MIH-Based eNB Selection for Untrusted Networks

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Abstract. In recent years, some mobile phones are equipped with more than one Radio Access Technology (RAT) to make themselves adapt to a heterogeneous environment which comprises networks of different technologies. Also, during a User Equipment's (UE's) handover, it would be better if we can choose a suitable eNB as the next eNB (NeNB) to serve this UE. Generally, this can be achieved with the help of Common Radio Resource Management (CRRM). In this study, we propose a NeNB selection scheme, called eNB Selection System (eSeS), for two adjacent networks, e.g., Q and R, to select an appropriate eNB in R for UE before UE hands over from Q, i.e., source network, to R, i.e., target network. In order to enable the communication between different types of RATs, such as Long Term Evolution Advanced (LTE-A) and Wireless Local Area Network (WLAN), we utilize the IEEE 802.21 Media Independent Handover (MIH) as their common data exchange mechanism. With the CRRM, the load balance in a heterogeneous network environment can also be maintained. In our simulation, the performance of this scheme in untrusted network handover cases is better than that of PMIPv6 and FMIPv6.

Keywords: MIH · CRRM · Untrusted networks · LTE-A · WLAN

1 Introduction

In recent years, some mobile phones are equipped with more than one Radio Access Technology (RAT) to make themselves adapt to a heterogeneous environment which comprises networks of different technologies. A typical example is that one is 802.16 Wimax [1] and others are 802.11 (WLAN) [2] and Long Term Evolution Advanced (LTE-A) [3]. Further, when UE hands over from a wireless system of model A to another one of model B, the delay time is relatively long [4].

On the other hand, two adjacent networks, e.g., Q and R, may be trustable or untrusted. The former is defined as that Q and R have signed a contract with which Q (R) offers R's (Q's) users with the same network services that these users receive when staying in R (Q), while the latter is the case in which Q (R) can only provide basic network services to R's (Q's) users, no matter what network services the users can receive from R (Q).

J.-L. Chen et al. (Eds.): WiCON 2018, LNICST 264, pp. 129–140, 2019.
https://doi.org/10.1007/978-3-030-06158-6_13

In 2008, the IEEE 802.21 (Media Independent Handover, MIH) protocol [5] was proposed for helping UE to hand over, aiming to shorten the handover delay and reduce packet loss rates. However, MIH works only when source network (S-Net for short) and target network (T-Net for short) are trustable. The handover based on MIH has been discussed in many studies [6–8].

Basically, during handover, it would be better if we can choose a suitable base station as NMAG to serve UE, and this choice truly balances network load [9] and supports session QoS. In fact, Common Radio Resource Management (CRRM) [10] as a network resource management scheme can help us to achieve this. Houda et al. [11] proposed a scheme to optimize handover decision in an LTE-A network by using MIH and CRRM. But CRRM entity and MIIS server need to exchange information frequently. Also, CRRM is applicable only when S-Net and T-Net are trustable.

Therefore, in this study, we propose a next eNB (NeNB) selection scheme, named eNB Selection System (eSeS), for two adjacent networks, e.g., Q and R, to select an appropriate eNB in R before UE hands over from Q to R. The selection is performed by LMA. Once S-Net eNB (i.e., PMAG) discovers that UE's signal is weak, it requests S-Net LMA autonomously choosing one of eNBs in T-Net as the UE's NMAG. A part of the results of this study was published in [12].

Also, in current wireless network, some terms are names of the same items, e.g., MN and UE. MAG, eNB and base station are the other example. In this study, we use MN and UE (MAG, eNB and base station) interchangeably, even though they are used in different systems, like PMIPv6, MIPv6 and LTE-5G/4G.

The remaining portion of this paper is structured as follows. Section 2 overviews the background and related work of this study. Section 3 presents the eSeS. The simulation and results are, respectively, performed and discussed in Sect. 4. Section 5 concludes this study and addresses our future studies.

2 Background and Related Studies

In this section, we introduce background and related work of this study

2.1 Related Work

Recent researchers have tried to improve handover performance for a heterogeneous environment by using IEEE 802.21 MIH standard. Mussabbir *et al.* [13] proposed a scheme to optimize FMIPv6 in a vehicular network. They designed a cross-layer mechanism for making an intelligent handover decision and creating a repository to store neighbor-network information. Its advantage is reducing network-prediction time. But MN's power consumption is high because the prediction is done by MN. This may seriously shorten the available time of battery. The scheme proposed by Ha *et al.* in [14] balanced network loads by using a traffic balancing architecture for heterogeneous wireless networks. But serious interference among base stations cannot be avoided. Wang *et al.* [15] proposed a framework which enhances MIH by developing a function providing seamless mobility management. Nevertheless, it may bring heavy signaling overheads to users. Buiati *et al.* [16] proposed a hierarchical MIIS architecture to diminish MIIS response time and reduce the latency of heterogeneous vertical handover.

2.2 Signals of FMIPv6 Handover

The primitives exchanged in FMIPv6 [17] for handover are that at first, each MN and MAG in the system periodically send their information, such as Signal-to-Interference-plus-Noise Ratio (SINR), Received Signal Strength Indication (RSSI), etc., to CRRM. The information is conveyed in some primitives defined in IEEE802.21 MIH standard. MN's MIHF sends MIH_Get_Information.request to CRRM to acquire the statuses of neighbor base stations. CRRM replies MN with MIH_Get_Information.response. When MN's RSSI is lower than RSSIth, MN's MIHF sends MIH_Link_Going_Down to the mobile user to indicate that an event will occur. The user then sends MIH_MN_HO_Candidate_Query.request back to its MIHF. MN's MIHF passes this primitive to MIIS Server through AP MIHF to enquire nearby base-station information which is then conveyed in the MIH_MN_HO_Candidate_Query.response sent by MIIS server to MN's MIHF through AP's MIHF. With this information, MN chooses its NMAG.

After that, MN sends MIH_MN_HO_Commit.request to CRRM through the serving MAG to request handover. On receiving this primitive, CRRM sends MIH_Resource_Reservation.request to NMAG to reserve the required resources (e.g., wireless uplink and downlink channels, backhaul transmission bandwidth, etc.) for MN. When NMAG receives this primitive, it internally delivers MIH_Resource_Allocation.request to its own RRC for resources allocation since in an eNB/MAG, wireless resources are managed by RRC. After that, MIH_Resource_Allocation.response will be sent to eNB's MIHF by RRC. Then the NMAG sends a MIH_Resource_Reservation.response primitive to CRRM. CRRM replies MN with MIH_MN_HO_Commit.response. When MN enters the communication area of the NMAG and attaches to it, NMAG sends a MIH_Resource_Report.request to CRRM telling CRRM the arrival of this MN, and CRRM replies NMAG with MIH_Resource_Report.response as an acknowledgement.

2.3 Signals of PMIPv6 Handover

In PMIPv6 [18], those primitives originally designed for handover and sent by MN in FMIPv6 are now delivered by previous MAG (i,e., PMAG), since PMAG is the proxy of MN. The main difference between FMIPv6 and PMIPv6 is which network entity decides to hand over. When MN's RSSI is lower than $RSSI_{th}$, PMAG sends MIH_MN_HO_Candidate_Query.request to CRRM to acquire the statuses of neighbor base stations with which to choose a suitable NMAG for MN. CRRM will deliver MIH_MN_HO_Candidate_Query.response, which carries the statuses of neighbor base stations, to PMAG. In FMIPv6, this primitive is issued by MN. The remaining sections of resources reservation are almost the same as those of FMIPv6. We do not redundantly describe them.

3 The eSeS Scheme

In the eSeS, MIH is utilized to assist handover in a heterogeneous environment and CRRM is used to balance network burden

3.1 eNB-Collection Subsystem

The main function of eNB-collection Subsystem is mediating the working processes of n untrusted networks, i.e., T-Net LMA, S-Net LMA and so on, $n > 1$. This subsystem basically is created by a trustable third party. In fact, S-Net LMA cannot directly enquire the information of T-Net MAGs. Generally, there are two types of eNB status collection policies. The first one is that eNB-collection Subsystem on demand dynamically requests its nearby network LMAs transferring the statuses of all candidate eNBs near the S-Net MAG to it. The disadvantage, as a dynamic inquiry approach, is that the information available time is relatively longer since the inquiry lasts longer. Its advantages are that the information is provided in a real time manner. Therefore, its statuses accuracy is higher. The storage required to store data is smaller. The second type is that it retrieves the information from its MIIS database or cloud system, indicating eNB-collection Subsystem needs to periodically gathers nearby eNBs' statuses. The disadvantage is that we need to prepare a large database or cloud system to keep eNB statuses that have been so far collected. Maintaining the data and database is another problem. Of course the information accuracy is a little poor, and LRRMs need to periodically collect eNB statuses and send the statuses to eNB-collection Subsystem, consequently increasing network loads. But the information available time is shorter since it accesses data from its local database or cloud system. In this study, we choose the cloud approach. It means we need to prepare a cloud system and periodically collect data from eNBs. This subsystem retrieves eNBs' statuses and then passes these statuses to S-Net LMA. S-Net LMA chooses an appropriate eNB as the NMAG for MN, and delivers related information to MN. With the help of eNB-collection Subsystem, the handover can be smoothly performed.

3.2 The Signaling of the eSeS

Assume that S-Net and T-Net are two adjacent untrusted networks, the primitives exchanged among network entities are shown in Fig. 1. MN is currently staying in S-Net. MN's serving MAG (i.e., PMAG) periodically sends MIH_Net_Measurement_Report which carries the status of the link between MN and PMAG (also called an active link) to S-Net LMA. When MN has to hand over to T-Net, the S-Net LMA sends the MIH_HO.Indication.request to eNB-collection Subsystem to request a suitable MAG for MN.

After receiving this request, eNB-collection Subsystem transmits this request to T-Net LMA. T-Net LMA delivers Authentication.request to T-Net AAA server. This server in turn requests S-Net AAA server to authenticate MN. After that, when receiving Authentication response from S-Net AAA server, T-Net AAA server passes this primitive to T-Net LMA, which then chooses an appropriate MAG as NMAG for MN and sends MIH_Resource_Reservation.request to NMAG. On receiving this

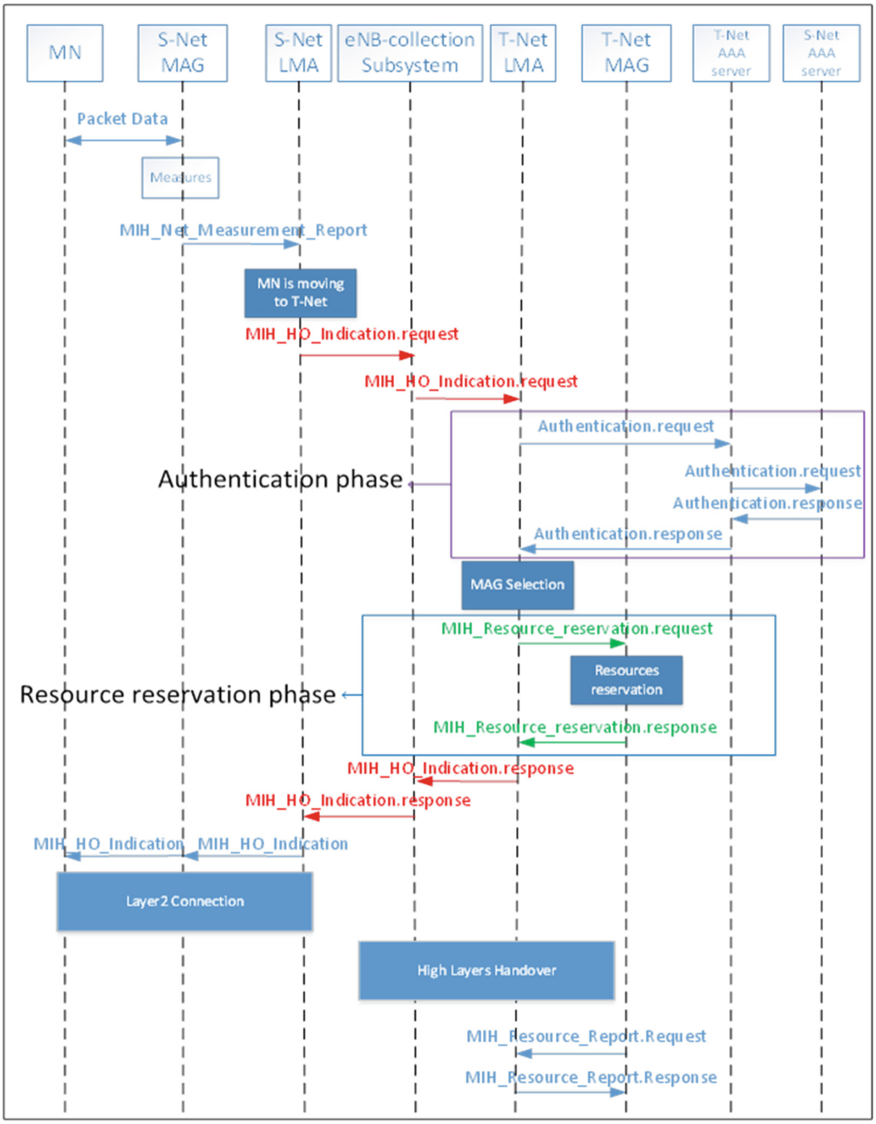

Fig. 1. The primitives exchanged in untrusted networks handover case (MN hands over from S-Net to T-Net) [12].

request, NMAG transmits a MIH_Resource_Allocation.request (not shown) to its RRC to reserve network resources for MN.

Then, NMAG sends a MIH_Resource_Reservation.response to T-Net LMA. T-Net LMA passes MIH_HO_Indication.response carrying IP of NMAG to eNB-collection Subsystem, which then delivers this primitive to CRRM in S-Net LMA. S-Net LMA transmits MIH_HO_Indication.response containing IP of NMAG to PMAG, which then transfers MIH_HO_Indication to MN. After MN is connected to NMAG, NMAG delivers a MIH_Resource_Report.request telling T-Net LMA that MN arrives. At last, T-Net LMA reports NMAG with MIH_Resource_Report.response as an acknowledgement to terminate this handover.

3.3 Cost Saving of the eSeS

In our scheme, several primitives originally utilized by MIH standard, including MIH_Get_Information, MIH_MN_Candidate_Query.request and MIH_Link_Going_-Down and MIH_MN_HO_Candidate_Query.response employed in FMIPv6 or PMIPv6 system, are deleted to reduce MN's handover cost and delay without losing the functions of handover and traffic offload.

Figure 1 also shows the primitives exchanged in the handover procedure of the eSeS. They can be divided into network selection and resources reservation phases. Here we assume that a mobile node, i.e., MN, will hand over from WiFi AP (i.e., PMAG) to LTE-A eNB (i.e., NMAG). When S-Net CRRM discovers that MN's RSSI value is lower than the predefined $RSSI_{th}$, it either chooses a NMAG based on the information collected in its cloud system, and chooses an appropriate one. After S-Net CRRM sends our proposed new primitive MIH_Resource_Reservation.request to MIHF of NMAG, requesting NMAG to reserve resources for the MN. The MIHF sends MIH_Resource_Allocation.request to its RRC. After reserving required resources, RRC replies the MIHF with MIH_Resources_Allocation.response. NMAG's MIHF then delivers MIH_Resources_Reservation.response to S-Net CRRM. Then the CRRM sends MIH_HO_Indication which carries the IP of NMAG to MN through PMAG.

3.4 eNB Selection

When receiving a primitive sent by eNB-collection Subsystem for requesting eNB statuses, LMA retrieves the statuses collected by its LRRM from MIIS database. On receiving eNB's statuses from eNB-collection Subsystem, CRRM calculates the scores for all provided MAGs. The scores are derived from the parameters reported by LRRMs. Assume that there are m base stations $B = \{b_1, b_2, b_3,\ldots, b_m\}$, including those under the CRRM in S-Net and those near the boundary of S-Net but in the T-Net where b_i is a base station, $b_i \in B$, $1 \leqq i \leqq m$. The score calculation formula can be seen in [12]. The information recorded in the MIIS database for a base station (MN) is shown in Table 1 (Table 2).

Table 1. Information recorded in the MIIS Server or MIH cloud for a base station.

Parameters	Weight
Location	0
Bandwidth	0.3
End-to-end delay	0.1
Throughput	0.1
Drop rate	0.1

Table 2. Information recorded in the MIIS Server or in MIH cloud for MN.

Parameters	Weight
RSS	0.1
MN's moving direction	0
$\boldsymbol{Angle}_{MN,MAG}$	0.2
$\boldsymbol{Distance}_{MN,MAG}$	0.1

4 Simulation and Discussion

In the study, two experiments were performed. The eSeS and current untrusted-network handover scheme (i.e., reactive mode) were simulated by using NS-2 and its mobility extension developed by National Institute of Standards and Technology (NIST) [19]. In the first experiment, the three tested schemes were evaluated given two untrusted homogeneous networks, including two LTE-As. An MN is equipped with two network interface cards, each of which is assigned a unique IP and channel. That is, it is a two-connections SCTP association. MN hands over from LTE-A to the other LTE-A. The second compared the performance of eSeS algorithm and current algorithm (based on RSS).

Three test metrics are employed, including throughput defined as the bit rate received, end-to-end delay defined as the time required by a packet to travel from sender to receiver, and drop rate defined as the number of packets received over the number of packets sent. The specifications and network parameters of the test-bed used are illustrated in Table 3. Figure 2 shows the simulation topology.

Table 3. The specifications and default parameters of our tested.

Network parameter	Value
LTE-A bandwidth	200 Mbps
Bandwidth of a wired link	100 Mbps
Data rate	80 Mbps
MN's moving speed	1 m/s
Simulation time	10 s

4.1 An Untrusted Homogeneous Network

In the first experiment, the three schemes are evaluated in an untrusted-homogeneous environment. At the beginning, MN is connected to an LTE-A, and it hands over to another LTE-A network at about the 10th sec. Figure 3 shows the throughputs. Owing to the employment of eNB-collection Subsystem and SCTP's multi-streaming and multi-homing characteristics, the performance of the eSeS is better than those of

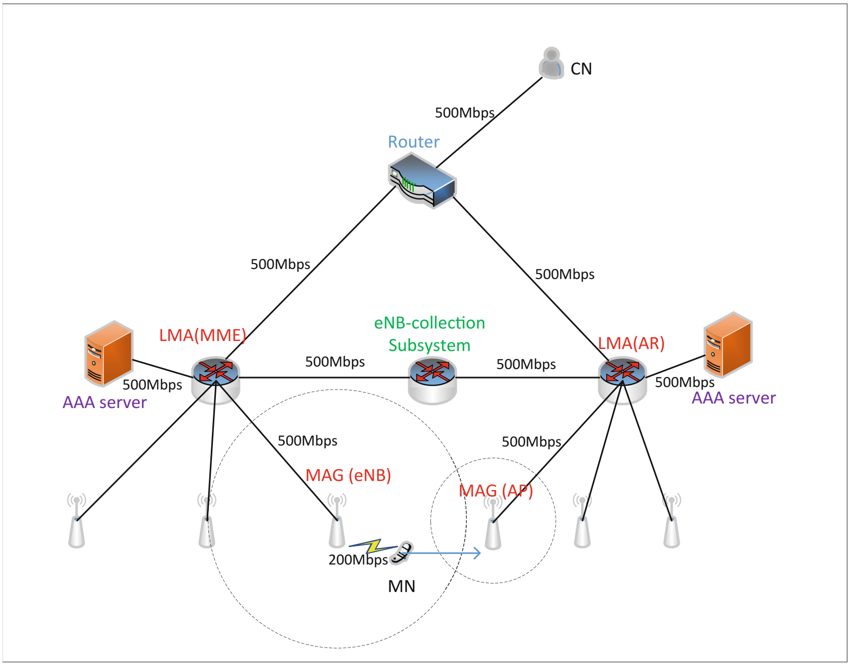

Fig. 2. The topology of our simulation.

FMIPv6 and PMIPv6. Figure 4 illustrates the drop rates. Because of active link disconnection, the drop rates of FMIPv6 (PMIPv6) are 100% between the 10th and 10.15th (between 10th and 10.10th) sec. The end-to-end delays are illustrated in Fig. 5. Because before connecting to NMAG, MN must disconnect its current active link. It is the reason why the end-to-end delays of FMIPv6 and PMIPv6 are higher than those of the eSeS.

4.2 The Performance of eSeS and Current Scheme

In the second experiment, MN hands over from S-Net to T-Net and there are 10 MAGs in T-Net. The topology of this experiment is shown in Fig. 6. Each MAG provides multiple parameters, the values of which are set randomly on each time of test. This experiment was performed ten times. Each time the direction of MN is randomly chosen and the scores of the 10 MAGs are calculated.

Table 4 shows the throughputs, drop rates and end-to-end delays of the eSeS and current scheme (used by PMIPv6 and FMIPv6) in this experiment. The throughput of eSeS is better than those of the current schemes which select NMAG only based on RSS. But the eSeS calculates multiple parameters for all MAGs and then chooses the one with the highest score as NMAG. The eSeS's drop rates is lower than the current

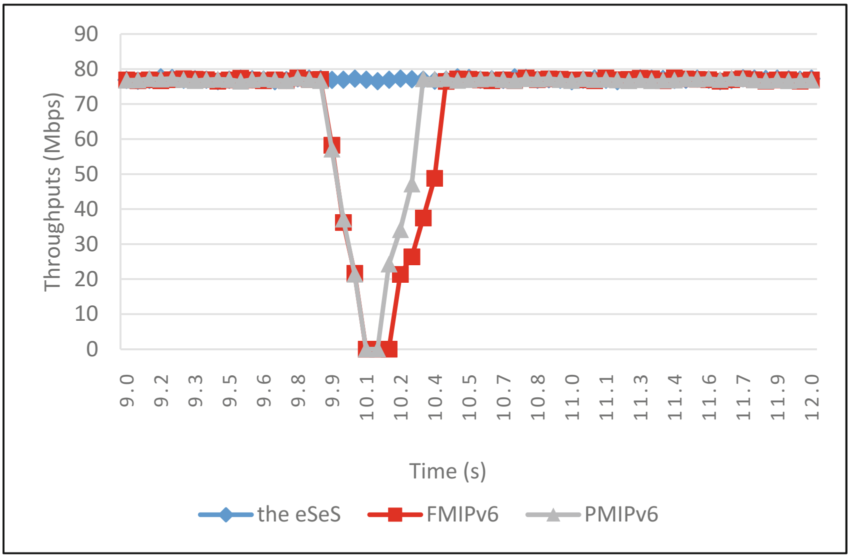

Fig. 3. The throughputs between the 9th and 12th sec when MN hands over from LTE-A to LTE-A in an untrusted-homogeneous network environment

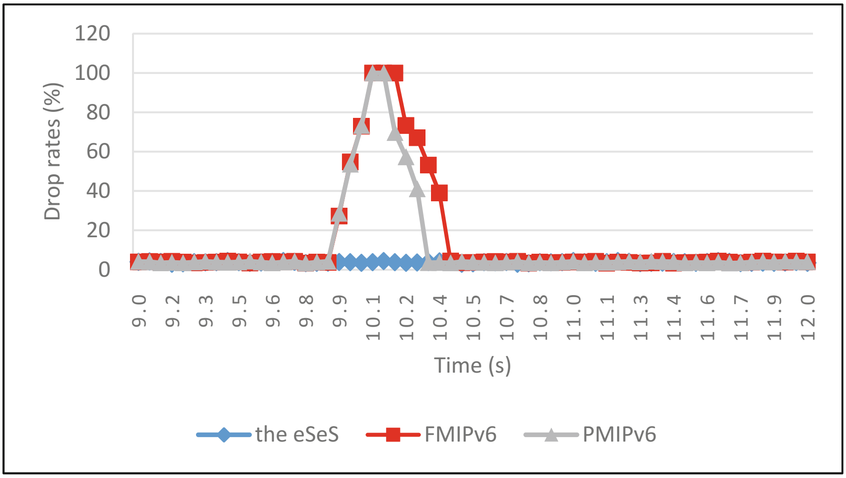

Fig. 4. The drop rates between the 9th and 12th sec when MN hands over from LTE-A to LTE-A in an untrusted-homogeneous network environment.

scheme's. Its End-to-end delay is shorter than that of current schemes. It is clear that multi-parameters reflecting current statuses of candidate MAGs are helpful in choosing an appropriate NMAG.

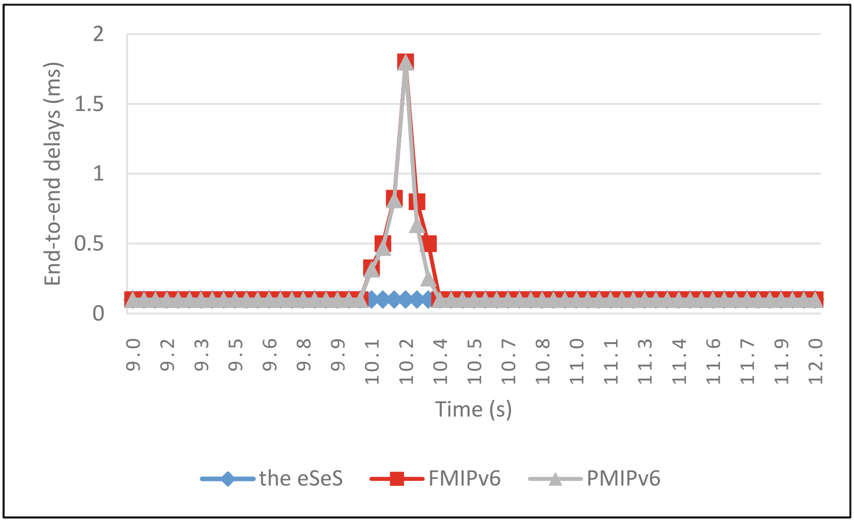

Fig. 5. The end-to-end delays between the 9th and 12th sec when MN hands over from LTE-A to LTE-A in an untrusted-homogeneous network environment.

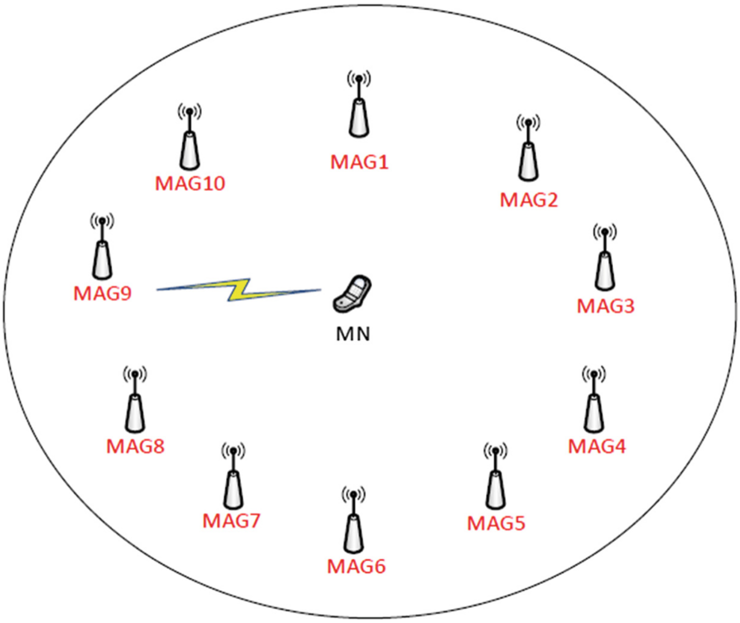

Fig. 6. The topology of performance test.

Table 4. The performance of the eSeS and current scheme.

Metric	eSeS	Current scheme (PMIPv6/FMIPv6)
Throughput (Mbps)	94.11	88.35
Drop rates (%)	5.88	11.64
End-to-end delay (ms)	0.24	0.69

5 Conclusions and Future Work

In this study, we propose a scheme to mitigate the network handover problem for two adjacent untrusted networks by introducing the eNB-collection Subsystem which constructed by a trustable third party is the mechanism helping two networks' LMAs to communicate with each other and mutually exchange network information. Due to the help of eNB-collection Subsystem and the feature of SCTP, the link between MN and NMAG will be established before handover starts. The association between MN and network will not disconnect during the handover. With the CRRM, NMAG can allocate resources required by MN before MN connects to it. CRRM can also help us to accomplish congestion control and network load balance. Considering the untrusted relationship between two adjacent networks, we can choose an appropriate MAG as NMAG with the help of eNB-collection Subsystem.

In the future, we will deal with another situation. Our proposed scheme only considers the case in which S-Net is MN's Home network. When stays in a foreign network and MN needs to hand over to another network, the problem is that T-Net's AAA server should communicate with S-Net's AAA server and MN's AAA server. The relationship among the three AAA servers may be heterogeneous/homogeneous and/or trustable/untrusted. In fact, the relationship among them is complicated. We hope we can propose a mechanism to solve this problem. Also, we would like to derive the behavior and reliability models so that users can predict its behaviors and reliability before using it. These constitute our future studies.

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