Seamless Multicast Handover in Fmipv6-Based Networks

Moneeb Gohar, Seok Joo Koh, Tae-Won Um, and Hyun-Woo Lee

***Abstract*—**This paper proposes a fast tree join scheme to provide seamless multicast handover in the mobile networks based on the Fast Mobile IPv6 (FMIPv6). In the existing FMIPv6-based multicast handover scheme, the bi-directional tunnelling or the remote subscription is employed with the packet forwarding from the previous access router (AR) to the new AR. In general, the remote subscription approach is preferred to the bi-directional tunnelling one, since in the remote subscription scheme we can exploit an optimized multicast path from a multicast source to many mobile receivers. However, in the remote subscription scheme, if the tree joining operation takes a long time, the amount of data packets to be forwarded and buffered for multicast handover will increase, and thus the corresponding buffer may overflow, which results in severe packet losses. In order to reduce these costs associated with packet forwarding and buffering, this paper proposes the fast join to multicast tree, in which the new AR will join the multicast tree as fast as possible, so that the new multicast data packets can also arrive at the new AR, by which the packet forwarding and buffering costs can be reduced. From numerical analysis, it is shown that the proposed scheme can give better performance than the existing FMIPv6-based multicast handover schemes in terms of the multicast packet delivery costs.

***Keywords*—**Mobile Multicast, FMIPv6, Seamless Handover, Fast Tree Join.

I. INTRODUCTION

AS wireless communications are rapidly growing in the networks, the seamless handover becomes one of the crucial issues to be addressed [1, 2]. The Mobile IPv6 (MIPv6) [3] was designed to manage the movement of MN in the network. To improve the handover performance of MIPv6, the Fast Mobile IPv6 (FMIPv6) was proposed [4]. FMIPv6 is primarily used to reduce the handover latency in the 'unicast' networks, whereas the issues on multicast handover support in the mobile networks are still for further study.

For support of IP multicasting, a lot of schemes have been proposed, which include the Internet Group Management Protocol (IGMP) [5, 6] and Multicast Listener Discovery (MLD) [7, 8] for multicast group join and leave, and also several multicast routing protocols for construction of multicast trees such as Protocol Independent Multicast [9] and Source Specific Multicast [10].

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It is noted that a lot of schemes have so far been proposed to support mobile multicasting in the MIPv6-based networks, which can be classified into the following two approaches: Remote Subscription (RS) and Bi-Directional Tunnelling (BT). In the RS scheme, a mobile node (MN) will subscribe to the multicast tree in the newly visited remote network. This RS scheme does not require the packet encapsulation, since it does not use the MIP Home Agent (HA), and it also gives an optimal multicast forwarding path from a multicast source to many mobile receivers. These benefits come from the new join to the multicast tree. However, some multicast data packets may be disrupted during the multicast tree join process. On the other hand, the BT scheme is based on the MIP HA, in which MN receives the data packets using the bi-directional (unicast) tunnelling from the HA in the point-to-point fashion. This BT scheme thus requires much overhead for packet encapsulation at HA, and also the multicast packet delivery path between a multicast source and a mobile receiver is not an optimum.

On the other hand, the BT scheme for MIP-based multicast handover has also the 'tunneling convergence' problem, in which the duplicate packets will arrive at MNs, even though they have subscribed to the same multicast group [11]. To solve this problem, the Mobile Multicast (MoM) protocol was proposed in [12], in which a new agent called 'Designated Multicast Service Provider (DMSP)' is employed in the remote network so as to forward the multicast packets from HA to MNs. The idea behind this approach is to decrease the number of duplicated multicast packets toward MNs in the HA side. The 'Range Based Mobile Multicast (RBMoM)' [13] was also proposed to find out the optimal trade-off between the shortest delivery path and the low frequency of multicast tree rebuilding, in which an agent called 'multicast home agent (MHA)' is introduced.

Some more works have been done to improve the MIP-based mobile multicasting scheme. In the 'Multicast by Multicast Agent (MMA)' protocol [14], the two agents were separately used: Multicast Agent who joins the multicast group, and Forwarding Agent who forwards the multicast data packets to MNs. Another proposal is the 'Timer-Based Mobile Multicast Protocol (TBMoM)' [15], which is purposed to find out a trade-off between the shortest path delivery and the disruption period of multicast packet delivery. In this scheme, a new agent called Foreign Multicast Agent (FMA) is introduced so as to decrease the disruption period, which selectively use the tunnelling between FMAs or the remote subscription.

Compared to the MIP-based mobile multicasting, the studies on FMIPv6-based multicasting have not been done enough yet. In this paper, we will review the existing FMIPv6-based multicast schemes, and then propose an enhanced scheme of FMIPv6-based mobile multicasting, which is based on the fast join to multicast tree for seamless multicast handover so as to reduce the costs associated with the packet forwarding and buffering during handover.

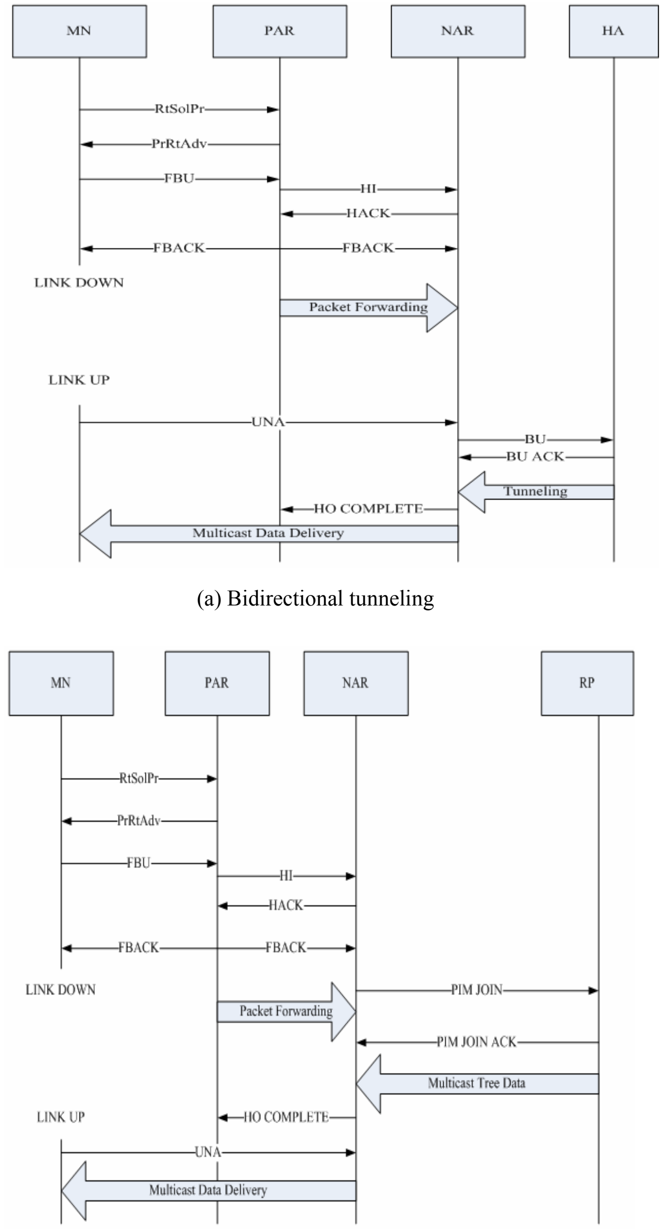
The rest of this paper is organized as follows. Section II reviews the existing works on the FMIPv6-based mobile multicasting. Section III describes the proposed scheme in details. Section IV evaluates the performance of the proposed scheme with numerical analysis. Section V concludes this paper.

II. Existing FMIPv6-based Mobile Multicasting

Some schemes for multicast fast handover in the FMIPv6 networks have been proposed. [1] proposed to use the multicast group information option in the FMIPv6 Fast Binding Update (FBU) and Handover Initiation (HI) messages, which that is used to establish a tunnel between PAR and NAR. In this paper, we note the scheme of FMIPv6-based multicast handover that was proposed in [16], which is denoted by 'FMIP-M' in this paper. In particular, we will focus on the following two schemes: Bidirectional Tunnelling (BT) and Remote Subscription (RS), which are based on the packet forwarding for multicast handover, as depicted in Fig. 1.

In the FMIP-M scheme, the following operations are commonly applied to the two cases, BT and RS. First, MN will receive an L2 trigger from the network, and sends a Router Solicitation for Proxy (RtSolPr) to PAR. The PAR replies to MN with a Proxy Router Advertisement (PrRtAdv). MN then obtains a new care of address (nCoA). The fast handover procedure actually starts by sending a Fast Binding Update (FBU) message towards PAR that contains a multicast group address. Given the information contained in the FBU message, PAR sends a Handover Initiation (HI) message to NAR. The NAR will check the validity and uniqueness of the nCoA. After that, NAR can reply to PAR with a Handover acknowledgement (HACK) message. It contains information on a specific method to be used by NAR for support of multicast handover. In addition, the HACK message may also contain the information of the sequence number of data packets (denoted by SEQNARBuff in [16]), that will be maintained in the new access router's buffer which is used for packet forwarding. This SEQNARBuff represents the sequence number of the first packet that will be stored in the NAR buffer. The PAR then sends the Fast Binding Acknowledge (F-BACK) message to MN and NAR both.

After sending the F-BACK message, PAR begins to forward the multicast data packets to NAR. The subsequent operations are differently performed, as per the two cases, BT (Fig. 1(a)) and RS (Fig. 1(b)).



(a) Bidirectional tunneling

(b) Remote subscription

Fig. 1 Existing FMIP-M schemes

In the BT scheme (Fig. 1(a)), PAR starts to forward the multicast packets (received via the bi-directional tunneling from the HA) to NAR. This packet forwarding will be continued, until PAR receives the HO COMPLETE message from NAR. This HO COMPLETE message will be triggered only when NAR receives the Unsolicited Neighbour Advertisement (UNA) message from MN, and also it completes the MIPv6 Binding Update (BU) operation with HA, as indicated in the figure. After this, the buffered data packets will be forwarded by NAR to MN.

In the RS scheme (Fig. 1(b)), NAR sends a tree join message (*e.g.*, PIM JOIN) to the upstream Rendezvous Point (RP), as shown in the figure. For the join message, the RP will respond to NAR with a Join ACK (PIM JOIN-ACK) message, and then the multicast data packets are now delivered to the NAR by using the newly configured multicast tree. During the tree join or configuration time, PAR will also forward the multicast packets to NAR. The subsequent operations include the transmission of HO COMPLETE message from NAR to MN and UNA message from MN to NAR, and the delivery of buffered data packets from NAR to MN.

It is noted that the packet forwarding in the existing scheme may be subject to the 'buffer overflow problem' at the buffer of NAR. That is, during the handover, PAR will continue to forward the data packets to NAR, until the MIPv6 BU operation (in case of BT) or the PIM Join operation (in case of RS) is completed. As the MIPv6 BU or PIM Join time gets larger, the buffer of NAR for packet forwarding may overflow and thus a significant amount of data packets could be lost. Thus, the existing schemes tend to give a large packet delivery cost during handover.

In this paper, we propose a fast join to multicast tree so as to reduce the packet delivery costs associated with packet forwarding and buffering, along with the probability of buffer overflow at NAR. IN the proposed scheme, NAR will try to join the multicast tree as soon as the handover event is detected (i.e., when NAR receives the HI message from the PAR).

III. Proposed Scheme

In this paper, we propose a fast tree join scheme for seamless multicast handover, which is based on the FMIPv6-RS scheme and thus denoted by 'FMIP-FTJ-RS' in this paper. The main idea of the proposed scheme is that NAR begins the tree join process as fast as possible, so as to the new multicast data packets arrive at the NAR earlier over the optimized multicast data path. In the proposed scheme, NAR will begin the tree join operation just when it receives HI message from PAR. Accordingly, if the tree joining process is completed before NAR receive the FBACK message from PAR, PAR does not need to forward the data packets to NAR, since NAR can receive the multicast data packets directly from the multicast tree.

Fig. 2 shows the basic operations of the proposed FMIP-FTJ-RS scheme.

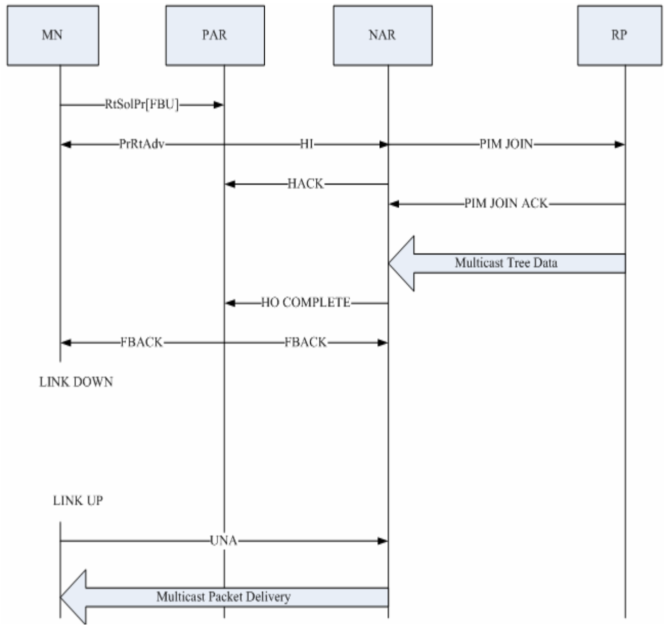


Fig. 2 Proposed FMIP-FTJ-RS scheme

In the figure, MN initiates the multicast handover by sending the RtSolPr message to PAR, the RtSolPr message contains both the FBU option and the multicast address, as shown in Fig. 3. Note that the handover latency could be more reduced by encapsulating the FBU option into the RtSolPr message.

After receiving the RtSolPr message, PAR sends the PrRtAdv message to MN. In addition, PAR will send the HI message to the NAR. When receiving the HI message, the NAR will immediately respond with the HACK message to PAR, and at the same time, it begins the tree joining process to RP by sending the PIM JOIN message it will receive the responding PIM JOIN-ACK message from the upstream RP.

Type	Code	Checksum
Subtype	Reserved	Identifier
LLA Option		
FBU Option		
Multicast Address		

Fig. 3 RtSolPr message including the FBU option

In the proposed scheme, if the tree joining operation is completed earlier (i.e., NAR can receive the multicast data packets from the multicast tree, before it receives the FBACK message from PAR), the NAR sends the HO-COMPLETE message to PAR in this case PAR does not need to perform the packet forwarding to NAR. Otherwise, if the tree joining process has not been completed until NAR receives the FBACK message from PAR, some of the multicast data packets may be forwarded by PAR to NAR, as done in the existing FMIP-M-RS scheme. In either case, it is noted that the fast tree join to the multicast tree can ensure that the number of data packets required for packet forwarding will be minimized and the overall handover latency also reduced.

IV. Performance Analysis and Comparison

For performance evaluation of the proposed scheme, we analyze the packet delivery cost for the existing schemes (FMIP-M-BT and FMIP-M-RS) and the proposed FMIP-FTJ-RS scheme. The packet delivery cost is calculated based on the number of packets to be forwarded from PAR to NAR and to be buffered at NAR.

For analysis, we consider a network model of Fig. 4 and define the following cost components:

- $T_{a\text{-}b}$: Transmission delay between two nodes *a* and *b*, which is applied between PAR and NAR, between NAR and RP (in the RS scheme) or HA (in the BT scheme);
- P_K: Processing delay of a message at node *K*, which is applied to PAR, NAR, HA and RP.
- λp: Arrival rate of multicast data packets (in unit of the number of packets per second).

$T_{L2/3\text{-HO}}$: Handover delay in the link-layer (L2) and IP layer (L3), which consists of L2 movement detection time and IP address configuration time.

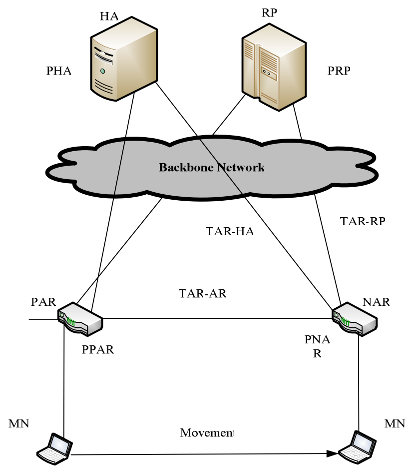


Fig. 4 Network model for performance analysis

1. Analysis of Packet Delivery Cost

In this paper, the packet delivery cost (PDC) contains the cost of the packet forwarding from PAR to NAR (denoted by $C_{forwarding}$) and the packet buffering at NAR (denoted by $C_{buffering}$) during handover. For each packet, $C_{forwarding}$ is equal to the transmission cost from PAR to NAR ($T_{AR\text{-}AR}$), and $C_{buffering}$ corresponds to the buffering cost at NAR (P_{NAR}). Then, the overall PDCs for the three candidate schemes can be obtained as follows.

A. FMIP-M with Bi-directional Tunnelling (FMIP-M-BT)

In the FMIP-M-BT scheme, as described in Fig. 1(a), the MIP Binding Update operation begins after the L2/3 handover is completed. Accordingly, all the data packets transmitted during both L2/3 handover and MIP Binding Update should be forwarded from PAR to NAR and also buffered at NAR. Accordingly, when the multicast sender transmits data packets at the rate of λp (in unit of the number of packets per second), the number of data packets to be forwarded and buffered (*N*) can be represented as follows:

$$N = \lambda p \text{ x (L2/3 handover delay + MIP Binding Update delay)}$$
$$= \lambda p \text{ x } (T_{L2/3\text{-HO}} + 2T_{AR\text{-}HA} + P_{HA})$$

Thus, we obtain the PDC of FMIP-M-BT scheme as follows:

$$PDC_{FMIP\text{-}M\text{-}BT} = N \text{ x } (C_{forwarding} + C_{buffering})$$
$$= \lambda p \text{ x } (T_{L2/3\text{-HO}} + 2T_{AR\text{-}HA} + P_{HA}) \text{ x } (T_{AR\text{-}AR} + P_{NAR}).$$

B. FMIP-M with Remote Subscription (FMIP-M-RS)

In the FMIP-M-RS scheme, as described in Fig. 1(b), the packet forwarding operation and the tree-joining operation will be performed at the same time when NAR receives the FBACK message from PAR. Accordingly, the number of data packets to be forwarded and buffered will depend on the maximum value of L2/3 handover delay and tree join delay. The multicast tree join delay ca n be represented as $2T_{AR\text{-}RP}+P_{RP}$. Accordingly, for the packet arrival rate of λp, the number of data packets to be forwarded and buffered (*N*) can be represented as follows:

$$N = \lambda p \text{ x max \{L2/3 handover delay, tree join delay\}}$$
$$= \lambda p \text{ x max } \{T_{L2/3\text{-HO}}, 2T_{AR\text{-}RP} + P_{RP}\}.$$

Thus, we obtain the PDC of the FMIP-M-RS scheme as follows:

$$PDC_{FMIP\text{-}M\text{-}RS} = N \text{ x } (C_{forwarding} + C_{buffering})$$
$$= \lambda p \text{ x max } \{T_{L2/3\text{-HO}}, 2T_{AR\text{-}RP} + P_{RP}\} \text{ x } (T_{AR\text{-}AR} + P_{NAR}).$$

C. FMIP-FTJ-RS with Remote Subscription (FMIP-FTJ-RS)

In the FMIP-FTJ-RS scheme, as described in Fig. 2, the tree-joining operation will begin when NAR receives the HI message from PAR. In this case, the number of data packets to be forwarded from PAR to NAR may be different that to be buffered at NAR.

First, the number of data packets to be forwarded from PAR to NAR depends on the ‘tree join’ delay and the ‘handover preparation’ delay. Here, the handover preparation delay represents the transmission and processing times associated with the HACK and FBACK messages between PAR and NAR, which will be equal to ($2T_{AR\text{-}AR} + P_{PAR}$). If the tree joining operation is completed before NAR receives the FBACK message from PAR, the packet forwarding is not required. In the opposite case, the data packets will be forwarded during ‘tree join delay’ minus ‘handover preparation delay’. Accordingly, for the packet arrival rate of λp, the number of data packets to be forwarded ($N_{forwarding}$) can be represented as follows:

$N_{forwarding}$ = λp x max {0, tree join delay – handover preparation delay}
= λp x max {0, $2T_{AR\text{-}RP}+P_{RP}-(2T_{AR\text{-}AR}+P_{PAR})$} (1)

On the other hand, the packet buffering operation at NAR will be performed for the data packets that are forwarded from PAR, and also for those that NAR newly receives from the multicast sender during L2/3 handover, which can be calculated by "L2/3 handover delay – max {0, tree join delay – handover preparation delay}."

Thus, the number of data packets to be buffered at NAR ($N_{buffering}$) can be represented as follows:

$N_{buffering}$ = $N_{forwarding}$ + λp x {$T_{L2/3\text{-}HO}$ – max {0, $2T_{AR\text{-}RP}+P_{RP}-(2T_{AR\text{-}AR}+P_{PAR})$}}.
= λp x max {0, $2T_{AR\text{-}RP}+P_{RP}-(2T_{AR\text{-}AR}+P_{PAR})$} + λp x {$T_{L2/3\text{-}HO}$ – max {0, $2T_{AR\text{-}RP}+P_{RP}-(2T_{AR\text{-}AR}+P_{PAR})$}}. (2)

Using the equation (1) and (2), we can obtain the PDC of the FMIP-FTJ-RS scheme as follows:

$PDC_{FMIP\text{-}FTJ\text{-}RS}$ = $N_{forwarding}$ x $C_{forwarding}$ + $N_{buffering}$ x $C_{buffering}$
= $N_{forwarding}$ x $T_{AR\text{-}AR}$ + $N_{buffering}$ x P_{NAR}

2. Numerical Results

Based on the analytical equations for the packet delivery cost given so far, we compare the performance of the existing and proposed schemes. For the numerical analysis, we configure the default parameter values as those described in Table I, in which $T_{L2/3\text{-}HO}$ is set to 165 ms, by referring to [17].

TABLE I
DEFAULT VALUES OF THE PARAMETER USED FOR NUMERICAL ANALYSIS

Delay Component	Notation	Default Values
Transmission Delay	$T_{AR\text{-}AR}$	10ms
	$T_{AR\text{-}RP}$	50ms
	$T_{AR\text{-}HA}$	50ms
Processing Delay	P_{PAR}	20ms
	P_{NAR}	20ms
	P_{RP}	20ms
	P_{HA}	20ms
Packet Arrival Rate	λp	5 packets/second
L2/3 Handover Delay	$T_{L2/3\text{-}HO}$	165ms

Fig. 5 shows the packet delivery costs of the existing and proposed schemes for different arrival rates of multicast data packet (λp). From the figure, it is shown that the packet delivery costs increases for all the candidate schemes, as λp gets larger. The two RS-based schemes (FMIP-M-RS and FMIP-FTJ-RS) give better performance than the FMIP-M-BT scheme. In particular, the proposed FMIP-FTJ-RS scheme provides lower packet delivery cost than the FMIP-M-RS, and the performance gaps between those two schemes increase, as the number of data packets get larger. This is because the proposed scheme can reduce the amount of data packets to be forwarded and buffered, compare to the other existing schemes.

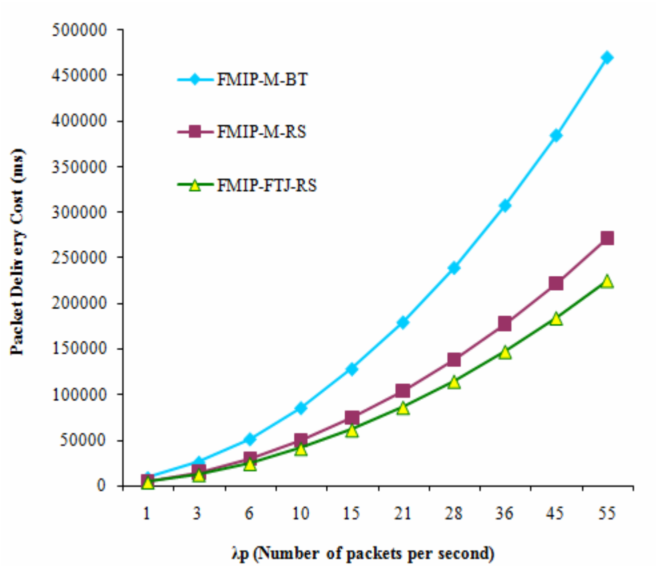


Fig. 5 Packet delivery cost for different packet arrival rates (λp)

Fig. 6 compares the packet delivery costs for different transmission delay between PAR and NAR ($T_{AR\text{-}AR}$). In the figure, we can see that the packet delivery costs of the two existing schemes increase, as $T_{AR\text{-}AR}$ gets larger, since the packet forwarding cost per packet ($T_{AR\text{-}AR}$) also gets larger. On the other hand, the packet delivery cost of the proposed scheme rather tends to decrease for a large $T_{AR\text{-}AR}$. This is because a large $T_{AR\text{-}AR}$ induces a long handover preparation delay ($2T_{AR\text{-}AR}$ + P_{PAR}), and thus the tree join operation will be completed relatively earlier. In this case, the packet forwarding may not be required, since MN can receive the multicast data packets directly from the multicast sources via NAR. This gives a lower packet delivery cost for a very larger $T_{AR\text{-}AR}$.

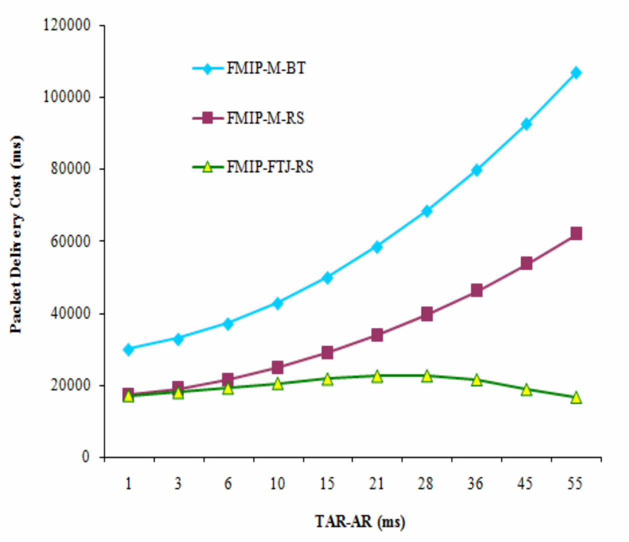


Fig. 6 Packet delivery cost for different T_{AR-AR}

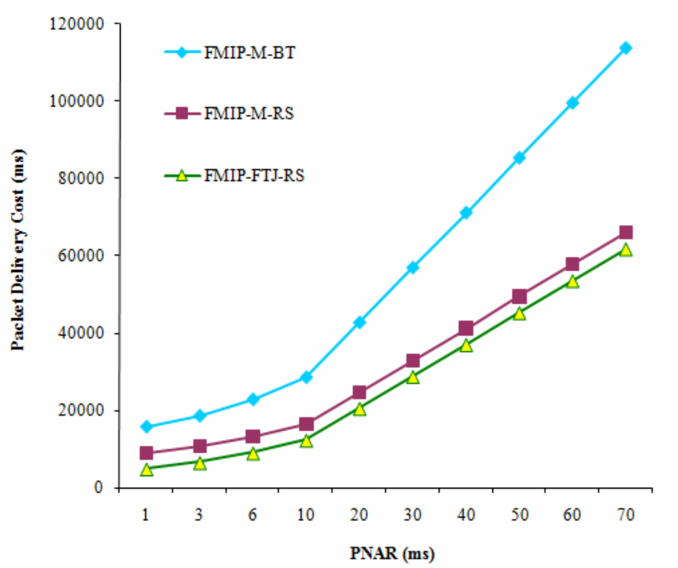


Fig. 7 Packet delivery cost for different P_{NAR}

Fig. 7 compares the packet delivery cost of the candidate schemes for different P_{NAR}, which is associated with the buffering cost per packet. From the figure, it is shown that the packet delivery costs tend to increase for all the candidate schemes, as the transmission cost of P_{NAR} gets larger. However, note that the proposed scheme gives better performance than the other two existing schemes.

Fig. 8 compares the packet delivery costs for different T_{AR-RP} and T_{AR-HA}, in which we assume that $T_{AR-RP} = T_{AR-HA}$. Note that these values are associated with the tree joining delays and the MIP binding updates delays, respectively. We see that the packet delivery costs tend to increase for the candidate schemes, as T_{AR-RP} and T_{AR-HA} get larger. In case of FMIP-M-RS, the packet delivery cost remains at the constant value for a small T_{AR-RP}. This is because the number of data packets to be forwarded and buffered is affected by the L2/3 handover delay, rather than tree join delay, for a smaller T_{AR-RP}. Nevertheless, the proposed FMIP-FTJ-RS scheme gives better performance than the other two existing schemes for all the values of T_{AR-RP}.

Fig. 9 compares the packet delivery costs for different L2/3 handover delay ($T_{L2/3-HO}$). From the figure, we can see that the packet delivery cost of the proposed FMIP-FTJ-RS scheme is smaller than the other existing schemes. Overall, the packet delivery costs will increase for all the candidate schemes, as the L2/3 handover delay gets larger. However, it is noted that in the FMIP-M-RS scheme, the packet delivery cost remains constant for a small value of $T_{L2/3-HO}$, in which the packet delivery cost is dominated by the tree joining time, rather than the L2/3 handover delay, as shown in the associated cost equation. The performance gap between FMIP-M-RS and the FMIP-FTJ-RS will get larger, as $T_{L2/3-HO}$ increases.

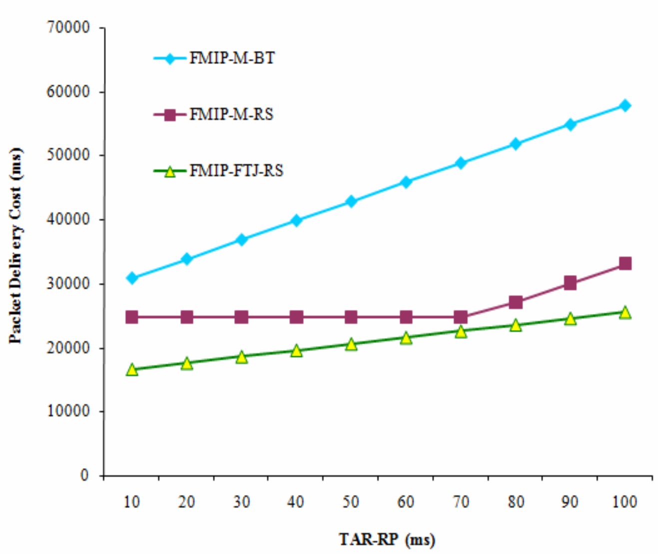


Fig. 8 Packet delivery cost for different T_{AR-RP}

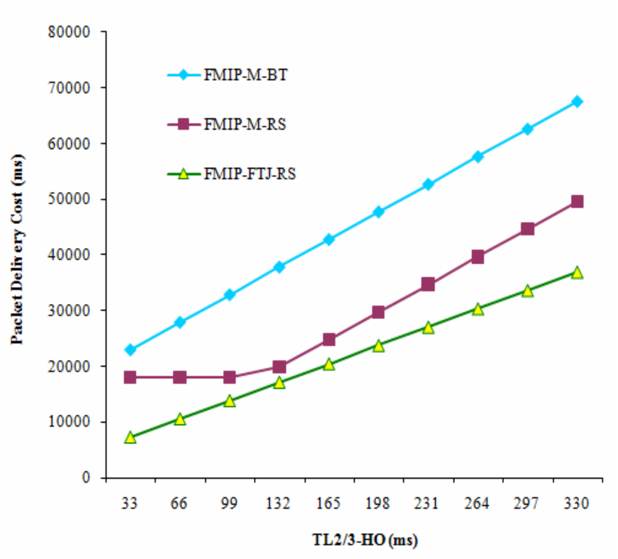


Fig. 9 Packet delivery cost for different $T_{L2/3\text{-}HO}$

V. Conclusion

This paper proposed a fast tree join scheme for seamless multicast handover in the FMIPv6-based wireless/mobile networks. The existing schemes are based on the packet forwarding and buffering during handover, which may tend to incur the buffer overflow and packet losses. To reduce the costs associated with packet forwarding and buffering, we propose the fast join to multicast tree, in which the multicast tree join will begin, as soon as the handover event is detected. From numerical analysis, we see that the proposed fast tree join scheme can reduce the packet delivery costs, including packet forwarding and packet buffering, much more the existing FMIPv6 multicast handover schemes.

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