Research Handover on Mobile IP

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Abstract – Combining the advantages of FMIPv6 and HMIPv6 (FHMIPv6) is more suitable for time –sensitive services. We propose an improvement based on it by optimizing the address configuration stage on MN (Mobile Node) and setting handover initation stage on MAP (Mobility Anchor Point) so that the handover delay and packet loss is reduced. Our paper presents simulation result of these solutions (Hierarchical MIPv6, FHMIPv6, optimized FHMIPv6) together in the testbed.

Our paper is organized as follows: Section 1 is the overview of Mobile IP (MIP) and handover. Section 2 presents several protocols of Mobile IP (Mobile IPv4, Mobile IPv6, Fast Mobile IPv6, Hierachical Mobile IPv6). Section 3 present our proposed solutions, simulation and Section 4 is conclusion and future works.

Keywords: Mobile IPv4 (MIPv4) , Mobile IPv6 (MIPv6) , Fast Mobile IPv6, Hierachical Mobile IPv6, handover, FHMIPv6, CP (Connection Point), CoA (Care-of-Address), HA (Home Agent), FA (Foreign Agent), HN (Home Network).

I. Introduction

In IP networks, routing is based on stationary IP addresses. A device on a network is reachable through normal IP routing by the IP address it is assigned on the network. When a device move away from its home network, it is no longer reachable by using normal IP routing. This results in the active sessions of the device being terminated. Mobile IP is an Internet Engineering TaskForce (IETF) standard protocol which a node to change its point of attachment to the Internet without needing to change its IP address and continue communication without sessions or connections being dropped even though they move from one network to the other. Mobile IP supports a current Internet Protocol in both wired and wireless networks [1, 9]

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When a Mobile Node is active and moves from the coverage of the connection point (CP) to the coverage of the other connection. Due to a factor makes the noise level increased or signal intensity reduced, or capaciry increased suddenly … To solve these problems, Mobile Node needs to change the CP that it is connected to get better signal quality, which can be served better QoS in a new CP.

During the handover, Mobile Node is often disconnected from the old network before connecting to new networks (especially if the Mobile Node use a single interface) and so it is the reason that Mobile Node is lost connection with Internet in a period. During this period, it can not send or receive packets to maintain existing applications. With the applications related to VoIP communications, the handover should be completely transparent to mobile clients, without interrupting, losing of connectivity or reducing the quality of voice (seamless handover) [9]

II. The protocols of Mobile IP

Section 2 presents the operations of several protocols of Mobile IP, the advantages and disadvantages of them.

A. Mobile IPv4 (MIPv4)

Operations of Mobile IPv4 include 3 main steps

Agent Discovery: The mobile agent (Home Agent - HA/Foreign Agent - FA) send packets (Agent Advertisements) to announce their presence on each route where it provides services. Agent Advertisements are sent periodically.

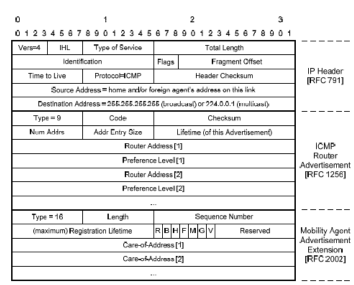

Fig 1: Agent Advertisement message [13]

When MN moves far from HN (Home Network), it tries to catch the Agent Advertisement message. If MN doesn't receive any Advertisement Message, it will broadcast Solicitation Message continuously to find out a Mobility Agent (HA or FA) and request the Agent to allocate to it's the Advertisement message immediately [13]

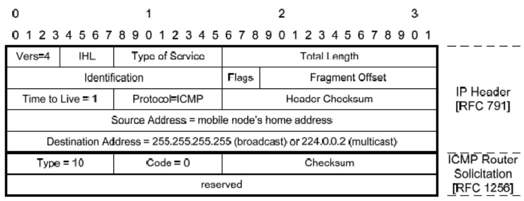

Fig 2: Agent Solicitation message [13]

Agent Registration:

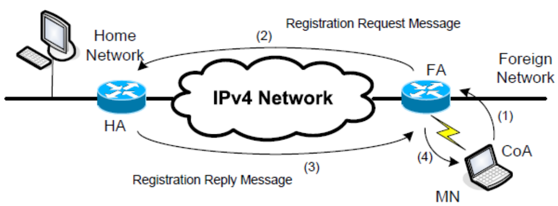

Fig 3: CoA registration [13]

When move away the original network, MN must register this address to HA in order to HA can forward packets destined to MN exactly to MN. Depending on the method associated with FA, MN can register directly with the HA or indirectly via FA (FA forwards the registration message between MN and HA). HA can forward packets destined to MN exactly to MN.

Data Transfer

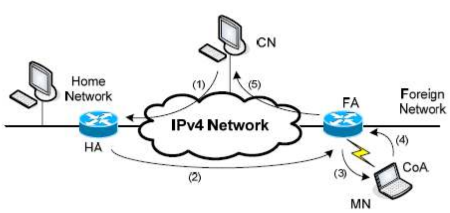

Fig 4: Data delivering between CN and MN [13]

After registering successfully, HA encapsulates each of packets with MN's CoA and forwards them to MN's current address via FA [13].

The packets destined to MN (data and Home Address of MN) is encapsulated into new packets (data and inner header and outer header). These packets can be compressed to reduce storage and transmission speed. the HA makes a tunnel (encapsulates the original packets inside a new IP packet) and sends them to FA. FA will remove outer header and send for MN. When MN receives packets, it decapsulates them and gets the original data sent from CN.

The packets sent from the MN are routed directly to the sender (CN - Correspondent Node). However, packets sent to the MN are routed through the HA. This problem is called triangle routing [1]

When MN sends a new registration message the old routing will be disabled. If MN is in the home network, binding cache and the process of handover is unnecessary.

The disadvantages of MIPv4 and the solution

It is the inefficiency in the routing. Because the Mobile Node uses its original address in the source address field, packets destined to MN will forward to its home network. Then, HA forward these packets to MN via FA. It is particularly serious problem because the computers usually communicate with each other in the local scope [1]

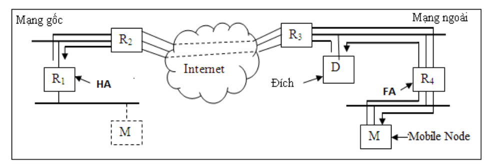

Fig 5 : The problem of triangle routing.

The solution of MIPv4

Each station must be required to maintain a binding cache, which includes CoA of MN. It means that each station wants to support this function, it needs to upgrade the software. Before sending packets to a MN, CN checks its binding cache, If it finds the binding cache entry then packets are delivered directly to MN at its CoA. Otherwise, CN sends the datagrams to HA which tunnels them to MN

B. MIPv6

Ability to support mobility in Mobile IPv6 is based on the experience gained from Mobile IPv4 and IPv6's improvements. Consequently, Mobile Ipv6 also has components which are similar to Mobile IPv4.

The operation of MIPv6

There are 4 stages: movement detection, CoA creation, CoA registration and data delivering [10, 13, 19, 20]

CoA creation

MN can configure its CoA automatically by using one of two methods: stateless or stateful.

- Stateless: MN combines IPv6-prefix it received with its MAC address to create a new IPv6 address, different from other addresses [13]

- Stateful: MN sends a CoA Request Message to the local router and then this router allocates a new IPv6 address to MN by using DHCPv6 [13]

MN's CoA used in IPv6 network is called Colocated CoA. The use of collocated address CoA allow MN to encapsulate, decapsulate packets or connect to HA and other nodes directly without intermediate router as FA in Mobile IPv4

To determine the uniqueness of the new MN's CoA requires a duplicate address detection (DAD) procedure. During DAD, a mobile node sends a neighbor solicitation message to ask whether its new address is being used. If no node replies within a set timer, a mobile node can assume the new address is unique on that network and it will use this address.

Advantages and Disadvantages of Mobile IPv6

Advantages

In Mobile IPv4, routing optimization function is an optional component that may not be supported by all stations IPv4. But in Mobile IPv6, this function is integrated in the protocol. It allows the routing process to be done directly without passing through the MN's home network. Foreign Agent in Mobile IPv4 doesn't need to deploy.

Disadvantages

Although the problem of triangle routing has been overcome in Mobile IPv6, but DAD procedure and Neighbor Discovery caused the long delay and can't be satisfy the real-time application.

In Mobile IPv4 and Mobile IPv6, during the period when the MN moves from one network to another network, before it requests an NCoA, the new FA or AR can't inform the old FA or AR about the moving of MN. So the packets forwarded to PCoA will be lost.

C. HMIPv6 (Hierarchical Mobile IPv6)

With the disadvantage in Mobile IPv6, To reduce the frequency of binding update by employing localized movement management. Hierarchical Mobile IPv6 (HMIPv6) is one of the solutions for this approach

The HMIPv6 protocol involves the following phases: MAP discovery, MAP registration, and packet forwarding [9, 19, 20]

Mobility Anchor Point Discovery:

When a mobile node enters into a MAP domain, it will receive AR's Router Advertisements. If HMIPv6 is used in the visited network, a new MAP option will be contained in Router Advertisement message to allow MN to discovery MAP address [19].

Each AR will store active MAP list and sent them periodically by using the RA message. When MN receives RA message, MN builds its LCoA and RCoA via the stateless autoconfiguration mechanism using information contained in Router Advertisements [20]

Prefix information for LCoA is contained in Prefix Information option of Router Advertisements. 64-bit prefix from Prefix Information option and 64-bit interface identifier from mobile node are concatenated together to create LCoA [20].

Map option in these Router Advertisements contain MAP address. The upper 64 bits of MAP address is used to create RCoA [20]

MAP registration

When MN builds RCoA, MN sends LBU to MAP. To make a difference between the original Binding Update message and the Local Binding Update message, the A and M flags in the Local Binding Update message should be set [20]

In the Local Binding Update message to MAP, RCoA is used as mobile node's home address and it is contained in the Home Address option. LCoA of Mobile node is used as the source address [20]

When MAP receives Local Binding Update message, it will bind mobile node's RCoA to its LCoA. After that, the MAP performs DAD to check the uniqueness of mobile node's RCoA [20]

The result of the binding update to MAP will be returned to the Mobile Node by MAP in a Binding Acknowledgement message to display whether the binding is successfully accomplished. If the binding update fails, MAP will return an appropriate error code in the Binding Acknowledgement message [20]

Packet Forwarding:

When the binding update to MAP is successful, a bi-directional tunnel between MAP and the nobile node is established. In the outer header: LCoA is source address, MAP address is destination address (the address is learned from Router advertisement message from the ARs on the visited network). In the inner header: RCoA is source address, CN's address is destination address.

MAP will capture any packet destined to the mobile node's and encapsulate it with LCoA as the destination address. Thus, MAP eventually tunnels the packet to the mobile node [20]

If the mobile node changes its physical location within MAP domain, only binding update to MAP is required. Binding updates to its home agent or correspondent nodes are not necessary [20]

D. FMIPv6 (Fast MIPv6)

To reduce delay and packet loss, a fast handover scheme (FMIPv6) is introduced into MIPv6. It allows Mobile Node to use its old CoA address in the old access point until it completed the registration of its new CoA address in the new access point

The mobile node initiates the fast handover when a layer 2 trigger takes places. An L2 trigger is information based on the link layer protocol, below the IPv6 protocol, in order to begin the L3 handover before the L2 handover finishes, An L2 trigger contains information on the MN L2 connection and on the link layer identification of the different entities (e.g., the link layer address) [19]

When an AR receives an L2 trigger, it must be capable of matching entity identification to an IP address. For example, when it receives access point identification, it must know to which subnet this access point belongs. To do so, the neighboring ARs have to exchange information to discover each other. The information exchanged can be a network prefix or a list of the access points operating in an AR subnet [19]

Fast Handover uses these L2 triggers to optimize the MN movements in two methods: predictive handover and reactive handover.

Predictive handover

In predictive handover, the MN or the current AR (when L3 handover is controlled by the network) receives an L2 trigger indicating that the MN is about to perform an L2 handover. This trigger must contain information allowing the target AR identification (e.g., its IPv6 address). [19]

When MN decide to move the new link, a Router Solicitation for Proxy advertisement message will be sent to Mobile Node's access router to require the information of neighboring networks.

The information list of the access routers associated with CP contained in PrRtAdv message will be responsed by PAR.

The mobile node forms a prospective new care-of address from the information provided in the Proxy Router Advertisement messages, after that it will send a Fast Binding Update message to PAR

When the previous access router receives the Fast Binding Update message, Handover Initiate message will be sent to the new access router to determine whether the new access router accept the new care-of address. When the new care-of address verified by the new access router, DAD is performed to check the uniqueness of MN's CoA when stateless address autoconfiguration is used. The handover Acknowledge message from the new access router must return confirmed new care-of address [20].

If the address is valid, a link between the PCoA and NCoA will be established and a tunnel will be created by PAR to forwards packages from PCoA -> NCoA and send FBack, the previous access router must in turn provide the new care-of address in a Fast Binding Acknowledgment. And so, CN will forward the packets to the new location of MN pass through the tunnel.

This process is still used until the MN completes BU registration procedures to HA and CN.

NAR will store any packet lost during the moving. After that, it will distribute them to MN when MN comes to the new link.

Reactive handover

However, for some reason, the MN does not receive FBA from PAR but still has to make new connections.

- The mobile node does not receive the Fast Binding Acknowledgment message on the previous link.
- The mobile node has left the link after sending the Fast Binding Update message but before receiving the Fast Binding Acknowledgment message[20]

So, when it attaches to the new access router, a Fast Binding Update message will be sent. The Fast Binding Update message should be encapsulated in the Fast Neighbor Advertisement message by Mobile Node to enable the new access router to forward packets immediately as soon as the Fast Binding Update message has been processed and allows the new access router to verify if the new care-of address is acceptable.

This disadvantage of reactive mode: there will be some packet loss during MN when it disconnects with PAR and establishes a connection to PAR

III. Improving handover problems

HMIPv6 and FMIPv6 were designed as completely different approaches. It is feasible to combine the two protocols in a system so that the performance of handover is improved the best. But a simple combination in which FMIPv6 protocol is put on top of HMIPv6 architecture does not provide optimal results. H. Y. Jung and S.J. Koh in [6] proposed a framework in which FMIPv6 is integrated in HMIPv6 named F-HMIPv6.

A. Integrating the FMIPv6 into HMIPv6

The main difference of F-HMIPv6 from the simple combination of HMIPv6 and FMIPv6 is that MAP instead of oAR (old Access Router) play the key role for CoA pre-configuration, establishment of bi-directional tunnel and so on. Such approach may be more practical and effective in the hierarchical architecture in which local agent such as MAP manages its lower level routers [19]

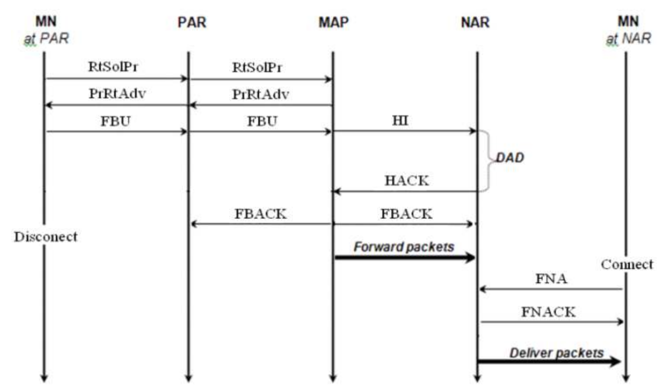

Fig 6 : FHMIPv6 framework

- The MAP receives this request, it replies with a PrRtAdv message (Proxy Router Advertisement) which contains the prefix information of NAR [6, 7, 19]

- Using the prefix information, the MN configures NCoA and requests a fast binding service by sending an FBU message (Fast Binding Update) to MAP in order to associate its NCoA with NAR [6, 7, 19]

- When the MAP receives FBU from MN, it starts the handover procedure by initiating a bi-directional tunnel to the NAR. To do this, MAP sends a HI message (Handover Initiate) to NAR. The HI message contains the request of verification for pre-configured CoA and of establishment of bi-directional tunnel for forwarding packets during handover [6, 7, 19]

- As reply to HI, NAR verifies the availability of NCoA through DAD (Duplicate Address Detection) and then sends the result to NAR and establishes bi-directional tunnel to MAP by using HACK (Handover Acknowledgement).

- On receiving HACK message, MAP sends the result to the MN by using FBack (Fast Binding Update Acknowledgement). When the MN gets the connection to NAR, it sends router solicitation message including FNA (Fast Neighbor Advertisement) option to inform its presence. The NAR receives FNA and finally delivers the packets to the MN [6, 7, 19]

To implement the proposed framework, there are some modifications to the standard messages of MIPv6 as follows:

- Firstly, RtSolPr, PrRtAdv, FBU, HI, HACK, FBACK message in FMIPv6 are needed to change destination or source address from PAR to MAP. It is because MAP in F-HMIPv6 plays the role of oAR in FMIPv6. Therefore the messages will use MAP address as source (or destination) address instead of PAR address.
- Another change is related to router advertisement message including MAP option. MAP option needs a minor change to indicate whether it supports F-HMIPv6 or not. F bit is added in the reserved field in existing MAP option. If F bit is set, the MN recognizes that the network can support F-HMIPv6.

B. The proposed framework (oF-HMIPv6)

Our framework is developed based on F-HMIPv6 model. In this proposed framework, after receiving RtSolPr message from MN, MAP did not send PrRtAdv message to MN, it send the HI message to NAR to establish tunnel. In addition, we also remove DAD procedure at NAR and request to perform DAD procedure at MN. This framework is optimized F-HMIPv6 (Optimistic F- HMIPv6) or oF-HMIPv6 [19]

The purpose of this proposal is to establish the tunnel between MAP and NAR as soon as possible to reduce the number of packets lost during the process of handover

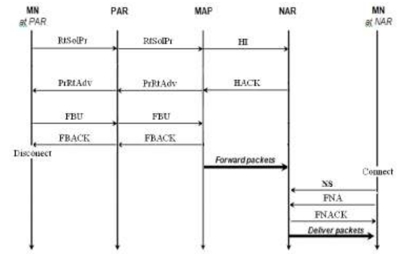

Fig 7: oF-HMIPv6 handover in "predictive" mode

The description for oF-HMIP as depicted in Figure 7 comprises the following steps:

- 1-Based on L2 handover anticipation, the MN sends RtSolPr message to MAP. The RtSolPr message includes information about the link layer address or identifier of the concerned NAR.

- 2-MAP receives RtSolPr and sends HI message to NAR to request bi-directional tunnel between MAP and NAR. HI message includes link layer address of MN.

- 3- Based on the MN's link layer address and network prefix of NAR, NAR create NCoA for MN to use in the NAR region. The HI message includes an indication that the MN will perform the Optimistic DAD itself. In response to the HI message, the NAR will respond immediately with a Optimistic Handover Acknowledge (oHACK) message.

- As a result, a bi-directional tunnel between MAP and NAR will be established. Over the tunnel, the data packets sent by MAP have the additional outer IP header with the following IP fields of <Source = MAP, Destination = NAR>. The NAR may cache those data packets flowing from the MAP, until it receives the FNA message from the newly incoming MN.

- 4- After receiving PrRtAdv, MN configure NCoA and requests a fast binding service by sending an FBU message (Fast Binding Update) to MAP in order to associate its NCoA with NAR.

- 5- MAP associate PCoA with NCoA and send FBACK to MN, after that, MAP will forward packets to MN pass through NAR by using established tunnel.

- 6-The MN set its address state to Optimistic and sends NS messages to initiate Optimistic DAD. At the same time, it sends FNA messages to NAR (note that the MN already has link-layer address of NAR from PrRtAdv message.

- Then, the NAR delivers the buffered data packets to the MN.
- 7-The MN then follows the normal HMIPv6 operations by sending a Local Binding Update (LBU) to MAP, as per HMIPv6.
- When the MAP receives the new Local Binding Update with NLCoA from the MN, it will stop the packet forwarding to NAR and then clear the tunnel established for fast handover.

- 8-In response to LBU, the MAP sends Local Binding ACK (LBACK) to MN, and the remaining procedures will follow the HMIPv6.

C. Simulation results

- The goal of our simulation was to examine the effect of handover schemes on handoff latency of an end-to-end TCP communication session. In particular, we wanted to examine the packet loss and packet re-ordering behavior. The extensions to *ns* described in the figure 8 [17, 18]

- The handoff performance result will be presented as concise summaries, the TCP disruption time and graph, corresponding to each handover scheme.

- The handover delay in this project is measured from the time the MN send request to PAR to init handover process until the time the first packet from CN, routed through NAR, reaches MN.

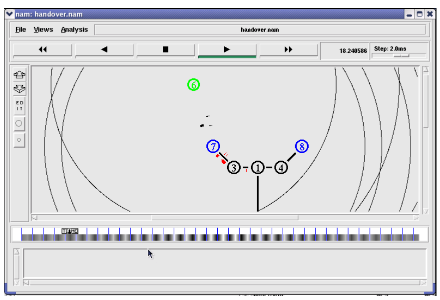

Fig 8 : MN communicate with PAR

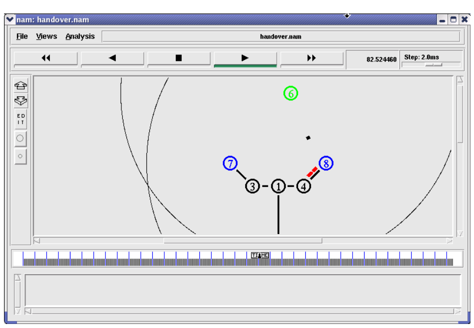

Fig 9 : MN communicate with NAR

<u>HMIPv6</u>

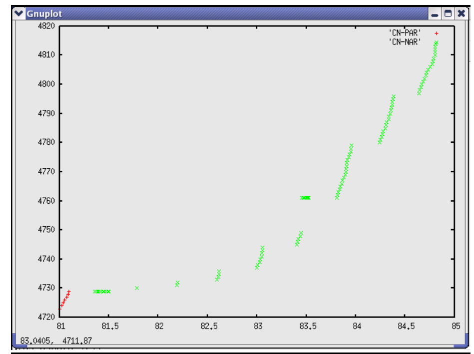

Fig 10 : The simulation result of HMIPv6

- The first dropped packet (sequence number 4729) is dropped at 81.095622. MN accepts the first transmitted packet at 81.356542. So, TCP disruption time of this case is 0.26092s
- The last packet which MN receives from PAR (sequence number 4729) is at 81.095622
- The first packet which MN receives from NAR (sequence number 4730) is at 81.785856
- Packet drop: 21 packets.
- Handoff delay: 0.690234s

<u>FHMIPv6</u>

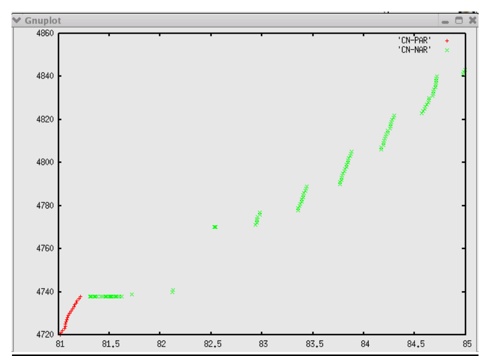

Fig 11 : The simulation result of FHMIPv6

- The first dropped packet (sequence number 4738) is dropped at 81.215352. MN accepts the first transmitted packet at 81.310446. So, TCP disruption time of this case is 0.095094s
- The last packet which MN receives from PAR (sequence number 4738) is at 81.215352
- The first packet which MN receives from NAR (sequence number 4739) is at 81.716415
- Packet drop: 4 packets.
- Handoff delay: 0. 501063s

oFHMIPv6

- The first dropped packet (sequence number 4739) is dropped at 81.223474. MN accepts the first transmitted packet at 81.356542. So, TCP disruption time of this case is 0.08228s
- The last packet which MN receives from PAR (sequence number 4739) is at 81.223474
- The first packet which MN receives from NAR (sequence number 4740) is at 81.718355
- Packet drop: 3 packets.
- Handoff delay: 0.494881s

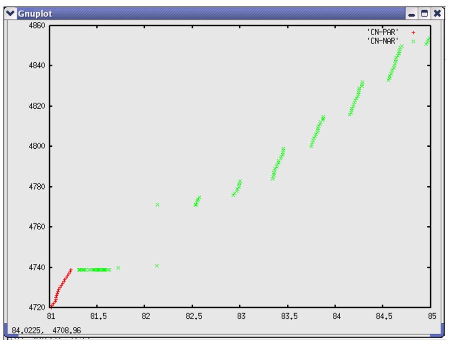

Fig 12 : The simulation result of oFHMIPv6

4. Conclusion and future works

Table 1: Comparison of simulation results of the protocols

Parameters / Protocol	TCP disruption time(s)	Packet drop	Handover delay
HMIPv6	0.26092	21	0.690234
FHMIPv6	0.095094	4	0.501063
oFHMIPv6	0.08228	3	0.494881

The oFHMIPv6 obviously provides improvement to the handover performance of Mobile IPv6. This paper has presented different handover improvement techniques that research groups have proposed in previous reports. However, the overall handover delay as well as the packet loss are still very high for time-sensitive applications to tolerate.

In the future we will continue to complete the implementation aspects of the framework:

- Optimizing other handover latency components such as movement detection time, registration time.
- Optimizing DAD procedure

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