แบบแผนการแฮนด์ออฟที่มีเวลาประวิงแฝงต่ำบนพื้นฐานของข่าวสารแสดงตำแหน่งโดยใช้ค่าเริ่มเปลี่ยนแบบพลวัตและปรับปรุงการสัญญาณประกาศสำหรับโครงข่ายไอพีเคลื่อนที่

นายมูฮัมหมัด เนอร์ ริซาล

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรตามปริญญาวิศวกรรมศาสตรมหาบัณฑิต
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A POSITIONAL INFORMATION BASED LOW LATENCY HANDOFF SCHEME USING A DYNAMIC THRESHOLD AND IMPROVING ADVERTISEMENT SIGNALING FOR MOBILE IP BASED NETWORK

Mr. Muhammad Nur Rizal

A Thesis submitted in Partial Fulfillment of the Requirements for the Degree

of Master of Engineering in Electrical Engineering

Department of Electrical Engineering

Faculty of Engineering

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มูฮัมหมัด นอ ริซัล : แบบแผนการแฮนด์ออฟต่ำด้วยจุดเริ่มเปลี่ยนปรับค่าได้ และปรับปรุงการให้สัญญาณประกาศบนพื้นฐานของข่าวสารตำแหน่งของโนดสำหรับพื้นฐานโครงข่าย Mobile IP (A POSITIONAL INFORMATION BASED LOW LATENCY HANDOFF SCHEME USING A DYNAMIC THRESHOLD AND IMPROVING ADVERTISEMENT SIGNALING FOR MOBILE IP BASED NETWORK) อ. ที่ปรึกษา: รองศาสตราจารย์ ดร.วาทิต เบญจพลกุล, 81 หน้า. ISBN 974-17-6257-7.

Mobile IP เป็นโพรโทคอลมาตรฐานการติดตามในอินเตอร์เน็ตที่เพิ่มสมรรถนะของโพรโทคอลอินเตอร์เน็ตที่มีอยู่เดิมให้สามารถรองรับสภาพเคลื่อนที่ของอุปกรณ์ปลายทางได้ เมื่อโนดเคลื่อนที่ได้เคลื่อนที่ออกจากเซลล์ปัจจุบันไปยังเซลล์ใหม่ ผลจากการที่โนดจะขาดการติดต่อ ทำให้เกิดการสูญหายของแพ็กเกต ด้วยเหตุนี้โนดจำเป็นต้องใช้กลไกที่เรียกว่า “การแฮนด์ออฟ” เพื่อให้การติดต่อสื่อสารสามารถดำเนินได้อย่างต่อเนื่อง ในที่นี้ เราจะกล่าวถึงการจำลองการใช้งานการแฮนด์ออฟในหลายวิธีการบนอุปกรณ์เข้าถึงไร้สายตามมาตรฐาน IEEE 802.11 ด้วยการใช้ Borland Delphi 7 สำหรับการจำลองโครงข่าย ในการวิเคราะห์สมรรถนะของแบบแผนการแฮนด์ออฟแบบ Mobile IP ดั้งเดิม, แบบแผนการแฮนด์ออฟด้วยการใช้ข่าวสารตำแหน่งของโนด และวิธีที่นำเสนอ จะวิเคราะห์จากปริมาณแพ็กเกตที่สูญหายและส่วนหัวของทราฟฟิก

ในวิธีการของ Mobile IP แบบดั้งเดิม การแฮนด์ออฟจะเกิดขึ้นเมื่อโนดได้รับข่าวสารประกาศจากเซลล์ใหม่ ซึ่งมีหมายเลขประจำโครงข่ายแตกต่างกันกับหมายเลขเดิม ซึ่งจะเกิดการสูญหายของแพ็กเกตมากเพราะว่าใช้เวลาในการแฮนด์ออฟนาน เราจึงได้นำแบบแผนการแฮนด์ออฟด้วยข่าวสารตำแหน่งของโนดที่มีระบบ GPS เพื่อกระตุ้นในการแฮนด์ออฟ ดังนั้นการแฮนด์ออฟจะเกิดขึ้นเมื่อโนดมีตำแหน่งเกินค่าเริ่มเปลี่ยนที่ได้กำหนดไว้ นอกจากนี้เรายังได้ศึกษาข้อเสียของวิธีทางตำแหน่ง เช่น กลไกการแฮนด์ออฟที่ไม่เป็นระเบียบและส่วนหัวของทราฟฟิก

ปัญหาของผลการแฮนด์ออฟที่ไม่เป็นระเบียบจากการตรึงการแฮนด์ออฟสามารถแก้ไขได้โดยการใช้กลไกการแฮนด์ออฟแบบพลวัตในวิธีการที่นำเสนอ จากวิธีการที่นำเสนอจะปรับปรุงข่าวสารการประกาศเพื่อที่จะใช้เวลาในการแฮนด์ออฟให้น้อยลง ส่วนหัวของทราฟฟิกในวิธีการที่นำเสนอสามารถแก้ไขให้มีส่วนหัวต่ำลงได้โดยการใช้ข่าวสาร T buffer ซึ่งจะสั่งการให้ตัวแทนต่างพื้นที่ (FA) สำรองแพ็กเกตในขณะที่โนดเคลื่อนที่ออกจาก FA ตัวเก่า

จากผลการจำลองแบบในวิธีการที่นำเสนอ พบว่าไม่มีการสูญหายของแพ็กเกต เมื่อ $T_{improving}$ ADV ใช้ความล่าช้าของข่ายเชื่อมโยงจากข่าวสาร NFA ต่ำสุดเมื่อเทียบกับความล่าช้าของข่ายเชื่อมโยงล่าสุด ในระหว่างการแฮนด์ออฟ วิธีการที่นำเสนอจะใช้ส่วนหัวทราฟฟิกและจำนวนการลงทะเบียนน้อยกว่าวิธีที่ได้กล่าวมาแล้ว สุดท้ายนี้ วิธีการที่นำเสนอยังใช้เวลาในการแฮนด์ออฟที่ต่ำกว่าวิธีอื่นๆ ที่กล่าวมาแล้วอีกด้วยและลดการสูญหายของแพ็กเกตได้มากกว่าวิธีอื่นๆ ที่ได้กล่าวมาแล้ว

ภาควิชา วิศวกรรมไฟฟ้า ลายมือชื่อนิสิต..........……………………..........................

สาขาวิชา วิศวกรรมไฟฟ้า ลายมือชื่ออาจารย์ที่ปรึกษา……......................................

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KEYWORD: MOBILE IP/POSITIONAL INFORMATION LOW LATENCY HANDOFF/DYNAMIC THRESHOLD/ADVERTISEMENT SIGNALING / BUFFER MESSAGE

MUHAMMAD NUR RIZAL, MR.: A POSITIONAL INFORMATION BASED LOW LATENCY HANDOFF SCHEME USING A DYNAMIC THRESHOLD AND IMPROVING ADVERTISEMENT SIGNALING FOR MOBILE IP BASED NETWORK /THESIS. ADVISOR: ASSOCIATE PROFESSOR WATIT BENJAPOLAKUL, D.ENG.

Mobile internet protocol (Mobile IP) is internet standard-tracking protocol that enhances the existing IP to accommodate mobility. When a mobile node (MN) moves out of current cell and moves into new cell, consequent lost connection causes many lost packets. A mechanism called handoff is needed to continue communication. We describe several handoff implementations based on the IEEE 802.11 standard on a Borland Delphi 7 for network simulation. Performance of the conventional Mobile IP handoff scheme, the positional information based handoff scheme and the proposed scheme are evaluated in terms of packet loss and traffic overhead.

In the conventional Mobile IP, handoff occurs when MN receives a new agent advertisement which contains different prefix network from previous one. This causes many lost packets because of high handoff latency. We also implement the positional information based handoff scheme using the position of MN equipped with a global positioning system (GPS) in order to trigger a handoff. The handoff occurs when MN's position exceeds a threshold. We, moreover study the disadvantage of the positional information based scheme such as unorganized handoff mechanism and traffic overhead.

The unorganized handoff resulted by fixed threshold can be solved by dynamic threshold handoff mechanism in the proposed method. The proposed scheme implements an improving advertisement message in order to lower handoff latency. The traffic overhead in proposed scheme can be lowered by using a T *buffer* message which commands a new FA to buffer packets while MN is moving out of previous FA.

From the simulation, we obtain low handoff latency and zero lost packets in the proposed method when $T_{improving}$ ADV implements the lowest link delay than the current link delay. During handoff, the proposed scheme occur less data forwarded and less number of shortened ADV message than those of the positional information handoff scheme. Finally, the proposed scheme achieves lower handoff latency and minimize packet loss than those of the positional information based handoff and the conventional Mobile IP scheme.

Department	Electrical Engineering	Student's signature………………..
Field of study	Electrical Engineering	Advisor's signature………………..
Academic year 2004		

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LIST OF ABBREVIATION

HA	Home Agent
FA	Foreign Agent
MH	Mobile Node
CoA	Care of Address
CCoA	Co-located Care of Address
IP	Internet Protocol
TCP	Transmission Control Protocol
IETF	Internet Engineering Task Force
QoS	Quality of Service
DHCP	Dynamic Host Control Protocol
CN	Correspondent Node
ICMP	Internet Control Message Protocol
MEP	Minimal Encapsulation Protocol
GRE	Generic Routing Encapsulation
BS	Base Station
ADV	Advertisement
LCS	Lazy Cell Switching
ECS	Eager Cell Switching
GPS	Global Positioning System
NFA	Neighbor Foreign Agent Message
REQ	Registration Request
REP	Registration Reply
TREG	Tentative Registration
R	Threshold
SADV	Shortening Advertisement
$\mathbf{t_0}$	Time to detect handoff
RtAdv	Router Advertisement
UDP	User Datagram Protocol
CBR	Constant Bit Rate
T_{buffer}	Time to buffer packet

CHAPTER 1

INTRODUCTION

1.1 LITERATURE RIVIEW

In today's networks, there is one layer in the protocol stack, which is becoming the most ubiquitous and obvious piece to allow voice, data, graphic and videoconferencing access to the users. That piece is the Internet Protocol of the TCP/IP protocol suite. Over the past few years, the explosive growth of internet and the increasing popularity of notebook computers, which are both portable and powerful, have been noticed. People want to work remotely from home and office almost everywhere. Workers must be able to log in to their companies' networks at any moment during the day, regardless of where they are working. Also consider how cellular phones have given people new freedom in carrying out their work.

There are still many isolated interconnected networks, which are not connected to the global internet but instead using the internet standard. Thus, the major strength is actually the seamless connectivity with devices in the neighborhood.

Consider to what we just discussed, the Internet Engineering Task Force (IETF) has proposed the mobile IP that is a mobility enabling protocol for the global Internet. Mobile IP is the best-known solution to solve the problem breaks under mobility of IP based network.

Mobile IP is internet standard-tracking protocol that enhances the existing IP to accommodate mobility [1]. Mobile IP in wireless network is intended to be a direct extension of the existing fixed network with uniform end-to-end QoS guarantees. Mobile IP is changing the way that everybody works. Anyone with access to the internet will be able to build a computing environment wherever one goes. In addition, seamless roaming and access to applications will make user more productive. Nowadays, IP networks are used not only for data, but also for real time applications such as voice over IP or video conferencing, etc. These applications become a critical issue in mobile networks. The Internet Engineering Task Force (IETF) has developed the mobile IP that is a mobility-enabling protocol for the global Internet [2].

The advantages of using mobile IP can be summarized as follows:

1. It continues low cost access to corporate networks in remote areas where there is no public telephone system and supports a wide range of application from internet access.
2. A user can take a laptop anywhere without losing the connection to the home network.

3. Mobile IP can move from one type of medium to another without losing connectivity. It is unique in its ability to accommodate heterogeneous mobility in addition to homogeneous mobility.

The basic mobile IP uses two different IP addresses that are a fixed home address and a care-of-address that changes every movement. Mobile IP requires two components i.e. the *home agent* (HA) and the *foreign agent* (FA). The mobile node (MN) is able to move across different networks while keeping the same IP address. The HA is placed on its home network, while the FA is placed on the network where MN is currently visiting.

In mobile IP, mobility agents such as HAs and FAs advertise their presence and services periodically by multicasting or broadcasting Agent Advertisement. MN constantly listens to this Agent Advertisement. MN can know whether it is on its home network or it is on a foreign network by examining the network prefix of the Agent Advertisement. If the MN is on its home network, it will act just like any other fixed node of that network and uses its fixed home address. When an MN is on a foreign network, it must obtain a Care-of-Address (CoA) or a Co-located Care-of-Address (CCoA). A CoA can be obtained by looking at the FAs Advertisement and a CCoA can be obtained directly from Dynamic Node Configuration Protocol (DHCP).

Once the MN moves to a foreign network, it must then register its new CoA/CCoA with its HA by sending mobile IP Registration Request to the HA. HA then responds to the MN with a Registration Reply. After these processes have been completed, the MN is ready to send or receive the information datagrams. If there exists corresponding node (CN) want to send packets, packets will be intercepted by HA and encapsulated in a new datagram contains the care-of address and are sent to the FA or to MN if it is moving in home network. Datagrams sent by MN on the FA need not to be returned to HA, but could be sent directly to the destination.

This procedure can be classified as three major component of mobile IP that are: agent discovery, registration, and tunneling.

Agent advertisement

The agent discovery procedure used in Mobile IP is based on the internet control message protocol (ICMP) that broadcast at regular interval once a second and in random fashion by HA and FA. There are two ways finding this agent, first is by selecting an agent from among those of periodically advertised. Second is by sending out a periodic solicitation until it receives a response from a mobility agent. MN uses these advertisements to determine their current point of attachment to the internet.

Registration

A MN registers whenever it detects that its point-of- attachment to the network has changed from one link to another. MN registers its CoA with HA in order to obtain service. After receiving advertisement (ADV), MN sends registration request, using the user datagram protocol (UDP) with the CoA information. This information is received by HA and if the request is approved, adds the necessary information to HA's routing table and sends a registration reply back to MN. Registration in Mobile IP must be made secure so it needs authentication in each process of HA, FA and MN. But, this research does not concern about how to obtain a secure authentication.

Tunneling

Tunneling is the method used to forward packets from HA to FA and finally to MN. It consists of encapsulation as entry point of tunneling and decapsulation as exit point of tunneling. When CN forwards packets, HA intercepts these packets and tunneling these by encapsulation algorithm that is taking a header in data packet that is done by encapsulation protocol such as *Minimal Encapsulation Protocol* (MEP) and the *Generic Routing Encapsulation* (GRE) protocol, while the decapsulation is the reverse process of encapsulation.

Although the basic mobile IP protocol proposes a simple and elegant mechanism to provide IP mobility support, there is a major drawback, where each packet destined to the mobile node must be routed through the home agent along an indirect path. This is known as the triangular routing problem. The mobile IP requires that the mobile node sends the location update to its home agent whenever it moves from one network to another, even though it does not communicate with other users. So, we should use this periodic updating connection by MN to HA in our proposed method as a trigger for handoff.

Another problem is that MN has to continue its connectivity to the network when MN migrates from one cell to another cell in case to change its access point in order to avoid packet loss. This phenomenon is called handoff.

Handoff

Handoff is defined as the change of radio channel used by MN. [3], the cause of handoff maybe poor radio quality due to a change in the environment or the movement of MN. In general, the handoff event is caused by the radio link degradation or is initiated by the system that rearranges radio channels in order to avoid congestion. Handoff can be classified into network controlled (hard handoff) and mobile controlled (soft handoff). In network controlled, the network invokes handoff when MN moves to edge of the cell boundary. The user will experience an interruption caused by frequency shifting. Hard handoff depends upon whether the new radio channel is with the same base station (BS) that is called intra-cell or with the new BS that is called inter-cell. Mobile-controlled handoff that is known soft handoff allows a MN to communicate with multiple BSs simultaneously. It has ability to select between the instantaneous received signals from different BSs.

The handoff procedure consists of initiation and registration period. The handoff initiation is how to obtain a method in order to initiate handoff at appropriate time in order to avoid losing connectivity to the network. The registration period is a time taken from MN requests registration until receiving registration reply from HA pass through FA in order to start receiving first packet. So, registration period is depending upon the time when MN receives advertisement (ADV) message once 1 second that is based on layer 3 (network layer).

The main problem of handoff in Mobile IP is packet loss and disruption time during handoff because handoff in network layer spends more time than traditional cellular network handoff. When Mobile Node (MN) moves out of previous Foreign Agent (pFA) transmission range causes pFA cannot send data to MN. In this term, we investigate that packets are dropped [4]. The disconnect period during handoff, called handoff latency represents the period of time that is measured between the time when last packet from previous FA is received to that when the first packet from new FA is received. Handoff latency depends upon how long MN obtains ADV message until registration process is complete. Many solutions have been proposed to deal with the packet loss and to shorten handoff latency.

Existing Handoff Scheme

In general, handoff method is based on layer 3 as ADV message’s platform. Well-known algorithms for handoff detection and triggering that managed at layer 3 are Lazy Cell Switching (LCS) and Eager Cell Switching (ECS) [5].

The first algorithm, LCS, is based on the lifetime of the advertisement sent by the network. The mobile node monitors any advertisements, records the lifetime and updates the expiration time when a new advertisement is received from the network. When the advertisement lifetime of the current foreign agent expires, the mobile node assumes that it has lost connectivity and attempts to execute a new registration with the new foreign agent. Although the mobile node might already be informed about the availability of a new foreign agent, the mobile node defers switching until the advertisement lifetime of the old foreign agent is expired. The latency for handoff detection incurred by the LCS algorithm corresponds directly with the lifetime of the advertisement that is a multiple of the advertisement interval. The advertisement lifetime is typically set to three times of the interval

The second algorithm, ECS, makes use of the network prefixes carried by the advertisement. If the mobile node detects an advertisement with a different network prefixes than the current network, the mobile node assumes that a handoff has happened and registers with the new foreign agent. The ECS algorithm reduces the service interruption, but when the mobile node receives an advertisement does not necessary mean that the link to the current foreign agent is broken so that MN should keep its connectivity to current FA but, in this case the mobile node registers with a new one. In these cases, an unnecessary handoff is triggered.

These take into account that, the rate of advertisement is rather slow when using the LCS algorithm. For the ECS algorithm, there might be no improvement and inherits disadvantage. In this simulation, researcher uses ECS method but in case of non-overlapping cell area.

An alternative to layer 3 handoff triggers is layer 2 triggers. These layer 2 triggers reduce the time to detect handoff.

Layer 2 Handoff and the problem

Low Latency handoff has proposed by IETF [6]. It uses the link layer (L2) to initiate handoff in order to shorten handoff latency and to prevent packet loss. With the facilities of link layer information such as signal strength and its fast-transmitted rate, allows a mobile node to detect the connectivity more quickly than a network layer (L3) in advertisement based algorithm. Link layer contains the information such as the new FA's IP address identifier or the previous FA's IP address identifier. L2 handoff is classified into two methods: Pre-Registration handoff and Post-Registration handoff [6]. Both methods use link layer to operate handoff

In pre-registration method, MN can request registration to new FA while still being connected to previous FA. And in post registration method, MN can use bidirectional edge tunnel (BET) that is established by handoff request and reply respectively between previous and new FA to receive forwarded packets destined to new FA before performing a formal Mobile Internet protocol (MIP) registration.

The Link layer could be a trigger handoff if there is an overlapping cell area between previous and new FA. In the real situation, there exists cell‘s coverage area not overlapped each other that cause the link layer can not trigger a handoff well. In order to solve this problem, the research provides other handoff method to support low handoff latency in both overlapping and especially in non-overlapping area that is a positional information handoff method.

Positional Information Handoff Scheme

Currently, most works concerning wireless network have been done without using positional information. But as GPS receivers become cheap, provider embedded them into cell phones, base stations and other wireless access devices. In addition to supporting uninterrupted network services, the mobile node needs to perform smooth handoff with possible packet losses [7]. Utilizing positional information can provide position specific services that are more attractive to users. A GPS-enabled application can then provide more precise and valuable services in response to present place and time [8]. Now, new mobile phone has GPS receiver in Japan. In the United States, E911 initiatives require that the wireless phone providers develop a way to locate any phone. In the near future, almost all mobile computers and Personal Data Assistants (PDAs) use positional information for services.

The positional information handoff method has four main functions as follow [9]:

1. It supports Discovering Neighbor FA Mechanism [10] in order that every FA knows its neighbor FA’s position and IP address. In this case, this method can notify handoff to only one FA as targeting handoff
2. It supports Forwarding Copies Packets Mechanism sends to new FA While current or previous FA detects MN’s position exceeds a threshold
3. After detecting MN’s position exceeds a threshold, Current FA sends a message to new FA to shorten its ADV interval time in order that MN can register earlier
4. New FA sends a tentative registration contains information as same as registration reply to MN after receiving registration request message from MN. By using this message MN can receive first forwarded packet.

By using this positional information handoff method, we assume that handoff can work well in both overlapping and non-overlapping cell area which could not support by layer 2. But, it has drawback when we investigate deeply from its function. First drawback is a fixed threshold problem which causes disorganized handoff.

There are two types of disorganized handoff. First, handoff is detected many times instead of processing and completing handoff itself. Second, MN loses connection to previous FA in case that FA has not yet detected handoff because MN while moves fast does not have opportunity to report its position while exceeds a threshold to FA thus, the handoff detection fail.

Second drawback is the disadvantage and complexity of $T_{shorten}$ ADV message. When FA detects MN's position exceed a threshold thus FA sends a message to new FA in order to shorten its interval ADV message period. It causes ADV broadcast more frequent. The number of $T_{shorten}$ ADV messages depend upon the time from MN's position while exceeds a threshold until MN receives first shorten ADV message in new FA. Longer time taken, more frequent shortened ADV sent causes increasing overhead. Other problem is the complexity to change back from $T_{shorten}$ ADV to $T_{default}$ ADV. Moreover many MNs are involved in this handoff process. The changing back to $T_{default}$ ADV happen when MN sends a neighbor FA (NFA) message to new FA as a sign that the handoff process is complete.

Third drawback is unnecessary traffic overhead emerges caused by the packet forwarding mechanism which is started when MN's position exceeds a threshold and stopped until MN receives a tentative registration message in new FA.

Our work motivates to evaluate the system performance of the positional information handoff scheme in order to achieve low latency handoff and minimize packet loss. For this objective, we propose a solution to avoid all those problem of disorganized handoff, $T_{shorten}$ complexity, and unnecessary forwarding packet overhead. Our proposed method is as follows:

1. A dynamic threshold that is defined from the multiplication between MN's velocity and ADV period rate
2. Improving ADV message which orders new FA to broadcast ADV at a moment when MN reaches new FA's boundary
3. Performance packet buffering message in order to avoid unnecessary overhead

This thesis is organized as follows. In Chapter 2 we describe the basic background of standard mobile IPv4 and the positional information handoff scheme with the problem are. Chapter 3 describes the proposed method. Chapter 4 explains the simulation model of the conventional

Mobile IP, the positional information handoff and the proposed method in Borland Delphi 7 for network simulation. The performance comparison between the conventional Mobile IP, the positional information handoff and the proposed method in terms of handoff latency, the number of lost packets, and traffic overhead are interpreted in Chapter 5. Finally, chapter 6 concludes and recommends our work.

1.2 SCOPE

1. The proposed method works only in handoff mechanism area in order to achieve low latency handoff and minimize packet loss without increasing traffic overhead
2. The research works in handoff mechanism is based on layer 3 using standardized of Mobile IP signaling
3. The research does not concern in determining MN's position because it is assumed that MN has GPS which embedded in its system.

1.3 MANIPULATION

1. Apply only one MN into the whole system and investigate the packet loss, handoff latency and traffic overhead in the conventional Mobile IP, the positional information handoff and the proposed method.
2. Increasing the velocity of MN and investigating the number of lost packets, handoff latency and traffic overhead in all those methods
3. Investigating the number of lost packet, handoff latency and traffic overhead performance as a functions of various paramaters such as MN's velocity, the distance between two neighbor FAs, $T_{shorten}$ ADV period, random link delay, and the position of MN while receives ADV message in all those method above
4. Implementing multiple mobile nodes in the simulation research in order to observe handoff latency, the number of lost packet, and the traffic overhead performance in all those methods

1.4 GOAL

1. To improve handoff performance of the positional information handoff by using a dynamic threshold in order to solve the disorganized handoff
2. To achieve zero handoff latency by using an improving advertisement message in order that MN can receive ADV immediately from new FA

3. To minimize traffic overhead during handoff by sending T_{buffer} message to new FA in order to lower the traffic overhead. T_{buffer} is measured when MN moves out of previous FA to the time when MN receives tentative registration in new FA's area. The proposed method purposes to avoid unnecessary overhead as a consequence of the forwarding packet mechanism moreover the number of MN is increased

1.5 EXPECTED BENEFIT

1. It solve the L2 handoff problem whereas L2 signal cannot trigger handoff in non-overlapping area
2. To study the original mobile IP and the positional information handoff method and their performance evaluation by using Borland Delphi 7 for network simulation.
3. The proposed method is expected to enhance the system performance and guarantee low latency handoff and packet loss during the ongoing communication

CHAPTER 2

MOBILE IP OVERVIEW

This chapter will provide the overview of mobile IPv4 in the section 2.1 and the positional information handoff method will describe in section 2.2.

2.1 MOBILE IP OVERVIEW

Mobile IP is an Internet standards-track protocol that enhances the existing IP to accommodate mobility. Mobile IP comes without changing the network infrastructure of the existing IP based network but it introduces the following new functional entities [1].

Mobile Node (MN): A host or router that changes its point of attachment from one network to another without changing its permanent address.

Correspondent Node (CN): A host that sends packets data to destination via home agent.

Home Agent (HA): A router on a mobile node’s home network that delivers datagram to the mobile node.

Foreign Agent (FA): A router on a mobile node’s visited network (foreign network) that cooperates with the HA to complete the delivery of datagram to the MN while it’s away from home.

The mobile IPv4 architecture, as proposed by IETF, is show in Figure 1.

The solution proposed by IETF suggests that the MN should use two different IP addresses: a permanent home address and a care of address (CoA) that changes at each point of attachment. This solution requires when the MN moves from one network or sub-network to another, it must register its CoA to the HA on its home network. Hence, the IETF proposes the following new messages for maintaining the service.

Advertisement message: A special message broadcasts from the FA to advertise its available service with which contains the CoA. The content of advertisement message can be shown in table 1.

Registration request: A message sending by the MN to the HA to inform about its CoA for handoff processing.

Registration reply: A message responses to the MN indicating that the registration has been accepted by HA.

Table 1 the content of Agent Advertisement [5]

IP Header
IP source : Agent's Address
IP destination : Broadcast
IP protocol : Internet Control Message Protocol (ICMP)
Agent Advertisement
I'm an : FA number(x), HA number (y)
FA's care of address

MN can know whether it is on its home network or it is on a foreign network by examining the contents of the agent advertisement shown in Table 1. If the MN is on its home network it will act just like any other fixed node of that network and uses its fixed home address. But when an MN is on a foreign network, it must obtain a Care-of-Address (CoA).

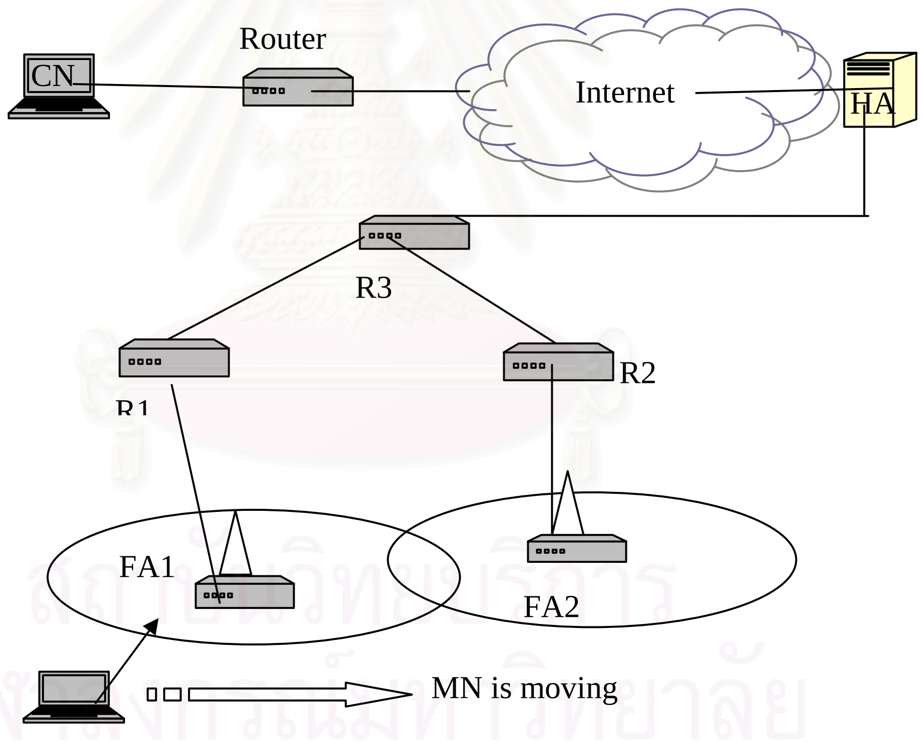

Figure 1. Mobile IP architecture

The mobile IP protocol works as follows [1]:

- Mobility Agents (HA or FA) advertise their presence and service by sending agent advertisement messages. An MN may optionally solicit an agent advertisement.

- After receiving an agent advertisement, an MN determines whether it is on its home network or a foreign network. An MN is on its home network, acts like any other fixed node.
- When an MN moves away from its home network, it obtains a CoA on the foreign network. Then, the MN registers its new CoA with the HA using a Registration Request and receiving the Registration Reply.
- Datagrams sent to the MN's permanent address are intercepted by its HA. They are encapsulated in a new datagram that contains the CoA and are sent to the FA, and finally the FA delivered them to the MN.
- In the reverse direction, datagrams sent by the MN directly to the destination.

Once the MN moves to a foreign network, it must then register its new CoA/CCoA with its HA by sending mobile IP Registration Request to the HA. HA then responds to the MN with a Registration Reply as shown in Figure 2. After these processes have been completed, the MN is ready to send or receive the information datagrams as shown in Figure 3.

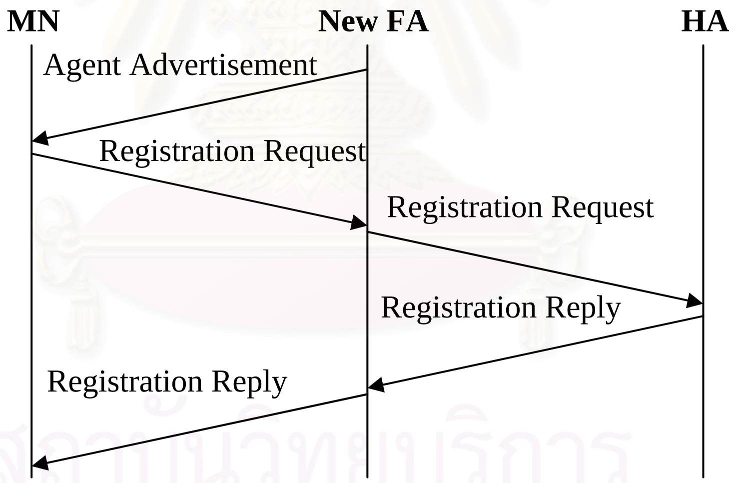

Figure 2. Mobile IP registration process

Figure 3 illustrates the routing of datagrams to and from a mobile node when it is away from home network, once the mobile node has registered with its home agent.

In Figure 3, a CN sends the datagrams to a MN along the direction 1 and a mobile node sends the datagrams to the correspondent node along the direction 2.

Mobile IP has disadvantages as follows:

- Handoff may be slow, because the mobile node must register its new CoA to the home agent. This may takes long time to process handoff especially the HA is far away.
- The signaling overhead may be significant, because the mobile node always sends the messages to its HA to report about its new care-of-address even though there is no communication. In order to effective this periodic signal, this research inserts a MN's position into the datagram header in order to trigger a handoff.

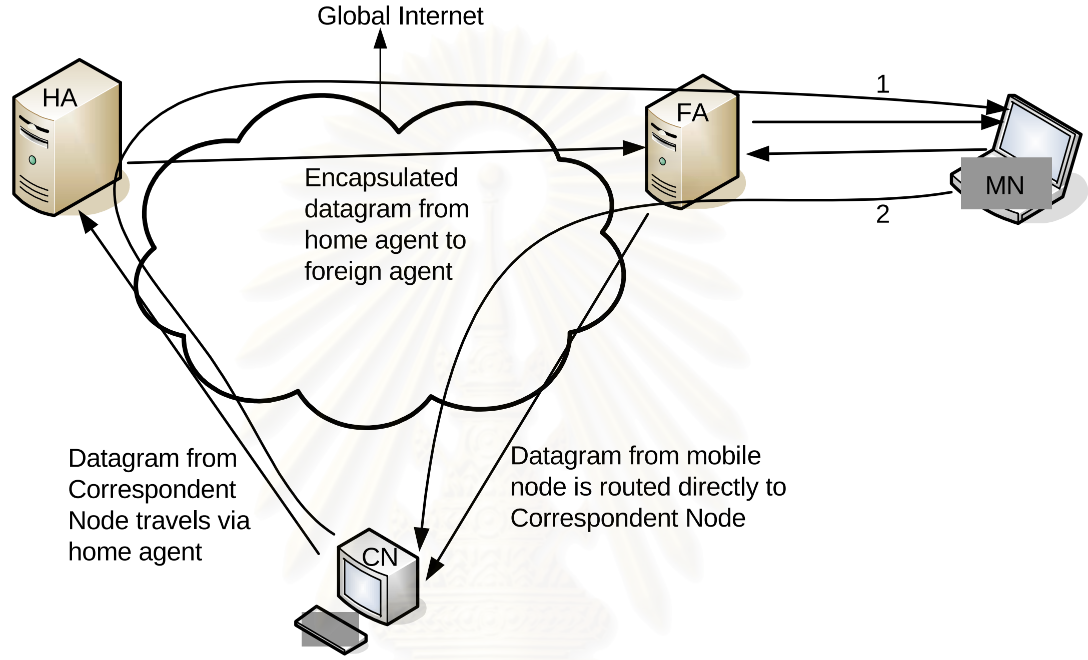

Figure 3. Mobile IP registration flow

From these problems, one of this research's works has proposed a positional information handoff method that is described in section 2.2 in order to lower the handoff latency.

2.2. OVERVIEW OF THE POSITIONAL INFORMATION HANDOFF METHOD

The concept of this method is first MN and FA can know its positional information by using a device such as GPS [8]. Every one second as ADV message interval period, MN besides report its connection to the network also announces its position to FA. Second, handoff detection is obtained when MN's position which reported to FA in ADV response exceeds a threshold. A threshold (R) is a fixed distance that is measured from FA to reach inner area's boundary of FA. It means that FA separates its transmission range into inner and outer area as shown in Figure 4.

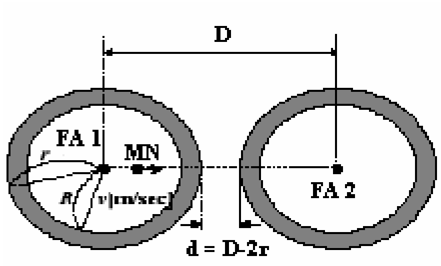

Figure 4. Inner and outer transmission range area [9]

In order to realize low handoff latency without increasing overhead in wired channel, the research tries to provide a handoff scheme using positional information for Mobile IP based networks. In the proposed scheme, FAs exchange IP addresses and positional information [10]. When a distance between FA and MN exceeds a threshold, FA copies packets and forwards them only to new FA. Moreover, in order for MN to receive first advertisement (ADV) message earlier, the transmission interval of ADV message is shortened in new FA. By shortening transmission interval of ADV message, MN can receive forwarded packets earlier. In addition, when new FA receives registration request (REQ) message from MN, FA replies tentative registration (TREG) message to MN. Adding tentative registration, MN can begin receiving forwarded packets without waiting for receiving registration reply (REP) message from home agent (HA).

The positional information handoff has additional functions such as Neighboring FA Discovery, Handoff Detection and Forwarding Packets, Shortening Advertisement Message Interval, and Tentative Registration.

2.2.1. DISCOVERING NEIGHBOR FA MECHANISM

In this scheme, every FA has a table containing the neighboring FA's IP address and position. Figure 5 shows the update of the table, MN which has completed its registration to new FA sends neighboring FA registration (NFA) message to previous FA via the new FA by the following procedure:

1. When MN receives registration reply message in the coverage area of new FA, MN sends NFA message to previous FA via new FA.
2. When new FA receives the NFA messages, adds its own address and position to the NFA and forwards it to previous FA.
3. When previous FA receives the NFA from new FA, previous FA registers the address and position of new FA to its neighboring FA table.

As shown above, each FA learns IP address and position of all neighboring FAs.

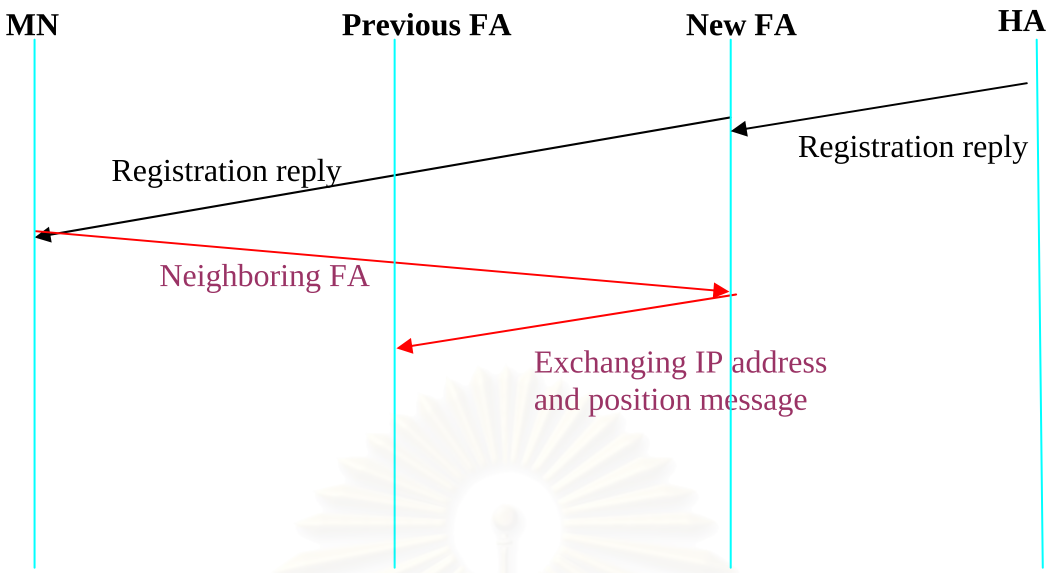

Figure 5. Discovering Neighbor FA Message

2.2.2. HANDOFF DETECTION AND FORWARDING PACKET

In this scheme, each FA can know the distance between FA and MN from MN's reporting. We set the handoff detection in fixed threshold *R* in meter. When the distance between MN and FA exceeds handoff detection threshold *R*, FA looks up the neighboring FA table copies and forwards packets to the nearest or new FA as shown in Figure 6. When FA receives the forwarded packet, if the MN is already registered to FA tentatively, FA forwards the packet to MN. In addition to the packet forwarding, conventional packet is also transmitted to MN in wireless channel. Since until completing MN's tentative registration to new FA, the forwarded packets are dropped by FA, no packets are transmitted to wireless channel. Since this scheme can specify the new FA, it can alleviate increasing overhead in wired channel.

2.2.3. SHORTENING ADVERTISEMENT MESSAGE INTERVAL

In this method, in order for MN to receive first advertisement (ADV) message from new FA earlier, ADV message interval of new FA is shortened by previous FA during handoff period. When previous FA detects a handoff, previous FA sends shorten ADV (SADV) message to new FA as shown in Figure 6. When new FA receives SADV message, the transmitting interval of ADV message is shortened from default value T_{adv} to $T_{shorten\ adv}$. When new FA receives NFA message and recognizes that the handoff is completed, the transmitting interval is brought back to the default value T_{adv}. By shortening ADV message interval, MN can receive forwarded packets from previous FA earlier.

Figure 6 shows the signaling message at the time that MN's position triggers a handoff and previous FA prepares copy and forward packets to new FA.

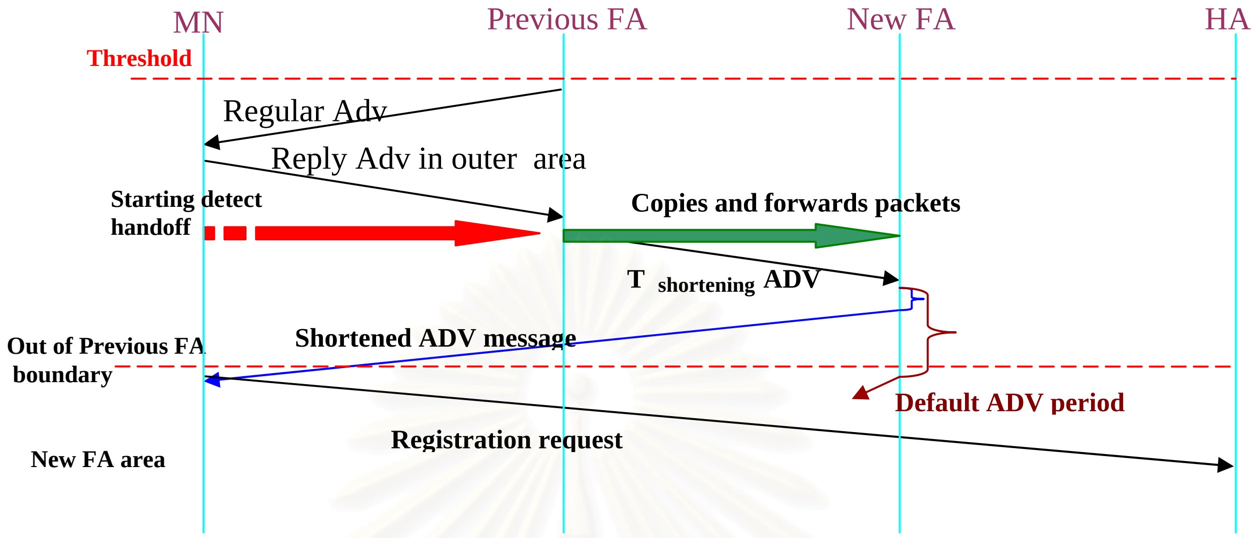

Figure 6. signaling time of the forwarding packet and shortening ADV message

2.2.4. TENTATIVE REGISTRATION

In order that MN can receive the forwarded packet before registration to the new FA is completed, tentative registration function of MN by new FA is added. When new FA receives registration request (REQ) message by MN, in addition that the FA forwards the REQ message to HA, the FA sends tentative registration message to the MN as shown in Figure 7. TADV response message has the same information as registration reply message. However, by setting the lifetime of the registration to be shorter than registration reply message, MN can receive the forwarded packet without waiting for the arrival of the registration reply message.

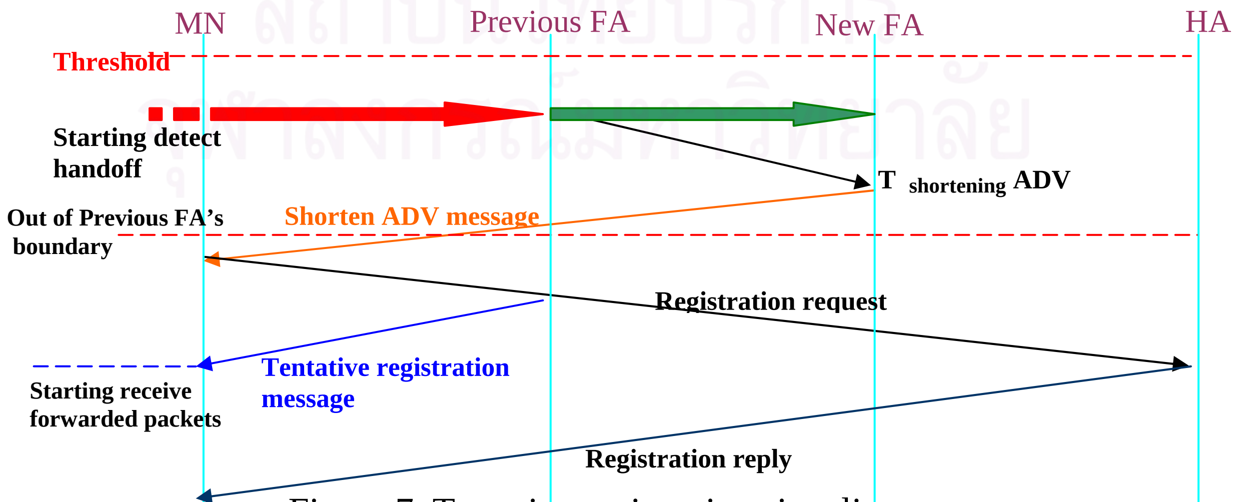

Figure 7. Tentative registration signaling message

2.3. THE DRAWBACK OF POSITIONAL INFORMATION HANDOFF SCHEME

Here, this report will describe the drawback of the positional information handoff scheme when it is implemented with the conventional Mobile IP registration. The problem which is occurred is disorganized handoff as a consequence of fixed threshold and unnecessary overhead caused by T $_{shorten}$ ADV and packet forwarding mechanism. The section 2.3.1 will show the drawback of disorganized handoff. Section 2.3.2 describes the drawback of T $_{shorten}$ ADV message, and the drawback of packet forwarding mechanism will outline in the section 2.3.3.

2.3.1 THE DRAWBACK OF DISORGANIZED HANDOFF

There are two types of disorganized handoff that is first, FA detects handoff many times instead of completing handoff. This happen when MN with slow velocity of 5 m/s moves along 20 meters as a fixed threshold range will occur four times of reporting MN's position instead of processing handoff as shown in Figure 8. Other problem of disorganized handoff is MN loses connection to previous FA before detecting handoff. This happen because MN moves with velocity of 35 m/s does not have opportunity to report its position while exceeds a threshold then after waiting for next ADV message, but MN has already moved out of FA, thus the handoff is failed as shown in Figure 9.

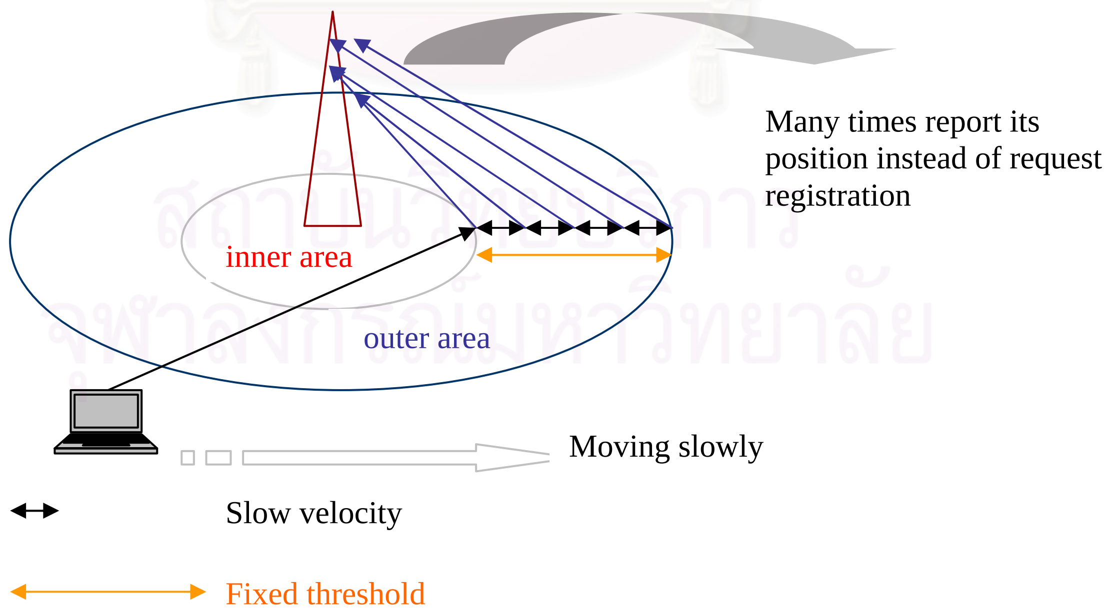

Figure 8 Reporting MN's position many times instead of process registration

2.3.2 THE DRAWBACK OF T $_{shorten}$ ADV MESSAGE

After detecting handoff, previous FA will sends notification to new FA to shorten its ADV period. The problem is happen as follows.

When MN has not yet moved in new FA, but T $_{shorten}$ ADV are broadcast frequently which causes unnecessary overhead.

1. Handoff latency will longer because when MN moves in new FA area, but MN has not yet received T $_{shorten}$ ADV
2. Complexity to change back from T $_{shorten}$ ADV to T $_{default}$ ADV message moreover if the number of MNs is increased

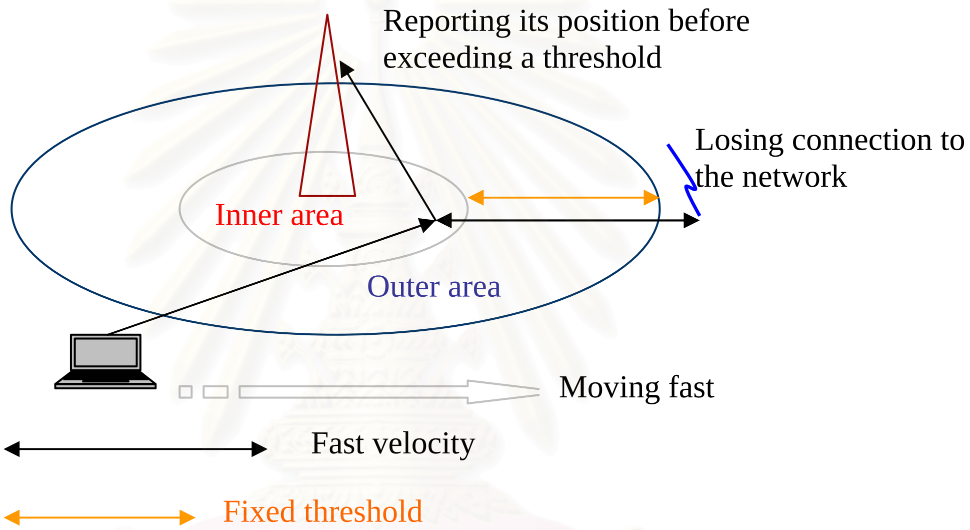

Figure 9. Losing connection to FA when MN moves very fast

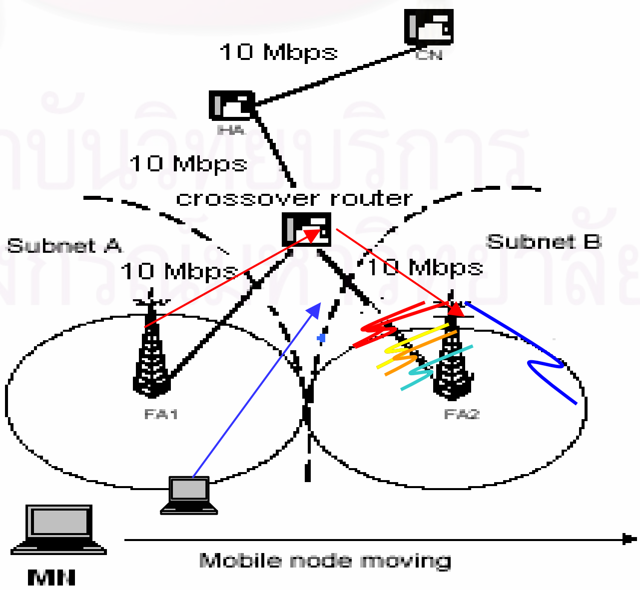

Figure 10. Frequent broadcasting of Shorten ADV message

2.3.3 THE DRAWBACK OF FORWARDING PACKET MECHANISM

The forwarding packet mechanism is begun when MN's position exceeds a threshold and stops when MN receives tentative registration in new FA. But, it causes unnecessary traffic overhead caused by many shortened ADVs broadcast during handoff. Longer time taken from MN's position to the new FA's area, higher traffic overhead happen caused by packet forwarding mechanism. Moreover, the number of MNs to request handoff is excessive as shown in Figure 11.

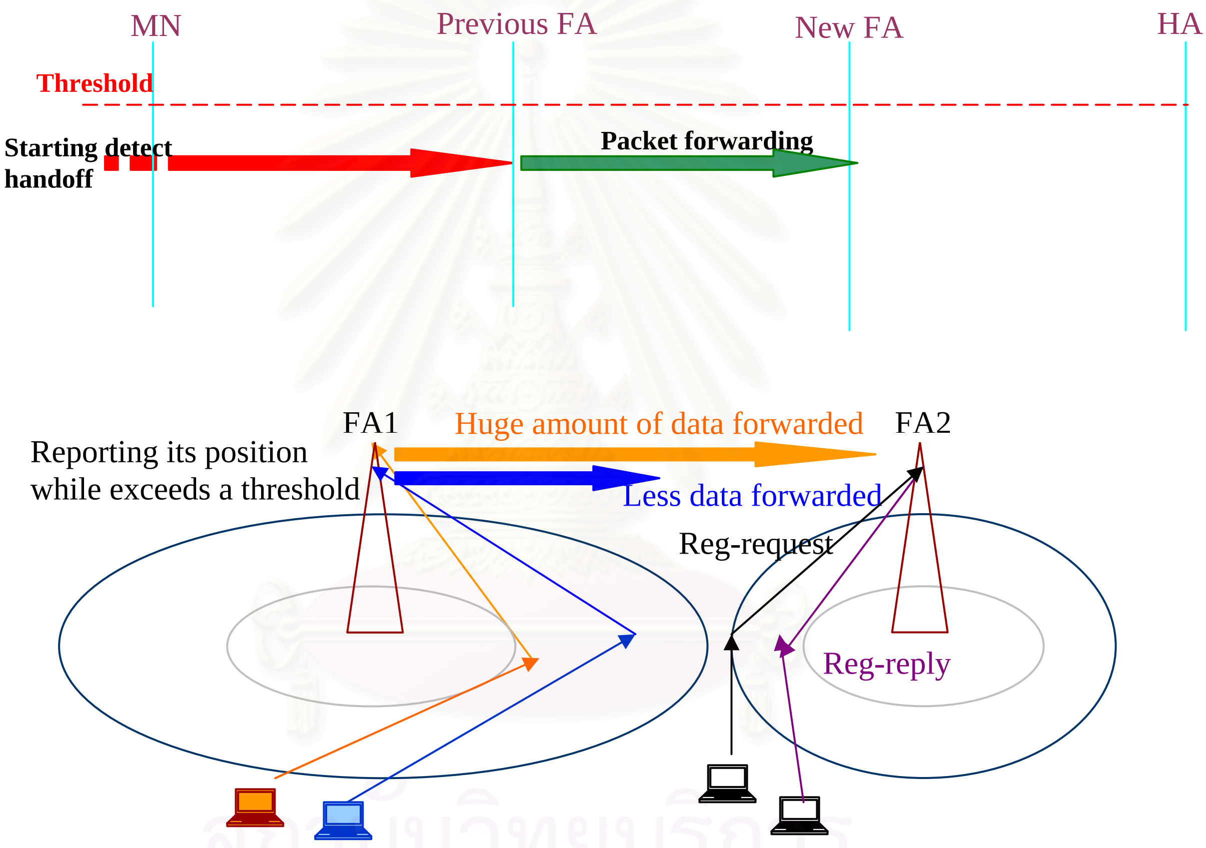

Figure 11. Different of the overhead of packets forwarded

CHAPTER 3

THE PROPOSED METHOD

Handoff procedure period contains movement detection period and registration period. Movement detection period is the movement detection latency starting from MN breaks from the previous FA until it receives new FA's agent advertisement. Registration period depends on link delay on the path between HA and requested FA. It is hard to predict exactly how long it takes for movement.

In the proposed scheme, in order to achieve short movement detection, the most important things are first, FA must know the position of MN while still in its transmission range to detect handoff with appropriate time and second, FA supports mechanism to discover the appropriate new FA for handoff. The problem of registration period which takes long delay has been solved by adding function known as tentative registration as described in the positional information handoff method. By using tentative registration, MN can receive the forwarded packets before the formal registration from HA is completed.

In order to support handoff detection based on the MN's positional information, FA separates its transmission range into inner and outer area. The border between the inner and the outer area can act as a threshold for handoff detection. Previous FA will notify new FA to process handoff if MN's position exceeds the threshold from ADV response of MN every 1 second.

This chapter will outline our proposed solution that motivates to enhance the system performance of Positional Information Handoff Scheme as described in the Chapter 2. In the section 3.1, we explain our proposed method to solve the drawback of fixed threshold by introducing a new idea that is called a dynamic threshold. In section 3.2, we explain our proposed method to cope with the problem of $T_{shorten}$ ADV message and finally in section 3.3 we enhance the system performance of the forwarding packet mechanism by replacing to be Packet Buffer Mechanism.

3.1. DYNAMIC THRESHOLD

Dynamic threshold is a method to determine the threshold range that is based on the movement and velocity of MN. It means that the range will be changed according to MN's velocity. As shown in Figure 12, this dynamic threshold can settle the problem of the disorganized handoff such as reporting MN's position many times instead of completing handoff's process and losing connection.

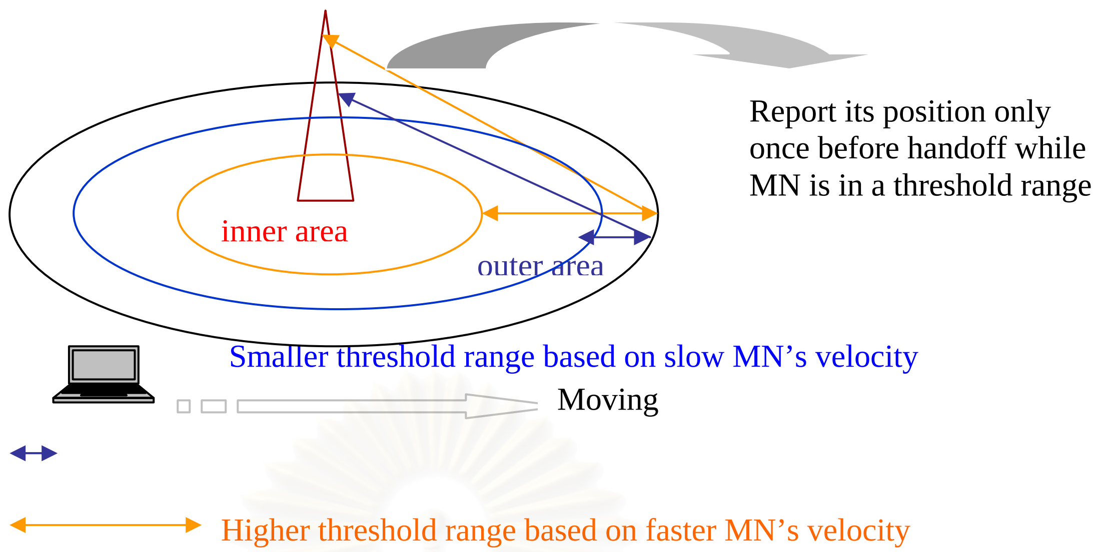

Figure 12. Dynamic threshold range mechanism

From Figure 12, we find that the size of dynamic threshold is obtained by this equation as follows: $D_{dynamicTH} = T_{ADV} * MN's^{*} Velocity$ (1)

It can avoid loss connection while MN's velocity is very fast and also avoid huge amount of registration attempts signaling while MN's velocity is very slow. For example, while MN within velocity of 10 m/s will have a threshold for handoff detection is 10 m/s * 1 s as standardized ADV period that is obtained of 10 meters. But, when MN's velocity is 7 m/s will calculate a threshold range of the multiplication between 7 m/s and 1 s that is 7 meters. So, it can avoid the disorganized handoff as a consequence of MN's movement.

For clearly proposed, it assumes that the diameter of FA's transmission range is 400 meters and the distance between two neighbor FA's is 0 ms. There exists a MN with velocity of 5 m/s is moving straight toward new FA. Then we calculate the threshold is 5 meters before reaching new FA's boundary from the multiplication between MN's velocity and ADV period. It means that when FA knows MN's position is at 394 meters from ADV response indicating that MN has not yet exceeded a threshold causes MN has to wait next ADV. For next ADV, MN then reports its position at 399 meters indicating MN exceeds a threshold then the handoff is triggered. From this case, we know that the dynamic threshold can solve the problem of disorganized handoff.

3.2. IMPROVING ADVERTISEMENT MESSAGE

In order to minimize packet loss, after handoff detection, the FA in [9] sends a T-shorten ADV message to new FA which contains a command to shorten the new FA's transmitting ADV period. But this method has drawback as described in section 2.3.2.

The objective of improving advertisement signaling is to achieve low handoff latency without broadcasting many shortened ADVs means that ADV message must be broadcast at a moment after MN reaches new FA's boundary. To achieve this objective, FA learns the characteristic of link delay between two neighbor FAs from the information header of NFA message. Second, when previous FA detects MN's position exceeds a threshold then, previous FA sends T $_{improving}$ ADV that is

$$T_{improving}\ ADV = [(D_{MN's\ position\ -\ new's\ FA's\ boundary} / MN's\ velocity) + (D_{pFA-nFA} / MN's\ velocity) - T_{delay\ pFA-nFA}] \quad (2),$$

T $_{improving}$ ADV signaling message is shown in Figure 13. With this scheme, the proposed method assumes that it can achieve low handoff latency which causes minimize number of lost packets.

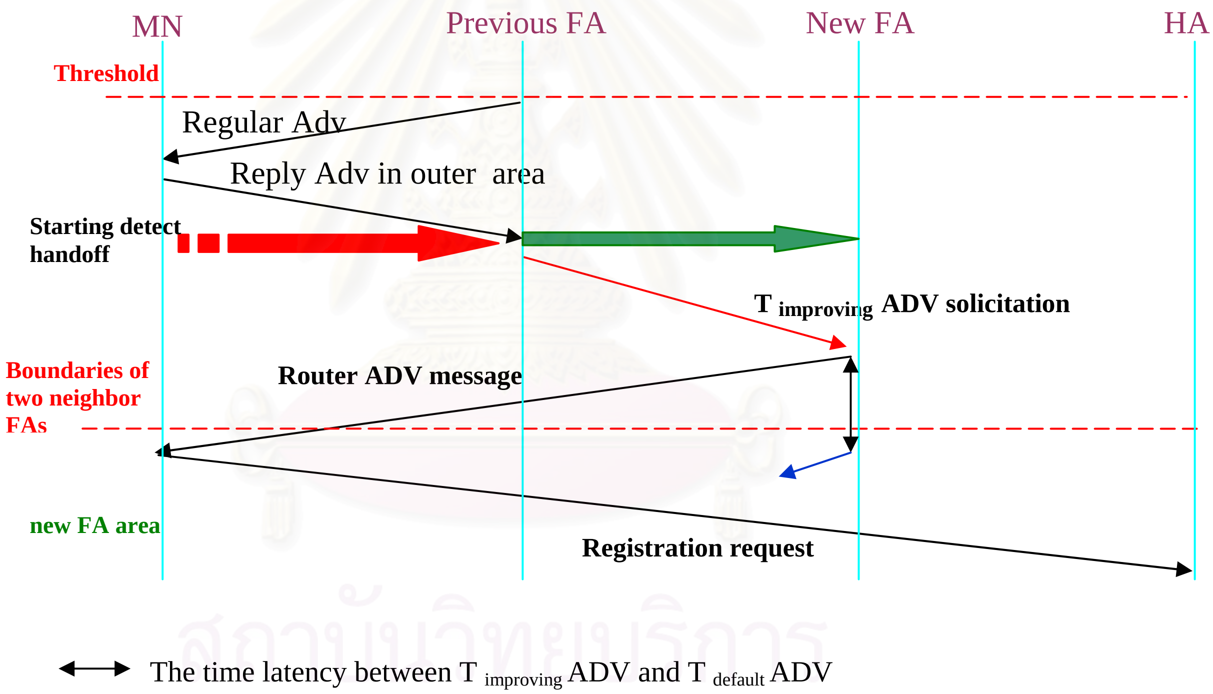

Figure 13. T improving ADV solicitation signaling

3.3. PERFORMANCE PACKET BUFFERING

In the proposed method shown in Figure 14 shows that in order to obtain minimized packet loss, the packet buffering at new FA is still needed moreover the distance between two neighbor FAs is high. The packet is still lost while the forwarded packet arrives at new FA when MN has not yet received tentative registration causes MN cannot receive packets. So, it needs a packet buffering. The proposed method implements packet buffering work at the time when MN moves out of FA, while in the positional information handoff method the packets are buffered when MN's position exceeds a threshold. It shows that the performance of packet buffering in the proposed method causes less forwarded packets than those of the positional information handoff method.

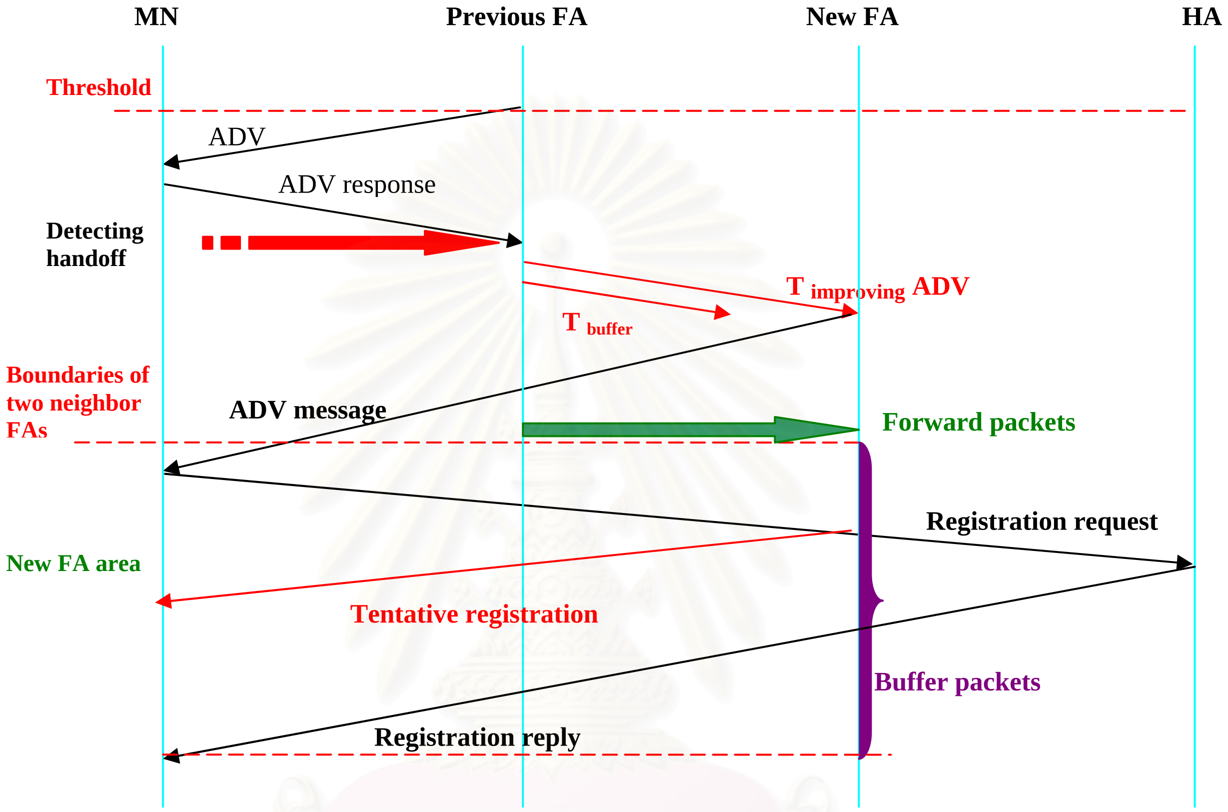

Figure 14. Time signaling of $T_{\text{packet buffering}}$

The packet buffering can be analyzed by the following procedure.

Assuming that:

$\mathbf{t_0}$ is the time to detect handoff and **T** indicates that every T (ms) packet arrives at HA

$\mathbf{t^k}$ **HFA** is the time that the $\mathbf{k^{th}}$ packet arrives at HA, so $\mathbf{t^k}$ **HFA** = $\mathbf{t^1}$ **HFA + (k-1)T**

$\mathbf{t^k}$ **pFA** is the time that the $\mathbf{k^{th}}$ packet arrives at previous FA (pFA)

$\mathbf{t^k}$ **nFA** is the time that the $\mathbf{k^{th}}$ packet arrives at new FA (nFA)

$\mathbf{t_{registration}}$ is the moment while registration request arrives at HA

$\mathbf{t_{LD}}$ is the moment while MN loses connection to pFA and start to moves to nFA coverage area

$\mathbf{t_{tent}}$**ADV** is the time that MN receives tentative registration from new FA

1. If the $\mathbf{t^k}$ **HFA** < $\mathbf{t_{registration}}$, the $\mathbf{k^{th}}$ packet is forwarded to the previous FA which has three possibilities as described below.

a. $\mathbf{t^{k}\ HFA < t_{0} + t_{LD}}$**,** shows that the $\mathbf{k^{th}}$ packet is forwarded to MN via current or previous FA

b. $\mathbf{t_{0} + t_{LD} < t^{k}\ oFA < t_{0} + t_{tent}\ ADV}$**,** shows that the $\mathbf{k^{th}}$ packet is lost so it needs buffering at new FA

c. $\mathbf{t^{k}\ pFA \geq t_{0} + t_{tent}\ ADV}$**,** shows that the $\mathbf{k^{th}}$ packet has been already copied and forwarded to MN via previous FA

2. If $\mathbf{t^{k}\ HFA} > \mathbf{t_{registration}}$**,** the $\mathbf{k^{th}}$ packet is forwarded via new FA

This analyzed model according to packet buffering should be concerned in order to avoid packet loss by using efficient packet buffering size in order to support real time application services as shown in Figure 14.

CHAPTER 4

THE SIMULATION MODEL

In this chapter, this research describes the simulation of the conventional Mobile IP handoff, the positional information handoff and the proposed method scheme in the Borland Delphi 7 for network simulation. In the section 4.1, we describe the overview of the handoff algorithm. In the section 4.2, we describe the simulation of the conventional Mobile IP handoff. In the section 4.3, we describe the simulation of the positional information handoff. Finally in the section 4.4, we depict the simulation of the proposed method scheme.

4.1 HANDOFF ALGORITHM

In the simulation of Conventional Mobile IP, a handoff is completely managed at layer 3. This implementation requires that: every FA broadcasts Router Advertisement (RtAdv) every 1 second. The MN captures Router Advertisements and makes a decision when to handoff to an nFA. Well-known algorithms for handoff detection and triggering that managed at layer 3 are Lazy Cell Switching (LCS) and Eager Cell Switching (ECS) [5]. The first algorithm, LCS, is based on the lifetime of the advertisement sent by the network. The mobile node monitors any advertisements, records the lifetime and updates the expiration time when a new advertisement is received from the network. When the advertisement lifetime of the current foreign agent expires, the mobile node assumes that it has lost connectivity and attempts to execute a new registration with the new foreign agent. Although the mobile node might already be informed about the availability of a new foreign agent, the mobile node defers switching until the advertisement lifetime of the old foreign agent is expired. The second algorithm, ECS, makes use of the network identification carried by the advertisement. If the mobile node detects an advertisement with a different network identifier than the current network, the mobile node assumes that a handoff has happened and registers with the new foreign agent.

The latency for handoff detection incurred by the LCS algorithm corresponds directly with the lifetime of the advertisement that is a multiple of the advertisement interval. The advertisement lifetime is typically set to three times of the interval [5]. The ECS algorithm reduces the service interruption, but when the mobile node receives an advertisement does not necessary mean that the link to the current foreign agent is broken. Thought the current foreign agent is reachable, the mobile node registers with a new one. In these cases, an unnecessary handoff is triggered.

These take into account that, the rate of advertisement is rather slow when using the LCS algorithm. For the ECS algorithm, there might be no improvement and inherits disadvantage.

4.2. SIMULATION MODEL OF THE CONVENTIONAL MOBILE IP HANDOFF SCHEME

The handoff process of the conventional Mobile IP has been specified [2][5]. In this simulation, we assume as the folowwing:

- Every cell has one base station within its equity like antenna and wireless device (802.11) that is reffer to be an foreign agent (FA).
- Every FA will broadcast router advertisement message once every 1 second in random time.
- MN uses the same channel and frequency with foreign agent thus MN can communicate with both FA in case of handoff
- Packets data using UDP and MN starts to receive first packet from FA after registration process is complete
- MN detects handoff when it identifies the network prefixe of new ADV message received is different from old one.

When MN moves in FA and receives ADV message, MN will send request registration message which contains the care of address of foreign agent to HA via its new FA. HA will revise the message and if the message is authenticated, HA updates its map table contains IP addresses and positions of all FAs. Then HA sends back registration reply to MN in new FA area. If the registration process is successful then packets sent by correspondent node (CN) for MN will be tunneled from HA to new FA. When MN receives registration reply from HA, MN starts to receive first packet.

Every 1 second ADV is broadcast by FA in order to check whether the connection of MN to FA still established. Then MN checks the header of ADV and responds back by sending a message to FA in order to report its connection.

The implementation of the conventional mobile IP handoff scheme is shown in the timing diagram in Figure 15. The events during the handoff are the following:

1. Router ADV message is broadcast once every 1 second
2. While MN moves in FA receiving ADV message, MN sends request registration to HA via its current FA
3. HA will authenticate the registration request and sends back registration reply message destined to MN in new FA area

4. After receiving registration reply, MN starts to receive tunneled packets from HA to MN via current FA. Then packets pass through to MN periodically.
5. While MN moves out of FA causes packets loss
6. Then MN moves in new FA, MN has to wait ADV message from new FA is broadcast.
7. At the time ADV broadcast destined to MN, MN requests registration to HA via new FA. HA will sends back registration reply message to MN.

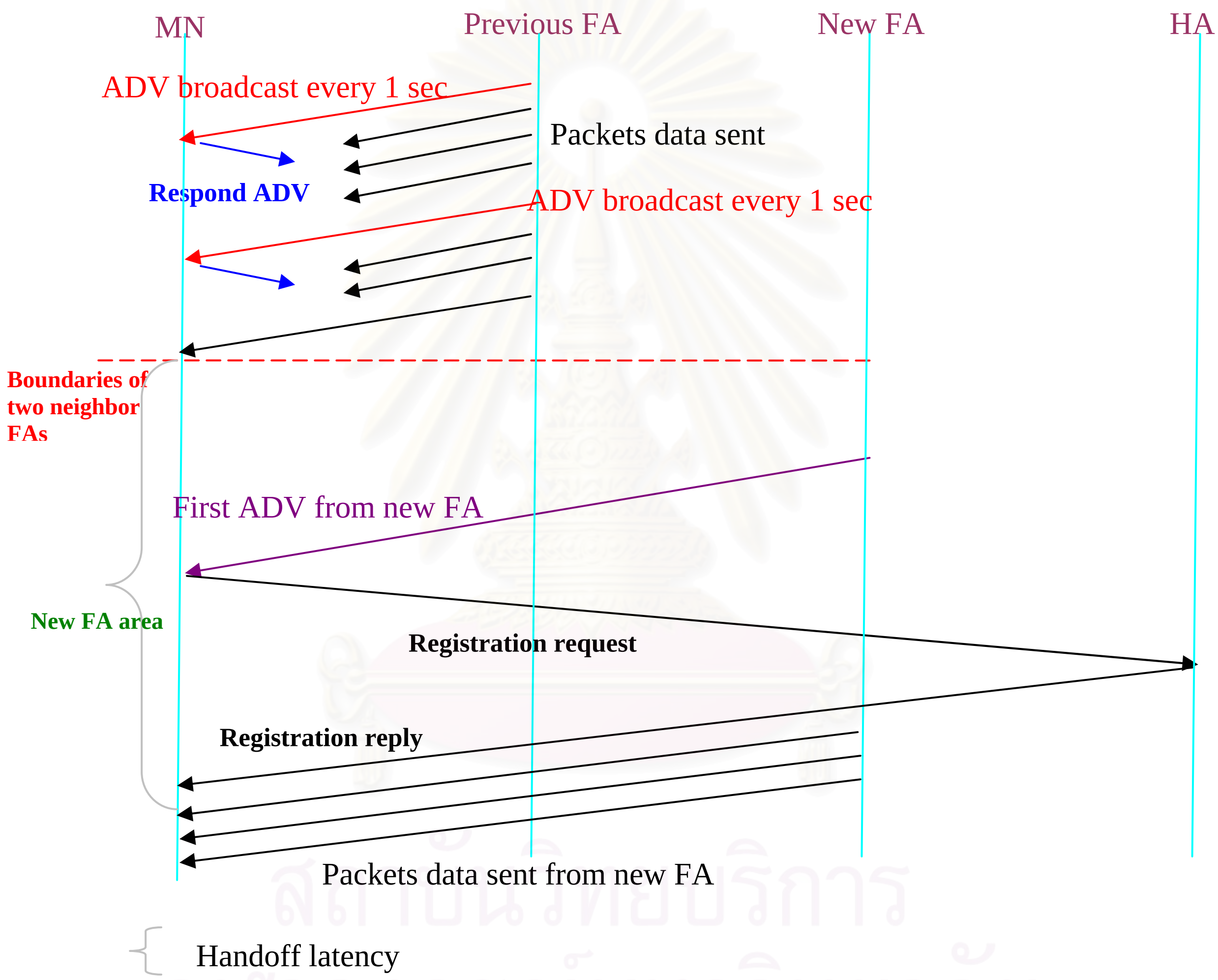

Figure 15. Handoff Process in Conventional Mobile IP Method

Figure 15 shows that the registration period takes a long delay depends on the link delay of the signal's journey from MN to HA. By obtaining registration reply, MN can start receiving first tunneled packet via new FA. A time from MN loses connection from previous FA until receiving first packet from new FA while registration reply received by is called handoff latency. During this handoff latency, packets will be lost. Longer handoff latency causes many lost packets.

4.3. SIMULATION MODEL OF THE POSITIONAL INFORMATION HANDOFF SCHEME

It implements low latency handoff scheme based on the positional information handoff using GPS receiver which embedded in cellular phone or laptop as mobile node which also uses wireless LAN 802.11 [8],[11]. It is assumed that in one coverage area, there are two FAs with IEEE 802.11 wireless devices and one mobile node equipped with IEEE 802.11 wireless device for ongoing communication.

Handoff is triggered by using layer 3 that is sent once every 1 second. Handoff is detected while position of MN exceeds a fixed threshold. MN can start to process handoff while being still in previous FA. This scheme results handoff latency low. In order to minimize lost packets, FA copies and forwards packets to new FA besides the original packet sent in wireless network.

In order to start receive packets earlier in new FA's area. First, shorten ADV period at new FA in order to register earlier. Second, New FA sends a tentative registration to MN message in order that MN unnecessary to wait registration reply, so MN can start to receive forwarded packets earlier. This scheme makes handoff latency lower. The tentative registration contains information as same as registration reply.

This method also supports a discovering neighbor FA mechanism in order to forward copied packet to only one FA as a target handoff by exchanging a neighbor FA (NFA) message between two neighbor FAs which contains IP address and position of FA [9].

This simulation model is shown in Figure 16. The events during the handoff are as follows:

1. Previous FA detects position of MN exceeds a threshold from ADV response, then previous FA sends a message to command new FA to broadcast $T_{shorten}$ ADV
2. At the same time, previous FA copies packets sent from CN and forwards to new FA
3. When MN already moved in new FA which receives $T_{shorten}$ ADV, MN can register earlier to HA pass through new FA
4. New FA will send tentative registration to MN in order to receive first copied packet from new FA besides new FA still proceed the registration request to HA
5. After registration is completed, MN sends neighbor FA (NFA) message to new FA to inform its and previous FA's position and IP address. Then, new FA inserts into its position and IP address to NFA message and sends to previous FA in order to learn FA's IP address and position by each other.
6.

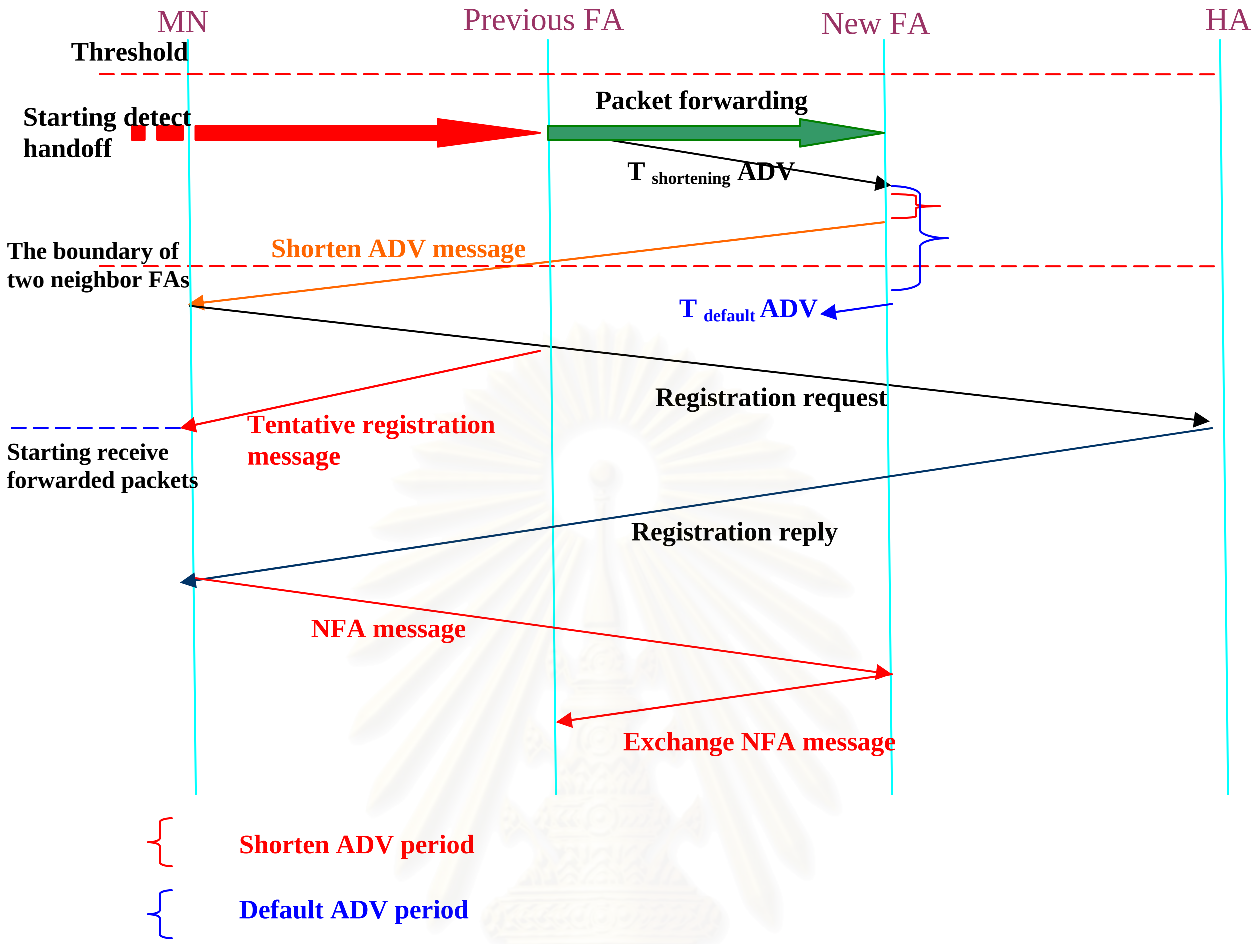

Figure 16. Signaling Time of the Positional Information Handoff Method

4.4. SIMULATION MODEL OF THE PROPOSED METHOD

The idea of the proposed method simulation is to improve the performance of the positional information method in terms of number of lost packets, handoff latency, and traffic overhead caused by forwarding packet mechanism and $T_{shorten}$ ADV message. The objective of the proposed method is how to obtain minimize packet loss and low handoff latency without increasing traffic overhead in both overlapping and non-overlapping cell area. The result of proposed method can be compared to the conventional mobile IP and the positional information handoff method.

To reduce overhead such as a huge amount of forwarded packets and many shortened ADVs broadcast, the proposed method implements a dynamic threshold scheme, $T_{improving}$ ADV message, and T_{buffer} message.

First scheme is implementing a dynamic threshold range that is determined based on the multiplication between MN’s velocity and ADV period time. This scheme plans to solve the disorganized handoff caused by MN's movement. It can avoid losing connection problem before detecting handoff and unnecessary reporting MN's position during handoff process.

When previous FA detects a handoff means that MN's position exceeds a dynamic threshold, then FA sends a $T_{improving}$ ADV message in order that MN can receive first ADV from new FA immediately when MN reaches new FA's boundary. With this scheme, MN can register earlier. $T_{improving\ ADV}$ is the time waiting for new FA in order to broadcast ADV. $T_{improving\ ADV}$ is obtained from this calculation as follows.

[$T_{MN's\ position\ while\ exceeded\ a\ threshold\ -\ FA's\ boundary} + T_{distance\ between\ two\ FAs} - T_{delay\ between\ two\ FAs}$].

The T_{delay} is obtained from the header of Neighbor FA (NFA) message sent to previous FA from new FA. In the header contains a time stamp which informs time delay between two neighbor FAs.

In order to reduce traffic overhead caused by forwarding packet mechanism, the proposed method implements a scheme which commands previous FA to send a T_{buffer} message to new FA. This message orders new FA to buffer the forwarded packet starting from MN while moves out of previous FA until registration process of MN in new FA is complete. We assume that the proposed method can reduce overload in wired network.

From Figure 17 we explain the events as follows:

1. Previous FA detects position of MN exceeds a threshold from ADV response, then previous FA sends a message to command new FA to broadcast $T_{improving}$ ADV at the same time MN reaches new FA's boundary
2. At the same time, previous FA sends a command message to new FA in order to buffer copied packets from previous FA at the time while MN loses connection from previous FA's boundary until receive tentative registration from new FA
3. While MN receives ADV message at the time MN reaches new FA's boundary, MN can register earlier to HA
4. New FA passes through the registration request to HA besides send tentative registration to MN in order to receive first buffered packet.

After registration is complete, MN sends a neighbor FA (NFA) message to new FA informs the position and IP address previous FA. Then, new FA exchanges NFA message to previous FA by inserting its position and IP address. Now, each FA can learn their position and IP address each other in order to support discovering neighbor FA mechanism

The events of time signaling during a handoff can be shown in Figure 17.

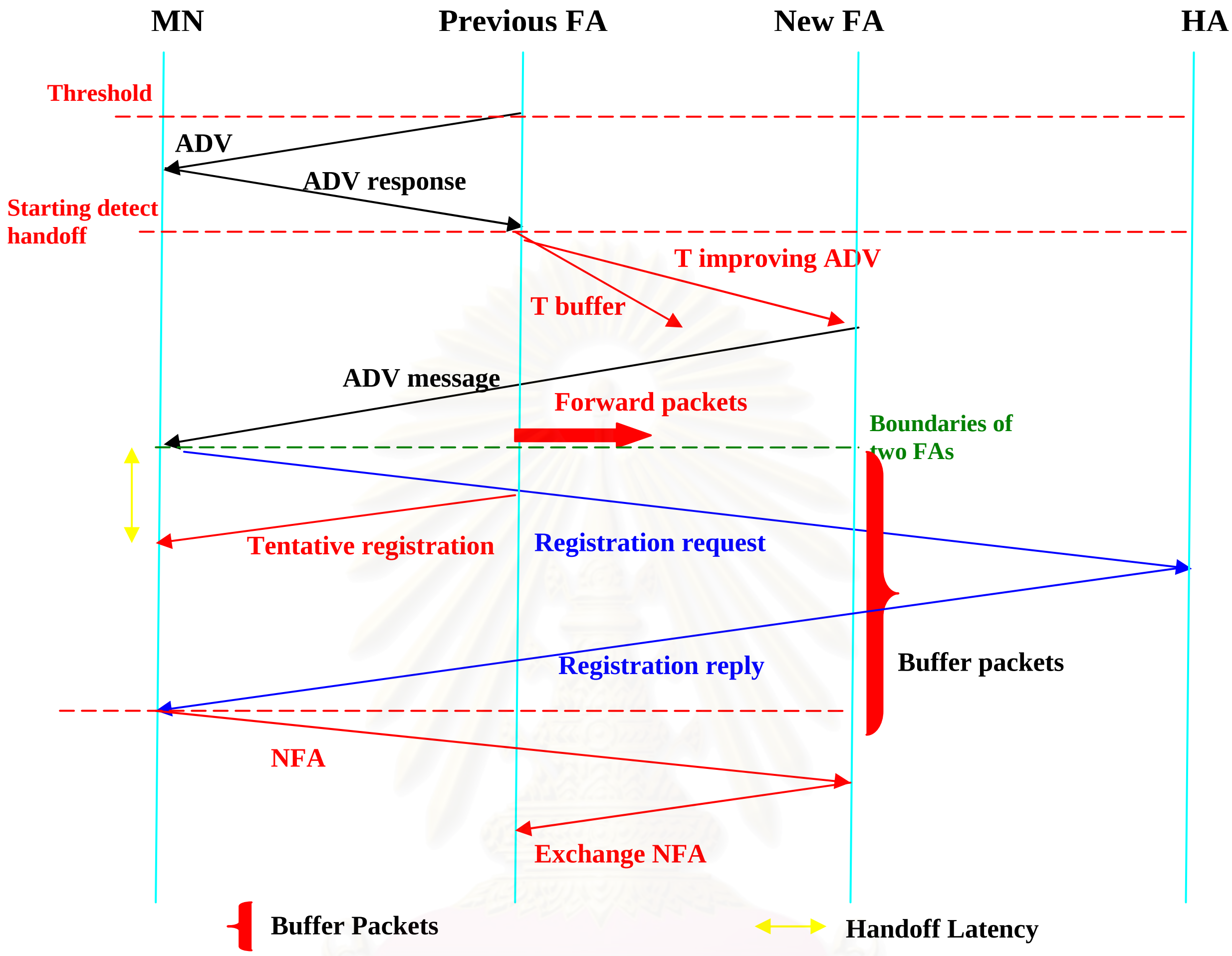

Figure 17. Time signaling of the proposed method

The proposed method also provides analytical model in terms of handoff latency that is according to packet loss, overhead of the number of shorten ADVs broadcast, and the amount of forwarded packets. This analytical scheme also implemented in simulation model run by Borland Delphi 7 for network simulation. The analytical models are described in section 4.4.1, 4.4.2, 4.4.3.

4.4.1 HANDOFF LATENCY

In MN, assuming that positional information is updated every T_{pos} MN, FA can get new positional information every $T_{pos}FA = T_{ADV} * T_{pos}MN / T_{ADV}$ When MN receives ADV message while its position exceed a threshold, FA can detect a handoff. Therefore, the probability p that FA detects a handoff is derived as the following [9].

$$P = \frac{R-r}{vT_{posFA}} if \rightarrow T_{posFA} \geq \frac{r-R}{v}$$
$$P = 1, else \qquad \textbf{(1)}$$

When previous FA detects a handoff, previous FA sends SADV message to new FA, and new FA shortens its transmission interval of ADV message to be T $_{shorten}$ ADV. If previous FA does not detect a handoff, previous FA cannot send Shorten ADV message to new FA. In this case, the ADV message transmission interval of new FA is still T ADV. The period from that MN goes out from the transmission range of previous FA until that MN enters the new FA's transmission range is T1 = D − 2r/v. The period T2 that from that MN enters new FA's transmission range until MN receives first ADV message is the following. In Mobile IP, the interval of transmitting ADV message is always T ADV, and hence, [9]

$$T_2 = \frac{1}{T_{ADV}} \int_0^{TADV} t dt \equiv \frac{t^2}{2} \Big|_0^{TADV} * \frac{1}{T_{ADV}} \equiv \frac{T_{ADV}}{2} \qquad \textbf{(2)}$$

In the proposed scheme, when previous FA detects a handoff, the interval of transmitting ADV message is shortened to be T $_{shorten}$ ADV, therefore, [9]

$$T_2 \equiv \frac{T_{shortADV}}{2} p \oplus \frac{T_{ADV}}{2}(1-p) \qquad (3)$$

When MN receives ADV message, MN responds registration request (REQ) message to new FA. In Mobile IP, when new FA receives REQ message, new FA forwards REQ message to HA. The forwarded REQ message arrives at HA, and HA responds registration reply (REP) message to new FA. New FA forwards REP message to MN and the handoff is completed. As the propagation delay of wireless channel between MN and FA is assumed to be T $_{air}$ and the propagation delay of wired channel between new FA and HA is assumed to be T $_{ha}$, the period from that MN receives REQ message until MN receives REP message is T3 =2*(T $_{air}$ + T $_{ha}$).In the proposed scheme, MN can receive packets after receiving tentative registration (TREG) message from FA. Therefore, the period is T3 = 2 * T $_{air}$. Consequently, the handoff latency L is derived to be L = T1 + T2 + T3.

4.4.2. OVERHEAD OF THE NUMBER OF SHORTEN ADVs BROADCAST

Overhead performance O is defined as the number of transmitting ADV messages during the interval of transmitting ADV message is shortened. Therefore, small overhead means small additional traffic load in wireless channel. The period from that MN enters the shadowed area or outer area as shown in Figure 4 until that goes out of the previous FA's transmission area is (r − R)/v [9].

$$T_{o1} = \int \frac{pvT_{posFA}}{2} \rightarrow if \rightarrow T_{posFA} \geq \frac{r-R}{v},$$
$$T_{o1} = \frac{r-R}{2v} \rightarrow else \qquad (4)$$

Therefore, a period from that MN receives first ADV message until goes out of previous FA's transmission range is derived as

$$T_{o2} = \frac{r-R}{v} - T_{o1} \qquad (5)$$

The period from that MN goes out for previous FA's transmission range until that MN enters new FA's transmission range is

$$T_{o3} = D - \frac{2r}{v} \qquad (6)$$

Since new FA transmits ADV message every $T_{\text{shorten ADV}}$ in this period, the expected number of transmitting ADV message in this period N is

$$N = \frac{To2 + To3}{T_{shortADV}} \qquad (7)$$

After MN's entering transmission range of new FA, new FA transmits ADV message and MN responds Request message to new FA. When new FA receives request from MN message, the interval of transmitting ADV message is set to be default value T_{ADV}. Consequently, the overhead O is derived to be O = N +1.

4.4.3. OVERHEAD OF THE NUMBER OF FORWARDED PACKETS

Traffic overhead due to duplicating and forwarding traffic to the neighboring FA is an obvious cost of forwarding packet mechanism in the positional information handoff method. One of the main concerns of forwarding packet mechanism is the traffic overhead. The total traffic overhead to the network is proportional to the handoff rate and the forwarding period at each handoff [12].

The case that each traffic source sends UDP packet to a MN at constant data rate c continuously, then the amount of data forwarded during a handoff is $n.\tau.c.\lambda$ whereas, n is the number of neighboring FAs, τ is the period during the data is forwarded, c is data constant rate sent by CN, and λ is the handoff rate.

The total data sent by CN to MN in the cell for the same unit time period is $m.c$ where m is the total number of active mobile node in the cell.

The fluid flow model [13, 14] is widely used to analyze the cell boundary-crossing problem. According to the model, the handoff rate is

$$\lambda = \frac{\rho v L}{\pi} \quad (8)$$

where: λ is handoff rate(1/sec), ρ is the active mobile density (1/m^2), v is MN's velocity (m/s), and L is the cell perimeter.

The traffic overhead ratio ξ_f, which is defined as the number of bytes forwarded to the neighboring FAs divided by the total number of bytes sent by CN is

$$\xi_f = \frac{n.\tau.c.\lambda}{m.c} = \frac{n.\lambda.\tau}{m} = \frac{\rho.v.L.n.\tau}{\pi.m} \quad (9)$$

But, in the positional information handoff case, to determine the traffic overhead ratio whereas n=1 (only one target FA that is received the forwarded packets), L is perimeter circle is $2.\pi.r$; so $\rho = \frac{m}{\pi r^2}$ then we find that the traffic overhead ratio while only one MN active in cell is

$$\xi_f = \frac{m.v.2\pi r.n.\tau}{\pi^2 r^2 m} = \frac{v.n.2\tau}{\pi.r} = \frac{v.2\tau}{\pi.r} \quad (10)$$

where τ is the data forwarding period that is determined by this sum as follows.

$$\tau = t_0 + t_{MN's\ process} + RTT_{pFA-nFA} + RTT_{MN-nFA} \quad (11)$$

Where t_0 is time at the moment FA detects handoff, $T_{MN's\ process}$ is the time at MN to process request registration, $RTT_{PFA-NFA}$ is round trip times between previous FA and target FA in wired, and finally RTT_{MN-NFA} is round trip times between MN and new FA.

CHAPTER 5

PERFORMANCE RESULTS AND EVALUATION

In this chapter, we explain our simulation environment and simulation model that is implemented. We show and analyze the simulation results of the conventional Mobile IPv4 and the positional information handoff scheme in terms of handoff latency, number of lost packets, and traffic overhead. We then, compare the system performance of the conventional Mobile IPv4 with the positional information handoff scheme. We also show the simulation results of our proposed method. Finally, we compare all methods above in as function of various parameters to investigate tendency of their handoff latencies, number of lost packets, overhead packets, overhead ADVs broadcast, disorganized handoff especially between the positional information and the proposed methods. We also simulate when the number of MNs involved in simulation is increase to achieve results in real application. This chapter is organized as follows. In the section 5.1, we describe the environment and model of the simulation. In the section 5.2, we show the simulation results of the conventional Mobile IP and the positional information handoff, and the proposed methods. In the section 5.3, we compare the system performance of all methods as function of various parameters such as MN's velocity, distance between previous FA and new FA, and the position of MN moving in random situation according to the time taken to receive ADV message. Finally, the system performances of all methods while the number of MNs increase, are illustrated in the section 5.4.

5.1 SIMULATION ENVIRONMENT

In order to evaluate the performance of the conventional Mobile IP and the positional information handoff scheme, the network diagram for our simulation shown in Figure 17 is used in Borland Delphi 7 for network simulation. The network topology is designed within inter-subnet handoff scenario that HA and FA are placed in different subnet.

Every FA, connected with each other by a router using cell topology instead of standard routing protocol causes forwarding packets to neighbor FA simpler than in wired network.

The other advantage by this cell topology is to avoid awareness in using regional registration which causes complexity in determining how many FAs should be beneath the gateway FA which acts as a central FA and manages all signaling process in registration procedure.

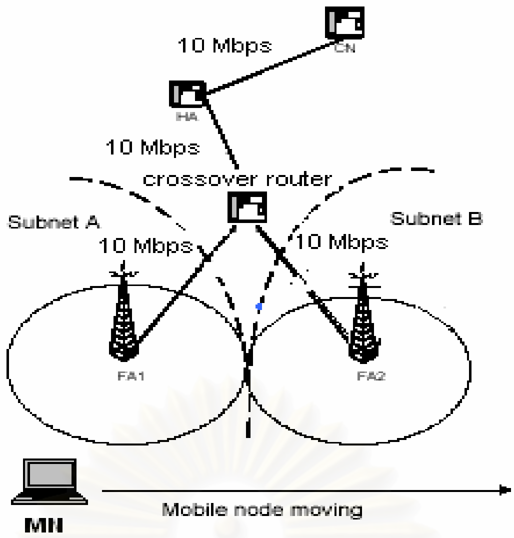

Figure 18. Network Topology for inter-subnet handoff in simulation

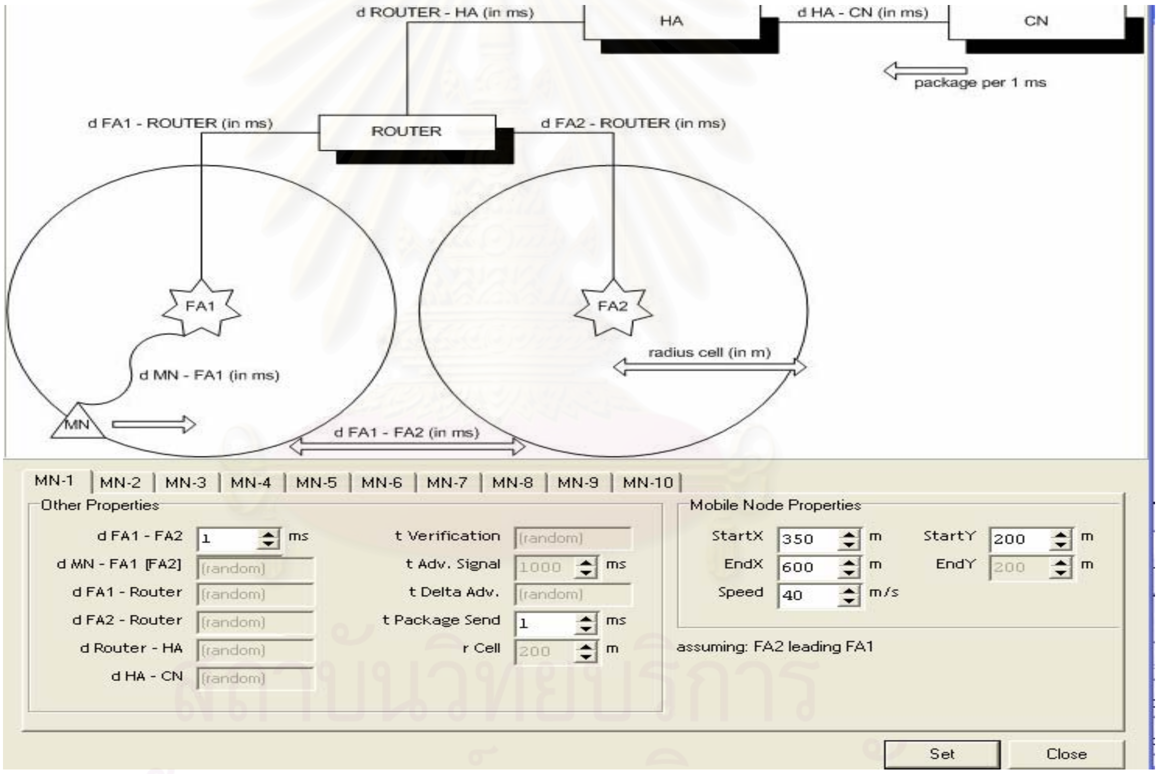

Figure 19. Simulation model using Borland Delphi 7

In order to lower the time taken in registration process of Conventional Mobile IP, the proposed method uses a tentative registration message sent by new FA while an MN requests registration to HA via new FA. So, it makes MN unnecessary to wait for registration completion. It means that the handoff latency can be low.

5.2 SIMULATION RESULTS

The simulation parameters are defined as follows.

- Topology : Non Overlap Network Coverage Area
- Link delay : set up in random time (ms)
- Mobile's velocity : varied in order to investigate in real application system
- The position of MN : varied and randomize while receiving ADV message
- Distance between previous FA to new FA : 0 ms
- Advertisement period : 1 second and broadcast in random time
- T shorten ADV : 100 ms in the positional information method
- Bandwidth : 10 Mbps
- Mobility Pattern : Straight Path
- Traffic : CBR / UDP sent every 5 ms
- Transmission range of BS : 200 meters within 20 meters for fixed threshold

5.2.1. CONVENTIONAL MOBILE IP

In the conventional Mobile IP, the handoffs are completely managed at layer 3 (L3). The simulation consists of the foreign agent sending the Router Advertisements that are captured by MN to decide when to handoff to a new foreign agent. However, the drawback of this implementation is that the Router Advertisement rate is low that is once every second; therefore it may happen that the MN receives the Router Advertisement from the new FA that triggers the handoff when it has already moved out of coverage from the previous FA. In this case, the packets tunneled to the previous FA when the MN has moved out of coverage would be lost. This situation is depicted in Figure 20. The trace shown in this Figure has been obtained using the Borland Delphi 7 for network simulation with the network topology shown in Figure 19.

The Figure shows the instants when the CN sends the packets and the instants when the MN receives them, as remarked in the Figure 20. The Figure also shows the instant when the nFA sends the Router Advertisement that causes the MN to perform handoff to the nFA by sending the registration message and then in turn, the Registration Reply is sent back to MN via nFA.

Figure 20 shows that the MN receives router ADV sent by FA at its position around 396.044 meters in FA's transmission range and has been disconnected from the previous FA while MN moves out of FA's boundary at position of 400 meters, but it cannot hear the Router Advertisement from the nFA.

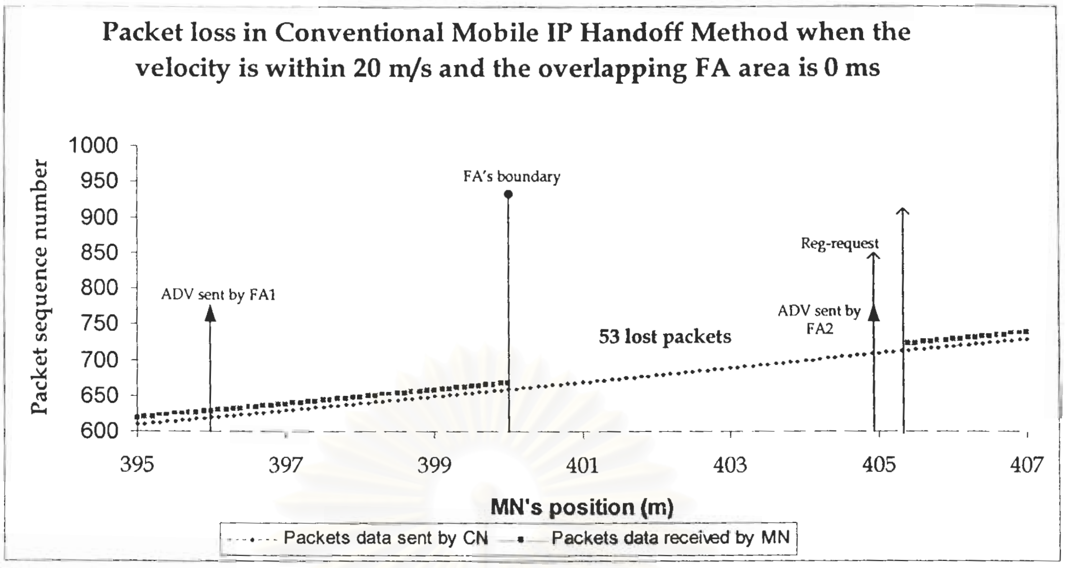

Figure 20. Conventional Mobile IP handoff process within zero overlapping

MN then moves straight and waits until receiving the Router Advertisement from the nFA at position of 4.96 meters after passing the new FA's boundary and then MN registers its CoA until receiving the Registration Reply from the nFA 0.0020591 s after requesting registration. Now, HA recognizes that MN has been already connected to nFA. The HA then intercepts the packets from the CN and forwards directly to the nFA. In this case we obtain 53 lost packets, because MN has to wait for 0.00268562 s after moving out of FA1's boundary until receiving registration reply from HA.

We also show the number of lost packets when MN moves velocity of 20 m/s in uncertain situation.

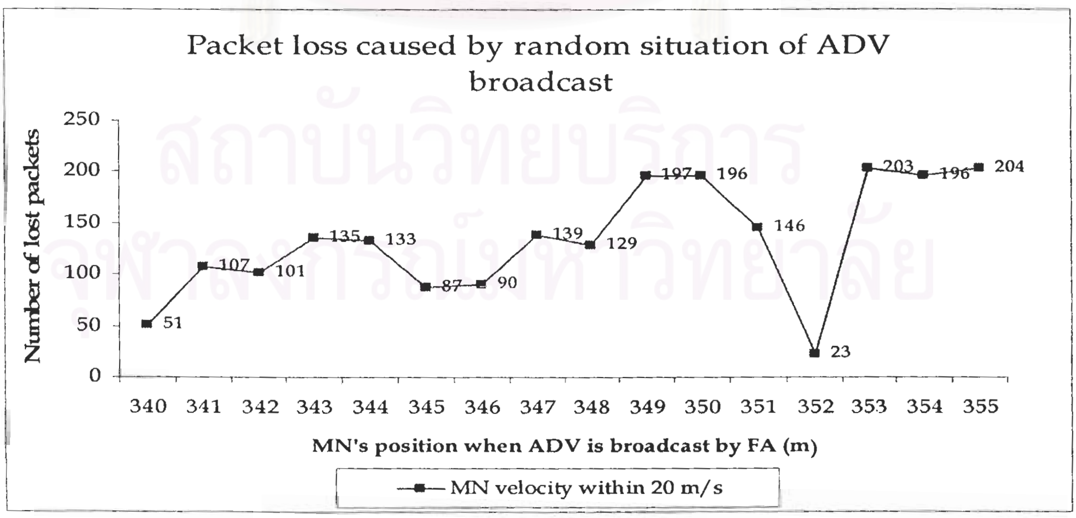

Figure 21. Packet loss caused by MN in random ADV's broadcast time

Figure 21 also explains that the time of ADV's broadcast varies the number of lost packets because MN has to wait for a period time to receive ADV and request registration until obtaining registration reply from HA.

Figure 21 shows that the minimum packet loss is 23 packets occur when ADV is sent by FA at the same time while MN's position is at 352.02 meter in FA 1's area, and the maximum result is 204 packets occurring while the position is at 355.04 meters in transmission range.

Figure 22 shows the number of lost packets according to MN's different velocity. MNs start moving from the same position randomly with varied velocity. When MN moves with slow mobility such as walking, running, taking bicycle obtain in the range of packet loss 56 to 87 packets. In fast velocity from 8 m/s until 20 m/s, packet loss has two trends, one, resulting around 50 - 60 lost packets and second, resulting around 116 – 202 number of packets. Finally, when MN moves within very fast speed the resulting number of lost packets is around 17 – 63 and 138 – 161 packets as shown in Figure 22.

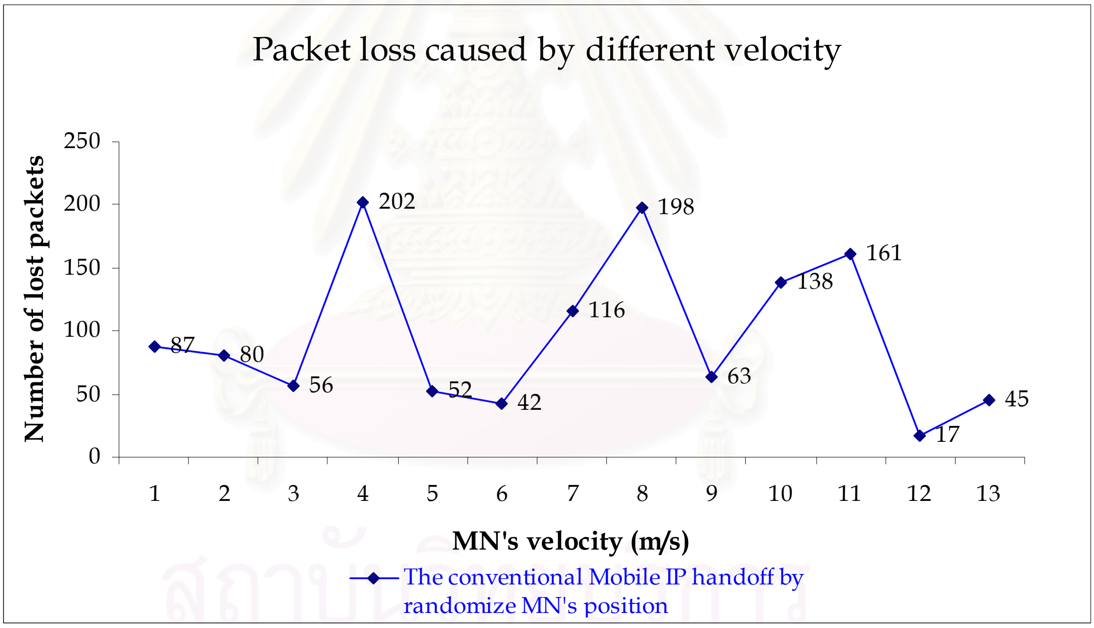

Figure 22. Packet loss caused by MN as a functions of velocity

The drawback of the previous conventional Mobile IP handoff method can be avoided using the Positional Information Handoff Method.

5.2.2. POSITIONAL INFORMATION HANDOFF METHOD

Since the shorten ADV sent by new FA are broadcast at a rate much higher than the Router Advertisements, the losses illustrated in Figure 23 are likely reduced. This scheme is implemented in three scenarios, the first is running by using slow velocity of 1 m/s like walking, the second is moving within 18 m/s as normal driving mobility, and the third is implementation in fast speed that is 35 m/s. All three scenarios as shown in Figures 23, 24, and 25 show the packet loss result and the other overhead according to our objective that is to achieve low handoff latency and to reduce traffic overhead. The trace shown in these Figures have been obtained using the Borland Delphi 7 for network simulation using the network topology in Figure 18.

Case 1: We suppose that the MN receives ADV from FA while its position exceeds a fixed threshold within velocity of 1 m/s. From analytical model, there occurs disorganized handoff that reports MN's position more frequent than completing registration process as shown in Figure 23. The starting position of MN while moving is randomly distributed at fixed position.

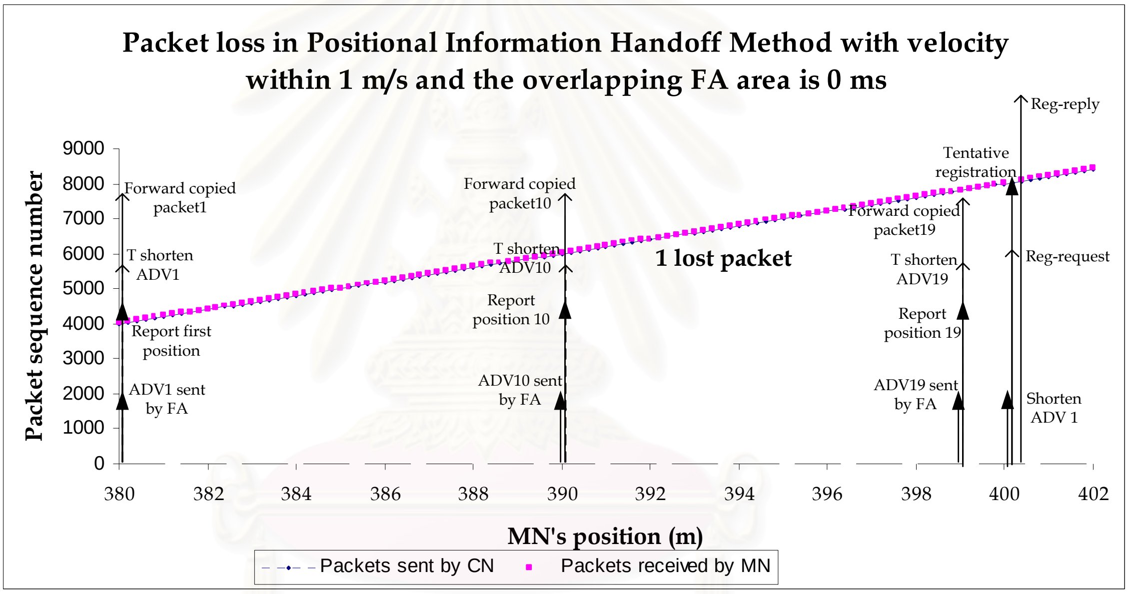

Figure 23. Packet Loss in the disorganized positional information handoff scheme with slow velocity

In this case, the simulation result shows the number of lost packets can be reduced compared with the Conventional Mobile IP Scheme but there are some lost packets besides the occurrence of disorganized handoff.

In our simulation; when the MN exceeds a fixed threshold, first ADV sent in outer area by FA and arrived at MN while its position is at 380.02 m as shown in the Figure 23, triggers the MN to report its position once a second. When MN located at 380.02 m indicating the excess of a fixed threshold causes FA start to notify new FA to shorten its ADV period to be 100 ms while at the same time FA prepares to copy and forward copied packets to new FA, and the original ones still broadcast via wireless. Figure 23 shows that MN reports its position nineteen times instead of completing handoff process with new FA. This is called disorganized handoff. The registration attempts occur at 380.02, 381.04, 382.04 m until 399.08 m in FA's transmission range.

Then, new FA receives this message and starts to broadcast the ADV once every 100 ms until registration process is complete. From simulation results as shown in Figure 23, the shortened ADV are broadcast 197 times in new FA's transmission range. The new FA also receives 4001 overhead packets forwarded once MN reports first exceeding threshold position to the previous FA. This process could be an important problem while the number of MNs to handoff is increased.

The 198th shortened ADV sent by new FA is received by MN while moving in new FA for 0.006992 s then followed by sending registration request. Upon receiving this registration request, the same new FA sends a tentative registration message to MN which contains information as the registration reply message in order that MN can start receiving the forwarded packets. At the same time, new FA passes a registration request to HA in order to obtain registration reply that arrives at MN after waiting for 0.0022423 s. From this simulation, we obtain only 1 lost packet during handoff.

Case 2: MN moves with velocity within 18 m/s as driving mobility.

Figure 24 shows that ADV message received by MN while its position exceeds a fixed threshold at 396.054 m followed by sending ADV response in order to report its position. Upon receiving this ADV response, FA starts to detect handoff by sending a notification message to new FA to shorten its ADV interval to be 100 ms, moreover, FA also prepares to forward copied packets. By receiving this shortened ADV message, new FA broadcast its shortened ADV once every 100 ms starting from this point. From simulation, we know that the number of shortened ADV broadcast message during handoff is 3 messages and the number of forwarded overhead packets is 61 packets. In this case, MN reports its position only once during handoff.

When MN has moved out of previous FA, MN has to wait as long as 0.0085992 s in order to receive shortened ADV message. Then, MN requests registration to HA via new FA. The tentative registration is sent to MN once new FA receives registration request. The registration process is completed after registration reply arrives at MN for 0.0019194 s after requesting registration to new FA.

The handoff latency occurring in this case is 0.0086692 s. This causes 17 lost packets during this handoff period as shown in Figure 24. So, this scheme can reduce handoff latency, because the delay to process handoff is lower than those of Conventional Mobile IP Handoff Scheme.

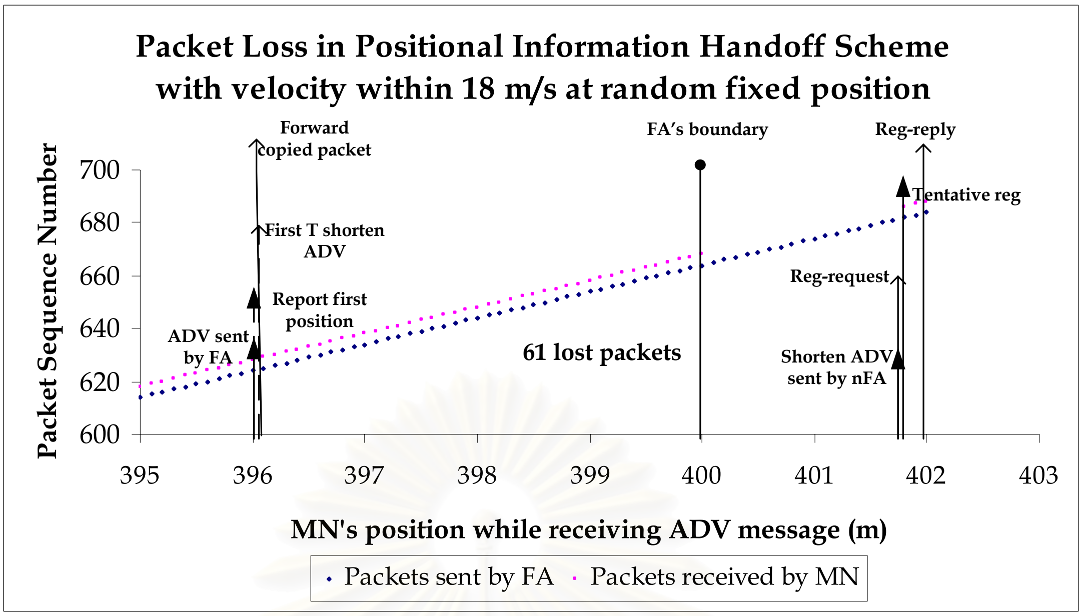

Figure 24. Packet Loss in Positional information's handoff scheme

Case 3: implement an MN to move with fast velocity within 35 m/s. We can see from Figure 25 according to other disorganized handoff that loses connection from previous FA instead of detecting handoff while MN is still in previous FA. This problem can occur because the fixed threshold range is 20 meters whereas MN moves with velocity within 35 m/s.

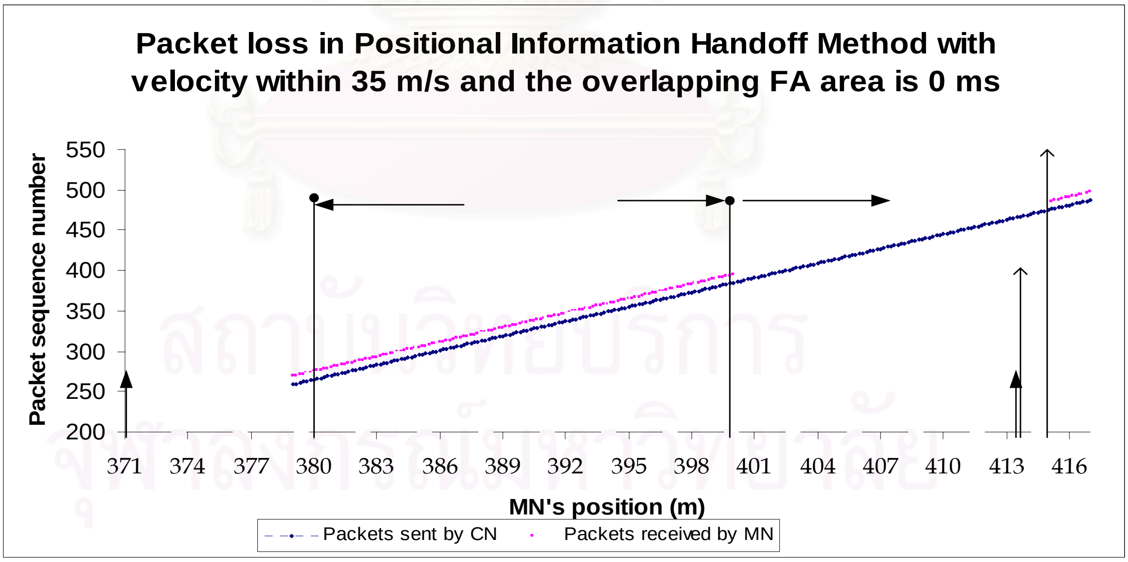

Figure 25. Packet Loss in the disorganized positional information handoff scheme with velocity within 35 m/s

When MN locates at 371.035 m in previous FA's transmission range, MN receives ADV message and reports its position while does not exceed a fixed threshold, so FA does not start to process handoff. MN has to wait the next ADV for one second later. But in the next one second, MN has already moved out of the previous FA in order to move in to new FA area. In this case, handoff detection based on positional information is failed, thus no forwarded packets and no shortened ADV messages are implemented in new FA. By this happening, there is no handoff detection occurring while MN is still in the previous FA in order that this method cannot achieve low handoff latency because the number of lost packets is increased until the lost packets is 90 packets as shown in Figure 25. Figure 25 shows that MN's position when ADV is broadcast sent by new FA is at 3.408 m or 0.00446992 s from new FA's boundary. MN sends a registration request to HA via new FA. The registration process is completed during 0.0020829 s while MN receives registration reply. In this case, we know that the number of lost packets occurred is 90 packets. This case also cannot determine the number of shortened ADV and forwarded packets in new FA's area.

In those previous simulations of Conventional Mobile IP and Positional Information Handoff Method, there occurs varying number of lost packets and handoff latency based on velocity and MN's position in receiving ADV message. The positional information handoff occasionally achieves low handoff latency and minimizes packet loss but once in a while obtains many lost packets, overhead packets and shortened ADV message resulted by the disorganized handoff.

To solve the unstable results, we try to simulate our proposed method in order to achieve low handoff latency and minimize packet loss without increasing the traffic overhead.

5.2.3. SIMULATION OF THE PROPOSED METHOD

The proposed method modifies some signaling from positional information handoff scheme to solve disorganized handoff problem and the disadvantage of shortened ADV message which cause increasing traffic overhead. First modification is the dynamic threshold. This dynamic threshold range depends upon the multiplication between MN's velocity and $T_{default}$ ADV which is broadcast every one second. The proposed method is implemented in order to avoid disorganized handoff happening. The second modification is $T_{improving}$ ADV. It can change the function of $T_{shorten}$ ADV message in order to reduce the traffic overhead. When FA detects MN's position exceeds a threshold then FA sends a $T_{improving}$ ADV to new FA in order to broadcast ADV very close to the time while MN reaches new FA's boundary. This scheme can be implemented because the previous FA learns the link delay between two neighbor FAs from the header of NFA message which contains delay time between two neighbor FAs. The third modification is T_{buffer} that is proposed to replace the forwarding packet mechanism which causes the traffic load in the wired network moreover the number of MNs processing handoff is increased.

In this simulation, we simulate the proposed scheme when using a method that $T_{improving}$ ADV subtracted by the latest link delay and the lowest link delay that is obtained from NFA message. The gap between two neighbor FAs is 0 ms. We can obtain and analyze the results in term of packet loss, handoff latency, and the number of overhead packets.

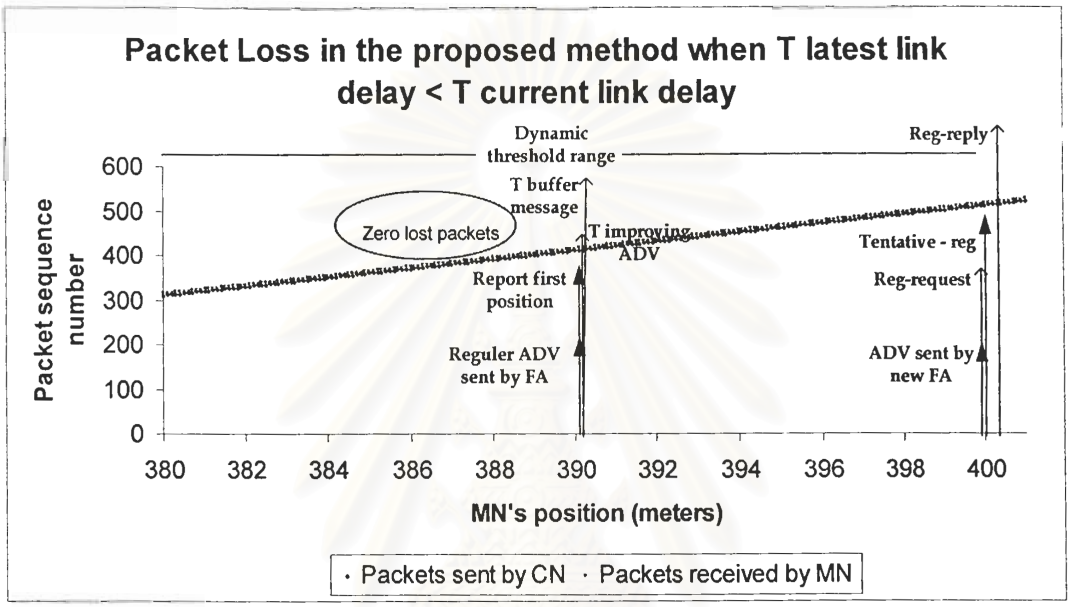

Figure 26. Packet Loss in Proposed Method with velocity of 20 m/s when $T_{link\ delay}$ of $T_{improving}$ ADV less than $T_{current}$ link delay

Case 1: Figure 26 shows that MN moves with velocity within 20 m/s. From ADV response every second, FA calculates the threshold range is 20 meters from FA's boundary. An MN moves straight and receives ADV message at position 390.0148 meters in FA's transmission range. MN responds by reporting its position to FA. FA determines that MN exceeds a threshold indicating an handoff is detected. FA then sends $T_{improving}$ ADV and T_{buffer} message to new FA as target FA. $T_{improving}$ ADV orders new FA to broadcast ADV message for 493.785 ms after new FA receives the $T_{improving}$ ADV. The time of 493.785 ms is defined from calculation of the time when MN exceeds a threshold until reaches new FA subtracted by T_{latest} link delay of previous NFA message. When MN reaches new FA's boundary, MN has to wait for 0.001275 s in order to receive ADV. Now, MN can request registration to HA via new FA. New FA then sends a tentative registration message to MN besides pass through the registration request to HA. By receiving this tentative registration message, MN starts to receive first forwarded packet. The registration reply message is arrived at MN after 0.0022523 s after requesting registration.

The simulation finds that the time taken from MN loses connection to previous FA until receiving a tentative registration is 1.275 ms and we obtain zero lost packets. We also investigate the amount of data forwarded during handoff is 2.56 kb.

Case 2: The proposed method simulates with MN's velocity of 20 m/s with different case as shown in Figure 27.

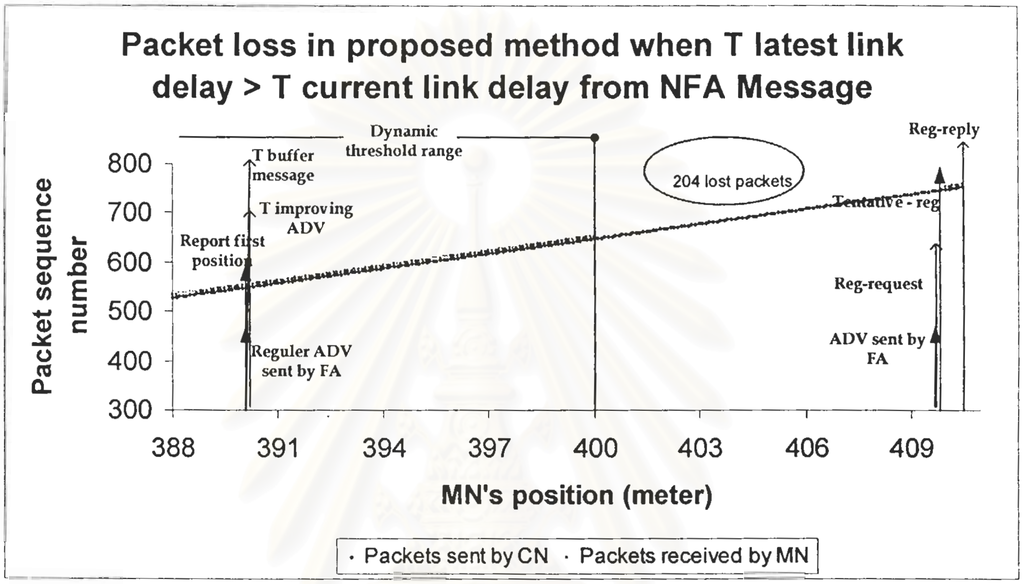

Figure 27. Packet Loss in Proposed Method with velocity of 20 m/s when $T_{link\ delay}$ of $T_{improving}$ ADV more than $T_{current}$ link delay

Figure 27 shows that the threshold range is same of 20 meters and FA detects handoff when MN's position which is reported to FA at 390.016 meters in FA's area. FA sends a $T_{improving}$ ADV and T_{buffer} to new FA.

$T_{improving}$ ADV orders new FA to broadcast ADV for 492.245 ms in order that MN can receive it immediately when reaches new FA area. Unfortunately, new FA broadcasts ADV at the time 498. 956 ms while MN will move in new FA at the time of 500.003 ms. By with this happen, MN misses the ADV message and has to wait for next ADV message causes high handoff latency. MN has to wait for 998.953 ms in order to receive next ADV and the registration period takes a time for 0.0019675 s. Figure 27 shows that the proposed method obtains 204 lost packets during handoff.

Figure 27 shows that at this case, the amount of data forwarded during handoff is 104.448 kb.

5.2.3.1. APPROPRIATE LINK DELAY

$T_{improving}$ ADV defined as the time taken from MN's position while exceeds a threshold until MN reaches new FA's boundary subtracted by the time of the link delay between two neighbor FAs.

Figure 26 and Figure 27 shows that when the link delay used is less than current link delay achieves zero lost packets and respectively, when the link delay used is more than current link delay causes 204 lost packets. It means that the proposed method scheme has to implement the link delay always less than current link delay in order to achieve low handoff latency.

In order to achieve appropriate link delay, we have to do many simulations for obtaining the lowest link delay.

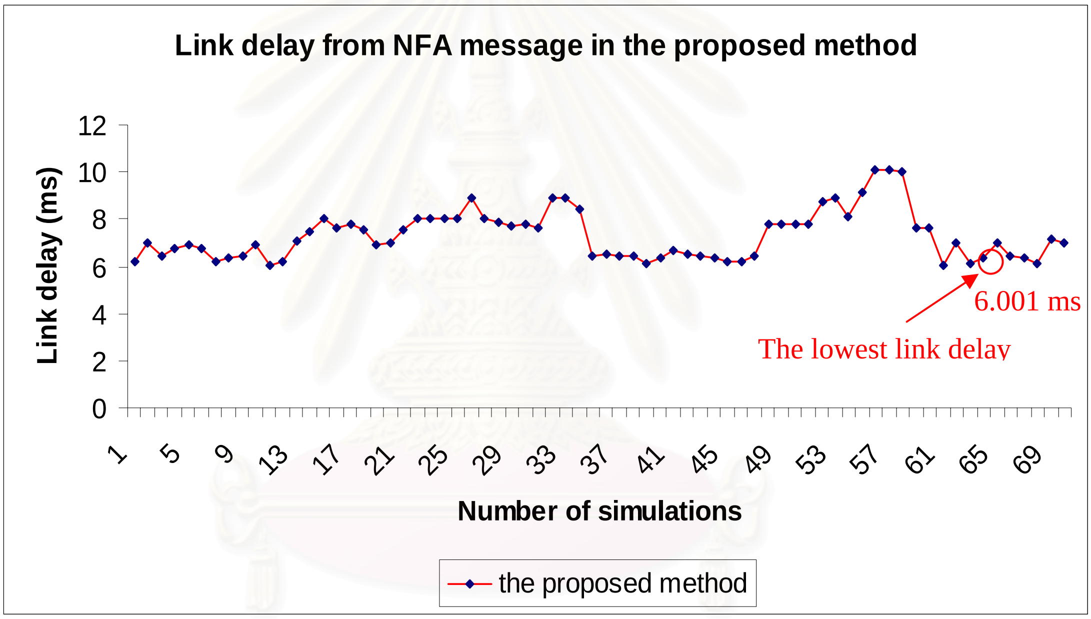

Figure 28 Link delay of NFA message from many simulations taken

Figure 28 shows the simulation results many links delay of NFA messages. After doing seventy times of simulation research, the proposed method scheme chooses 6.001 ms as the lowest link delay in order to develop new $T_{improving}$ ADV as the division between the distance of MN's position to new FA and MN's velocity subtracted by $T_{link\ delay}$ of 6.001 ms. With using this link delay of 6.001 ms will achieve low handoff latency.

5.3. PERFORMANCE RESULTS AS FUNCTIONS OF VARIOUS PARAMETERS

In this section, we investigate the comparison result of the conventional Mobile IP, the positional information handoff, and the proposed method in terms of handoff latency, the number of lost packets, the overhead of forwarded packets and the number of ADVs broadcast when we vary parameters such as MN's velocity, distance between two neighbor FAs, shortened ADV period, and randomize MN's position when ADV is broadcast.

5.3.1. PERFORMANCE RESULTS AS FUNCTIONS OF VARIOUS PARAMATERS IN TERMS OF HANDOFF LATENCY AND PACKET LOSS

Handoff latency is time taken for processing handoff that is started when MN receives last packet from previous FA until receives first packet from new FA. In the conventional Mobile IP registration method, MN starts to receive first packet when the registration reply message is arrived at MN, but in the positional information handoff and the proposed method receiving first packet from new FA is started when MN receives a tentative registration.

Some parameters can influence the handoff latency performance. The first, MN's velocity has correlation to how fast for the time taken since MN moves out of previous FA until moves in new FA in order to get ADV message. The second, randomize link delay has correlation to how long for $T_{improving\ ADV}$ and T_{buffer} message arrive in new FA. The third, the distance between previous and new FA significantly affects to the time needed for MN reaches new FA's area. The forth, varying MN's position when ADV is broadcast causes randomize time for handoff. Finally, varied $T_{shorten}$ ADV period in the positional information handoff scheme causes the different time for MN to register earlier.

5.3.1.1. VARYING MN'S VELOCITY

By using the same parameter as described in section 5.2, we compare the result in terms of handoff latency for all three methods that is run by Borland Delphi 7 for network simulation. The velocity which has been simulated is 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 18, 20, 25, 30, 35, 37, and 40 m/s in order to analyze the trend of handoff latency. This simulation is assumed that MN receives ADV message at same position in FA's area.

Figure 29 shows that the conventional Mobile IP scheme results high handoff latency than those of positional information and proposed method. The result of handoff latency of the conventional method is 86.552 ms to 1021.502 ms. In the conventional method shows that the first trend that is high handoff latency of 800 – 1021 ms occur when MN moves in new FA but misses the ADV causes MN has to wait next ADV. The second trend of handoff latency of 200 – 800 ms occur when MN has to wait ADV for long time, and the third trend of handoff latency of 86 – 200 ms occur when MN moves in new FA with lower time for waiting ADV. In the positional information handoff scheme has three tendencies of handoff latency. First, handoff latency occurs 6 – 8 ms when MN moves with velocity within 1, 2, 4, 5, 10 and 20 ms. Second, the handoff latency of 400 ms to 600 ms when MN moves with velocity within 25 dan 30 m/s which causes losing connection from FA before FA detects handoff. Third, low handoff latency occurs around 30 – 80 ms. We also obtain that the minimum handoff latency in the positional information scheme is 6.992 ms and the maximum one is 582.991 ms as shown in Figure 29.

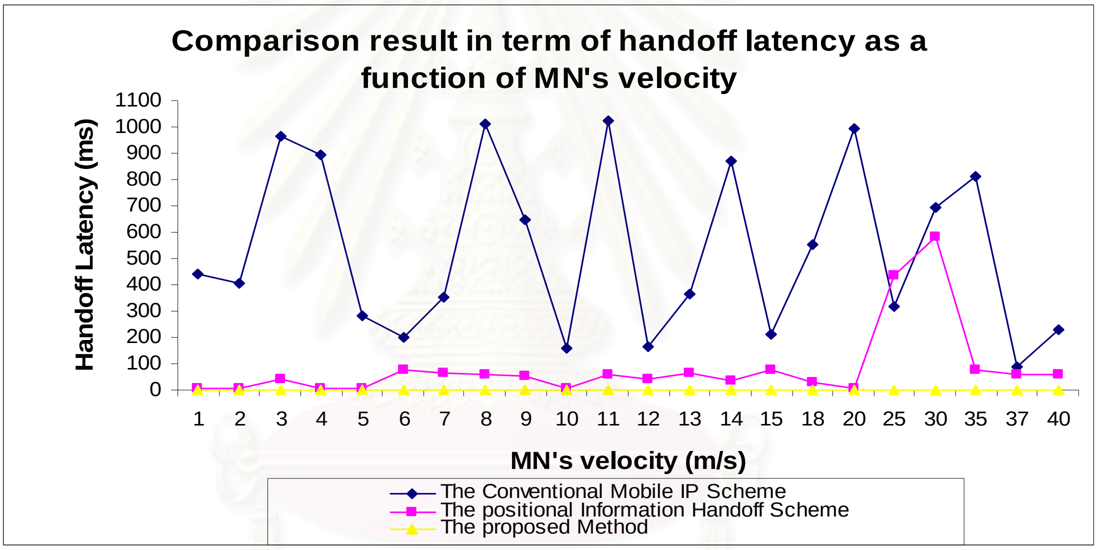

Figure 29. Comparison Result in terms of Handoff Latency as a functions of MN's velocity

The handoff latency result in the proposed method is much better than those of the conventional and positional information handoff method as shown in Figure 29. The minimum is 0.595 s while the maximum one is 1.859 ms. Figure 29 shows that the proposed method can achieve lower handoff latency than those of the positional information handoff scheme as a consequent of new $T_{improving}$ ADV message.

We also see Figure 30 shows that the packet loss in the proposed method achieves zero lost packets as a result of low handoff latency. Low handoff latency occurs because the proposed method implements new $T_{improving}$ ADV message. The conventional Mobile IP scheme which has high handoff latency causes many lost packets. The minimum lost packet of 18 packets occur when MN moves with velocity within 37 m/s which causes MN waits for 86.552 ms to receive registration reply. The maximum lost packets of 205 packets obtained by MN while moves with velocity of 11 m/s. MN will miss ADV when moves in new FA so MN has to wait for next ADV.

Positional information handoff scheme which has three tendencies of handoff latency also results three trends of lost packets happen. Maximize lost packets of 87 and 117 packets occur when MN loses connection to FA before detecting handoff caused by MN's movement with velocity within 25 and 30 m/s as shown in Figure 30.

Figure 30 shows that the proposed scheme obtains zero lost packets during handoff.

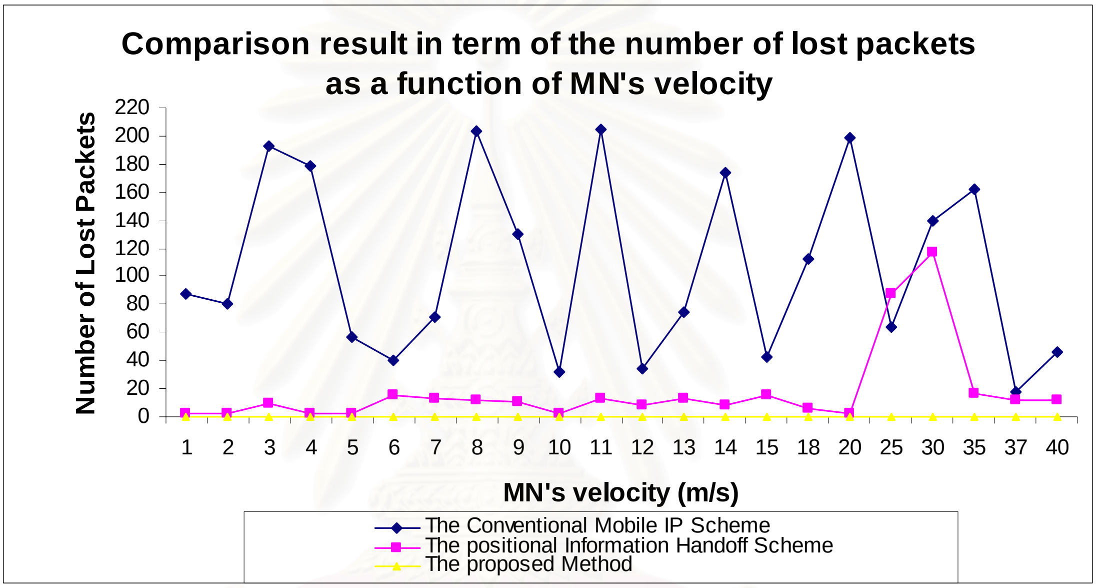

Figure 30. Comparison Result in terms of Packet Loss VS MN's velocity

5.3.1.2. AS A FUNCTIONS OF THE MN'S POSITION WHEN ADV IS BROADCAST

From previous section 5.3.1.1 describes that the handoff latency and packet loss will be varied as a functions of various MN's velocity. In this section, we use various MN's position when ADV is broadcast. Other parameters are MN's velocity is 20 m/s and the shortened ADV period in the positional information handoff scheme is 100 ms. Then we will analyze the handoff latency and packet loss trend.

Figure 31 shows that the maximum handoff latency of 1020.66 ms occur in Conventional Mobile IP when MN receives ADV message at position of 355.017 m in FA's area, while the minimum handoff latency of 258.406 ms is occur when the position of MN is located at 340.001m. The graph of Conventional Mobile IP scheme's tends to decline when MN's position closer to new FA.

In the positional information handoff method, the handoff latency has two trends. first trend of 6.991 ms to 7.992 ms and second trend of 57.992 ms. Figure 31 shows that the trend of graph declines at 340 m and incline at 341 m then decline again at 342 m and incline again at 343 m. It is happen because the ADV is broadcast every 100 ms which will occur handoff latency less than 100 ms. Finally, we obtain low handoff latency in the proposed method scheme that is occur from 0.61 ms to 1.771 ms for all MN's position. The minimum handoff latency occur as a result of an new $T_{improving}$ ADV.

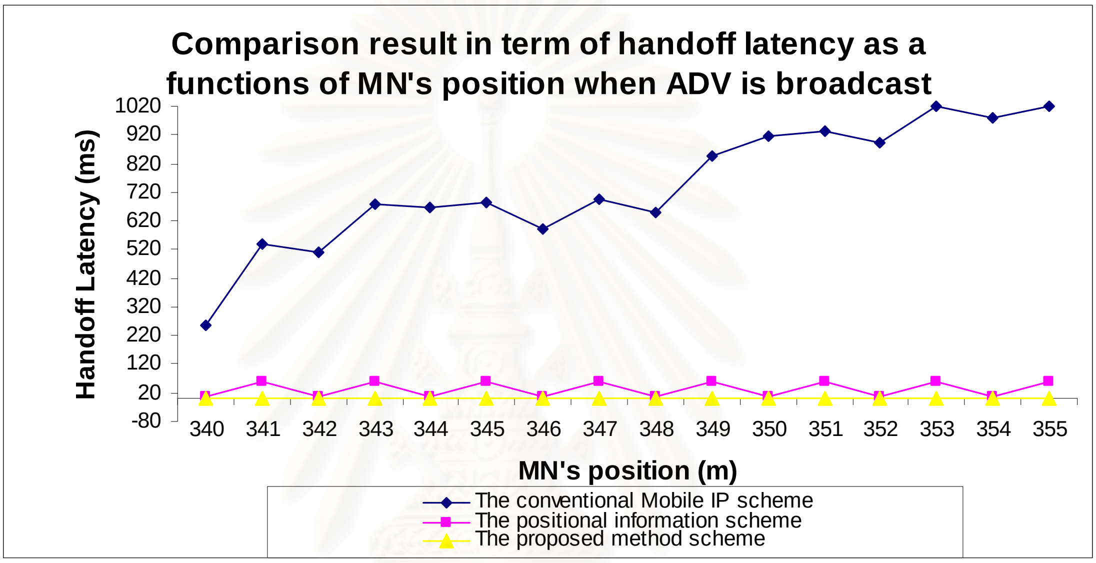

Figure 31. Comparison Result in terms of Handoff Latency as a functions of MN's position when ADV is broadcast with velocity of 20 m/s

Figure 32 shows that the proposed method achieves zero lost packets in all MN's position when ADV is broadcast as result of $T_{improving}$ ADV. The positional information handoff scheme obtains the number of lost packets with two trends that are two lost packets and twelve lost packets as shown in Figure 32. The trend of Positional Information handoff scheme declines when MN's position is at 340 m and inclines at position 341 m. This trend of graph will occur up and down continuously. The number of lost packets in Conventional Mobile IP scheme is high as a consequent of the high handoff latency. The maximum number of lost packets is 204 packets, the minimum one is 52 packets, and Figure 32 shows number of lost packets mostly occur around 107 - 200 packets.

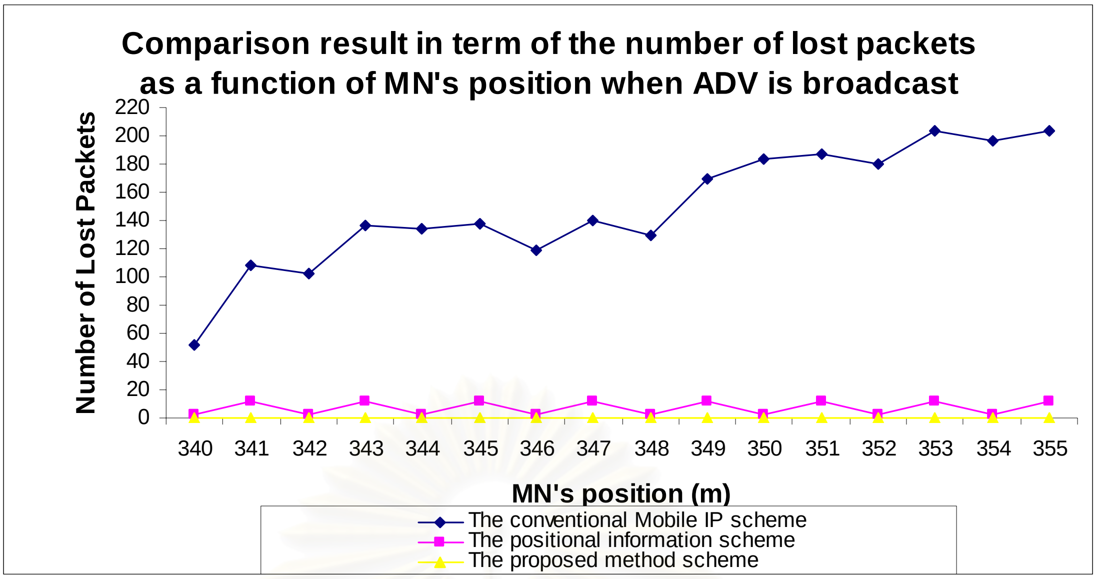

Figure 32. Comparison result in terms of Packet Loss as a functions of MN’s position when ADV is broadcast with velocity of 20 m/s

5.3.1.3. AS A FUNCTIONS OF DISTANCE BETWEEN FAs

Varied the distance between FAs causes various handoff latency. Different distance between two FAs causes various time delay of arriving $T_{improving}$ ADV message at new FA which causes different time for MN to request registration.

This simulation is run with velocity of 20 m/s. The position of MN while receives ADV message is same. Other parameters as described in section 5.2 are also followed by this simulation.

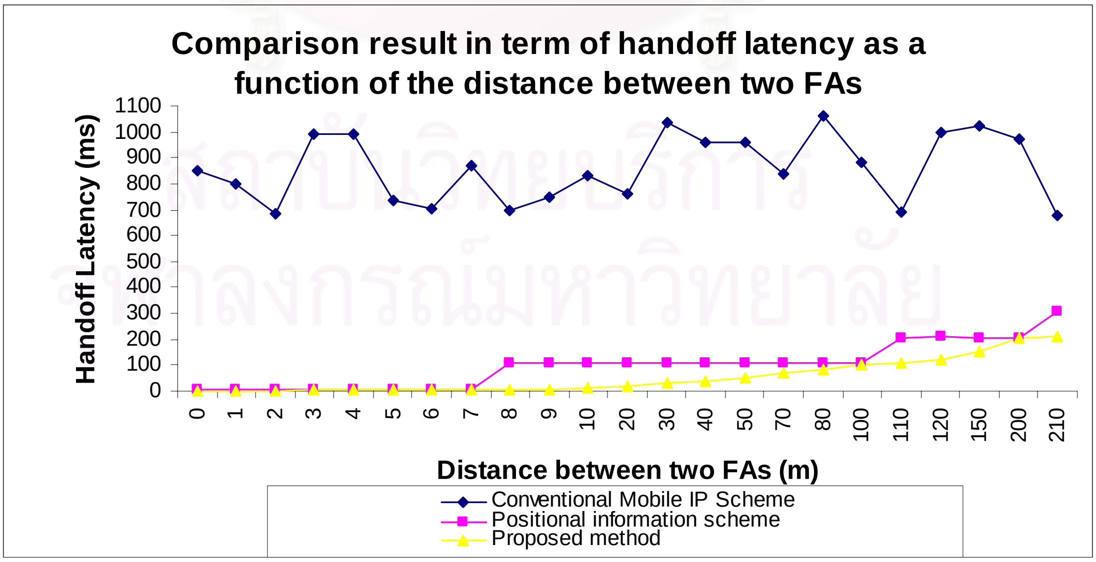

Figure 33. Comparison Result in terms of Handoff Latency as a functions of the distance between two FAs with velocity of 20 m/s

Figure 33 shows that the trend of handoff latency at Conventional Mobile IP scheme tends to high. The graph is up and down as a functions of the distance between two neighbor FAs. Higher gap does not automatically cause higher handoff latency because the time for ADV's broadcast is random as the time for MN moves in new FA as a consequent of various gaps between two neighbor FAs. The maximum handoff latency is 1058.566 ms and the minimum handoff latency is 680.515 ms.

The trend of handoff latency at Positional information handoff scheme inclines as a consequent of higher gap between two FAs. It has three steps inclining. First inclining occur when the gap between two FAs of 8 ms with handoff latency from 7.991 ms to 106.992 ms, second inclining occur when the gap between two FAs of 110 ms with handoff latency from 108.993 ms to 206.993 ms and the third inclining when the gap between two FAs of 210 ms with handoff latency from 206.994 ms to 307.994 ms.

The trend of handoff latency at the proposed scheme tends to incline orderly as a result of higher gap between two FAs. The maximum handoff latency of 210.661 ms occur when the gap between two FAs of 210 ms and the minimum handoff latency of 0.955 ms occur when the gap between two FAs of 0 ms.

From this simulation result, we conclude that handoff latency of proposed scheme is lower than those of other methods scheme, also higher gap between two FAs tends to higher handoff latency.

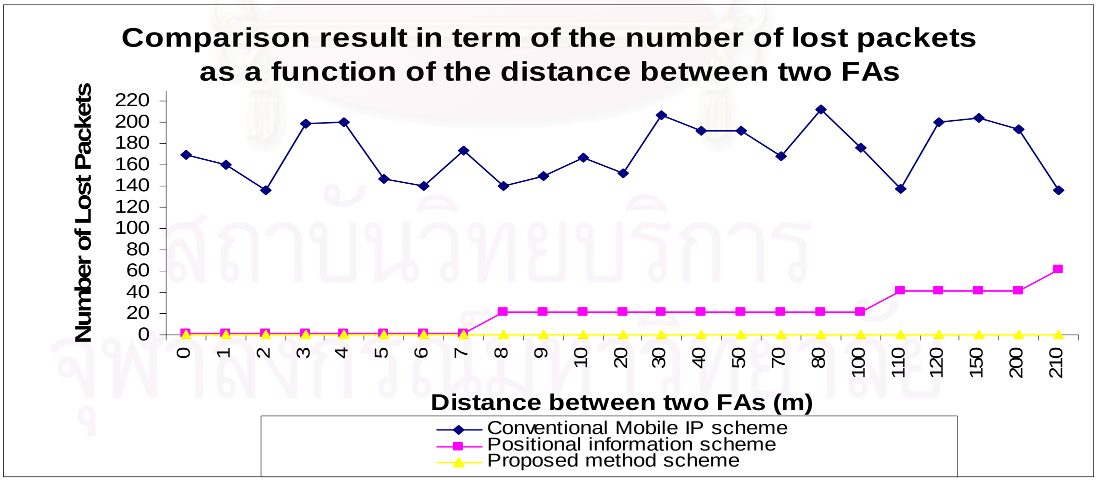

Figure 34. Comparison Result in terms of the number of lost packets as a functions of the distance between two FAs with velocity of 20 m/s

Figure 34 shows the trend of number of lost packets follows to the trend of handoff latency for all three methods. The number of lost packets of the conventional Mobile IP scheme, mostly occur from 130 to 200 packets. The positional information handoff scheme achieves less number of lost packets than those of Conventional Mobile IP scheme with four trends packet loss. First trends occurs two lost packets, second trend occurs twenty two lost packets, third trends occurs forty two lost packets and finally when the gap between two FAs is 210 ms will occur sixty two lost packets. It shows that higher gap causes more number of lost packets. Finally the proposed method obtains zero lost packets even though the gap is higher because when MN moves out of FA, the original packet will be buffered at new FA.

5.3.1.4. VARYING T $_{shorten}$ ADV

Varying T $_{shorten}$ ADV can cause various handoff latency in the positional information handoff. Because different shortened ADV message broadcast emerges variation of the time delay for MN to receive shortened ADV which has correlation to request registration to the new FA. Analytically, shorter ADV period, earlier registration request happen which makes lower handoff latency. But, there exists other parameter like the MN’s position when receives first ADV message in FA which can cause various handoff latency too as shown in Figure 35.

The simulation is run with velocity within 1 m/s and 17 m/s as representation of walk and driving mobility. The shortened ADV that is implemented in the simulation is come from 50 ms until 500 ms then we can start to analyze the handoff latency and the number of lost packets.

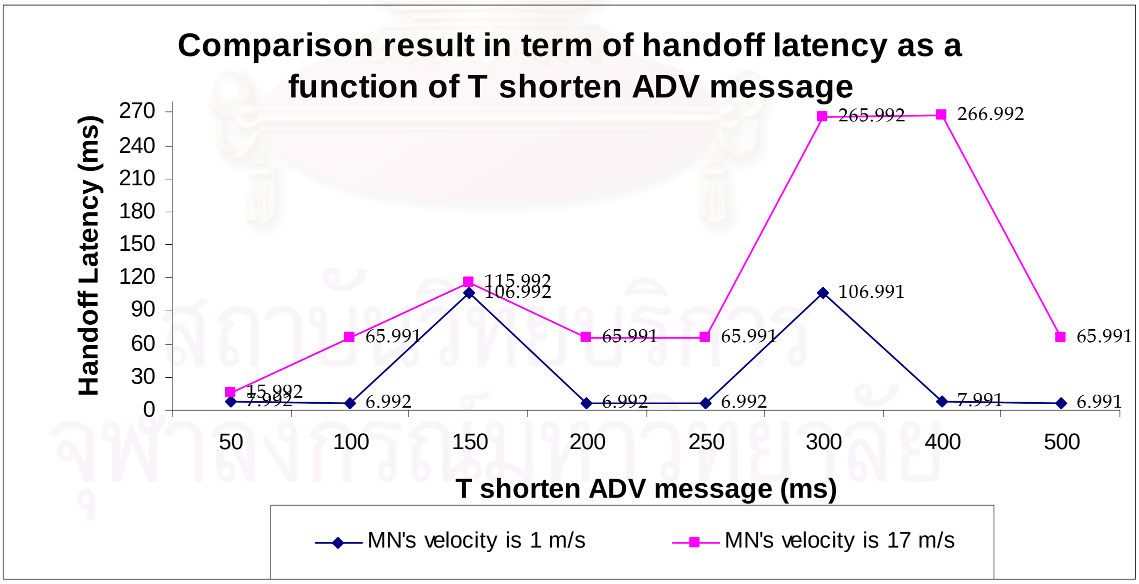

Figure 35. Comparison Result in terms of Handoff Latency as a functions of T $_{shorten}$ ADV between the velocity of 1 m/s and 17 m/s

From Figure 35 shows that shorter ADV period tends to achieve lower handoff latency, but when we show the result of T $_{shorten}$ ADV at 150 ms, we obtain that the handoff latency is higher than those of T $_{shorten}$ ADV at

200 ms, 250 ms and 500 ms both in velocity of 1 m/s and 17 m/s. Figure 35 shows that the handoff latency of T $_{shorten}$ ADV at 150 ms is 106.992 ms for velocity of 1 m/s and 115.992 ms for velocity of 17 m/s. This case also happen when T $_{shorten}$ ADV is at 300 ms comparing with T $_{shorten}$ ADV at 400 ms and 500 ms. But, generally that shorter T $_{ADV}$ message that is broadcast achieves lower handoff latency as shown in Figure 35.

Figure 36 shows the impact of handoff latency according to the number of lost packets happen. As described in Figure 36, so we obtain that shorter T $_{ADV}$ message that is broadcast, minimize number of lost packets occur except when T $_{shorten}$ ADV at 150 ms and 300 ms. Figure 36 shows that the maximum number of lost packets is twenty one packets for velocity of 1 m/s and fifty eight packets for velocity of 17 m/s, while the minimum one is one packet for velocity within 1 m/s and three packets for velocity within 17 m/s.

From Figure 29 until Figure 36, we have conclusion that the handoff latency and the number of lost packets depend on various parameters as a functions of MN's velocity, MN's position when ADV is broadcast, the distance between two FAs, and T $_{shorten}$ ADV period in the positional information handoff scheme.

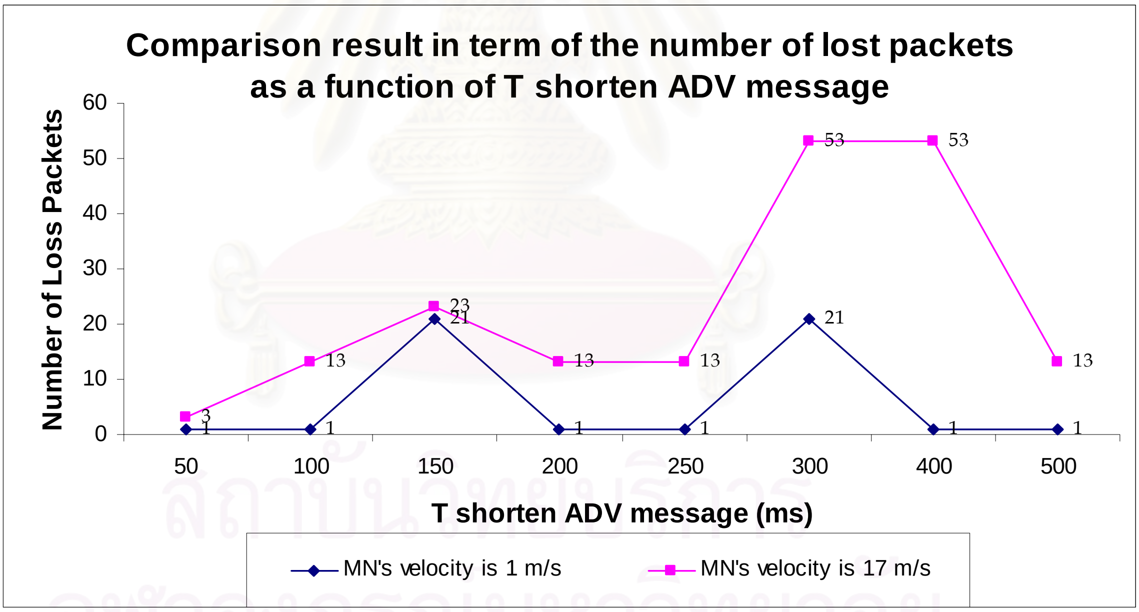

Figure 36. Comparison Result in terms of the number of lost packets when varying T $_{shorten}$ ADV between velocity of 1 m/s and 17 m/s

5.3.2. PERFORMANCE RESULTS IN TERMS OF OVERHEAD DATA FORWARDED AND ADV MESSAGE BROADCAST

ADV overhead performance is defined as the number of transmitting ADV messages during the interval of transmitting ADV message is shortened. The overhead shortened ADV message is calculated since FA sends a T $_{shorten}$ ADV message to new FA until MN receives a registration reply from new FA. T $_{shorten}$ ADV is sent by FA when detecting handoff that is triggered by MN's position when exceeds a threshold.

Packet forwarding overhead is defined as the amount of data forwarded from previous FA to new FA during handoff process. In the positional information handoff scheme when FA detects MN's position exceeding an threshold, packets will be copied and forwarded to the new FA. The packet forwarding will be stop after MN completes registration process in new FA, while in the proposed method packets start to forward to the new FA when MN moves out of FA until the registration reply via new FA is arrived at MN. From the theory we assume that the proposed method will result less packet forwarding overhead than those of the positional information handoff method.

In the simulation, we investigate the handoff latency and the number of lost packets result as a functions of MN's velocity, MN's position when ADV is broadcast, and the distance between two FAs.

5.3.2.1 AS A FUNCTIONS OF MN'S VELOCITY

The velocity which has been simulated is 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 18, 20, 25, 30, 35, 37, and 40 m/s in order to analyze the trend of traffic overhead caused by the number of shortened ADV broadcast and the amount of data forwarded during handoff as shown in Figure 37 and Figure 38.

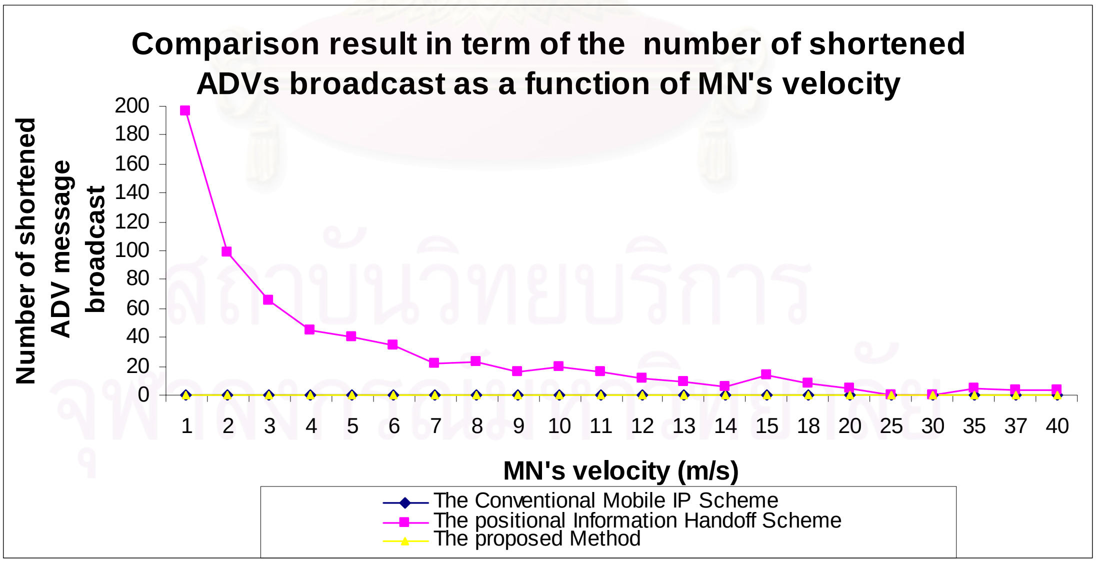

Figure 37. Comparison Result in terms of the number of shortened ADVs broadcast as a functions of MN's velocity

Figure 37 shows that the number of shortened ADV message in the conventional Mobile IP and the proposed method scheme achieve zero because both methods do not implement shortened ADV message. The positional information handoff scheme obtains many shortened ADVs broadcast during handoff. Slower MN's velocity, more number of shortened ADVs broadcast. Figure 37 shows that the maximum number of ADVs of one hundred ninety seven ADVs is obtained when MN moves with velocity of 1 m/s and the minimum one of three ADVs is obtained at MN's velocity of 40 m/s. Figure 37 also shows that when MN moves with velocity of 25 m/s and 30 m/s occurs losing connection to FA before detecting handoff causes no shortened ADV implement.

Figure 38 also shows that the amount data forwarded in the positional information handoff scheme occur of 2048.512 kb when MN moves with velocity of 1 m/s and it decreases at 31.232 kb when MN moves with velocity of 40 m/s. So, we can conclude that slower MN's velocity causes a huge amount of data forwarded during handoff.

We also got that the overhead of data forwarded in the proposed method is less than those of the positional information handoff method as a result of T_{buffer} message. The proposed method occurs 2.048 to 2.56 kb of data forwarded during handoff as shown in Figure 38. So, figure 38 shows that the proposed method can avoid increasing traffic overhead during handoff.

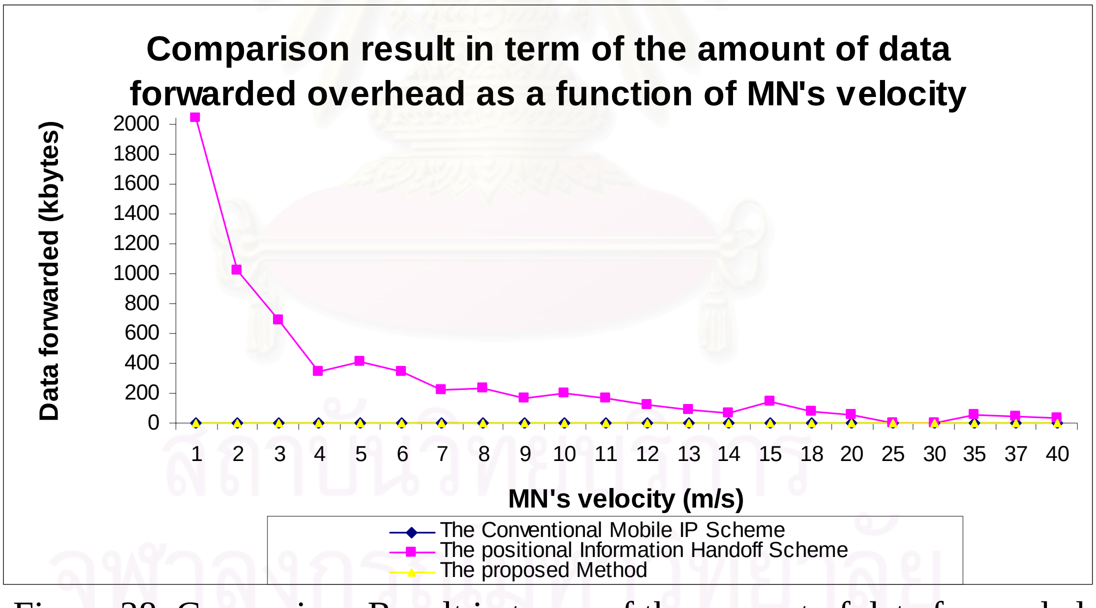

Figure 38. Comparison Result in terms of the amount of data forwarded overhead as a functions of MN's velocity

5.3.2.2 AS A FUNCTIONS OF MN'S POSITION WHEN ADV IS BROADCAST

In this section, we do simulation by MN's velocity of 20 m/s, $T_{shorten}$ ADV is 100 ms, and MN starts to move in FA at same position in order to receive ADV message.

Figure 39 shows that the traffic overhead caused by frequent shortened ADV in both of the conventional Mobile IP and the proposed method achieve zero, while in the positional information handoff obtains from three to ten shortened ADVs broadcast during handoff.

Figure 39 shows that closer MN's position to new FA, less number of shortened ADVs broadcast. The graph of number of shortened ADVs overhead occur ten ADVs when MN positioned at 340.001 meters and will decline orderly to three ADVs overhead when MN located at 354.015 meters in FA area.

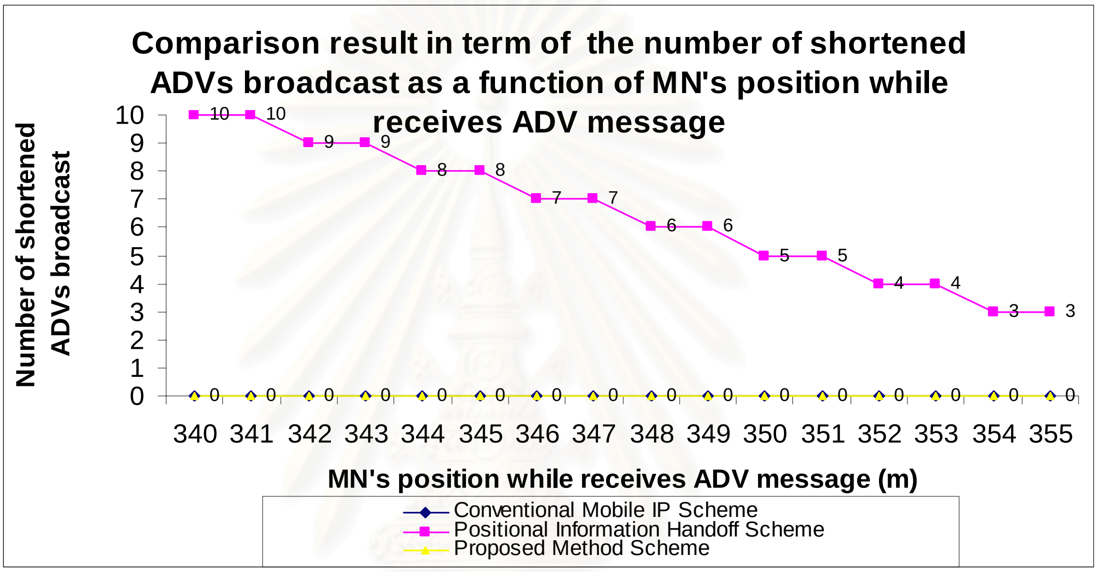

Figure 39. Comparison Result in terms of the number of shortened ADVs broadcast as a function of MN's position when ADV is broadcast

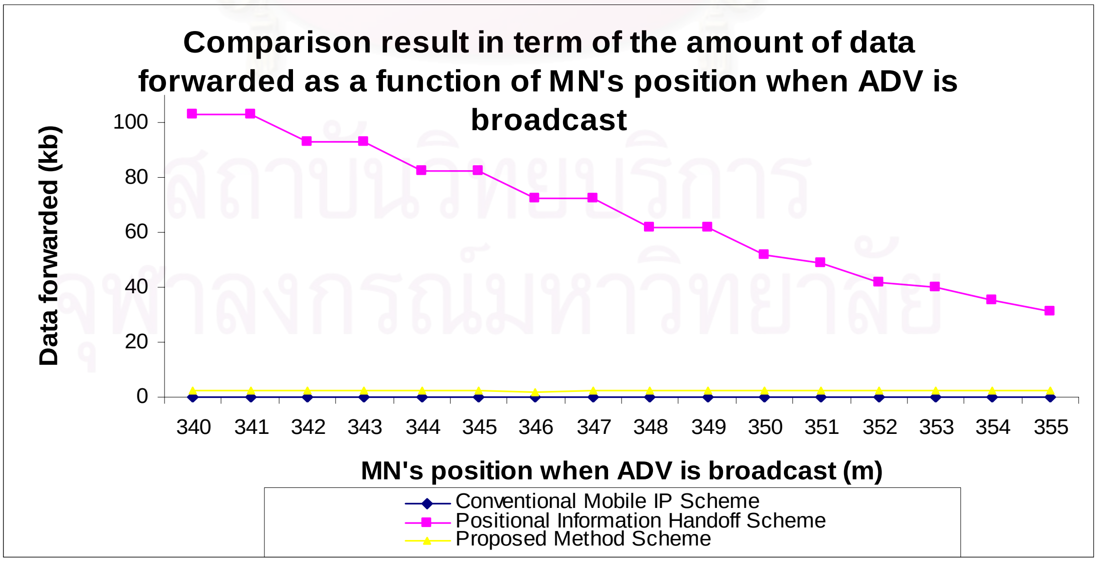

Figure 40. Comparison Result in terms of the amount of data forwarded overhead as a function of MN's position when ADV is broadcast

Figure 40 shows that the amount of data forwarded during handoff in the proposed method scheme less than those of the positional information handoff scheme. We obtain zero data forwarded overhead in the conventional Mobile IP and we get only 2.048 to 2.56 kb of data forwarded to new FA in the proposed method. But, in the positional information handoff method occur 31.232 kb to 102.913 kb of data forwarded during handoff.

Figure 40 shows that at the positional information handoff scheme, closer MN's position while detects handoff to new FA tends to obtain less data forwarded to new FA because the time for MN to move in new FA is short. We also have conclusion that the amount of data forwarded performance in the proposed method scheme less than those of the positional information handoff method, thus the objective of the proposed method to avoid increasing traffic overhead can be achieved.

5.3.2.3. AS A FUNCTIONS OF DISTANCE BETWEEN TWO FAs

Traffic overhead also has correlation to the various distance between two FAs because , $T_{shorten}$ ADV, $T_{improving}$ ADV and T_{buffer} will arrive at new FA in different time. Higher the gap between two FAs, longer delay time occur which causes increasing of the traffic overhead as shown in Figure 41 and Figure 42.

The simulation is run with velocity of 20 m/s. Other parameters such as described in section 5.2 are also followed.

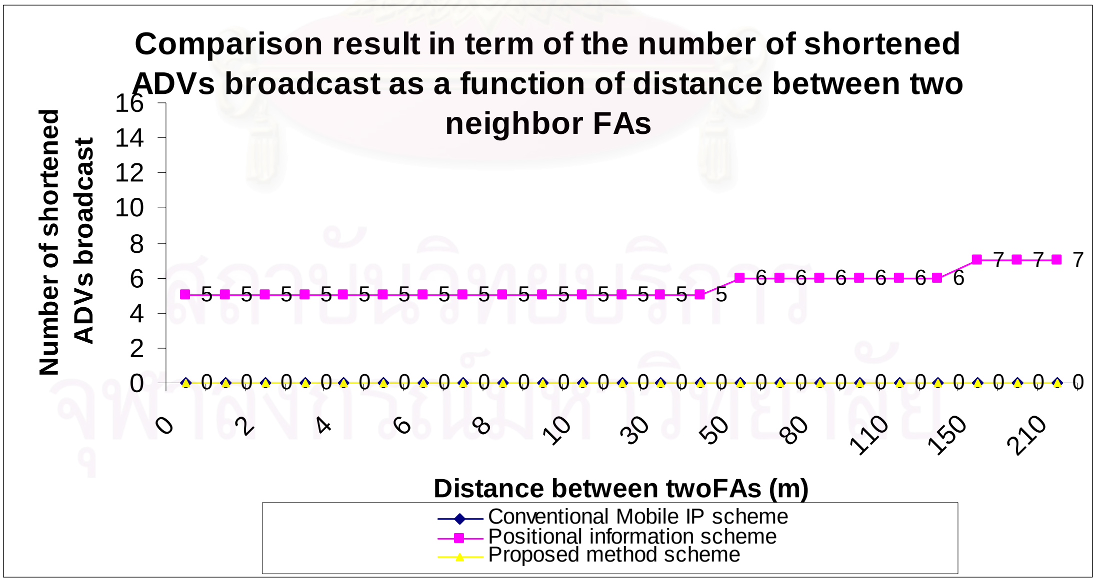

Figure 41. Comparison Result in terms of the number of shortened ADVs broadcast as a functions of the distance between two FAs

We know that the conventional Mobile IP and the proposed method scheme do not implement shortened ADV during handoff.

Figure 41 shows that number of shorten ADVs s that is broadcast during handoff in the positional information handoff scheme increases as a consequent of higher gap between two FAs. Figure 41 shows that every increasing of 100 ms of gap between two FAs occur more one shortened ADV. Figure 41 shows that six ADVs occur when the gap is 50 ms incline to seven ADVs when the gap between two FAs of 150 ms.

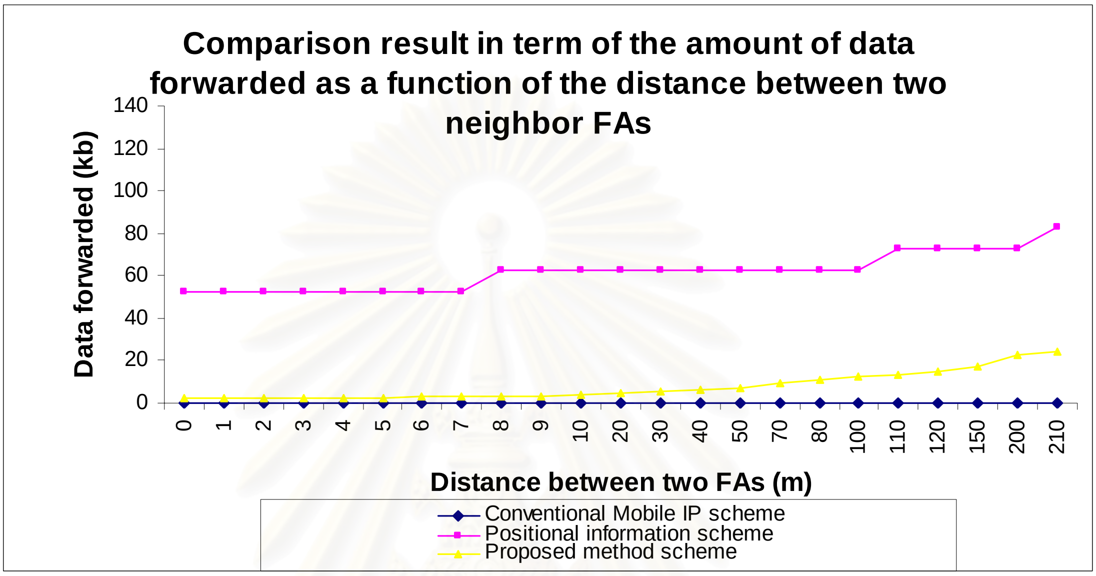

Figure 42. Comparison Result in terms of the amount of data forwarded overhead as a functions of the distance between two FAs

Figure 42 shows that the overhead of data forwarded in the positional information handoff and the proposed method scheme incline significantly as a consequent of the increasing of the distance between two FAs. The minimum of data forwarded in the positional information handoff is 52.224 kb obtained when the gap between two FAs is from 0 ms to 7 ms, while the maximum result of 82.994 kb obtained when the distance between two neighbor FAs is 210 ms.

In the proposed method, the data forwarded increases significantly as a functions of the increasing distance between two neighbor FAs as shown in Figure 42. Highber distance or gap between two FAs causes longer time for MN to reach new FA results higher data forwarded to new FA as shown in Figure 42.

5.4 MULTIPLE MOBILE NODES

In this section, we will compare the performance of the conventional Mobile IP, the positional information handoff, and the proposed method scheme in terms of the number of lost packets and traffic overhead as a functions of multiple MNs involved in handoff process whereas each MN will be investigated by each other.

In this simulation, we develop a new program in Borland Delphi 7 in order to implement multiple MNs which achieves until ten MNs that are simulated in the same topology network as shown in Figure 18.

We start to investigate number of lost packets, shortened ADVs overhead and also a huge amount of data forwarded to new FA during handoff for all MNs and at each MN. Same parameters as described in section 5.2 are followed.

5.4.1. IN TERMS OF PACKET LOSS

In the simulation, when each MN exceeds a threshold, the interval of shortened ADV period in the positional information handoff scheme is set to be 100 ms. The position of MN while receives ADV message also set in random for all three methods. The distance or gap between two FAs set to be 0 ms. By this parameter, we can obtain the lost packet performance closer to real situation. The result can be shown in Figure 43.

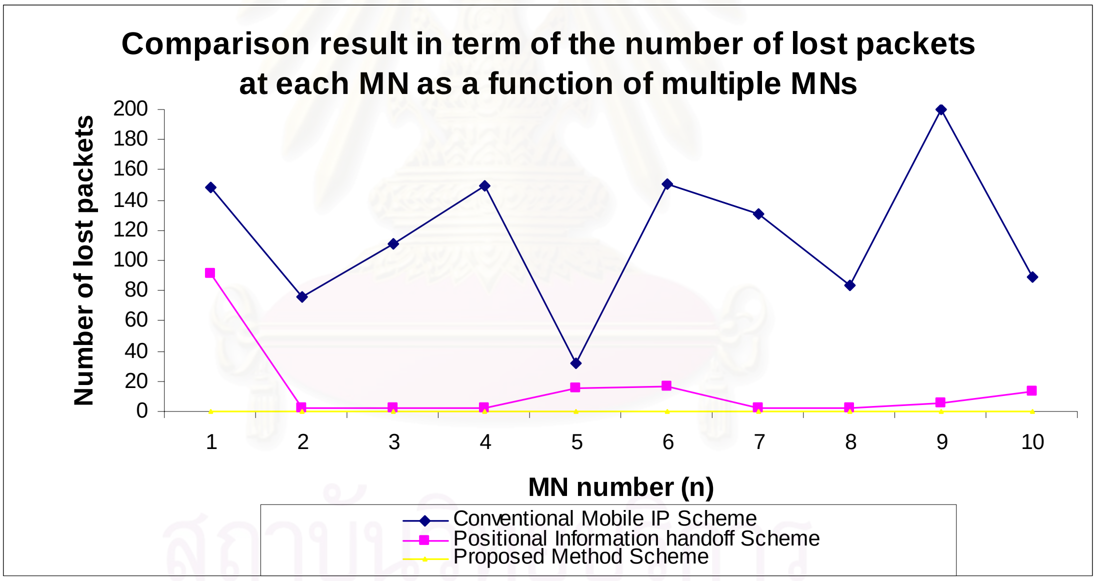

Figure 43. Packet loss performance at each MN as a functions of random MN's velocity and MN's position when ADV is broadcast

Figure 43 shows that the number of lost packets that are occurred in the proposed method achieves to be zero at each MN. The time taken for MN to receive tentative registration in new FA after moving in is 0.223 ms to 1.788 ms at each MN which causes no lost packet.

The conventional Mobile IP results many lost packets at each MN as a consequent of high handoff latency. When MN has already moved in new FA but MN has to wait for next ADV which is broadcast once a second. In the positional information handoff scheme occurs number of lost packets less than those of the conventional Mobile IP scheme. Figure 43 shows that first MN in Positional information handoff scheme occurs ninety one lost packets because MN loses connection to FA before detecting handoff causes shortened ADV broadcast every 100 ms is failed, but at other MN the number of lost packets is not as many as packet loss of Conventional Mobile IP scheme. The simulation shows that the proposed method scheme still achieves zero lost packets at uncertainty condition at each MN.

When we set the same parameter that is used at each MN, we got results as shown in Figure 44. The figure 44 shows that the trend of number of lost packets incline as a functions of increasing number of MNs in the conventional Mobile IP and the positional information handoff scheme.

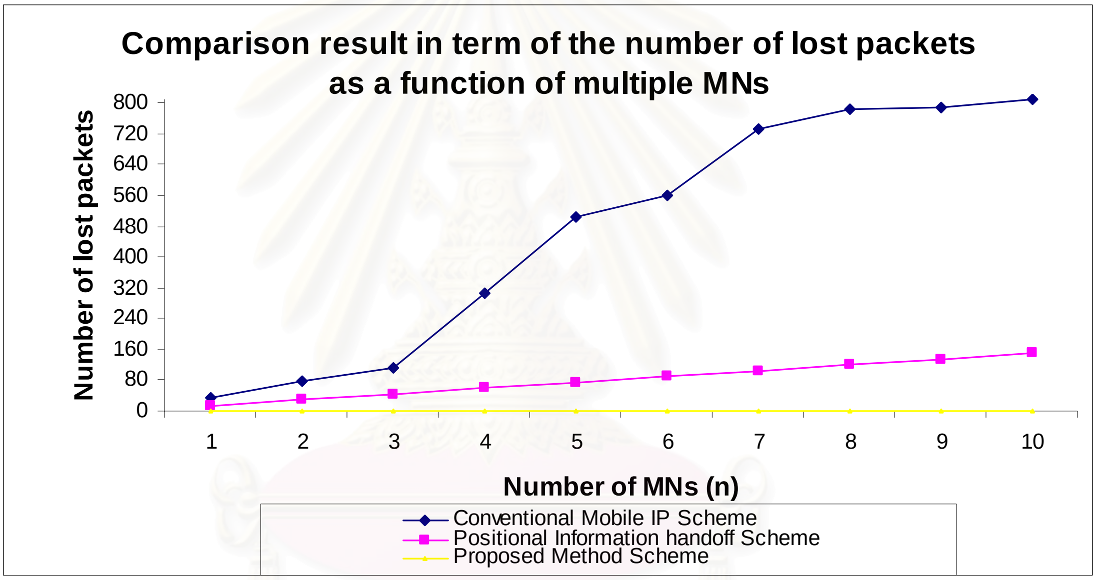

Figure 44. Total number of lost packets as a functions of multiple MNs

5.4.2. IN TERMS OF TRAFFIC OVERHEAD

In this section, we investigate the amount of data forwarded to new FA during handoff process. As we know, that the data forwarded only occur in the positional information handoff and the proposed method scheme. In the positional information handoff method, packets will be copied and forwarded to new FA for a moment after FA detects MN's position exceeds a threshold. The packet forwarding mechanism will stop after MN receives registration reply from HA via new FA. But, in the proposed method, the packet will be forwarded to new FA when MN has moved out of FA. From the theory then we can assume that the traffic overhead performance in the proposed method less than those of the positional information handoff method.

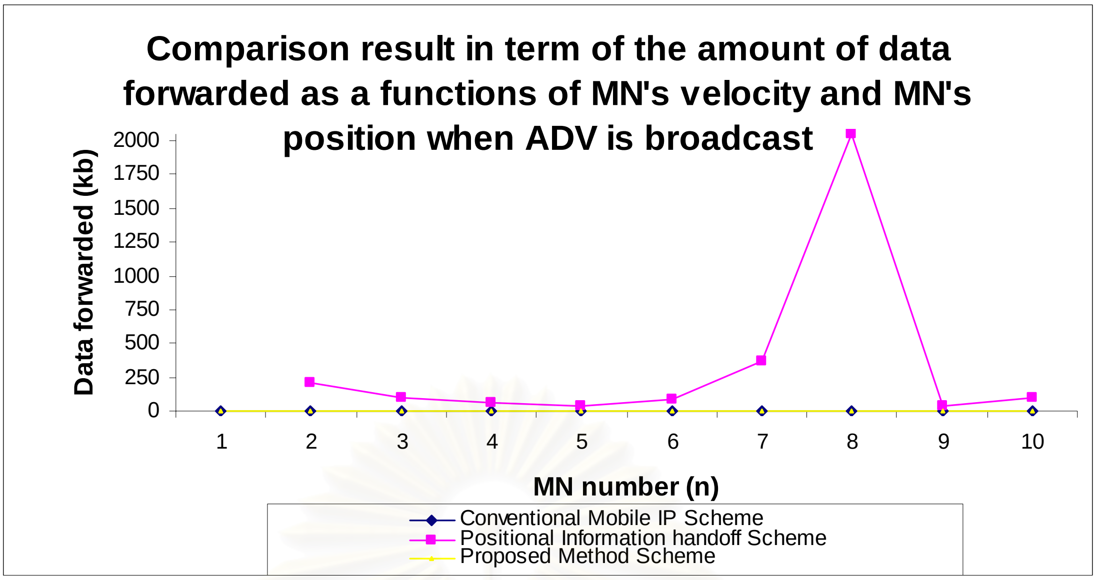

Figure 45. The amount of data forwarded at each MN as a functions of random MN's velocity and MN's position when ADV is broadcast

Figure 45 shows that the data forwarded in the positional information handoff scheme obtains in various results. The proposed method scheme for all MNs can achieve low data forwarded overhead. The amount of data that is forwarded to new FA is from 2.048 kbytes to 3.072 kbytes, so if we total all of the data forwarded at each MN, we find that the proposed method's traffic overhead performance achieves better result than those of the positional information handoff scheme as shown in Figure 46.

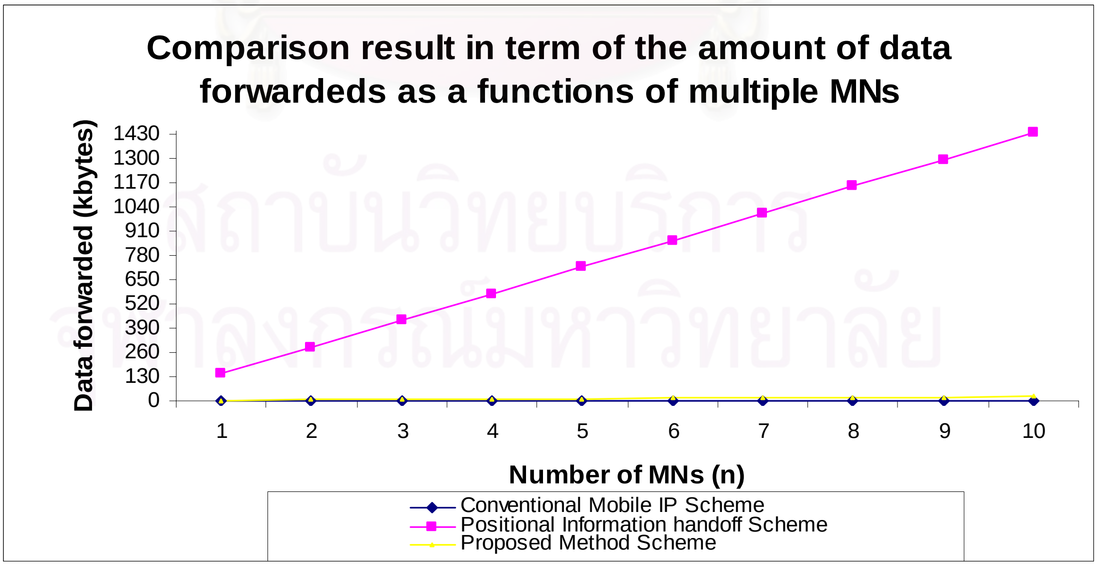

Figure 46. Total amount of data forwarded as a functions of multiple MNs

5.5 HIGHLIGHT OF COMPARISON BETWEEN THE PROPOSED METHOD AND POSITIONAL INFORMATION BASED HANDOFF SCHEME

This section briefs the comparison between the positional information based handoff and the proposed method scheme in terms of handoff latency and the amount of data forwarded during handoff. We compare the proposed method with the positional information based handoff scheme instead of the conventional Mobile IP scheme because the positional information based handoff and the proposed method scheme use GPS embedded in mobile phone while the conventional Mobile IP scheme not.

The thesis objective is to achieve low latency handoff without increasing traffic overhead. This section wants to show the performance results between the positional information based handoff and the proposed method scheme as thesis objective's recommend, so we will show the results of handoff latency and the amount of data forwarded during handoff. The simulation research implements as a functions of MN's velocity and distance or gap between two neighbor FAs.

5.5.1 PERFORMANCE RESULTS IN TERMS OF HANDOFF LATENCY

Handoff latency is time taken for processing handoff that is started when MN receives last packet from previous FA until receives first packet from new FA. The positional information based handoff and the proposed method scheme starts to receive first packet from new FA after a tentative registration arrives at MN. But, these both methods use different router solicitation signaling in order to lower handoff latency. The positional information based handoff scheme uses $T_{shorten}$ ADV message while the proposed method scheme uses $T_{improving}$ ADV message as mentioned before. Then we compare the performance results as a functions of MN's velocity and distance between two neighbor FAs as shown in Figure 47 and Figure 48.

In the positional information handoff scheme has three tendencies of handoff latency. First, handoff latency occurs around 6 – 8 ms when MN moves with velocity within 1, 2, 4, 5, 10 and 20 ms. This happens because when MN moves in new FA, MN has to wait for short period time for receiving ADV message.

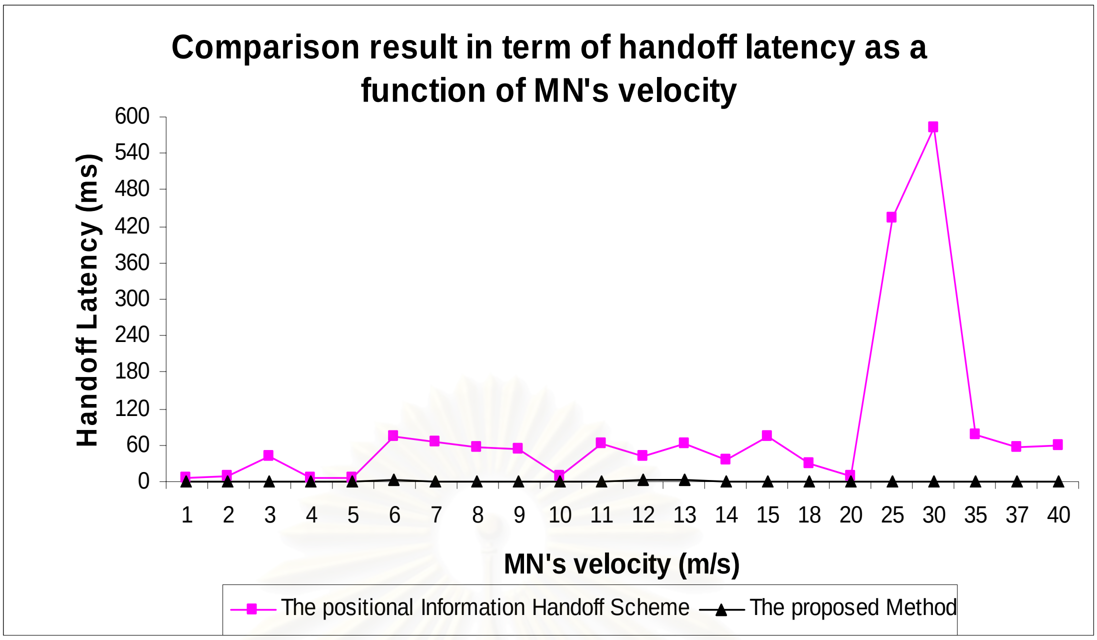

Figure 47. Comparison Result in terms of Handoff Latency as a function of MN's velocity

Second, mostly handoff latency occurs around 40 – 80 ms when MN moves with velocity of 3, 6, 7, 8, 9, 11, 12, 13, 14, 15, 18, 35, 37, 40 m/s. It happens because MN which has already moved in new FA, MN still has to wait for receiving ADV message longer than MN's expected. Third, handoff latency around 400 ms to 600 ms when MN moves with velocity of 25 dan 30 m/s which causes losing connection from FA before FA detects handoff.

The handoff latency result in the proposed method is much better than that in Positional information handoff method as shown in Figure 47. The minimum is 0.595 s while the maximum one is 1.859 ms. It happens because the proposed method scheme uses $T_{improving}$ ADV which can lower the time of MN for waiting ADV message in new FA.

Varied the distance between FAs causes various handoff latency. Different distance between two FAs causes various time delay of arriving $T_{shorten}$ ADV of the positional information based handoff scheme and $T_{improving}$ ADV of the proposed method scheme at new FA which causes different time for MN to request registration. This simulation is run with velocity of 20 m/s.

The trend of handoff latency in the positional information handoff scheme inclines as a consequent of higher gap between two FAs. It has three steps inclining. First inclining occurs handoff latency from 7.991 ms to 106.992 ms when the gap between two FAs is 8 ms. Second inclining occurs handoff latency from 108.993 ms to 206.993 ms when the gap between two FAs is 110 ms. Third inclining occurs handoff latency from 206.994 ms to 307.994 ms when the gap between two FAs is 210 ms.

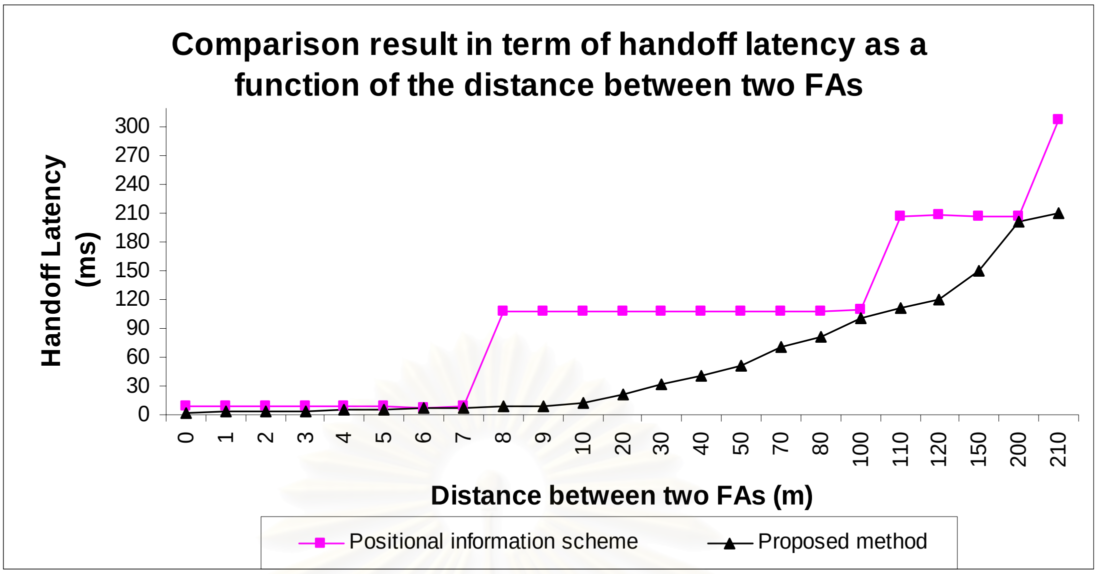

Figure 48. Comparison Result in terms of Handoff Latency as a function of distance between two neighbor FAs

The trend of handoff latency at the proposed scheme tends to incline orderly as a result of higher gap between two FAs. First trend of handoff latency occurs around 0.9 – 11 ms. Second trend, handoff latency of 20 – 80 ms achieved by the gap between two FAs of 20 – 80 ms. And the third trend of handoff latency of 100 – 210 ms achieved by the gap between two FAs of 100 – 210 ms.

From this simulation results, we conclude that handoff latency of the proposed scheme is lower than that in the positional information based handoff scheme as a functions of MN's velocity and distance between two neighbor FAs.

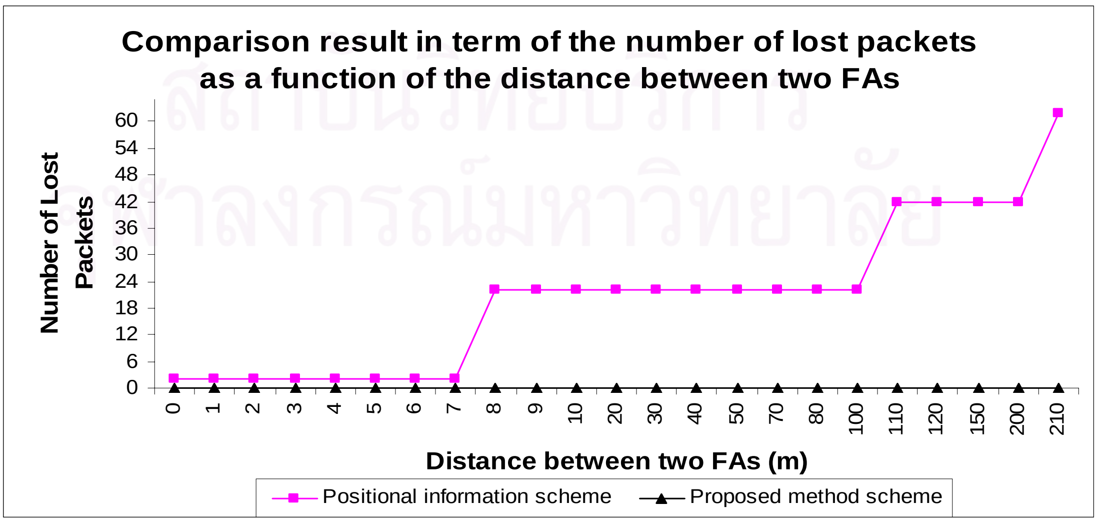

Figure 49. Comparison Result in terms of number of lost packets as a functions of the distance between two FAs

Figure 49 shows that the number of lost packets as a function of distance between two FAs in the proposed method still achieves zero packet even though the handoff latency increases as a consequence of increasing gap between two FAs. It happens because the proposed method scheme implements buffering during a time when MN moves out of previous FA until completing registration process in new FA.

5.5.2 PERFORMANCE RESULTS IN TERMS OF DATA FORWARDED

Packet forwarding overhead is defined as the amount of data forwarded from previous FA to new FA during handoff process. In the positional information handoff scheme when FA detects MN's position exceeds an threshold, FA starts to copy and forward packets to new FA while in the proposed method scheme, packets start to be forwarded at the time when MN moves out of FA as an impact of T_{buffer} message.

This simulation shows the results of data forwarded performance as a functions of MN's velocity and distance between two FAs.

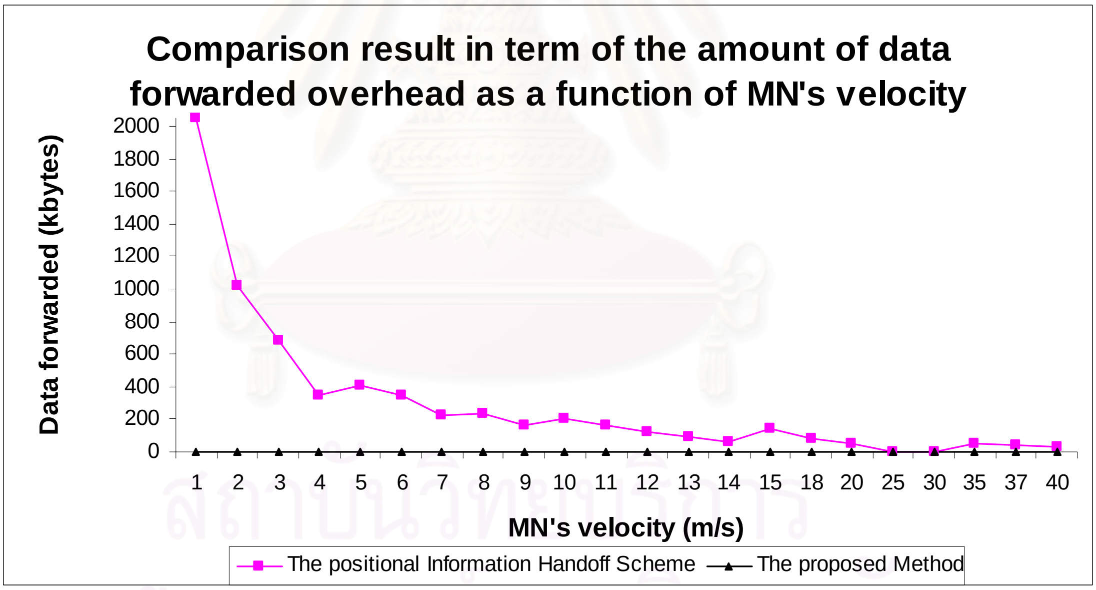

Figure 50. Comparison Result in terms of Data forwarded as a function of MN's velocity

Figure 50 shows that the amount data forwarded in the positional information handoff scheme is 2048.512 kb when MN moves with velocity of 1 m/s and it decreases at 31.232 kb when MN moves with velocity of 40 m/s. It happens because packets start to be forwarded at the time when MN's position exceeds a threshold. Slower MN's velocity to arrive at new FA, longer time for processing handoff causes higher data forwarded to new FA.

We also got that the overhead of data forwarded in the proposed method achieves less data forwarded overhead. The proposed method occur data forwarded of 2.048 to 2.56 kb during handoff as shown in Figure 50. It happens because the gap between two FAs is 0 ms, so the results of data forwarded as a function of MN's velocity is not significantly influential.

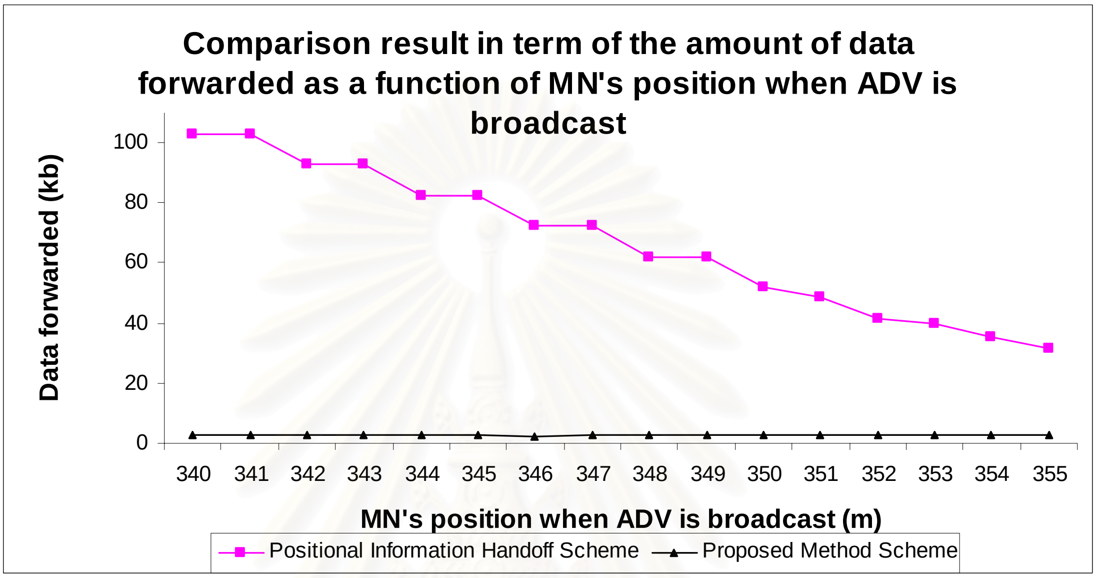

Figure 51. Comparison Result in terms of Data forwarded as a function of distance between two neighbor FAs

Figure 51 shows that the overhead of data forwarded in the positional information handoff and the proposed method scheme incline significantly as a consequent of the increasing of distance between two FAs. The minimum data forwarded in the positional information handoff is 52.224 kb occur when the gap between two FAs of 0 - 7 ms, while the maximum result of 82.994 kb obtained when the distance between two neighbor FAs is 210 ms.

In the proposed method, the data forwarded increases significantly as a function of the increasing distance between two neighbor FAs as shown in Figure 51. Higher distance or gap between two FAs causes longer time for MN to reach new FA results higher data forwarded to new FA as shown in Figure 51. The minimum data forwarded in the proposed method is 2.048 kb when the gap between two FAs is 0 ms, while the maximum one is 24.064 kb when the gap between two FAs is 210 ms.

The simulation results show that the proposed method scheme achieves less data forwarded during handoff than that in the positional information based handoff scheme.

CHAPTER 6

CONCLUSION AND RECOMENDATION

This research tries to investigate and evaluate the system performance of the positional information based handoff method and the proposed method scheme over the conventional Mobile IP method in terms of handoff latency, the number of lost packets, and the traffic overhead that are based on network layer by (L3) recommended.

We have implemented all methods based on L3 triggers in the Borland Delphi 7 for network simulation. In the conventional Mobile IP method, handoff is detected when MN receives new agent advertisement which contains a new network prefixes, while in the positional information handoff and the proposed method, handoff is triggered by MN's position when it exceeds a threshold.

Since the L2 handoff method can solve the problem of handoff in overlapping area but L2 handoff does not work well in non-overlapping area referred in many papers, so the proposed method tries to do simulation and investigate whether the proposed method can work well or not in the bordering of non-overlapping area.

The research also simulates multiple mobile nodes that are involved in handoff process in order that the proposed method does simulation research closer to the real application.

The simulation investigates about how the positional information handoff and the proposed method avoid lost packets by using MN's position for triggering handoff. The simulation shows that the number of lost packets in the positional information based handoff and the proposed method are less than those of the conventional Mobile IP method because both methods allow MN to process handoff while still being in the previous FA.

During handoff, in the positional information based handoff and the proposed method scheme, FA solicits a Router ADV to new FA in order that MN can register earlier then it is followed by copying and forwarding packets to new FA. New FA sends the forwarded packet to MN after MN receives a tentative registration. The tentative registration indicates that MN can receive first packet before registration is completed which causes lower handoff latency.

The simulation results show that the positional information based handoff causes a disorganized problem as a consequence of fixed threshold mechanism. When MN moves with slow velocity, FA will detect handoff many times instead of processing handoff, but when MN moves so fast, MN loses connection to FA instead of detecting handoff.

Furthermore, the proposed method scheme implements a dynamic threshold. The dynamic threshold is defined as the multiplication between MN's velocity and ADV period which causes the range of the threshold change as a functions of MN's velocity. The simulation results show that a dynamic threshold can avoid the disorganized problem whether MN moves with fast or slow velocity which result in low handoff latency and minimize lost packets.

We also observed that the positional information based handoff scheme obtains unnecessary overhead as a consequence of $T_{shorten}$ ADV and packet forwarding mechanism. Shorter ADV period rate, lower handoff latency, and higher traffic overhead are caused by shortened ADV message, and longer handoff processing time and, higher traffic overhead are caused by packet forwarding mechanism.

The proposed method provides $T_{improving}$ ADV message which orders a new FA to broadcast ADV immediately when MN reaches new FA's boundary. The simulation results show that $T_{improving}$ ADV obtains low traffic overhead because there is no shortened ADV broadcast during handoff.

The proposed method also proposes T_{buffer} message which commands new FA in order to buffer packets at the moment when MN moves out of FA coverage area until registration process is completed. T_{buffer} message causes less traffic overhead than that in the positional information based handoff method as shown in the simulation.

The simulation results show that the proposed method has the best performance in the number of lost packets comparing with those of the positional information based handoff and the conventional Mobile IP method whereas the number of lost packets is always zero packet in all situations.

We also find the disadvantage of the proposed method scheme when the simulation implements previous link delay from NFA message as a component of $T_{improving}$ ADV more than the current link delay. The number of lost packets will be maximized up to two hundred and four packets. In order to avoid this problem, we do simulation many times in order to get the lowest link delay as a new component of $T_{improving}$ ADV.

Finally, we see that the simulation results have shown that the proposed method has the best performance system in terms of handoff latency, the number of lost packets, and traffic overhead. The simulation has been done as functions of MN's velocity, the distance between two FAs, random link delay, and MN's position when ADV is broadcast.

Now, we have conclusion that the proposed method can achieve low handoff latency and minimize packet loss without increasing traffic overhead in both bordering and non-overlapping areas.

Future Work

In this research, we assume that MN knows its position from Global Positioning System (GPS) embedded in mobile phone. In the next research, we recommend to develop a new algorithm which supports to determine MN's position in order to implement in real application.

The simulation program can only do simulation up to ten mobile nodes. However, future research should be observed to develop a new program simulation which can implement up to hundred or thousand MNs.

We also recommend for next research to investigate the signaling cost of wired network caused by the amount of data forwarded by packet forwarding mechanism.

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Biography

Muhammad Nur Rizal was born in 1975 in Surabaya, Indonesia. In 1999, he received his Ing. in Electrical Engineering from Gadjah Mada University, Indonesia. From 2000 to now, he has been a lecturer at Electrical Engineering Department, Faculty of Engineering, Gadjah Mada University, Indonesia. From 2001 to 2002, he worked as an assistant of vice rector to General Administration in Information Technology Auditing Area. From 2001 to 2002, he worked for Faculty of Engineering at Gajah Mada University as Head of Computer Training Centre. His research interest is in the Mobile Internet Protocol in telecommunication system.