decoding by the BTS or User Equipment receiver if there is no interference. Receiver sensitivity can be calculated by the following equation

$$S_{Rx} = N_{th} + SINR_{Req} + NF \quad (2)$$

where N_{th} is the thermal noise and its equation is

$$N_{th} = -174 + 10log\ (BW_{RB} \times BW_{RX} \times \#RB) \quad (3)$$

where BW_{RB} and BW_{RX} values should by in KHz

Maximum Allowable Path Loss (MAPL)

MAPL of the radio wave crossing the air interface excludes clutter data (e.g. penetration loses, gain against shadowing) is expresses as [10]

$$MAPL = EIRP - S_{Rx} + G_{RX} - BL - IM \quad (4)$$

If Propagation data is included in the calculation such as average penetration loss, Gain against shadowing, considering the Log Normal Fading margin (LNF), the maximum propagation loss considering clutter is given by

$$MAPL_{clut} = MAPL - L_{ave.Pent} - LNF + G_{shdw} \quad (5)$$

Choosing COST231-Hata model which can be used in LTE cells as the propagation model. The model is suitable used for the following range of parameters:

- Base station height (h_b): 30 meters to 200 meters.
- Terminal antenna height (h_m): 1 meter to 10 meters.
- Distance between the transmitter and receiver: 1 km to 20 km.

The COST231-Hata model for urban area can be expressed by the following formula [23]:

$$MAPL = 46.3 + 33.9\,log(f) - 13.82\,log(h_b) - 0.0573 + 35.22 \times log(d) + (-13.14) \quad (6)$$

Equating (5) and (6), the required cell range (d) is obtained in Km.

3.2 WiMAX Coverage Planning

The coverage planning for WiMax have similar steps of LTE with some differences in parameters, values and the propagation model any mobile network is link budget calculation. Therefore, the link budget calculations is proposed to estimate the cell range of the WiMAX. The cells BS and End User parameters used in the calculation of coverage radius are given in Table 2

***Table** 2. The Wimax cell BTS and End User parameters*

Parameter	Value
Transmitted power	30 dBm
Number of transmit antennas	2
Power amplifier backoff	0
Transmit antenna gain	18 dBi
Transmitter losses	3 dB
Channel bandwidth	5 MHz
Number of subchannels	15
Receiver noise figure	8 dB
Required SNR	0.8 dB
Macro diversity gain	0 dB
Data rate per channel (kbps)	151.2
Receiver antenna gain	0 dBi
Shadow-fade margin	10 dB
Building penetration loss	0 dB
Operating frequency	3.5 GHz

Effective Isotropic Radiated Power (EIRP)

EIRP in WiMAX is defined as:

$$EIRP = P_{TX} + G_{TX} - L_{Feeder} - L_{cc} + G_{TX} \quad (7)$$

Receiver Sensitivity

Receiver sensitivity can be calculated by the following equation

$$S_{Rx} = N_{th} + SINR_{Req} + NF \quad (8)$$

Where N_{th} is the thermal noise and its equation

$$N_{th} = -174 + 10log\,(BW_{ch}) \quad (9)$$

Where BW_{CH} and BW_{RX} values should by in Hz

Maximum Allowable Path Loss (MAPL)

Maximum Allowable Path Loss (MAPL) is defined as [11]

$$MAPL = EIRP + CPE\ DL\ Rx\ antenna\ gain + CPE\ other\ DL\ Rx\ gain - Head/Body\ loss - Rx\ Senestivity - lognormal\ fading\ margin - fast\ fading\ margin - interference\ margin - Bulding\ penetration\ loss \quad (10)$$

Choosing Walfish-Ikegami model which can be used in WiMAX cells as the propagation model. The model is suitable used for the following range of parameters is as follows:

- Building height: 4 meters to 50 meters.
- Terminal antenna height: 1 meter to 3 meters.
- Distance between the transmitter and receiver: .2 km to 5 km.

This model for urban area can be expressed by the following formula [12]:

$$\overline{PL} = L_{fs} + L_{rts} + L_{mds} \quad (11)$$

where, L_{fs} is the free-space loss, L_{rts} is the rooftop-to-street diffraction loss, and L_{msd} is the multiscreen loss. The model provides analytical expressions for each of the terms for a variety of scenarios and parameter settings. For the standard NLOS case, with BS antenna height 12.5m, building height 12m, building-to-building distance 50m, width 25m, MS antenna height 1.5m, orientation 30° for all paths, and in a metropolitan center, the equation simplifies to:

$$\overline{PL} = -65.9 + 38\,log_{10}\,d + \left(24.5 + \frac{1.5f}{925}\right) log_{10} f \quad (12)$$

Equating (10) and (12) the required cell range (d) is obtained in Km.

4. Optimization of Vertical Handover Decision

Handover is defined as a capability for managing the mobility for a mobile terminal or a moving network in active state. The important issue in handover is the need to decide when handover is necessary, and to which cell. In addition when the handover occurs it is necessary to activate the call to the relevant base station along with changing the communication between the mobile and the base station to a new channel. Handover within a homogeneous system is defined as horizontal handover, but handover between different access technologies is defined as vertical handover. When connections have to switch between heterogeneous networks for performance and high availability reasons, seamless vertical handover is necessary. Depending on the network types involved, handovers can be classified as either horizontal or vertical. A horizontal handover or intra-system handover takes place supporting the same network technology, e.g., two geographically neighboring BSs of a 3G cellular network. On the other side, a vertical handover or inter-system handover by supporting different network technologies, e.g., an IEEE 802.11 AP and a 3G BS. The figure below shows the horizontal handover versus the vertical handover.

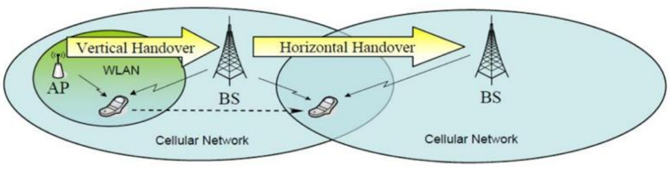

***Figure 3** Horizontal and vertical handovers in heterogeneous networks*

4.1 Handover Necessity Estimation

The algorithm used for time threshold calculation is introduced. This algorithm contains two parts which aim to minimize handover failures and unnecessary handovers, respectively, which are both built on probability calculation. Assuming that the entry and exit points Pi and Po can be any arbitrarily chosen points on the circle enclosing the WLAN coverage area, with equal probability, then the angles θ_i and θ_o are both uniformly distributed in $[0, 2\pi]$, and $\theta = |\theta_i - \theta_o|$. The first step is to calculate the probability density function (PDF) of θ. The PDFs of the locations of P_i and P_o are equal $1/2\pi$

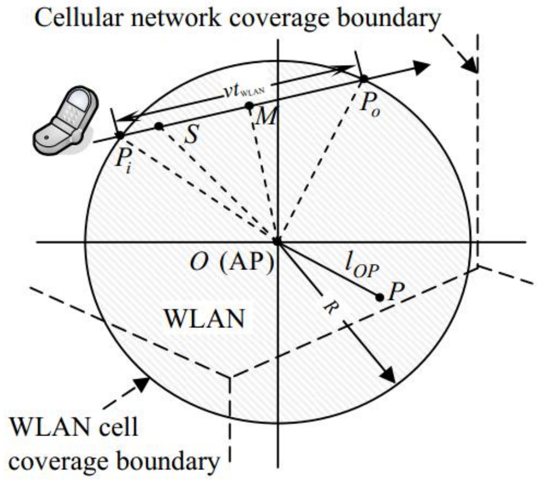

***Figure** 4 Horizontal and vertical handovers in heterogeneous networks*

A time threshold parameter T_1 is introduced to make handover decisions: whenever the estimated traveling time tWLAN 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, the probability of a handover failure for the method using the threshold T_1 is given by

$$P_f = \frac{2}{\pi}\left(\sin^{-1}\left(\frac{v\tau_i}{2R}\right) - \sin^{-1}\left(\frac{vT_1}{2R}\right)\right) \qquad 0 \le T_1 \le \tau_i$$

$$T_1 = \frac{2R}{v}\sin\left(\sin^{-1}\left(\frac{v\tau_i}{2R}\right) - \frac{\pi}{2}P_f\right)$$

An unnecessary handover occurs if the traveling time inside the WLAN cell is shorter than the sum of the handover time into (τi) and out of (το) the WLAN cell. Similar to the arguments used in the probability of a handover failure, another parameter T2 (T1 < T2) is introduced to minimize the probability of unnecessary handovers. The probability of an unnecessary handover is calculated as

$$P_u = \frac{2}{\pi}\left(\sin^{-1}\left(\frac{v(\tau_i +}{2R}\right) - \sin^{-1}\left(\frac{vT_1}{2R}\right)\right) \qquad 0 \le T_1 \le \tau_i$$

$$T_1 = \frac{2R}{v}\sin\left(\sin^{-1}\left(\frac{v\tau_i}{2R}\right) - \frac{\pi}{2}P_f\right)$$

The handover failure probability for Mohanty's methods is given by

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

Where:

V= velocity of the mobile terminal

R=WLAN radius.

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

$$Pf = \begin{cases} \frac{2}{\pi}[\sin^{-1}\frac{v\tau_i}{2R} - \sin^{-1}\frac{L}{2R}] & 0 \le L \le \tau_i \\ 0 & vt_i < L \end{cases}$$

$$L = 2R\sin(\sin^{-1}(\frac{v\tau_i}{2R}) - \frac{\pi}{2}\mathrm{Pf})$$

Where:

L= distance threshold parameter

The unnecessary handover probability for Mohanty's methods is given by

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

Where:

τ_0= handover latency from WLAN to the cellular network.

τi= handover latency from cellular network to the WLAN.

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

Where:

C = parameter used to minimize unnecessary handover

4.2 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, The probability of a connection breakdown Pb is calculated as

$$P_b = \begin{cases} 1 - \frac{1}{\pi}\cos^{-1}\left(\frac{2r^2}{R^2} - \frac{(R^2 - r^2 - v^2{\tau_0}^2)^2}{2v^2{\tau_0}^2R^2} - 1\right) & C_4 \cap C_1 \\ \frac{1}{\pi}\cos^{-1}\left(1 - \frac{2v^2\tau_0}{R^2}\right) & C_2 \\ 1 & R < r \\ 0 & C_5 \cap C_1 \end{cases}$$

Where $C_4 = R - v\tau_0 \le r \le R$, $\quad C_5 = R - v\tau_0 \le r \le R$

This method calculates a RSS threshold for triggering a handover based on the estimated radius of the WLAN cell, handover latency, speed of the MT and connection breakdown tolerance. HTCE is able to provide the user with control over the tradeoff between connection breakdowns and WLAN usage. Various strategies have been developed to compare the RSS of the current point of attachment with that of the candidate point of attachment. The proposed Algorithm Considers that the MT moves between LTE and WiMAX. First the MT is tested, if it is in LTE or WiMAX network, if it is in the two networks at the same time, it compares the RSS for the two networks (LTE & WiMAX), then it measures the network performance for the two networks.

5. The Experimental Work

This section presents the coverage performance of LTE with adding Wimax cell to enhance the coverage calculations using MATLAB software. The coverage planning is used to obtain the cells range based on the required receiver sensitivity assuming all the base stations have the same coverage range. Along the path between the cells centers within the site for the user equipment the received signals power is calculated from both LTE and WiMAX base stations then the nearest one is selected assuming that the cell base station is assumed that the power spreads out equally in all directions therefore the locations are distributed uniformly by measuring the distance between the user and center of each cell to select the base station which provide the maximum value, then the selected LTE power will be compared with the power received from the WiMAX base station the one which transmit the higher value is selected to connect with the user equipment. The results of LTE and WiMAX link budget are explained in Table 3. Table 4. And the site layout is shown in Figure 5.

Table *3. The LTE link budget results*

Parameter	Value
Effective Isotropic Radiated Power	37.6 dB
Receiver Sensitivity	-104.8
Maximum Allowable Path Loss	148.9 dB
Maximum Allowable Path Loss considering clutter	131.4 dB
Cell radius	1.2127Km

Table *4. The WiMAX link budget results*

Parameter	Value
Effective Isotropic Radiated Power	45 dB
Receiver Sensitivity	-84 dBm
Maximum Allowable Path Loss	144.98 dB
Cell radius	0.7925 Km

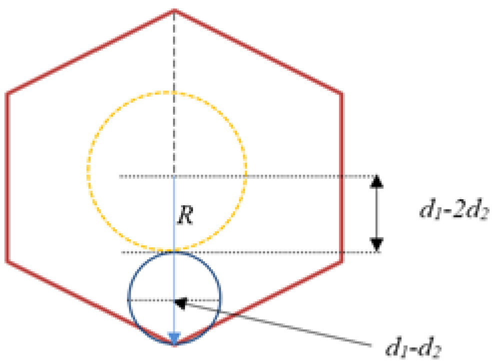

Figure *5 The site Layout*

Assume that the user have a straight path from the LTE cell center to the AP center the received signals from both LTE and WiMAX access points will be calculated from the path loss equations with varying distance to get the related received power. same link budget equations for both cells are used but the cell radius is replaced by distance points and Receiver Sensitivity is replaced by Received Power, i.e as shown in Figure 1 at the small cell edge the user equipment receives two signals, the received signal from LTE is measured as result of receiver power calculation at distance (d_1-$2d_2$) which is equal to -102.5 dB, and the received signal is the same receiver sensitivity of the small cell which is equal to -84dB in this location the received signal improvement is 18.5dB

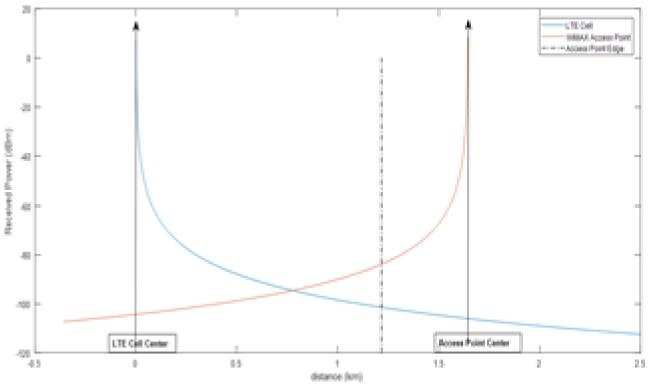

Figure *6 The received power performance*

This simulation also discusses the vertical handover between LTE and WIMAX considering the performed metrics such as unnecessary handover, handover failure and connection breakdown. The simulation parameters are listed in Table 5.

Table 5. *The network parameters for handover estimation*

Parameter	Value
WiMax radius (R)	150 m
AP transmit power (PT_x)	20 dBm
Distance between the AP and the reference point (d_{ref})	1 m
Path loss at the reference point (PL_{ref})	40 dB
Path loss exponent (β)	3.5
Standard deviation of shadow fading (σ)	4.3 dB
Handover delay from cellular network to WLAN (τ_i)	2 s
Handover delay from WLAN to cellular network (τ_o)	2 s
Tolerable handover failure probability (P_f)	0.02
Tolerable unnecessary handover probability (P_u)	0.04

In the fixed RSS threshold based method, a handover to the WLAN is triggered when the RSS from the WLAN is above a threshold. The probabilities of handover failures and unnecessary handovers of the RSS threshold based, hysteresis based and HNE methods are shown in Figures 6 and 7.

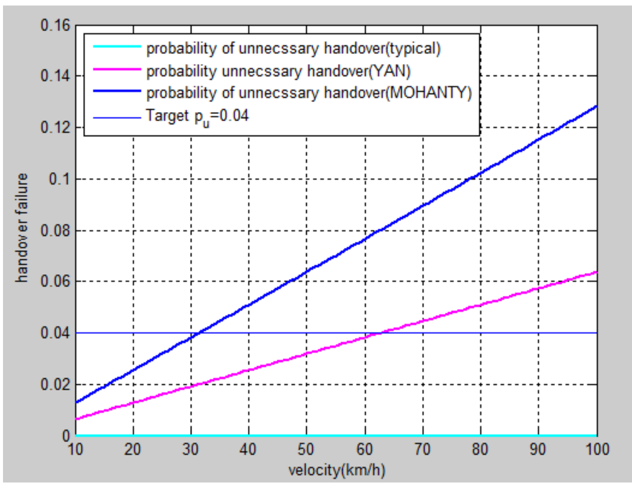

Figure *6. Probability of unnecessary handover*

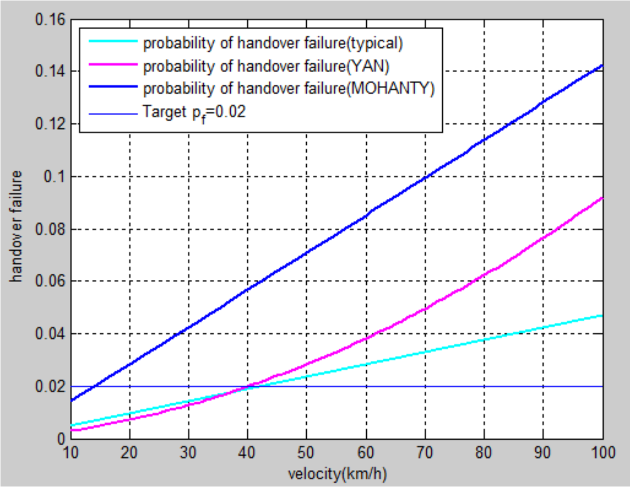

Figure 7. *Probability of handover failure*

In experimental work the MATLAB software has an efficient tool to generate random values so, generating 50 run iterations each one have a random different direction an distance representing MT trajectories across the WLAN cell coverage area for speeds from 1 km/h to 100 km/h in 2 km/h increments. For each trajectory, a random WLAN cell entry point was chosen, and a uniformly distributed random angle between0and2 was generated representing the movement direction of the MT. Figure 8 denotes the number of handover failures and unnecessary handovers of the RSS threshold based, hysteresis based and HNE methods under different velocities of the MT, it is clearly observed that the number of failure and unnecessary handovers are reduced using the proposed methods.

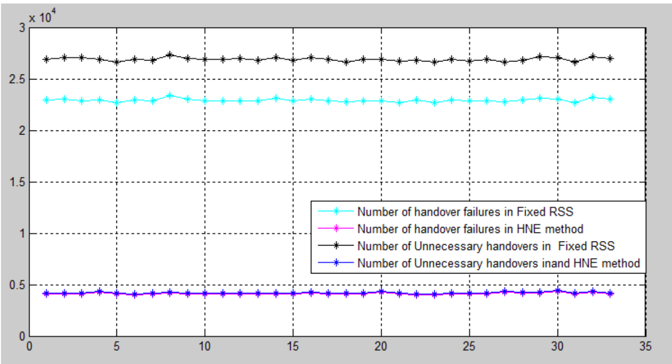

Figure 8. *Number of handover failures and unnecessary handovers in both Fixed RSS and HNE method*

The probabilities of connection breakdowns of the RSS threshold based (R2fixed=130 m), hysteresis based (R2hyst= 120 m) and HTCE methods are shown in Figure 8 Since the handover necessity approach is designed to keep the probability of connection breakdowns below preset levels, even though the velocity of the MT increases, the probabilities remain the same. As illustrated by the figure, for high velocities, HTCE yields much lower probability of connection breakdowns than the other two methods.

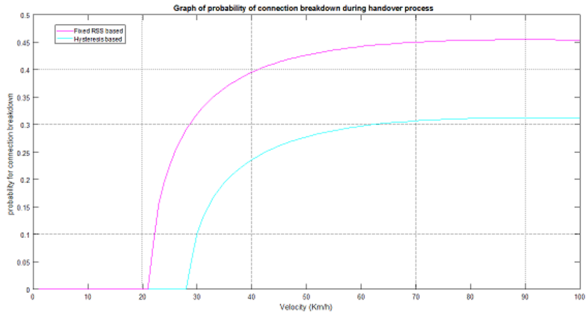

Figure 9. *The Probability of connection breakdowns using HTCE method.*

5. Conclusion

In this paper, a link budget models using heterogeneous network combined from LTE and WiMAX cells is proposed. Based on this model, the received power of the base stations is compared if WiMAX cell is installed at the edge. HetNets deployment improves the overall system performance. Used in urban areas are designed for high traffic areas to support a larger number of users. It improves coverage, by extending the cell range. Small cells can provide coverage in areas that are poorly serviced by macrocells due to building placement, distance, and interference. This is especially useful at the edge of a macrocell's covered area, where service is degraded. Small cells can even extend the coverage area of a macrocell. Mathematical justification of the HTCE module was presented. This method is devised to keep the connection breakdown probability below user specified limits under different MT speeds, as well as to provide the user with control over the tradeoff between connection breakdown probability and WLAN usage. HTCE calculates a RSS threshold for triggering a handover based on the estimated radius of the WLAN cell, handover latency, speed of the MT and connection breakdown tolerance.

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Author Profile

M. Elalem received the B.S. and M.S. degrees in Electrical and Electronic Engineering from University of Tripoli, Libya in 1990 and 2006, respectively, and PhD degree in Electrical and Computer Engineering from Ryerson University, Toronto, Canada in 2013. During 1993-2008, he worked in Elmergib University, Libya as academic instructor. During 2013-present, he is working in the same university as assistant professor. His interesting areas are in Telecommunications, optimization techniques, cognitive radio networks and advanced digital communication schemes.