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A Simulation Based Study of IP Mobility over IPv6 Networks

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***Abstract*—IP mobility, one of the current research topics for the researchers. With the emergence of Internet of Things (IoT); the world of interconnected physical objects, IP mobility has taken a great pace. Most of the interconnected things in IoT would be mobile and need efficient mobility management schemes to handle their mobility. There are standardized mobility management protocols; host based (MIPv6 and its extensions) and network based (NEMO and PMIPv6 and it extensions). These protocols are being used to carry the mobility of Mobile Node (MN) with the minimum handover delay and keep the MNs connected to the network all the time to avail the network services. In this paper, we have evaluated the performance of MIPv6 with its extensions and PMIPv6 with its extensions. Through the simulation over Network Simulator (NS2) different performance parameters were calculated by increasing the simulation time to show their performance. We observed from the results, the extension of basic mobility protocols are best to reduce handover delay and to avoid packet loss and also where host based protocols are not suitable, network based mobility protocols provide fruitful results.**

Keywords— IP Mobility, MIPv6, PMIPv6, handover latency, IOT.

I. Introduction

From the last few years, portable devices like mobile gadgets, laptops etc. are increasing tremendously and are being used for IP services. These devices are seen everywhere in day to day life, hence they need to be connected to the internet. Also the people carrying such devices need unbroken network services. Mobility was introduced in Internet Protocol Version 4 (lPv4) to provide connectivity to such devices. But now Internet Protocol Version 6 (IPv6) has an inbuilt feature of mobility and better results were obtained when we used mobility management schemes in IPv6 enabled networks. When the MN moves from one network to another, new address is obtained in the visited network (foreign network) called care of address (CoA). In IPv4 networks the CoA needed to be configured manually but on the other hand in IPv6 networks it gets configured automatically due to the auto configurable feature of IPv6. Also with the introduction of IPv6, every object on earth is addressable and can be made to communicate by embedding some electronics in the physical objects; called machine to machine communication (M2M). This embedding of electronics is made possible by the Nano technology and by deploying of sensor devices on objects. M2M communication gives rise to a new technology; Internet of Things (IOT) [3] which simply means, most of the physical objects connected to the network. To carry the mobility of MN, there should be an appropriate mobility management schemes. Mobile Internet Protocol version 6 (MIPv6) addresses numerous issues that existed in MIPv4 but time to time its extensions came into existence and were standardized by IETF in order to reduce the Handover latency. This paper aims to simulate the MIPv6 and its extensions (HMIPv6 and FHMIPv6) along with network based mobility management protocol; Proxy mobile IPv6 (PMIPv6) by increasing the simulation time. It also provides their comparison in terms of different performance parameters specifically handover latency and average throughput.

Remainder of this paper is organized as: Section II presents brief review of related work done; Section III and Section IV explain Mobility management initiated by the host and their simulations respectively. Section V and Section VI provides a study of Network based mobility and its simulation with results obtained. Finally section VII concludes the paper and tells about the future work.

II. Literature Review

IETF has standardized the both categories of Mobility Management Schemes and a tremendous work have been carried out over these schemes.

Wei QU et al. [23], gave Simulation-based Performance Comparison of Video Transmission over MIPv6, FMIPv6, HMIPv6, and FHMIPv6 by considering parameters like degree of mobility, wired link delay, jitter, error rate, and throughput with traffic as CBR, Video, VolP and TCP. In our earlier work [8], we only presented the simulation of Host based mobility management Schemes. The performance results follow the routine FMIPv6>HMIPv6>MIPv6. ***Kempf*** [14], Studied all existing host based mobility management schemes and offered their shortcomings like involvement of Host in mobility management. ***S. Gundavelli et al.,*** [13], Introduced Proxy Mobile IPv6 (PMIPv6) that was intensely standardized by the IETF-NETLMM working group. This protocol was expected to support the real deployment of IP mobility management where Mobile Nodes (MNs) were not supposed to carry the signalling related to mobility. ***Myung-Kyu Yi et al.*** [20], Studied and compared PMIPv6 and hierarchical Mobile IPv6 (HMIPv6). LI Yun et al. [22] provided a performance study of MIPv6 and its extended protocols only and indicated that delay and packet loss in FMIPv6, HMIPv6 and FHMIPv6 are reduced greatly. ***Dizhi Zhou et al.*** [19] did the theoretical analysis and evaluated the handover latency of PMIPv6, Fast handovers for PMIPv6 (FPMIPv6) and Transient Binding for PMIPv6 (TPMIPv6) through simulations in vertical handover environment. ***Jong-Hyouk Lee et al.*** [21], Analysed and compared existing host based IPv6 mobility management protocols like MIPv6, FMIPv6 etc. including the recently standardized network based PMIPv6 and FPMIPv6. From the related work we observed that many similar attempts were made but still mobility in real time application is an issue. Also for the mobility of resource constrained devices, Network based protocols are proved to be best suitable.

III. HOST BASED MOBILITY

Host based Mobility Management Schemes require Mobile host/Mobile Node (MH/MN) involved in all signaling related process. So there is a need for protocol stack modification of MN for the session continuity during handover. This signaling process includes movement detection, Router Solicitation request (RtSolReq), Duplicate address detection (dad) and Binding updates (BUs) etc. Already existing Host Based Mobility Schemes have been used for different applications and are explained below:

A. Mobile IPv6: Mobile IPv6 (MIPv6) [1, 2, 4, 5, 6, 7] allows nodes to move between different network domains, while maintaining reachability and on-going connections between mobile and correspondent nodes (CN). MN acquires a new address, called Care-of-Address (CoA) as soon as it moves to new subnet. Binding Update (BU) containing CoA are sent to its Home Agent (HA) and all Correspondent Nodes (CNs), every time MN moves to new domain to maintain session continuity. Then home agent (HA) intercepts data packets and tunnels them to the new CoA. In the visited domain, foreign agent (FA) acts like HA in home domain (see fig. 1).

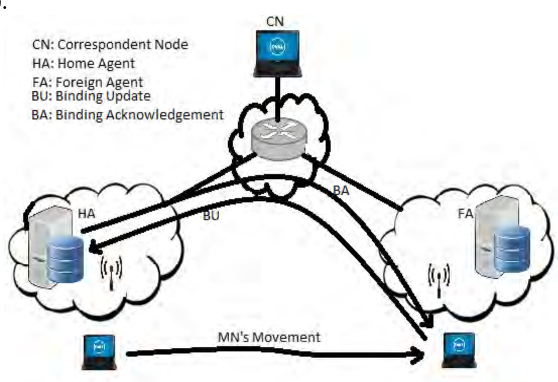


Fig.1: MIPv6 Basic Model

Route Optimization can be done eliminate the Triangle Routing problem. For Route Optimization, the MN sends Home test initialization (HoTI) message to the correspondent node (CN) through Home Agent (HA) and receives back HoT message as acknowledgement through the same route. HoTI contains home address which is permanent and CoA in order to tell the CN about the new location of MN. After that MN sends Care of Test initialization (CoTI) message to the CN directly without intervention of HA and receives back CoT message as an acknowledgement. Then MN and CN start communication directly without passing packets via HA. The handover latency is calculated through the following equations [8]:

$$TM = Tmdd + Tdadd + Tbud \quad \text{(See appendix)}$$

After route optimization, another delay T_{ro} is added but this delay is only at the start of communication between MN and CN [8].

$$TM = Tmdd + Tdadd + Tbud + Tro \quad \text{(See Appendix)}$$

B. Hierarchical MIPv6 (HMIPv6): HMIPv6 [9, 10] introduces the hierarchical mobility management model as shown in the figure 3. Same approach is used as in MIPv6 for its working, to take care with the movement in the region (that is, micro-mobile or local mobility) and inter domain Mobile (macro mobile or global mobility). HMIPv6 [2] introduces mobility anchor point (MAP) to distinguish movement in the region and inter-region. MN has to register with MAP only once, by sending binding updates (BU), thus MAP acts as home agent for MN. Then all the packets for MN are intercepted by MAP and are tunneled to MN. Two addresses are associated with MN when it is in the MAP's domain: the regional care-of address (RCoA) and local/Link care of address (LCoA). The BU consists of RCoA. When MN's movement is only within MAP region, it needs to register a new LCoA to MAP and no need to send BU to HA as well as to CN because RCoA has not changed thus it reduces the signaling overload over the network and also reduces the packet loss and ultimately reduces the handover delay (See figure 3). The handover latency can be calculated by the equation below [8]:

$$T_H = T_{mdd} + T_{dadd} + T'_{bud} \quad \text{(See Appendix)}$$

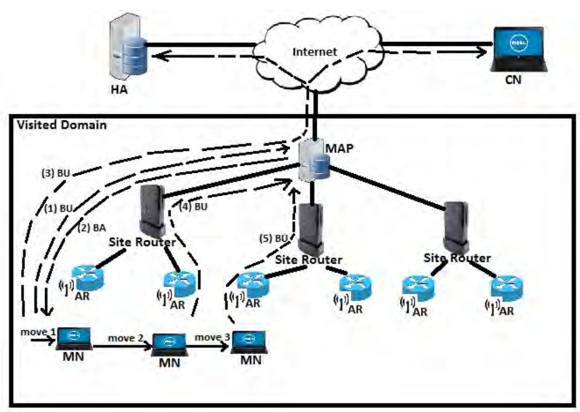


Fig. 3: HMIPv6

C. Fast Handovers for Mobile IPv6: Fast Handovers for Mobile IPv6 (FMIPv6) [11, 9, 5, 12] is implemented based on the MIPv6. Its goal is to reduce the handover latency. The idea is to allow the MN to establish a new temporary address with the new access router before breaking connection with the previous access router.

In FMIPv6, the CoA configuration and the duplicate address detection is done before it disconnects from the previous link, thus removes T_{dadd} delay. The handover latency is calculated through the equation below [8]:

TF = Tmdd + T'bud (See Appendix)

FMIPv6 mechanism works in two different modes: Predictive mode and Reactive mode.

1. Predictive Fast Handover Mode: As illustrated in Figure 4, in this mode when the mobile node (MN) realizes that the handoff is necessary, it performs the scan sometime earlier to the handover, and sends a Router Solicitation for Proxy (RtSolPr) message in order to find neighbor access routers. The currently default access router or previous access router (PAR) responds to MN with a Proxy Router Advertisement (PrRtAdv) resolving the specified access point (AP) identifiers. Therefore, it is able to send the Fast Binding Update (FBU) and Handover Initiate (HI) prior to the new access router (NAR) via PAR. NAR confirms the message by sending back a Handover Acknowledge (HAck). Then, a Fast Binding Update Acknowledgement (FBack) with the CoA will be sent from PAR to both MN and NAR. Packets sent to the MN during its handover will be buffered at the NAR. After the handover process finished, only the fast neighbor advertisement (FNA) is sent; and the buffered packet will be delivered to the MN.

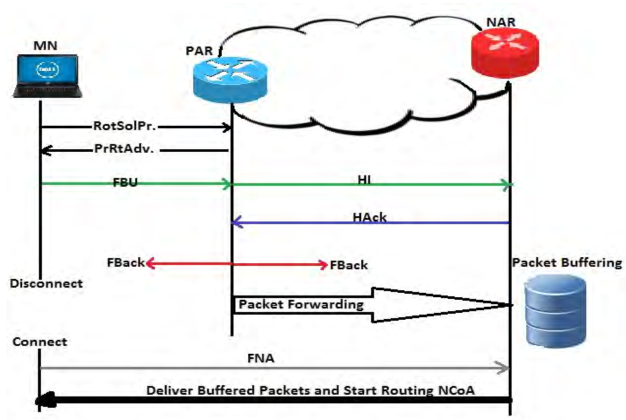


Fig. 4: Predictive Fast HO

2. Reactive Fast Handover Mode: Mechanism of FMIPv6 in reactive mode is illustrated in Figure 5. Contrary to predictive mode, the wireless mobile node cannot send FBU prior to the handover. During the handover time, packets destined to the wireless node will be buffered at the PAR. Therefore, FBU is sent to the PAR after the handover to inform the PAR to forward packets to the wireless mobile node under NAR (see figure 5).

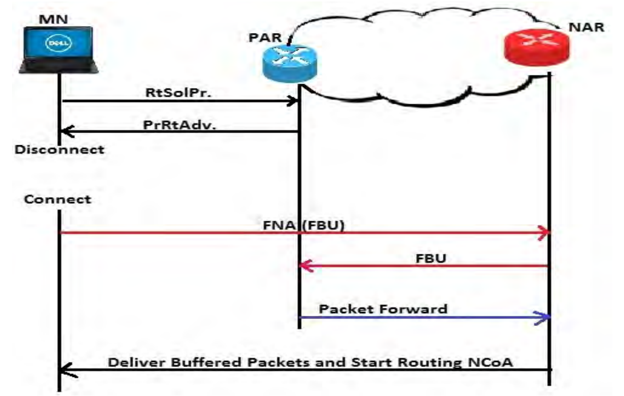


Fig. 5: Reactive Fast HO

IV. Simulation of Host Based Mobility

The simulation of host based mobility management schemes were done by using NS2 Simulator on LINUX Fedora 14 OS. The studied simulation model is shown in the figure 6 below:

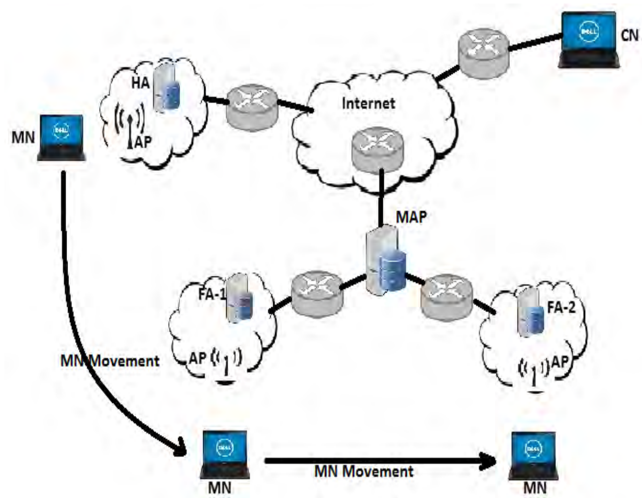


Fig. 6: Studied Simulation Model for Host Based Mobility

The goal of simulation was to evaluate the performance of MIPv6, HMIPv6 and FHMIPv6 from the above model. Simulation Results for performance parameters like handover delay, throughput and jitter were taken by increasing the simulation time.

Results are shown in tables i, ii, iii, iv and v by increasing the simulation time from 90 secs to 160 secs., as shown below:

TABLE I: Simulation Time is 90 secs

Performance Metrics	FHMIPv6	HMIPv6	MIPv6
Pkt. delivery Ratio (%)	96.6097	77.3996	62.3115
Avg. end-to-end delay (ms)	8.7598	8.73209	8.7321
Avg. throughput (kbps)	615.23	564.06	563.61
Avg. handover-delay (secs)	0.22552	2.17132	3.26544
Avg. jitter (secs)	0.00562	0.03248	0.37142

TABLE II: Simulation Time is 100 Secs

Performance metrics	FHMIPv6	HMIPv6	MIPv6
Pkt. delivery Ratio (%)	96.6214	77.4054	62.4063
Avg end-to-end delay (ms)	8.76	8.73257	8.73258
Avg. throughput (kbps)	619.05	573.41	569.25
Avg. handover-delay (secs)	1.31775	2.38745	3.11875
Avg. jitter (secs)	0.00554	0.03374	0.38471

TABLE III: Simulation Time is 110 Secs

Performance Metrics	FHMIPv6	HMIPv6	MIPv6
Pkt. delivery Ratio (%)	96.6678	77.4906	62.5418
Avg end-to-end delay (ms)	8.76011	8.73295	8.73295
Avg.throughput (kbps)	622.20	581.02	577.63
Avg. handover-delay (secs)	1.30927	2.37554	3.11875
Avg. jitter (secs)	0.00577	0.03469	0.39451

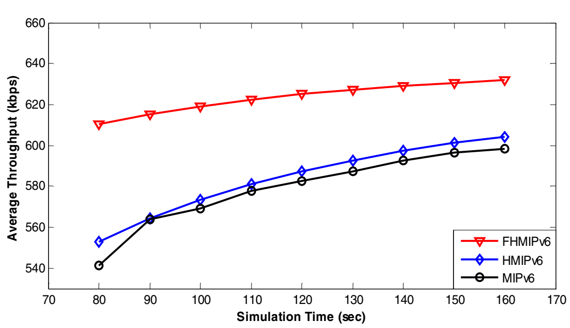
TABLE IV: Simulation Time is 120 Secs

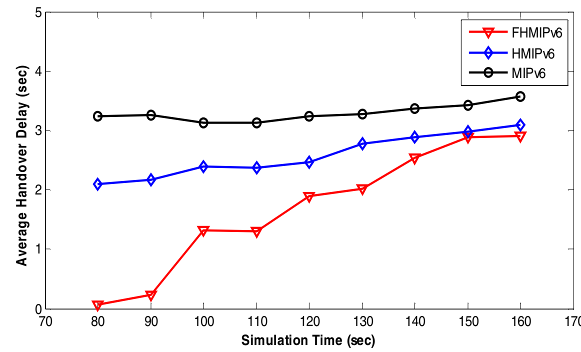
Performance metrics	FHMIPv6	HMIPv6	MIPv6
Pkt. delivery Ratio (%)	96.7218	77.5252	62.6198
Avg end-to-end delay (ms)	8.7602	8.73325	8.73326
Avg.throughput (kbps)	625.05	587.25	582.47
Avg. handover-delay (secs)	1.89625	2.46546	3.24442
Avg. jitter (secs)	0.00595	0.03621	0.41792

TABLE V: Simulation Time is 130 Secs

Performance metrics	FHMIPv6	HMIPv6	MIPv6
Pkt. delivery Ratio (%)	96.7367	77.5352	62.6223
Avg end-to-end delay (ms)	8.76027	8.7335	8.7335
Avg.throughput (kbps)	627.12	592.66	587.22
Avg. handover-delay (Secs)	2.01175	2.77228	3.27479
Avg. jitter (secs)	0.00576	0.03589	0.40265

We took some results by increasing simulation time from 90 Secs to 160 Secs but here we are presenting results upto Simulation time 130 Secs. The TCP session between the CN and the MN starts after 5 seconds of the simulation, the packet size was 1000 bytes. The graphical representation for average throughput and average handover delay is shown below:





From the simulation results we observed the extended protocol; FMIPv6 is showing better performance as compared to MIPv6 and HMIPv6. Handover Latency and packet loss is very less and acceptable in FMIPv6. Therefore, we can say FMIPv6 is best suitable protocol for host based mobility management Schemes including some real time applications.

V. Network Based Mobility

Network Based Mobility Management Schemes attract attention in the Internet and telecommunication societies by improving the performance of the MN's communication to fulfill the requirements of QoS for real-time services. In Network Based Mobility Management Schemes there is no involvement or less involvement of MN in signaling process (Network components are involved in Signaling). These protocols are providing very similar and acceptable results to the host based mobility management schemes and are best suitable in mobility scenarios where resource constrained devices (Sensor Nodes) are involved in mobility. Two protocols were came into existence over time; NEMO-BS (Nemo Basic Support) and Proxy Mobile IPv6 (PMIPv6) and recently proposed extension of PMIPv6 is Fast handovers for PMIPv6 (FPMIPv6). PMIPv6 is the only standardized protocol by the Internet Engineering Task Force (IETF).

A. *PMIPv6:* In august 2008 PMIPv6 [13] was proposed by NETLMM working group to resolve the problems faced by MIPv6, HMIPv6 and FMIPv6. The purpose of PMIPv6 was to reduce the handover latency of MIPv6 and does not require MN to participate in mobility related signaling [14]. In PMIPv6, MN is also allowed to access different interfaces simultaneously and perform handover between them. Although the handover latency in PMIPv6 is quite lesser than the MIPv6 and its extended protocols [15] [16] [17], but it does not satisfy the real time application and also during handoff period, there is termination of connection and that time data packets get lost; that is not acceptable in some critical situations where time criticality is of great importance. To address this problem, an extension of PMIPv6 was proposed as fast handovers for PMIPv6 (FMIPv6) [18].

B. *FPMIPv6:* FPMIPv6 works on an approach to buffer the transmitted packets either at previous MAG (pMAG) or new MAG (nMAG) during handover phase of MN. After the

handover is complete, the buffered packets are delivered to MN's new position and in this way it avoids the packet drop and is very useful in time critical situation. Although buffering of packets and FPMIPv6 operations involve increased signaling and overhead but ultimately throughput increases and is also suitable for real time applications.
FPMIPv6 works in two modes:

1) Predictive Mode (FPMIPv6-Pre): when the MN finds Handover is imminent, then it sends its ID (MN-ID) and new access point identifier (nAP-ID) to its MAG (pMAG). After examining the nAP-ID, pMAG establishes a bidirectional tunnel with nMAG and starts transferring the data packets which are buffered at nMAG and are delivered to MN after completion of Handover [19].

2) Reactive Mode (FPMIPv6-Reac): sometimes MN performs the handover first due to the failed prediction for Handover; called Reactive mode. Here the data packets are buffered at the pMAG and after the completion of handover these packets are tunneled to the nMAG on the request of nMAG and are ultimately delivered to MN [19].

In our work we also presented the Simulation of Network Based Mobility Management Schemes. Our next section presents the Simulation Model used for the simulation of PMIPv6 and FPMIPv6 and the corresponding performance results.

VI. Simulation Model for Network Based Mobility

Fig. 7: shows the network model used for the simulation of PMIPv6 and FPMIPv6 by using NS2 Simulator.

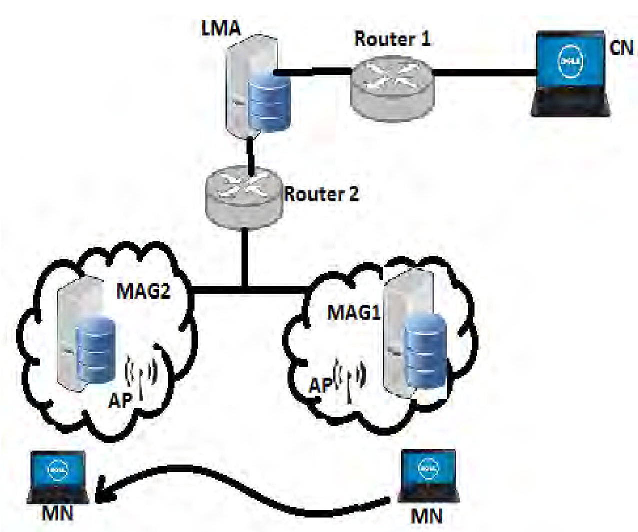


Fig. 7: Simulation Model for Network Based Mobility

In our simulation model shown in fig. 7, link Bandwidth from CN to Router1, Router1 to LMA, LMA to Router2 and Router2 to both MAGs is 100Mbps. Transmission delay is 10ms from CN to Router1, Router1 to LMA and from LMA to Router2 and it 2ms from Router2 to MAGs.
After simulation we got the following results shown in table vi below:

TABLE VI: Performance parameter results for Network Based Mobility

	Handover Latency (ms)	TCP throughput (Mbps)
PMIPv6	1079	21
FPMIPv6-Pre.	1618	21.84
FPMIPv6-Reac.	1230	27.72

From the results shown in the above table, it is clear that the throughput is increased in the FPMIPv6 protocol and that is best suitable for real time scenarios. We also observed the increased handover latency time and that is due to the increased signaling overhead and allocating buffer for storing the packets and protecting them from being lost during handover.

VII. Conclusion

In this paper, we presented the performance evaluation of IP mobility protocols; both host based and network based. Performance parameters were calculated by simulation on NS2 simulator. This paper gives the brief introduction about hose based and network based mobility Schemes and then provides the simulation models for both the schemes. We presented the performance results in the tabular form and observed that the extended protocols of both the schemes are providing fruitful and very acceptable results especially for real time applications. Also we observed that in source constrained device's (Sensor Devices) mobility host based mobility schemes are not suitable so we prefer Network based protocols to carry their mobility. In future, our focus will be on the mobility of resource constrained devices and security in IP Mobility.

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APPENDIX

Acronyms	Description
T_m	Total Handover delay in MIPv6
T_{mdd}	Movement detection delay
T_{dadd}	Duplicate address detection delay
T_{bud}	Binding update delay
T_{ro}	Route optimization delay
T_h	Total handover delay in HMIPv6
T'_{bud}	Binding update delay comparatively lesser than T_{bud}
T_f	Total handover delay in FMIPv6
PAR	Previous access router
NAR	New access router
LMA	Local Mobility Anchor
MAG	Mobile Access Gateway
CN	Correspondent Node
HA	Home Agent
FA	Foreign Agent
MAP	Mobility Anchor Point
AP	Access Point