Micro mobility improvement in proxy mobile IPv6 domain

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Abstract

Micro mobility is one of the most important topics that had and still has a great interest in wireless networks. The growing need for mobility inside the network without losing the connection or any data transferred has motivated the researchers to work on this topic. The IETF has standardized a group of protocols that provide a seamless mobility across the wireless networks. There are two types of mobility management, the host based mobility management and the network based mobility management. In the host based mobility management protocols operation, the mobile node is involved in the mobility-related signaling exchange within the domain. This in fact increases the complexity of the network stack and consumes the limited power sources available on the mobile nodes. In the network based mobility management protocol, the network has the responsibility to perform the required mobility-related signaling exchange on behalf of the mobile node. The proxy mobile IPv6(PMIPv6), which is a network based mobility management protocol, aims to reduce the complexity of the network stack and improve the mobility of the mobile node in wireless networks. In spite of the fact that the protocol presents a very smart solution to improve the mobility and reduces the complexity of mobile node network stack but it still has some limitations. These limitations due to the handover time delay, the handover packet loss and the handover overhead.

This Thesis presents an implementation of a test bed for the PMIPv6 protocol, an evaluation of this protocol and some proposed enhancements that attempt to overcome the protocol's limitations.

1. Introduction

The mobile IP [1] is considered a solution that allows the mobile node to keep its connection to the network while changing its point of attachment. The (IETF) has introduced some new entities like Home Agent(HA) and Foreign Agent (FA) to support mobility in mobile IPv4 [2]. This step was followed by mobility support in IPv6 [3]. The registration between these agents is necessary in order to keep tracking the changes of the mobile node's location and address. The mobile node should update its location and address every time it connects to a new point of attachment. The signaling messages exchange between the network entities in Mobile IP protocol causes a huge overhead inside the network. For this reason there was a need for new versions that provide efficient solution for the increasing in handover mobility between the network entities.

The proposed solutions from IETF were Cellular IP [4] , Hawaii [5], Hierarchical Mobile IPv6 (HMIPv6) [6]. The main idea in these solutions was to create kind of hierarchical router distribution, that keeps the registration and signaling traffic in the nearest point to the mobile node instead of doing this through a long path.

Recently proposed the proxy mobile IPv6(PMIPv6) as a network based management protocol. The main advantage of PMIPv6 is the non involvement of the mobile node in the mobility-related signaling exchange between the network entities. The network takes the responsibility of all the signaling exchange procedures on behalf of the mobile node. There is no need for the mobile node to have the proxy mobile mobility stack in order to be served in the PMIPv6 domain. In addition the mobile node as a battery dependent device can save a significant amount of power and this result from the non-involvement in the signaling exchange process. The motivation behind this work is to achieve an improvement in the mobility inside PMIPv6 [7] and this improvement is presented by reducing the limitations in the protocol. These limitations are due to handover delay, packet loss and handover overhead.

The work is based on a test bed for the PMIPv6 beside a modification in some procedures of the protocol in order to achieve the main goal of the work which is the improvement in the micro-mobility of the mobile node inside PMIPv6 domain. The rest of this paper is organized as follows. The next section 2 presents a survey of the related work in this area, which includes the proxy mobile IPv6 overview, Fast handover for proxy mobile IPv6 and buffering mechanisms. Section 3 presents a detailed view of the proposed solutions. Section4 goes over the solution's implementation details. Section 5 presents the evaluation of the implemented solutions, which includes functional tests results. Finally, section6 draws the final conclusion and lays out foundation for future work in the studied area.

2. State of the art

The proxy mobile IPv6 is one the solutions that has been proposed by IETF to overcome the need of the mobile node's involvement in the signaling updates while the mobile node in motion through the network. The network takes the responsibility of the mobility management on behalf of the mobile node. This feature makes the proxy mobile IPv6 a distinct solution because it gives the network operator the facility to support the mobility without any additional mobility stack on the mobile node. This reduce the signaling overhead every time the mobile connects to a new point of attachment comparing to the previous mobility management solutions. The mobile node keeps the same address inside the PMIPv6 domain and the network is in charge to keep tracking its location. There are two main functional entities inside PMIPv6 network as defined in [7], Local Mobility Anchor (LMA) and Mobile access gateway (MAG).

Once a Mobile Node enters a PMIPv6 domain, the first MAG provides it with access link and performs the identification process. The MAG sends a proxy binding update (PBU) message includes an identifier for the mobile node. The mobile node identifier (MN-ID) can be the mobile node's MAC address or any other identifier. In this case the LMA allocates an address (es) prefix (es) to the mobile node and reply to the MAG with Proxy Binding Acknowledgment (PBU) that includes all the prefixes assigned for that particular

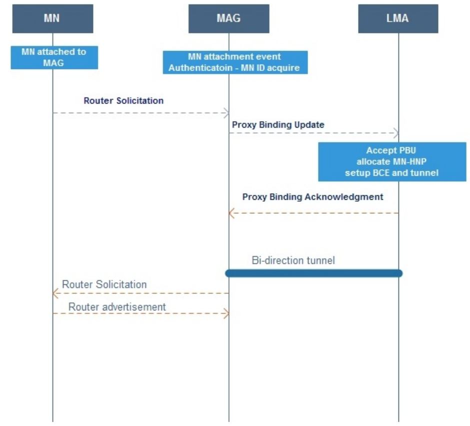

Figure 1: MN attachment in PMIPv6

mobile node. Figure 1 shows the signal flow of the mobile node attachment in PMIPv6.

In spite of the PMIPv6's ability to reduce the significant signaling delay exists in previous mobility management protocols, but it still has some limitations regarding the handover process. These limitations due to the mobility-related signaling exchange of the authentication procedures, binding update exchanges and lack of packet buffering mechanism. The approaches in [8],[9] provide a proactive fast handover scheme to minimize the handover delay and eliminate the packet loss by providing a buffering mechanism. The proposals in [10], [11] propose a buffering mechanism to eliminate the packet loss in PMIPv6. In [10] the implementation of buffering mechanism is in the LMA entity. The packets that are sent to the mobile node are buffered in the LMA until the attachment of the mobile node to a new MAG (NMAG). The buffering mechanism starts after receiving a de-registration message from the serving MAG which updates the disconnection of the mobile node from its access link. The buffering mechanism in this approach operates in three stages, packet classification to determine the packet that should buffered, packet buffering and the packet forwarding. The proposal in [11] presents a scheme to prevent a packet loss by a proactive buffering mechanism. The scheme provides a solution to eliminate redundant packets by reordering mechanism at the packet destination. The proactive way in this scheme achieved by informing the serving MAG the exact time for the mobile node handover and the target MAG after the handover process. The difference in this scheme from the fast handover scheme in [8] is that the prediction mechanism here performed from the network side with the help of the MAG discovery mechanism. The scheme presents the buffering mechanism in four phases: packet buffering, redundant packet elimination, serving MAG discovery and packets reordering in the NMAG.

3. Proposed enhancements

The authentication procedures modification, proposed by this work, focuses on the handover time delay, which consists of different components during the hand over period. One of these component is the time delay that is resulted from the authentication procedures, the mobile node once enters the domain, the first MAG directly performs the authentication procedures to check the availability to serve this particular mobile node in the PMIPv6 domain. The MAG starts these procedures by sending an authentication request to AAA server, which in order reply with acceptance or rejection according to the policies provided to this mobile node. In acceptance case the MAG starts directly the binding update process.

The protocol that is used in authentication stage is the RADIUS protocol. The same procedures are repeated every time the mobile node changes its point of attachment and moves to a new one. The proposed solution attempts to shorten the authentications procedure to occur once, just in the entry of the the mobile node to the PMIPv6 domain. As shown in figure 2 the mobile node once connected to the MAG then the later sends the authentication request and waits for a response from the LMA. The LMA in this CASE sends

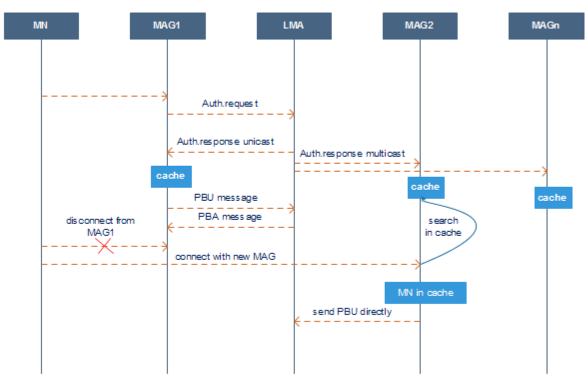

Figure 2: Authentication procedures modification signal flow

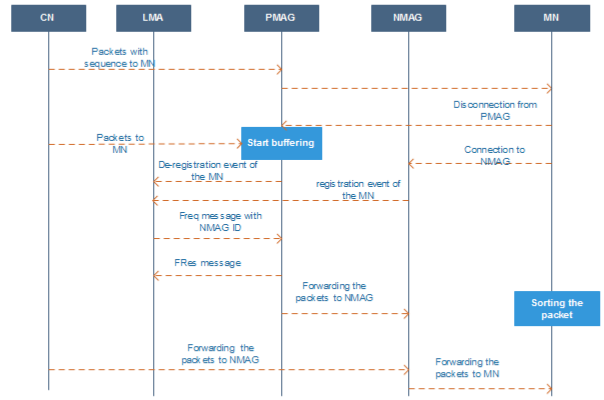

Figure 3: Buffering mechanics optimization sequence flow

a uni-cast response to the serving MAG and in the same time sends a copy of that message to all the MAGs serving in this domain. This message contains the mobile node ID and the authentication response for this mobile node.

The rest of the MAGs that are serving in the same domain once receive this information from the LMA, they cache it in a specific entry for that mobile node. The next time the mobile node connects to any one of these MAG , it searches in its cache for this mobile node instead of sending an authentication request to the LMA. If the mobile node is in cache, the serving MAG starts directly the binding process to update the location of the mobile node.

The buffering mechanism optimization, focuses on the packet loss problem in PMIPv6. It is based on the proposed scheme in [10]with some additional functionality to improve the buffering mechanism in PMIPv6.

The solution focuses on the case when there is a big latency in the network and presents a mechanism that could deal with this situation efficiently.

The mechanism's operation as shown in figure 3 starts by sending a sequence of packets to the mobile node through the LMA entity. The mobile node then disconnected from the previous MAG (PMAG) and connects with the new MAG (NMAG). The PMAG starts the buffering mechanism directly after receiving the disconnection event message from the mobile node. The MAG sends the de-registration message to the LMA which in this case keeps the tunnel that is established between itself and the PMAG. This tunnel exists for a period of time till the LMA receives a new registration message from the NMAG. At this step the LMA sends a forward request to the PMAG to forward the packets from its buffer. The PMAG forwards the packet and sends a forward reply to LMA. The LMA then forwards the packets to the NMAG which has to reorder the packet with sorting function and then forwards the packets to the mobile node.

4. Implementation

The proposed solution tries to overcome the authentication overhead during the handover process by distributing the authentication response to all MAG nodes within the network. Each MAG stores this response in its local cache so that on the incidence of mobile node changing the point of attachment, the new point of attachment already has the authentication information. In such a case the new point of attachment skips the authentication procedure thus getting rid of the authentication overhead. The changes that are made to the LMA and the MAG entities in order to apply the solution are shown in algorithm 1, algorithm 2 and can be summarized as following:

- LMA sends the authentication response to all MAG nodes within the network not only the current point of attachment.
- Each MAG node is ready all the time for the authentication responses from the LMA and adds this response to its local cache.

Algorithm 1 Changes to the LMA

```
function HandlingNewMN(MN)
    Response ← authenicateMN(MN)
    SendTo(MN.AP, Response)    ▷ Sends the authentication response to the mobile node attachment point
    MAGs ← GetAllConnectedMAGs(config)    ▷ Get all the MAG nodes within the network
    MAG.LP ← GetMAGListeningPort(config)
    for all MAG in MAGs do
        if MAG ≠ MN.AP then
            SendTo(MAG, Response, MAG.LP)
        end if
    end for
end function
```

Algorithm 2 Changes to the MAG

```
function Init    ▷ code that is executed when the MAG node is initiated
    StartNewThread(AuthRespListener)    ▷ fork a new thread for the listener that will be receiving authentication responses
    AuthRespListener    ▷ listener function forked in a single thread
    MAG.LP ← GetMAGListeningPort(config)
    socket ← OpenSocket(MAG.LP)
    while True do
        msg ← ReceiveData(socket)
        HandleResponse(msg)
    end while
end function
function HandleResponse(msg)
    data ← Parse(msg)
    MN ← data.MN
    resp ← data.resp
    InsertIntoCache(MN, resp)
end function
function InsertIntoCache(MN, resp)
    if MN not in cache then
        Cache.CreateEntry(MN, resp)
    else
        CacheUpdateEntry(MN, resp)
    end if
end function
```

The implementation for the additional functions to the buffering mechanism source code implemented by [12] in order to apply the the second optimization can be summarized as follows :

1) The implementation of the buffering optimization starts with initializing a buffer at the MAG entity, the buffer as mentioned in [10] is related with two factors the handover time delay and the expected packet number in this period. The buffer size is limited with specific period of time which is the maximum handover time delay in the domain.
2) The second step is the modification in the LMA entity to send the forwarding message contains the NMAG address.
3) The third step is the reordering function at NMAG to arrange the packets coming from the LMA and the PMAG.

The changes that have been done in the LMA, PMAG and NMAG are shown in algorithm 3, algorithm 4 and algorithm 5 respectively

Algorithm 3 Changes to the LMA

```
function RECEIVEPACKETATLMA(packet)
    mnAddr ← packet.dest
    servingMAG ← ROUTINGTABLE.FIND(mnAddr)
    packet.sqNumber ← GENERATOR.NEXTNUMBER(mnAddr)    ▷ generates sequential numbers for each MN
    SENDTO(servingMAG, packet)
end function
function RECEIVECONNECTIONATLMA(mnAddr)
    currentMAG ← ROUTINGTABLE.FIND(mnAddr)
    SENDNEWLOCATION(currentMAG, newAddrMAG)
end function
```

Algorithm 4 Changes to the current MAG

```
function RECEIVEPACKETATMAG(packet)
    SENDCONNECTONTOLMA(addrLMA, mnAddr)
    mnAddr ← packet.dest

    if mnAddr is connected then
        SENDTO(mnAddr, packet)

    else
        BUFFERMAG.INSERT(packet)

    end if
end function
function RECEIVENEWLOCATIONATMAG(newAddrMAG)

    while bufferMAG is not Empty do
        packet ←BUFFERMAG.POP
        SENDTO(newAddrMAG, packet)

    end while
end function
```

Algorithm 5 Changes to the new MAG

```
function RECEIVECONNECTIONATMAG(mnAddr)
    SENDCONNECTONTOLMA(addrLMA, mnAddr)
end function
```

5. Evaluation

The handover time delay in the PMIPv6 protocol can be divided into four different components. The first component is the layer 2 time delay which occurs at the entry of the mobile node to the domain and it consists of three phases, the scanning phase, the authentication phase and the association phase. The second component contains the authentication procedures for the mobile node in the domain and it is calculated from the time the MAG sends the authentication request to the time it receives the authentication reply.

The third component is the binding time delay and it is calculated from the time the MAG sends the Proxy Binding Update (PBU) message to the time it receives the Proxy Binding Acknowledgment (PBA) message.

The fourth and last component is the time taken to set up the tunnel, sending the router advertisement and the address auto-configuration for the mobile node. The total handover delay in PMIPv6 can be calculated as in equation 1.

$$T_{Total-delay} = T_{core} + T_{L2} + T_{address} \qquad (1)$$

While Tcore in this equation is the time from receiving the syslog message at the MAG to the time of sending the router advertisement, TL2 is time delay of layer 2 and Taddress is the time for autoconfiguration of the IPv6 address for the mobile node.

5.1. Authentication procedures modification evaluation

The first proposed enhancement provides a mechanism to reduce authentication procedures in PMIPv6. The test has been done in two scenarios as following:

In the first scenario, the test was setup with the network in normal case to compare between the handover time delay without applying the solution and the handover time delay with applying the solution.

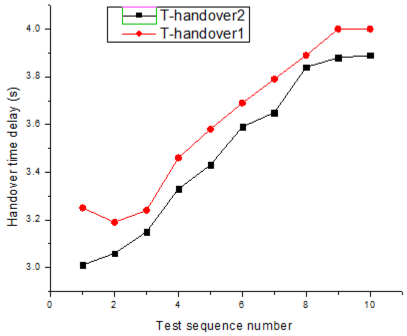

Figure 4: first solution first scenario

$T_{handover1}$ presents the handover time delay without the enhancement solution and $T_{handover2}$ presents the handover time delay with the enhancement solution. the results for this test are shown in figure 4 which indicate that the first solution has slightly better performance than the normal case. it is expected that with increasing the movement of the mobile node between a big number of MAGs, the modification can show better performance than the regular case.

In the second scenario, the delay has been increased in the implemented software to test the effect of the solution in the case of network delay, the delay has been increased gradually from 1 to 5 second and the result are shown in figure 5

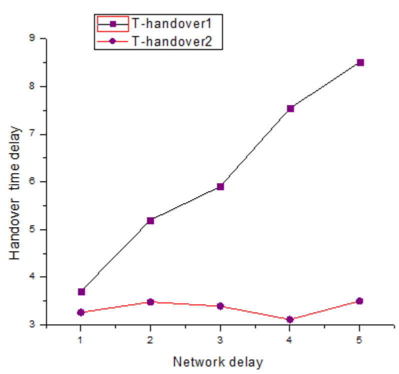

Figure 5: Handover time delay in second scenario

5.2. Buffering mechanism optimization evaluation

This evaluation is setup to test the proposed optimization, that is presented in the additional functionality added to [10] in order to move the buffering mechanism to the MAG entity. The test has been done with client /server application implemented in java. The purpose of this test is the measurement of the packet loss during the handover period. The test has different phases:

In the first phase, the client, which is the Correspondent node (CN)in this scenario, sends packet sequence to the server which is the mobile node (MN). The MN is moving to perform the handover from MAG1 to MAG2. The number of the received packet is counted to measure the packet loss percentage. The test is measuring the packet loss in two cases, the normal PMIPv6 case and the case with buffering mechanisms is performed. The results in figure 6 show a better performance of the solution due to the initializing of the buffering mechanism directly at the MAG once the later receives the detachment event message from the mobile node.

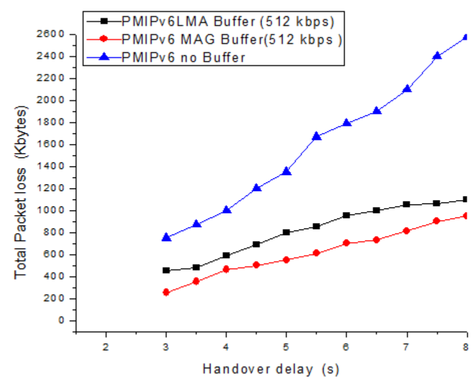

Figure 6: Buffering system performance

In the second phase as shown in figure 7, the test measures the influence of increasing the packet rate on the percentage of packet loss with big handover time delay. the results show that with increasing the packet rate there is increasing in the number of lost packets.

In the third phase the CN sends the packet to MN in sequence. The mobile node disconnected from the MAG link and the binding time is increased to prevent the LMA from receiving the detachment event of the

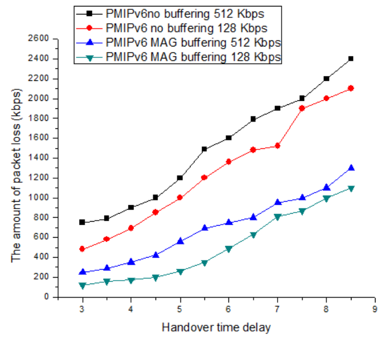

Figure 7: Packet rate effect

mobile node. The LMA keeps sending the packets to the MN which is disconnected at this period.

A comparison between PMIPv6 with LMA the buffering mechanism and the PMIPv6 with the MAG buffering to see the influence of the solution on the packet loss in this period. The results are shown in figure 8

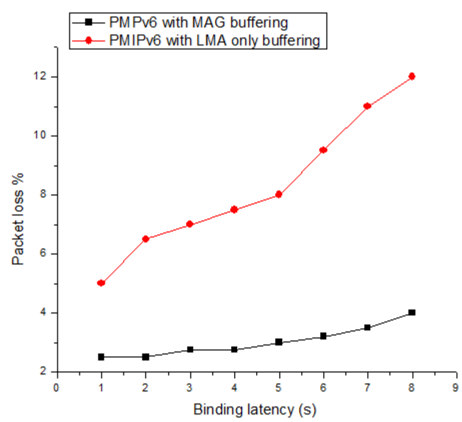

Figure 8: Packet loss with high binding latency

6. Conclusion

This project purposes two enhancement techniques to overcome the limitation exist in the proxy mobile IPv6 protocol. The authentication procedures modification attempts to reduce the handover time delay within the movement of the mobile node in the domain. The Buffering mechanism optimization provides a modification to the buffering mechanism proposed in [10] in order to reduce the packet loss percentage during the handover period. The results for the enhancement in authentication procedures, show a good performance of the solution regarding the high latency case in the PMIPv6 domain.

The buffering mechanism optimization is evaluated in three tests, the first test results show a better performance in the case of increasing of the handover in the domain with the applying the buffering mechanism. The second test shows the influence of increasing the packet rate on the number of lost packets. The number of lost packets increased with the increase of the data rate. The third test shows the performance of the system in the case of high latency between the MAG and the LMA prevents the later from receiving the PBU message to internalize the buffering mechanism and in this time the existence of buffer at MAG side prevents the packet loss occurs during the handover period.

The future work will focus on the movement from the centralized mobility management to the distributed mobility management in order to anchor the traffic closer to the point of attachment of the mobile node.

References

[1] C. E. Perkins and A. Myles, "Mobile IP," *Proceedings of International Telecommunications Symposium*, pp. 415–419, 1994.

[2] C. E. Perkins, "IP mobility support for IPv4," Internet Requests for Comment, RFC Editor, Fremont, CA, USA, RFC 3344, Aug. 2002.

[3] D. B. Johnson, C. E. Perkins, and J. Arkko, "Mobility support in IPv6," Internet Requests for Comment, RFC Editor, Fremont, CA, USA, RFC 6275, Jul. 2011.

[4] A. G. Valkó, "Cellular IP: a new approach to Internet host mobility," *SIGCOMM Comput. Commun. Rev.*, vol. 29, no. 1, pp. 50–65, Jan. 1999.

[5] R. Ramjee, T. F. La Porta, S. R. Thuel, K. Varadhan, and L. Salgarelli, "IP micro-mobility support using HAWAII," Working Draft, IETF Secretariat, Fremont, CA, USA, Internet-Draft draft-ietf-mobileip-hawaii-01.txt, Jul. 2000.

[6] H. Soliman, C. Castelluccia, K. El Malki, and L. Bellier, "Hierarchical mobile IPv6 mobility management (HMIPv6)," Internet Requests for Comment, RFC Editor, Fremont, CA, USA, RFC 4140, Aug. 2005.

[7] S. Gundavelli, K. Leung, V. Devarapalli, K. Chowdhury, and B. Patil, "Proxy mobile IPv6," Internet Requests for Comment, RFC

Editor, Fremont, CA, USA, RFC 5213, Aug. 2008.

[8] H. Yokota, K. Chowdhury, J. Arkko, R. Koodli, B. Patil, and F. Xia, "Fast handovers for proxy mobile ipv6," Internet Requests for Comment, RFC 5949, 2010.

[9] B. Sarikaya and F. Xia, "Mobile node agnostic fast handovers for proxy mobile ipv6," Working Draft, IETF Secretariat, Internet-Draft draft-xia-netlmm-fmip-mnagno-02, Nov. 2007.

[10] C. Park, N. Kwon, H. Woo, and H. Choo, "Buffering in proxy mobile ipv6:implementationand analysis," *The Journal of Supercomputing June 2014, Volume 68, Issue 3, pp 1503-1520*, 2014.

[11] H.-Y. Choi, K.-R. Kim, H.-B. Lee, S.-G. Min1, and Y.-H. Han, "Smart buffering for seamless handover in proxy mobile ipv6," *Wirel Commun Mob Comput 11(4):491-499*, 2011.

[12] "Open source board," http://monet.skku.ac.kr/, retrieved October 2014.