Vertical Handoff Algorithm for Different Wireless Technologies

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Abstract

Transferring a huge amount of data between different network locations over the network links depends on the heterogeneous wireless network. Such a network consists of several networks with different access technologies. Traditionally, a mobile device may be moved to achieve the operations of vertical handover, considering only one criterion, that is, the received signal strength (RSS). The use of a single criterion may cause service interruption, an unbalanced network load, and an inefficient vertical handover. In this paper, we propose enhanced vertical handover decision algorithm based on multiple criteria in the heterogeneous wireless network. The algorithm consists of three technology interfaces: Long-Term Evolution (LTE), Worldwide interoperability for Microwave Access (WiMAX), and Wireless Local Area Network (WLAN). It also employs three types of the vertical handover decision algorithms: equal priority, mobile priority, and network priority.

The simulation results illustrate that the proposed handover decision algorithm outperforms the traditional network decision algorithm in terms of handover number probability and the handover failure probability. In addition, it is noticed that the network priority handover decision algorithm produces better results compared to equal priority and mobile priority handover decision algorithm. Finally, the simulation results are validated by the analytical model.

Introduction

The demand of data transfer rate and traffic capacity of mobile communication is growing rapidly; thus the concept of heterogeneous network is introduced to meet this demand. In a heterogeneous network, mobility feature is essential because mobile devices must be able to roam throughout the network and able to connect to various radio access technologies. Conventionally, mobile device considers the point of attachment based on single criteria such as Received Signal Strength (RSS). General opinion has been that the simplest algorithm to determine handoffr is based on RSS [1], but RSS fluctuates, making in unreliable [2]. This is caused by each element in a heterogeneous network having different threshold of RHS, causing high packet delay, excessive handoff, high handoff failure probability, and decreases overall throughput in RSS-based algorithm. Furthermore, vertical handoff have several issues that are worth noting. They are as follows:

1. *T*he algorithm should be reliable – inaccurate vertical handoff decision may cost network resources.

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2. *T*he algorithm should be able to distribute mobile devices fairly – this is to balance traffic loads on the networks.

3. *T*he algorithm should be accurate – it must be able to identify the need to increase data transfer rate to mobile devices on the network.

Moving on, implementing multiple criteria on the algorithm of vertical handoff help to provide alternative network that might be the best network target. The rest of this paper is organized as follows: a brief related work of the approaches in the network selection area is given in section 2, followed by the description of multiple criteria handoff decision algorithm in section 3. The simulation methodology is described in section 4. Section 5 presents the results with the related discussions. Section 5 presents an analytical model for validated the simulation results; finally, the conclusions constitute the last section.

1 Related Work

There are several methods of vertical handoff decision algorithm, as follows:

RSS based algorithms: This method use RSS algorithm as the handoff trigger [3] and to decide handoff [4]. RSS based algorithm has been optimized by adapting RSS threshold [5] and by combining RSS threshold with user's velocity and location [6].

Context-aware based algorithms: Handover is decided based on signal quality, network and the context of the mobile device [1]. Context can be defined as the situation of an entity [7] or a location, environment, identity and time [8].

Cost function based algorithms: This method can be approached in two ways – network-related cost function and user-related cost function [9, 10]. Variables involved in user-related cost function are security, monetary cost and power consumption [11, 12].

Fuzzy logic based algorithms: The two steps involved are: (a) Fuzzification and weighting procedure [13]. (b) Decision making. This step uses multi attributes decision making (MADM) [14, 15].

Multiple criteria based algorithms: This method combines multiple criteria-based algorithm to reduce power consumption [16–18].

Generally, RSS based algorithms is the least complex system (Table 1), but it is also the least accurate. Meanwhile, algorithms such as fuzzy logic and cost function is highly complex, but they are also highly accurate and provide higher network efficiency. So far there has been many research done on multiple criteria vertical handoff decision algorithms. It is found that it can make quantitatively calculated decision using some criteria of the candidates [19]. This conclusion is derived by comparing Multiple Criteria Exponent Weighting (MEW), Simple Additive Weighting (SAW), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), and Grey Relational Analysis (GRA) [20]. Their performance in handoff efficiency is also examined [21].

The comparison was simulated in the heterogeneous network environment of WLAN, UMTS, and GPRS. Network performance (BER, delay, jitter, and bandwidth) was compared. There is also a comparison and performance evaluation between SAW and weighted product model (WPM) in terms of processing delay [22] in the environment of WLAN and WiMAX. The results indicated that WPM has better accuracy in choosing a target network compared to SAW. Another multiple criteria algorithm, ELECTRE, has been implemented as vertical handoff decision and evaluated using numerical analysis. ELECTRE (Elimination et Croix Traduisant la Realite or elimination and choice expressing reality) is compared to the algorithm of SAW and TOPSIS [23]. It should be noted that appropriate choice of the criteria is

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Table 1. A comparative summary of the vertical handoff decision algorithms.

Categories	***Heuristic***	***Advantages***	***Disadvantages***
RSS based algorithms	[3] Eshanta et al. [4] Yan et al. [5] Mohanty et al.	Low complexity	Reduced reliability
Context-aware based algorithms	[1] Zekri et al. [7] Maaloul et al. [8] Ahmed et al.	High throughput	Long handoff delay
Cost function based algorithms	[10] Ong and Khan. [11] Tawil et al. [12] Hasswa et al.	High users' satisfaction	Very complex
Fuzzy logic based algorithms	[13] Xia et al. [14] Nasser et al. [15] Pahlavan et al.	High reliability	Very complex
Multiple criteria based algorithms	[16] Alsalem et al. [17] Ismailet al. [18] Ismailet al.	Low handoff failure	No support on fuzzy decision

crucial to ensure decision accuracy. There are many criteria, user-related or network related, such as RSS, mobility, application, and bandwidth.

2 Multiple Criteria Handoff Decision Algorithm

Moving on, TOPSIS has several advantages over other multiple criteria algorithms. Its concept is simple, it has efficient computing characteristic and is able to measure relative performance for each alternative [24]. Furthermore, it only requires one subjective input to calculate the decision. During simulation, compared to other algorithms TOPSIS provides higher throughput and lower packet loss [25]. In a different perspective, handoff decision algorithm is composed of four criteria – RSS, cost function, mobile speed and network occupancy. Moreover, the algorithm needs network (network topology and radio) and mobile (cost function and mobile speed) as input. More details about the network parameters are explained in the next section.

There are two mobile station parameters in this study: cost function and mobile speed.

There are three types of cost function, listed as follows:

1. *G*old Cost: A premier user subscription that allow the use of the highest-level of Quality of Service (QoS). Cost function is irrelevant.

2. *S*ilver Cost: A medium priority user subscription that would try to balance between QoS requirements and cost function.

3. *B*ronze Cost - A lower user subscription where the cost function is significantly more important than any QoS parameters.

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There are five different mobile speed between low speed vehicular mobile station (5 m/s) to high speed vehicular mobile station (25 m/s) [26]. Figure 1 illustrates the flowchart of the handoff decision algorithm to select the networks.

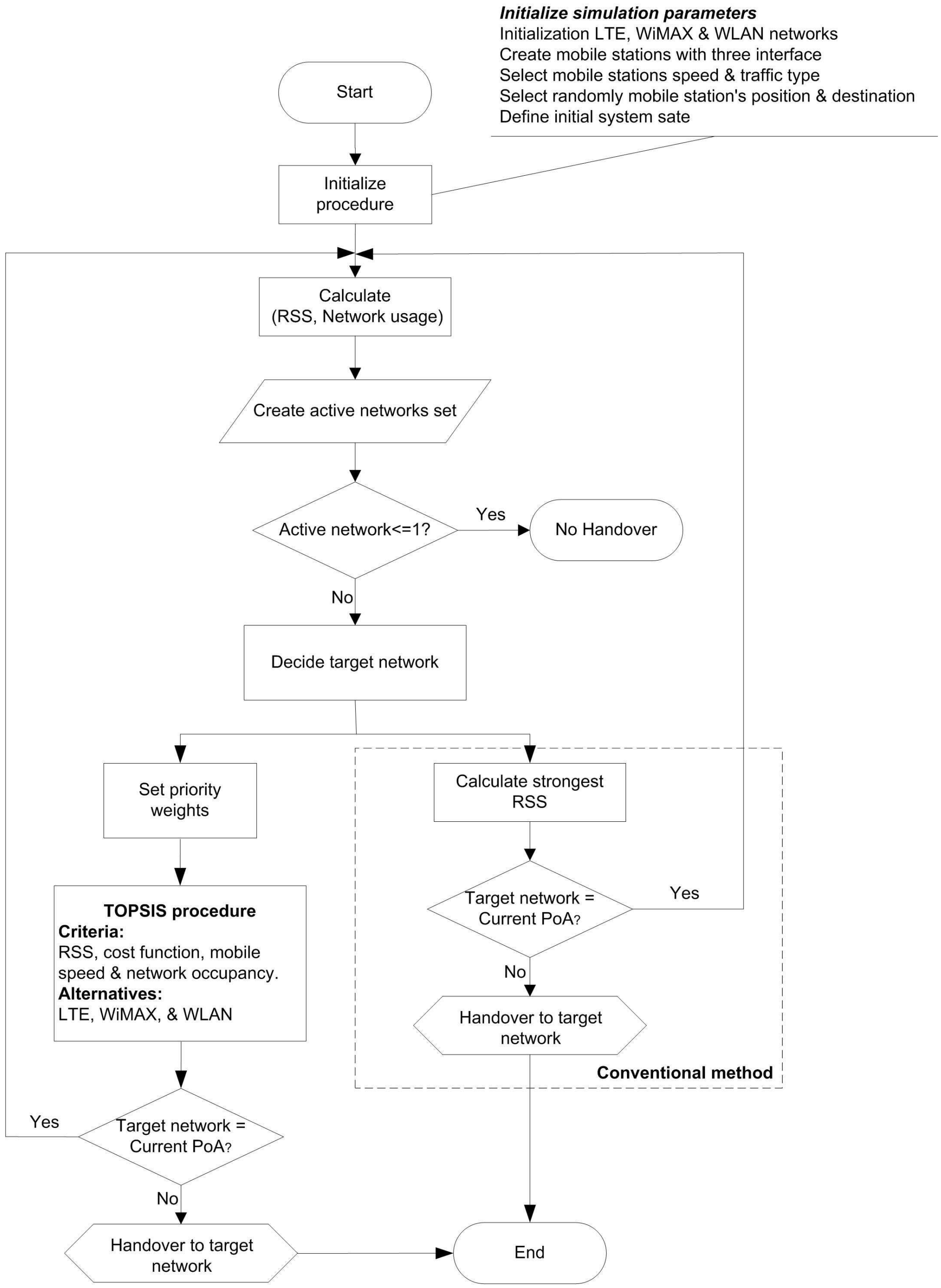

Fig 1. Message flow diagram for the MHB-MN control method

TOPSIS method provides flexibility in defining the weights of the multiple criteria priority.There are three types of priority in multiple criteria vertical handoff decision: equal priority, mobile priority, and network priority. Priority method emphasizes

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mobile parameter (cost function and mobile speed); meanwhile network priority emphasizes network occupancy. Each priority has a certain weight as presented in Table 2.

Table 2. Priority Weights

Criteria	Equal priority	Mobile priority	Network priority
Cost function	0.25	0.4	0.1
Mobile speed	0.25	0.4	0.1
RSS	0.25	0.1	0.4
Network occupancy	0.25	0.1	0.4

In these three types of priority, we utilize the weights to compute the expected impact of each criterion on selecting the most appropriate network for handoff purpose. This is performed by employing TOPSIS method to compare between the available candidate networks. Suppose there are M alternatives (options) of candidate networks available for handoff selection. Building on previous discussion, TOPSIS will be the based method in selecting the most appropriate network for handoff. The steps are as follows [26]:

1. *Construct the normalized decision matrix.* To transform dimensional attributes into non-dimensional ones. This will allow comparison across criteria, using the following equation:

$$r_{ij} = \frac{N_{ij}}{\sqrt{\sum_{i=1}^{m} N_{ij}^2}} \qquad i = 1 \ldots m,\ j = 1 \ldots n \tag{1}$$

   where

   r_{ij} represents the non-dimensional matrix.

   N_{ij} represents the score of option i with respect to criterion j.

   m represents the alternatives (LTE, WiMAX & WLAN).

   n represents the criteria (RSS, cost function, mobile speed, & network occupancy).

2. *Construct the weights decision matrix.* The TOPSIS method is used to multiply each column of the normalized decision matrix by the weights. An element of the new matrix is:

$$V_{ij} = Wr_i * r_{ij} \tag{2}$$

   where

   W represents the weight

3. *Determine the ideal and negative ideal solutions.*

   (a) Ideal solution:

$$A^+ = \left\{V_1^+, \ldots, V_n^+\right\}, \tag{3}$$

   where $V_j^+ = \{\max(V_{ij})\ if\ j \in J; \min(V_{ij})\ if\ j \in J^-\}$

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(b) Negative ideal solution:

$$A^- = \{V_1^-, \ \ldots, V_n^-\}, \tag{4}$$

where $V^- = \{\min(V_{ij}) \ if \ j \in J; \max(V_{ij}) \ if \ j \in J^-\}$
J is the set of benefit attributes or criteria (more is better)
J^- is the set of negative attributes or criteria (less is better)

4. *Calculate the separation measures for each alternative.*

(a) The separation from the positive ideal alternative is:

$$S_i^+ = \sqrt{\sum_{j=1}^{n}(V_{ij} - V_j^+)} \qquad i{=}1, \ldots, \ m \tag{5}$$

(b) The separation from the negative ideal alternative is:

$$S_i^- = \sqrt{\sum_{j=1}^{n}(V_{ij} - V_j^-)} \qquad i{=}1, \ldots, \ m \tag{6}$$

5. *Calculate the relative closest to the ideal solution.*

$$C_i^+ = \frac{S_i^-}{S_i^+ + S_i^-} \tag{7}$$

where $0 < C_i^+ < 1, \quad i = 1, \ldots, m$

$$C_i^+ = 1, \ if \ A_i = A^+$$
$$C_i^+ = 0, \ if \ A_i = A^-$$

6. *Rank the preference order.*

A set of alternatives can now be preference ranked according to the descending order of C_i^+.

3 Simulation algorithm

To obtain performance results, the proposed algorithm is implemented by using the NS-2 simulation [27]. Initially, we implemented the traditional network according to RSS in vertical mode. This product is taken as the benchmark for the analysis of handoff process. after that, evaluate the handoff efficiency is done by examining the probability of success and failure of handoff.

Moving on, handoffs are calculated based on the total vertical handoff occurrence during an active call. It is crucial in assessing a mobile network performance as it is influenced by signaling load and delivery of QoS. It is worth noting that unnecessary handoff will waste network resources and time, consequently contributing to inefficiency. The handoff failure probability is the average of incoming handoff request that cannot be serviced due to lack of resources.

The network topology consists of the LET, WiMAX, and WLAN networks. The radius of WiMAX 2500 m, LTE 1000 m, and WLAN is 300 m. WiMAX covers 75% of the simulation area; meanwhile LTE covers 65% and WLAN covers 75%. Radio parameter is presented in Table 2. The tracks of MNs are randomly paths [27]. The User Datagram Protocol (UDP) is used to transmit 4,960 bytes of video and 320 bytes of audio traffic between MN and CN. Meanwhile, the inter-packet transfer duration is 0.004s. The simulation time is set at 480s while the results are computed by taking the average speed of 10 times executing the scenario.

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4 Results and Analyses

Looking at different point of discussion, there are three types of priority to be considered in multiple criteria handoff decision. They are equal priority, mobile priority and network priority, and there are implemented in a heterogeneous network environment. Each priority performance is compared to traditional method which only considers RSS as it's criteria – multiple criteria method considers cost function, mobile speed and network occupancy.

Figure 2 presents the number of handoff allocations of equal priority multiple criteria, for 100 mobile users.

Equal priority has been proven to reduce the number of handoff by 22.9% - the number of handoffs are reduced to 33 from 44 after implementation of equal property multiple criteria. This improves network efficiency and increase resource availability.

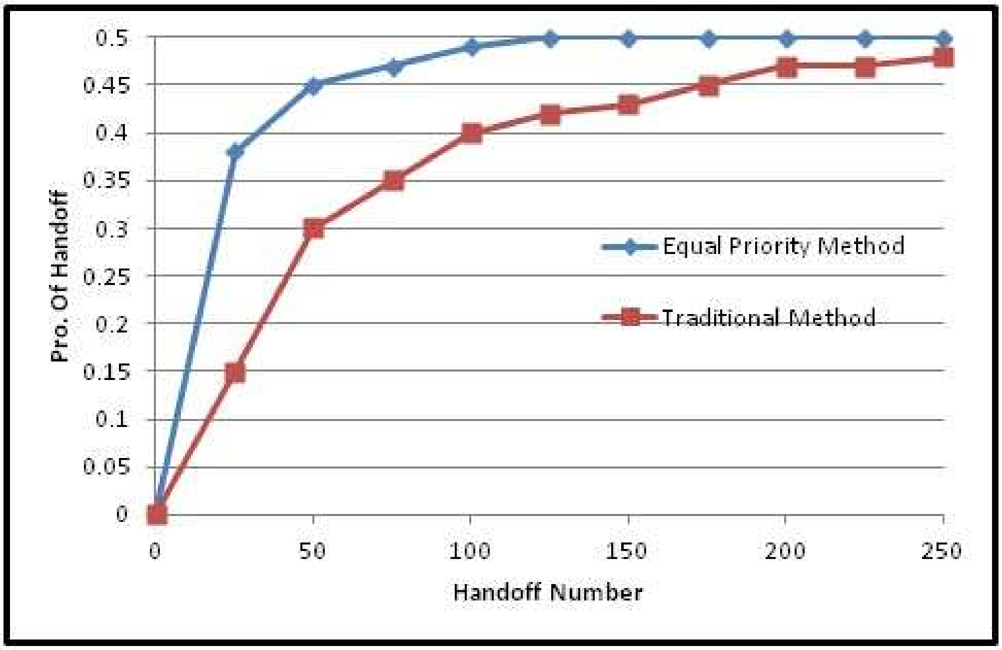

Fig 2. Handoff number probability of equal priority method

Figure 3 presents the number of handoffs after the implementation of mobile priority multiple criteria. Mobile priority reduced the number of handoffs by 40.29% - the number of handoffs from 44 to 30 after the implementation of mobile priority multiple criteria.

Number of handoffs for network priority multiple criteria is presented in figure 4. The improvement is 60%, where the number of handoff averages for traditional method are 44 and the number of handoff averages for network priority multiple criteria is 25.

Building on previous discussion, traditional method vertical handoff decision produces a higher volume of handoffs. This lead to the increase of signaling load on the network. As shown in previous paragraph, mobile priority multiple criteria method performed better than equal priority and network priority. The weights of mobile priority multiple criteria has a large ratio on cost function and mobile speed. Mobile speed is linked to the number of handoffs, where mobile users with higher speed are more likely to experience ping pong effect. This proves that focusing on cost function and mobile speed reduces unnecessary handoffs.

Figure 5 presents the average handoff failure probability for equal priority multiple

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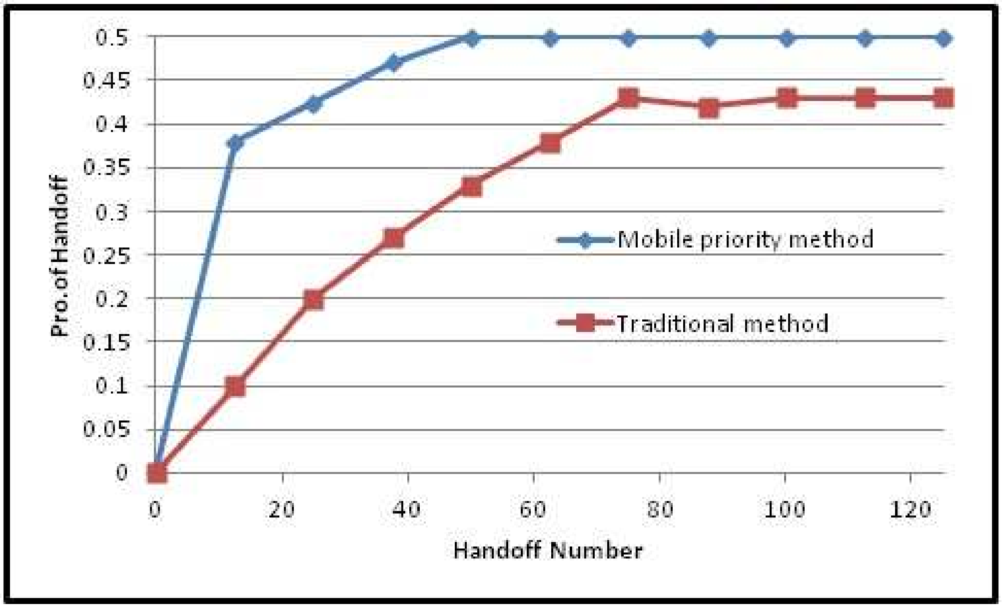

Fig 3. Handoff number probability of mobile priority method

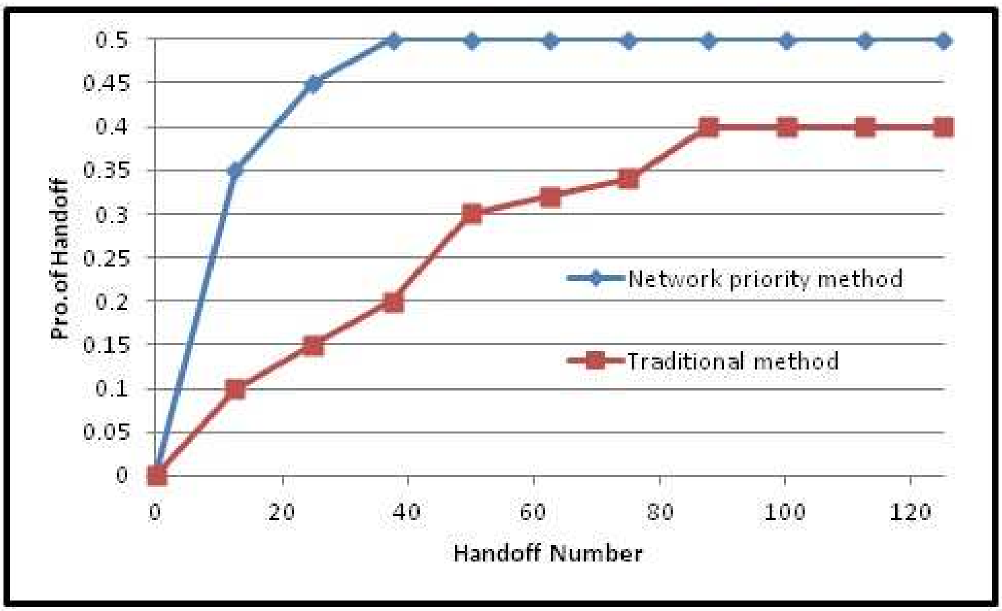

Fig 4. Handoff number probability of network priority method

criteria method. Handover failure probability is a fundamental performance metric because it indicates the ability of the network to serve incoming mobile users. However, equal priority multiple criteria improved the average handoff failure probability by 24.62%. The average handoff failure probability for traditional method is 0.24 and the average handoff failure probability for equal priority multiple criteria is 0.18. Equal priority has an equal proportion for all criteria (mobile criteria and network criteria); meanwhile handoff failure probability is closely related to the network.

Apart from that, providing larger network occupancy and mobile priority multiple criteria can improve handoff failure probability – the average increased by 33.79%. As demonstrated in Figure 6, the average probability value for traditional method is 0.27

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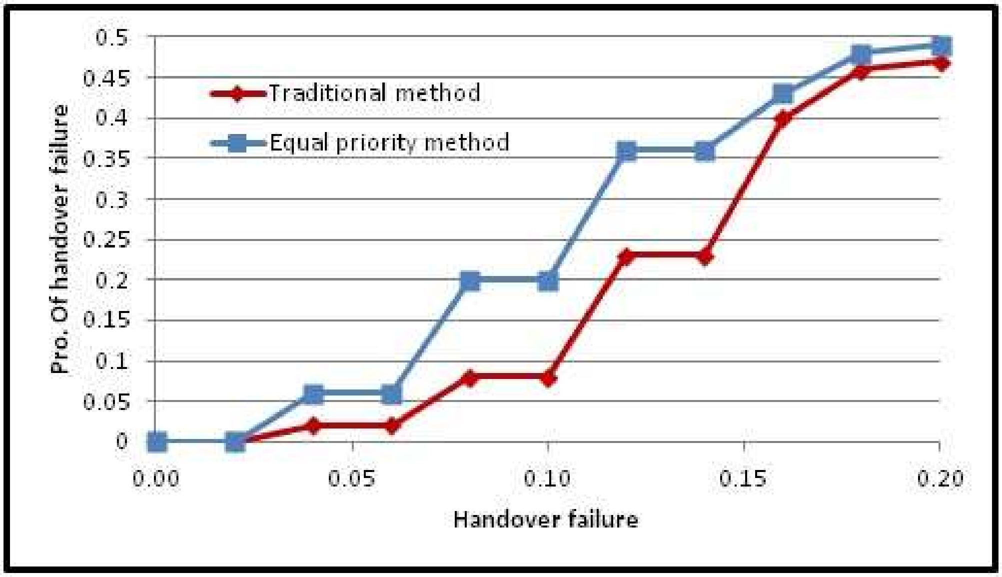

Fig 5. Average handoff failure probability of equal priority method

while for mobile priority multiple criteria is 0.18. The network priority multiple criteria significantly improved average handoff failure probability by 43%. Meanwhile, the average handoff failure probability is 0.27 for traditional method and 0.15 for network priority multiple criteria method. From this, it can be concurred that average handoff failure probability is linked to network occupancy. It should be noted that in network priority multiple criteria method, the load on network in higher than RSS, cost function and mobile speed. Hence, prioritizing network will reduced the average failure probability (Figure 7).

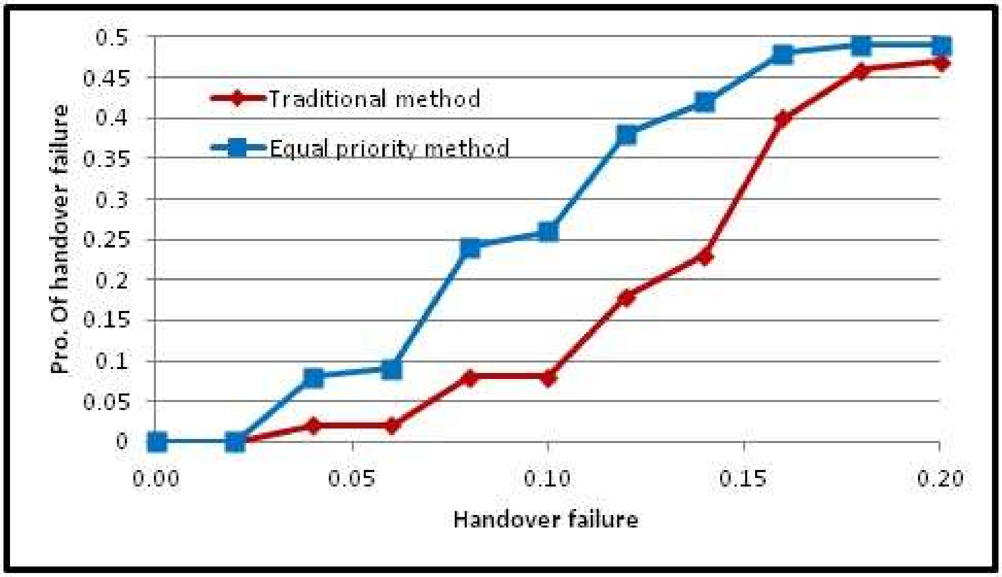

Fig 6. Average handoff failure probability of mobile priority method

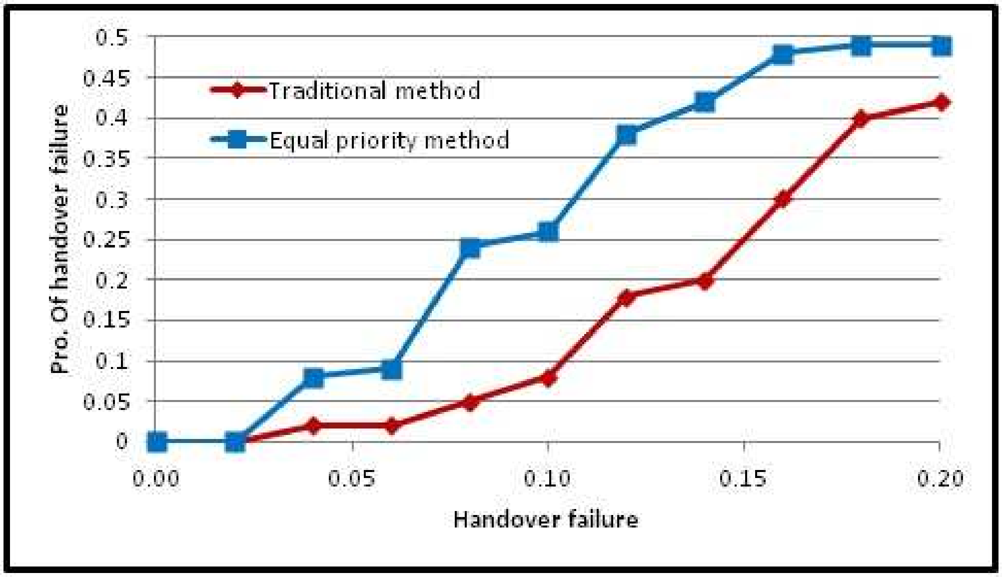

Fig 7. Average handoff failure probability of network priority method

5 Analytical model

The number of handoff can also be defined as the number of handoff requested during a call connection. Such requests affect the handoff arrival traffic and call admission control policy design [28]. This is why number of handoff is chosen as a parameter to assess algorithms. Definition of call holding time and the call residence time (Figure 8) should be clear in an analytical model.

1. Call holding time (T_C): the duration from the accepted call instant to the call completed instant.

2. Network residence time in the origination network (r_1): the mobile user travel duration from the original call point to the edge of the network.

3. Network residence time in the handoff network *(t_n, i= 2, 3, 4...)*: the mobile user travel duration through a network (edge to edge) reached after *(n −1, n=2, 3, 4,...)* handoff(s).

This paper will now focus on the configuration of the calculation of the number of handoffs.
Let *(NH)*= the number of a non-blocked call during a call connection. Then;

1. If the network residence time in the original network r1 is longer than the call holding time (T_C), *NH = 0.*

2. If the call is terminated because first handoff failure or the call make the first successful handoff and is completed successfully in a new network, *NH = 1.*

Apart from that, a non-blocked call handoff probability (P_{NH}) is as follows.

To find the approximating of network residence times $(r_1 + t_2 + .. + t_{NH})$ for mobile nodes, we will use the probability density function (*pdf*) [29].

$$P_{NH}= \begin{cases} P_{NH}\left(T_C < r_1\right) & NH=0 \\ P_{NH}(r_1 + t_2 + .. + t_{NH} < T_C \le r_1 + t_2 + .. + t_{NH+1})\left(1-P_{fh}\right)^{NH} & \\ +P_{NH}\left(T_C > r_1 + t_2 + .. + t_{NH}\right)\left(1- P_{fh}\right)^{NH-1} P_{fh} & NH \ge 1 \end{cases} \tag{8}$$

where P_{fh} is the handoff failure probability because of lack of resources. Then can be simplified as follows:

$$P_{NH}= \left\{ \begin{array}{ll} 1- P_{NH}\left(T_C > r_1\right) & NH=0 \\ P_{NH}(T_C > r_1 + t_2 + .. + t_{NH})\left(1-P_{fh}\right)^{NH-1} - & \\ P_{NH}\left(T_C > r_1 + t_2 + .. + t_{NH+1}\right)\left(1- P_{fh}\right)^{NH} & NH \ge 1 \end{array} \right\} \tag{9}$$

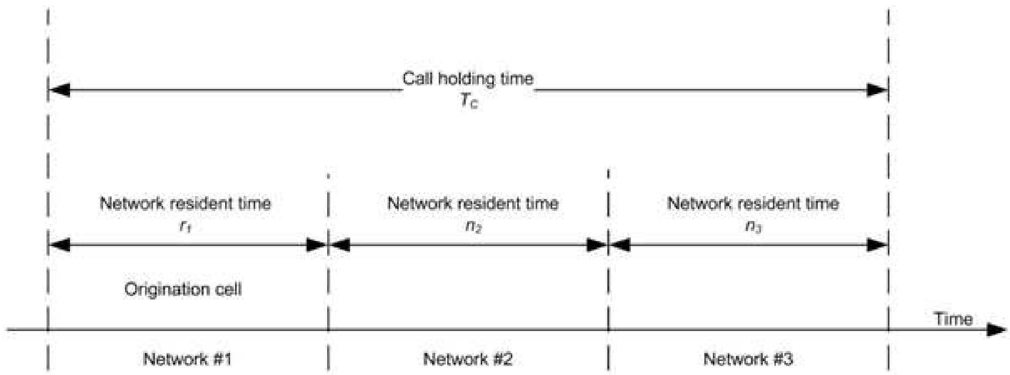

Fig 8. Timing Diagram for Network Residence Time and Call Holding Time

Assume that the random variable $R_{NH} = (r_1 + t_2 + .. + t_{NH})$. Then; • The residence time in the first network r_1 is the gamma distributed random variable that has the same mean as R_{r_1} [30] • The residence time in all subsequent networks is the gamma distributed random variable that have the same mean R_{t_i} and variance $\sigma^2_{t_i}$

$$pdf_{r_1}(t) \cong \frac{\beta_1^{\alpha_{1_t}\alpha_1 - 1} e^{-\beta_1^t}}{\Gamma(\alpha_1)} \tag{10}$$

and

$$pdf_{r_i}(t) \cong \frac{\beta_i^{\alpha_{i_t}\alpha_i - 1} e^{-\beta_i^t}}{\Gamma(\alpha_i)} \tag{11}$$

where $pdf_x(t)$ is the random variable x, and $\Gamma(x) = \int_0^\infty t^{x-1} e^{-t} dt$.

Hence, the mean and the variance of the random variable t_i may be found from 11, respectively, as

$$R_{t_i} = \frac{\alpha_i}{\beta_i}, \qquad \sigma^2_{t_i} = \frac{\alpha_i}{\beta_i^2} \tag{12}$$

Solving 12 for $\alpha_i\ and \beta_i$, we have

$$\alpha_i = R_{t_i}\beta_i, \beta_i = \frac{R_{t_i}}{\sigma^2_{t_i}} \tag{13}$$

Similarly, for the residence time in the first network, we have $R_{t_1} = \frac{\alpha_1}{\beta_1}$, and letting $\beta_1 = \beta_i$, we have

$$\alpha_1 = R_{r_1}\beta_1 = \frac{R_{r_1} R_{t_i}}{\sigma^2_{t_i}} \tag{14}$$

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It can be seen that R_{NH} is the sum of (NH) gamma distributed random variables with the same shape parameter β_i. Hence, R_{NH} is also a gamma distributed random variable with parameters.

$$\alpha_{NH} = \alpha_1(m-1)\alpha_i, and\beta = \beta_1 = \beta_i \tag{15}$$

hence, the *pdf* of R_{NH} may be found as

$$pdf_{R_{NH}}(t) = \frac{\beta^{\alpha_{NH}} t^{\alpha_m - 1} e^{-\beta t}}{\Gamma(\alpha_{NH})} \tag{16}$$

From 9 we have

$$P_{NH} = \begin{Bmatrix} 1 - P_{NH}(T_C > r1) & NH = 0 \\ P_{NH}(T_C > R_{NH})(1 - P_{fh})^{NH-1} - & \\ P_{NH}(T_C > R_{NH-1})(1 - P_{fh})^{NH} & NH \geq 1 \end{Bmatrix} \tag{17}$$

then

$$P_{NH} = \begin{Bmatrix} 1 - \int_0^\infty pdf_{R_1}(t)(1 - D_{T_C}(t))\,dt, & NH = 0 \\ (1 - P_{fh})^{NH-1} \int_0^\infty pdf_{R_{NH}}(t)(1 - D_{T_C}(t))\,dt - & \\ (1 - P_{fh})^{NH} \int_0^\infty pdf_{R_{NH-1}}(t)(1 - D_{T_C}(t))\,dt & NH \geq 1 \end{Bmatrix} \tag{18}$$

We select the network priority handoff decision algorithm which gives the best results compared to equal priority and mobile priority handoff decision algorithm for evaluation by use the equation 11.
Our method by calculating the probability function of the number of handoff and compare with simulation results as show in Figure 9.

The discussion that have been built demonstrated that the analytical results from the introduces technique and computer simulation agrees with different system parameters. The former also leads to high accuracy of results.

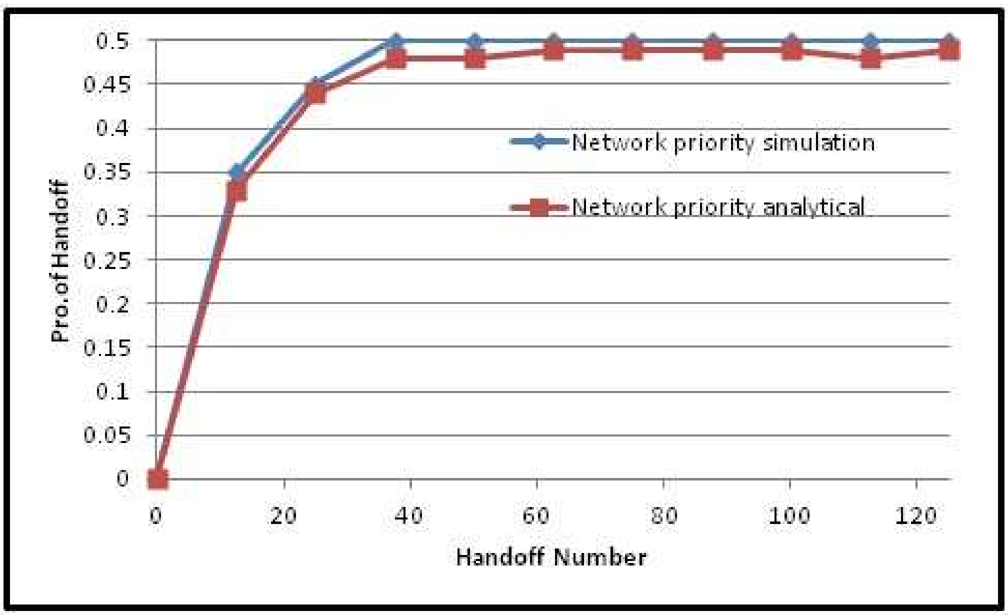

Fig 9. Handoff number probability

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6 Conclusions

To overcome the problem of the excessive handoff for mobile devices in the environment of heterogeneous network, we proposed an improved vertical handoff decision algorithm based on multiple criteria, which will enable the mobile devices to make the right handoff decision. From the simulation results, we can observe that our proposed enhanced the number of handoffs probability and the handoff failure probability in comparison with the traditional network decision algorithm. The network priority handoff decision algorithm gives good results compared to equal priority, mobile priority handoff decision algorithm.

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