International Journal of Advanced Smart Convergence Vol.7 No.4 197-205 (2018)
http://dx.doi.org/10.7236/IJASC.2018.7.4.197

IJASC 18-4-24

Analysis of a NEMO enabled PMIPv6 based Mobility Support for an Efficient Information Transmission

Ronnie D. Caytiles and Byungjoo Park*

Department of Multimedia Engineering, Hannam University, Daedeok-gu, Daejeon, Korea
rdcaytiles@gmail.com, bjpark@hnu.kr

Abstract

Nowadays, wireless sensor networks (WSNs) have been widely adopted in structural health monitoring (SHM) systems for social overhead capital (SOC) public infrastructures. Structural health information, environmental disturbances and sudden changes of weather conditions, damage detections, and external load quantizing are among the capabilities required of SHM systems. These information requires an efficient transmission with which an efficient mobility management support for wireless networks can provide. This paper deals with the analysis of mobility management schemes in order to address the real-time requirement of data traffic delivery for critical SHM information. The host-based and network-based mobility management protocols have been identified and the advantages of network mobility (NEMO) enabled Proxy Mobile Internet Protocol version 6 (PMIPv6) have been leveraged in order to address the SHM information transmission needs. The scheme allows an efficient information transmission as it improves the handover performance due to shortened handover latency as well as reduced signaling overhead.

Keywords: *network mobility (NEMO), PMIPv6, WSN, information transmission, social overhead capital (SOC), SHM*

1. Introduction

The implementation of WSNs in SHM systems for SOC public infrastructures becomes a requirement in measuring structural health information, environmental disturbances and sudden changes of weather conditions, damage detections, and external load quantizing. Signal processing and transmission for WSNs will be the critical part for the success of SHM systems. For signal processing, essential and critical signals must be separated from insignificant signals before it can be transmitted into the network infrastructure to lessen the processing and network load to preserve network resources. Thus, an efficient filtering algorithm is required in such a way that only the significant signals will be transmitted to the receiving gateways as well as into the monitoring system.

SHM application systems require continuous and real-time information transmission in order to safeguard

---

Manuscript Received: Nov. 10, 2018 / Revised: Nov. 15, 2018 / Accepted: Nov. 28, 2018
Corresponding Author: bjpark@hnu.kr
Tel: +82-42-629-8489, Fax: +82-42-629-8480
Department of Multimedia Engineering, Hannam University, Daedeok-gu, Daejeon, Korea

the public in SOC infrastructures [1]. A real-time traffic updates in bridges, railroads, and expressways are necessary to prevent untoward incidents that can cause injuries or even the loss of human lives. In this regard, a robust information transmission is required to address the requirements of SHM systems [2]. Moreover, to achieve such information transmission, a seamless mobility management support for wireless networks will be required.

In the host-based mobility management support schemes, the mobile terminals are required to get involved in the mobility related signaling which results into higher signaling overhead. It also requires the modification of the protocol stack and the mobile terminals changes its IP address every time it moves across a different access network. Moreover, the host-based mobility management schemes suffer from several drawbacks that hinders the efficiency of the information transmission such as longer handover latency, and higher packet loss. This schemes may not be appropriate for SHM systems since quality of service (QoS) for real-time information transmission is required.

The implementation of network-based mobility management schemes alleviates the limitations of host-based mobility management schemes. It improves the handover performance of host-based schemes by shortening the handover latency, signaling update time, and disruption period is reduced. Network-based handover seems to be relatively faster as compared to the host-based schemes, however, its link layer handover needs some time to complete resulting to communication interruptions. During this period, all data packets that were sent will be lost.

This paper deals with the integration of the advantages of network mobility (NEMO) which is designed primarily for moving vehicles into PMIPv6 to provide mobility support in the information transmission of SHM systems for SOC public infrastructures. The scheme can guarantee a seamless handover for wireless network systems specifically for moving networks as well as mobile terminals. The N-PMIPv6 based mobility support for information transmission is expected to deliver a QoS continuous and real-time monitoring of vehicular traffic conditions, structural health conditions, environmental disturbances, as well as unexpected weather changes.

The rest of this paper is organized as follows: Section 2 provides an overview of the motivations to improve the mobility management support for information transmission in SHM systems for SOC public infrastructures; the analysis of the mobility management support schemes was outlined in Section 3; the N-PMIPv6 mobility management support for WSN based information transmission in SHM systems is presented in Section 4; and the concluding remarks in Section 5.

2. Motivations

Recently, there is a great increase in the occurrences of tragic incidents in SOC public infrastructures such as bridges, railroads, national highways, dams, tunnels, towers, cable cars, buildings, and others that are caused by natural calamities. The sudden changes in weather and environmental disturbances such as early morning fog, earthquakes, heavy snow, rainfall, strong winds can cause tragic accidents in national highways, railroads, bridges, and other SOC infrastructures. In Figure 1, traffic accidents caused by SOC infrastructure damages were graphed with the number of deaths and injured persons. Although the number of injury and deaths seems to be decreasing, the number is still significant that a need for accident prevention will be required for every SOC public infrastructure as shown in Table 1.

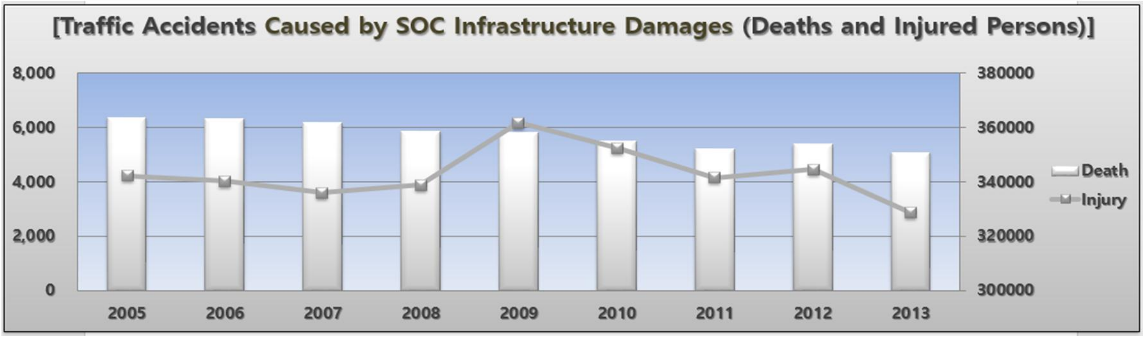


Figure 1. Traffic Accidents Caused by SOC Infrastructure Damages

Table 1. Traffic Accidents [Police Agency (Traffic Police Business Management Systems)]

	2005	2006	2007	2008	2009	2010	2011	2012	2013
Accident	214,171	213,745	211,662	215,822	231,990	226,878	221,711	223,656	215,354
Death	6,376	6,327	6,166	5,870	5,838	5,505	5,229	5,392	5,092
Injury	342,233	340,229	335,906	338,962	361,875	352,458	341,391	344,565	328,711
Per 10,000 cars Traffic Accident	3.4	3.3	3.1	2.9	2.8	2.6	2.4	2.4	2.2
Per 100,000 People Traffic Accident Deaths (Persons)	13.2	13	12.7	12.1	12	11.3	10.7	10.8	10.1
Fatal Pedestrian Traffic Accident Composition Ratio (%)	40	38.6	37.4	36.4	36.6	37.8	39.1	37.6	38.9

SOC public infrastructure safety and efficiency is essentially important specifically since human's life is at stake. Catastrophic events such as, typhoons, avalanche, earthquake, flood, forest fire, hurricane, lightning, tornado, tsunami, and volcanic eruption can cause damages to SOC public infrastructures and can cause numerous casualties and monetary losses. This has led to the evolution of the management strategies from the traditional visual inspection methods to wireless structural health monitoring systems.

Structural health monitoring becomes crucial to the maintenance, up keeping and safeguarding SOC public infrastructures. Traffic accidents on roads, bridges, and expressways have been significant that needs to be taken care of. In addition, it is also important to keep such infrastructures run smoothly, and maintain safety and public health. New technological developments and methodologies are being implemented to support the economic vitality of the society. The use of smart sensors, efficient data collection, transmission, and analysis greatly improves and increase the public safety [3]. Continuous real-time monitoring detects design flaws and damages, environmental factors for public safety, detect early safety risks, and detect ground movements to prevent tragic accidents in case of earthquakes, landslides, and other disasters. This makes the applications of SHM becomes prominent to SOC public infrastructures.

3. Handover Mobility Management

Mobility support is one of the major concerns in any wireless network systems. This section deals with the analysis of various network layer mobility management protocols in order to determine the most suitable mobility support for an efficient information transmission in traffic management systems. Mobility management in general provides two primary services of location management and handover management as shown in Figure 2.

An efficient mobility management allows the network to keep track and locate the mobile nodes (MNs) for possible connectivity. MNs are required to register and update their current location in order for the network to deliver the data packets for its current location within the access network. A minimized signaling overhead and faster registration/update procedures are required to optimize the mobility of MNs. On the other hand, handover management allows the MN to maintain its connectivity whenever it moves from one access network to another. The best available network must be provided which indicates lower packet loss rate and delay during handovers. The network layer mobility management solutions are classified into either host-based or network-based categories. The host-based handover mobility management requires the MN to be involved in the mobility related signaling, while the network-based solutions relegate the responsibilities of mobility related signaling into the network entities.

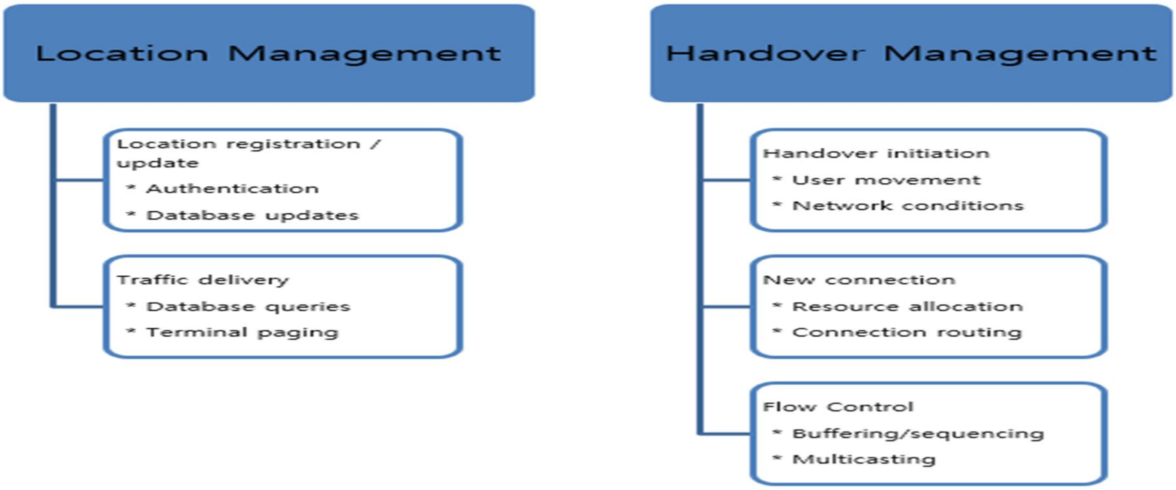


Figure 2. Mobility Management

The standard mobile internet protocol version 6 (MIPv6) [4] allows the MN to roam across the Internet domain while maintaining its connectivity directly to its correspondent node (CN). The CN can reach the MN at anytime and anywhere. The MN is allocated with a fixed home address (HoA) by its Home Agent (HA) and a temporary care-of address (CoA) is assigned to the MN whenever moves into another network. That is, if the MN is in its home network, the data packets destined to the MN will be intercepted by the HA and delivered to the MN's HoA without any alterations. If the MN moves into another network, it became unreachable through its HoA, thus, the HA intercepts the data packets and tunnels them towards the current CoA of the MN. The data packets however will be encapsulated by the HA before the delivery. This concept leads into a triangular routing problem and has been addressed by the route optimization operation. Route optimization allows the direct communication between the CN and MN, thus, data packets can be routed directly without the intervention of the HA. The MIPv6 operations however poses significant limitations of high handover latency, high packet loss, and signaling overheads [5]. Every time the MN changes its point of attachment (PoA), it needs to send update signals into its HA and CN in order to maintain its ongoing sessions causing significant delays in the handover.

The Fast MIPv6 (FMIPv6) was introduced in order to address the limitations of MIPv6 such as higher handover latency [6]. Link layer event triggers are used in order to improve the handover performance through anticipating the MN's movement and tunneling the data packets into the new access router (AR) in advance. The MN will then be able to start receiving data in the new CoA as soon as the HA and CN receives a binding update (BU) message. The main operations of FMIPv6 depicted in Figure 3 are described as follows:

1. Router Solicitation for Proxy Advertisement (RtSolPr) message is sent by the MN to the previous AR requesting the CoA as it anticipates the handover.
2. Proxy Router Advertisement (PrRtAdv) message is sent back by the previous AR containing a new CoA to be used on the new AR's link.
3. A fast binding update (FBU) message with the new CoA is sent by the MN to previous AR. This will indicate that the packets from the previous AR should now be forwarded to the new AR.

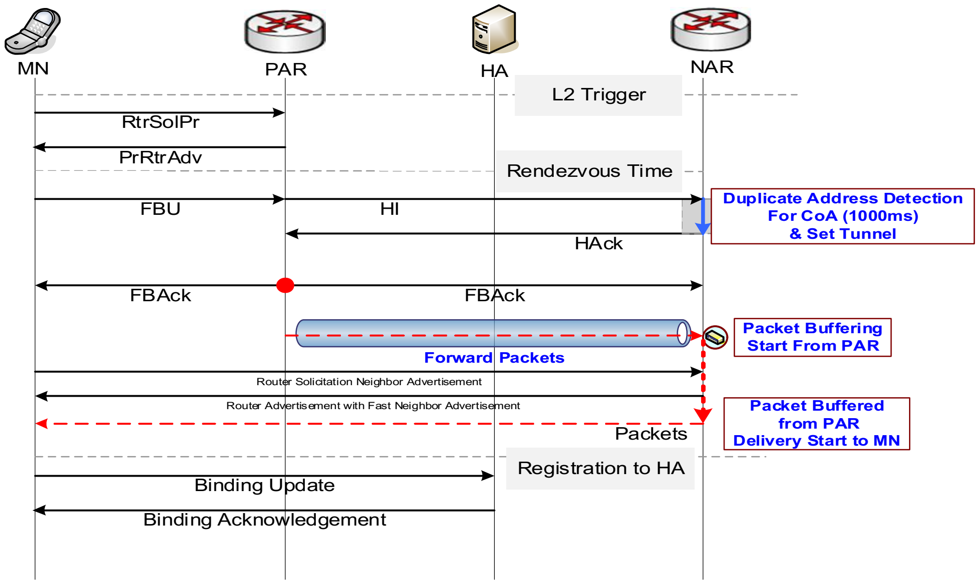


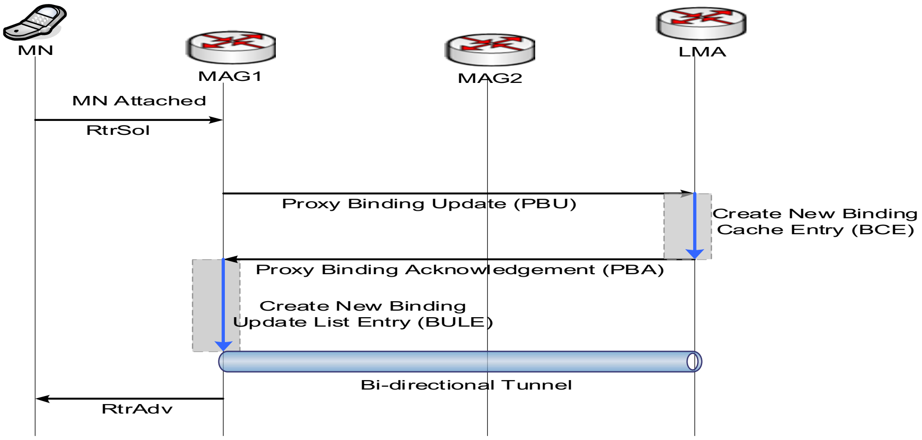
Figure 3. FMIPv6 Handover Operations

4. A bidirectional tunnel is established between the previous AR and the new AR.
5. A handover initiate (HI) message is sent by the previous AR to the new AR for address duplication check.
6. A handover acknowledge (HAck) message is sent back by the new AR indicating that there is no address duplication and the tunnel is established successfully.
7. The previous sends a fast binding acknowledgment (FBack) to the MN through both access links.

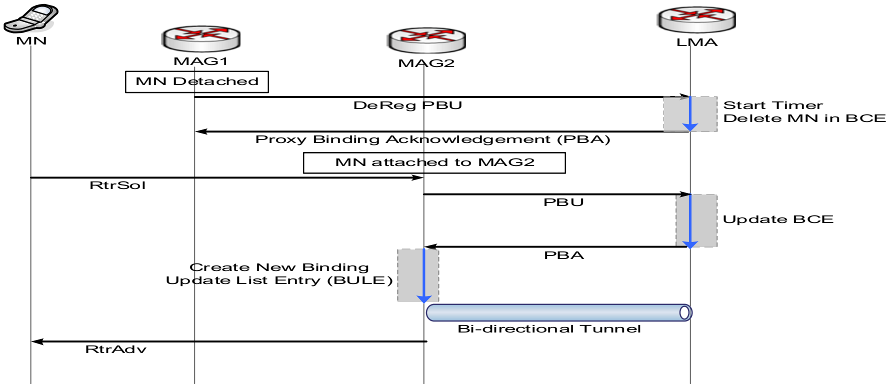
The FMIPv6 optimization provides a substantial improvement in terms of handover latency and packet loss, however, it is always based on a reliable handover prediction. Inaccurate predictions can cause erroneous handovers that can significantly affect the seamlessness of the mobility management support. The Hierarchical MIPv6 (HMIPv6) [7] also aims to address the limitations posed by the standard MIPv6 of longer handover latency and frequent exchange of mobility related signaling whenever the MN moves from one access network to another. A new network entity mobility anchor point (MAP) is introduced and is responsible for the local mobility of MNs. Data packets are tunneled to the MAP addressed by a regional CoA and these data packets are then tunneled by the MAP to the local CoA allocated to the MN. During the local handover, the MN only needs to update its MAP with its local CoA. The MAP acts as the local HA for the MN, making the mobility signaling local and reduces the handover latency. The host-based mobility management protocols however require a protocol stack modification and IP addresses are changed in order for its mobility to be supported, thus, increases the complexity of the MN. The quality of service (QoS) requirements of some applications requiring real-time transmissions can still get affected by the limitations that it poses such as long handover latency, high packet loss, and signaling overhead.

The Proxy MIPv6 (PMIPv6) [8] is a network based mobility management protocol allowing the MN to maintain its connectivity without being involved in the mobility related signaling. The mobility related signaling responsibilities were relegated to the network entities allowing the MN to become independent of its movements. The mobile access gateway (MAG) performs the movement detection and signaling operations in lieu of the MN. The MN movement and routing state updates are coordinated by the MAG.

The local mobility anchor (LMA) on the other hand acts as the local HA and anchors the IP addresses used by MNs within a localized mobility domains (LMD). A bidirectional tunnel is setup between the LMA and MAG allowing the MN to keep the assigned IP address while moving within the LMD. The data packets intended to the MN are intercepted by the LMA, encapsulates them, and tunnels them into the designated MAG wherein the MN is currently attached. The MAG then decapsulates the data packets and forward them locally to the MN. The handover operations on PMIPv6 are depicted in Figure 4.



(a) Initial Attachment of MN



(b) Detachment of MN from previous MAG and Attachment into a new MAG

Figure 4. PMIPv6 Handover Operations

The MAG and LMA exchanges proxy binding update (PBU) and proxy binding acknowledgement (PBA) messages whenever the MN attaches into the MAG and sends a Router Solicitation (RtrSol) message. A bidirectional tunnel is then established between the LMA and the MAG to enable the MN to communicate with its CN as shown in Figure 4(a). In Figure 4(b), whenever the previous MAG detects that the MN moves away from its access link to the new MAG, a deregistration message (DeReg PBU) message is sent by the previous MAG to the LMA. The LMA replies with a PBA message accepting the request. Whenever the new MAG detects the attachment of the MN into its link, it sends PBU message to the LMA to update its binding cache entries. A bidirectional tunnel will then be established between LMA and the new MAG. The PMIPv6 provides a significant improvement to the handover performance of MIPv6, providing a localized mobility that alleviates the handover latency and shortens the signaling update time.

4. Network Mobility (NEMO) Support for Traffic Management System

The Network Mobility (NEMO) allows a mobile network to move across different access networks while maintaining the reachability of every device attached to its mobile access router [9]. The mobile router takes the responsibility of the mobility management in lieu of the nodes on the mobile network. The nodes are referred to as mobile network nodes (MNNs) and its IP addresses belong to the mobile network prefix (MNP) that is anchored at the HA of the mobile access router (MAR). Instead of a single node mobility functionality in the standard MIPv6, the MAR will be the one that moves in the case of NEMO. It aims to address the transparent mobility support for moving vehicles. Figure 5 depicts the handover process for NEMO protocol. Whenever the MAR moves from one network to another, it has to discover an available AR in order to obtain CoA. As in the standard MIPv6, the MAR sends a binding update to its HA in order to register. Data traffic sent by the CN will be intercepted by the HA, have to be encapsulated before they can be tunneled to the MAR. The MAR then decapsulates the data packets and forward them to the intended MNN.

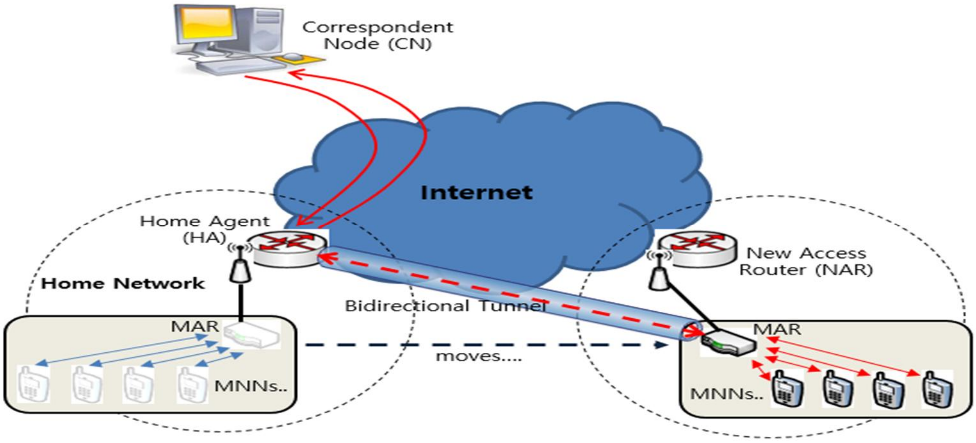
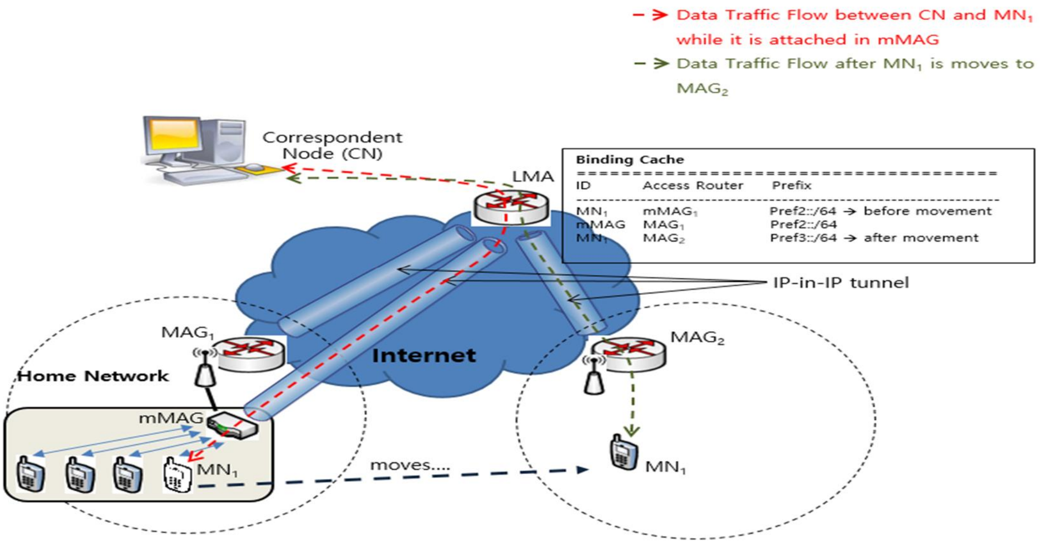
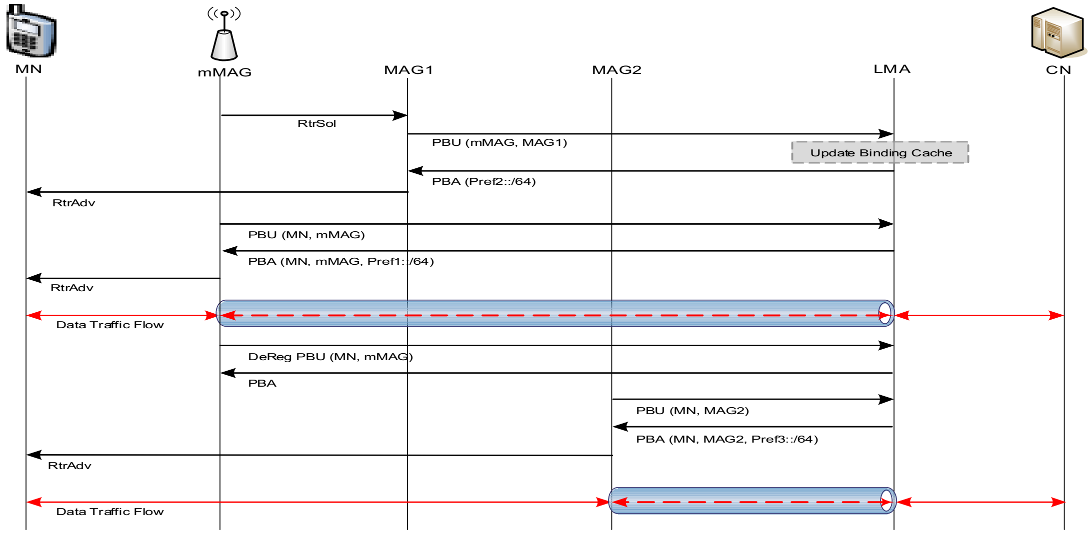


Figure 5. NEMO Handover Process

The limitations of MIPv6 were inherited by NEMO, thus, routing is suboptimal that results into additional network infrastructure load, vulnerability to link failures, higher latency, higher packet loss rate, signaling overhead, etc. Moreover, the repeated encapsulation and decapsulation of data packets require additional processing in the HA which creates a bottleneck since all data packets are also traversing through the HA (i.e., NEMO does not incorporate route optimization mechanism).



(a) N-PMIPv6 based Information Transmission Architecture



(b) More Detailed Signaling

Figure 6. N-PMIPv6 based Information Transmission for Traffic Management Systems

In order to address the limitations posed by the NEMO framework for information transmission, this paper analyzed the implementation of the extended PMIPv6 with NEMO support as depicted in Figure 6. The NEMO enabled PMIPv6 (N-PMIPv6) based mobility management support scheme fully integrates the mobile networks into the LMDs. The mobile terminals can choose either to obtain their connectivity from fixed gateways (MAGs) or from the existing mMAGs. These mobile terminals can move between them without losing their connectivity and ongoing sessions with their CNs. The mMAG acts as MN when it comes to the fixed gateways (MAGs) and can move across different MAGs. It also acts as a regular gateway whenever the MN attaches to one of its links. The LMA intercepts the data packets sent by the CN and tunnels them directly to the either MAG or mMAG wherein the MN is currently connected.

This architecture leverages the advantages of a network-based mobility management support in handling the handover of moving wireless devices in the SOC public infrastructure traffic management system. This architecture can be considered as a network-based solution since the mobile terminals are not required with the mobility related signaling operations. Moreover, the handover performance is improved with shortened handover latency as well as in signaling overhead. Thus, an efficient information transmission is guaranteed for traffic management systems.

5. Conclusion

This paper deals with the analysis of NEMO enabled PMIPv6 based mobility management support for information transmission is SHM systems for SOC public infrastructures. The scheme takes advantage of the features of the network mobility which is primarily designed for moving vehicles and implemented with the network-based mobility support of PMIPv6 to provide a seamless handover for mobile terminals. This scheme can guarantee a robust real-time information transmission that is required by the SHM systems in order to prevent the occurrences of tragic incidents in SOC public infrastructures.

Acknowledgement

This paper was supported by the 2018 Hannam University Research Fund.

References

[1] Structural health monitoring, *https://en.wikipedia.org/wiki/Structural_health_monitoring*.

[2] J. P. Lynch, "An overview of wireless structural health monitoring for civil structures", Philosophical Transactions of the Royal Society, Vol. 365, pp. 345-372, 2007.
DOI: https://doi.org/10.1098/rsta.2006.1932.

[3] Y. Wang, J. P. Lynch, and K. H. Law, "Wireless Sensing, Actuation and Control – With Applications to Civil Structures", In: Smith I.F.C. (eds) Intelligent Computing in Engineering and Architecture, EG-ICE 2006, Lecture Notes in Computer Science, Springer, Berlin, Heidelberg, Vol. 4200, (2006).
DOI: https://doi.org/10.1007/11888598_60.

[4] D. Johnson, C. Perkins and J. Arkko, "Mobility Support in IPv6", IETF RFC 3775, June 2004.

[5] I. Al-Surmi, M. Othman and B. M. Ali, "Mobility Management for IP-Based Next Generation Mobile Networks: Review, Challenge and Perspective", Journal of Network and Computer Applications, Vol. 35, no. 1, pp. 295-315, January 2012.

[6] R. Koodli, "Fast Handovers for Mobile IPv6", IETF RFC 4068, July 2005.

[7] H. Soliman, et al., "Hierarchical Mobile IPv6 (HMIPv6) Mobility Management", IETF RFC 4140, August 2005.

[8] S. Gundavelli, et al., "Proxy Mobile IPv6", IETF RFC 5213, August 2008.

[9] V. Devarapalli, et al., "Network Mobility (NEMO) Basic Support Protocol", IETF RFC 3963, January 2005.