Mobile IP에서 멀티캐스트 트리 확장 방법
(A Multicast Tree Extension Scheme in Mobile IP)

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요 약 이 논문은 IP 기반의 무선망에서 멀티캐스트를 위한 멀티캐스트 트리 확장(MTE) 방법을 제안한다. 그룹의 수신자가 방문한 외부망에서 멀티캐스트 그룹에 가입하고자 할 때, 만일 그 외부망이 멀티캐스트 라우터를 가지고 있지 않으면 멀티캐스트 서비스는 중단될 것이다.

따라서 멀티캐스트 패킷의 중단을 피하기 위해서 우리의 방법은 만일 이동 노드가 멀티캐스트 능력을 갖는 외부망으로부터 멀티캐스트 능력이 없는 외부망으로 이동하면, 이전의 외부 에이전트와 새로운 외부 에이전트사이에 양방향 터널을 만든다. 따라서 이동 노드는 이전의 외부 에이전트로부터 터널을 통해 멀티캐스트 패킷을 계속해서 수신한다. 우리의 방법은 이동노드가 멀티캐스트 능력이 없는 외부망으로 이동하더라도 그룹 멤버쉽에 대한 긴 터널에 따른 지연과 멀티캐스트 서비스 중단을 피할 수 있다. 시뮬레이션 결과를 통해 멀티캐스트 패킷 배달, 터널링 그리고 핸드오프 지연에 대해 기존의 방법보다 더 낮은 비용을 제공할 수 있음을 보인다.

키워드 : IP 무선망, 멀티캐스트 핸드오프, 멀티캐스트 트리 확장

Abstract This paper proposes a Multicast Tree Extension (MTE) scheme for multicast in IP-based wireless networks. If a group receiver joins a multicast group in a visited foreign network, multicast service may be disrupted when the foreign network does not have a multicast router. To avoid disruption, our scheme creates a bi-directional tunnel between the previous foreign agent (FA) and new foreign agent, if a mobile node (MN) moves from a foreign network with multicast capability to another foreign network with non-multicast capability. The MN thus continues to receive the multicast packets through the tunnel from the previous FA. Our scheme can avoid a long latency due to a long tunneling for group membership as well as multicast service disruption, even if the MN enters foreign networks with non-multicast capability. Simulation results show that our scheme offers lower costs for multicast delivery, tunneling and handoff latency than the existing scheme.

Key words : IP-based wireless network, Multicast Handoff, Multicast Tree Extension

1. Instroduction

A wide spectrum of portable, personalized computing devices ranging from laptop computers to handheld personal digital assistants have recently been introduced. Their explosive growth has led to considerable interest in providing continuous network coverage to such MNs regardless of their locations. In particular, wireless multicasting has attracted much interest for integration of wireless networks with the Internet since multicasting is much more advantageous than multiple unicasts as it reduces the communication cost. Actually, multicast communications are widely utilized in various applications, including information dissemination, multimedia conferencing, shared whiteboards, multicast file transfer, multi-party games and distributed computing.

More and more users would like to maintain Internet access without disruptions while in transit. Mobile IP [1] is able to maintain an established

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connection while in movement but cannot avoid disruption. In Mobile IP, each MN is assigned a long-term IP address on a home network called a home address. While away from home, an MN acquires a care-of address, which is either a foreign agent care-of address or a co-located care-of address in the foreign network. A home agent (HA) of an MN maintains a Mobility Binding Table between the home address and the care-of address. An MN registers with its HA to update its mobility binding when it moves across IP subnets. All IP packets for an MN are routed using regular IP routing, to its HA, which then tunnels them to the care-of address of the MN.

If all routers in networks support multicasting, an entering MN belonging to a multicast group can receive multicast traffic using multicast routing in a visited foreign network. However, when the MN visits a foreign network, the foreign network may do not have a multicast router since the multicast router is more expensive than a non-multicast router. The MN is unable to rejoin the multicast session until it moves to another network with multicast capability. Thus, multicast service may be disrupted in the foreign network. To avoid disruption, multicast packets can be delivered to the MN through tunneling. When tunneling is used, it produces an overhead due to encapsulation and decapsulation of multicast packets and the transmission time of encapsulated multicast packets becomes increased.

In this paper, we propose a Multicast Tree Extension (MTE) scheme for multicast in all-IP wireless networks to reduce tunneling. When a group member enters a non-multicast capable foreign network, multicast packets are delivered to the group member through tunneling from the previous FA with multicast capability. We evaluated our scheme through simulation, focusing the delivery cost for multicast packets and handoff latency with respect to multicast group size and we got an improved performance over existing scheme.

This paper is organized as follows: Section 2 reviews related works, Section 3 presents our scheme tunneling bi-directionally between the previous FA and new FA. Our scheme is evaluated in Section 4. Finally, Section 5 concludes the paper.

2. Related Works

The IETF proposed two schemes for MNs to receive multicast packets for Mobile IP [1]. One is called home subscription, where an MN joins a multicast group via bi-directional tunneling (or reverse tunneling) [2] to its HA, assuming that its HA is a multicast router. In this scheme, the HA performs multicast routing by the IGMP (Internet Group Management Protocol) [3] and delivers multicast traffic to the MN as if it is at home. The advantage of this scheme is that it is possible for the MN to receive multicast traffic in the foreign networks with non-multicast capability. If the MN is far away from its home network, the tunnel from home network and foreign network will be long. Thus, the MN will have a significant join and leave latency [5] due to the long tunnel. In addition, multicast routing may be suboptimal since the scheme produces an overhead due to encapsulation and decapsulation of multicast packets. When group members with different HAs are at the same FA, a tunnel convergence problem [4,6,7] occurs.

The other scheme is called remote subscription, where an MN joins a multicast group in the visited foreign network, assuming that there is a multicast router in the foreign network. In this scheme, the FA gathers group membership information from group members and forwards the multicast packets to them. This approach uses the optimal IP multicast routing to the current locations of group members. The disadvantage is that all foreign networks must have multicast routers. Unfortunately, group members may enter a foreign network that does not have a multicast router. In this case, multicast service may be disrupted until the members again move to another foreign or home network with multicast capability.

In Mobile IP, several studies have addressed some of the problems in supporting multicast for MNs [4,5]. Harrison *et al.* [6] proposed the MoM

(Mobile Multicast) protocol to solve some of the problems associated with the home subscription. In the MoM protocol, when an HA has more than one group member at the same FA, only one copy of the multicast packets is forwarded from the HA to the FA. When multiple different HAs send the packets to the same FA, it causes a tunnel convergence problem. To solve this problem, the FA appoints one FA as the designated multicast service provider (DMSP) for a given multicast group. Thus, the MoM is more efficient than the home subscription with respect to the delivery cost for multicast packets [6]. However, as the MoM uses the home subscription scheme, it may have a long latency for group membership if the tunnel is long, so the routing cannot be efficient.

Wang and Chen [7] proposed a three-layer architecture where a multicast agent (MA) is used as the access point to the multicast backbone as shown in Figure 1. In this figure, it is assumed that a correspondent node (CN) is a source for a multicast group, and MN$_1$ and MN$_2$ are receivers. HA$_1$ and HA$_2$ are HAs for MN$_1$ and MN$_2$, respectively. The bold lines illustrate the established multicast tree for the group. This scheme combined the home and remote subscription in Mobile IP. The MA provides multicast services to mobile group members in multiple foreign networks. The agent joins the multicast groups on behalf of the group members in its service area. Thus, MA1 and MA$_2$ join the multicast group on behalf of MN$_1$ and MN$_2$, respectively. When MA1 receives multicast packets through the multicast delivery tree, it tunnels the packets to FA1 that has a visiting group member, MN$_1$. The scheme is more efficient than the MoM protocol, especially when a group size is small, with respect to the delivery cost for multicast packets [7]. However, as the group size increases, a tunneling cost that is the delivery cost for encapsulated multicast packets also increases linearly.

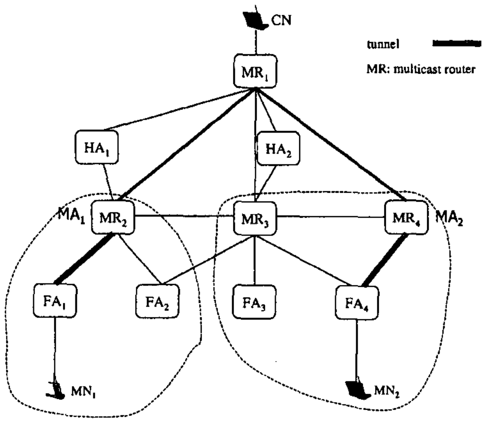

Fig. 1 MA scheme

3. Multicast Tree Extensions Scheme

We propose a Multicast Tree Extension(MTE) scheme to reduce the tunneling cost. To do this, the MTE scheme uses the remote subscription if a visiting foreign network supports multicasting. However, if the visiting foreign network does not support multicasting, the MTE scheme uses tunneling to avoid disruption. Initially, if a group member wants to join a multicast group and a visiting foreign network does not support multicasting, multicast packets are delivered to the group member through tunneling from a multicast capable FA that is located in a network close to the group member's visiting foreign network. When the group member moves from a foreign network with multicast capability to another foreign network with non-multicast capability, multicast packets are delivered to the group member through tunneling from the previous FA.

For our scheme, the mobility agent should maintain a Binding Cache that contains such fields as Home Address, Care-of Address, Lifetime and a Tunneling flag(which indicates whether tunneling is made). The Binding Cache is used for tunneling the multicast packets to a new foreign network without multicast capability when they arrive at an old foreign network with multicast capability. In addition, each FA with non-multicast capability should maintain a Group Information Table that contains fields such as Group Identifier, Previous FA's IP Address, Home IP Address and Lifetime. In addition, each MN should maintain the IP address of its FA if the FA is a multicast router. The Group Information Table is used to tunnel the multicast packets sent by an MN to an old foreign network when it is in a new foreign network with non-multicast capability.

Figure 2 shows the basic operation of the MTE scheme when an MN moves from a multicast router to a non-multicast router. In this figure, it is assumed that both FA$_1$ and FA$_4$ are multicast routers, but both FA$_2$ and FA$_3$ are non-multicast routers. Thus, the receivers can receive the multicast packets and IGMP Query messages from FA$_1$ and FA$_4$. When MN$_1$ enters a new subnet from FA$_1$ to FA$_2$, the latter cannot be included in the multicast tree because it is not a multicast router. Multicast packets may thus be disrupted while the MN stays in the foreign network. If the new foreign network does not have a multicast router, a bi-directional tunnel is made between the previous FA and the new FA in our scheme. Thus, the multicast packets for the MN are tunneled from the previous FA to the new FA.

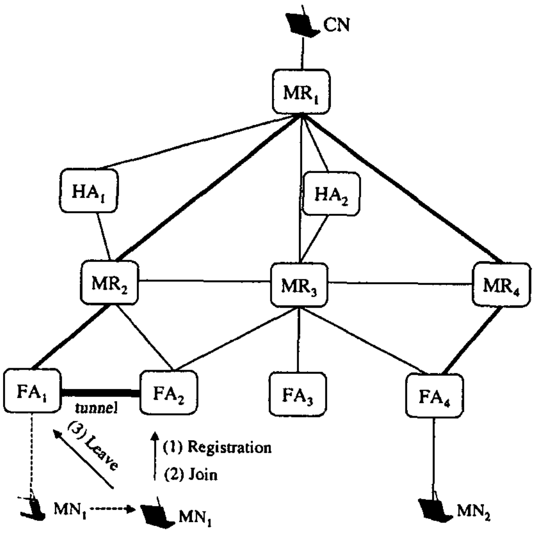

Fig. 2 MTE for handoff

0 1 2 3 4

<table>
<tr><td>Type</td><td>Length</td><td colspan="2">Reserved</td></tr>
<tr><td colspan="4">Previous Foreign Agent Address</td></tr>
<tr><td colspan="4">New Care-of Address</td></tr>
<tr><td colspan="4">Multicast IP Address</td></tr>
</table>

Fig. 3 Multicast Tree Binding extension

The entering MN1 sends a Mobile IP Registration [1] message, which includes a Multicast Tree Binding extension, to FA2. The Binding extension is only used when a new foreign network does not have a multicast router. Its format is shown in Figure 3. HA$_1$ updates its Mobility Binding Table by associating the MN's care-of address with its home address, and FA$_2$ constructs a Group Information Table using the Binding extension. At this time, the MN sends an IGMP Join (Report) message to FA$_2$ to join the group. The FA encapsulates the Join message using the Group Information Table and forwards it to FA$_1$. When FA$_1$ receives the encapsulated message, it adds the MN's group membership to its Group Membership Table for reverse tunneling and then constructs the Binding Cache using the message. The Lifetime field is set to the interval time between the IGMP Query messages and the Tunneling flag is set to 'Yes' when the MN is the first group member in the new foreign network. Next, the MN sends an IGMP Leave message to FA$_1$ to leave the group. FAS then removes the old entries of the MN from its Group Membership Table.

When the multicast packets for the group arrive at FA$_1$, the FA looks up its Group Membership Table. If there are entries for the group, the FA multicasts the packets to its local group members. If there are any entries for the group on the Binding Cache, the FA finds out the MN's care-of address and constructs a new IP header that contains the MN's care-of address as the destination IP address. When the encapsulated multicast packet reaches FA$_2$, the FA decapsulates the packet and forwards it to the MN using data-link multicast.

FA$_1$ sends periodic IGMP Query messages for group membership in its subnet. The Query message is tunneled to FA$_2$ and the message decapsulated by FA$_2$ is forwarded to the MN. To reply to the Query, the MN sends an IGMP Report message to FA$_2$. FA$_2$ encapsulates the Report message using the Group Information Table and then forwards it to FA$_1$. The message decapsulated by FA$_1$ is used for group membership by the multicast router.

First, we consider a group receiver that moves from a foreign network with non-multicast capability to another foreign network with non-multicast capability as shown in Figure 4. When MN1 moves from FA$_2$ to FA$_3$, it sends a Mobile IP Registration message, which includes a Multicast Tree Binding extension, and a Join message to FA$_3$. FA$_3$ constructs the Group Information Table and tunnels the Join message to FA$_1$. FA$_1$ adds the MN to its Group Membership Table and constructs the Binding Cache using the message. The Tunneling flag is set to 'Yes' because the MN is the first member of the group in the foreign network. Following this step, the MN sends a Leave message to FA$_2$ and then forwards the message to FA$_1$. FA$_2$ will remove the entry of the MN from its Group Information Table, then FA$_1$ will remove the old entry of the MN from its Group Membership Table. Thus, the multicast packets arrive at FA$_1$ and are tunneled to FA$_3$.

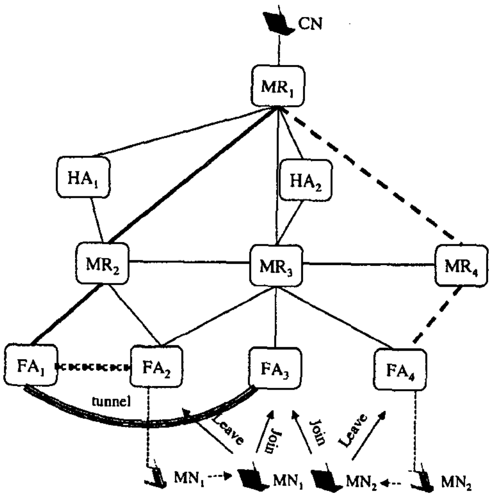

Fig. 4 Mobility from a non-multicast router to a similar router and a tunnel convergence problem

Second, we considered what would happen when a group receiver moves to a foreign network that has members of the same group but does not have a multicast router as shown in Figure 4. MN$_2$ sends a Mobile IP Registration message, which includes a Multicast Tree Binding extension, and a Join message to FA$_3$. If a bi-directional tunnel is created between FA$_3$ and FA4 for the MN, then FA$_3$ will receive duplicate multicast packets from both FA$_1$ and FA$_4$. In this case, a tunnel convergence problem can occur, where a non-multicast foreign network has members belonging to the same group. To solve this problem, we use the tunnel already established for the group instead of making a new tunnel when there are entries of the same group in the Group Information Table. Thus, the Previous Foreign Agent IP Address field is set to the same value as that of the other members of the group. At this time, FA$_3$ tunnels the Join message to FA$_1$, not to FA$_4$. However, if the MN is the first member of the group in the foreign network, its FA sends the message to FA$_4$ after the MN sends a Leave message to FA$_4$. Thus, an old group membership entry will be removed from FA$_4$'s Group Membership Table and the branches that no longer lead to the MN will be pruned.

Finally, we considered the situation in which a group receiver moves from a foreign network with non-multicast capability to another foreign network with multicast capability. As shown in Figure 5, assume that MN$_1$ moves from FA$_3$ to FA$_4$ which has any member of the group. As soon as the MN decides to perform a handoff, it sends a Mobile IP Registration message and a Join message to FA$_4$. Incidentally, it is not necessary to send a Multicast Tree Binding extension because the FA is a multicast router. Next, the MN sends a Leave message to FA$_3$ and then tunnels to FA$_1$. The old entry will be removed from the Group Information Table at FA$_3$, both the Binding Cache and the Group Membership Table at FA$_1$. The branches

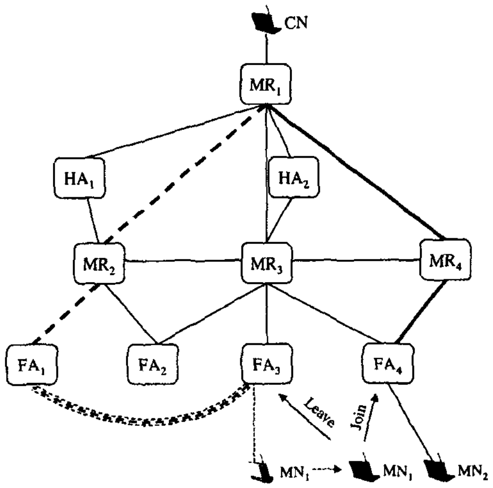

Fig. 5 Mobility from a non-multicast router to a multicast router

that no longer lead to FA_1 will be pruned via the multicast routing protocols like DVMRP [9], MOSPF [10], CBT [11] and PIM-SM [12].

Optimal multicast routing is not possible because of the bi-directional tunneling when an MN moves from a foreign network with multicast-capability to another foreign network with non-multicast capability. However, when the MN finds FA with multicast capability, the tunnel will be destroyed, thus leading to optimal routing.

4. Simulation

We have evaluated performance of the proposed scheme using a discrete-event simulation via C language. For performance evaluation of our scheme, we used a mesh network where each vertex is regarded as an IP subnet capable of link layer multicast. It was assumed that the size of the mesh network used in the simulation is 36 × 36 LANs, all recipients of the multicast group are mobile nodes and the group membership is static. The initial locations of all group members were randomly distributed in the IP subnets. Moreover, we considered one multicast group with a single source as a fixed node. To compare our scheme with a multicast agent scheme, it was assumed that the service area of the multicast agent is 6 × 6 square with 36 IP subnets, denoted by MA. The multicast agent is located near the center of the square, whose coordinate is (2,3) in each IP subnet. In our simulation, we considered two network ratios. One is a 10% ratio of non-multicast routers to multicast routers in the network, denoted by MTE1. The other is 20% in the network, denoted by MTE2. It was assumed that mobility agents in neighboring IP subnets can communicate directly through wired links (i.e. the number of links between them is 1). The distance from the source to a recipient is measured by the minimum number of links. Furthermore, to add a branch to the multicast delivery tree, a Join message travels along the reverse shortest path until it reaches a branch in the tree. To show handoff latency, a group member randomly moves to adjacent network, multicast handoff call arrivals form a Poisson process with an average of 400 seconds and the simulation is performed for 1.0E6 seconds. We varied the size of the multicast group from 2^2 to 2^{13} in the simulation. A number of simulation runs were performed and their averages were computed.

The cost for delivering a multicast packet is measured by the total number of links that a multicast packet travels from the source to all group members. This includes the number of links in the multicast tree and in all the tunnels that are used to deliver the multicast packets as well as the wireless link between an FA and MNs. In the MA scheme, multicast agents receive the packets from the source along the multicast tree and then tunnel the packets to each FA that has group members. In our scheme, if an MN visits a foreign network that does not have a multicast router, one of the neighboring FAs tunnels the packets to its foreign network.

Figure 6 shows that both MTE1 and MTE2 offer lower delivery costs than MA when the group size is larger than 2^8 (i.e. when the group is in a dense mode). However, when the group is in a sparse mode, there is no significant difference among them. We can also see that MTE2 produces a little

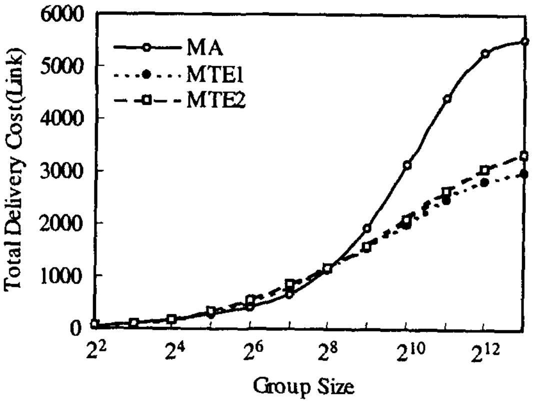

Fig. 6 Total delivery cost per multicast packet

higher delivery cost than MTE1. This is because the number of foreign networks with non-multicast capability in MTE2 is larger than that in MTE1.

In the case of MA, there is a high probability that group members move to a foreign network that has already established a multicast tree even when the group is in a sparse mode as shown in Figure 7. In our scheme, however, group members can move to a foreign network that has already established a multicast tree only when the group is in a dense mode. This is because the number of IP subnets is 36 in the MA, while there are 36 * 36 subnets in our scheme. Thus, when the group is in a dense mode, the total delivery cost is much lower in our scheme than in the MA scheme.

The total delivery cost consists of two factors. One is the delivery cost over the multicast tree and wireless link using data-link multicast. The other is delivery cost over the tunnels. Figure 8 and Figure 9 show these two costs for MA, MTE1 and MTE2.

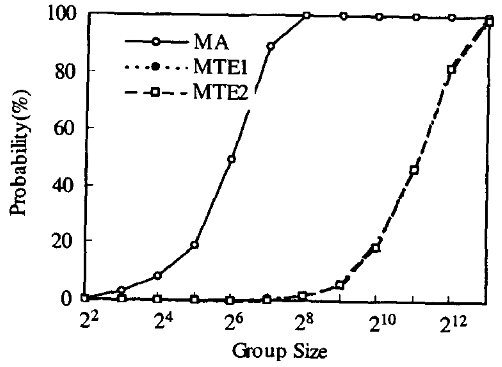

Fig. 7 Probability that the visited network has already registered the group

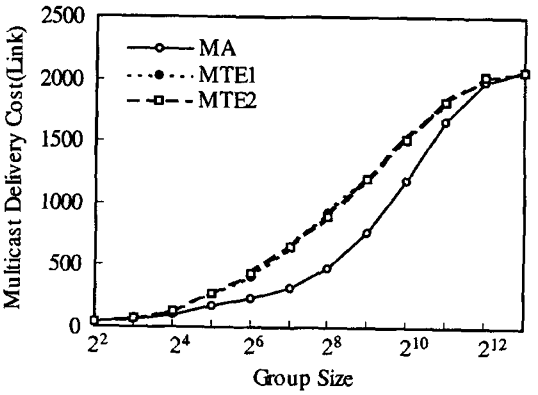

Fig. 8 Total delivery cost by multicasting

Figure 8 shows the multicast delivery cost. Our scheme has a little more multicast delivery cost than the MA. However, it should be noted that the multicast delivery cost takes only a small portion of the total delivery cost as the group size increases.

In MA, as the group size increases, the tunneling cost steeply increases as shown in Figure 9. This is because the MA tunnels multicast packets as many as the number of MNs in the service area of a multicast agent. However, in our scheme, the

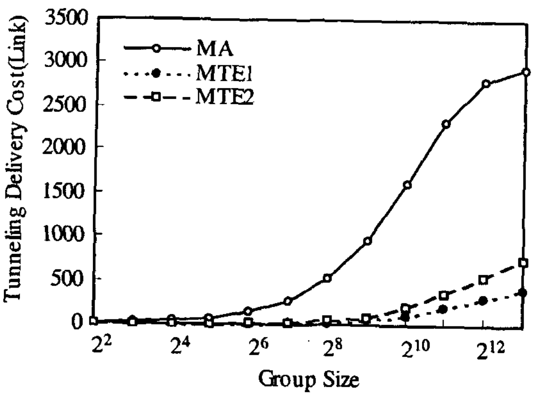

Fig. 9 Total delivery cost by tunneling

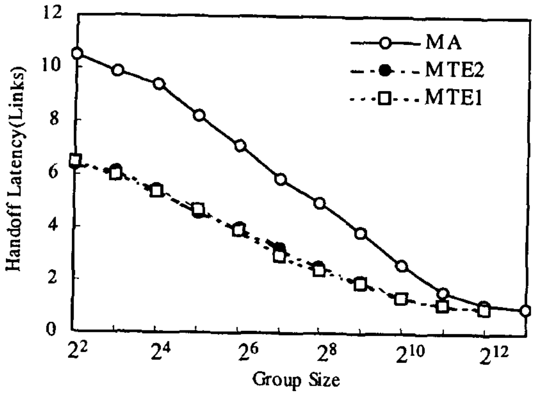

Fig. 10 Average handoff latency

tunneling cost only gently increases as the group size increases since tunneling is performed only when a foreign network does not have a multicast router.

Figure 10 shows the handoff latency for the MA, MTE1 and MTE2 when the multicast group size varies. We can see that as the multicast group size increases, the latency decreases. This is because when an entering MN is not the first group member in a visited foreign network, it is not necessary to establish the multicast tree. Comparing with the MA, the MTE cause much less handoff latency since the IGMP Join and Leave messages is transmitted from the MN to the multicast agent.

5. Conclusion

Mobile IP provides a home subscription and a remote subscription scheme for MNs to receive multicast packets. In the remote subscription, optimal multicast routing is possible, but each foreign network should have a multicast router. In the home subscription, the delivery cost for a multicast packet is high due to tunneling. However, it is not necessary for each foreign network to have a multicast router. When the remote subscription is used, if an MN enters a foreign network with non-multicast capability, multicast service may be disrupted until the MN moves to a foreign or home network with multicast capability.

In this paper, we proposed an MTE scheme that uses a remote subscription even when group members enter a foreign network with non-multicast capability. When a group member moves from a foreign network with multicast capability to another foreign network with non-multicast capability, a bi-directional tunnel is created between the previous FA and new FA. Moreover, when the group member moves to another foreign network with multicast capability again, the tunnel will be destroyed and the routing will be optimized again. Thus, our scheme can largely reduce a tunneling cost per multicast packet and handoff latency.

Our scheme is compared with the MA scheme via simulation. We showed that the tunneling cost of our scheme is better than that of the MA scheme. In addition, handoff latency of our scheme is less than that of the MA scheme. We can see that our scheme can offer a much lower tunneling cost and handoff latency. Thus, when mobile networks have few non-multicast routers, our scheme is more efficient than the existing scheme.

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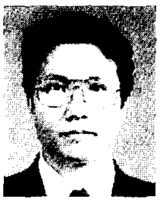

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