國立交通大學

資訊工程系

碩 士 論 文

以 IEEE 802.11 為輔的快速無線網路基地台交換

Speedy handover: Improving handover performance based on IEEE 802.11 mechanism

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中文摘要

當可攜式無線設備進行基地台轉換的時候，會有一段時間無法接收封包。在連接上新的基地台之前，無論封包的傳送者或是可攜式無線設備的原網域之代理伺服器皆無法得知新基地台的相關資訊。送給這個可攜式無線設備的封包還是會被先送往舊的機地台，但舊基地台已無法和可攜式無線設備取得聯繫，因此，這些封包會遺失在舊基地台。

為了解決這個問題，很多改進的方式已經被提出來，其中一種是舊基地台會幫可攜式無線設備將封包暫存起來，使得當可攜式無線設備移開後，封包不至於會遺先，並在它連上新的基地台之後，將這些封包轉送給它。

但是，將封包暫存封包的時機是很值得研究的，因為漫無目的地暫存會行成記憶體的浪費。本篇論文中，使用基地台和可攜式無線設備間快速地 RTS/CTS 訊息交換，來偵測可攜式無線設備是否離開基地台的傳送範圍。如果離開了，便為給它的封包暫存起來。等到新基台確定後，再予以轉送。

Speedy handover: Improving handover performance based on 802.11 mechanism

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Abstract

During handover period, packets for the mobile node maybe lost in its old foreign agent (FA), because it will attach to another new FA and has detached from the old one.

We want to keep these packets and forward them to the mobile node. However, when to buffer and to forward packets is a big subject. If packets are buffered too often, the buffer size will be wasted too much.

In our scheme, we use RTS/CTS messages exchange between FA and the mobile node to detect if the mobile node still attaches to the FA or not. When a FA have send RTS for several times but not being responded by the mobile node, it buffer packets for the mobile node. After the mobile node attaches to a new FA, the old FA forwards these packets to the mobile node.

We reduce packet loss rate and handover time successfully.

致　謝

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中華民國九十三年六月

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Chapter 1 Introduction

Unlike wired devices a mobile node does not always stay at the same place. While moving, they need to associate with another access point and router. They must exchange some information with a new agent for registration. The registration procedure needs some time, and during this time the mobile node can not receive any data packets. It is a serious problem for wireless.

There are more and more applications, especially multi media services on wireless devices. For example, we can speak to others through internet phone or watch a movie with our note book, so we can have a call and see a movie when drinking a coffee in a coffee shop, taking a bus and so on everywhere. It is very convenient for us.

On the other hand, clients also care about the quality of there services. Watching a movie, they need smooth frames. Using the internet phone, they want the voice be continuous. Clients want comfortable services. Quality services are what we want to support.

The quality degrades when the mobile node moves because of handover. Some researches have focused on the problem of handover such as fast handover, hierarchical mobile IP, and HAWAII. These works upgrade the performance successfully but there are still some drawbacks need to be improved.

Some methods let a router to buffer and to forward packets for mobile nodes, but these methods do not have a good mechanism to judge when to buffer. Therefore they can not utilize the buffer space efficiently.

In this thesis, we propose a new enhanced method in layer 2 to monitor the mobile nodes, as well as a new mechanism to forward the packets. Our new method is called "Speedy handover: Improving handover performance based on 802.11 mechanism".

The rest of this thesis is organized as follows. In Chapter 2, we introduce the background and related works. We also show the problems to be addressed and related researches. In Chapter 3, we discuss the proposed method in detail. The simulation results are based on ns-2 simulator and are presented in Chapter 4. Chapter 5 concludes the work.

Chapter 2 Background and Related Works

In this chapter, we describe the background and related works. We introduce some layer 2 functions and some other methods used during the handover. We focus on RTS/CTS exchanges, fast handover, hierarchical structure, and HAWAII in this chapter.

2.1 RTS/CTS exchange

In IEEE 802.11, when a wireless device wants to send data packets to another one, it firstly sends a “request to send” (RTS) message which can clean up wireless channel and avoid interference from other devices. After receiving “clear to send” (CTS) message, that device can start sending packets.

2.1.1 Hidden terminal problem

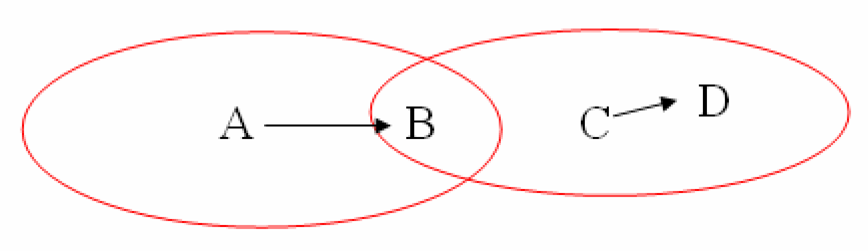

Figure 2.1 Hidden terminal problem.

In figure 2.1, there are four wireless devices, A, B, C and D. The device B can hear the radio signal from both device A and device C, but device A and device C can not hear each other. When device A sends a data packet to device B, device C can not hear A. Thus device C may send data packet to device D at the same time period. In this case, these two packets may collide at device B, neither packet from A nor packet from C can be received by B.

The problem described above is called "hidden terminal problem".

2.1.2 The solution

In IEEE 802.11, RTS-CTS exchange is used to solve hidden terminal problem as follows:

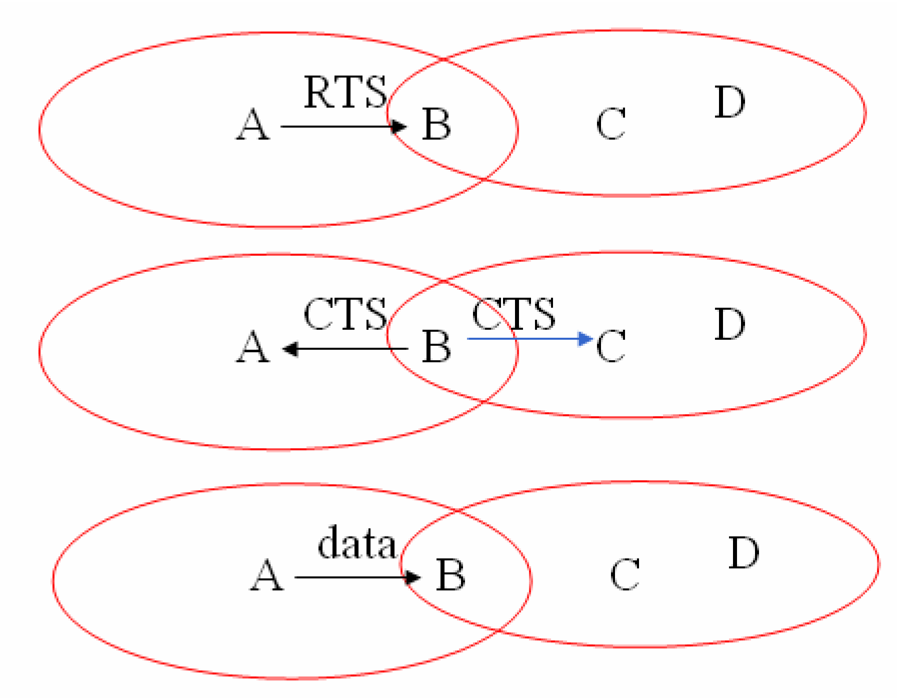

Figure 2.2 RTS/CTS exchange.

Before sending a data packet, device A sends out a RTS message to tell the wireless devices around it and device B. Device B returns a CTS message. Every wireless device excluding device A which has received the CTS will not send any packet until device A finish the packet transmission, so no collision will occur.

A RTS and a CTS message include the information called NAV regarding the time when device A need to send the data packet.

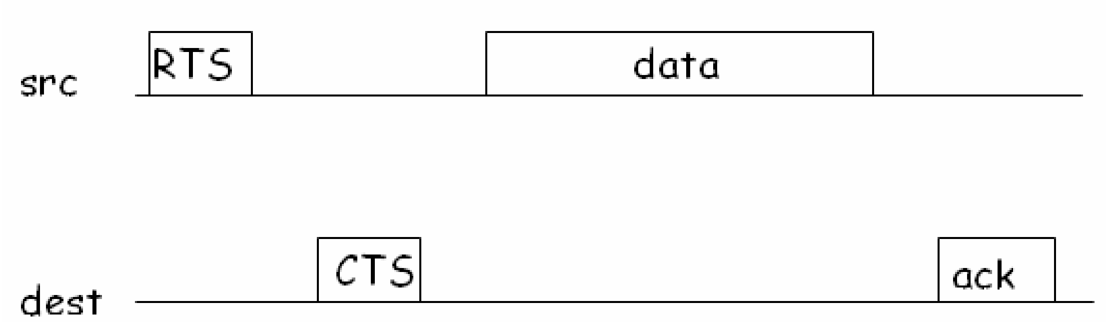

Figure 2.3 RTS/CTS mechanism.

2.1.3 The mobile node detection

Because a RTS/CTS message is short, it can be transmitted quickly, and less affected by random loss, thus it can also be used by an AP or an AR to detect whether the mobile node has moved away or not. This is the main idea of this thesis. We will describe the details in Chapter 3.

2.2 Fast handover

Fast handover is a layer 2 trigger mechanism. A mobile node can be informed that it is associating with a new access router by a layer 2 trigger.

2.2.1 Handover mechanisms

The main idea of the fast handover is to anticipate the layer 3 handover of a mobile node. The layer 2 mechanism triggers the mobile node movement anticipation. We want to let the layer 3 handover starts before the layer 2 handover terminates. Some layer 2 protocol informs us that layer 2 starts. There are some useful information from layer 2 trigger such as which new access point the mobile node will attach to. The link layer address of the new access point is what we need for the anticipative layer 3 handover. There are three kinds of the layer 2 triggers, as described in the following: (1), Link Up: showing that the mobile node has attached to a new access point; (2), Link Down: showing that the mobile node has detached from an old access point; (3), Layer 2 Handover Start: showing that layer 2 handover of a mobile node starts and going to attach to a new access point.

An old access router can get the link layer address of the new access point in a layer 2 trigger, but we also need the IP address of the new access router that the new access point belongs to. Since we can only get the new access point identification from the layer 2 trigger, the neighbor discovery is necessary for exchanging information between access routers. The information exchanged can be a network prefix or a list of the access points associated with the new access router subnet.

There are two different mechanisms described in the draft of the fast handover, there are anticipated and tunnel-based handover. Tunnel-based handover needs more information in the layer 2 trigger than anticipation-based handover, so a layer 2 independent solution will make tunnel-based handover infeasible. In principle, a layer 2 independent solution would be a more desirable solution. Therefore we often prefer to use anticipation-based handover, which only depends on layer 3 information. We describe these two mechanisms briefly below.

2.2.2 Anticipated handover

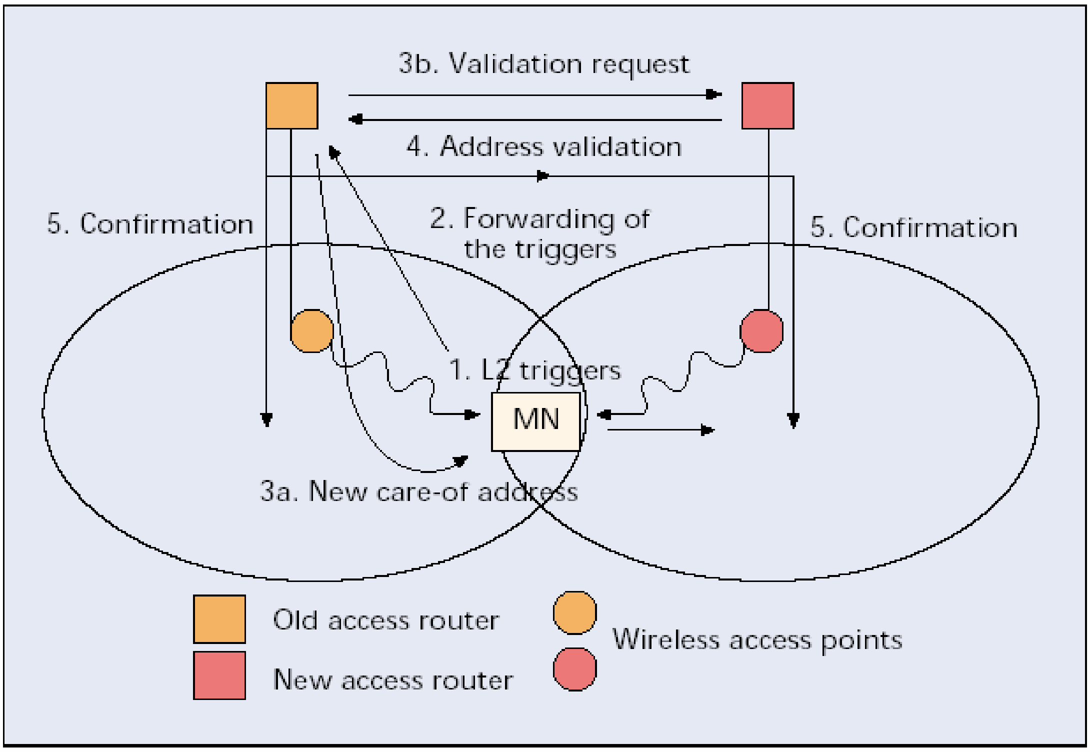

Figure 2.4 Fast handover.

The main idea of anticipated handover is to setup a new link before breaking the old one. Anticipated Handover proposes a "make-before-break" approach. When a MN has predictive information about the next point of attachment to which the MN will move, e.g. reception of a Router Advertisement from a new access router (nAR), it sends a Router Solicitation for Proxy (RtSolPr) to the old AR (oAR) with an identifier of the attachment point to which it wants to move. Once the oAR receives information that a MN wants to move to an nAR, it constructs an nCoA based on the MN's interface ID and the nAR's subnet prefix. It then sends a Proxy Router Advertisement (PrRtAdv) to the MN containing the proposed nCoA and the nAR's IP address and Link Layer Address. At the same time, the oAR sends a Handover Initiate (HI) message to the nAR, indicating the MN's oCoA and the proposed nCoA. Upon receipt of the HI message, the nAR .validates whether the nCoA is a valid address on its subnet, and performs checking to ensure that it is not a duplicate. If the nCoA is accepted by the nAR, the nAR adds the nCoA to the Neighbor Cache for a short time period so it can defend it. The nAR then responds with a Handover Acknowledge (HACK), indicating that the proposed nCoA is valid. In case the nCoA is not valid (duplicated address) the nAR adds a host route for the oCoA pointing to its mobility interface, for a short time period and responds to the oAR with a HACK indicating that the proposed nCoA is not valid. Upon receipt of the HACK, if the HACK indicates that the nCoA is valid, the oAR prepares to forward packets for the MN to the nCoA. If the HACK indicates that the nCoA is not valid, the oAR prepares to tunnel packets for the MN to the oCoA at nAR. As soon as the MN received confirmation of a pending Layer 3 handover through the PrRtAdv and has a nCoA, it sends a Fast Binding Update (F-BU) to oAR, as the last message before the Layer 2 handover is executed.

On receipt and validation of the F-BU, the oAR responds with a Fast Binding Acknowledgement (F-BAck), destined to the nCoA. The oAR waits for a F-BU from the MN before actually forwarding packets. On receipt of the F-BU, the oAR forms a temporary tunnel for the lifetime specified in the F-BAck, and the F-BAck is sent through the tunnel to the MN on the new link. When the MN arrives on the nAR and its Layer 2 connection is ready for Layer 3 traffic, it sends a Fast Neighbor Advertisement (F-NA) to initiate the flow of packets that may be waiting for it. The nAR will deliver packets to the MN as soon as it receives an indication that the MN is already attached to it, usually receiving a F-NA from the mobile node. The oAR is responsible for forwarding any packets that arrive for the MN under its oCoA after the MN has moved.

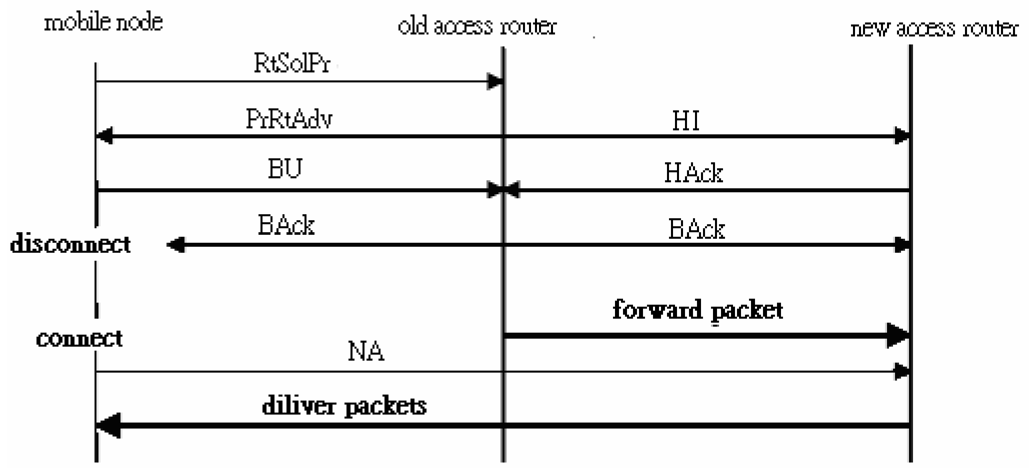

Figure 2.5 message flow of fast handover

2.2.3 Tunnel based handover

In tunnel-based handover, the MN delays the new care-of address establishment when it moves to a new AR. Therefore, it only performs an L2 handover and continues to use its old care-of address in the new subnet. Moreover, the MN does not need to exchange any packets: the two ARs set up a bidirectional tunnel from the L2 triggers without interacting with the MN. The packets intended for the MN reach the old subnet where they are captured and forwarded to the new AR by the old AR. The outgoing packets of the MN take the reverse path from the new AR to the old AR, which forwards them in the Internet. Later, the MN will create and register a new care-of address in parallel with its communications. Otherwise, if the MN moves quite fast, the tunnel would be extended to a third AR (handover to a third).

The use of L2 triggers allows the AR to detect MN movement without the need to send any packet. This is very useful because the cost to send a packet on a wireless interface is more expensive than on the wired interface.

The mechanism of buffering and forwarding packets is very useful, but the mobile node must pass through the overlapped area of radio of two access routers. If not, the mechanism will not work anymore, because the old AR has no idea about when the mobile node moves away and where the mobile node wants to go.

2.3 Hierarchical structure

Hierarchical structure can shorten wireless handover period in a micro network. It adds a new router called MAP router. The MAP router manages micro handover very well. By reducing handover time, we can also reduce the packet losses.

2.3.1 Hierarchical mobile IPv6

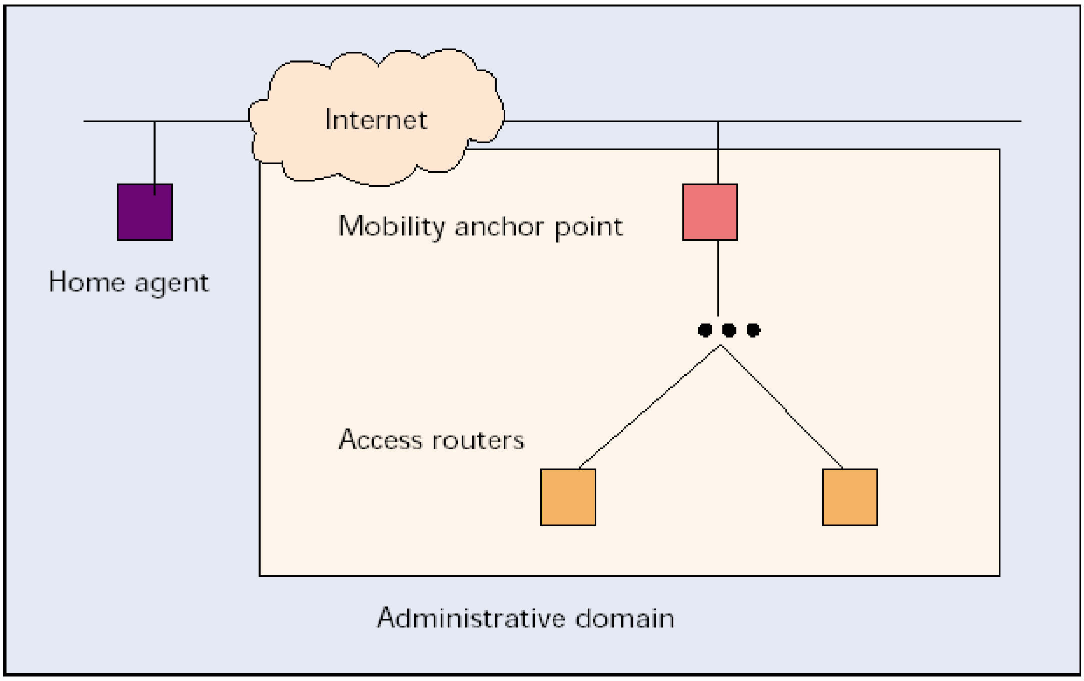

Figure 2.6 The hierarchical structure.

Flat Mobile IPv6 requires that the MN send a binding update to each of its correspondents and/or home agent. According to their locations, the time to reach them and the signaling load generated is very important. Hierarchical Mobile IPv6 is designed to minimize the amount of signaling to correspondent(s) and to the home agent by allowing the MN to locally register in a domain.

The global Internet is divided in regions defining local area mobility. These domains are independent of subnets and are generally managed by a unique administrative authority (e.g., a campus). Each domain is connected to the rest of the Internet by a mobility anchor point (MAP) witch acts like an anchor point for the MN. The mobility anchor point is an AR with a publicly routable IP address at the top of several ARs.

When the MN first enters a domain, it needs to make a *regional registration* to advertise to its home agent and correspondent(s) regarding its rough new location. It indicates a global care-of address for the domain (see next paragraph). Later, after each movement between ARs in the same domain, the MN needs to send a local registration to the mobility anchor point to update its location in the domain (on-link care-of address). Thus, all MN movements within the domain are hidden from the home agent and correspondent(s) because the global care-of address of the MN does not change.

2.3.2 The two modes of hierarchical MIPv6

The mobility anchor point is announced in the agent advertisement messages sent by the AR of the domain. When an MN enters a visited domain for the first time, it must perform a home registration. Next, when it moves within this domain, the MN can choose between *basic mode* and *extended mode*. In basic mode, the MN has two addresses: a regional care-of address based on the mobility anchor point prefix and an on-link care-of address based on the current AR prefix. In this scheme, the mobility anchor point acts as a home agent: it intercepts the packets destined to a regional care-of address and tunnels them to the corresponding on-link care-of address. These operations are totally transparent to the MN home agent, which does not need any modification.

However, not every MN can acquire an individual regional care-of address because of scalability or a network operator policy. In extended mode, the regional care-of address is (one of) the mobility anchor point address(es). The mobility anchor point keeps a binding table with the current on-link care-of address of an MN matched with the MN home address. When it receives the packets destined to an MN, it detunnels and retunnels them to the on-link care-of address. This implies that each packet must contain the MN home address.

2.3.3 Bicasting in hierarchical architecture

The bicasting done by the home agent, presented in an earlier section, is not scalable and can generate too long delay in packet delivery. The hierarchical model allows bicasting from the mobility anchor point. When an MN moves within a domain, it can request bicasting in its local registrations. This request is forwarded to the mobility anchor point, which adds a new entry for the MN (simultaneous bindings). Then the mobility anchor point forwards the same traffic to both the old and new MN locations. When bicasting is performed in this way, the packets are only duplicated within the domain.

However, the problem of scalability is not resolved if the mobility anchor point handles too many MNs. Considering several mobility anchor points per domain that are at the same level could resolve the scalability problem, becaouse these mobility anchor points could share the number of MNs. However, this method is still under discussion since it causes some problems: discovery of the other mobility anchor point(s), selection of one mobility anchor point by the MN, and load balancing among multiple mobility anchor points.

Although hierarchical mobile IP can shorten the handover time, the old AR never buffers and forwards packets for mobile nodes. Therefore, the packets maybe lost at the old AR when the mobile node leaves.

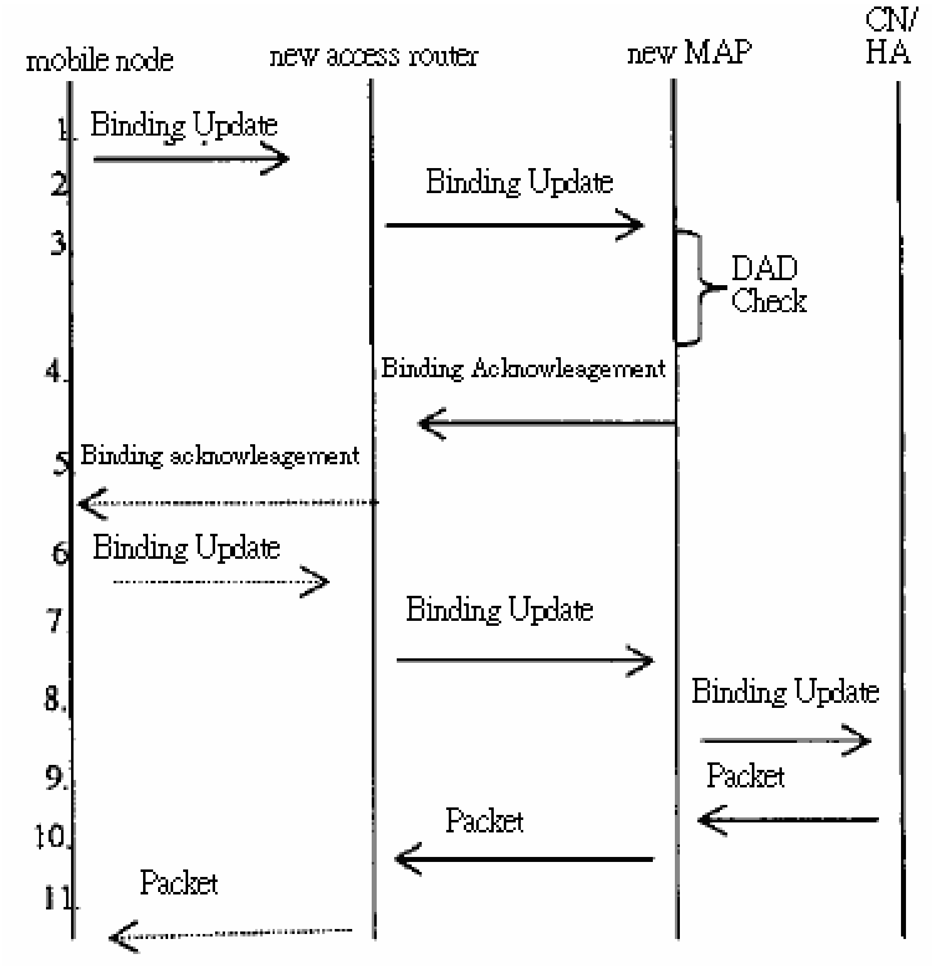

Figure 2.7 Message flow of hierarchical mobile IP.

2.4 HAWAII

HAWAII was proposed to the IETF by researchers from Lucent Bell Labs. Like in Cellular IP, HAWAII is responsible for the micro-mobility support while the macromobility is handled by Mobile IP.

In HAWAII a hierarchy based on domains is used. The gateway in each domain is called domain root router. A HAWAII domain comprises several routers and BSs running the HAWAII protocol, as well as MHs. There are three types of HAWAII path setup messages: (1), power-up, (2), update and (3), refresh.

On power up a MH sends a Mobile IP registration request message to the corresponding BS. The BS then sends a HAWAII path setup power-up message to the domain root router, this is processed in a hop-by-hop manner. On all routers on its way to the domain root router this power-up message adds a routing entry for the concerned MH. The domain root router finally acknowledges this path setup power up message to the BS, which finally notifies the MH with a Mobile IP registration reply.

The routing entries in the routers are in soft state, i.e. they have to be refreshed periodically by path setup refresh messages, which are sent independently by each network node and which can be aggregated.

Routers, not passed by a path setup message related to a MH, do not have any knowledge about its whereabouts. Whenever a router receives a packet for such an unknown MH, e.g., from another MH within the domain, it uses a preconfigured default interface pointing towards the domain root router. This packet will be forwarded in this direction until it will arrive at a router knowing a route to the addressed host. In the worst case this will be the domain root router.

Similarly to Cellular IP, a paging mechanism is foreseen for standby MHs. Mobile hosts in standby state only have to notify the network on a change of *paging area* and not on each BS handoff. When a packet arrives for a MH in standby state, the network has to page it before it delivers the packet. This paging induces the MH to switch to active state immediately. For using HAWAII'S paging support, it is necessary to have link-layer paging functionality on the wireless link which means that the MH is able to identify its paging area and to detect paging requests.

The network has to maintain paging information for each MH and has to deliver paging requests for these hosts up to the BSs from where on link-layer paging mechanisms are responsible. To achieve this HAWAII relies on the IP multicast routing protocol: each paging area is assigned a multicast group address, and all BSs within that paging area join this multicast group.

2.4.1 HAWAII path setup schemes

We now describe the operations of four path setup schemes used to establish path state when the MH moves from one BS to another. The four path setup schemes can be classified into two types based on the way packets are delivered to the MH during a handoff.

We define the cross-over router as the router closest to the MH that is at the intersection of two paths, one between the domain root router and the old BS, and the second between the old BS and the new BS.

2.4.2 Forwarding path setup schemes

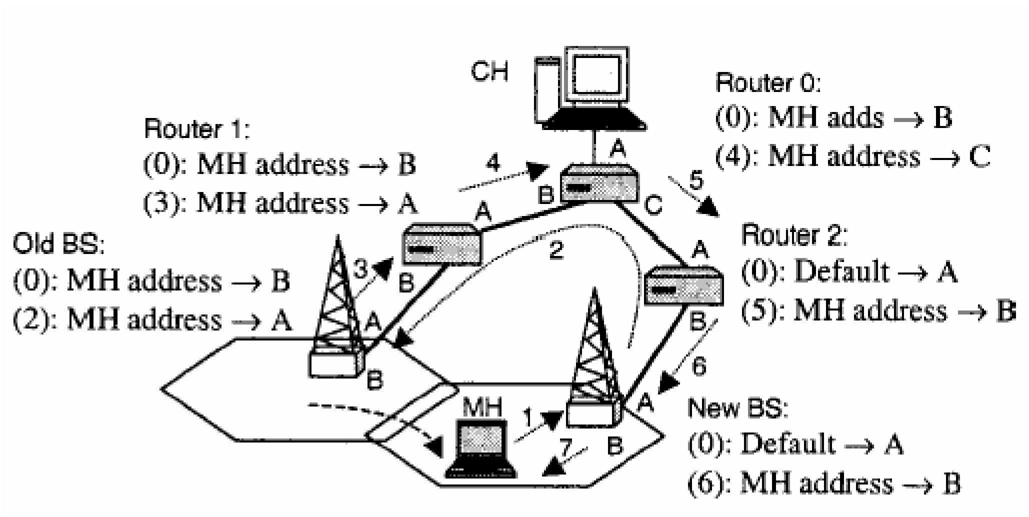

Figure 2.8 Forwarding path setup schemes.

In these path setup schemes, packets are first forwarded from the old BS to the new BS before they are diverted at the crossover router. Two variants of forwarding schemes in HAWAII are proposed, one that works with standard IP routing tables to update the host-based entries and, another scheme where the IP routing table is extended to accommodate interface-based information. These schemes are known as Multiple Stream Forwarding (MSF) and Single Stream Forwarding (SSF). In the following the MSF scheme analyzed in this paper is described.

The forwarding table entries are shown adjacent to the routers. For example, MH address→B means that the packets with destination the *MH address* are routed through interface B. These entries are prepended with a message number indicating which message was responsible for establishing the entry (a message number of zero indicates a preexisting entry). The letters denote the different interfaces. When the MH initiates the handoff it connects to the new BS (and thus, no more packets can be received from the old BS through the air interface). Then the MH sends a path setup message (Message 1) to the old BS along the new BS (Message 2). Message 2 contains the new BS address. The old BS performs a routing table lookup for the new BS and determines the interface, interface A, and next hop router, Router 1. The old BS then adds a forwarding entry for the MH's IP address with the outgoing interface set to interface A. It then forwards Message 3 to Router 1.Router 1 performs similar action and forwards the message to Router 0. which the cross-over router in this case, changes the forwarding entry that result in new packets being diverted to the MH at the new BS. It then forwards the message towards the new BS. Eventually Message 6 reaches the new BS that changes its forwarding entry and sends an acknowledgment of the path setup message to the MH, shown as Message 7.

Note that this sequence of updating the routers can lead to the creation of multiple streams of disordered packets arriving at the MH. For example, during transient periods newer packets forwarded by Router 0 may arrive at the MH before older packets forwarded by Router 1 which might in turn arrive before even more older packets forwarded by the old BS. This scheme can also result in the creation of transient routing loops (for example, after old BS has changed its entry to forward packets but before the Router 1 processes Message3). However, note that the disordered streams and routing loops exist for short periods of time. The main benefit of this scheme is that it is simple and results in no loss.

The BSs use a *forwarding buffer* for each MH in order to store the packets to be forwarded in the handoff procedure. All packets addressed to a MH are stored in the buffer (even after being transmitted to the MH). This allows that packets sent to the MH but lost because the MH moved out of coverage, will have the opportunity to reach the MH when forwarded to the new BS. Furthermore, the forwarding buffer is provided with a time out mechanism such that the buffer holds a packet only for a limited time period. When the path setup update message arrives at the old BS, all packets outstanding in the buffer for which the time out is not expired are forwarded to the new BS.

2.4.3 Non-forwarding path setup schemes

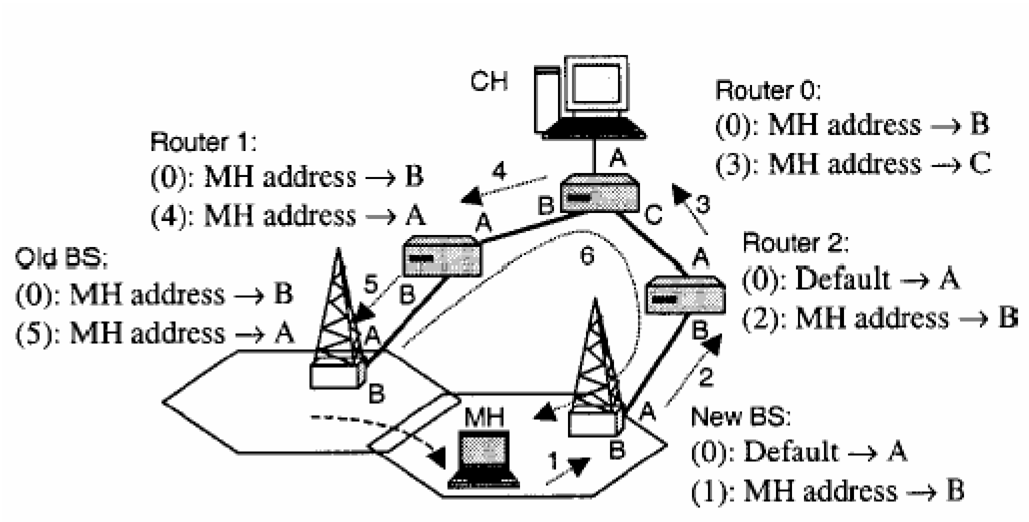

Figure 2.9 Non-forwarding path setup schemes

In these path setup schemes, as the path setup message travels from the new BS to the old BS, data packets are diverted at the cross-over router to the new BS, resulting in no forwarding of packets from the old BS.

There are two variants of the Non-Forwarding scheme, motivated by two types of wireless networks. The Unicast Non-Forwarding (UNF) scheme is optimized for networks where the MH is able to listen/transmit to two or more BSs simultaneously for a short duration, as in the case of a WaveLAN or Code Division Multiple Access (CDMA) network. The Multicast Non-Forwarding (MNF) scheme is optimized for networks where the MH is able to listen/transmit to only one BS as in the case of a Time Division Multiple Access (TDMA) network. In the following the UNF scheme analyzed in this thesis is described.

In this case, when the new BS receives the path setup message, it adds a forwarding entry for the MH’s IP address with the outgoing interface set to the interface on which it received this message. It then performs a routing table lookup for the old BS then forwards Message 2 to Router 2. This router performs similar actions and forwards Message 3 to Router 0. At Router 0, the cross-over router in this case, forwarding entries are added such that new packets are diverted directly to the MH at the new BS. Eventually Message 5 reaches the old BS that then changes its forwarding entry and sends an acknowledgment, Message 6, back to the MH.

Chapter 3 Speedy handover

When a mobile node hands over from an old FA to a new one, the packets destined to the mobile node will be still sent to the old FA before the binding update. This will cause packets loss since the old FA can no longer communicate with the MN.

If the old FA expect that a MN has left its coverage area, there are many actions can be done for expected handover. The old FA, for example, can buffer packets for the moving MN to avoid packet loss.

3.1 RTS/CTS exchange

In DCF period (it is widely implemented in IEEE 802.11) with infrastructure network structure, access point (AP) sends a RTS message to clean up the wireless channel when it tends to transmit data, and waits for the responding CTS message from a mobile node (Figure 3.1). We have to know whether the mobile has left or not only if there is any packet destined to it. Therefore we can add a function to this mechanism. If the AP receives CTS, it will know that the mobile node does not leave, otherwise, the mobile node maybe hand over to other AP.

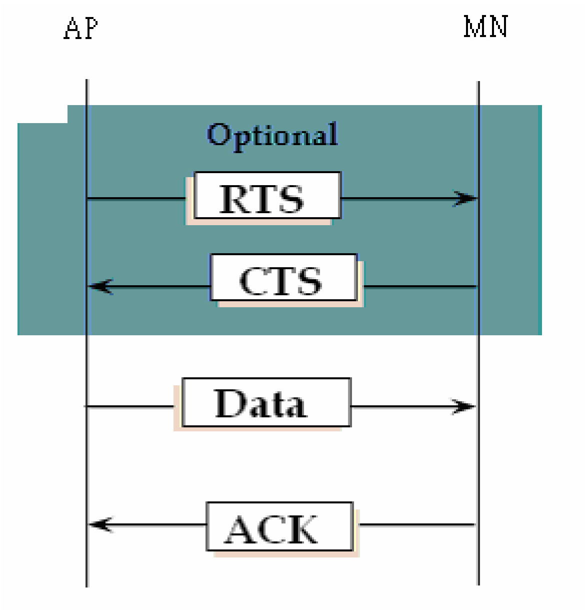

Figure 3.1 RTS/CTS exchange.

Some features of RTS/CTS message are suitable for the detection:

(1), The RTS/CTS (total 20 bytes for RTS and 14 bytes for CTS) messages are very short. They do not, therefore, use too much wireless bandwidth.

(2), They can be transmitted frequently, hence they can be used to inform the AP regarding the handover situation of a mobile node as soon as possible.

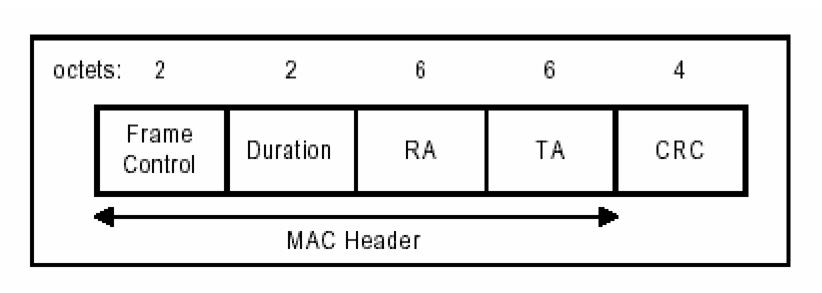

Figure 3.2 RTS frame format

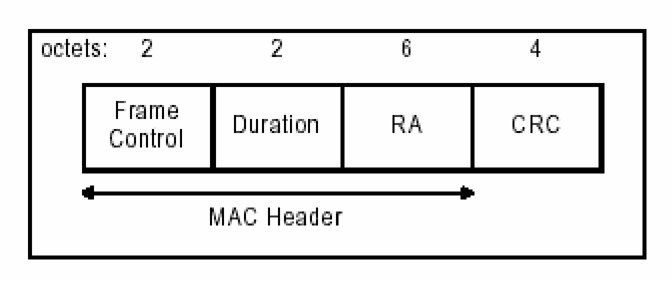

Figure 3.3 CTS frame format.

(3), They are less affected by random loss. Since RTS is short and takes much less time in transmission, it can be sent by AP for several times successively. As long as one pair of the RTS/CTS dose not lose randomly, we can ensure that the mobile node still stay with current AP. Therefore, mobile node movement can be determined accurately.

3.2 Packet buffer for mobile node

In speedy handover, the packets buffered in the old FA is forwarded after the whole handover, including layer 2 handover, obtaining care of address, binding update and so on, have been done. In fact, the new FA can forward the packets to the mobile node just after routing update to mobile node finishes when the handover process is complete. The mobile node in our proposed speedy handover allows the packets forwarded earlier than in the original structure, so the time during which the mobile node temporarily out of connection is reduced. The scenario of speedy handover is shown in Figure 3.4.

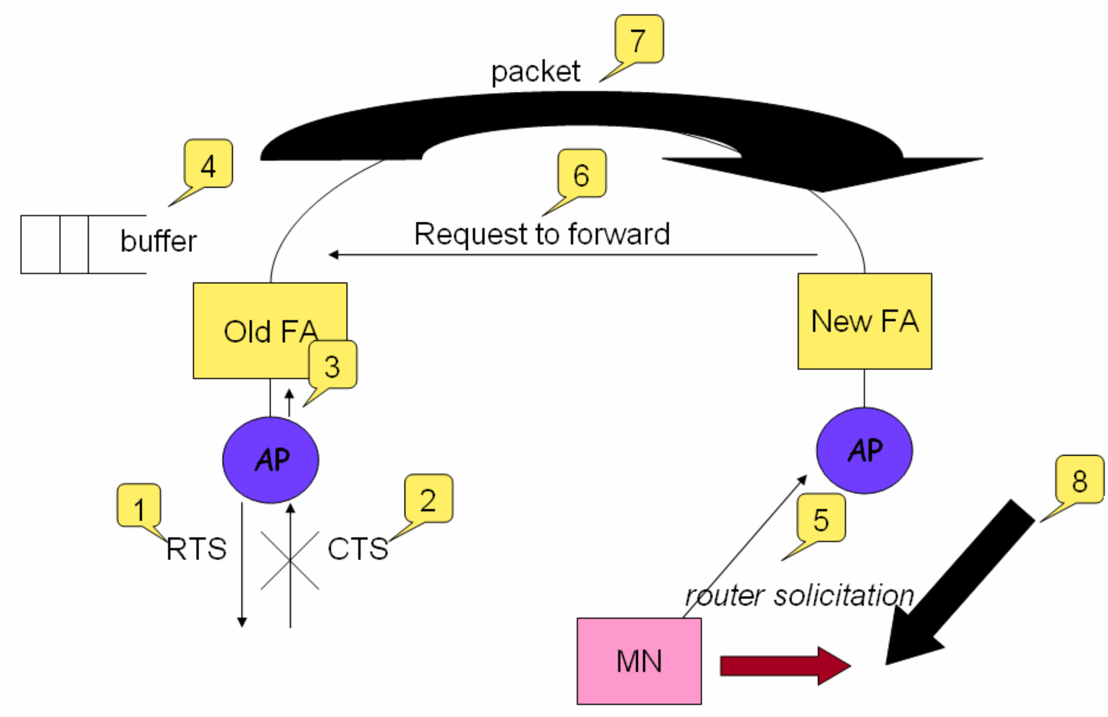

Figure 3.4 Speedy handover.

In Figure 3.4, procedure 1 and 2 show that the AP of the old FA sends multiple RTS's and does not receive any CTS, so that AP sends a point-to-point protocol message which is a link layer message to the old FA in order to request the FA to buffer packets for the mobile node as procedure 3 and 4.

When the mobile node gets the beacon from the new AP, it delivers "router solicitation" message in procedure 5. That message tells the new FA that a mobile node has come and informs the FA . The new FA sends "request to forward" message as soon as the routing table to mobile node is updated.

In the end, procedure 6 and 7 show that the old FA forwards the packet to the mobile node through the new FA.

The time saved is the duration from the routing update to that the mobile node completes the handover.

3.3 Modification in a mobile node

To realize the speedy handover, we modify a mobile node a little.

Because the mobile node wants the new FA to send the "request to forward" message, it must let the new FA know where itself come from (the old care-of-address that is the IP of the old FA in IPv4).

When a mobile node finishes the handover, it gets a new care-of-address, and replaces the old care-of-address with the new one. As the mobile node sends a router solicitation message to the new FA, we add the old care-of-address which is recorded in the mobile node to the router solicitation message to tell the new FA which is the old FA, and the old FA is able to know the destination of the "request to forward" message. After the mobile node gets an advertisement from the FA, we replace the old care-of-address with the address of new FA.

3.4 The mobile node in fast movement

In this session, we discuss cases that the mobile node moves very fast through multiple FAs.

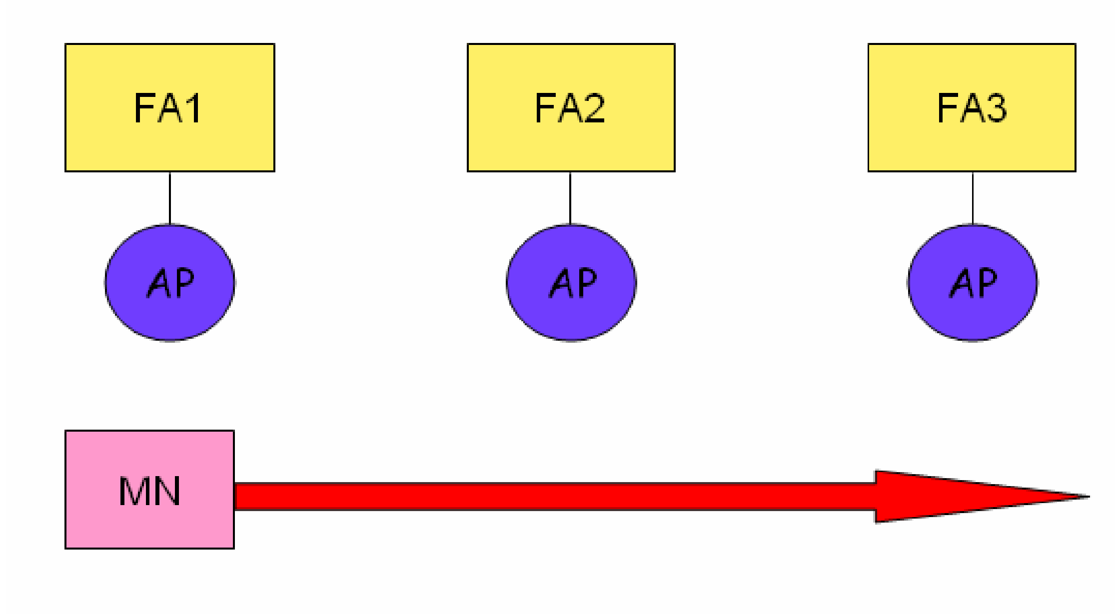

Figure 3.5 The mobile node in fast movement.

In Figure 3.5 the mobile node moves from FA1 to FA3 via FA2.

Regarding how fast the mobile node moves, there are three cases:

(1), case I: The mobile node leaves FA2 quickly before router solicitation is sent. After the mobile node reaches FA3, the old care-of-address record still keeps the IP address of FA1. Therefore, FA3 will send "request to forward" message to FA1 instead of FA2. The mobile node does not complete the handover to FA2, so packets sent to the mobile node are still sent to FA1 before the handover to FA3 finishes, and are forwarded to FA3 from FA1. It is clear that in this case speedy handover did work.

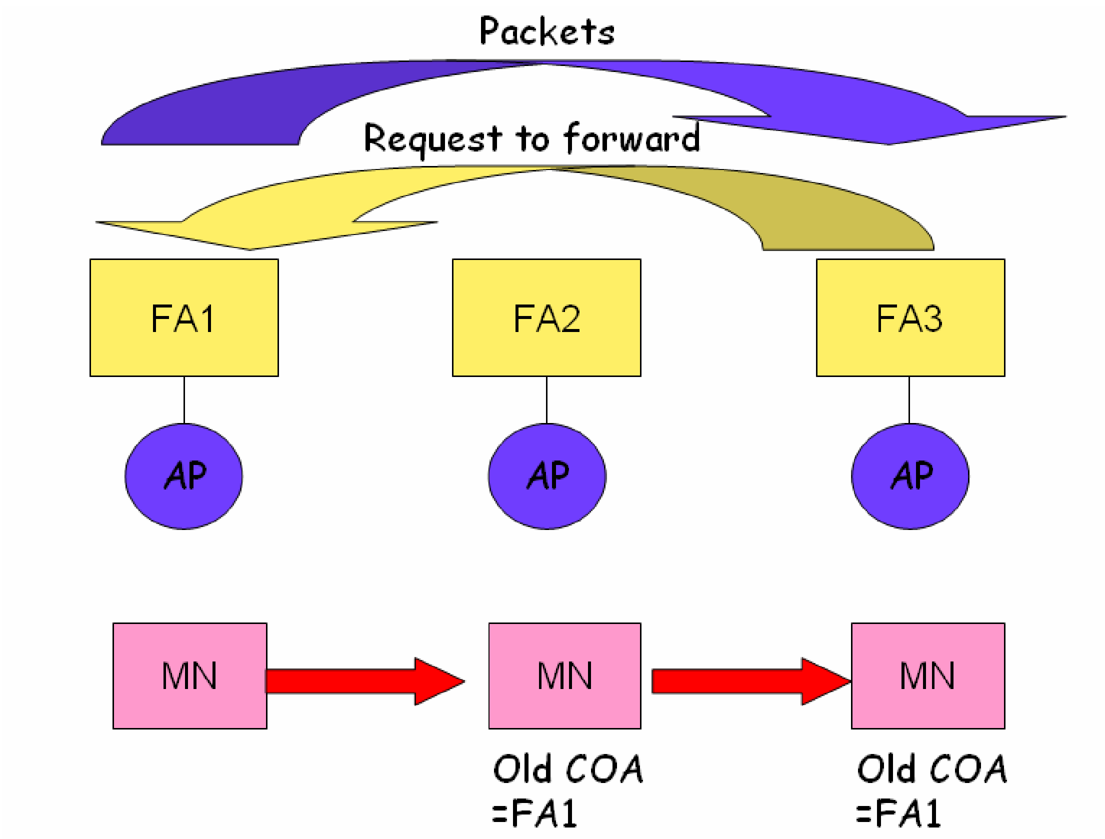

Figure 3.6 Case I.

(2), case II: The mobile node leaves FA2 after router solicitation is sent but before the handover finishes. Because of the router solicitation, packets destined to the mobile node are forwarded to FA2 from FA1. After the mobile node associates with FA3, the FA3 send a "request to forward" message to FA2. Therefore packets sent to the mobile node are forwarded from FA1 to FA2 and then from FA2 to FA3. The mobile node still can receive the packets successfully.

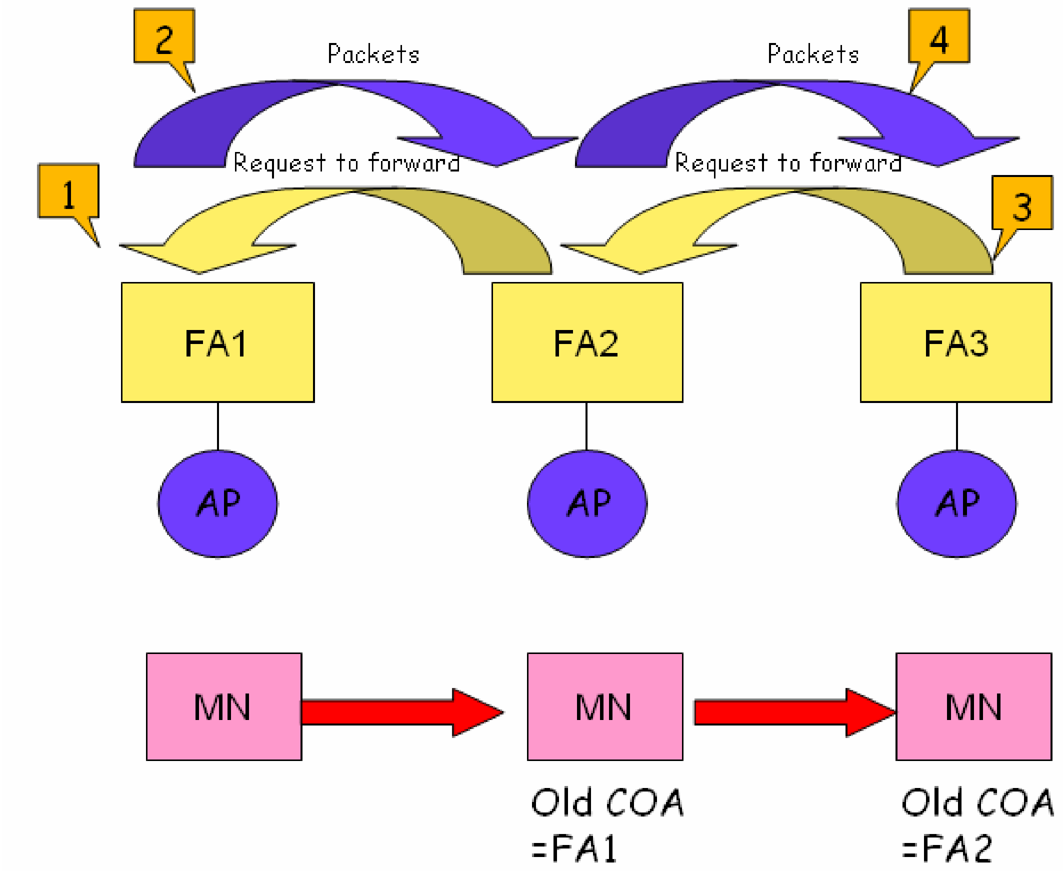

Figure 3.7 Case II.

3.5 Detection failure

Wireless network environment is quite unreliable, so the loss of three successively RTS or CTS, which causes handover detection to fail, is very likely to heppen. The FA may consider that the mobile node has left but actually it does not. Under this situation, the FA still put the packets to its buffer unnecessarily. To avoid such waste of buffer space, the FA could continue to detect the handover of the mobile node with RTS/CTS message. As long as the FA gets any CTS responded or receives a “forwarding request” message, it cleans up its buffer.

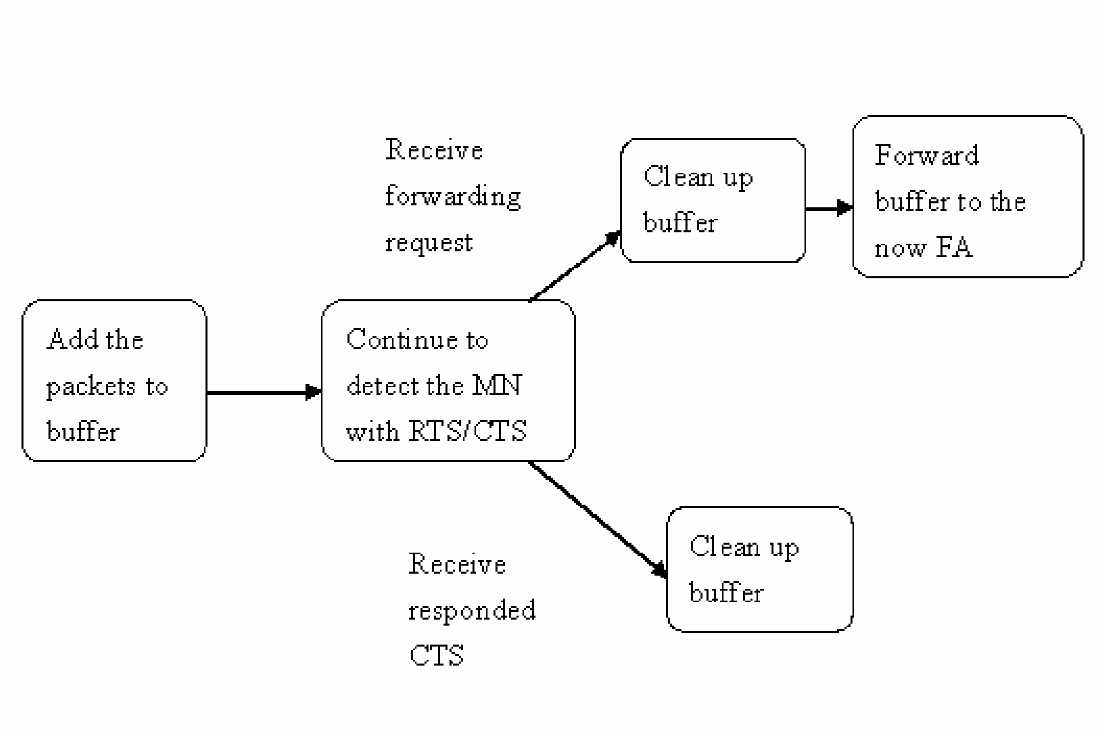

Figure 3.8 Detection failure.

3.6 Comparison

In this section, we compare the method proposed in this thesis with those existing methods for wireless handover.

3.6.1 Fast handover

The method of Fast handover can shorten the period when a mobile node can not receive packet during handover, also can avoid packet loss caused by the handover. The mobile node can get information of the new FA (or AR) before detaching from the old FA (or AR) and requests the old FA to buffer packets for it. Finally, the old FA forwards those packets to the mobile node as soon as the mobile node attaches to the new FA.

Advantage-faster: Compared with our method, Fast handover can forward the packets for mobile node faster. Because the old FA is able to know where the mobile node will be going to before the MN detaching from it, it forwards the packets as soon as possible. On the other hand, our method must wait for the mobile node attaching to the new FA and sending forwarding request.

Disadvantage-more restriction: In order to forwarding packets faster, the radio coverage area of the two FA must overlap. Otherwise the mobile and the old FA have no idea when the mobile node is going to handover before it detaches from the FA, as mobile node can not listen to both two FAs at the same time.

	Fast handover	Speedy handover
Main idea	Layer 2 enhancement	Layer 2 enhancement
Who buffers and forwards packets	The old AR	The old AR or FA
Method	Get information from the new AP before detaching from the new one.	RTS/CTS exchange
Who detects the movement	Mobile node	Access point
When to detect	When the mobile node get a new advertisement from new AR	When there are packet for the mobile in AP
Overlap	Need	Do not need

3.6.2 Hierarchical structure

The MAP router is proposed in hierarchical structure. It manages intra-subnet handover. When one mobile node wants to handover in a subnet, it only needs to give

MAP router rather than home agent a binding update message, and MAP router keeps a map from it self to the mobile node. Due to shorter path from a mobile node to MAP router than to the home agent, handover time is shortened.

Advantage-shorter handover time: Powerful MAP routers make shorter handover time passible. It is shorter than the handover time of our method which is same as original method.

Disadvantage-more packets losses: In Hierarchical structure the old FA never buffers packets and forwards them for mobile node, so some packets may be lost in the old FA during handover period although it is short. In this point of view, our method does a better job than it.

3.7 Other applications

The method of RTS/CTS detection can be also applied to other wireless handover approaches. In this section, some examples is illustrated.

3.7.1 HAWAII

With HAWAII, every router keeps a map from its output port to a mobile node, so they all know how to forward packets for mobile nodes. When a mobile node handovers to a new FA, it sends mapping update to both the gateway router and the old FA. Every router along the path will update its mapping to that mobile node.

The old FA helps the mobile node to buffer packets, but every packet for the mobile node will be buffered regardless of being received successfully by the mobile node. The buffer space will be wasted.

If we can use RTS/CTS to detect the handover of mobile nodes, we can use buffer space more efficiently. In other words, the FA buffer the packets only when the mobile node is expected to move out of the current coverage area.

3.7.2 Hierarchical structure

The packets loss problem presented in last section can be solved by RTS/CTS detection and packets buffering/forwarding. Therefore packets will be never lost in the old FA.

3.7.3 fast handover

Fast handover only works when a mobile node can listen to more than one FA simultaneously. If we can add our method to it , its application range can be extended.

Chapter 4 Performance evaluation

To verify that the new model proposed in Chapter3, we perform simulation with network simulator ns2 version 2.26. There is a mobile IP extension included in this version. We modify some code for our model, and record the result. The result is satisfying and described as follows.

4.1 Simulation I

In this simulation, we want to see whether the speedy handover works well or not. We can observe the performance of wireless handover with packet buffering and forwarding. To avoid the complex TCP mechanism such as retransmission, we use UDP as the test traffic. By checking the sequence number, the number of packets loss can be detected.

4.1.1 Network topology

We would like to evaluate the performance during handover of a mobile node, so we built up a network topology which has one mobile node (MN), one corresponding node (CN), two foreign agent (FA), and one home agent (HA) as shown in Figure 4.1.

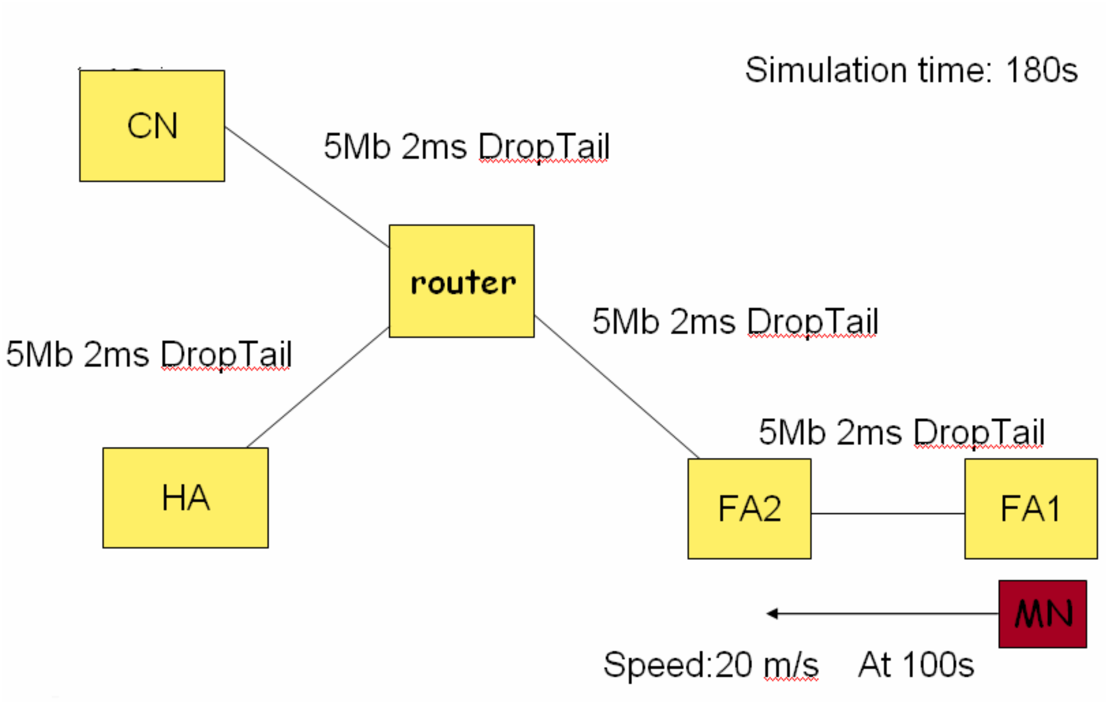

Figure 4.1 The topology of simulation I.

In Figure 4.1 each wired link has 5Mb bandwidth, 2ms delay time and drop tail queue policy. CN and router are wired device and only support wired routing. HA, FA1 and FA2 are wireless agents including access router with access point together. They have wire and wireless interface and routing policy. MN (mobile node) is a wireless device with wireless routing only.

The radio propagation model setup in ns2 is as follows:

Distance = 550m

Propagation model: TwoRayGround

Selected parameters:

Transmit power: 0.281838

Frequency: 9.14e+08

Transmit antenna gain: 1

Receive antenna gain: 1

System loss: 1

Transmit antenna height: 1.5

Receive antenna height: 1.5

Receiving threshold RXThresh_ is: 1.55924e-11

The communication range of all nodes with wireless interface is 550m. The distance between FA1 and FA2 is 856m and the overlap of communication range is about 244m.

The simulation starts at 0s and ends at 180s. A UDP sender (CN) starts to send packets at 100s until the end of simulation, and the mobile node begins to move from the FA1 to the FA2 at the same time with speed 20m/s.

The CN is the sender of UDP traffic, which is setup as follows:

```
$cbr set type_ CBR
$cbr set packet_size_ 1000
$cbr set rate_ 1mb
$cbr set random_ false
```

The packet size is 1000bytes and the sending rate is 1 Mbps. The receiver of UDP is a mobile node. We give each packet a sequence number, by checking the packet sequence numbers the mobile node received, we can observe which packet is delivered successfully and which one gets lost.

We run the simulation with existing method and speedy handover, the result is described in the next section.

4.1.2 Simulation result

The handover begins at about 127.46s, so we show the result from 127s to 131.5s as follows:

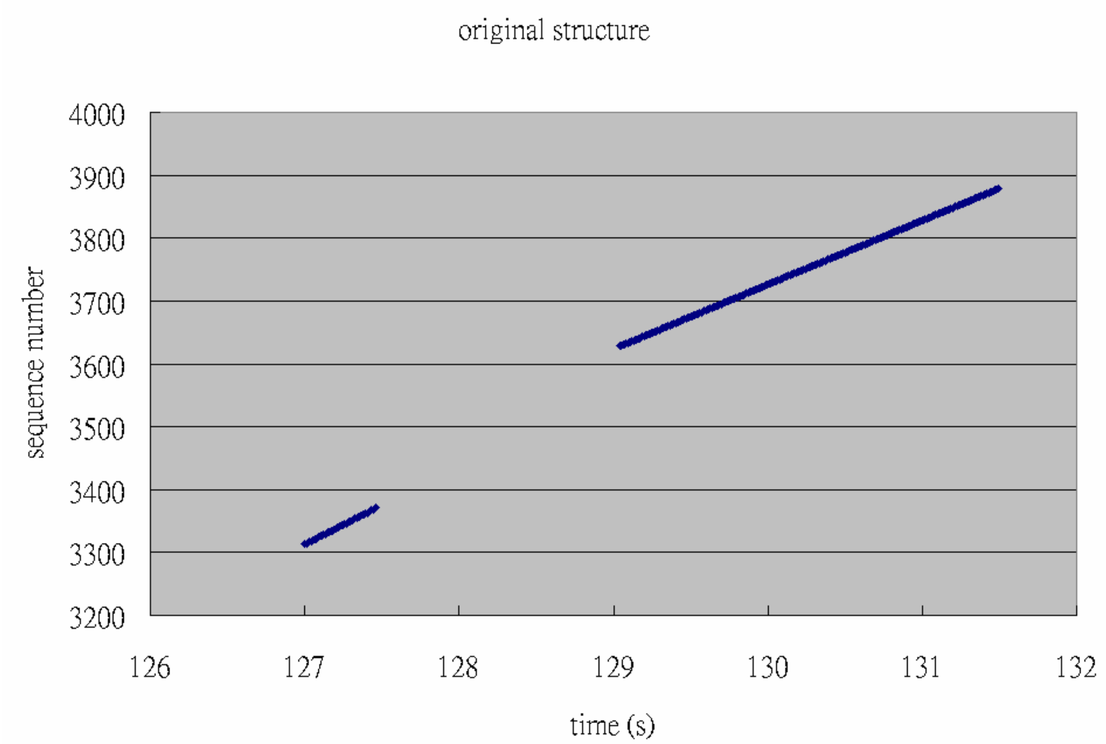

Figure 4.2 Packet sequence number the mobile node received in the original structure in simulation I.

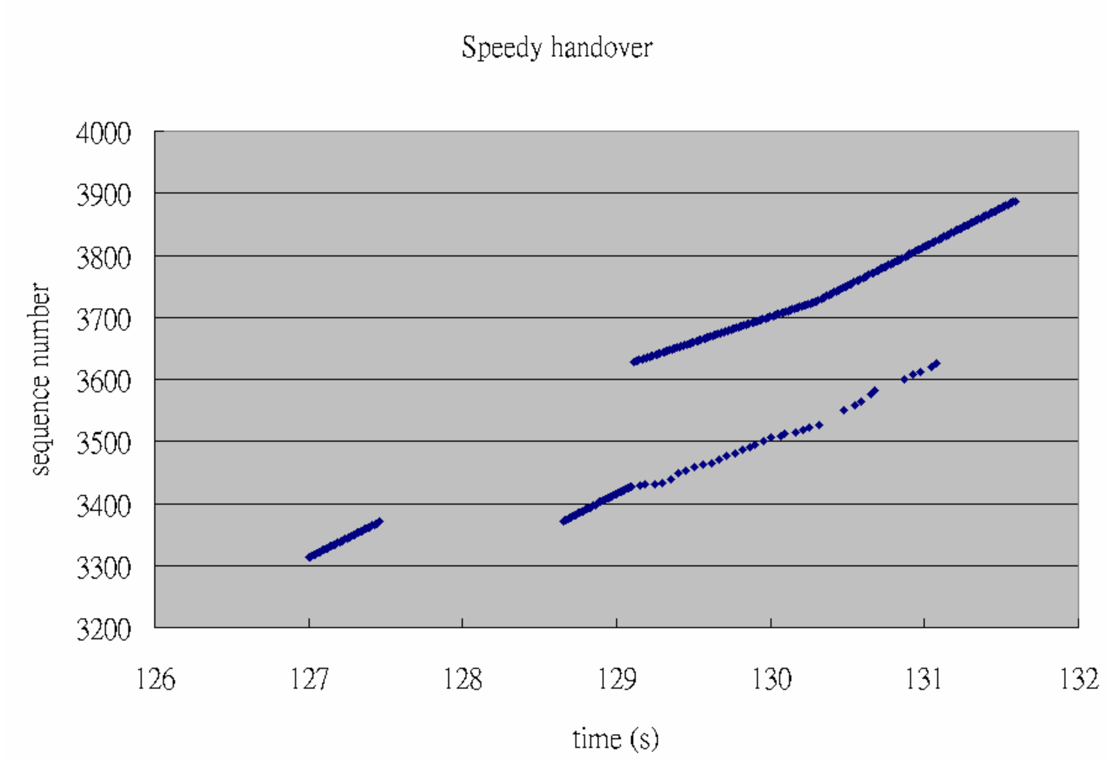

Figure 4.3 Packet sequence numbers the mobile node receives with speedy handover in simulation I

In Figure 4.2, during handover period when the mobile node is unable to receive any packet from UDP sender, (CN) every packet get lost because no mechanism is available to buffer and forward the packets for the mobile node. Obviously the packet loss rate is very high and the performance is degraded seriously.

In Figure 4.3 the speedy handover is used. The old FA buffers the packets, and forwards them as soon as the new FA knows where to deliver the packets to the mobile node which just completed the routing update. The mobile node can receive packets before handover procedure finishes. The handover procedure is complete at around 129.15s and the mobile receives forwarded packets at around 128.66s, so we shorten the time during which the mobile node can not receive any packet. After handover procedure finishes, the new packet stream toward the mobile node make the packet arrival out of order. It is the cause of the heavy line in Figure 4.3.

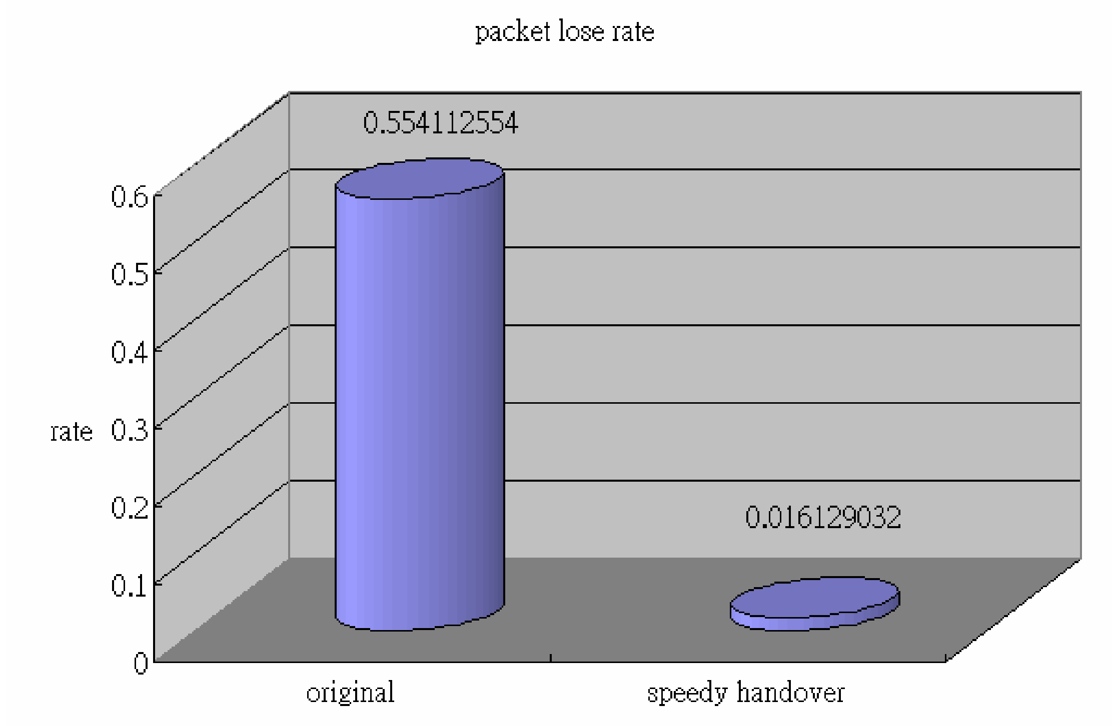

Figure 4.4 Packets loss rate.

Observing Figure 4.4, we can find clearly that packets lose rate with speedy handover is much lower than with original structure. With original structure the rate is 55.41%, and with speedy handover the rate is 1.61%. By bufferring and forwarding packets loss is only caused by out of space of interface queue and random loss. That is why lower packets loss rate is achieved.

When we have a multi-media service, low packet lose rate is an important requirement for quality of service. According to the Figure 4.4, our proposed method is suitable for multi-media service.

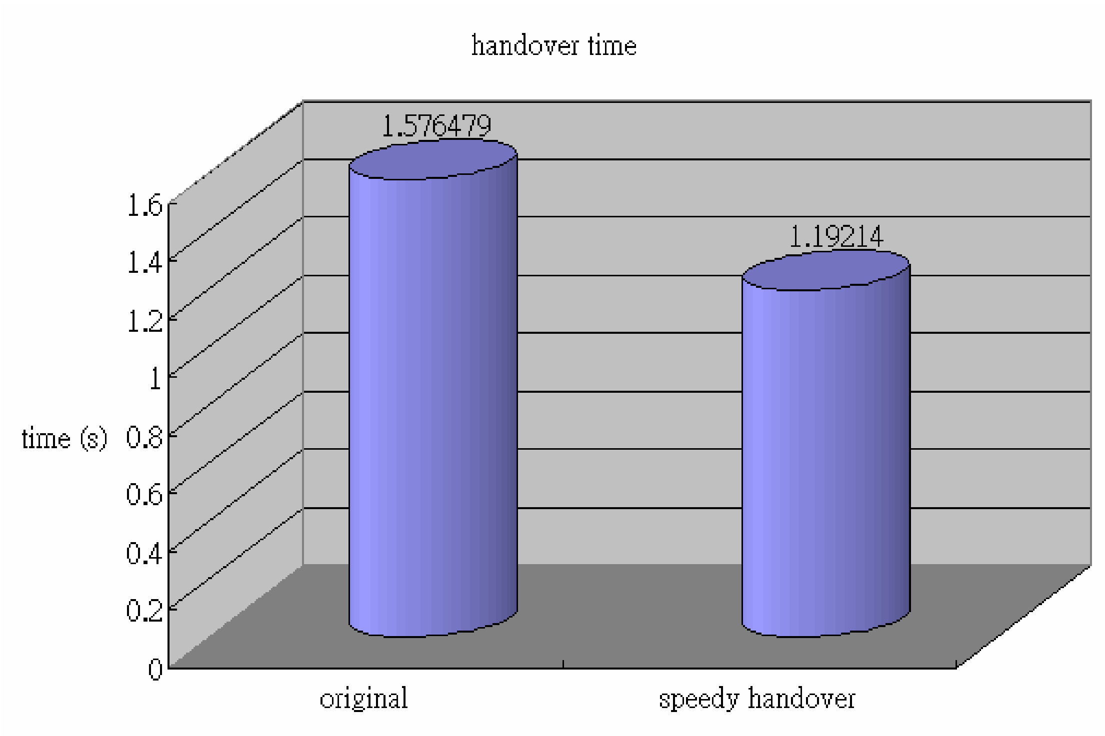

Figure 4.5 Handover time of simulation I.

Figure 4.5 shows that the time from the start to the end of handover period while the mobile node can not receive any packet. It is clear that in speedy handover the handover time can be shorten..

The total handover time is about 1.576439 seconds. Since the old FA in speedy handover forwards packets before the handover finishes, the mobile node can receive packets earlier than in the original structure. On the other hand, the time spent in speedy handover is only 1.19214 seconds, that is, it spends 384.299 ms less.

For multi-media service, the shorter handover time means a smoother quality of service. For example, the frames of movie can be played out much smoothly and the client can experience a higher quality.

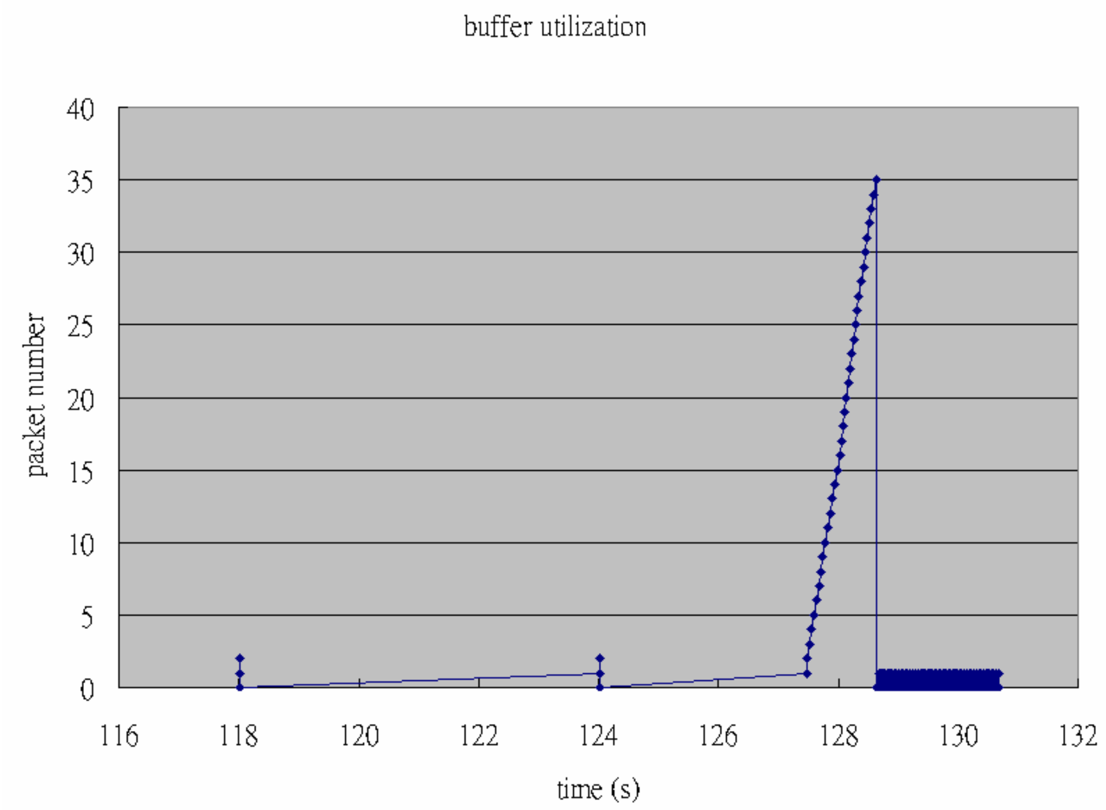

Figure 4.6 Buffer utilization of simulation I.

The buffer utilization is another issue we have to address, thus we observe the buffer utilization during simulation. The result is shown in Figure 4.6. The mobile node detaches from the old FA at about 127.5s, so a burst of packets is queued in buffer after 127s until “request to forwarding” message is received, after that the packets are removed to the output interface queue.

Although there are a little detection failure before handover and packets are added to the buffer, through further detection with RTS/CTS the buffer can be cleared immediately. The detection failure therefore does not cause a big problem, and we never waste too much buffer due to this reason.

4.2 Simulation II

In this simulation we would like to evaluate the performance when the coverage areas of the two FAs do not overlap. In this situation the fast handover does not work.

4.2.1 Network topology

Performance during the handover of a mobile node is what we would like to know, so we build up a network topology consisting of one mobile node (MN), one corresponding node (CN), two foreign agent (FA), and one home agent (HA) as that in simulation I in the Figure 4.1. However, the radio propagation model is different.

Distance = 400m

Propagation model: TwoRayGround

Selected parameters:

Transmit power: 0.281838

Frequency: 9.14e+08

Transmit antenna gain: 1

Receive antenna gain: 1

System loss: 1

Transmit antenna height: 1.5

Receive antenna height: 1.5

Receiving threshold RXThresh_ is: 5.57346e-11

The communication signal range of all nodes with wireless interface is 400m. The distance between FA1 and FA2 is 856m and the overlapped range of communication signal is none. The distance between the margins of two communication range is about 56 m as shown in Figure 4.7:

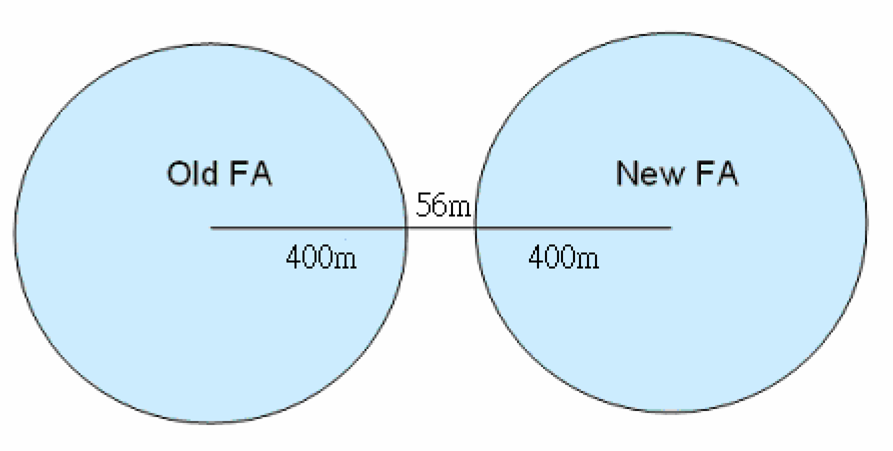

Figure 4.7 Communication signal range of simulation II.

The simulation starts at 0s and ends at 180s. An UDP sender (CN) starts to send packets at 100s until the end of the simulation, and a mobile node begins to move from FA1 to FA2 at the same time with speed 20m/s.

The CN is a sender of UDP traffic, which is setup as follows:

```
$cbr set type_ CBR
$cbr set packet_size_ 1000
$cbr set rate_ 1mb
$cbr set random_ false
```

The packet size is 1000bytes and the sending rate is 1 Mbps. The receiver of UDP is the mobile node. We give each packet a sequence number. By checking the packet sequence numbers the mobile node has received, we are able to determine which packet is delivered and which is lost.

We measure the performance with the sequence numbers of packets received by the mobile node. The result is described in the next section.

4.2.2 Simulation result

Every time we get a packet we record its sequence number and the time it is received by the mobile node. We record the result using the original structure as well as in the speedy handover in Figure 4.8.

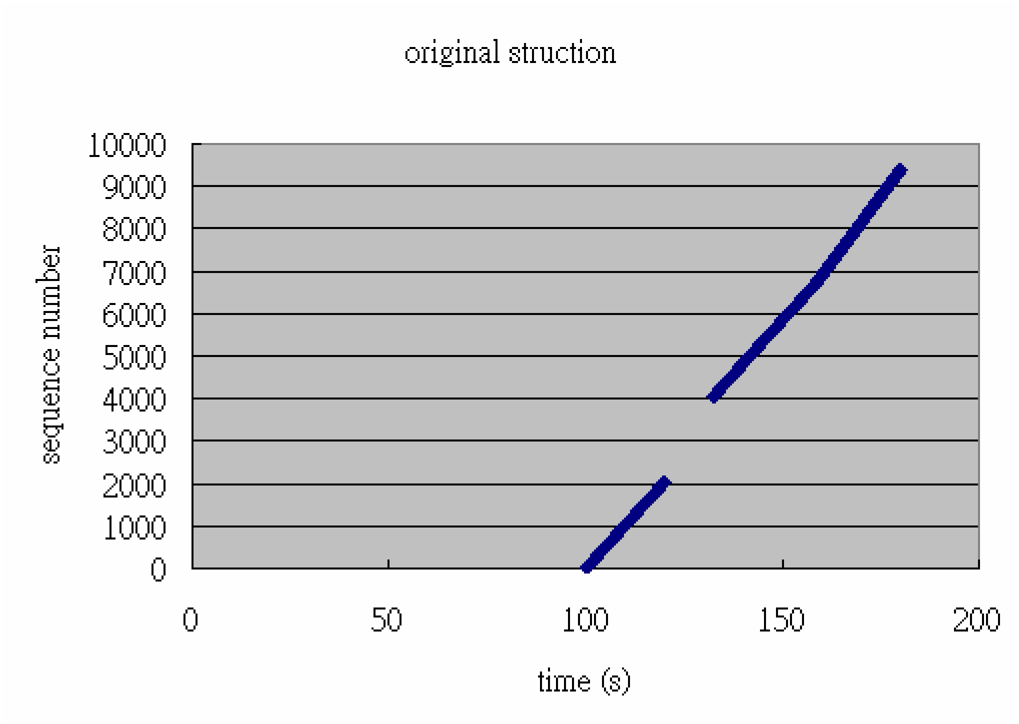

Figure 4.8 The result of the original method in simulation II.

We compare the result with that in simulation I. Because of the longer distance of two FAs, the handover time is longer, and more packets get lost. To show the effectiveness of our new method, we show the result of speedy handover in Figure 4.9.

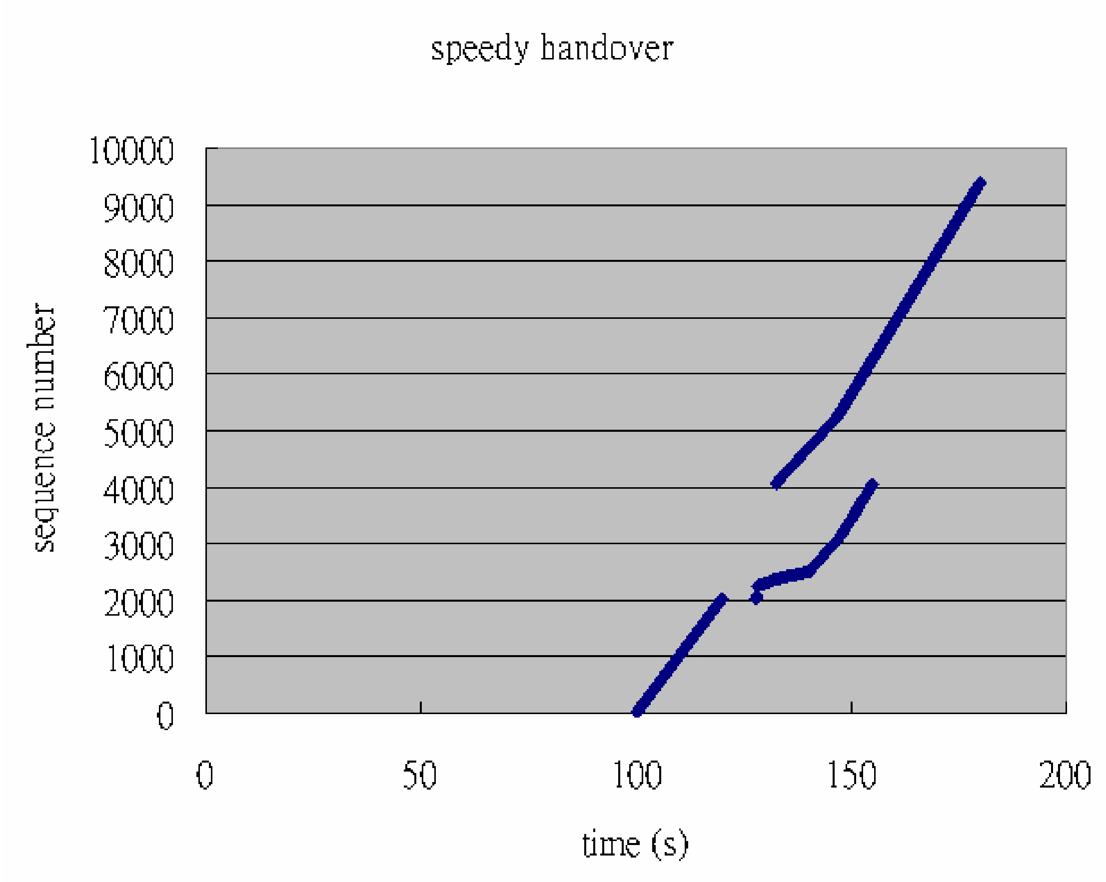

Figure 4.9 The result of speedy handover in simulation II.

In Figure 4.8 and Figure 4.9, it is clear that speedy handover does work when the communication ranges of two FAs do not overlap. In Figure 4.8, every packet get lost during handover, which in speedy handover this problem is improved. The packets are forwarded by the old FA, and are received by the mobile node successfully. Besides, we also can find that the time period during which the mobile node can not receive any packet is shortened significantly. The mobile node is able to receive packets before the whole handover processes finishes.

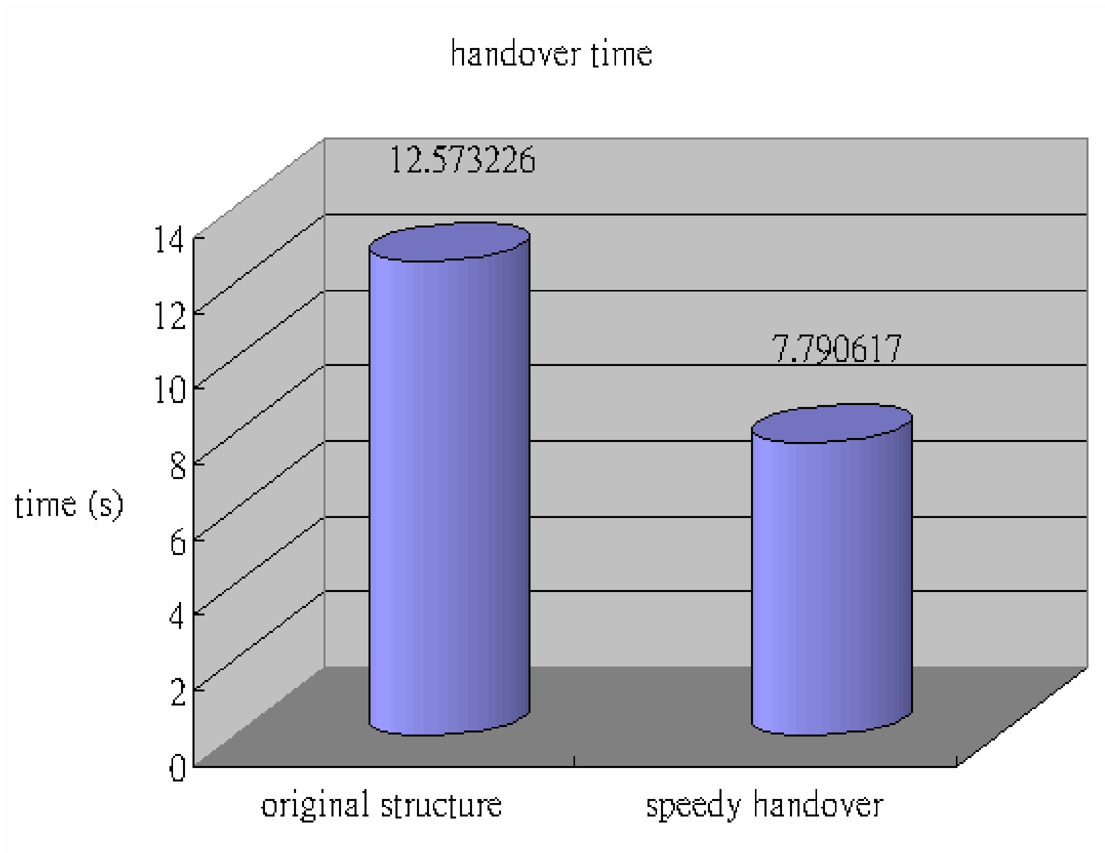

Figure 4.10 The handover time of simulation II.

The total handover time period during which a mobile is unable to receive any packet has been shortened in our proposed speedy handover as shown in Figure 4.10. We also demonstrate that speedy handover also works well when the communication signal ranges of two FAs do not overlap.

On the original structure the elapsed time a mobile node can not receive packets is about 12.573266 s. Because of shorter communication range, the handover time is much longer than that in simulation I.

With speedy handover the time a mobile node can not receive packets is about 7.790617 s. It is much shorter (38.04% less) than in the original structure.

Just as that in simulation I, there is a problem regarding out-of-order packets. For on-demand video service, we can set a buffer in the mobile node to solve the problem. When the mobile node receives out-of-order packets, it can put them into the buffer, and wait other packets for a short period. When packets become in order, the mobile node plays out the video frame of that packets. The user also can get a smooth video. However, for VoIP service, out-of-order packets problem is serious, because VoIP is interactive service and we can not buffer packet too long in the mobile node. Therefore we will consider this problem of out-of-order packets in the future work.

Chapter 5 Conclusion

In this thesis, we propose a new approach to detect the handover activity of mobile nodes and buffer packets at a suitable time without wasting buffer space. We use short RTS/CTS messages for detection. The old FA buffers packets and forwards them as soon as possible. We successfully avoid packets loss during handover and allows the mobile node to receive data packets before handover completes. For multi-media service, the delay time can be shortened, so the quality can be improved.

With simulation result, the UDP packet loss rate during handover decreases significantly from 55.41% to 1.61% (speedy handover). The time period mobile nodes are unable to receive packets is also shortened from 1.576439s to 1.19214s which is 24.38% , based on our method. Thus we can be sure that our proposed method works greatly and improves delay time for multi-media service. Besides, we only buffer the packets when the mobile node has left. In other words, we never waste any buffer resources in either FA or AR, although there may be a little detection failures before handover.

When the communication signal ranges of two FAs do not overlap, speedy handover can still work well. In the simulation II, it is clear that the mobile node get more packets in 180s than the one with original method. The packet loss is decreased successfully and the handover time is shortened, too.

There are some problems remained to be solved. With simulation II result, out-of-order packets may be a problem. For on-demand video service, if we set a video buffer in the mobile node, the problem is not so serious, but for VoIP service, it is a big problem. The voice delay is not tolerated when we speak to somebody through VOIP. It is a good subject for future studies.

The method proposed in this thesis is designed under the DCF structure. We may use the similar method under the PCF structure, too. We can let the polling messages work as RTS/CTS messages. This method under PCF structure also remains to be a future research.

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