Designing Improved Traffic Control in Network-based Seamless Mobility Management for Wireless LAN

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Abstract—**Seamless mobility management which prevents packet loss when mobile terminals (MTs) move is an indispensable feature for future mobile networks. Proxy Fast Mobile IPv6 (PFMIPv6) has been standardized to reduce packet loss of user data in network-based mobility management. By predicting the movement of MTs, it can minimize packet loss by forwarding user data from the previous mobile access gateway (MAG) to the new MAG where MT makes a handoff, and by buffering the forwarded data at the new MAG until the MT is attached to it. When shared wireless access technology (e.g., wireless LAN) is employed as a wireless access network, the released packets from the buffer in the new MAG degrade the communication quality of the other (resident) MTs already attached to the wireless access network. In this paper, we propose a MAG design treating the buffered packets to prevent degradation of the communication quality of all MTs (resident MTs and MTs making handoffs). Using a packet-based simulation, we investigate the communication quality and show the proposed method's validity.**

***Keywords*− Network-based seamless mobility management; Wireless LAN; QoS; VoIP**

I. INTRODUCTION

Wireless access technologies have greatly advanced in the past few years. Among these advances IEEE 802.11-based wireless LAN plays an important role in offering convenient network connectivity and high-speed access at affordable costs. With these wireless access technologies, wireless networks are evolving toward all-IP systems. IP (network-layer) mobility needs to support transparency with applications and independence within mobile networks.

Mobile IPv6 (MIPv6) [1], a mobility protocol within the IP layer, provides mobility management for mobile terminals (MTs), but only MTs with the host implementation of MIPv6 can acquire the function of the mobility management. Proxy Mobile IPv6 (PMIPv6) [2], network-based mobility management without MTs participating in related signaling, has now been standardized. When PMIPv6 is adopted in mobile networks, all MTs with IPv6 functions can acquire mobility management service. MTs adopting PMIPv6 cannot communicate while the MT makes a handoff, that is, the MT changes mobile access gateways (MAGs), and in many cases some packet loss occurs in this period.

To minimize this packet loss, Proxy Fast Mobile IPv6 (PFMIPv6) [3] has been standardized as network-based seamless mobility management. When the MT makes a handoff, PFMIPv6 can prevent packet loss by buffering the MT's user data forwarded from the previous MAG (PMAG) to the new MAG (NMAG), to which the MT is attached before and after the MT's handoff. PFMIPv6 will be utilized in future mobile networks to provide seamless mobility management for numerous MTs

When multiple MTs in PFMIPv6 simultaneously make handoffs into the same NMAG, a multiple set of buffered user data is concurrently released in a bursty manner, as described in Section II-A. This leads to degraded communication quality for the other MTs ("resident MTs" hereinafter) already attached to the NMAG. Even if IEEE 802.11e [4] is applied to guarantee QoS, the buffered packets in the MAG lead to degraded communication quality of the resident MTs when they are categorized as high-priority traffic that the resident MTs are also using.

For seamless mobility management, the one-way delay of the traffic into the MTs making handoffs ("handoff MTs" hereafter) should also be a concern. Real-time applications have acceptable values for a one-way delay. Some have the standardization [5] defining requirements of one-way delays as a QoS requirement. Packets with a large one-way delay exceeding the acceptable value are treated as actual losses by these applications, even if they are ultimately delivered to the applications. If the traffic of the resident MTs is prioritized and the delay of the traffic into the handoff MTs is prolonged, seamless mobility management sometimes becomes meaningless. A traffic control method that does not degrade the communication quality of resident MTs and handoff MTs should also be considered for cooperating with seamless mobility management.

Considering these issues, we propose a MAG design that treats the traffic of the resident MTs and the handoff MTs separately along with a buffered-packet releasing traffic control method to prevent degraded communication quality for all the MTs. This paper evaluates the effects of the proposed traffic control method. Section 2 addresses issues of wireless LAN in seamless mobility management. Section 3 introduces the design of MAG and the proposed traffic control method. Section 4 discusses an experiment with packet-based simulation. Section 5 concludes the paper.

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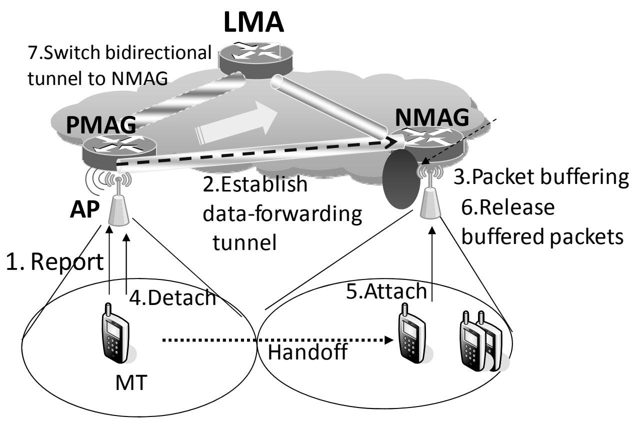
II. WIRELESS LAN ISSUE IN NETWORK-BASED SEAMLESS MOBILITY MANAGEMENT

This section explains the handoff procedure used in PFMIPv6 and shows that PFMIPv6 potentially causes bursty traffic in the wireless LAN.

A. Handoff Procedures of Network-based Seamless Mobility Management Protocol



Figureure. 1. PFMIPv6 handoff procedure

Figure 1 shows the PFMIPv6 handoff procedure. It begins after an MT connects to a PMAG that has a bi-directional tunnel with a localized mobility anchor (LMA) for the MT's traffic. In this procedure, the MT makes a handoff to the NMAG. The following procedures take place:

1. Before the MT makes a handoff, the PMAG is notified which MAG the MT will make a handoff into.
2. The NMAG begins preparation for the MT's handoff, and the PMAG and NAMG establish a data-forwarding tunnel to transfer the traffic.
3. The PMAG begins to transfer the downlink user data to the NMAG through the data-forwarding tunnel, and the NMAG begins to buffer the user data arriving through the tunnel.
4. The MT is notified that the preparation for the seamless mobility procedures is finished, and starts to be detached from the PMAG.
5. The MT is attached to the NMAG. Layer 2 authentication optionally takes some time for the MT to connect the new wireless access network.
6. The NMAG begins to release the buffered user data.
7. The LMA switches the bidirectional tunnel from the PMAG to the NMAG.

A method to adjust the timing in releasing the buffered packets has been proposed [6]. For mobile networks that accommodate many MTs, it is not feasible for the MAGs to adjust the timing adaptively for each MT in consideration of the characteristics of the application each MT is using. When the MAG adjusts the timing for each packet in releasing it, it needs a great deal of buffer space (e.g., the resources to buffer user data and compute until buffered packets are released). When multiple MTs execute step 6, we assume that the buffered data is released one after the other from the MAG and that some amount of buffered packets is released simultaneously. There has been no research into how the MAG should manage the buffer space for each MT and executes the traffic control method for the buffered packets when MT makes a handoff.

In many cases, buffered-packet releasing must cooperate with the packet delivery scheduler realized (or implemented) in the wireless access network when the wireless access technology has QoS control capabilities. Studies on the control of buffered packets of TCP traffic [7, 8, 9] have improved the throughput of TCP traffic by discarding some packets beforehand, before the wireless LAN becomes congested. Because the real-time application of UDP traffic is sensitive to packet loss, the method of these studies treating TCP traffic cannot be applicable. The proposed design can cooperate with the design of the existing research concerning TCP traffic.

B. Wireless LAN Issue in Releasing Buffered Packets

The IEEE 802.11e EDCF (enhanced distributed coordination function) classifies the traffic into four access categories (AC*i*, *i*=0, 1, 2, 3) according to QoS requirements for access points (APs). EDCF is a typical example of decentralized controlled mechanisms that do not require a centralized controlled coordinator. Because the decentralized controlled mechanism is used in most cases for wireless access network, we assume that APs adopt the IEEE 802.11e EDCF in this paper.

Each access category in the IEEE802.11e EDCF treats the traffic class that the network operators defined and follows carrier sense multiple access with collision avoidance (CSMA/CA). The IEEE 802.11e assigns different parameter values to different access categories in order to differentiate the flows based on the defined traffic class. Each traffic class is shared by the same multiple users. As a result, a bundle of flow transferred from an access category in an AP into the resident MTs and the handoff MTs is treated in the same way as the same flow transferred from the same access category.

APs that support IEEE 802.11e EDCF do not mitigate the influence of bursty traffic released from the MAG. Bursty traffic degrades the communication quality of the traffic categorized in the same access category. In this case, delay fluctuation is still very large, owing to the burst feature of the back off mechanism in the 802.11e EDCF. The traffic transferred to the resident MTs and the handoff MTs is delayed longer because of the burst traffic. It degrades the communication quality of the resident MTs and handoff MTs because of the congestion in the wireless LAN.

A great deal of research has focused on developing QoS capabilities of the MAC protocol for real-time applications [10] [11]. These researches accommodate real-time traffic by differentiating real-time traffic from non-real-time in order that real-time traffic achieves relatively small delay.

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However, these researches do not address the case where the MAG treats bursty traffic in releasing the buffered packets when multiple MTs make handoffs. In this case, even if the wireless LAN supports IEEE 802.11e, the bursty traffic released from the buffer space of the MAG is stacked altogether in an access category used for the traffic class. We adopt IEEE 802.11e as the wireless access technology and propose a novel traffic control method for the case in which multiple MTs make handoffs.

Mobile service providers are now considering data offloading in the wireless LAN in order to achieve cost reduction of data service and availability of higher bandwidth compared to cellular networks. If the data offloading technology is adopted, most traffic that flowed into the cellular networks will be transferred into the wireless LAN, and the chance of MTs making handoffs into the wireless LAN will increase. QoS capability of seamless mobility management into wireless LAN is important for the future mobile networks.

III. PROPOSED DESIGN FOR SEAMLESS MOBILITY MANAGEMENT

This section explains the proposed MAG structure and two-phase traffic control in consideration of handoffs of numerous MTs in the wireless LAN.

A. Requirements of MT, AP, and MAG

To have novel traffic control in consideration of the handoff of multiple MTs, we assume the following properties are included in the MT, AP, and MAG.

1. MAG establishes point-to-point links when MTs are attached.
2. MAG has output queue management for the traffic and AP has the QoS capability specified in IEEE 802.11e EDCF.
3. MT, AP, and MAG support Layer 2 Handoff (L2 HO) signaling and prediction of which MAG the MT will be attached to, in order to inform the MT’s decision beforehand.
4. MAG can identify whether resident MTs or handoff MTs the traffic will be transferred into.

The PMIPv6 standard defines that the logical connections between the MAG and MT are point-to-point links and unique network prefix is assigned for each MT. To assign the network prefix for each MT, the MAG needs to establish the logical connections with each MT by using the IP tunnel in the network segment of the wireless LAN.

To reduce packet loss during the handoff, it is important to exploit the timing of the MT’s handoff, and which AP the MT will be attached to, as early as possible. L2 HO signaling has been used to detect the MT’s handoff decision in advance [12]. This signaling contains the information about an MT identifier and new MAG identifier. For IEEE 802.16e, MOB_HO_IND messages play the L2 HO signaling role for the handoff. The current IEEE802.11 product does not usually support such signaling, but some research [13] [14] is addressing this. In this paper we assume that MAGs, APs, and MTs support such signaling and functions.

In order to report to the NMAG that the traffic will be transferred the handoff MTs, the PMAG executes packet marking for the traffic of the data-forwarding tunnel. As the NMAG knows the rule of the packet marking beforehand, NMAG can identify whether the resident MTs or the handoff MTs the traffic will be transferred into based on the rule of the packet marking.

We propose a MAG structure that controls the buffered packets into the handoff MTs and the traffic which are transferred directly into the resident MTs separately. The current mobility protocol and MAC protocol in wireless LAN do not consider how the MAG should perform the traffic control for the traffic which will be transferred into the wireless LAN when many MTs make handoffs. The detail of the proposed traffic control is described in III-C. Note that the proposed method requires no modification to the MAC protocol in the wireless LAN and extends the function of the MAG.

B. Proposed MAG Structure for Seamless Mobility Management

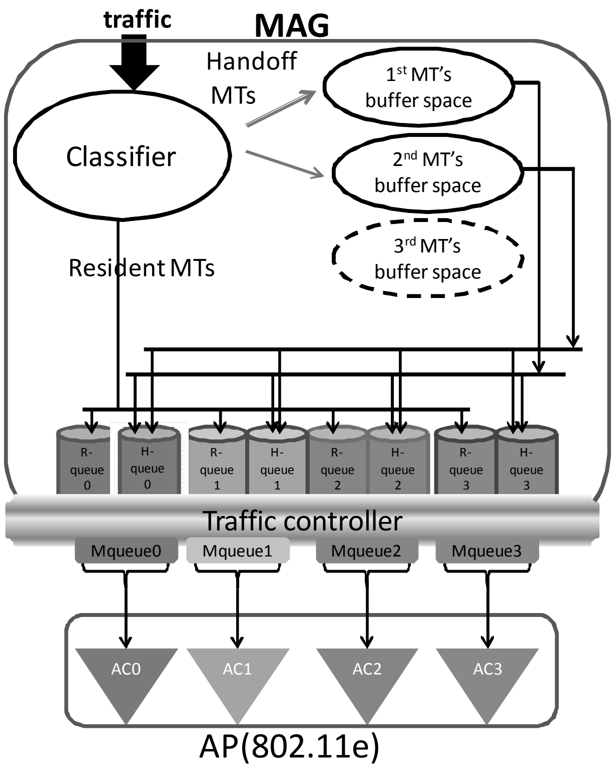

Figure. 2. Proposed MAG structure in the consideration of handoffs of multiple MTs

Figure 2 shows the proposed MAG structure, which adopts IEEE 802.11e as the wireless access technology. To control the traffic which is transferred into the handoff MTs and resident MTs separately, we propose that the MAG has queues dedicated for both types of MT. The queues labeled H-queue are dedicated for the handoff MTs, and those labeled R-queue are for the resident MTs in Figure 2. In Figure 2, the traffic of H-queue[0-3] and R-queue[0-3] are transferred into Mqueue [0-3] and AC [0-3] in AP. Mqueue corresponds to the IP queue of the interface in MAG. We assume the number of the queues that the MAG needs to prepare is not large because IEEE 802.11e defines a maximum of just four types of access category and the AP cannot support so many queues.

Classifier in Figure 2 distinguishes whether the traffic is transferred into the handoff MTs or the resident MTs based on the rule of the packet marking which the PMAG executed. When Classifier recognizes the traffic of the handoff MT, the traffic is transferred into the dedicated buffer space for the MT. When it recognizes the traffic of the resident MT, the traffic is transferred into the R-queue based on the traffic class when the packets is released from the buffer space. Traffic Controller transfers the traffic from each R-queue and H-queue into each Mqueue in the first phase of the proposed traffic control method based on the defined traffic class, as described in the next subsection.

C. Proposed Traffic Control Method in MAG

We propose that the MAG executes two-phase traffic control for the traffic into all the MTs in the wireless LAN. In the proposed method, first the MAG transfers the traffic from each R-queue and H-queue, which treats the same traffic class in a round-robin manner. Second the MAG executes the priority queueing (PQ) for the traffic from each Mqueue following the policy of the traffic control in AP.

We assume it is not suitable for the communication quality of either type of MT to be significantly degraded. Whether the traffic of the resident MTs or the MTs making handoffs is prioritized actually depends on the network operator's policy. However, if the delay characteristics of the traffic which is transferred into the handoff MTs are too large, the procedures of the seamless mobility management themselves become meaningless. We aim here to prevent degraded communication quality of all the MTs when multiple MTs make handoffs in the wireless LAN. Thus, we propose the traffic of resident MT and handoff MT in a round-robin manner in the first part of the two-phase traffic control method. And then we aim not to generate the bursty traffic into the wireless LAN in a round-robin manner. In the second part, the MAG prioritizes the traffic following the priority that IEEE 802.11e defined for each access category. In the second-phase, the MAG executes the PQ discipline in a normal way.

IV. EVALUATION

This section shows the experiment environment of the simulation for the proposed traffic control and the result of the simulation.

A. Experiment Environment

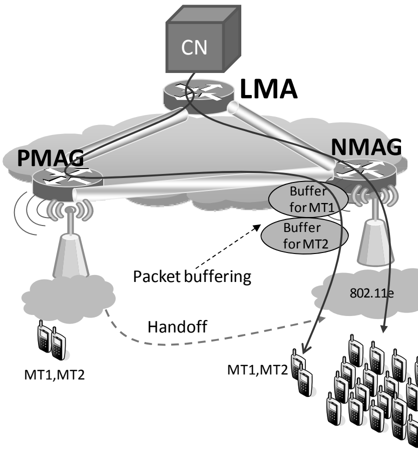

Figure. 3 Overview of experiment environment

Table 1 IEEE 802.11a default parameter values

Parameter	Value
SIFS	10 (*usec*)
SlotTime	20 (*usec*)
BasicRate	54 (*Mbps*)
DataRate	54 (*Mbps*)
LongRetry	4
ShortRetryLimit	7

Table 2 IEEE802.11e EDCF default parameter values for the 802.11a physical layer

Parameter	Value
CWmin	7
CWmax	15
AIFSN	2
TXOP	3.264

We evaluated the degree to which our proposed design would affect the one-way delay values of the high priority traffic after handoff in a simulated environment where certain MTs make handoffs by adopting PFMPv6 as the seamless mobility protocol. This simulation was performed with the QualNet software package [15]. We implemented the two-phase traffic control by extending the queueing discipline of the Qualnet. We employ an IEEE 802.11a-based wireless LAN in AP with an RTS/CTS mechanism and adopt the default IEEE 802.11a configuration, as shown in Table 1. For VoIP traffic, the AP followed the IEEE 802.11e EDCF, which the parameters of the configuration are shown in Table 2.

Twenty MTs communicated with the corresponding node (CN) through the LMA, as shown in Figure 3. The bandwidth of the physical link was 1Gbps. We focused on the downlink traffic buffered from the NMAG when certain MTs make handoffs. We adopt VoIP traffic as the high priority traffic during the seamless mobility. The CN and MTs sent CBR traffic (UDP packet, 200-byte packet, and 20-millisecond inter-packet gap). We considered a case in which only VoIP traffic exists in the wireless LAN.

We evaluated the delay characteristics of VoIP traffic from CN to MTs by changing the number of MTs making handoffs (1, 2, 4, and 6). In the simulation, we assumed multiple MTs concurrently making handoffs. We compared the delay characteristics in two cases of traffic control. In the first case, the MAG does not execute traffic control for the buffered packets in the first of the two-phase traffic control. In the second case, the MAG executes traffic control for the buffered packets in the first of the two-phase traffic control in a round-robin manner (which is the proposed traffic control).

B. *Experiment Result*

We simulated four cases, in which one, two, four, and six MTs make handoffs concurrently. One-way delay values are shown spanning the time when the MAG buffered the packets to 50 ms after when the last buffered packets were released from the MAG (we term this period "handoff affection period"). To investigate the affect of the buffered packets into the communication quality of nineteen, eighteen, sixteen and fourteen resident MTs, we get the one-way delay values in the cases where MTs do not make handoffs. Seeing those delay characteristic values in the cases which no MTs make handoffs, we show how much the traffic of the resident MTs is delayed.

The delay values of the handoff MTs in the case that the MAG executes traffic control in the first of the two-phase traffic control in a round-robin manner are termed "RR Handoff" and those of the resident MTs are "RR Resident". In the same way, we define "No Control Handoff" and "No Control Resident" respectively as the delay characteristics of handoff MTs and resident MTs when the MAG does not execute traffic control in the first of the two-phase traffic control. The delay values of the MTs in the case that no MTs make handoffs are termed "No Handoff".

The parameters of CSMA/CA were randomized by the seed in QualNet. We executed simulations 10 times for each case by changing the value of the seed in order to get the affection of the proposed traffic control. Figure 4 shows the average delay values of all the handoff MTs and all the resident MTs over the ten times. Figure 5 shows the maximum delay values during the handoff affection periods over the ten times. The X-axis shows the number of the handoff MTs in Figures 4 and 5. Y-axis in Figure 4 shows the average delay values (milliseconds). Y-axis in Figure 5 shows the maximum delay values (milliseconds).

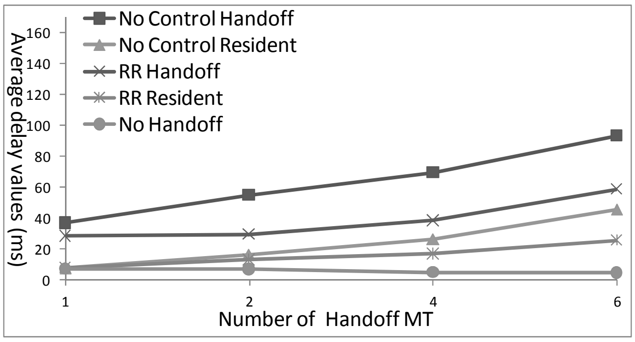

Figure 4. Average delay values of the traffic during handoff affection period

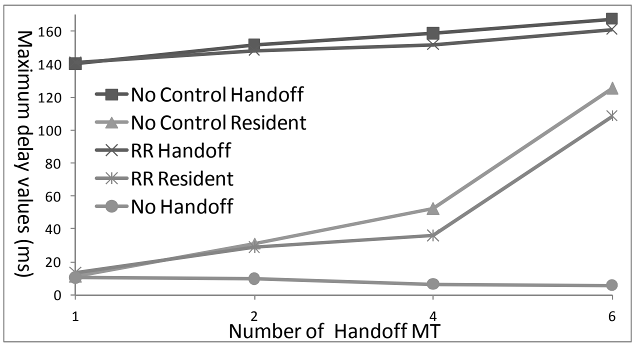

Figure. 5. Maximum delay values of the traffic during handoff affection period

The average and maximum delay values of "No Handoff " in Figures 4 and 5 decrease as the number of handoff MT increases. It is because the number of MTs which receive the traffic through the wireless LAN decreases. Compared with the delay values of the handoff MTs and those of the resident MTs, the values of handoff MTs become much larger because some periods are required for the seamless handoff procedures of PFMIPv6. Figure 4 shows that the released packets from the MAG give large impact on the communication quality of the resident MT. The value of "No Control Resident" becomes much larger than one of "No handoff". When only one MT makes a handoff, the differences between "No Control Handoff" and "RR handoff", and between "No Control Resident" and "RR Resident" is little.

However, applying the proposed traffic control method ("RR Control") when two, four or six MTs make handoffs, the average delay values of both resident MTs and handoff MTs become 0.5-0.6 times smaller than those of "No Control". The bursty traffic in the case of "No Control" delays the traffic which is transferred into both resident MTs and handoff MTs in AP because the backoff mechanism of EDCF makes transferring the bursty traffic into the wireless access networks wait for a few times. When the traffic is transferred in a round-robin manner by preparing the dedicated queue for resident MTs and handoff MTs, the ratio of the bursty traffic is reduced and the backoff

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mechanism does not make the traffic of each MT wait for being transferred from AP. The proposed traffic control method improves one-way delay for both resident MTs and handoff MTs when multiple MTs make handoffs.

Figure 5 shows that the maximum delay values in all the cases are almost same. This shows that the maximum time during that the traffic is made to wait for a few times is not changed even if the traffic is transferred into the wireless LAN in a round-robin manner.

I. CONCLUSION

Much existing research has tackled the prevention of packet loss and effective signaling for the mobility management protocol. Assuming that the MAG can predict the movement of the MT, packet buffering in the MAG is a key technique for the seamless mobility management because it can prevent packet loss during the handoff. However, such buffered packets give large impact on the one-way delay of the resident MTs in the wireless LAN. The current researches do not treat the communication quality of the resident MTs.

This paper focuses on the management of the buffered packets in the MAG in consideration of the communication quality of resident MTs and handoff MTs. We proposed a MAG structure which prepares the dedicate queue for resident MTs and handoff MTs and two-phase traffic control method using a round-robin manner in the first phase. We used packed-based simulation to evaluate the proposed traffic control method. When only one MT makes a handoff, the effect of the proposed traffic control method was not large. However, when multiple MTs make handoffs, the proposed traffic control method always improved on the delay values of the resident MTs and the handoff MTs because it prevent the generation of the bursty traffic in the wireless LAN which adopts the IEEE802.11e EDCF. As the future work, we need to execute the evaluation in the environment where MTs use the various applications with multiple priorities beside the VoIP.

The proposed traffic control method does not need to modify the AP's functions and is easy to deploy in the commercial mobile networks. The proposed traffic control method is applicable for the cases e.g., passengers in a car are always located in the same network and move in the same direction. In addition, family members and friends tend to spend a significant amount of time together. These cases will more often appear in the future mobile networks.

In this paper, we adopt PFMIPv6 as the seamless mobility protocol. However, the proposed traffic control method and design of the MAG is applicable for the other mobility management protocol (e.g., [16] [17]) besides PFMIPv6. It is because our proposal does not require the change of the protocol and focuses on the function of access gateway. Our proposal can devote the traffic management of the future mobile networks.

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