Minimizing Load at Local Mobility Anchor in PMIPV6 Network

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Abstract— In PMIPV6 network, mobile nodes' mobility is handled by network elements such as Local Mobility Anchor (LMA) and Mobile Access Gateway (MAG). LMA is also responsible for inflow and outflow data movements to/from PMIPV6 domain. So, LMA is always heavily loaded even in normal scenarios. This paper aims to reduce the load and the network traffic towards LMA by reducing the location updates that are sent towards LMA. When a mobile node roams without active data sessions (Idle nodes), it is unnecessary for LMA to know mobile node's current location. LMA can be freed from getting location updates of idle mobile nodes. This reduces network traffic towards LMA and hence saves network resources. We have proposed a mobility management scheme which handles idle mobile nodes' mobility efficiently to reduce load at LMA. The proposed scheme groups topologically nearby MAGs together and location updates are kept inside the group until the mobile node gets incoming or outgoing traffic. Hence this scheme reduces the location update signalling and network traffic at LMA.

Keyword- PMIPV6, Binding update, Binding acknowledgement, Signalling reduction

I. Introduction

PMIPV6 is a network-based mobility management protocol, designed to support mobile node's movement inside PMIPV6 domain without the respective node's involvement. In PMIPV6, network elements are involved in mobility management signalling on behalf of mobile nodes. Mobile node retains its IP address, even if it changes the point of attachment inside PMIPV6 domain. So the on-going data sessions are not affected. Network elements are responsible to identify the current location of mobile nodes and route packets to them. An example PMIPV6 network is shown in Fig. 1. PMIPV6 has two network elements called as Local Mobility Anchor (LMA) and Mobile Access Gateway (MAG). MAG acts as an Access Point (AP) for the mobile nodes in PMIPV6 domain. It sends mobility-management signalling on behalf of the mobile nodes which are connected to its access link. PMIPV6 domain contains multiple MAGs. LMA has information about all the mobile nodes in PMIPV6 domain. The information consists of mobile node id, MAG to which the mobile node is connected and the Home Network Prefix (HNP) allocated to the mobile node. Packets addressed to or sent from mobile nodes are transmitted via the channel between LMA and the corresponding MAG.

Fig. 2 shows basic steps in PMIPV6 operations. When mobile node enters into PMIPV6 domain, it sends Router Solicitation (RS) message in order to find the point of attachment. The MAG which receives RS message verifies mobile node's authentication and sends Proxy Binding Update (PBU) to LMA on behalf of the mobile node. LMA allocates network prefix to the mobile node and creates Binding Cache Entry (BCE) which consists of mobile nodes' id and the MAG to which the mobile node is attached and the allocated network prefix. LMA sends Proxy Binding Acknowledgement (PBA) with the allocated network prefix to MAG. Bidirectional tunnel is established between LMA and MAG to transfer mobile node's packet. On receiving PBA, MAG sends router advertisement along with the allocated network prefix to mobile nodes. Thus the mobile node receives address to be used inside PMIPV6 domain. Whenever a mobile node moves and attaches to new MAG inside the same PMPV6 domain, similar procedures are repeated. LMA find entry in BCE table and allocates the same network prefix. So on-going data sessions in mobile nodes are not affected.

Let us assume a scenario where the mobile node simply roams with no active data sessions. It is inefficient to update the location of idle mobile node to LMA. In cellular network, this problem is resolved with paging mechanism. In PMIPV6 network, research work is in progress, but the solution is not yet standardized by IETF.

This paper suggests an efficient binding update mechanism in PMIPV6 network. It groups topologically nearby MAGs together and location updates are kept inside the group until the mobile node gets incoming or outgoing traffic. Thus LMA can be freed from getting location updates of idle mobile nodes. This also reduces network traffic towards LMA and saves network resources.

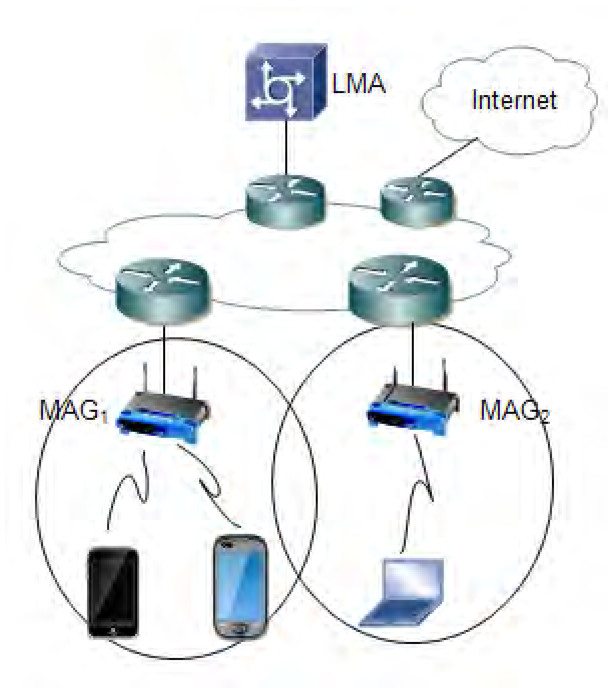


Fig. 1. PMIPV6 network

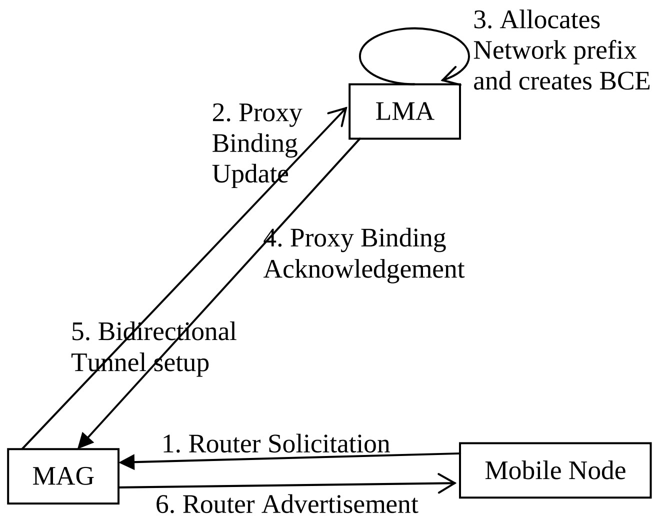


Fig. 2. PMIPV6 operation

Section 2 analyses existing architectures which reduces signalling cost in PMIPV6 network. Section 3 presents the proposed architecture. The performance analysis of the proposed architecture with the existing schemes is compared in section 4 and conclusion of the paper is given in section 5.

II. Existing Architectures

There are plenty of mobility signalling reduction architectures available in literature ([1]-[3], [5]-[7], [9]-[14]) for MIPV6 network and cellular networks. But, only very few architectures were addressing signalling cost reduction in PMIPV6 network. They are analysed below and their shortcomings are also discussed.

Myung-Kyu Yi. et.al [8] have defined an architecture based on pointer forwarding scheme to reduce signalling cost. Mobility signalling is exchanged only in every "k" number of point of attachment changes, not always. i.e. after a mobility signalling is sent, the next mobility signalling is deferred for "k" times the mobile node changes its point of attachment. Chain is maintained between those MAGs and the data packet is transferred in this chain. This method entails extra cost in MAG to maintain the chain of MAGs. Also the data packet has to be routed through the entire chain, i.e. it has to pass thorough "K" number of MAGs which is really a time consuming procedure.

Zhiwei Yan and Jong-Hyouk Lee [15] have proposed an architecture similar to Kyu Yi. et.al [8]. In this architecture, serving MAG creates direct tunnel between MAG and LMA, if the mobile node is busy. Otherwise mobility signalling is deferred and the chain of MAG is created, until the mobile node gets incoming or outgoing traffic. This architecture overcomes the disadvantage of data packet passing through the entire chain of MAG by making the direct tunnel between the serving MAG and LMA. But this architecture requires indication from mobile node to know whether the mobile node is busy or not. It also needs change in mobile node as well. This method also involves extra cost in MAG to maintain the chain of MAGs. Also the data traffic which occurs after the mobile node's idle time has to go through chain of MAGs till the tunnel is established between MAG and LMA.

Jong-Hyouk Lee et.al [4] applies paging technologies in PMIPV6 to reduce signalling cost. MAGs are clustered into several paging area and the mobility signalling is exchanged only if the mobile node changes the paging area. Inside one paging area, mobility signalling is exchanged, only if mobile node is active. To know mobile node's current point of attachment, MAG and LMA send paging request to the paging area from where mobile node is registered. The current serving MAG replies to the paging request and establish the tunnel with LMA. This method overcomes all the disadvantages mentioned in the previous schemes. But the incoming packets are delayed until the paging mechanism is completed to find the current MAG and the time required to establish the tunnel between LMA and MAG. Similarly outgoing traffic is delayed till the tunnel establishment. Also it adds paging overhead to LMA.

III. PROPOSED ARCHITECTURE

The objective behind this research work is to reduce the number Location Update message of an idle mobile node. Geographical nearby MAGs are grouped and mobility signalling of idle mobile nodes are restricted inside the group itself. Mobility signalling is sent to LMA only if the mobile node is active or it moves to new group. The below subsections explains the procedures in detail.

A. Grouping MAGs

Geographically nearby MAGs are grouped. The MAGs with fewer loads is selected as Lead MAG of that group. Lead MAG can be selected based on different measurement criterions, e.g. MAG which has lesser number of nodes attached, MAG which forwards fewer amount of data traffic. The Head node can be changed dynamically in periodic time interval or depending on the load of the current Lead MAG. All the MAGs broadcast the measurements values to other MAGs inside the group. The MAG with lesser load is chosen as Lead MAG. Fig. 3 shows the example PMIPV6 network after grouping the MAGs.

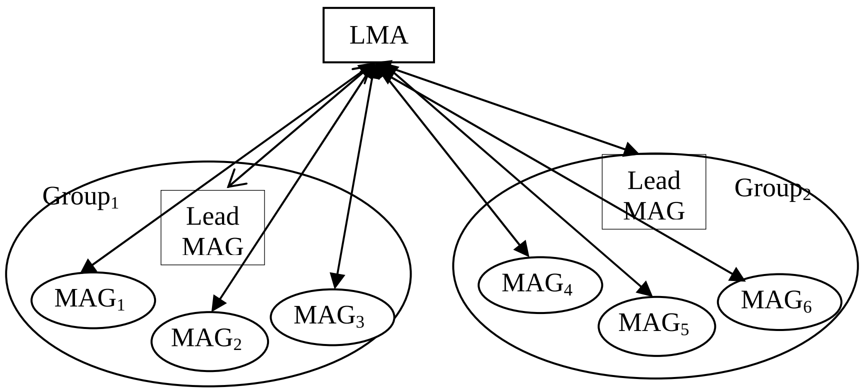


Fig. 3. Grouping MAGs

B. Idle Mobile Node Table (IMNT)

Each MAG maintains a table of idle mobile nodes present in the group. MAG uses the time-based state which is an extension of binding timer managed in the MAG to identify whether the mobile node is idle or not. If a mobile node is found to be idle, MAG broadcasts Idle Mobile Node Info_Add (IMNI_Add) message to insert mobile node's information in Idle Mobile Node Table (IMNT). On receiving IMNI_Add, other MAGs add the idle mobile nodes' information in their own IMNT. Fig. 4 shows the steps in the addition of mobile node in IMNT. MAG_1 finds MN_1 becomes to be idle. It broadcasts IMNI_Add (MN_1) to all MAGs in the group. MN_1 is added in the IMNT of all the MAGs. Now IMNT has 2 entries MN_2 and MN_1.

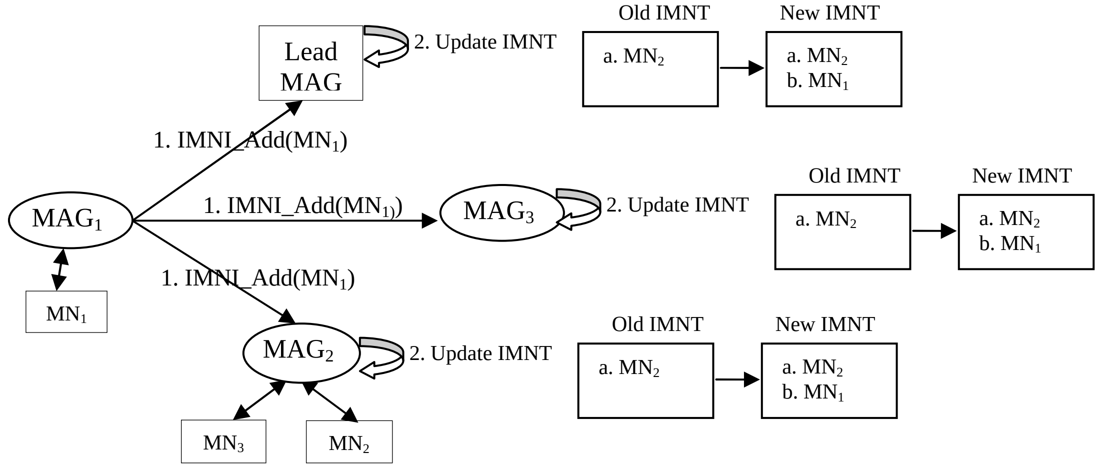


Fig. 4. Adding an entry in IMNT

Similarly if a mobile node becomes active, MAG broadcasts Idle Mobile Node Info_Remove (IMNI_Remove) to delete the mobile nodes' information from the IMNT. Hence all the MAGs inside the group maintain same information in the idle mobile node table. The Entry in idle mobile node table is associated with expiration time after which the entry becomes invalid. Fig. 5 shows a scenario to remove entry from IMNT.

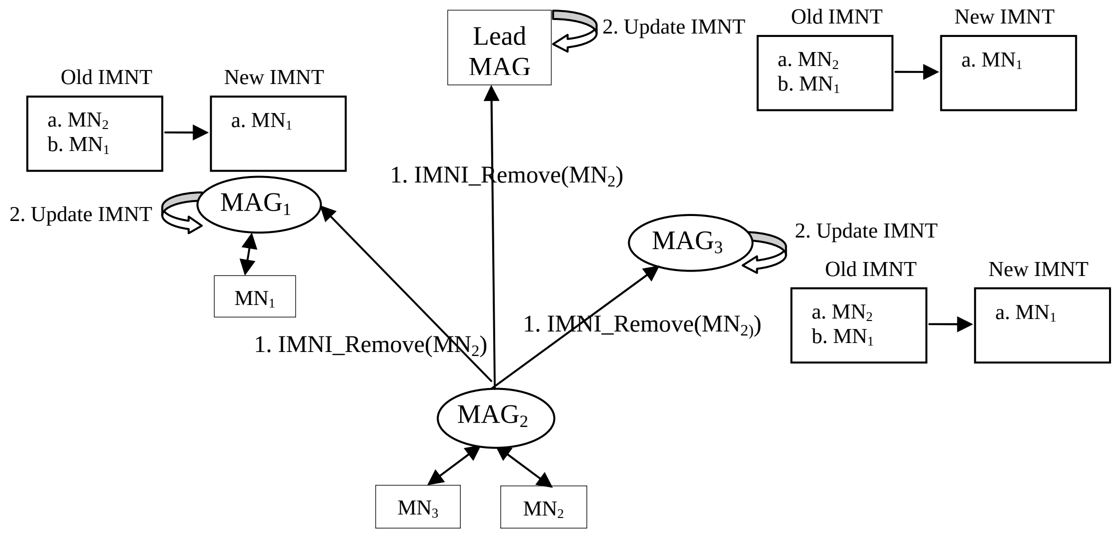


Fig. 5. Deleting an entry from IMNT

C. Proxy Binding Cache Entry (PBCE)

Lead MAG maintains a table called Proxy Binding Cache Entry (PBCE) table which is similar to Binding Cache Entry (BCE) maintained by LMA. PBCE maintains the list of idle mobile nodes present inside the group and the MAG to which the idle mobile node is attached. All idle mobile nodes' information (i.e nodes which are in IMNT) need not present in PBCE. Idle mobile node information is added in PBCE table, while it changes its point of attachment after it becomes idle.

Fig. 6 shows how the entries are added in PBCE. If a node changes its point of attachment, new MAG checks IMNT to find whether the mobile none is idle or not. If it is idle, new MAG sends PBU to Lead MAG instead of LMA. Lead MAG forwards PBU to LMA. LMA sends back BA to Lead MAG. Lead MAG adds the entry in PBCE, and then it sends BA to new MAG.

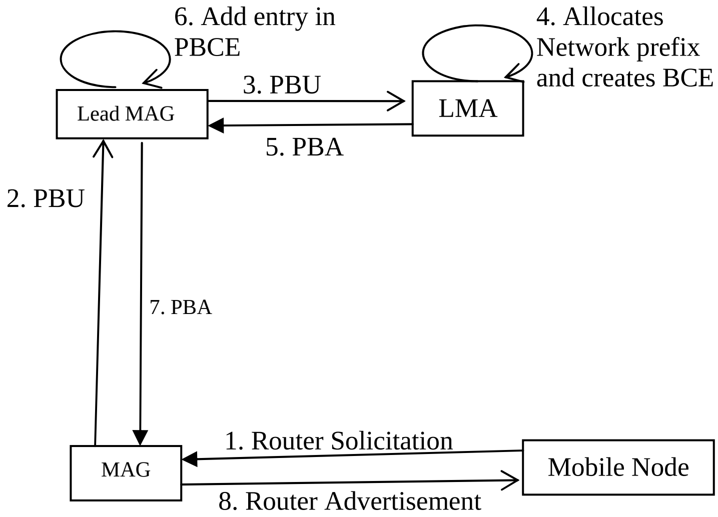


Fig. 6. Adding an entry in PBCE

Henceforth, if the same idle mobile node changes its location inside the same group, PBU is not forwarded to LMA. Instead, Lead MAG fetches information from PBCE and sends PBA to new MAG. Thus idle mobile node's mobility is restricted inside the group itself. Mobility signalling is not sent to LMA which is shown in Fig. 7.

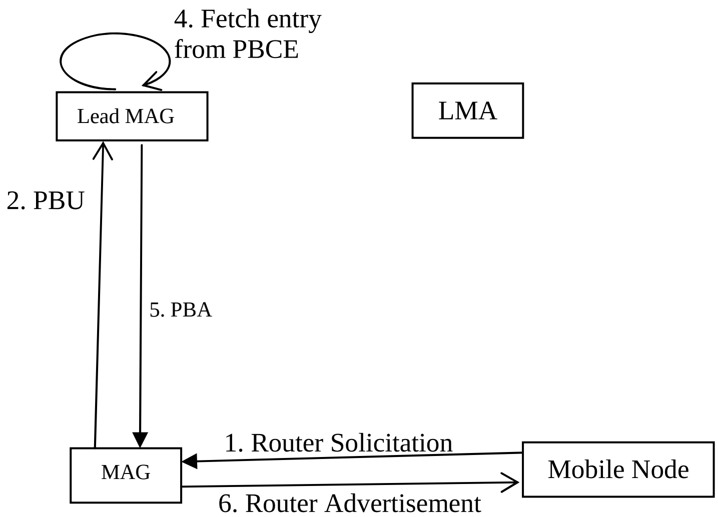


Fig. 7. Fetching an entry from PBCE

D. PMIPV6 network with new IMNT and PBCE data structures

Fig. 8 shows the sample PMIPV6 network, BCE maintained by LMA, PBCE maintained by Lead MAG_1 and IMNT maintained by $Group_1$ MAGs. Each MAG maintains a separate IMNT. For simplicity only one instance of IMNT is shown.

In the sample network, MN_1, MN_2 and MN_4 are idle mobile nodes. The path between LMA and mobile nodes are given below.

MN_1 : LMA-> Lead MAG_1 -> MAG_1

MN_2 : LMA -> Lead MAG_1 -> MAG_2

MN_3 : LMA -> MAG_2

MN_4 : LMA -> MAG_1 (MN_4 is idle. It is listed in IMNT, but not found in PBCE and the reason is that MN_4 has not changed its location after it becomes idle).

For the active mobile nodes, direct tunnel is established between LMA and the MAG to which the mobile nodes are attached. For the idle mobile nodes, Lead MAG sits between LMA and the MAG to which idle mobile node is attached.

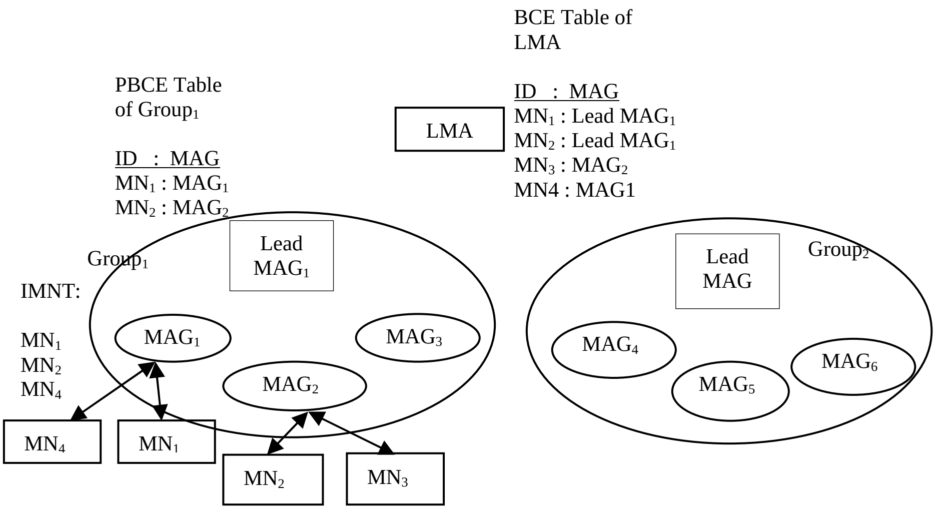


Fig. 8. PMIPV6 network with new IMNT and PBCE data structures

If the idle mobile node changes its point of attachment from one MAG to another MAG inside the same group, the path between LMA and Lead MAG remains intact. Only the path between Lead MAG and the MAG is changed. PBU is sent to Lead MAG instead of LMA. Only PBCE is updated with the new MAG information. Fig. 9 shows the idle mobile node movement from MAG_1 to MAG_2.

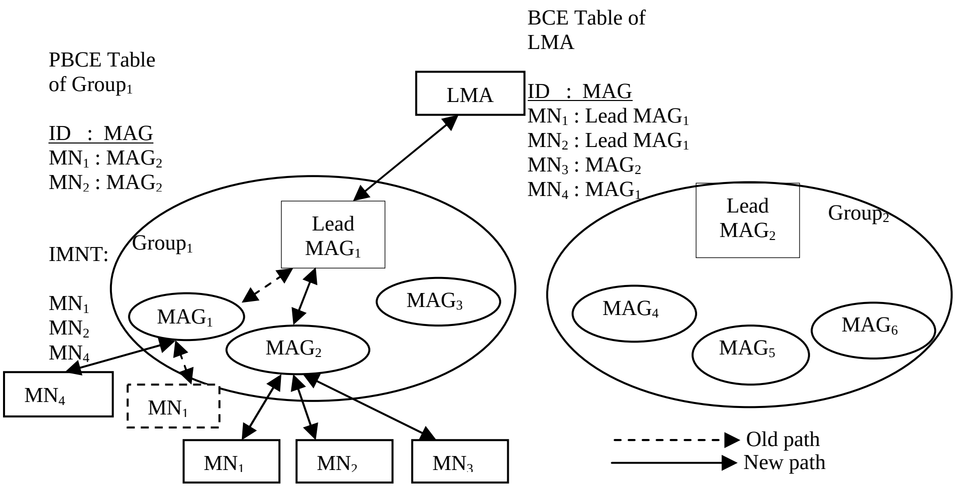


Fig. 9. PMIPV6 network after an idle mobile node movement

MN_1's old path: LMA -> Lead MAG -> MAG_1

MN_1's new path: LMA -> Lead MAG -> MAG_2

LMA is not affected due to this movement. Only the path between Lead MAG and MAG is changed. As long as the idle mobile node is roaming inside the same group, idle mobile node's mobility information is not sent to LMA and restricted inside the group itself.

E. Mobile node's registration in a new group

If a mobile node joins a group, i.e., mobile node attaches to a MAG which belongs to new group; MAG doesn't find corresponding entry in IMNT. MAG follows normal registration procedure to register the mobile node with LMA. The message flow is as shown in Fig. 2.

F. Active mobile node's movement

MAG cannot see mobile node's entry in IMNT, if mobile node is active. MAG follows normal registration procedure to register the mobile node with LMA. The message flow is as shown in Fig. 2. In Fig. 10, MN_3 which is active, moves from MAG_2 to MAG_3 is shown. Mobility signalling procedure is same as basic PMIPV6.

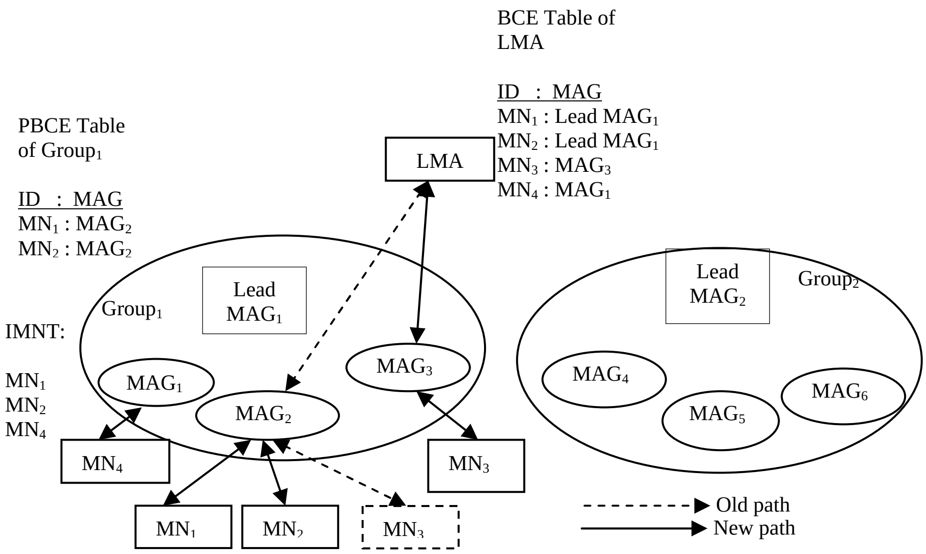


Fig. 10. PMIPV6 network after a active mobile node movement

MN_3's old path: LMA -> MAG_2

MN_3's new path: LMA -> MAG_3

G. Idle mobile node's movement

MAG finds entry in IMNT, if a mobile node has already joined in the group, and it is idle now. One of the old MAGs with which the mobile node was attached before, has already broadcasted the request of adding mobile node's information in idle mobile node table. MAG sends BU to the Lead MAG. Lead MAG looks up into PBCE table for the newly joined mobile node's information. Lead MAG proceeds further, which depends on whether mobile node entry is present in PBCE table.

1) *New entry to be added in PBCE:* An entry is added to PBCE as shown in Fig. 6. Then bidirectional tunnel is established between LMA and Lead MAG. One more bidirectional tunnel is established between Lead MAG and new MAG. Fig. 11 shows the idle mobile node MN_4 movement from MAG_1 to MAG_2.

   MN_4's old path: LMA -> MAG_1

   MN_4's new path: LMA -> Lead MAG_1 -> MAG_2

2) *Entry is already present in PBCE:* Lead MAG finds entry in PBCE. Lead MAG sends back BA to new MAG as shown in Fig. 7. Then bidirectional tunnel is established between Lead MAG and new MAG. LMA is not affected due to this movement. Fig. 12 shows similar movement. MN_4 moves from MAG_2 to MAG_3. As shown in Fig. 12, the LMA is not aware of this movement, only path between Lead MAG and the MAG is altered.

   MN_4's old path: LMA -> Lead MAG_1 -> MAG_2

   MN_4's new path: LMA -> Lead MAG_1 -> MAG_3

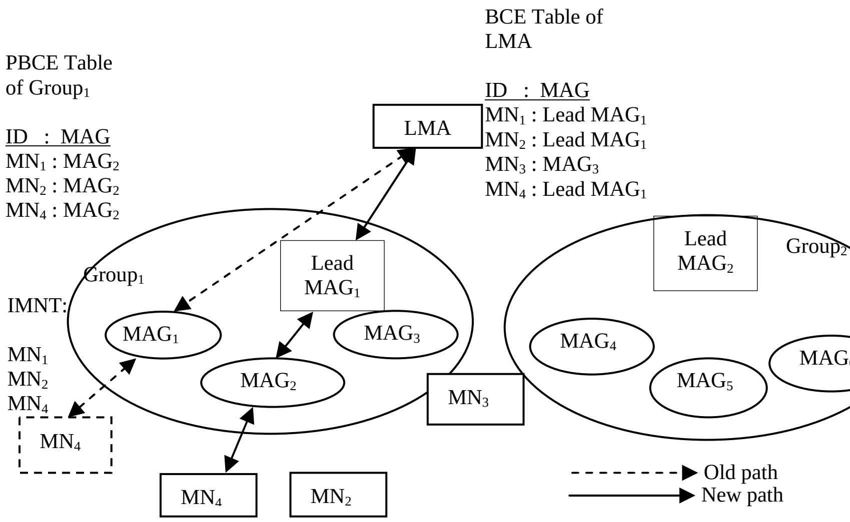


Fig. 11. PMIPV6 Idle mobile node's movement – New entry is added to PBCE

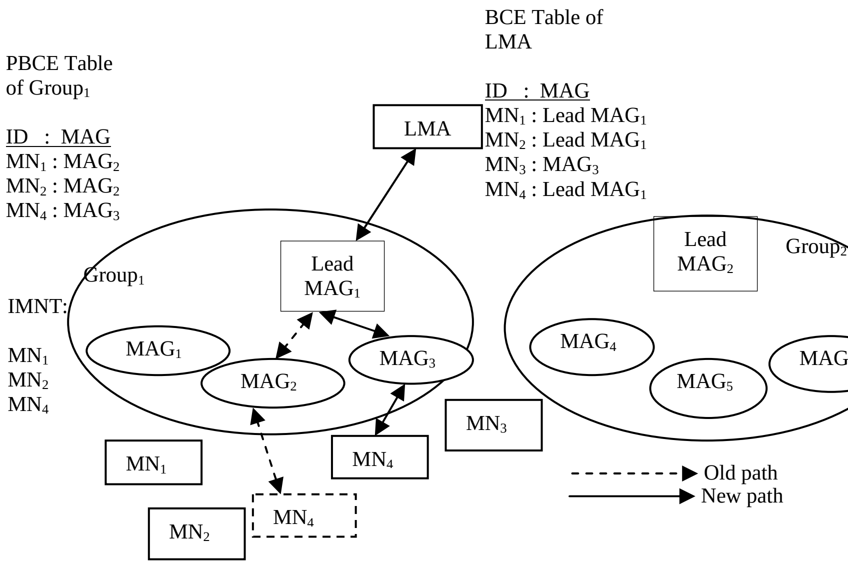


Fig. 12. PMIPV6 Idle mobile node's movement – Entry is already present in PBCE

H. Idle mobile node gets incoming or outgoing traffic

Fig. 13 shows the message sequence while the idle node gets incoming message. The packet from LMA should go through two tunnels, one tunnel between LMA and lead MAG and another tunnel between lead MAG and MAG. When the mobile node gets incoming or outgoing traffic, the packet is forwarded via these two tunnels. Also direct tunnel is established between MAG and LMA in parallel, so that the future packets can go via the new single tunnel, bypassing Lead MAG. Also the mobile node information is removed from IMNT. The same procedure is applicable while the mobile starts sending out messages.

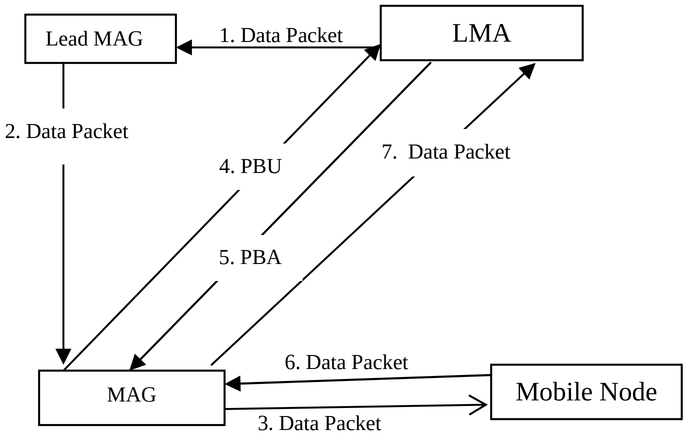


Fig. 13. Idle mobile node gets incoming traffic

While the idle mobile node gets incoming or outgoing message, only the initial packets are forwarded via two channels. Once the MAG detects incoming or outgoing traffic towards LMA, MAG establishes direct bidirectional tunnel with LMA, so that packets goes via single channel.

IV. Performance Analysis

This section analyses the performance of the proposed architecture with basic PMIPV6.

A. Analytical models

The system parameters used in performance analysis and their typical testing values are given below [15].

Table 1. System Parameters

Notation	Description	Values
CBU	Cost for Binding Update	3
CBA	Cost for Binding Acknowledgement	3
C_{Tunnel}	Cost to establish tunnel between two entities	5
N_{active}	Number of Active nodes in the network	50 ~ 200
N_{idle}	Number of Idle nodes in the network	10 ~ 150
N	Number of nodes in the network. $N = N_{active} + N_{idle}$	60 ~ 350
$N_{idle\_to\_active}$	Number of nodes whose state is changed from idle to active. If a node's state changes from idle to active, $N_{idle} = N_{idle} - N_{idle\_to\_active}$	10 ~ 100
L_{LMA_MAG}	Number of nodes between LMA and MAG	5 ~ 10
WL_{MAG_MN}	Constant for Wireless link transfer between MAG and MN	2
$L_{LMA\_LeadMAG}$	Number of nodes between LMA and Lead MAG	5 ~ 10
$L_{LeadMAG\_MAG}$	Number of nodes between Lead MAG and MAG	1 ~ 3
SC_{LMA_BA}	Signaling cost at LMA in basic PMIPV6	Based on nodes present in the network
SC_{LMA_EX}	Signaling cost at LMA in the proposed architecture	Based on nodes present in the network

1) Signalling cost: Signalling cost in basic PMPV6 can be calculated as below.

$$SC_{LMA\_BA} = (C_{BU} + C_{BA} + C_{Tunnel}) \times N$$

$$= (C_{BU} + C_{BA} + C_{Tunnel}) \times (N_{active}) + (C_{BU} + C_{BA} + C_{Tunnel}) \times (N_{idle}) \quad (1)$$

Mobility signaling of both active and idle nodes reaches LMA is indicated in equation (1).

In the proposed architecture, only mobility signaling of active nodes reaches LMA as indicated in equation (2).

$$SC_{LMA\_EX} = (C_{BU} + C_{BA} + C_{Tunnel}) \times (N_{active})$$

$$= (C_{BU} + C_{BA} + C_{Tunnel}) \times (N_{active}') + (C_{BU} + C_{BA} + C_{Tunnel}) \times (N_{idle\_active}) \quad (2)$$

Where $N_{actie} = N_{active}` + N_{idle\_active}$

$$Nidle\_active = \begin{cases} 0, & if\ none\ of\ the\ idle\ node\ becomes\ active, \\ \leq N_{idle}, & Number\ of\ nodes\ whose\ state\ is\ changed\ from\ idle\ to\ active \end{cases}$$

$$SC_{LMA\_EX} \leq SC_{LMA\_BA} \quad (3)$$

As indicated in equation (3), signaling cost at LMA of the proposed architecture is always lesser than the basic PMIPV6 while $N_{idle\_active} = 0$, or equal to the basic PMIPV6 while $N_{idle\_active} = N_{idle}$.

2) Packet Delivery Time: The packet delivery time represents the time taken for a packet to travel from LMA to the intended mobile node.

In PMIPV6 network, the packet delivery time of a mobile node is expressed as follows

$$T_{BA} = (L_{LMA\_MAG} + WL_{MAG\_MN}) \times T \quad (4)$$

In the proposed architecture, the packet delivery time of an active mobile node is expressed as follows

$$T_{EX\_active\_node} = (L_{LMA\_MAG} + WL_{MAG\_MN}) \times T \quad (5)$$

From equations (4) and (5), it is evident that $T_{BA} = T_{EX\_active\_node}$. i.e. the packet delivery time in basic PMIPV6 is same as the packet delivery time of active mobile nodes in the proposed architecture.

The packet delivery time of an idle mobile node is expressed as follows.

$$T_{EX\_idle\_node} = (L_{LMA\_LeadMAG} + L_{LeadMAG\_MAG} + WL_{MAG\_MN}) \times T_1 + (L_{LMA\_MAG} + WL_{MAG\_MN}) \times T_2 \quad (6)$$

Where $T_1 + T_2 = T$

Initially, packets have to pass through LMA, Lead MAG and MAG for T_1 duration, until the direct tunnel is established between LMA and MAG. After that, packets flow via only LMA and MAG, which is same as the basic PMIPV6.

B. Experimental results

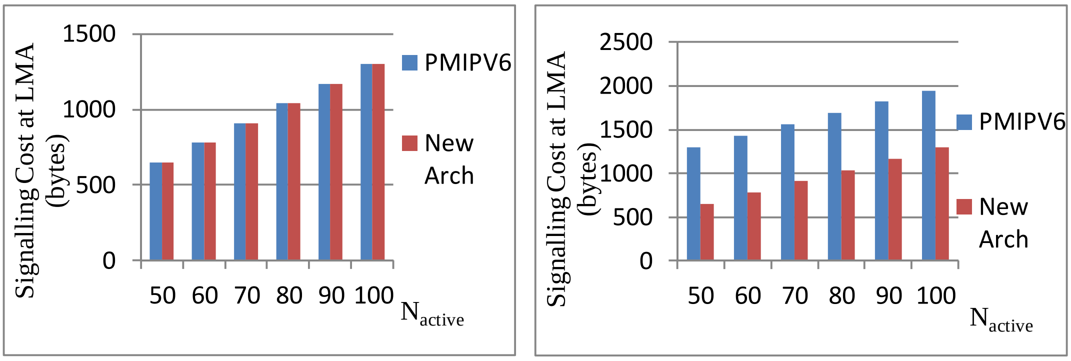
This section shows numerical results comparison of basic PMIPV6 and the proposed architecture. Performance analysis is done in ns-3 along with PMIPV6 package. The typical values of system parameters used in performance analysis are given in Table I.

1) Analysis of signalling cost: signaling cost at LMA is analyzed in following three different ways.

(i) Impact of number of active nodes present in network:

Increase in number of active nodes (N_{active}) increases Signalling cost at LMA in both the basic PMIPV6 and the proposed architecture, as LMA processes active node's mobility signalling in both the architectures. This is shown in Fig. 14(a). Fig. 14(b) shows that signalling cost of PMIPV6 is high compared to proposed architecture. The difference is due to the number of idle nodes (N_{idle} = 50) in the network. The proposed architecture does not include the signalling cost of idle mobile nodes.

N_{idle} = 0, N=200 N_{idle} = 50, N=250



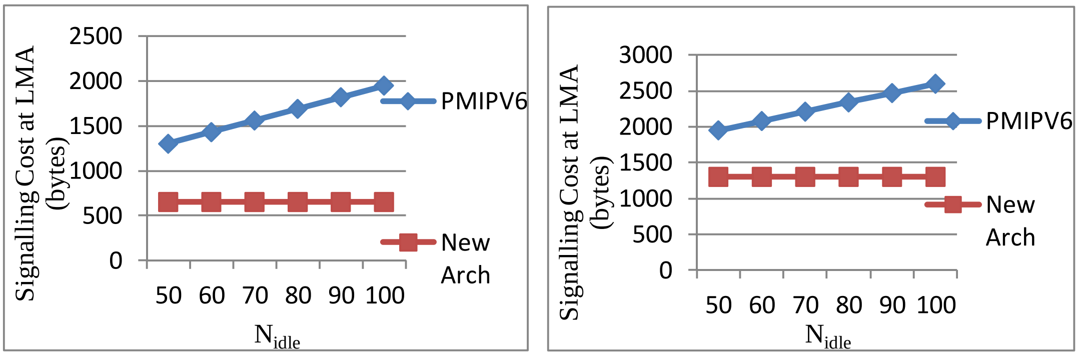
(a) Signalling cost at LMA while varying N_{active} and N_{idle} = 0. (b) Signalling cost at LMA while varying N_{active} and N_{idle} = 50

Fig. 14. Impact of number of active nodes in Signalling cost at LMA

(ii) Impact of number of idle nodes present in network:

Increase in number of idle nodes shows no effect on signalling cost at LMA in the proposed architecture. Performance analysis is done by increasing the number of idle nodes N_{idle}. Fig. 15(a) and 15(b) show that signalling cost of the basic PMIPV6 increases proportionally to increase in number of idle nodes. But the proposed architecture is not affected due to the increase in number of idle nodes.

N_{active} = 50, N=200 N_{active} = 100, N=250

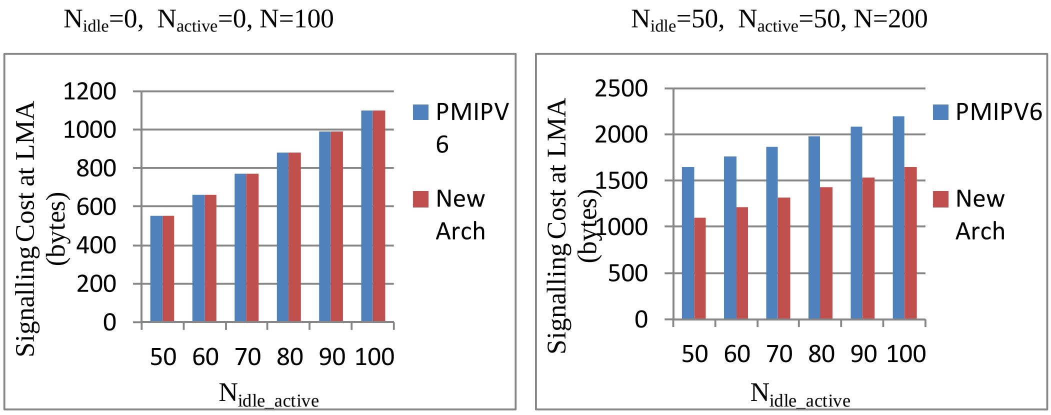


(a) Signalling cost at LMA while varying N_{idle} and N_{active} = 50 (b) Signalling cost at LMA while varying N_{idle} and N_{active} = 100

Fig. 15. Impact of number of idle nodes in Signalling cost at LMA

(iii) Impact of number of nodes which move from idle to active

Increase in number of nodes, which move from idle to active state, increases the number of active nodes in the network. As discussed earlier, increase in number of active nodes shows similar effect in both the architectures. It is shown in Fig. 16(a). The difference between PMIPV6 and the proposed architecture in Fig. 16(b) is due to the idle nodes, as the proposed architecture does not include signalling cost of idle nodes.



(a) Analysis while varying N_{idle_active} and N_{idle}=0, N_{active}=0 (b) Analysis while varying N_{idle_active} and N_{idle}=50, N_{active}=50

Fig. 16. Impact of N_{idle_active} in signalling cost at LMA

2) *Analysis of Packet Delivery Cost:* The packet delivery cost is measured in terms of the number of hosts a packet should travel from LMA to reach the mobile node. The packet delivery cost is analysed in following two different ways.

(i) Number of hosts to travel for an active node's packet:

Active node's packet follows the same path in both PMIPV6 and in the proposed architecture. So time taken for a packet to reach mobile node is same in both the architectures as shown in Fig. 17.

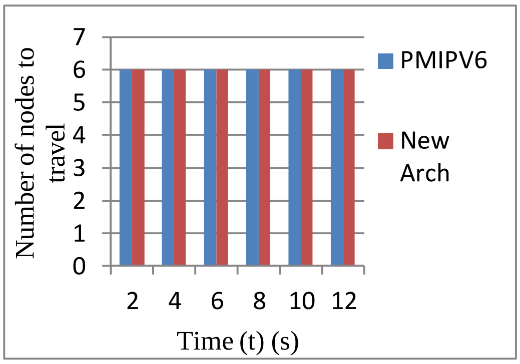


Fig. 17. Number of hosts to travel for an active node's packet, while L_{LMA_MAG} = 6

(ii) Number of hosts to travel for an idle node's packet:

The packet, destined for idle node, takes different paths in PMIPV6 and in proposed architecture for T1 duration until the tunnel is established between LMA and MAG. Afterwards packets flow in the same path in both the architectures. Systems parameter values are set as follows. L_{LMA_MAG} = 6, $L_{LMA\_LeadLMA}$ = 6, $L_{LeadLMA\_MAG}$ = 3, T = 6, T_1 = 2, T_2 = 4. Performance analysis is shown Fig. 18. Till T_1 duration, packets in the proposed architecture flow via more number of hosts than PMIPV6. Once the tunnel is established between LMA and MAG, i.e. after T_1 duration, packets flow in the same path and both the architectures shows similar performance.

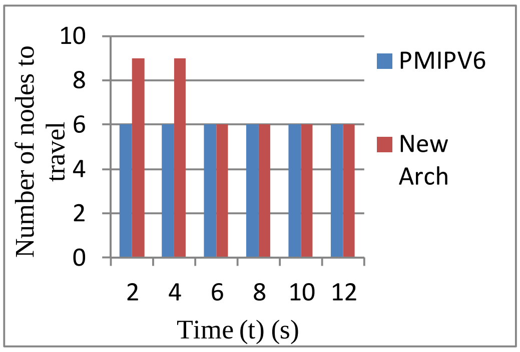


Fig. 18. Number of host to travel for an idle node's packet

V. CONCLUSIONS

LMA is the central point to route the packets in and out of PMIPV6 network. Also it participates in tracking mobile node's current location. So LMA is heavily loaded even in normal scenarios. This paper tries to reduce the load at LMA by blocking idle node's mobility signalling, as LMA need not know idle node's current location. This also reduces network traffic towards LMA. While the number of idle mobile nodes increases in the network, the proposed architecture shows significant reduction of load at LMA, compared to basic PMIPV6. In all other scenarios, the proposed architecture shows similar performance as PMIPV6 network and does not introduce any extra signaling.

REFERENCES

[1] C.-H. Chu and C.-M. Weng, "Pointer forwarding MIPv6 mobility management," in Proc. IEEE Global Telecommun. Conf., Dec. 2002, pp. 2133–2137.
[2] S. Gundavelli, Extensions to Proxy Mobile IPv6: Motivation, IETF Internet Draft, draft-gundavelli-netext-extensions-motivation-00, May 2009.
[3] J. Kempf and P. Mutaf. IP Paging Considered Unnecessary: Mobile IPv6 and IP Paging for Dormant Mode Location Update in Macrocellular and Hotspot Networks. In Proc. of IEEE WCNC, pages 1032–1036, March 2003.
[4] J. Lee, T. Chung and S. Park, "Shall We Apply Paging Technologies to Proxy Mobile IPv6", in Proc. ACM Workshop on Mobility Architecture in the Evolving Internet Architecture (MobiArch) 2008 conjunction with ACM SIGCOMM 2008, Seattle, WA, USA, (2008) August.
[5] K.-P. Lin and H.-Y. Wei, "Paging and location management in IEEE 802.16j multihop relay network," J. Comput. Syst. Netw. Commun., vol. 2010, no. 916569, p. 15, 2010.
[6] W. Ma and Y. Fang, "Dynamic hierarchical mobility management strategy for mobile IP networks," IEEE J. Sel. Areas Commun., vol. 22, no. 4, pp. 664–676, May 2004.
[7] W. Ma and Y. Fang, "Two-level pointer forwarding strategy for location management in PCS networks," IEEE Trans. Mobile Comput., vol. 1, no. 1, pp. 32–45, Jan. 2003.
[8] Myung-Kyu Yi, Jae-Young Choi, Jin-Woo Choi, Seok-Cheon Park and Young-Kyu Yang, "A Pointer Forwarding Scheme for Minimizing Signaling Costs in Proxy Mobile IPv6 Networks", CCNC, (2010).
[9] S. Pack, B. Lee, T. Kwon, and Y. Choi, "A pointer forwarding scheme with mobility-aware binding update in mobile IPv6 networks," Comput. Commun., vol. 31, no. 5, pp. 873–884, Mar. 2008.
[10] S. Pack, B. Lee, and Y. Choi, "Proactive load control scheme at mobility anchor point in hierarchical mobile IPv6 networks," IEICE Trans. Inform. Syst., vol. E87-D, no. 12, pp. 2578–2585, Dec. 2004.
[11] C. Perkins, IP Mobility Support for IPv4, IETF RFC 5944, Nov. 2010.
[12] H. Soliman, C. Castelluccia, K. ElMalki, and L. Bellier, Hierarchical Mobile IPv6 (HMIPv6) Mobility Management, IETF RFC 5380, Oct. 2008.
[13] M. Yi and C. Hwang, "A pointer forwarding for minimizing signing cost in hierarchical mobile IPv6 networks," in Proc. Int. Conf. EUC, vol. 3207. Aug. 2004.
[14] X. Zhang, J. Castellanos, and A. Campbell. P-MIP: Paging Extensions for Mobile IP. ACM Mobile Networks and Applications, 7(2):127–141, March 2002.
[15] Zhiwei Yan and Jong-Hyouk Lee, "State-aware Pointer Forwarding Scheme with Fast Handover Support in a PMIPv6 Domain", IEEE Systems Journal, vol. 7, no. 1, pp. 92-101, March 2013. (IF: 0.825(2009), 0.619(2010), 0.923(2011), SCIE).