HANDOVER OPTIMIZATION FOR HOST AND NETWORK MOBILITY

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Abstract: Mobile IP and NEMO (network mobility) provide continuous connectivity to the Internet to a node or a mobile network when moving from one access router to another. Because of link switching delay and IP protocol operation, packets destined to mobile nodes or mobile networks can be delayed or lost during the handover period. This paper proposes solutions to improve the performance of handover in the context of Mobile IPv6 and NEMO. We introduce a new control entity for both MIPv6 and NEMO to manage the traffic between access routers and mobile nodes or mobile routers, to provide low-latency and low packet loss for real-time services during the handover.

1 INTRODUCTION

The need of keeping connection with Internet in everywhere and at every time is more and more demanded in recently years. We can find two kinds of mobility scenarios. In the first one, only mobile node moves and attaches to different locations in the Internet topology through immovable routers, using MIPv4 (Perkins, 2002) or MIPv6 (Johnson, 2004) mechanisms, we call it *Host Mobility.* The second one concerns the scenario where a set of hosts move collectively as a unit, we call it *Network Mobility*. There are many situations where an entire network might move and attach to the Internet topology from "anywhere" at "anytime", like a mobile network that can be contained in a train or a ship. In both cases, continuous connectivity must be supported. Hence, recently, several extensions to MIPv6 have been proposed aiming to reduce the handover latency and packet loss to improve the handover performance for real-time applications support.

In the case of network mobility, host mobility support protocols may produce enormous signaling which is not suited to the whole network movement. Moreover, not all nodes in a large mobile network may be sophisticated enough to run such mobility support protocols. Network Mobility support protocols have then been proposed in the context of a recent IETF working group called NEMO. In mobile networks, the weakest part comprises mainly the mobile router. If the MR is down, all connections between Internet and mobile node are disrupted. Hence, multihomed architecture with multiple mobile routers which offers multiple connections to the Internet is proposed for mobile networks. This architecture enables connections to be maintained even if one of the mobile routers fails. Our work related to handover optimization for network mobility focuses on this specific NEMO architecture.

The goal of this paper is to optimize handover process both in host and network mobility but considered separetely. Firstly, we propose a new scheme to achieve MIPv6 fast handover by introducing a component called *Handover Control Function* (HCF) in Hierarchical Mobile IPv6. This function allows us to predict a new attachment point while a mobile node moves. Secondly, we enhance the handover performance in the case of multiple mobile routers installed in mobile network, by using a new component called *Intelligent Control Entity (ICE).*

The remainder of the paper is organized as follows. Section 2 presents background and related work of mobile IP and NEMO. Section 3 presents our HCF Based Handover Function for a novel MIPv6 scheme and the detailed protocol operation.

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Section 4 deals with NEMO with multiple mobile routers via a general architecture and a new scheme. Finally, conclusion and future work are mentioned in section 5.

2 BACKGROUND AND RELATED WORK

As our paper deals with both host and network mobility, we describe the several proposals related to these two kinds of mobility separately.

2.1 Host Mobility with Mobile IPv6

Many kinds of wireless technologies, such as GSM, UMTS, Wireless LAN, using the Host Mobility architecture currently co-exist and are likely that their number will further increase in the near future. Recently, as the WLAN technologies, especially the IEEE 802.11 standards have got great attention, a growing number of WLANs have been set up in public buildings or corporate environments as access networks to the Internet. In this paper, we focus on improving the handover performance of Mobile IPv6 over Wireless LAN.

Actually, the main proposals accepted by IETF are Hierarchical Mobile IPv6 (HMIPv6) (Soliman 2005) and Fast Handover for MIPv6 (FHMIPv6) (Koodli, 2005). HMIPv6 introduces Mobility Anchor Point (MAP) (a special node located in the network visited by a Mobile Node (MN)) who acts somewhat like a local Home Agent (HA) for the visiting MN. Moreover, HMIPv6 separates MN mobility into micro-mobility (within one domain or within the same MAP) and macro-mobility (between domains or between MAPs). With this hierarchical network structure, MAP can limit the amount of signaling required outside the MAP's domain. Therefore, the amount and latency of signaling between a MN, HA and one or more Correspondent Nodes (CNs) decrease.

FHMIPv6 reduces packets loss by providing fast IP connectivity as soon as a new link is established. The network uses layer 2 triggers to launch either Pre-Registration or Post-Registration handover scheme. In Pre-Registration scheme, the network provides support for pre-configuration of link information (such as the subnet prefix) in the new subnet while MN is still attached to the old subnet. By reducing the pre-configuration time on the new subnet, it enables IP connectivity to be restored at the new point of attachment sooner than would otherwise be possible. In Post-Registration scheme, by tunneling data between the previous point of attachment and a new point of attachment, the packets delivered to the old Care-of-Address (CoA) are forwarded to the new CoA during link configuration and Binding Update. So it is possible to provide IP connectivity in advance contrarily to the actual Mobile IP registration with the HA or CN.

Besides the main proposals, there have been numerous approaches for providing lossless handover and minimizing the handover delay. In (Chaouchi, 2004), a Pre-Handover Signaling (PHS) protocol is proposed to support the triggering of a predictive handover and to allow the network to achieve accurate handover decisions. In (Bi, 2004), a Hierarchical Network-layer Mobility Management (HNMM) framework is described in which an integrated IP-layer handover solution is proposed to provide optimized network connectivity. Also, a Competition based Soft Handover Management (CSHM) protocol (Kristiansson, 2004), and the Multi-path Transmission Algorithm (Kashihara, 2002) are proposed to decrease packet loss during handover.

2.2 Network Mobility

Network Mobility (NEMO) provides continuous connectivity to the Internet to a set of nodes within a mobile network. As illustrated in figure 1, a mobile network is composed of one or more mobile IP-subnets (NEMO-link) and is viewed as a single unit. This network unit is connected to the Internet by means of one or more Mobile Routers (MRs). Three types of nodes behind the MR are defined : Local Fixed Nodes, Local Mobile Nodes and Visiting Mobile Nodes.

At a home link, an entity named Home Agent (HA) is presented (figure 1), with which the mobile router will register its care-of address and prefix. While the mobile network is away from home, the home agent intercepts packets on the home link destined to the mobile network, encapsulates them, and tunnels them to the MR’s registered care-of address. At the foreign link, MRs get network layer access to the global Internet from the Access Router(s) (AR) (figure 1), via which packets from/to Internet are transported.

The NEMO basic protocol (Devarapalli, 2005) requires the MR to act on behalf of the nodes within its mobile network. When an MR configures a new CoA at a foreign link, it sends a Binding Update message to its home agent, which contains its CoA and its prefixes (in the case where the MR’s prefix can be determined by home agent, prefix is not included in Binding Update message). These prefixes are then used by the HA to intercept packets

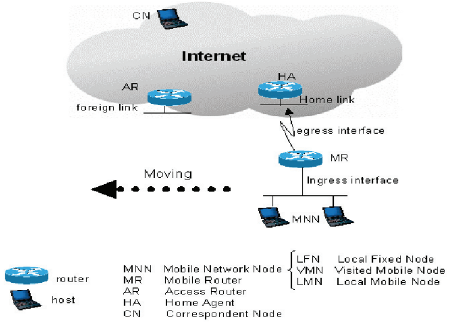

Figure 1: Architectural Components of NEMO.

addressed to the mobile nodes and these packets are tunnelled to the MR. In response to the Binding Update message, HA returns a Binding Acknowledgement message to MR, which indicates whether the HA has successfully processed the Binding Update and has set up forwarding for the Mobile network. If the procedure of Binding Update is successful, a bidirectional tunnel between the MR and the HA should be established. From now, the MR encapsulates the packets from the mobile network and tunnels them to HA, the latter decapsulates the packets and forwards them to the Correspondent Nodes (CNs). In the opposite direction, the HA encapsulates the packets to the mobile network and tunnels to the MR, the MR decapsulates the packets and forwards them to the mobile nodes.

As described above, the packets from/to mobile network must go through the bidirectional tunnel, which increase the packet's size (add an additional tunnel encapsulation) and the end-to-end delay. A straight-forward approach to route optimization in NEMO is proposed. Instead of preceding the Binding Update with HA, MR sends Binding Updates containing one or more Mobile Network Prefix options to the CN. The CN having received the Binding Update, can then set up a bi-directional tunnel with the MR at the current care-of address of the MR, and inject a route to its routing table so that packets destined for addresses in the mobile network prefix will be routed through the bidirectional tunnel between the CN and the MR (Ng, 2005). But establishing this kind of tunnel can be difficult to perform, especially in the case where the CN belongs to a mobile network node, and this mobile network is away from its home link. However, we can establish a tunnel to CN's MR. To extend this idea, if a tunnel can be established between the MR and an entity which is located closer to the CN than the HA, the route between mobile network and the CN can be said to be optimized.

2.3 Open Research Issues

Besides the problems of handover delay and packet loss in wireless LANs, there are many important issues related to handover such as handover architectures and handover decision algorithms that should be studied. The handover architectures concern mobility management and admission control while the handover decision algorithms decide some parameter adoptions and user preferences. In addition of handover issues, quality-of-service (QoS) and security are also the open research issues that are addressed at current and future wireless networks.

The most attractive feature for NEMO is the simplicity of its NEMO basic protocol. Since it is an extension of the Mobile IPv6 operation at the mobile routers and home agents, the effective deployment of mobile networks will strongly depend on how we can overcome some critical issues such as sub-optimal routing, handoff optimization, QoS management, multihomed configurations, security issues especially in nested configurations, compatibility with Mobile IPv6, access control, billing, and scalability. Some solutions have been proposed to tackle some of these issues but some other remain open and need further research like handover, security and QoS support.

When moving from an AR to another, because of a handover situation, traffic can be lost due to link switching delay and IP protocol operation (CoA configuration, Duplicate Address Detection, etc). Up to now, there are no proposals and we aim to propose some mechanisms to enhance NEMO handover performance in the case of multiple MRs installed in the mobile network (see section 4). This type of mobile network is one kind of multihomed mobile network; the latter can be configured into serveral types (Ng, Paik, 2005): when a MR has multiple egress interfaces, the mobile network has multiple MRs, the mobile network is associated with multiple HAs, and multiple global prefixes are available in the mobile network. Advantages of such architectures are listed in (Ernst, 2005) including permanent and ubiquitous access, reliability, load balancing, and preference settings.

3 HANDOVER CONTROL FUNCTION (HCF) BASED HANDOVER FOR MOBILE IPV6

As mentioned in Section 2.1, MIPv6 handover has been studied in some paper. We introduce a local intelligent entity called Handover Control Function (*HCF*) which should be capable of controlling several ARs and MNs.

3.1 HCF General Architecture

Linking with ARs, Handover Control Function (*HCF*) enables to decide the MN's new attachment. We define four new messages: Handover Request (*HOReq*), Handover Reply (*HORep*), Connection Establish Information (*CEInf*) and Handover Finish Confirmation (*HFCon*) messages in Mobile IPv6. It is necessary to mention that HCF can manage handover, resources distribution and security. Figure 2 illustrates the considered architecture.

Based on Figure 2, MN surveys periodically the received signal strength. Once the signal strength drops below the threshold predefined, MN will begin to scan and discover the new available AP. It reports to HCF the APs' BSSID (Basic Service Set Identifier) and signal strengths that it can probe. Based upon the reported information, AR/AP's loading, and MN's QoS demand, by using a predefined algorithm, HCF decides whether or which AP MN shall associate with and notifies MN about the new AR/AP's information, such as AP's BSSID, AR interface address, and sub-network prefix. HCF decides which AR's interface MN should move to as well. Consequently, the new network prefix of MN will be notified by HCF through *HCFRep* message accordingly.

The "IPv6 address allocation and assignment policy" issued by RIPE (Ripe, 2003) provides the guidelines for allocation and distribution of IPv6 addresses. This draft reveals that in an IPv6 access network as MN moves across the subnets, the only change in its IPv6 address occurs in subnet identifier field of the address. The remaining portion of the address, including 48 bit global routing prefix and the 64 bit interface identifier remains unchanged. Moreover, in our proposal, MN's interface identifier is allocated according to the norm of EUI-64. It ensures that the MN's new CoA is unique in Mobile IPv6. Consequently, MN could configure its new CoA and launches the Binding Update process even if it is still attached with previous AR/AP. HCF also knows MN's new CoA according to MN's old CoA and MN's new network prefix. Furthermore, Duplicated Address Detection (DAD) can be omitted during handover.

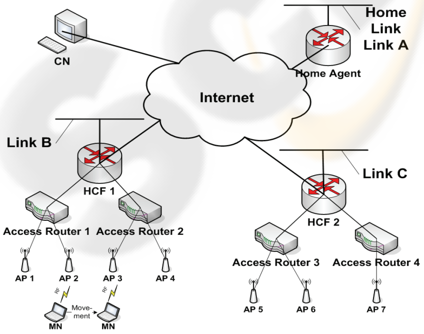

Figure 2: HCF Based Handover for Mobile IPv6.

After HCF sends the *HCFRep* message, HCF will intercept all packets sent to the MN's previous CoA, and buffers these packets. MN will send *CEInf* to HCF as soon as it finishes its handover process at the layer 2. HCF then encapsulates these packets and sends to MN with the *HFCon* message. Figure 3 shows messages exchange during the handover procedure.

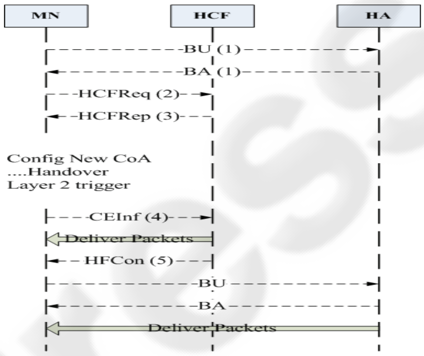

Figure 3: Protocol for HCF based handover.

3.2 HCF Procedure

HCF procedure is detailed as follows:

1) When MN registers to HA at the first time after it attaches to a new AR/AP, it sends *Binding Update* message to HA and HA responses with *Binding Acknowledgement.*

2) Moving at sub-network, if the threshold of received signal strength is overstepped, MN begins to probe all neighbor AP's information, including signal strength once. Then MN sends *HCFReq* message directly to HCF to report the information of its neighbor AP.

3) Receiving the *HCFReq* message, HCF decides whether or which AR/AP MN shall associate with. The choice of AR/AP is based mostly on the signal strength that MN receives and AR/AP's loading. For example, if the number of registered MNs in one AR or AP has reached a limit, HCF will not accept MN to move to that network. After making the decision, HCF sends the *HCFRep* message to MN. HCF notifies MN about new AR/AP's information, such as link prefix and AR's address. The information

will help MN to obtain a new CoA before it attaches to the new AR/AP.

4) After MN receives the *HCFRep* message, it knows that which AR/AP it will associate with and will configure its new CoA. Once MN attaches to the new AP and finishes the new CoA configuration, it sends the *CEInf* message to HCF.

5) After receiving this message, HCF begins to send the buffered packets to MN's new CoA. Thus, HCF sends the message *HFCon* to end the handover procedure.

As shown in HCF procedure, a MN can obtain its new CoA before it really attaches to the new AR/AP, so handover is optimized to reduce handover latency and packet loss.

4 HANDOVER FOR NEMO WITH MULTIPLE MOBILE ROUTERS

To support handover optimization for network mobility, we define a new architecture (figure 4). In this architecture, we introduce a local Intelligent Control Entity called ICE which should be capable of controlling several ARs and the MRs attaching to these ARs. In our case, the ICE can manage handover, but it can also be used in the future for managing connections, resources, QoS, security, etc. An ICE domain contains an ICE and several ARs. The ICE should possess the information of each its ARs, like capacity, preferences, etc. Once an MR attaches to an AR within an ICE domain, the ICE should also collect this MR's information, this information is sent by the MR which knows the ICE's address by AR's router advertisement message. The information includes MR's home address, MR's CoA, address of the attached AR, capacity, preference, etc.

Our mechanism for handover optimization is conceived for the case of multiple mobile routers installed in mobile network. As illustrated in figure 4, if MRs are located separately in the mobile network, as the mobile network moves, the MR at the right end of the mobile network (MR1) will perform handover firstly, when two others connect always to previous AR (AR1). When the behind MRs begin to perform handover, the MR at the right end of the mobile network should complete its handover. So in any time, it can exist at least one MR which does not perform handover, and which can transport the traffic addressed to the MRs being performing handover. However, if the distance between the MRs is not long enough, all MRs can perform handover overlapping in time, so the distance impacts the performance of handover proposed by our mechanism.

When the MR1 (in figure 5) begins to perform handover, as a response to some link-specific event (L2 "trigger"), which anticipates the handover, the MR1 sends the *handover initiate* message to its ICE. Upon receiving this message, the ICE knows that MR1 will begin the handover, it should, according to the collected information (capacity, preference, etc), choose another MR which is at the same mobile link and which is the best candidate to transport the MR1's traffic. If ICE can not find any candidate MR, it returns a *handover response* message indicating that the handover procedure has failed. After having chosen the candidate MR (for example, MR2 in figure 5), ICE sends a *traffic transfer* message to MR1's previous AR (AR1), to inform it to transfer the packets addressed to MR1 to MR2. From now on, AR1 encapsulates the packets addressed to MR1 and sends them to MR2, the latter decapsulates these packets and sends them to MR1 through the mobile link. To indicate whether the procedure of establishment of the tunnel is achieved, AR1 sends a *handover response* message to MR1. If AR1 succeeds the establishment, this message must contain the identity of the candidate MR (the identity of MR2), this identity enables the MR1 to know which MR transports its traffics. If not, the MR1 knows that the procedure of establishment of the tunnel has failed, and NEMO basic operation is performed. If MR1 does not receive this message over a certain time period, MR1 considers that the establishment of the tunnel fails. In the case where MR1 has disconnected to AR1, this message should be sent to MR2, MR2 then transmits it to MR1.

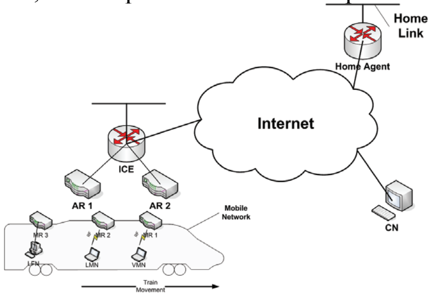

Figure 4: Our new NEMO architecture with 3 MRs.

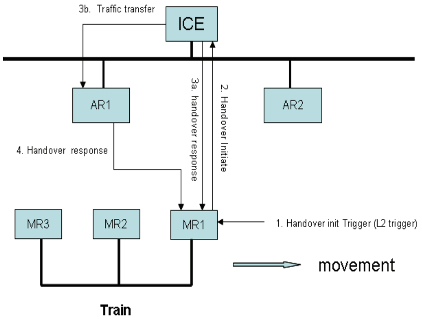

Figure 5: MR1 performs handover.

In the opposite direction, MR1 should send the packets from the mobile network to Internet to MR2 until it completes the Binding Update, MR2 should forward these packets to AR1. This procedure enables all packets from the mobile network to Internet to be transmitted without buffering even MR1 at the handover state. Additionally, this procedure ensures that packets are not dropped due to ingress filtering. When MR1 has established the connection with the new AR (AR2), i.e. it obtains the new CoA, it involves the procedure of Binding Update, which similarly as in NEMO. At the same time, it performs the information registration procedure as described above. Once the MR1 receives the Binding Update Acknowledgement message, it stops transmitting the packets from mobile network to Internet via MR2.

As described above, if it exists at least an MR at non handover state (does not perform handover) at any given time, the packets can always be transported without being buffered during handover.

5 CONCLUSION AND PROSPECTS

In this paper, we propose mechanisms to enhance handover operation both in host and network mobility. In the case of host mobility, HCF scheme is proposed without modifying the part of classical Access Router and Access Point in MIPv6. This new HCF scheme allows MN to get the new CoA and to launch Binding Update procedure before moving to the new AR/AP. Moreover, the omission of DAD process optimizes greatly handover performance. Furthermore, by the means of buffering the traffic during the layer 2 handover processes, then resending to the new AR/AP attachment by HCF after the layer 2 handover, the packet loss could be minimized and overcome.

For NEMO mobility, our proposition provides not only the minimization of delay and packet loss, but takes into consideration the resource management as well during handover. Additionally, our protocol is compatible with the ingress filter policy. However, since during handover, one MR may transport other MRs' traffics, the capacity of the MRs should be designed to be large enough.

This paper details our primary concepts and mechanisms. In the next step, our mechanisms will be simulated and evaluated by using simulation tools. In the future, we intend to investigate the other MIPv6 or NEMO issues, such as cross-layer solution, security aspects and QoS support taking benefit of using the introduced new intelligent entities to better manage the mobility and the network resource.

ACKNOWLEDGEMENTS

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