Journal of Advanced Research in Applied Sciences and Engineering Technology

Journal homepage:
https://semarakilmu.com.my/journals/index.php/applied_sciences_eng_tech/index
ISSN: 2462-1943

Handover Network Selection for Vehicle in LTE-A Communication Networks

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ARTICLE INFO

Article history:
Received 1 February 2023
Received in revised form 8 June 2023
Accepted 15 June 2023
Available online 29 June 2023

Keywords:
Handover; relative direction index; proximity index; residence time index

ABSTRACT

One of the challenges to achieving smooth communications in heterogeneous networks is to find the right balance between various handover parameters for network selection. The Receive Signal Strength (RSS) from a network's Point of Attachment (PoA) is the primary factor used in traditional approaches to network selection. Therefore, network selection is vital for a successful handover in the vehicle communications network. However, vehicles moving through such diverse networks faced difficulties like frequent unwanted handovers, selecting the wrong candidate networks for handovers, and taking too long to finish the drawn-out handover procedure, which results in failed handovers. All of these factors will impair the efficiency of the handover process, which will affect the smooth operation of the vehicles. Hence, the main idea of this research is to improve the handover network performance selection performance. The proposed work is for vehicles to self-evaluate a candidate list of Access Points (AP) that are located in the vehicle movement direction and select the best underlying candidate network. In this project, the network selection framework of the vehicle communications network with the distance between the target candidate and the trajectory of the vehicle movement was developed as well as the vehicle mobility information. The important parameters which are the relative direction index, proximity index and residence time index are chosen to identify the best candidate network. Once the target of the base station has been identified, then the optimum value of the distance is calculated using the Particle Swarm Optimization (PSO) technique to initiate the handover process. The performance of the proposed handover network selection is simulated and evaluated using MATLAB software. The results show that the proposed handover network selection method improved the successful handover rate as compared to the conventional method.

1. Introduction

LTE-A communication networks feature the seamless coexistence of various access technologies (UMTS, HSPA, WiMAX, LTE, and WiFi) and underlying cells of various sizes (macro, pico, and femto). Vehicles moving through such diverse networks will face difficulties like frequent unwanted handovers, selecting the wrong candidate networks for handovers and taking too long to finish the

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https://doi.org/10.37934/araset.31.1.373382

drawn-out handover procedure, which results in failed handovers. All of these factors will impair the efficiency of the handover process, which will affect the smooth operation of the vehicles [1].

According to the aforementioned claim, the deployment of small cells in LTE-A communication networks has numerous benefits, including the provision of high-quality service, an increase in traffic capacity and data rate, increased capacity through macro cell traffic offloading, and reduced costs. Additionally, small cells can offer network services in regions with poor macro-cell signal coverage. However, vehicles may face difficulties due to the presence of multiple underlying networks with various coverage areas, traits, and QoS requirements. Hence, the existing network selection methods are not suitable for vehicular handover in multitier heterogeneous networks.

There are many researchers have investigated the problem of vehicle-to-infrastructure communication in multi-network and proposed various methods in terms of troubleshooting the problem [1-3]. The research from the paper by E. Ndashimye *et al.,* [2] presented a mobility-aware network selection for vehicle-to-infrastructure communication over LTE-A multi-tier network. The authors proposed that an LTE-A user equipment from the vehicle or user can self-select itself with a suitable target network for handover and can improve the network packet delivery ratio by 20% and reduce the end-to-end delay by 14%. The network selection can be divided into two types which are upward selection and downward selection to improve the upward selection and downward selection efficiently. The method selected the most suitable candidate network line for both while moving from a femto/pico to a macro cell (upward selection) and macro to a femto/pico cell (downward selection). From downward selection, the authors proposed method will prevent the UE from selecting the wrong candidate cell by considering the possible dwelling period in the service area of the candidate HeNB. Another paper by E. Ndashimye *et al.,* [3] introduced the concept of Access Network Discovery and Selection Function (ANDSF) to select the most appropriate target networks for handover. ANDSF selects the target network in heterogeneous networks where a vehicle OBU can discover and select the underlying access policies and parameters obtained from the ANDSF server. The authors developed the analytical model to derive the relative direction index, proximity index and residence time index to short-list candidate networks for vehicles with reasonable coverage but the authors didn't further investigate the capability of accommodating new handover sessions.

Paper [4] proposed an algorithm to reduce frequent handovers based on user velocity and small cell density, which separates the frequency handover experienced users into either ping-pong or fast-moving users by utilizing a user history information system. Since moving users do not always behave the same way, the algorithm identifies them separately. The conventional frequency handover experienced schemes are unable to detect potential FHE users caused by changes in mobility state. However, the proposed algorithm detected those users earlier and helped to reduce unwanted handovers. Paper [5] proposes a novel coverage model of overlapping small cells in the ultra-dense network (UDN) to capture the nature of both inter-tier and intra-tier handovers. Analytical results in this work can provide a guide to optimize network parameters based on user velocity and small cell density to reduce handover overheads and improve UE experience in UDNs.

Various techniques have been proposed to address these impairments but they still encounter some drawbacks in terms of throughput degradation [6-20]. This project mainly focused on the development of a network selection framework for vehicle communication networks. The main idea is to improve the handover network performance selection performance. Hence, this study is to identify network selection parameters to self-select the most suitable network for potential handover in multiple locations. The remainder of this paper is organized as follows. Section II explains the methodology performed for this study which is verified by the simulation results and discussion in Section III. Finally, concluding remarks are summarized in Section IV.

2. Methodology
2.1 Network Selection Framework

The network selection framework based on moving vehicles across multiple APs from one location to another is proposed by considering relative direction index, proximity index and residence time index parameters. Figure 1 shows the framework of network selection consisting of a mixture of small cells.

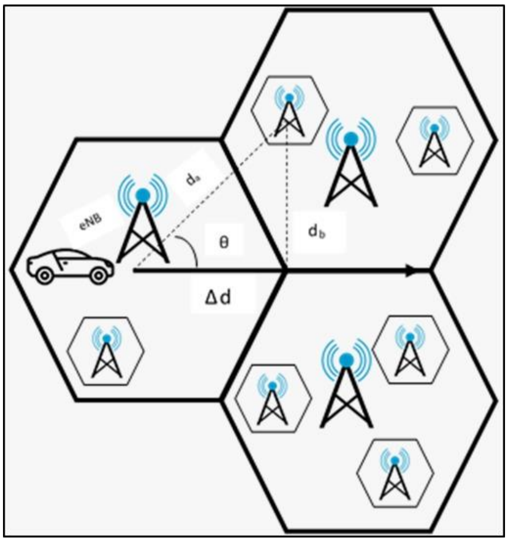

Fig. 1. Framework of network selection

The small cell networks, which have constrained coverage regions, are overlaid by the LTE macro network, which spans the whole service area. Vehicles equipped with dual-mode such as LTE-A and have a variety of network alternatives to select from for handover in the overlapping regions between small cell networks. Vehicles operating within the small cell service area, for instance, can switch to either the macro-network or another small cell network, provided that the target network (for the handover) has sufficient resources to enable continuous communication.

The proposed solution allows a vehicle with a dual-mode on-board unit (OBU) to choose the best target network for a potential changeover based on several parameters as it is moving across the multi-tier network of macro and small cells. The cars OBU compiles a preliminary list of prospective targets of the Service Access Point (SAP) for handover in the first stage based on the relative direction index, proximity index and residence time index parameters. Detailed descriptions of the handover parameters are explained in the next section.

2.2 Relative Direction Index

A preliminary idea of this parameter was given in Ndashimye *et al.,* [1] and this work employs a modified framework of the paper. The relative direction index uses distance calculations to assess the vehicle's travel direction with the geo-location of a potential SAP. Consider the vehicle's V1 and V2 sequential points along the moving trajectory as shown in Figure 2.

Then, at each of these positions, the vehicle OBU calculates its distance from all available SAP. Latitude and longitude of vehicles, (Latv; Lonv) and latitude and longitude of SAP (LatSAP; LonSAP), respectively, denote the coordinates of the vehicle and the candidate SAP, and Δlat and Δlon, respectively, denote the latitude and longitude separations, then the distance, d between the vehicle and candidate SAP can be calculated as

$$d = 2\ R\ sin(K) \tag{1}$$

K can be calculated as

$$K = \sqrt{sin^2\left(\Delta lat/_2\right) + \cos(lat_v) * \cos(LatSAPi) * sin^2\left(\Delta lon/_2\right)} \tag{2}$$

where the angle is in radians and R = 6371 km is the radius of the earth.

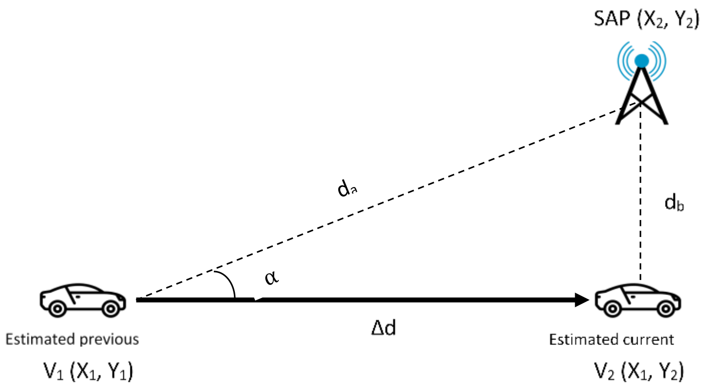

Fig. 2. Estimating the direction of the relative movements

2.3 Proximity Index

Next, the proximity index parameter is to calculate the proximity of an SAP to the movement trajectory of the vehicle. The proximity index, i indicates how near the target SAPs are to the movement trajectory of the vehicle and it is related to the angular displacement of the vehicle. The angular index can be calculated as:

$$\omega i = \cos\alpha = \frac{\Delta d}{d_a} \tag{3}$$

However, important to note here that the angle cos θ is restricted between 0 and π since only those SAPs are considered to which the vehicle shows progressive movement [1].

2.4 Residence Time Index

The residence time index is also one of the parameter networks proposed in this paper. The residence time index shows the duration the vehicle spent within the base station service area of the candidate network target. This parameter depends on the vehicular speed and the coverage radius of SAP. Hence, the residence time index, tr equation can be calculated as

$$tr = \frac{Cr * \cos\alpha}{V} \tag{4}$$

where Cr is the maximum coverage radius of the candidate SAP.

2.5 Optimum Distance Value by Using Particle Swarm Optimization (PSO) Technique

This part is to determine the value of optimum distance to initiate the handover process by using speed, v and handover signaling delay, t information once the target of the base station is known based on the above parameters. The value of optimum distance, d has been calculated for a desired probability of handoff failure, pf by using this equation

$$pf = cos^{-1}\frac{d}{vt} = \frac{\pi}{2} - \frac{d}{vt} \quad (5)$$

PSO technique has been used to find the optimum value of distance, d for a certain value of pf. In this project, pf value is set to 0.02 which means out of 100 handovers, only two attempts will fail. Another 98% attempt will succeed to be handover to the target base station.

3. Results

The proposed network selection method in this project is simulated and evaluated through the simulation performed in MATLAB software. This part analyses the efficiency of the suggested network selection method in terms of handover performance.

3.1 Parameter Performance Evaluation

Numerical results based on parameter selection which are relative direction index, proximity index and residence time index is as shown in Figure 3 to 5.

The various distance of the vehicle relative to each SAP surrounding indicates as shown in Figure 3. Based on the result, the value of relative direction become decreases from longitude 10 until 50. This is because the vehicle moving nearer to the coverage area of SAP. Hence, the distance between the vehicle and candidate SAP, d becomes shorter. The value of relative direction becomes increases from longitude 50 until 80. The reason is that the vehicle moving further into the coverage area of SAP. Hence, by using the relative direction index parameter, the direction movement of the vehicle towards the network candidate selection of SAP can be estimated.

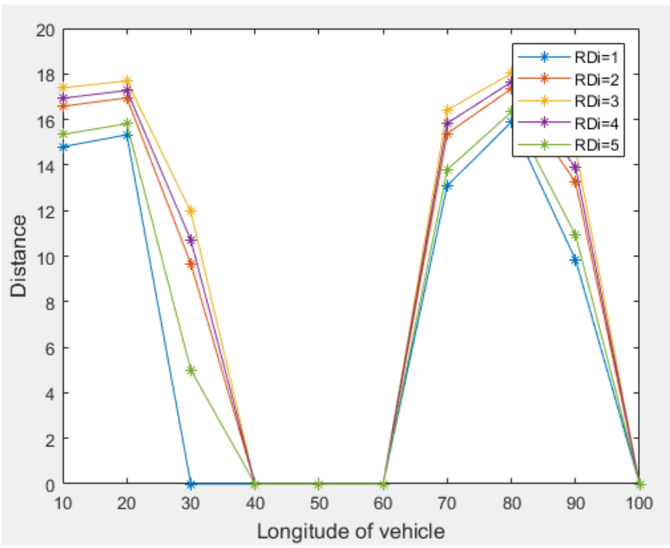

Fig. 3. Graph of distance versus longitude of the vehicle

Next, the trajectory movement of the vehicle to each SAP surrounding with different distances between the vehicle and candidate SAP is shown in Figure 4 below. Same as the previous result but this graph is related to the angular displacement, α of the vehicle. Based on the theory, the angular trajectory indicates the direction of the vehicle moving from the estimated previous position to the current position based on Figure 2. The result from Figure 4 shows the proximity index decreases when the relative direction index is from 10 to 40. The value of the proximity index is in the radian which is at 0.8 rad, the angle value is 36.80 and if 0.2 radian, the value angle in degree is 780. Other than that, the value of the proximity index is 0 when the relative direction is from 40 to 60. It is because the position of the vehicle is at 900 with the SAP (cos 90=0). Hence, we can indicate the movement of the trajectory of the vehicle and estimate how near the target SAP are to the movement trajectory of the vehicle related to the angular displacement.

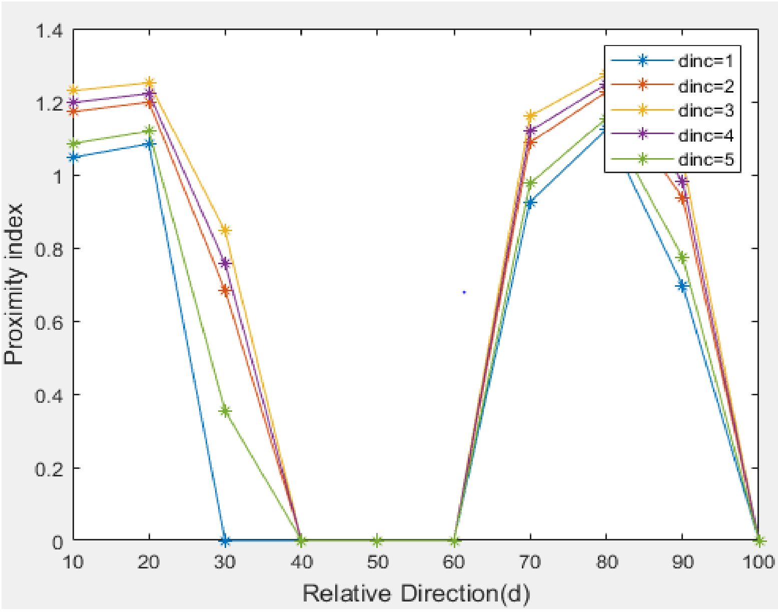

Fig. 4. Graph of proximity index versus relative direction

A graph of residence time index versus velocity for 2 different proximity indexes, cos x is shown in Figure 5. The residence time index shows the duration the vehicle spent within the base station service area of the candidate network target. This factor will depend on the vehicular speed and the coverage radius of SAP. From the graph, it can be seen that as the speed is slow, the duration the vehicle spends within the base station service area of the candidate network target is longer as compared with high-speed vehicular.

The result also shows that the residence time index at cos x=50 is longer than the residence time index at cos x=30. At cos x=50, the plot line indicates the vehicle trajectory of angular displacement moves for about 50 degrees while at cos x= 30, the plot line indicates the vehicle trajectory of angular displacement moves for about 30 degrees in the network candidate. As a result, the distance traveled at cos x=50 is longer than cos x=30 and causes the residence time index of cos x=50 to be longer than cos x=30. Hence, if the angle is larger, the residence time index will be longer.

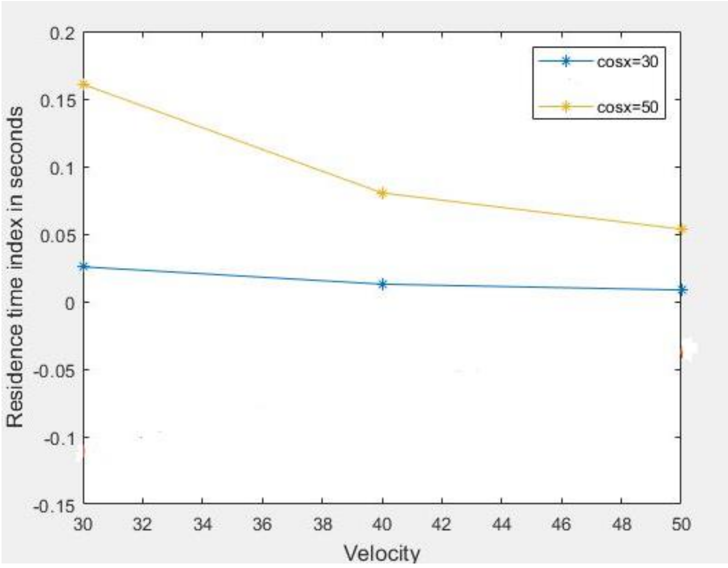

Fig. 5. Graph of residence time index versus velocity

3.2 Optimum Distance from PSO Technique

To find the optimum value of distance, d for the value of pf, the PSO technique has been used. Figure 6 shows the optimum distance, d identified from the PSO analysis to initiate the handover process for the low-speed user which is below 30km/h for three different handovers signaling delay. It is shown that as the speed of the vehicle increases, more distance is required for the UE to initiate handover from the current base station to the target base station. The result also shows the higher signaling delay requires a longer distance for the UE to initiate handover from the serving base station to the target base station.

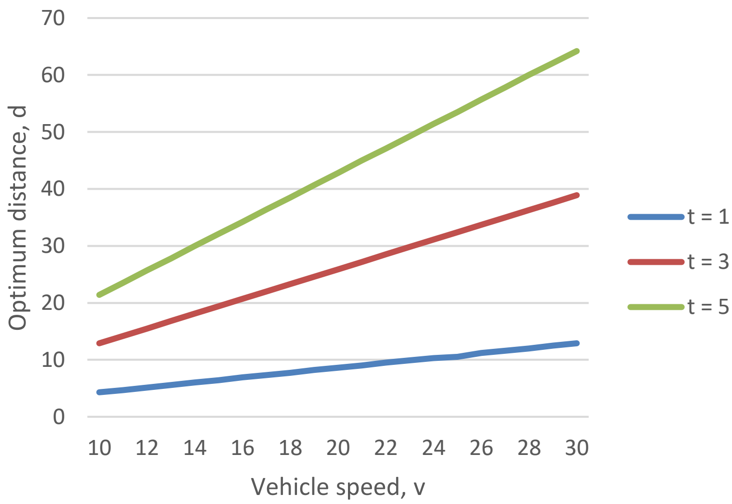

Fig. 6. Graph of optimum distance versus vehicle speed

3.3 Network Cell Scenario Evaluation

This section shows the rate of successful handover of the vehicle users with the targeted network selection by considering the above parameters. The design of the 49 cells used in the simulation scenario is shown in Figure 7. The radius of each cell is 5 km. The red X indicates the position of the

UE while the black X indicates the new location of the vehicle users. The next section shows the handover performance of the vehicle users with the targeted network selection using the proposed technique.

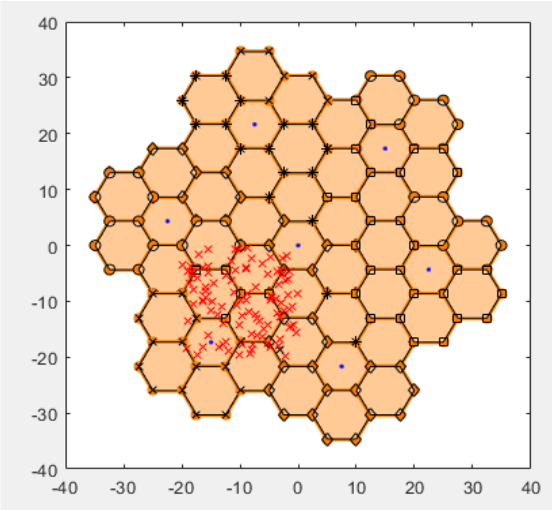

Fig. 7. The network cell scenario

The number of successful handovers versus the number of vehicle users is shown in Figure 8 for the proposed and conventional techniques. Based on Figure 8, the number of successful handovers performed by the conventional technique is less than compared to the number of successful handovers performed by the proposed technique. It can be seen that the proposed technique can improve the number of successful handovers and therefore, reduce the handover failure rate as compared with the conventional technique.

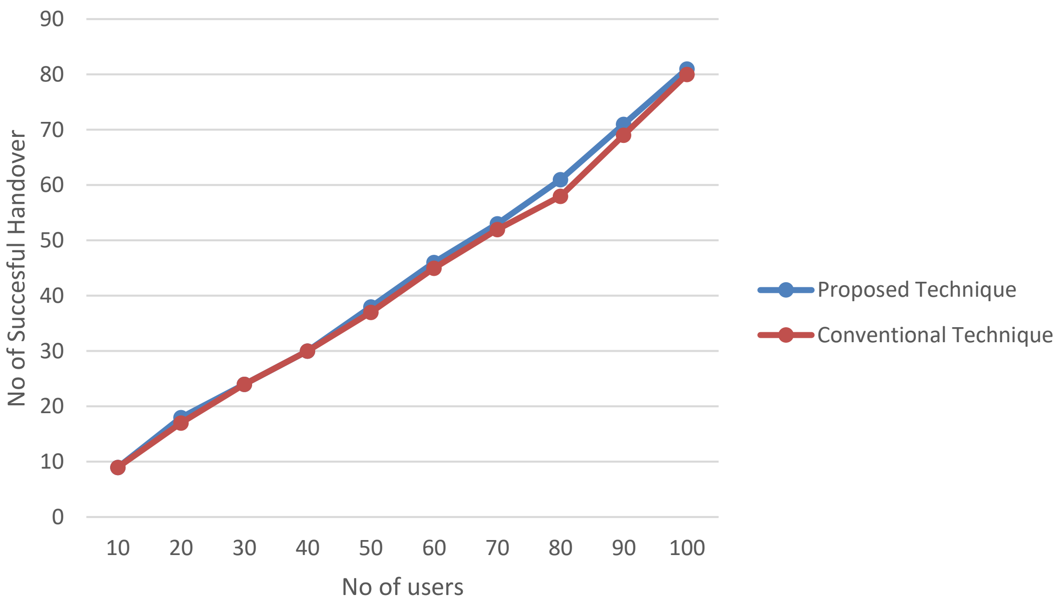

Fig. 8. Graph of the number of successful handovers versus the number of vehicle users

If an underlying network is chosen for a changeover activity that is not the most suited one, this might result in an increase in the frequency of unwanted handovers, which can then lead to packet losses and even call failures. In most cases, the quality of the ongoing communication and the overall performance of the handover are negatively impacted when there is a rise in the number of handover activities. This is because, in the proposed technique, the vehicle OBU scanned and examined only those networks that matched the criteria for being the most acceptable target network for handover.

SAPs that are situated in the direction that the vehicle will be moving and that offer an acceptable residence time with the velocity of the vehicle are desirable. On the other hand, with conventional approaches, the OBU of the vehicle scanned and examined all of the advertising networks regardless of the direction in which it was moving [1].

4. Conclusions

In conclusion, this research identifies network selection parameters to self-select the most suitable network for potential handover in multiple locations. Once the target base station is identified, then the optimum distance is calculated by using the PSO technique to initiate the handover process. The network selection scenario is developed to see the impact of handover performance on vehicle communication networks. The performance of the proposed technique is evaluated and compared to the conventional technique. The results show that the proposed network selection technique can improve the handover performance compared to the conventional technique. For future works, the research will proceed the see the impact of how the vehicle moving from a lower speed to a higher speed can affect the handover performance.

Acknowledgment
This paper is part of research work supported by MOHE Grant file no.: FRGS/1/2019/TK04/UITM/02/26 and School of Electrical Engineering, College of Engineering, Universiti Teknologi MARA Shah Alam.

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