Asian Info-communications Council

Document No 118
19-23 November 2007
36th Conference (Manila)

Working Group 2

(Services & Applications)

TITLE: A COMPARATIVE SURVEY OF SEAMLESS HANDOVER MECHANISMS
THEME: Services & Applications related
SOURCE:

Tran Cong Hung, Ph.D (**P**ost & **T**elecommunication **I**nstitute of **T**echnology, Viet Nam)
E-mail : conghung@ptithcm.edu.vn

Le Phuc, M.Eng (**P**ost & **T**elecommunication **I**nstitute of **T**echnology, Viet Nam)
E-mail : lephuc@ptithcm.edu.vn

Tran Thi To Uyen, Eng. (**P**ost & **T**elecommunication **I**nstitute of **T**echnology, Viet Nam)
E-mail : tranthitouyen@gmail.com

Hae Won Jung, Ph.D (**E**lectronics and **T**elecommunications **R**esearch **I**nstitute, Korea)

E-mail : hw-jung@etri.re.kr

Yoohwa Kang, Ph.D (**E**lectronics and **T**elecommunications **R**esearch **I**nstitute, Korea)
E-mail : yhkang@etri.re.kr

Summary

A seamless handover scheme with low latency and low packet loss is an important issue to maintain end-to-end TCP performance of mobile users. Several solutions have been proposed as extensions of Mobile IPv6 to improve the handover performance of mobility, each solution has its own advantages and disadvantages, and therefore, an standardized handover mechanism is not accepted yet.

In this paper, we propose a comparative survey of typical handover mechanisms with an aim to figure out the way of optimization of the handover process. The handover mechanisms we choose to analyze are Mobile IPv6, Hierarchical Mobile IPv6 and Fast handover protocol. Before the survey, we examine the impact of latency and packet loss as result of the handover process on TCP performance. We also present the simulation result of these solutions together with the evaluation model we use in the testbed.

1. Introduction:

The Mobile IPv6 specification enables hosts to change their point of attachment to the Internet whilst not breaking existing application sessions. This is achieved primarily through the fact that mobile node (MN) always being reachable at its home address (HoA) via its home agent (HA). When a MN changes its point of attachment to the network, the MN usually has disconnected from the current network before connecting to the new network and thus there is a time interval in which the MN has lost connectivity to the Internet. This disconnection prevents on-the-flight packets from being delivered to the MN and therefore degrades the performance of the transport layer protocol.

The process of switching from the current point of attachment to a new point of attachment of the MN is refered to as handoff or handover. To maintain quaility of service for users, the handoff process should be seamless, i.e the number of lost packets is low and the delay time is short. A seamless handoff schem makes the network switching tranparent to higher layer services and this is very important for time-sensitive services.

To improve the performance of the TCP stream in mobile environment, there are many extensions to Mobile IPv6 as well as new protocols proposed to smoothen the handoff process. The aim of these proposals is to reduce the latency and the number of lost packets in the handoff period.

This paper focuses on a comparative survey of three typical mechanisms of handover: Mobile IPv6, Hierarchical Mobile IPv6 and Fast Handover protocol. The paper therefore is organized as follows: the next section gives a brief analysis of handoff latency in which components of the delay are identified. Section 3 describes the operations of the choosen handoff mechanism and section 4 introduces the simulation results as well as the evaluation model we used in the testbed.

2. Identifying the handoff latency components

When an MN detects that it has moved to a new subnet by analyzing the *router advertisement (Ra)* message sent by access routers (AR), it creates a new care of address (CoA) based on the information contained in the advertisement of the routers. In some cases, an MN may also request a router advertisement message by sending a *router solicitation (Rs)* message. As stated in IPv6 specification, the MN needs to be sure that its link-local address in the new link is unique by implementing the duplication address detection (DAD) procedure. After the DAD process, the autoconfiguration procedure is performed by the MN to form its new CoA. Another DAD procedure may be carried out to check the duplication of CoA, but in most cases, this step is omitted because the time it takes is too long for the overall handover process.

When the new CoA construction is finished, the MN then registers this address with its HA using a *binding update (BU)* message. The handoff process is now completed and packets from the *corespondent node (CN)* can be delived to the MN via its HA.

The handoff process can be divided into three steps as follows (figure 1):

Detection: This step lasts from the time a MN moves to a new network to the time it receives a Ra message from the new AR. When the MN on its movement is under the coverage of of a new network, it can detect the change by actively sending a Rs or just waiting for a Ra from the access router. If the MN is configured to actively send the Rs message, it can immediately receive the Ra message and then configure its CoA using information provided in Ra. However, for a MN to actively request for Ra, there must be a trigger at the link layer or from the user. Alternatively, the MN has to wait for the router advertisement. The interval between two consecutive router advertisement messages can be from a minimum of 30ms to a maximum of 70ms.

Configuration: This step takes place from the time a MN receives a router advertisement to the time its network interface is configured with a new CoA based on the information contained in the Ra message.

Registration: This step takes place from the time a MN sends BU messages to its HA and CN to the time it receives the first data packet from its CN. In Mobile IPv6, the binding acknowledgement from the CN is not mandatory, so the handoff process can only be done if the MN receives a packet from its CN.

If we denote the duration of the detection step as Td, of the configuration step as Tc and of the registration step as Tr, then the overall handoff delay Th can be given by:

$$\mathbf{Th = Td + Tc + Tr}$$

This observation reveals that to reduce the handoff delay Th, we can optimize the process so that Td and Tr components are minimized. The Tc component, however, depends mostly on the processing speed of the mobile device.

The Td component can be optimized by decreasing the router advertisement interval or by using a link layer trigger so that the MN always actively request for the router advertisement by sending a router solicitation. However, the Tr component depends on the link latency and can only be optimized by a complicated procedure.

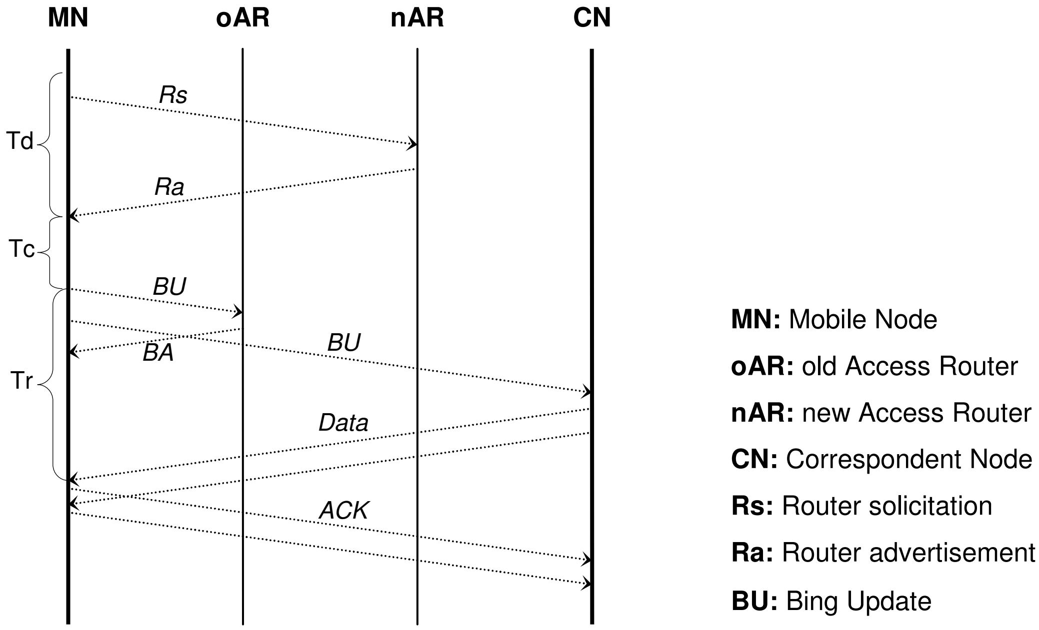


Figure 1: Components of handoff latency in MIPv6

3. Optimizing the handover process:

3.1. Mobile IPv6:

MIPv6 already provides some enhancement to the handoff procedure. In some cases, an MN can be connected via several wireless links from several neighboring APs. If these APs are on different subnets, the MN can configure a CoA for each of them. One of these CoAs is selected as primary CoA for a default AR that will be registered in the MN's home agent and correspondent. Then, when the default AR becomes unreachable, the MN can change to a new AR quickly with available CoA addresses.

Because the packets sent by CNs in the handoff process are lost until these CNs receive the binding update signal indicating the new CoA of the MN, the MN can request the old AR to forward all its incoming packets to the new AR. To do so, the MN has to send a binding update to a HA on its old link indicating its new CoA, but with its old CoA instead of the home address. Then, the HA on the old link intercepts the packets intended to the old CoA of the MN and forwards them to the current localization of the MN.

Depending on the MN's movements, an MN can switch forth and back between two ARs several times. In this case, Mobile IPv6 requires that the MN create and register a new CoA after each movement and this process is refered to as bicasting. Bicasting allows the MN to simultaneously register with several ARs. All the packets intended for the MN are then duplicated in several potential localizations. This solution is very important, particularly if the multiple associations could be set up by anticipation. However, the bicasting performed by the HA is not scalable and generates lots of traffic on both the wired and wireless links.

3.2. Hierarchical MIPv6

Mobile IPv6 (flat MIPv6) requires the MN to send a binding update to each of its correspondents.Depending on their localization, the time to reach them and the traffic load generated can be very high. Hierarchical Mobile IPv6 is designed to minimize the amount of signaling messages to be sent to CNs and to the HA by allowing the MN to locally register in a domain.

Hierarchical schemes separate mobility management into intra-domain mobility and inter-domain mobility by introducing a special entity called Mobility Anchor Point (MAP). It is a router that maintains a binding between itself and the MNs currently visiting its domain. MAP is normally placed at the edges of a network, above the access routers, to receive packets on behalf of the MNs attached to that network. When a MN attaches itself to a new network, it registers with the MAP serving that network domain (MAP domain).

The MAP operates as the local HA for the MN. It intercepts all the packets addressed to the MN it serves and tunnels them to the corresponding on-link CoA of the MN. If the MN changes its current address within a local MAP domain, it only needs to register the new on-link address with the MAP because the global CoA is still the same. If a MN moves into a new MAP domain, it needs to acquire a regional address (RCoA) and an on-link address (LCoA). The MN then uses the new MAP's address as the RCoA. After forming these addresses, the MN sends a regular BU message to the MAP, which will bind the MN's RCoA to its LCoA. If successful, the MAP will return a *binding acknowledgement (BAck)* to the MN indicating a successful registration. In addition to the binding at the MAP, the MN must also register its new RCoA with its home agent by sending another BU message that specifies the binding between its home address and the RCoA. Finally, it may send similar BU message to its current CNs, specifying the binding between its home address and the RCoA.

3.3. Fast handover protocol:

The Fast Handover Protocol is an extension of MIPv6 that allows an AR to provide services to an MN in order to anticipate the layer 3 handover.

Fast-handoff schemes introduce four additional message types for use between access routers and the MN. These four messages are: *Router Solicitation for Proxy* (*RtSolPr*), *Proxy Router Advertisement* (*PrRtAdv*), *Handover Initiation* (*HI*) and *Handover Acknowledgement* (*HAck*). In fast-handover, the old Access Router (oAR) is defined as the router to which the MN is currently attached, and the new Access Router (nAR) as the router to which the MN is about to move to. The fast-handoff initiation is based on an indication from a wireless link-layer (layer 2) trigger, which informs that the MN will be handed off. Essentially, this indication mechanism anticipates the MN's movement and performs packet forwarding accordingly.

In the wireless LAN environment, to initiate a fast-handover, the MN sends a *RtSolPr* message to the oAR indicating that it wishes to perform a fast-handover to a new attachment point. The *RtSolPr* contains the attachment point link-layer address to indicate the new destination attachment. The MN will receive a *PrRtAdv* message from the oAR with a set of possible responses indicating that the point of attachment is i) unknown, ii) known but connected through the same access router or iii) is known and specifies the network prefix that the MN should use in forming the new CoA. Based on the response, the MN forms a new address. Subsequently, the MN sends a BU message using its CoA as the last message before the handover is executed. The MN then receives a Back either through the oAR or the nAR indicating that the binding was successful. When the MN moves into the nAR's domain, it sends the Neighbour Advertisement, *NA*, to initiate the flow of packets at the nAR.

4. Simulation result

To evaluate the performance of the three handoff mechanisms, the Network Simulator, *ns*, was used with ns-wireless extensions and HFMIP extensions to simulate the operations. The network topology we used in the simulation is illustrated in figure 2. In the simulation scenario, the MN move from its present access router (oAR) to a new access router (nAR). At the beginning of the simulation the MN is close to HA and starts an ftp session with CN. Ten seconds later, MN starts to move at speed of 1 m/s towards NAR. We observe the time when the MN receive the first Ra message from NAR until the first data packet is reveived by MN at its new CoA.
The topology is used for simulation:

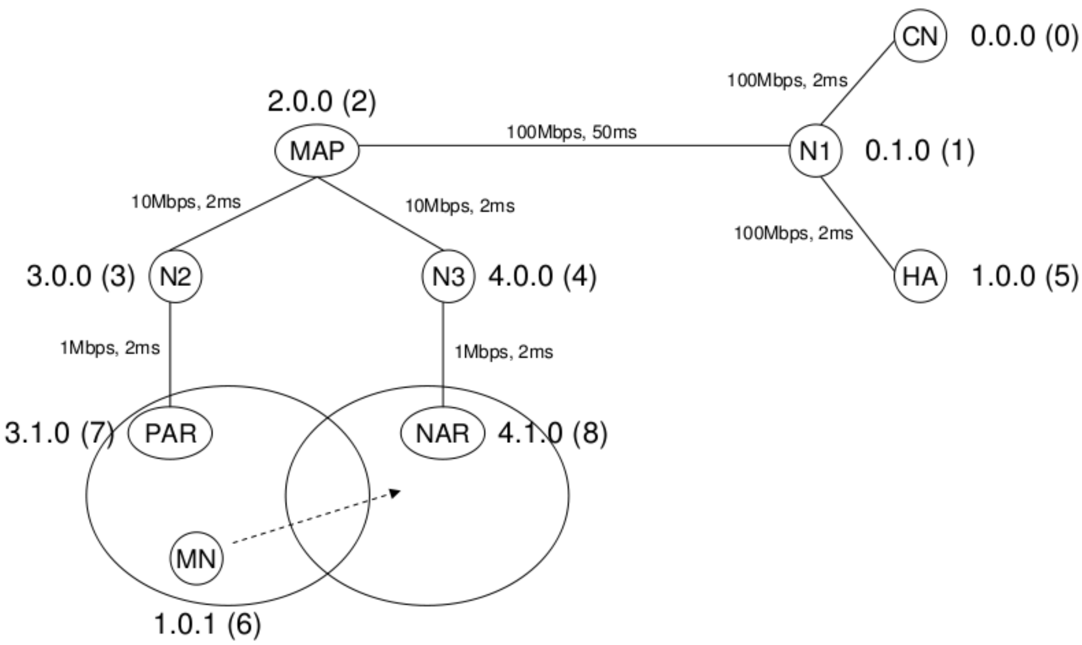
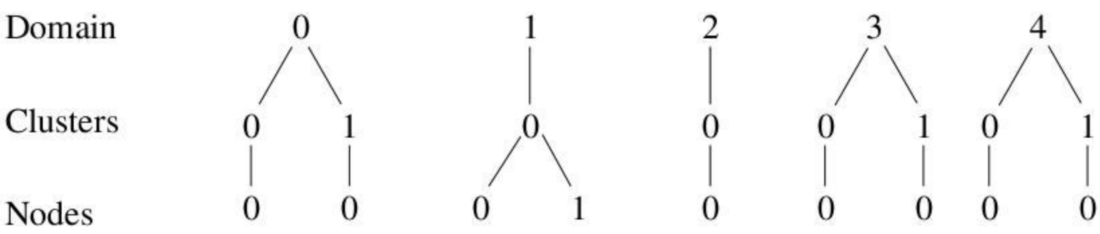


Figure 2: The simulation network topology

For FHMIP, all nodes possess a hierarchical address. There are 5 domains - the distribution of the nodes in the domains is shown below:



Both CN and HA are connected to an intermediate node (N1) with 2ms link delay and 100 Mbps links. The link between N1 and the MAP is a 100 Mbps link with 50 ms link delay. The MAP is further connected to the intermediate nodes N2 and N3 with 2ms link delay over 10 Mbps links. N1 and N2 are connected to PAR and NAR with 2ms link delay over 1 Mbps links. In order to simulate the handover, the MN starts to move towards NAR at the speed of one m/s. The L2 handover time is modeled by 20ms. The address resolution time is ¯fixed to 100ms. This is the time taken for the MN to obtain a new CoA from NAR.
The handover is initialized by the MN as soon as it receives a router advertisement from an unknown router on Layer 3. Thus, no layer 2 triggering is involved in the handover decision.
CN and MN are involved in a TCP session in which a bulk data transfer application transfers packets from CN to MN. The packet size is 512 bytes and the TCP window size is 32. Further, no route optimization is used, which means that all packets are ¯rst routed to HA and then tunneled to MN. The handover latency is measured through the disruption of the TCP stream between the communicating stations. As soon as MN

starts the registration process with NAR it is no longer able to receive TCP segments arriving from CN. The TCP session remains active and the CN continues to inject TCP segments in the network. When registration is completed, the MN begins to receive out-of-sequence segments. TCP conform, the MN sends (negative) acknowledgment messages, containing the expected sequence number. Upon receiving three such essages, the CN starts retransmission from the requested sequence number upwards. The reception of the ¯rst retransmitted segment by the MN is regarded as the end of disruption time. Basically, the sooner the MN starts receiving out-of-sequence segments, the shorter the disruption time will be.

TCP disruption time:

- Flat MIP: 358 ms
- FHMIP: 270 ms

Mobile IPv6 (flat MIPv6) case:

In this scenario the MN starts registration immediately after it receives an ad from nAR (like in priority MIP and HMIP). The registration is initiated via oAR, by the MN sending a *RtSolPr* message to it. oAR and nAR then exchange *HI– HAck* messages and build a tunnel. oAR responds to MN with a *PrRtAdv* message. Then MN sends a registration request to nAR which is forwarded to HA. After the tunnel has been built oAR starts forwarding all incoming packets for MN to oAR. Additionally it also broadcasts them on the medium. However, MN drops all packets as long as they come from oAR—to simulate channel switching as described before. Further, nAR has no buffering capabilities, so all packets received at oAR before MN 's registration with nAR is completed, are lost.

Hierarchical Mobile IP with Fast Handover case

The FHMIP functionality is a mix of the FMIP functionality of the extension and the F-HMIPv6 draft . After hearing the ad from nAR, MN sends a *RtSolPr* message to oAR. Instead of forwarding the message to MAP (F-HMIPv6 conform) oAR and nAR make a *HI– HAck* exchange (like FMIP). This is not necessary since they are not going to build a tunnel. Then oAR sends the *PrRtAdv* to MN and MN sends a registration request to nAR. nAR forwards the request to MAP upon which MAP starts forwarding packets destined to MN to nAR. This is not really a
tunnel which reduces packet loss since the forwarding starts when the registration is completed

The simulation result shows that Hierarchical Mobile IPv6 with Fast Handover gives best performance, next comes Hierarchical Mobile IPv6; the Mobile IPv6 (flat mobile IP) provides the highest handoff latency.

5. Conclusion

The survey of three typical handoff optimization schems reveals that it is possible to reduce the latency of the handoff process and in fact, there are some proposals about this in recent years (such as the Seamless Handoff architecture for Mobile IP or S-MIP), and these proposals have proved their success in some aspects . In future works, we plan to examine some newly proposed mechanisms and based on these implementations, we will design a new schem with the expectation to give a better seamless handoff procedure .

6. References

[1] Robert Hsieh and Aruna Seneviratne , *A Comparison of Mechanisms for Improving Mobile IP Handoff Latency for End-to-End TCP,* School of Electrical Engineering and Telecommunications, The University of New South Wales, ACM, 2003.

[2] Hsieh, R., and Seneviratne, *A Performance analysis on Hierarchical Mobile IPv6 with Fast-handoff over End-to- End TCP*. In Proceedings of GLOBECOM, Taipei, Taiwan 2002.

[3] *S-MIP: A Seamless Handoff Architecture for Mobile IP*, Robert Hsieh, Zhe Guang Zhou, Aruna Seneviratne, School of Electrical Engineering and Telecommunications, The University of New South Wales, IEEE, 2003.

[4] Vivaldi1, Mohd Hadi Habaebi1, Vivaldi1, Mohd Hadi Habaebi1*, Borhan Mohd Ali1 and V *Fast handover algorithm for hierarchical mobile IPv6 macro-mobility management*, Indra. Prakash1, 2004.

[5] Hsieh, R., Zhou, Z.-G., and Seneviratne, A. *S-MIP: A Seamless Handoff Architecture for Mobile IP*. In Proceedings of NFOCOM, San Francisco, USA, 2003.

[6] Koodli, R. (eds.). *Fast Handovers for Mobile IPv6*. Internet Draft, IETF, September 2002.

[7] VTsuguo Kato VRyuichi Takechi VHideaki Ono, *A Study on Mobile IPv6 Based Mobility Management Architecture*, 2001.

[8] Srikant Sharma, Ningning Zhu, Tzi-cker Chiueh, Low-Latency Mobile IP Handoff for *Infrastructure-Mode Wireless LANs*, IEEE communications, vol. 22, no. 4, may 2004.

TRAN CONG HUNG was born in VietNam in 1961
He received the B.E in electronic and Telecommunication engineering with first class honors from HOCHIMINH university of technology in VietNam, 1987.
He received the B.E in informatics and computer engineering from HOCHIMINH university of technology in VietNam, 1995.
He received the master of engineering degree in telecommunications engineering course from postgraduate department HaNoi university of technology in VietNam, 1998.
He received Ph.D at HaNoi university of technology in VietNam, 2004.
His main research areas are B – ISDN performance parameters and measuring methods, QoS in high speed networks, MPLS.
Currently, he is a lecturer, Dean of Faculty of Information Technology II in Posts and Telecoms Institute of Technology (PTIT), in HOCHIMINH City, VietNam.

Le Phuc, received the Diploma of Telecommunications Engineering from the Posts and Telecommunications Institute of Technology in 1998, the Diploma of Information Technology from Hochiminh City University of Natural sciences in 2002, the Master of Engineering degree in Computer science from Asian Institute of Technology (AIT), Thailand, in 2006.
He is currently a faculty member of IT faculty, Posts and Telecommunications Institute of Technology, Hochiminh City, Vietnam. His research interest is on computer networking, computer security and wireless networking.

TRAN THI TO UYEN was born in Vietnam in 1984
She received B.E of Information Technology form Post and Telecommunication Institute of Technology (PTIT), campus in Hochiminh City, Vietnam, 2007.
She graduated with the thesis "Load Balancing in MPLS".