

MOBILE IP HANDOVER: A COMPARATIVE SURVEY OF SEAMLESS HANDOVER MECHANISMS

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Abstract: *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 referred to as handoff or handover. To maintain quality 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 scheme makes the network switching transparent 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 chosen 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 *correspondent node (CN)* can be delivered 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 T_d , of the configuration step as T_c and of the registration step as T_r , then the overall handoff delay T_h can be given by:

$$T_h = T_d + T_c + T_r$$

This observation reveals that to reduce the handoff delay T_h , we can optimize the process so that T_d and T_r components are minimized. The T_c component, however, depends mostly on the processing speed of the mobile device.

The T_d 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 T_r component depends on the link latency and can only be optimized by a complicated procedure.

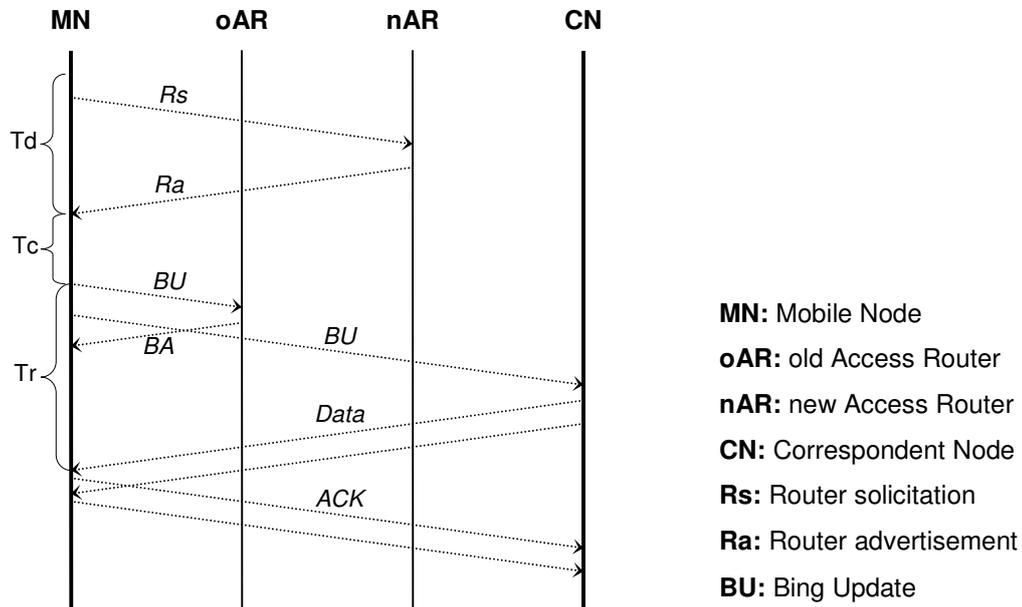


Figure 1: Components of handoff latency in MIPv6

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 referred 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 received by MN at its new CoA.

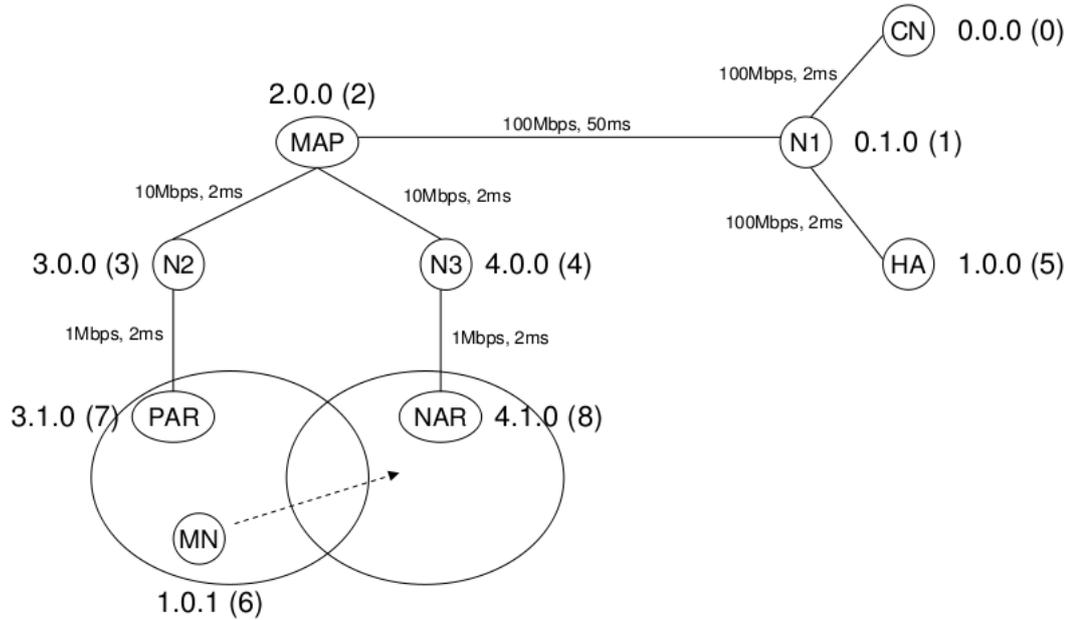


Figure 2: The simulation network topology

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 schemes 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 scheme with the expectation to give a better seamless handoff procedure.

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