OPTIMIZED LOCATION PREDICTION HANDOVER ALGORITHM FOR LONG TERM EVOLUTION ADVANCED (LTE-A) NETWORK

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DEDICATION

This thesis is dedicated to my father, who taught me that the best kind of knowledge to have is that which is learned for its own sake. It is also dedicated to my mother, who taught me that even the largest task can be accomplished if it is done one step at a time.

ABSTRAK

Permintaan untuk kelancaran sambungan internet memerlukan penyediaan komunikasi jalur lebar tanpa wayar walaupun dalam kenderaan yang bergerak pantas. Salah satu penyelesaian untuk mengatasi pertumbuhan peranti mudah alih tanpa wayar adalah penggunaan sel kecil. Dalam usaha untuk menyediakan kualiti perkhidmatan (QoS) untuk pengguna berkelajuan tinggi, penyerahan adalah salah satu daripada unsur penting dalam rangkaian tanpa wayar. Walau bagaimanapun, pembinaan yang tidak terkawal terhadap pusat akses (AP) dalam rangkaian sel kecil yang meningkat terutama di kawasan bandar mencabar pengurusan penyerahan antara kenderaan. Di samping itu, kenderaan hanya mempunyai masa yang terhad apabila ia melalui kawasan pertindihan di dalam sel kecil. Ia boleh menyebabkan penyerahan kerap berlaku dan penambahan bilangan penyerahan yang tidak perlu kerana perubahan pergerakan kenderaan. Objektif utama tesis ini adalah untuk membangunkan algoritma penyerahan cekap yang dapat memperuntukkan sejumlah penyerahan yang sesuai dalam masa yang singkat. Kerja yang dicadangkan ialah algoritma penyerahan ramalan yang memastikan dapat memberi QoS yang tinggi dan menyediakan sumber penyerahan terlebih dahulu. Ramalan lokasi kenderaan (VLP) menggunakan rantaian Markov dibangunkan untuk meramalkan pergerakan pengguna berdasarkan jejak data pengguna yang sebenar. Algoritma penyerahan ramalan lokasi kenderaan (VLP-HA) dibangunkan berdasarkan hasil ramalan dari VLP. Manakala peningkatan algoritma penyerahan ramalan lokasi kenderaan (OVLP-HA) adalah peningkatan VLP-HA dengan strategi keputusan berdasarkan pemberat penghantaran optimum. Prestasi ramalan dinilai dari segi kadar ketepatan ramalan bagi VLP. Manakala prestasi penyerahan untuk VLP-HA dan OVLP-HA dinilai berdasarkan jumlah kesan ping-pong dan kadar pemprosesan data. Keputusan ketepatan ramalan menunjukkan bahawa VLP telah meningkatkan kadar ketepatan masing-masing sebanyak 32% dan 5% berbanding teknik ramalan berasaskan tingkah laku manusia (HBP) dan ramalan lokasi menggunakan penapis Kalman (LPKF). Kemudian, ramalan dari VLP digunakan dalam VLP-HA. Simulasi dilakukan dalam tiga tahap kepadatan trafik untuk mencerminkan senario sebenar samada di kawasan bandar dan luar bandar. Keputusan menunjukkan banyak peningkatan dalam VLP-HA iaitu tidak terdapat kesan ping-pong apabila VLP-HA digunakan berbanding dengan algoritma penyerahan secara A2A4 (A2A4-HA) dan algoritma penyerahan ramalan berasaskan tingkah laku manusia (HBP-HA). Untuk mendapatkan titik penyerahan yang optimum supaya VLP-HA dapat memberikan QoS yang lebih tinggi pada masa yang sama dengan kurang kesan ping-pong, VLP-HA dioptimumkan dengan menggunakan OF yang dibangunkan berdasarkan algoritma koloni semut (ACO). Dua parameter dipertimbangkan iaitu nisbah penghantaran paket (PDR) dan bilangan penyerahan yang tidak perlu. Nilai parameter terbaik digunakan dalam OVLP-HA. Didapati bahawa prestasi penyerahan OVLP- HA telah meningkatkan sebanyak 7% data hasil dan 33% kurang kesan ping-pong berbanding A2A4-HA dan HBP-HA. Algoritma penyerahan yang dicadangkan didapati telah meningkatkan prestasi penyerahan dengan ketara melalui jumlah kesan ping-pong, keluaran data dan peruntukan sumber yang optimum. Cadangan algortima penyerahan dapat disesuaikan dengan variasi tahap kepadatan AP dan boleh digunakan dalam mana-mana kawasan rangkaian seperti kawasan bandar dan luar bandar.

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LIST OF ABBREVIATIONS

3G	-	Third Generation
4G	-	Fourth Generation
5G	-	Fifth Generation
3GPP	-	Third Generation Partnership Project
A2A4-HA	-	A2A4 Handover Algorithm
ACO	-	Ant Colony Optimization
AP	-	Access Point
ARQ	-	Automatic Repeat reQuest
BS	-	Base Station
CDF	-	Cumulative Distribution Function
D2D	-	Device-to-Device
DL	-	Downlink
DTN	-	Delay Tolerant Network
eNB	-	enhanced Node B
EPC	-	Evolved Packet Core
EPS	-	Evolved Packet System
E-RAB	-	E-UTRAN Radio Access Bearer
E-UTRA	-	Evolved Universal Terrestial Radio Access
E-UTRAN	-	Evolved Universal Terrestial Radio Access Network
GPS	-	Global Positioning System
HBP	-	Human Behavior Prediction
HBP-HA	-	Human Behavior-based Prediction Handover Algorithm
HeNB	-	Home enhanced Node B
HetNets	-	Heteregeneous Network
HSPA	-	High Speed Packet Access
ID	-	Ientification
IP	-	Internet Protocol

ITS	-	Intelligent Transportation Stystem
LPKF	-	Location Prediction using Kalman Filter
LTE-A	-	Long Term Evolution Advanced
M2M	-	Machine-to-Machine
MAC	-	Medium Access Control
MeNB	-	Macro Evolved Node B
MIMO	-	Multiple-In Multiple-Out
MME	-	Mobility Management Entity
MR	-	Measurement Report
MTC	-	Machine Type Communication
NCL	-	Neighboring Cell List
NHO	-	Neighbor Handover Offset
NS-3	-	Network Simulator 3
OBU	-	On Board Unit
OF	-	Optimal Forwarding
OFDM	-	Orthogonal Frequency Division Multiplexing
OPEX	-	Operating Expenditure
OVLP-HA	-	Optimized Vehicular Location Prediction Handover Algorithm
PCI	-	Physical Cell Identity
PDCP	-	Packet Data Convergence Protocol
PDN	-	Packet Data Network
PDN-GW	-	Packet Data Network Gateway
PDR	-	Packet Delivery Ratio
PDU	-	Packet Data Unit
PHY	-	Physical Layer
PSO	-	Particle Swam Optimization
QAP	-	Quadratic Assignment Problem
QoS	-	Quality of Service
RAN	-	Radio Access Network
RAT	-	Radio Access Technology

RB	-	Resource Block
RF	-	Radio Frequency
RLC	-	Radio Link Control
RRC	-	Radio Resource Control
RSS	-	Received Signal Strength
RSRQ	-	Reference Symbols Received Quality
RSRP	-	Reference Signal Received Power
RSSI	-	Received Signal Strength Indicator
RSU	-	Roadside Unit
RTLD	-	Real Time with Load Distribution
S-GW	-	Serving Gateway
SAE	-	System Architecture Evolution
SeNB	-	Serving enhanced Node B
SINR	-	Signal-to-Interference-Noise Ratio
SIR	-	Signal-to-Interference Ratio
SN	-	Sequence Number
SON	-	Self-Organizing Networks
TeNB	-	Target enhanced Node B
TPM	-	Transition Probability Matrix
TSP	-	Travelling Salesman Problem
TTT	-	Time-to-Trigger
UE	-	User Equipment
UL	-	Uplink
UMTS	-	Universal Mobile Telecommunications System
UTM	-	Universiti Teknologi Malaysia
WiMAX	-	Worldwide Interoperability for Microwave Access
WLAN	-	Wireless Local Area Network
V2B	-	Vehicle-to-Broadband
V2I	-	Vehicle-to-Roadside Infrastructure
V2V	-	Vehicle-to-Vehicle

VANET	-	Vehicular Ad-hoc Network
VLP	-	Vehicular Location Prediction
VLP-HA	-	Vehicular Location Prediction Handover Algorithm
VoIP	-	Voice over Inter Protocol

LIST OF SYMBOLS

T_n	-	Handover Time-to-Trigger
h	-	Hysterisis
Rx	-	Number of packets that received by the user
Tx	-	Number of transmitted packet
δ	-	Handover delay
d	-	Point where the user trigger the handover
v	-	User's velocity
S	-	Set of states
s_n	-	State of system at time n
M	-	Number of cells
P	-	Current transistion probability matrix
p_t	-	Initial distribution matrix
x	-	Probability of initial state for source AP
y	-	Probability of initial state for destination AP
n	-	Number of state transistion
C	-	Set of access point
T	-	Total time taken
p_k	-	User point trajectory at position k
t_g	-	Maximum interval time that user connect to a point p
t_i	-	Interval time between two sequence points
p_{i+1}	-	Probability of user's trajectory at a point
N_{cp}	-	Number of correct prediction
N_p	-	Number of prediction
t_h	-	Handover threshold
S_C	-	Serving cell
T_C	-	Target cell
O_C	-	Cell offset

λ	-	Optimal forwarding probability

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Nowadays private and the public vehicles are used daily by many people. Citizens spend most of their time in vehicles aside being at home and office due to the longer trip between their destination place and because of the traffic congestion. Every year the total number of traffic on the road always increase [6]. According to [7], 30% of Malaysians spent hours driving to work, 23% of them spend more than an hour on the train, and 13% of Malaysian spent over an hour on the bus. Only 18% go to work by walking. Indeed, more time spends on the vehicle make the communication during commuting in much higher demand for the users. Most of them are wiling to pay more for seamless connectivity service while on the road [8].

Global mobile data traffic is growing tremendously over the past few years. This is because of the rise in the use of the smart electronics devices with having the connection to the internet capability such as smartphones, smartwatch, wireless printer, WiFi enabled camera and others around the world. Moreover, the emergence of new application such as online multimedia gaming, and social media network, required the internet connectivity to be present at any place, anytime, using any devices. The demand for seamless internet connectivity drives attempts to provide broadband mobile wireless communication even in a fast moving vehicle. With the support of wireless communication, Intelligent Transportation System (ITS) will play a major role in the vehicular communication system. ITS can manage the operation of vehicles, manage vehicle traffic, assist drivers with safety and other information and also provide convenience applications for passengers [9, 10, 11, 12, 13].

The fifth-generation (5G) communication system have emerge to satisfy the need for large wireless communication society, and provide unlimited access to information and data sharing for anywhere, anytime and for any devices. 5G network is the solution to overcome 4G issues such as spectrum crisis and energy consumption. 5G is reported able to achieve 1000 times system capacity, 20 times spectral efficiency, energy efficiency and data rate, and 25 times data throughput [14, 15, 16, 17, 18]. 5G expected to have 1000 times of throughput improvement over 4G, cell data rate up to 10 Gb/s, and signaling loads that less than 1 - 100%. 5G also likely reduced latency down to 2 - 5 ms end-to-end latencies [19]. Deployment of 5G technology provide seamless connection to the entire world and ubiquitous communication between people as well as devices anytime, anywhere. Hence, 5G is not aim to replace new technologies, but to enhance current technologies with new Radio Access Technologies (RAT) depending on the case and scenario [20, 21, 22, 23, 24, 25]. One of the solution to overcome the growth of wireless mobile devices is the deployment of small cells in dense heterogeneity network [22, 26, 27, 28].

However, it may not always be feasible to provide low-latency reliable communication between end users due to the nature of mobility. To achieve an ensuring system reliability and real-time performance, underlying technologies that are determined by handover performance must be in the first place. To provide Quality of Service (QoS) for mobile users, the handover is the main element in the wireless network [29]. In dense traffic areas, the massive load are generated by repetition message transmissions from several vehicles strongly challenges the 5G capacities. The installation of WiFi access points (AP) or Femto AP in residential and business environment have massively increased in 5G small cell network particularly in dense populated urban areas challenging handover management among vehicles [19, 30, 31]. AP dense deployment provides possible access for mobile devices in vehicles to connect to the internet. Some researchers have already explored various possible applications and performance for such access [32]. However, this approach may challenge several technical aspects. Each practice might need different hardware, software or even processing units. Some of them might need cooperative communications among the vehicles to assist data exchange. However, the vehicle may or may not receive the packets due to the time limit within access range and size of data transfer. A solution needs to be introduced to provide seamless and reliable communication among the vehicles, requiring shorter set-up times and delay, and reduced signaling overhead.

Most of the research proposed modify handover decision based on signal strength [33, 34, 35]. These parameter is useful to delay handover trigger until the user is close to AP's location. However, location prediction technique can assist handover decision by predict the next AP's location before user arrive at actual handover location. The handover location prediction can reduce handover process time compared to normal handover algorithm. Moreover, the handover decision making can change simultaneously depends on the user's mobility [36]. The aim of this technique is to reduce number of unnecessary handover by predicting best AP in advance. Prediction method also can reduce resource allocation time and reduce ping-pong effect. At the same time it will enhance handover performance in terms of network throughput.

1.2 Problem Statement

The deployment of small cell widely believed to be fundamental for improving capacity and quality of service (QoS) in future communication networks especially for outdoor and indoor environment [37]. The main challenge in small network is to provide handover management for mobile user especially travel in vehicle in order to provide good Quality of Service (QoS) and maintain the network connection throughout the journey .

The problem with conventional handover is that the procedure take many wireless and backbone signaling data exchange. It may required some time in order to complete a handover transaction between source AP to the next AP. Ineffective handover algorithm resulting call drop and leads to user's dissatisfaction. Thus, handover decision making criteria is introduced to decide next location to handover [29]. Handover decision always relies on signal strength of target cell to handover to next location. However, in densely small cell network, this may lead to the frequent and unnecessary handover. A ping-pong effect may happen when a call is handover to a next cell and handed back to the source cell which will result in waste of resources. Therefore, efficient handover algorithm is needed to ensure the user connection is maintain.

In dense populated network, signal strength received from each cell will always changing due to user's movement. Furthermore, the size of coverage area for small network is limited [38]. So, the vehicle has limited time to spend when it passes through overlapping region in small cell network. When the minimum handover process time is larger than the interval for the vehicle passing through the overlapping region, handover process fails to complete and resulting call drop. One of the ways to handle the problem is to predict next cell location in advance. However, the prediction handover will lead to too early handover if the user arrive too late at the handover decision optimal location at target cell. It will cause the connection link between the user and target cell drop. Besides, it also lead to less network throughput. Since the main goal of handover algorithm is to lower the probability of call dropping, there must be an optimal solution to ensure the user handover to next cell at right time and get higher network throughput while taking advantage of location prediction.

There are several techniques for location prediction throughout the literature [39, 40, 41, 42]. One of the techniques relies on user's mobility history to predict the next location in advance [5, 43]. Thus, the network required a lot of history information with more complex computational technique and more sophisticated parameter configuration [44, 45]. Since there are many small cells in one area, prediction technique that has complex computational technique involve many matrix multiplications is not practical to be implemented. Therefore, less complex prediction technique that able to provide high accuracy is needed.

As mentioned earlier, allowing prediction handover may lead to handover failure due too early handover. Therefore, in order to use prediction handover effectively, there is need for efficient solution which leverages the trade-off between achieving better network throughput and reducing signal overhead caused by unnecessary handover.

1.3 Research Objectives

The main goal of the research is to develop the handover algorithm that assigns requested resources depending on how fast vehicles pass by at one place at a time. The specific objective of the research are:

1. To develop prediction user movement based on user's location.
2. To develop a handover algorithm in small cell that can improve the handover performance in terms of ping-pong effect reduction and throughput increment.
3. To optimize the proposed handover algorithm to improve throughput while having low ping-pong effect.

In this thesis, the database of vehicle's trajectory is developed in order to predict next location of vehicle's movement. On the other hand, the handover prediction algorithm is developed to mitigate unnecessary handover. Optimization of the handover prediction algorithm aims to enhance the achievable network throughput with guaranteed QoS.

1.4 Research Scope

The scope of this research is mainly focused on the handover management in small cell network where user equipment (UE) is moving with connected mode mobility (there is traffic connection between the UE and the source AP). It is noted that the technical details and system procedures of handover in heterogeneous networks for 5G attribute system have a few fundamental differences with other systems. However, not much specification has been designed or released. As the main contributions of this research based on the frame structures, protocol, and measurement procedure, the system information and handover procedure are designed and analyzed on the basis of the LTE-Advanced (LTE-A) network which is the nearest technology to the 5G network. Thus, this procedure allowed the predictability and generality of this network architecture to be maintained. Since the research is focused on the handover management, any interference is neglected.

This research is applicable to users traveling in vehicles. The simulation considered scenario is in Universiti Teknologi Malaysia (UTM) Johor Bahru campus area where more than hundred residential APs are installed along the road. All APs apply an open access mode. Thus, UE can connect to all APs without any restriction. For open access mode, AP can serve all users either close subscriber group (CSG) or non-CSG user. This can be used in public places such as hotspot, malls, campus, airport and others [46]. All APs are attached to the residential building in UTM campus, which is why when UE move around the residential building, it will be connected to the APs.

This research assumed that all APs have enough bandwidth to serve the UE. The handover scenario used is inter-vehicle communication. Even though inter-vehicle communication includes vehicle-to-vehicle (V2V), vehicle-to-broadband cloud communication (V2B) and vehicle-to-roadside infrastructure communication (V2I) using roadside units (RSU), this research did not cover for V2V and V2B communication. Hence, UE is allowed to communicate with source and destination APs that are along the roadside.

The handover type is X2-handover where all the messages between the source and target AP are sent directly without involving the Mobility Management Entity (MME). All necessary information for handover process is exchanged via the X2 interface. Once a new connection between UE and target AP is established, the complete handover message is sent to MME. Intra-X2-based handover is usually used for handover between AP which is the interface between source and target AP is an X2 interface, and they must serve within same MME. The UE moves through space with different velocity, which is from 5 km/h and above. Besides, physical cell identity (PCI) collisions within two neighbor will not happen. Two cells with the same PCI that have same neighbor cell will not occur in this research. Therefore, the network could identify the specific AP based on the measurement sent by UE to the source AP. The handover only performed with adjacent APs even though the range area between source AP and destination AP is close. Performance evaluation for database is done in MATLAB. Then, the proposed handover algorithm is developed in Network simulator-3 (NS3). NS-3 is used to simulate the proposed handover algorithm based on LTE-A network. The simulation should reflect real access mechanism.

1.5 Research Contribution

The proposed handover management system is developed for ultra-dense small cell network. This system consists of mobility prediction technique and handover optimization algorithm. The following have been identified as the main original contributions to the knowledge in handover management in ultra dense small cell network:

1. Mobility pattern database

   The user's mobility data traffic is collected using global positioning system (GPS) information of the vehicle, speed, and direction around the UTM campus area. The focus was be on the graduate students, the postgraduate students and also the staff that resides, study or working in the UTM campus area. From the mobility history data, the process of data mining is required to get any valuable information for next step. With a lot of user's mobility data traffic information which cause of complex process of mobility prediction, it is worthy if the information in the database can be minimized. Mobility pattern database is introduced to overcome this issues by introducing three parameters in the user's mobility data traffic information. These data are the user ID, source access point ID, and destination access point ID. The user's mobility data traffic information is tabulated according to the most frequent location that user visits.

2. Provide seamless connection for vehicular user.

   Vehicular location prediction (VLP) is developed in order to predict the next location of the user in advance. The input of VLP is denoted from the user's mobility pattern database. VLP also manages to predict the user's movement until the user reaches their final destination. Due to reasonable amount of information of mobility pattern database, faster prediction can be performed leading to an enhanced prediction accuracy.

3. Velocities independent for vehicular user

   Due to the small coverage of small cell and speed of the vehicle, handover failure may occur. It is crucial to reduce the handover latency in order to gain seamless mobility connection. The proposed vehicular location prediction based on mobility pattern handover algorithm (VLP-HA) relies on the prediction results from the proposed VLP. VLP-HA choose the best access point for the user to reduce the handover latency and improve packet delivery ratio. VLP-HA also manages to trigger handover as fast as possible in order to minimize the unnecessary handover. Optimized vehicular location prediction handover algorithm (OVLP-HA) is capable of maintaining the handover even if the next access point is not the same as a prediction in case if user change its direction or new user enter the network. The optimized handover algorithm is modified by using optimal forwarding probability. This algorithm is capable to implement in LTE-A network where there are various density of small cell networks. Since there are wide variety of geographical topology and route condition, the velocities of the user is changing along the routes. Therefore, the velocities of mobile user is not considered in this research.

1.6 Significance of the Research

The proposed handover algorithm offers a solution to enhance the handover performance regarding the packet delivery ratio by reducing the number of handover and handover decision delay. The probability of the serving AP in choosing the best next AP is increased by predicting the next AP in advance, and finally reducing the number of unnecessary handover and ping-pong effect. Therefore, the goal of seamless and faster handover for mobile user can be achieved.

Furthermore, the proposed algorithm can be applied in the low to high populated network area. The algorithm is capable of supporting various density of small cells network with mobile users. LTE-A technology provides a very high data rate which can help the network provider to meet demand for higher bandwidth with low latency service that is exponentially more stronger than 3G. The proposed algorithm ensures user's QoS demand which includes a user with various velocities and various types application such as web browsing, online video streaming, Voice over Inter Protocol (VoIP), and others can be fulfilled.

1.7 Thesis Outline

The thesis elaborates on the development of mobility pattern database that uses prediction technique and optimized handover algorithm. Chapter 1 highlights the background of the research problem, statement of the problem and objectives of the research. It followed by research scope, contribution of the research, significance of the research and thesis outline.

Chapter 2 highlights the technology features of LTE-A system, which includes network architecture, mobility management, and the access control management. The issues in handover decision technique which include mobility prediction and optimization method are discussed, and the latest related approaches to solving the handover performance problems are presented and analyzed. Several loopholes are identified which become the driver for this research work.

Chapter 3 mainly focuses on the design framework of the proposed vehicular location prediction technique (VLP) and vehicular location prediction handover algorithm (VLP-HA). It also covers the basic design concept of optimization technique in OVLP-HA. The chapter elaborates the proposed concept as well as the overall process. Moreover, the network topology and simulation parameters that applied in this work is presented. Also, the performance metrics used to evaluate the research performance are discussed.

Chapter 4 presents the development of prediction technique and handover algorithm that is proposed in chapter 3. The chapter presents an analytical study of the accuracy of prediction technique and handover network performance for handover algorithm in a vehicular network. The simulation results for VLP-HA are analyzed and discussed as well. The performance of this algorithm is validated by comparing with another proposed handover algorithms. The handover performance metrics for this work are a number of unnecessary handovers, packet delivery ratio, and handover delay. The detail algorithm design for OVLP-HA also described in chapter 4. Formulation of optimal forwarding by incorporating ant colony optimization (ACO) is described, followed by handover algorithm description which includes the prediction and optimization. The performance of OVLP-HA is analyzed with comparison other handover algorithm based in literature.

Finally, Chapter 5 concludes the thesis with a summary of the research work, together with recommendations for future studies.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Small cells network is one of the solutions to overcome the growth of connected wireless mobile devices. Despite the benefits, deployment of access points increases rapidly in small cell network imposes challenging handover management in order to ensure the connection of mobile user. In addition, the reliability and real time performance in communication is highly demanded especially for the user in the moving vehicle. This work will focus on urban area since AP deployment in urban area have higher density compared to rural area. Hence, the experimental location is in UTM campus since it reflects the real urban area. In addition, the vehicular speed in campus area mostly around 35 - 60 km/h. Over the decades, many works have been proposed to tackle the mobility management issues which includes handover schemes and handover algorithms. This work is envisioned to explore the open issues and provide an efficient approach to solve the mobility management in the network.

This chapter provides literature review for this research. In Section 2.2, LTE-A features are discussed briefly. Small cell technology and network architecture also discussed in Section 2.3. Then, the handover management is described in detail consisting the types of handover, handover scheme and algorithms in Section 2.4. In Section 2.5, the related works for mobility prediction are described and predictor tool used in this research is discussed. Then, an enhancement for handover algorithm is discussed in Section 2.6. Finally, the summary for this chapter is highlighted in Section 2.7

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Appendix A VLP-HA Simulation Result

High Density Traffic

Figure B.1 demonstrate the result for a route from Cengal to K27 which is resident building in Kolej Tun Rahman (KTR). This simulation area consists 22 APs with the simulation time is 186 second. It shows from Figure B.1b that the data throughput is related with each of the handover. It seems that A2A4-HA has better data throughput transfer compared with the HBP-HA and VLP-HA. Although HBP-HA has considerable total of data throughput, it also has minimum data throughput from 80 seconds until 110 seconds. While VLP-HA has low data throughput each time the handover is triggered. Despite that, the number handover for VLP-HA far lower than the other two algorithms especially for A2A4-HA that was found has the highest number of handover.

Figure B.2 displays the result from source AP at CICT to destination AP at DSI. This simulation scenario has 27 APs with the simulation time of 218 seconds. Comparing Figure B.2b and Figure B.2c, even so, the data throughput for VLP-HA is the lowest, but the number of handover for A2A4-HA and HBP-HA algorithm are the highest that have caused high ping-pong effect. Data throughput for A2A4-HA is in line with HBP-HA. Beside that, the number of handover and ping-pong effect, A2A4-HA also has similar result with HBP-HA.

Figure B.3 gives the result of handover simulation for Meranti-Lab Tanaman Fertigasi UTM simulation area. This simulation area contains 18 APs which runs in 153 seconds. Data in Figure B.3b suggest that there is a relation between data throughput and number of handover. It appears that this simulation area has many APs with little simulation time that cause fast handover between the APs. As can be seen, the data throughput for HBP-HA from range 0 seconds has negative slope with minimum data throughput is at 20 seconds and the data throughput has positive slope until it reach maximum throughput at 40 seconds. It seem related with the location of APs that user go through which is at this point has very dense and close APs. HBP-HA probably have delayed handover triggered during this point. On contrary, A2A4-HA has nearly linear result, while VLP-HA has minimum data throughput each time handover triggered. Despite the data throughput of VLP-HA is fewer than other two algorithms, the ping-pong effect for this handover algorithm not occur and a number of handover barely than the other two algorithms. The result for number of handover and ping-pong effect is shows in Figure B.3c.

The result of the simulation from source AP at P16 to destination AP, KP which is residential building for students as indicated in Figure B.4. This simulation area consists 16 APs with the simulation time 257second. There is slightly changed for A2A4-HA as can be observed in Figure B.4b which is the data throughput is lowest at time 150 second, and data throughput for HBP-HA is lowest at time 160 second while data throughput for VLP-HA is lowest at time 200 second. It have much different handover time for lowest data throughput for VLP-HA compared to A2A4-HA and HBP-HA. It could be inferred that these may have reacted with AP location. VLP-HA predicted AP if the current AP signal strength is less than required and the user will stay with the serving AP until the signal is lower than requirement. As for A2A4-HA, the user always handover back and forth to the next cell which make use of excessive resources. This result is consistent with the evident in Figure B.4c which is number of handover for HBP-HA and A2A4-HA are much more than VLP-HA.

LIST OF PUBLICATIONS

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2. Hasbollah A.A., Ariffin S.H.S., Ghazali N.E. (2017) Optimal Forwarding Probability for Vehicular Location Prediction Handover Algorithm. In: Mohamed Ali M., Wahid H., Mohd Subha N., Sahlan S., Md. Yunus M., Wahap A. (eds) Modeling, Design and Simulation of Systems. AsiaSim 2017. Communications in Computer and Information Science, vol 752. Springer, Singapore
3. Arfah Ahmad Hasbollah, Sharifah Hafizah Syed Ariÿn, Nurzal Eÿyana Ghazali, Kamaludin Mohamad Yusof, Hiroaki Morino. "Handover Algorithm Based VLP Using Mobility Prediction Database for Vehicular Networks,". International Journal of Electrical and Computer Engineering (IJECE), 2018.(In Press)