Proactive Correspondent Registration for Proxy Mobile IPv6 Route Optimization

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Summary
In this paper, a proactive correspondent registration mechanism is proposed for the Proxy Mobile IPv6 (PMIPv6) route optimization between the correspondent node (CN) and the mobile access gateway (MAG) on behalf of the mobile node (MN) in wireless access networks. Two scenarios are considered according to the type of CN. For the proposed mechanism, the proxy home test and the concurrent care-of test are defined newly with parameters specified by information on candidate MAGs. The proposed correspondent registration mechanism is performed before actual handover for candidate MAGs where the MN can attach newly. Therefore, the proposed mechanism can reduce correspondent registration latency, which can reduce handover latency and thus enhance throughput degradation caused by the bidirectional tunneling via the local mobility anchor (LMA).
Key words:
Proxy Mobile IPv6, Proactive correspondent registration, Handover latency, Binding latency, Concurrent care-of test.

1. Introduction

In recent, to support IP mobility for all hosts irrespective of the presence or absence of Mobile IPv6 (MIPv6) functionality in [1], the Proxy Mobile IPv6 (PMIPv6) is being standardized in Internet Engineer Task Force (IETF) [2][3]. This protocol to supporting mobility does not require the mobile node (MN) to be involved in the signaling required for mobility management. The mobility access gateway (MAG) in the network performs the signaling and does the mobility management on behalf of the MN. The PMIPv6 can be the L3 handover solution for wireless access networks from now on.

For the successful deployment of PMIPv6, the need to communicate efficiently on the move and to minimize the packet loss caused by a handover is becoming increasingly important because handover latency is unacceptable for real-time IP services. The L3 handover latency in PMIPv6 can be caused mainly by the network access authentication latency and the correspondent registration latency for the route optimization, etc. These latencies are inevitable in PMIPv6 because of its basic operations. These latencies could be appreciable for real-time applications and throughput sensitive applications. Among them, in this paper, the correspondent registration latency for the route optimization will be considered and reduced by the proposed mechanism.

The PMIPv6 protocol specification [2] doesn't provide any route optimization. Therefore, when the MN moves and attaches to a new link connected to the new MAG in the PMIPv6 domain, the bidirectional tunneling between the CN and the MAG on behalf of the MN via the local mobility agent (LMA) cannot be avoided before the correspondent registration procedure is completed between two entities. This bidirectional tunneling via the LMA may not allow the shortest communication path to be used. That is, data packets between two entities are often routed along paths that are significantly longer than optimal, which can cause end-to-end delay between two entities. In addition, this can also cause congestion at the LMA and its link. Moreover, the impact of any possible failure of the LMA or networks on the path to or from it can increase. Therefore, two entities suffer from significant throughput degradation caused by the bidirectional tunneling for interactive and real-time applications. As shown in [4], TCP bulk-data transfers are likewise affected since long handoff latencies may lead to successive retransmission timeouts and degraded throughput. That is, the correspondent registration procedure using cryptographic functions can help secure the PMIPv6 communication between two entities, but it also introduces significant quality of service (QoS) issues such as delay, congestion, etc. This means there is a tradeoff between security and QoS.

In order to solve the mentioned problem in the route optimization procedure, the correspondent registration between the CN and the MAG on behalf of the MN should be completed within short time as possible to reduce the correspondent registration latency. However, as shown in [3], the proxy home test and the concurrent proxy care-of test including the proxy binding update (PBU) and the proxy binding acknowledgement (PBA) for the correspondent registration are somewhat time-consuming and computationally burdensome since cryptographic functions for authentication and encryption require considerable computation and CPU processing time, which might introduces the correspondent registration latency.

In this paper, therefore, a proactive correspondent registration mechanism between the CN and the MAG on behalf of the MN is proposed in order to reduce correspondent registration latency for the PMIPv6 route optimization. As shown in [3], two scenarios are considered according to the type of CN. The first scenario is that the CN has the MIPv6 function and recognize PMIPv6 messages. The second scenario is that the CN doesn't have MIPv6 function and are provided mobility support by PMIPv6. The proxy home test and the concurrent care-of test including the PBU and the PBA are defined newly with parameters specified by information on candidate MAGs. The correspondent registration through above messages is performed before actual handover for candidate MAGs where the MN can attach newly. Therefore, the proposed mechanism can reduce correspondent registration latency, which can reduce handover latency and thus enhance throughput degradation caused by the bidirectional tunneling via the LMA.

The paper is organized as follows. In Section 2, the network configuration is discussed briefly. In Section 3, the proactive correspondent registration mechanism is proposed. In Section 4, advantages of the proposed mechanism are discussed. Finally, conclusions are made in Section 5.

2. Network Scenarios

This paper considers the Proxy Mobile IPv6 (PMIPv6) based IEEE 802.16e wireless network which consists of only several mobile access gateways (MAGs) that typically run on corresponding access routers, as shown in Figure 1 and Figure 2. This network configuration might be feasible because, in broadband wireless access (BWA) networks such as IEEE 802.16e wireless network [5][6], several access routers can cover quite a wide area where the MN can move.

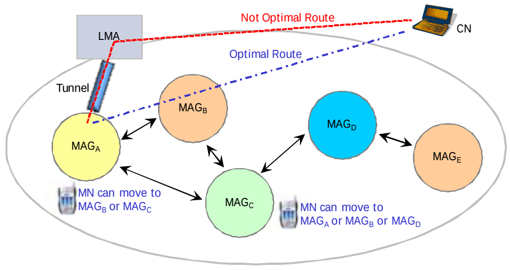

Figure 1. PMIPv6 based Wireless Access Networks (1st Scenario)

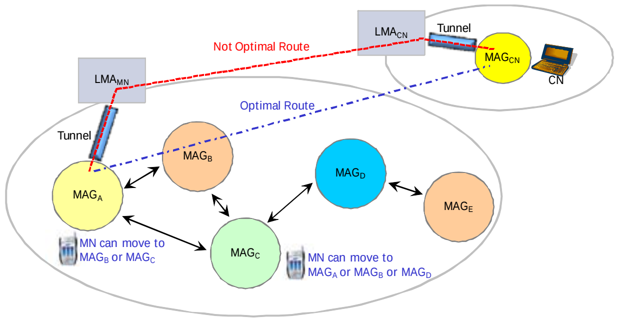

Figure 2. PMIPv6 based Wireless Access Networks (2nd Scenario).

Table 1. Information on MAGs

MAG	MID	Network Prefix	Candidate MAGs
MAG_A	0x01	3ffe:2e01:2a:101	MAG_B, MAG_C
MAG_B	0x02	3ffe:2e01:2a:102	MAG_A, MAG_C
MAG_C	0x03	3ffe:2e01:2a:103	MAG_A, MAG_B, MAG_D
MAG_D	0x04	3ffe:2e01:2a:104	MAG_C, MAG_E
MAG_E	0x05	3ffe:2e01:2a:105	MAG_D

In this paper, it is assumed that all MAGs can share information on other MAGs which exist in same PMIPv6 domain. As shown in Table 1, for all MAGs, the information consists of the MAG identifier (MID), the network prefix for proxy care-of address (Proxy-CoA) configuration, the list of candidate MAGs where the MN can attach newly. The MAG can acquire this information from the policy store. As shown in [3], there are two scenarios according to the type of CN. The first scenario is that CNs have MIPv6 function and recognize PMIPv6 messages as shown in Figure 1. The second scenario is that CNs don't have MIPv6 function and are provided mobility support by PMIPv6 as shown in Figure 2. Note that this paper borrows all of the terminology from the IETF specification [1]-[3] and the IEEE 802.16e specification [5].

3. Proactive Correspondent Registration Mechanism

3.1 Tradeoff between Security and QoS in PMIPv6 Handover Procedure

The PMIPv6 protocol specification [2] doesn't provide any route optimization. Therefore, when the MN moves and attaches to a new link connected to the new MAG in the PMIPv6 domain, the bidirectional tunneling between the CN and the MAG on behalf of the MN via the LMA cannot be avoided before the correspondent registration procedure is completed between two entities. This bidirectional tunneling via the LMA may not allow the shortest communication path to be used. That is, data packets between two entities are often routed along paths that are significantly longer than optimal, which can cause end-to-end delay between two entities. For example, a VoIP application is much more sensitive to delays than its traditional data counterparts. A few seconds' slowdown is negligible for downloading a file. However, a mere 150 millisecond delay can turn a crisp VoIP call into a garbled, unintelligent mess. In addition, this can also cause congestion at the LMA and its link. Moreover, the impact of any possible failure of the LMA or networks on the path to or from it can increase. Therefore, two entities suffer from significant throughput degradation caused by the bidirectional tunneling for interactive and real-time applications. As shown in [4], TCP bulk-data transfers are likewise affected since long handoff latencies may lead to successive retransmission timeouts and degraded throughput. That is, the binding procedure using cryptographic functions can help secure the PMIPv6 communication between two entities, but it also introduces significant QoS issues such as delay, congestion, etc. This means there is a tradeoff between security and QoS.

In order to solve the mentioned problem in the route optimization procedure, the correspondent registration between the CN and the MAG on behalf of the MN should be also completed within short time as possible to reduce the correspondent registration latency. However, as shown in [3], the proxy home test and the concurrent proxy care-of test including the early PBU and the PBA for the correspondent registration are somewhat time-consuming and computationally burdensome since cryptographic functions for authentication and encryption require considerable computation and CPU processing time, which might introduces the correspondent registration latency.

3.2 New Proxy Home Test and Concurrent Care-of Test Procedures

In this section, the proxy home test and the concurrent proxy care-of test for the correspondent registration are newly defined with parameters specified by information on candidate MAGs.

For simplicity, hereafter, the MAG on behalf of the MN and the MAG on behalf of the CN are called the MAG_{MN} and the MAG_{CN}, respectively. The LMA for the MN and the LMA for the CN are called the LMA_{MN} and the LMA_{CN}. Figure 3 ~ Figure 6 show overall operation procedures of proposed and existing mechanisms for both two scenarios of Figure 1 and Figure 2.

□ New Proxy Home Test Procedure

As soon as the MAG_{MN} makes decision on which the CN or the MAG_{CN} needs the route optimization, the MAG_{MN} initiates the proxy home test procedure. The CN or the MAG_{CN} verifies the reachability of MN's home address (MN-HoA) via this procedure. For the new proxy home test, two messages are defined with parameters specified by information on candidate MAGs where the MN can attach newly.

▪ Proxy Home Test Init (PHoTI)

The MAG_{MN} sends the PHoTI message to acquire home keygen tokens for candidate MAGs. In this message, the field of parameters can be defined by MIDs, proxy care-of addresses (Proxy-CoAs), home init cookies, which are generated by the MAG_{MN} for candidate MAGs.

In case of the 1st scenario of Figure 1, the PHoTI message is sent to the CN via the shared tunnel between the MAG_{MN} and the LMA_{MN} as shown in Figure 3. On the other hand, in case of the 2nd scenario of Figure 2, the PHoTI message is sent to the LMA_{MN} via the shared tunnel between the MAG_{MN} and the LMA_{MN}, as shown in Figure 5. Then, this PHoTI message is forwarded to home address of the CN by the LMA_{MN}. At the LMA_{CN}, this message is tunnelled into the shared tunnel between the LMA_{CN} and the MAG_{CN}. Then, the MAG_{CN} intercepts the PHoTI message and extracts MN-HoA and Proxy-CoAs for candidate MAGs from it.

▪ Proxy Home Test (PHoT)

The PHoT message is sent in response to a PHoTI message. In this message, the field of parameters can be defined by MIDs, home keygen tokens, home init cookies, home nonce indices, which are generated by the CN or the MAG_{CN} for candidate MAGs. Home init cookies from the MAG_{MN} are returned in the PHoT message, to ensure that the message comes from a node on the route between the LMA_{MN} and the CN or between the LMA_{MN} and the MAG_{CN}. Home nonce indices are delivered to the MAG_{MN} to later allow the CN or the MAG_{CN} to efficiently find the nonce value that it used in creating home keygen tokens. Home keygen tokens for corresponding candidate MAGs are computed by processing cryptographic functions in [7].

In case of the 1st scenario of Figure 1, the CN sends the PHoT message back to the MAG_{MN} via the shared tunnel between the MAG_{MN} and the LMA_{MN}, as shown in Figure 3. On the other hand, in case of the 2nd scenario of Figure 2, the MAG_{CN} sends the PHoT message back to the MAG_{MN} and adds Proxy-CoA of the CN into PHoT message, as shown in Figure 5. The MAG_{CN} creates a binding cache entry for this MAG_{MN}. This PHoT is sent via the shared tunnel between MAG_{CN} and the LMA_{CN}. Then, the LMA_{CN} forwards this message to the MN-CoA which tunnels it to the MAG_{MN}. When the MAG_{MN} receives PHoT message, it extracts the Proxy-CoA of CN and adds this information to the binding cache entry for CN.

□ New Concurrent Proxy Care-of Test Procedure

The CN or the MAG_{CN} also needs to prove the reachability of the Proxy-CoA, which is called the proxy care-of test. This proxy care-of test is piggybacked on a Proxy Binding Update (PBU) which is sent by the MAG_{MN} to register with the CN or the MAG_{CN}. That is, the proxy care-of test is done concurrently with the early PBU exchange, so it is called the concurrent proxy care-of test.

▪ Proxy Care-of Test Init (PCoTI)

The MAG_{MN} sends the early PBU which contains the PCoTI option to acquire the care-of keygen token for candidate MAGs. In the PCoTI option, the field of parameters can be defined by MIDs, Proxy-CoAs, care-of init cookies for candidate MAGs, which are generated by the MAG_{MN}.

In case of the 1st scenario of Figure 1, it is sent directly to the CN, as shown in Figure 3. On the other hand, in case of the 2nd scenario in Figure 2, it is sent directly to the Proxy-CoA of CN, i.e. to the MAG_{CN}, as shown in Figure 5. The field of parameters in the early PBU can be defined as [1] for candidate MAGs.

▪ Proxy Care-of Test (PCoT)

The Proxy Binding Acknowledgement (PBA) message with PCoT option is sent in response to the early PBU message with PCoTI option. In the PCoT option, the field of parameters can be defined by MIDs, care-of init cookies, care-of keygen tokens, care-of nonce indices for candidate MAGs, which are generated by the CN or the MAG_{CN}. Care-of nonce indices are provided to identify the nonce used for care-of keygen tokens. Home and care-of nonce indices may be the same, or different, in PHoT message and PCoT option. Care-of keygen tokens for corresponding candidate MAGs are computed by processing cryptographic functions in [7].

This message is sent directly to the MAG_{MN} for both scenarios, as shown in Figure 3 and Figure 5. In the PBA message, the field of parameters can be defined as [1] for candidate MAGs.

4. Operation Procedure and Advantages over Existing Mechanism

To describe the operation procedure of the proposed proactive correspondent registration mechanism, it will be assumed that the MN moves and attaches to the 'MAG_C' from the 'MAG_A' and then moves and attaches to the 'MAG_E' in Figure 1 and Figure 2. The existing mechanism was explained in [2][3] as shown in Figure 4 and Figure 6.

For the proposed proactive correspondent registration mechanism as shown in Figure 3 and Figure 5, when the MN moves and attaches to 'MAG_A', the 'MAG_A' on behalf of the MN performs the proposed correspondent registration for candidate MAGs, 'MAG_C' and 'MAG_E', at appropriate time using MAG information cached beforehand, such as the MID, the network prefix for Proxy-CoA configuration, the list of candidate MAGs where the MN can attach newly as shown in Table 1. In real-time communication, when the 'MAG_A' performs actual PMIPv6 handover to 'MAG_C', the 'trigger' may arrive from specific L2 events that might determine the need for handover. In this paper, this trigger itself is not specified in detail. After the network access authentication, the direct communication between CN and 'MAG_C' or between MAG_{CN} and 'MAG_C' can be started without the correspondent registration on 'MAG_C'. Therefore, the correspondent registration latency between two entities can be reduced because somewhat time-consuming and computationally burdensome tasks are performed beforehand. That is, the proposed proactive correspondent registration mechanism can reduce handover latency and thus enhance throughput degradation caused by the bidirectional tunneling. On the other hand, in the existing mechanism [2][3], these time-consuming and computationally burdensome tasks for correspondent registration are performed during the PMIPv6 handover procedure. In addition, the proposed mechanism can also avoid congestion at the LMA and its link during PMIPv6 handover. Moreover, the impact of any possible failure of the LMA or networks on the path to or from it can decrease.

5. Conclusions

This paper has proposed the proactive correspondent registration mechanism for the PMIPv6 route optimization between the MAG_{MN} and the CN or the MAG_{CN} in wireless access networks. Two scenarios have been considered according to the type of CN. For the proposed mechanism, the proxy home test and the concurrent care-of test are defined newly with parameters specified by information on candidate MAGs. The proposed correspondent registration mechanism is performed before actual handover for candidate MAGs where the MN can attach newly. Therefore, the proposed mechanism can reduce correspondent registration latency, which can reduce handover latency and thus enhance throughput degradation caused by the bidirectional tunneling via the LMA.

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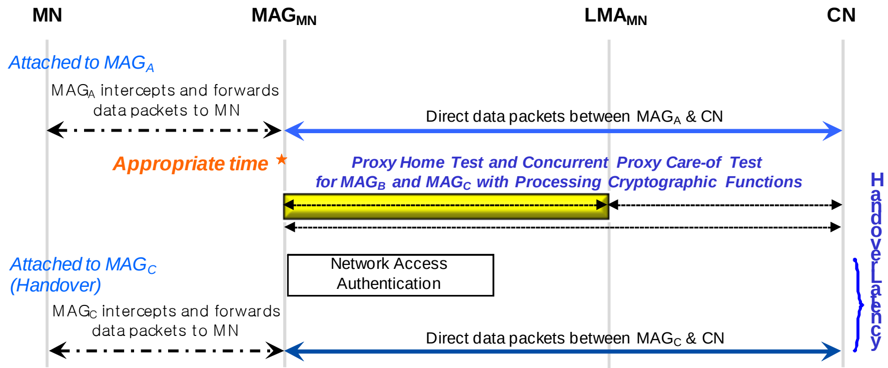

Figure 3. Operation Procedure for Proposed Mechanism for 1st Scenario.

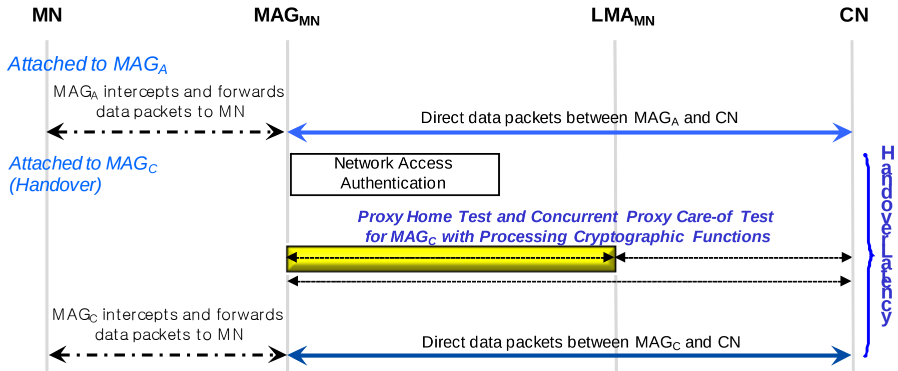

Figure 4. Operation Procedure for Existing Mechanism for 1st Scenario.

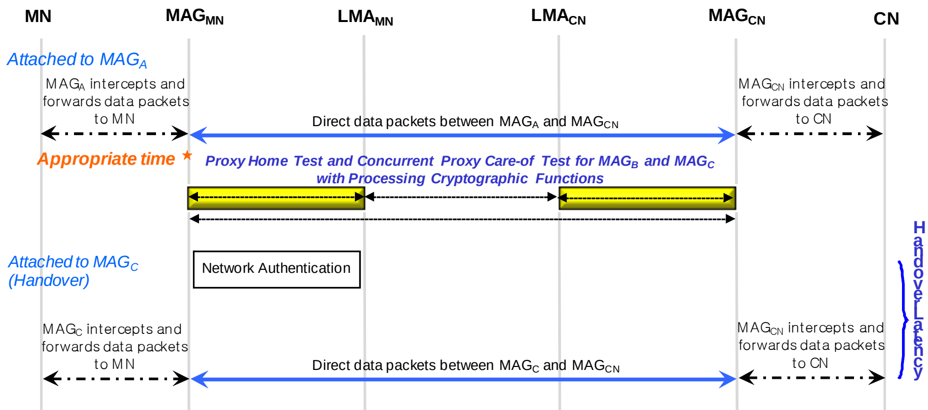

Figure 5. Operation Procedure for Proposed Mechanism for 2nd Scenario.

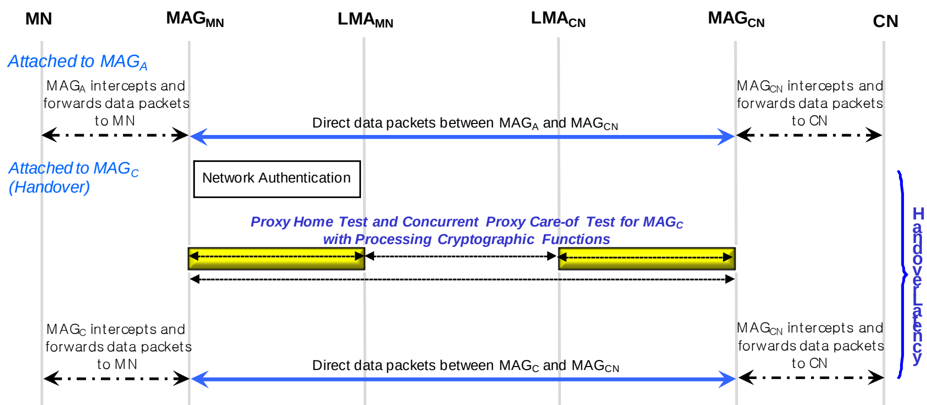

Figure 6. Operation Procedure for Existing Mechanism for 2nd Scenario.