



An Improved Handover Strategy in Heterogeneous Wireless Network

Abubakar Muhammad Miyim¹, Hadiza Mohammed Kaigama², Abubakar Wakili², Binta Ali Shuwa³ and Kabira Umar²

¹Department of Information Technology, Faculty of Computing, Federal University Dutse

²Department of Computer Science, Faculty of Computing, Federal University Dutse

³ Department of Intelligence and Cyber Security, Faculty of Military Science and Intelligence, Nigerian Defense Academic

abubakar.miyim@fud.edu.ng, {[abubakarwakili9](mailto:abubakarwakili9@gmail.com), [kaigamahadiza](mailto:kaigamahadiza@gmail.com), [bintashuwa](mailto:bintashuwa@gmail.com), [kabiraumarmustapha](mailto:kabiraumarmustapha@gmail.com)}@gmail.com

Abstract

The rapid escalation in demand for faster transmission speed, broader coverage has led to the invention of more standards to improve mobile communications. Heterogeneous wireless networks (Hetnet) were introduced to meet the data rate and traffic demands. Mobile terminals should be able to seamlessly handover to the best access link among all existing candidates without interruption. The most challenging issues in heterogeneous wireless network is handover management. Many different handover algorithms were developed to overcome the challenges, but the problem still persist Hence, this work aims to propose a Mobile Velocity-Distance (MVD) algorithm capable of reducing/minimizing number of HOs and to measure the performance of the MVD algorithm against other empirical methods: RSSI based, cost-based and bandwidth. VoIP and video streaming traffic were transmitted in order to analyze the quality of service during the vertical handover with each algorithm. Throughput, handover delays, number of handovers, and packet delivery ratio were the performance metrics used. It is observed that MVD algorithm performs better than RSSI based, bandwidth-based and cost-based. It is capable of providing good quality voice call and video streaming during vertical handover and performs better than other algorithms.

Keywords: Heterogeneous wireless networks; vertical handover Algorithms; throughput; Handover Delay

1. Introduction

The increase in demand for a faster transmission speed, broader coverage has led to invention of more standards to improve mobile communications. Xiaonan et al (2020) expressed that in request to accommodate various conditions of clients and the improvement of different sorts of business, wireless networks having contrasting architectures form a multiple diverse integrated network, wherein the most representative is the joining of two sorts of heterogeneous networks: WLAN and cellular. According to Huertas et al (2018), WLAN networks have moderately wide transmission capacity and little coverage, while cellular series networks, for example, current 3G/4G wireless networks have generally restricted transfer speed and wide coverage, so the mix of cellular series network and WLAN network can supplement one another, giving full play to their individual qualities and controlling their limits simultaneously. Therefore, the vertical handover algorithm is necessarily considered with variation of disturbing factors and different network types (Siyu et al, 2020). Several vertical handover algorithms are found to exist with each having its own advantage and otherwise. Then, to overcome the weakness of existing vertical handover algorithm which include: the high complexity of the running process as well as RSS-based handover decision as regards to the conventional handover procedure is not desirable for two-tier networks, thus require additional input parameters along with RSS. Moreover, new challenges arise due to the large number of heterogeneous eNBs in a small coverage area that causes unnecessary handovers. Transmitting power between the eNB and that of HeNB is yet another challenge, with eNB recording high transmitting power enough for wider coverage as compared to the transmitting power of HeNB. As a result of these, a new algorithm will be proposed that periodically scan the distance between the UE positions while considering the UE velocity and direction and its called Mobile Velocity-Distance



(MVD). The proposed algorithm tends to minimize the time taken to search for resourceful base station as well as reduce the number of handovers.

2. Overview of Hetnet Algorithms

Tao et al (2017) defined Heterogeneous network as a network that is based on different types of communication technologies, Heterogeneous network face many issues for the ubiquitous information services in urban cities; Issue of Network Convergence, Issue of Load Balancing in Cell Networks, Issue of Handoff and that of Interference. Heterogeneous network can also be defined as an organized mixture of networks where high power budget macrocells are combined with many nodes usually low power nodes like picocell, distributed antennas, femtocells and relays. The low power nodes are mostly deployed to compensate for poor coverage experienced by some selected indoor and outdoor environments. The low power may also be deployed to relief the high power cells during off peak period in order to minimize the energy consumed by the network (Ayeni et al 2014). In other emerging markets like Nigeria, the inadequacy of power has raised the need to have more energy efficient networks capable of saving energy and optimizing the overall power consumption of the network (Salami et al, 2020).

Handoff in heterogeneous wireless network is referred to as a vertical handoff. Handoff algorithms can be classified into two classes with regards to the handoff criteria:

- i) Conventional handoff algorithms – these algorithms rely on signal strength, distance, velocity, power budget etc.
- ii) Intelligent handoff algorithms – these algorithms rely on artificial intelligence techniques such as pattern cognition, fuzzy logic, neural networks and prediction. There are several issues that need to be taken into considerations, before designing heterogeneous wireless network architecture which includes mobility management, handoff management and wireless technologies. There are many classification of handover algorithms based on the handover decision criteria used as well as the methods used to process them. In this work we compared RSS based algorithm, Bandwidth based algorithm and cost function based algorithm with propose Mobile Velocity-Distance (MVD) algorithm.

i. RSS based Vertical Handover Algorithms

The core handover decision standard in the RSS based vertical handover algorithms classification is RSS. It compares the RSS of the present point of attachment against others to make handover decisions. Representative of the RSS based vertical handover algorithms includes: Zahran et al (2005), Obayiuwana & Falowo (2017) then Yan et al (2010).

ii. Bandwidth based Vertical Handover Algorithm

Available bandwidth is considered as the main vertical handover decision criterion with this algorithm which enables achievement of high system Throughput and lower handover latency for delay-sensitive applications (Yan et al, 2010). Representative of these algorithms includes: Edia et al (2018), Iago et al (2019) and Chinnapan & Balasubramanian (2016).

iii. Cost Function based Vertical Handover Algorithms

This class of algorithms compound metrics such as bandwidth, monetary cost, power consumption and security in a cost function, then the handover determination is made by comparing the outcome of this function for the candidate networks (Yan et al, 2010). Some of the representative of the cost function based vertical handover algorithms are: Zhu and McNair (2016), Hassawa et al (2006) and Tawil et al (2008).

3. Related Works

Shufei et al (2017) proposed a vertical handover Algorithm dependent on noticeable light correspondence framework for choice. By using scientific progression measure and a two-man helpful game model to think about various attributes including dynamic network parameters and actual traffic preferences. Despite the fact that handover was decreased. Overhead, it considered less handover factors. Dinesh et al (2018), proposed to maximize network usage as more than one target network existed during vertical handover. Additionally, they showed how network parameters



could be implanted into IEEE 802.21-based signaling systems to give seamless connectivity during a handover. However, the algorithm required consideration of the significant factor of network transmission rate.

Miyim et al (2017) propose handover algorithm which employed fuzzy logic theory and multi-attributes decision making in selecting the best network to optimize the vertical handover algorithm, but did not involve the network attribute of SINR. Shidrokh et al (2018) designed an intelligent algorithm for Seamless Vertical Handover in vehicular networks, which were basically on a hybrid model merged the biogeography-based advancement or BBO with the Markov chain, and applied to the vertical handover between various accesses technologies such as WiMAX, WiFi, and UMTS. Notwithstanding, this handover interaction was more complicated.

Consequently, to solve the drawback of existing vertical handover algorithm including the high complexity of the running process as well as RSS-based handover decision as regards to the conventional handover procedure is not desirable for two-tier networks, thus require additional input parameters along with RSS. Moreover, new challenges arise due to the large number of heterogeneous eNBs in a small coverage area that causes unnecessary handovers. Transmitting power between the eNB and that of HeNB is yet another challenge, with eNB recording high transmitting power enough for wider coverage as compared to the transmitting power of HeNB. As a result of these, a new algorithm will be proposed that periodically scan the distance between the UE positions while considering the UE velocity and direction and it is called Mobile Velocity-Distance (MVD).

4. Proposed Model

The RSS-based handover decision as regards to the conventional handover procedure is not desirable for two-tier networks, thus require additional input parameters along with RSS. Moreover, new challenges arise due to the large number of heterogeneous eNBs in a small coverage area that causes unnecessary handovers. Transmitting power between the eNB and that of HeNB is yet another challenge, with eNB recording high transmitting power enough for wider coverage as compared to the transmitting power of HeNB. As a result of these, a new algorithm is proposed that periodically scan the distance between the UE positions while considering the UE velocity and direction and it is called Mobile Velocity-Distance (MVD) algorithm. The proposed algorithm tends to minimize the time taken to search for resourceful base station as well as reduce the number of handovers, while improving the handover performance. It is based on three main factors:

- The UE velocity: to eliminate speedy mobile users from connecting to HeNBs.
- The range between mobile UE and HeNB: ensure that the UE hands over to the HeNB, once the distance of the UE is less than the predefined value.
- The UE trajectory: predicts the direction of UE to eliminate out-of-range neighbor cells

Moreover, the nomination of the candidate cell uses cosine function from the list of cells and the weight adjustment function selects the target cell. The proposed model considers open access type for all HeNBs and accepts any handover request presented by the UE.

4.1 Velocity of UE

The speed of the user equipment is given consideration as it regards Where ϕ_p is the angle between P_s , UE's Q(last), and candidate cell (P). Alpha is the angle between the BTS and the UE. d_P is the distance between P and UE's Q(last) positions, and W is the output of the algorithm, which includes the weight value for each candidate cell and thus the target cell is selected based on its value. In addition, for the sake of unifying between the distance and the angle in the algorithm, normalization will be performed for both. The angle was normalized to the maximum value of ϕ . The distance is normalized to P coverage area which is called $2r$, where r is the radius of P. Lastly, the output of the algorithm calculation includes the W variable.

Vertical handover decision due to the small coverage of the HeNBs invoke ping-pong effect. The movement of the UE is achievable by through HeNBs during the in-bound scenario and so needs to perform the out-bound within a short timeframe once high velocity of the UE is recorded. Thus, high speed UE that successfully cross the HeNBs

boundary, increases unnecessary handovers and causes QoS degradation. Therefore, the proposed model did avoid high speed of the UE in handing over to HeNBs but makes it limited to eNBs.

4.2 Range of UE from HeNBs Locations

HeNB coverage area was equally considered as a circular geometrical cell, while that of the eNB coverage area to be a regular hexagonal cell. More so, the difference in the transmitting power between the two technologies is relatively high due to their closeness to the eNB tower. However, the periodically scanned distance and movement of the UE along with the RSS was added. As the movement of the UE toward the HeNBs registers the distance (d) as less than the predefined value, the measured report was sent to the serving cell that triggered the handover procedure as depicted in Fig. 4. The movement of UE from P1 to P4 as shown in the figure tried finding the distance and position between the UE and HeNB1 (less than the threshold value (r)) where r is the radius of the HeNB. Due to the space and time characteristics of the traffic, the eNB cannot allocate resources effectively, which results in wasting energy consumption and low energy efficiency (Dahal, et al, 2019). This could be translated into the significant role energy saving through deployment of eNBs play in uplifting the energy efficiency.

4.3 The UE Trajectory and Cells Selection

Therefore, to predict the upcoming trajectory of the UE through using the earlier UE positions, the polynomial function need to be utilized for every UE to describe its own pathway. Based on Fig. 1, P1, P2, P3, and P4 are considered to estimate the future UE direction. Moreover, each UE position consists of two coordinates (x and y), which are obtained from the GPS every S distance threshold, as illustrated in Fig.1 The queue (Q) is used to trace the newest four positions of UE, and the future direction of the UE is based on the polynomial equation for these four positions.

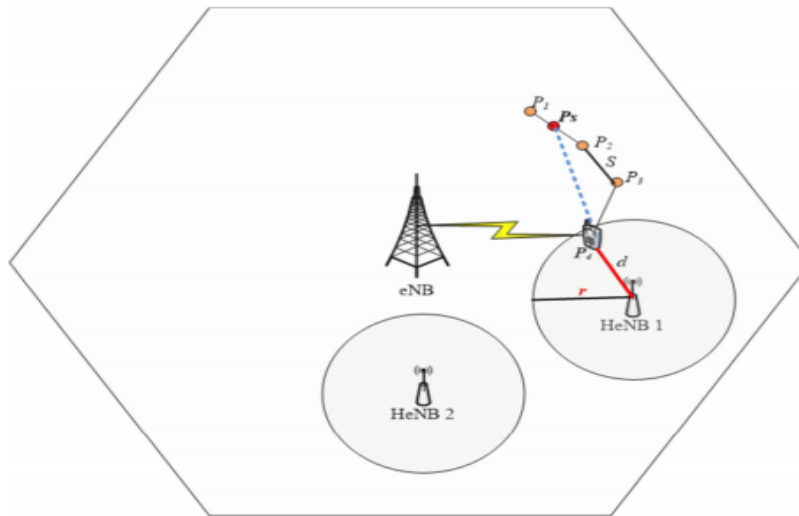


Fig. 1 Proposed Deployment Scenario Source: (Huang et al, 2013)

- The polynomial function $f(x)$ generates 4 positions and each position is saved in the UE's cache as (x_i, y_i) , where i is from 1 to 4 and presented in Eq. (1):

$$f(x) = a_0x_j + a_1x_j^{-1} + a_2x_j^{-2} + \dots + a_j \quad (1)$$

Where j is the last UE positions and $a_0 = 0$.

The trajectory of the UE as it moves from Cells 2 to 1 is based on linear prediction between positions $P_s(x,y)$ and $P_4(x_4, y_4)$, as presented in Fig. 2

A different way of selecting candidate cells was introduced by applying a filter so as to avoid time delay for in-bound, inter-HeNB as well as out-bound handovers. This was an effort to reduce the message length

while selecting the target cell in the handover processes between the neighbour cells and the serving cell within a range. Hence, the out-of-range neighbour cells within the trajectory of the mobile equipment (UE) is being ignored. Therefore, every neighbour cell is verified by computing the angle of Ps using Eq. (2), location of the neighbour cell to avoid being ignored.

$$\phi = \frac{\cos^{-1} (P - P_s) * (Q(Last) - P_s)}{|P - P_s| |Q(Last) - P_s|} \tag{2}$$

Where, P(x₃, y₃) is the location of the neighbour cell, and ϕ is the angle between Q(last), P_s, and P, as shown in Fig.2. Thereafter, the target cell is selected from the candidate cell list depending on the smallest ϕ and closest distance to the UE's Q(last) position. The Weight Adjustment algorithm is used to apply this technique is given in Algorithm below:

Algorithm : Weight Adjustment
Input: ϕ_p and d_p
Output: W
1: $B = 1 - \phi_p \alpha$
2: $D = 1 - d_p / 2r$
3: $W = (D - B) + B$

Where ϕ_p is the angle between P_s, UE's Q(last), and candidate cell (P). Alpha is the angle between the BTS and the UE. d_P is the distance between P and UE's Q(last) positions, and W is the output of the algorithm, which includes the weight value for each candidate cell and thus the target cell is selected based on its value. In addition, for the sake of unifying between the distance and the angle in the algorithm, normalization will be performed for both. The angle was normalized to the maximum value of ϕ . The distance is normalized to P coverage area which is called 2r, where r is the radius of P. Lastly, the output of the algorithm calculation includes the W variable.

5. Simulation Scenario

This section will discuss the simulation set up which has been performed on a laptop that runs on Ubuntu version 16.04. The simulator environment that is used is OMNeT++ 5.1, due to its compatibility of libraries in these simulations. INET Frame version 3.5.0 and SimuLTE version 0.9. The simulation scenario is implemented in the OMNeT++ simulator and conducted 20 simulations with different randomly generated seeds with its default pseudo-random number generator.

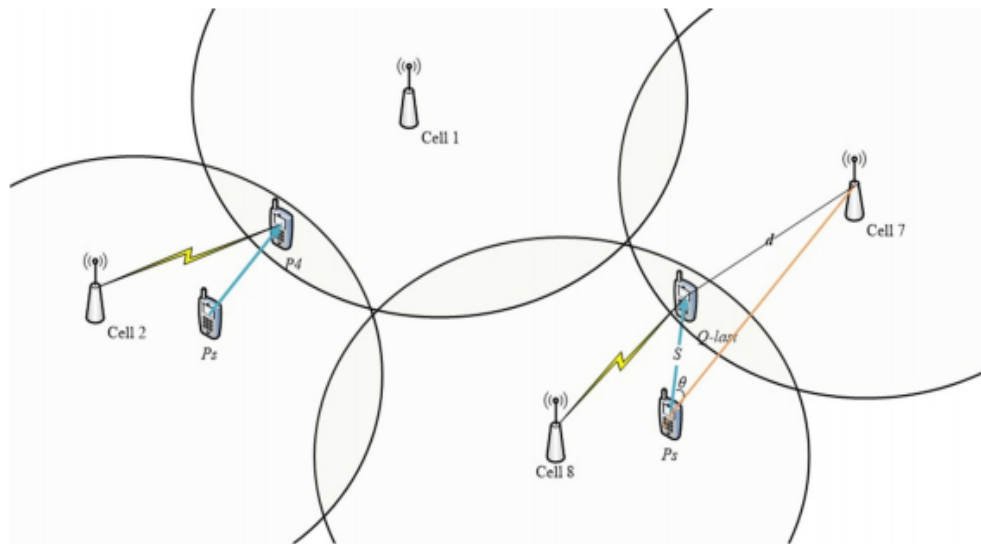


Fig. 2 Mobility of UE in Selecting Candidate Cell

It is used to provide autonomous streams of random variables, for each respective probabilistic model. SimuLTE for OMNeT++ implements the LTE protocol stack for communication between the mobile users with the eNBs connected with different kinds of mobile nodes, which moves at different speeds: 25 nodes move with speeds between 0-5 km/h (pedestrian); and 35 nodes moves with speeds between 10-60 km/h (vehicular speed). The figure 3 is the considered scenario composed of LTE eNodeB, WiMAX and UMTS networks that depicts the simulation scenario.

The simulations consist of transmission of voice over internet protocol (VoIP) traffics and video streaming traffics, available from an Internet repository/server. It has been conducted with four different handover algorithm to analyze their impact to deliver VoIP traffics and video streaming traffics with good quality level. The first algorithm considered is RSSI-Based handover algorithm, because it is the most common and old handover algorithm which regards only the signal strength for handover decision where a handover take place as soon as there is a radio base station with higher signal strength value than the existing one,

Then bandwidth based algorithm is considered, in this algorithm both bandwidth and RSS information are used in the decision process, dependent on whether RSS or bandwidth is the main criterion considered. Thirdly, Cost function based algorithm is considered: This algorithm combines metrics such as security, monetary cost, bandwidth and power consumption in a cost function, and the handover decision is made by relating the result of this function for the prospect networks. Different weights are given to different input metrics dependent on the network states and user preferences. Finally, Mobile Velocity-Distance (MVD) algorithm is also considered. The Path loss model for the propagation scenario found from the ITU (3GPP, 2015) for Urban Macro model is given below:

$$L = 161.04 - 7.1 \log_{10}(W) + 7.5 \log_{10}(h) - (24.37 - 3.7(h/h_{BS})^2) \log_{10}(h_{BS}) \\ + (43.42 - 3.1 \log_{10}(h_{BS})) (\log_{10}(d) - 3) + 20 \log_{10}(f_c) - (3.2 (\log_{10}(11.75 h_{UT}))^2 - 4.97)$$

Where W is the street width, and h is the average building height,

f_c : carrier frequency (GHz), h_{BS} and h_{UT} are the effective antenna heights at the base station and the user terminal respectively.

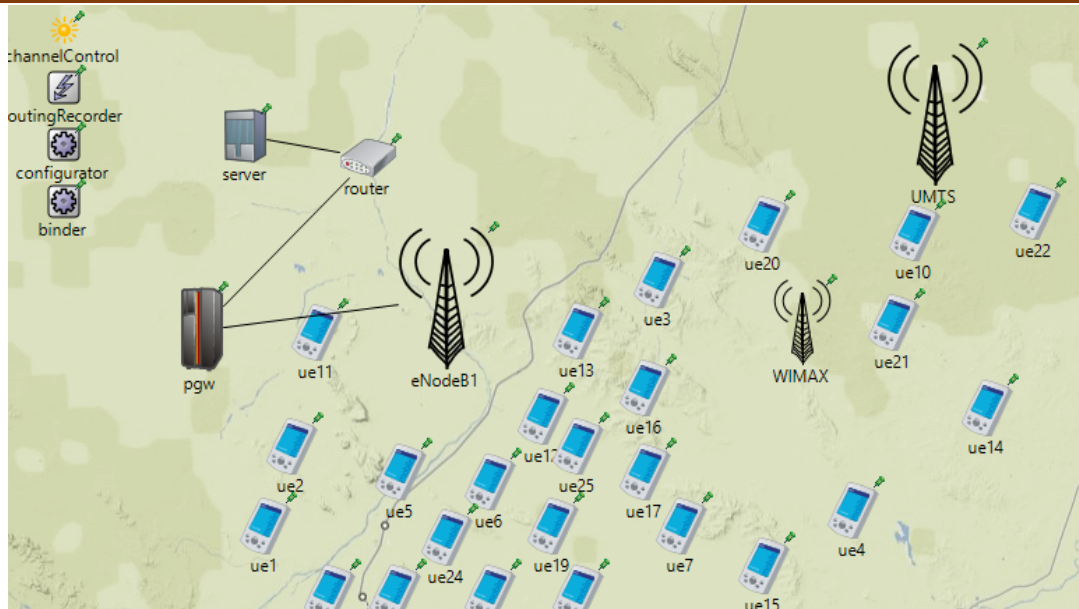


Fig. 3 Simulation Topology

6. Simulation Parameters

The parameters of the simulation are those that affect and control the behaviors of the simulation. These parameters are mostly defined in the omnetpp.ini file. The simulation parameters considered are in table 1.

Table 1: Simulation Parameters

Parameter	Value
LTE Coverage Area	400m ²
UMTS Coverage Area	150m ²
Bandwidth	2 GHz
Pathloss Exponent	2 - 4
WIMAX Coverage Areas	100m ²
Traffic Type	VoIP, Video Streams,
Pathloss model	ITU-U, Urban Macro
Transmission power	LTE 40dBm, UMTS 30dBm, WIMAX 26dBm, UE 20dBm,
Number of Nodes	60
Speed of Mobility	30mps
Antenna Height	25 m (eNodeB)
Average Building Height	15 m
Street Width	6 m



Operation Frequency Bands	2.1 – 2.4 GHz
Simulation time	1200 seconds

7. Performance evaluation metrics

Vertical Handover algorithms can be assessed by comparison under various usage scenarios in assessing the mean and maximum handover delays, the number of handovers, the total number of failed handovers as a result of incorrect decisions, as well as the overall throughput of a session upheld over a typical mobility pattern. Handover has to be executed judiciously by the Handover Manager to avoid wasting of limited network resources. Therefore, the above mentioned metrics will be considered to evaluate the unnecessary handover decisions by different algorithms.

8. Simulation Results

The simulation results for the VoIP transmission scenario is shown in Figure 4. to compare throughput performances of both algorithms. Throughput is the amount of data transferred from the source to mobile terminal destination in a specified amount of time. Its unit is bits per seconds. Handover to a network candidate with higher throughput is typically required. The throughput for the different handover techniques permits us to simply see the quality of service. It is observed that both techniques display almost the same throughput when it reaches 400 seconds, however as the mobile device moves further away, the throughput related to the handover process between the access technologies for the proposed MVD algorithms increases, and other techniques further degrade, when compared to that of the proposed MVD algorithm. Once the vertical handover manager selects a preferred network, the mobile terminal disconnects from its current serving network and connects to prefer one. Therefore, as shown in the simulation plots, it is clearly that the proposed MVD handover algorithm has better overall throughput compared to RSSI based, bandwidth based and cost based.

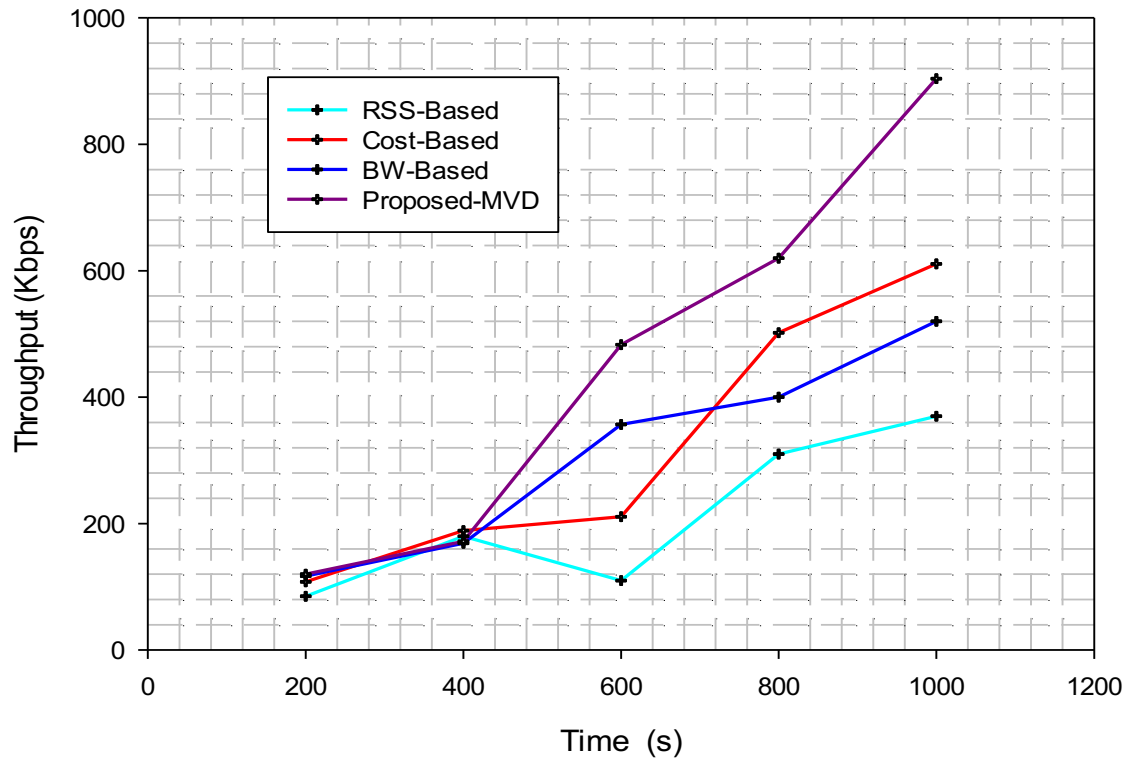


Figure 4, Network Throughput Performance

Figure 5, below depicts the average end to end delay for the network. Handover delay is defined as the total time taken between the initiation and completion of the handover process. It is interrelated to the complication of the vertical handover process, and its decrease is very important for delay-sensitive sessions, such as voice or multimedia sessions. As shown in figure 5, the average end-to-end delay for the proposed MVD algorithm handover is lesser when compare to that of the RSSI based, cost base and bandwidth based.

Also by analyzing the results of Figure 6, it can be concluded that the proposed MVD algorithm attained the best values concerning packet delivered for video streaming simulation. That is to say, proposed MVD algorithm has a better packet delivery ration than the other algorithms based on the average comparison for all the evaluated videos transmitted.

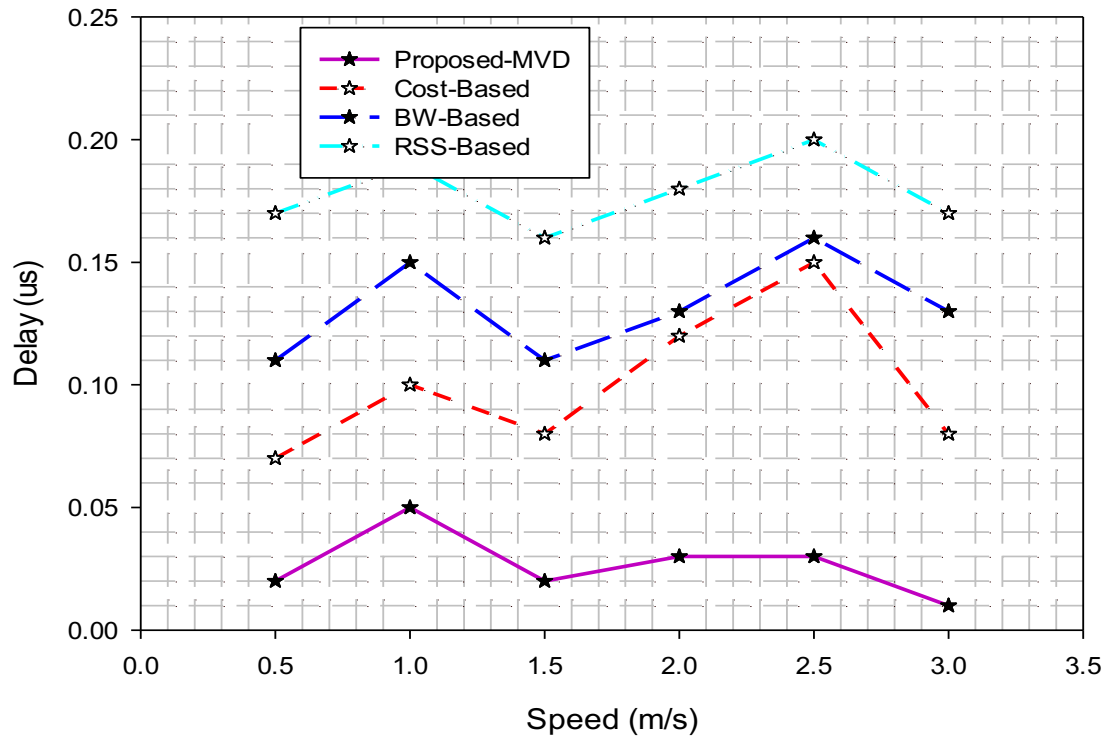


Figure 5. Average Network Delays

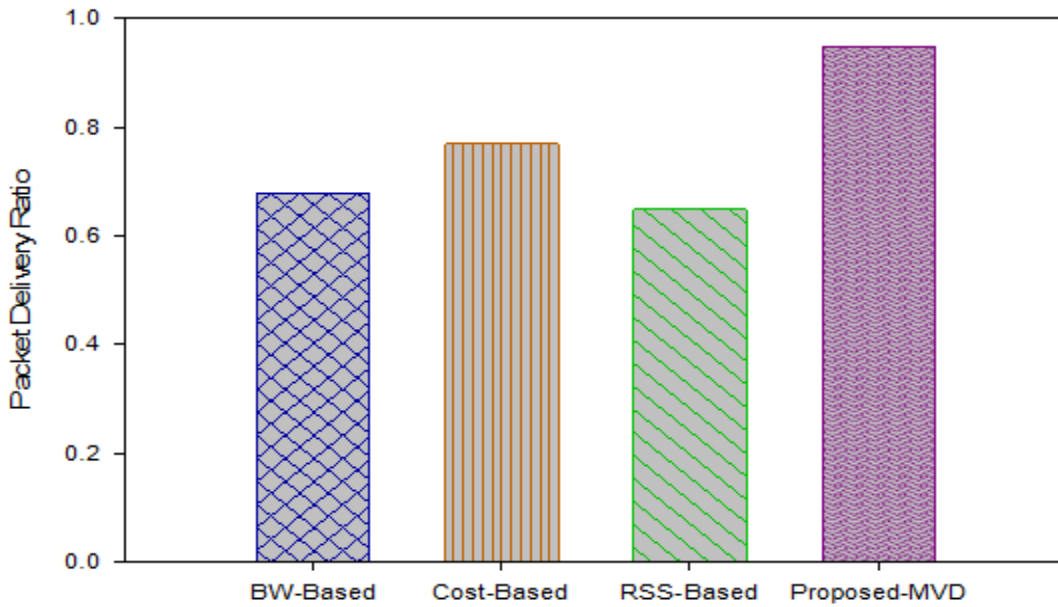


Figure 6, Packet Delivery Ratio for Video Streaming delivered by Different Handover Algorithms.

Number of handovers is another metrics for evaluating the performance of handover algorithms, therefore, it is usually ideal as frequent handovers would cause waste of network resources. A handover is considered to be unnecessary when a user returned back to the initial point of attachment is desired within a certain time duration. This phenomenon is also termed ping-pong effect and the need to eliminate or should be reduced drastically. The table 2, below shows the presentation of how effective the handover is as a result of the ping-pong. This is an evaluation of the proposed which is directly associated with the performance of the network. By considering the number of handovers in Table 2, it can be seen that RSSI-based algorithm executed about 15 handovers because the system executes a handover each time the mobile node detects a candidate radio base station (RBS) with higher RSSI than the connected RBS, which eventually causes the ping-pong effect up to 35%. However, for cost based scenario, the algorithm executed an average of 8 handovers during a video streaming session with a ping-pong occurrence of about 12%, while in the case of the bandwidth-based, the algorithm was able to execute 4 handovers, recording a 5% unnecessary handover. Finally, for the MVD algorithm, it executed only 2 handovers without the ping-pong effect being recorded and hence mobile node remained connected throughout the communication session, thus, an indication of great achievement with the quality of service (QoS) ensured.

Table 2 Effectiveness of Handover Algorithms

Algorithms	Number of Handovers	Ping-pong Occurrences
RSSI based	15	35%
Cost based	8	12%
Bandwidth based	4	5%
Proposed MVD Algorithm	2	0%

9. CONCLUSION

This paper presented a proposed MVD algorithm for heterogeneous wireless network. The implemented algorithm was compared with RSSI-based, cost-based and bandwidth-based algorithms using the OMNeT++ simulator. Two types of traffics were considered; Voice over internet protocol (VoIP) traffics and video streaming traffics in order to analyze the quality of service of the network during vertical handover with each of the mentioned algorithms. Three metrics were considered in evaluating the performance of the proposed algorithm namely: throughput, handover delays, number of handovers and packet delivery ratio. Based on the results in this work, it is observed that the proposed MVD algorithm performs better than RSSI based, bandwidth based and cost based as it was able to provide good quality voice call and video streaming during vertical handover and performs better than the other other algorithms.

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