A Multicast Handover Scheme in HMIPv6 Mobile Networks

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Abstract Multicast service, which is one of the multi-point communication methods, should be applied to adjust it to evolving mobile network environment. In this paper, we propose a fast multicast management scheme for mobile terminals in HMIPv6-based mobile networks. In HMIPv6-based mobile network environment, multicast management scheme provides multicast service during mobile handover depending on the change of multicast transmission routing. Changed impact of the multicast routing is determined by handovers processed intra AR, inter AR, or MAP. Our multicast supporting scheme, which is proposed in this paper, uses tunneling scheme for intra AR handovers, and advance registration scheme for intra AR handovers to support multicast service management scheme depending on the changed impact of the multicast routing.

Keyword: multicast, handover, HMIP, MAP, AR

1. Introduction

Mobility support for Internet users will be an important internet service in the future, and research for this service is making progress actively [1][2]. Mobility users request multi-point communication services more and more to adjust it to complicate and various service extension and to get out of simple point-to-point communication methods [3]. However, multicast service support, which is a multi-point communication method, has much complicated service management than unicast service method, because it should control many connectors at the same time. Especially, if we consider mobility of mobile users, communication routing being changed continuously imposes much heavy burden on the management than fixed multicast service [5],[6],[7]. Multicast service management methods, therefore, should be researched continuously along with the development of Mobile IP (MIP). IETF (Internet Engineering Take Force) has suggested two approaches to provide multicast service for users who use mobile IP-based internet. The two approaches are bi-directional tunneled multicast approach and remote subscription approach [8]. In bi-directional tunneled multicast approach, all mobile terminals, which take part in multicast, give and take multicast traffic through its home agents (HA). Though a mobile terminal is anywhere, multicast communication is processed only through home agents during multicast service. That is, the core of multicast service is home agent. For this, a mobile terminal uses home agent and unicast tunneling. This approach, however, has a disadvantage that it causes much longer total operation time due to remote tunneling and routing if the terminal is far from the home agent. It also causes bandwidth waste due to remote movement. Therefore, this approach is not suitable for the network environment in which the mobility of terminals is large.Remote subscription approach embodies multicast service according to the external network which a mobile terminal visits, and requires re-registrations whenever the terminal visits the external network. Through the remote subscription approach, mobile terminals not transfer traffic to home agent, but use multicast service using the multicast routing constructed in the external network. Therefore, the remote subscription approach can form the optimum multicast routing without any relation to mobile terminal movement, and it has an advantage that it can increase multicast QoS. However, this approach also has a disadvantage. Because of frequent movement of mobile terminals, the delay for remote subscription to the external network can occur. Multicast QoS also can be decreased due to the delay. Hence, the multicast management approach, which reduces the delay, should be necessary.

In this paper, we made use of multicast management method based on the remote subscription approach, which guarantees the mobility of mobile terminals in aspect of multicast QoS management. Our method is also based on HMIPv6 for mobility management of terminals on mobile internet, and used AR approach which performs MAP role for fast multicast management. In HMIPv6, we added MAP (Mobile Anchor Point), which is element that takes a role of temporary home agent, to improve the binding management problem of MIPv6 [4]. Mobile terminals in HMIPv6 assign particular AR (Access Router) as its MAP. As the assigned MAP is performing the temporary home agent, it can increase stability of binding delay or service connection by providing fast handover management of mobile terminals. In this paper, we consider that the mobile terminals use multicast services through the management of multicast handovers which occurs in both cases: intra AR and inter AR. We suggest to use tunneling scheme for the management of intra AR multicast handovers, and advance subscription scheme for the management of inter AR multicast handovers.

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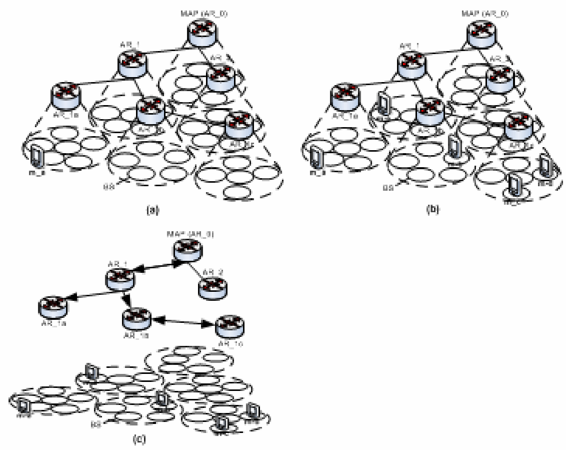
Thus, mobile terminals, which are transferred dynamically through ARs that perform the role of MAP, can use multicast services without heavy burden of delay for remote subscription.

This paper consists of 5 sections. Section 2 describes our suggestion, HMIPv6-based multicast service support approach, and section 3 describes the management schemes for multicast handover occurred by mobile terminals. In section 4, we show the performance analysis for the proposed multicast handover approach. Finally, we make a conclusion in section 5.

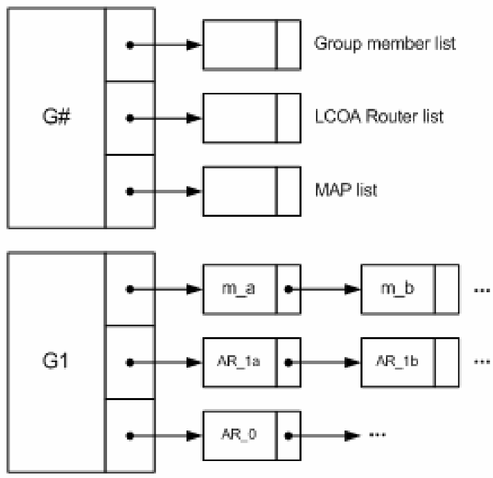
2. HMIPv6 multicast routing

In this paper, we consider multicast routing support through HMIPv6-based network construction. As we described in previous section, mobile terminals based on HMIPv6 are supported the mobility through the dynamic, hierarchical network structure. By the structure, multicast routing is formed for the hierarchical network construction through MAP and AR. The mobile range of terminals is referred as the movement among local ARs and the movement among ARs referred MAP. Fig. 1 shows an example of the multicast service execution depending on HMIPv6-based mobile network construction. In Fig. 1(a), if a mobile terminal *m_a* gets out its home network and enters into local AR_1a, then the mobile terminal *m_a* selects a AR (MAR) in charge of RCOA (Regional Care-of-Address) and a AR (local router) in charge of LCOA (on-Link COA). In the figure, we suppose that a local AR, AR_0, performs MAP role in charge of RCOA for the mobile terminal *m_a*, and router AR_1a is LCOA AR in charge of the terminal *m_a*. Figure 1(b) shows that mobile terminals {*m_a*, *m_b*, *m_c*, *m_d*, *m_e*} construct multicast group (*G1*) to provide multicast services. That is, ARs including terminals, which are getting the multicast services, manage the mobility of each terminal, and are ARs in charge of multicast. Figure 1(c) shows an example of multicast routing for traffic transmission to mobile terminals that take part in multicast. In the figure, AR of multicast group *G1* consists of local routers {*AR_0*, *AR_1*, *AR_1a*, *AR_1b*, *AR_1c*}, and it performs necessary functions of multicast services for the terminals in charge of the inside router range.

Multicast group management: For the multicast service support, each AR possesses and manages a terminal information table for multicast group management. Therefore, when a user transmits multicast traffic, the multicast services are provided through the terminal information table. Fig. 2 describes the data structure for the terminal information table in ARs. Each AR gets the information for the information table periodically through query/report messages to keep the multicast routing. If a particular mobile terminal enters the mobile network in Fig. 1(b) and uses multicast services as a member of multicast group G1, then the terminal should select MAP and local AR first, and binds with RCOA and LCOA. When MAP and local AR is defined, a registration message for the registration in multicast group G1 is sent to the AR in charge of multicast. The multicast router received the registration message registers the terminal information in its table and transmits the information to other routers in the same multicast group. When the corresponding multicast router constructs the multicast routing construction after the registration, it should be considered that whether the router is included in ARs of existing multicast group G1.



(Fig.1) Multicast management in HMIPv6 networks



(Fig. 2) Multicast information table.

If the corresponding multicast router is one of the local routers {*AR_0*, *AR_1*, *AR_1a*, *AR_1b*, *AR_1c*}, the information of the mobile terminal is registered. If the router is not included in ARs of G1, it should find and set link the rendezvous point in existing multicast ARs. For example in Fig. 1(c), when a new mobile terminal enters into local router *AR_2* and requests registration in multicast group G1, the local AR, AR2, sets link to local router *AR_0* (rendezvous router) as multicast router of corresponding terminal. Multicast group withdrawal of particular mobile terminal for the multicast service suspension stats as transmission of withdrawal message to its corresponding multicast AR. The AR received the withdrawal message deletes the terminal information and announces it to other ARs. In case of that the withdrawing mobile terminal is the last multicast terminal, the corresponding multicast AR withdraws in multicast routing and announces it to other ARs. For example, if mobile terminal *m_a* in router *AR_1a* region withdraws in multicast group, then the multicast link set between routers *AR_1a* and *AR_1* is deleted because *m_a* is the last terminal in the corresponding region.

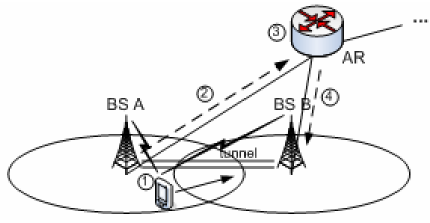
Multicast routing change: Multicast routing is changed due to the continuous movement of mobile terminals in a group. Multicast routing, therefore, is changed continuously depending on the movement type of terminals. The movement types for multicast service support are divided into two types: intra AR movement and inter AR movement. Intra AR movement means that the terminal moves between BSs (Base Station) in corresponding multicast router, and inter AR movement means that it moves out its corresponding multicast AR and enters into other AR region. The corresponding multicast AR of the mobile terminal has the record of BS, in which the terminal locates at that time, during the multicast service. As a result, when a mobile terminal moves between BSs in an AR through handovers, namely intra AR movement, the only thing what the corresponding AR should do is to change corresponding service BS. Additionally, the BS information change in multicast router does not request the multicast routing change, so additional time for reset of routing change is not consumed. In the other hand, when a mobile terminal moves out its multicast AR or MAP region and enters other multicast AR or BS in other MAP region, the corresponding multicast AR of the terminal should be changed. If the multicast AR of corresponding BS is a router taking part in multicast services, then only the terminal registration is necessary without multicast routing change. If the terminal moves into a new AR region, then multicast routing update as well as the mobile terminal registration should be performed. Continuous movement of mobile terminals in multicast services, therefore, requires much complete management than the terminal mobility management in unicast services. Especially, the management should control all terminal members at the same time, so only one movement of a terminal can have an effect the total multicast routing process. Therefore, more stable and fast multicast management scheme for terminal mobility should be necessary. This paper suggests multicast service management scheme for the handovers of terminals which take part in these multicast process.

3. Multicast handover management

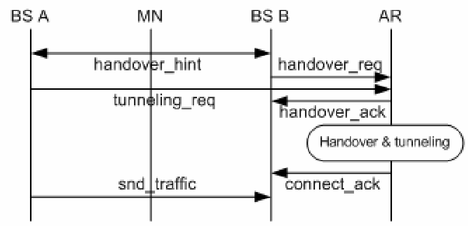
In the HMIPv6-based mobile network, the mobility of terminals is managed by the hierarchical characteristics of MAP and AR. Mobile terminal also requests stable maintenance of communication services through its handovers. Therefore, methods for continuous service connection during the terminal's handover are necessary. In HMIPv6-based mobile network, the movement types of mobile terminals are classified to two types of handovers; handovers generated in between BSs in an AR, and handovers generated in between two different ARs or MAPs. As stated above, multicast services are more complicated than unicast in group management or other management problems. When developers consider the mobility of terminals in HMIPv6-based mobile network, the approach that consider its mobility type rather than unified multicast handover methods should be suggested. In consequence, this paper suggests tunneling method for intra AR handovers, and advanced subscription methods for the inter AR handovers.

3.1 Multicast handover management for intra AR

In case that a mobile terminal which uses multicast service moves to another BS in same AR, multicast routing is not changed and only the link of BS connected with router is changed. Multicast change management occurred in AR needs less small amount of cost than multicast occurred outside AR, but it also has additional problems such as terminal handover management or the delay for the multicast processing. Thus multicast management scheme for movement in AR is needed. This paper uses handover tunneling scheme for fast multicast management on movement in AR.



(Fig.3) Tunneling for intra AR handover



(Fig.4) Signaling for tunneling

When a mobile terminal moves to other BS region in same AR, it is not waiting IGMP message received periodically but more actively requests its service update to multicast AR in charge. In Fig. 3, we suppose that a mobile terminal moves from BS A region to BS B region and the terminal transmits AR handover hint message to BS A and BS B (①). BS A received the handover hit message from the terminal requests higher link for tunneling with AR and prepares traffic forwarding (②).As the mobile terminal requests tunneling to BS A and BS B, it performs handover to BS B. The AR received tunneling request updates information of its multicast information table for the mobile terminal (③), and performs multicast routing change (leaf routing change) by preparing lower link formation to BS B (④). If the tunneling is finished, the mobile terminal receives traffic delivered to old base station BS A during handover. After the handover completion, the terminal successfully receives new multicast traffic from its corresponding AR. Fig. 4 shows signaling delivered between each component for tunneling method during AR inside handover. As you can see in the figure, the corresponding AR has the tunneling to keep stable link without traffic loss between old base station BS A and new base station BS B, and it processes handovers with BS B at the same time. The tunneling method for AR inside handover, therefore, can reduce traffic loss which can occur during handover delay. The tunneling method depending on the multicast change inside AR is only kept until the handover is processed, and it released after handover completion. (In the figure, you can see the tunneling release between BS A and AR.)

If AR is the router which performs Diffserv QoS management and provides multicast services by the WFQ traffic control mechanism, then the multicast transmission bandwidth for each Diffserv traffic level is as follows [10],[11].

$$\Delta mB_i = \frac{m\Psi_i}{\sum_{k=1}^{n} m\Psi_k} B_A \quad (1)$$

where B_A is the total bandwidth of link, and $m\Psi_i$ is service weight of the corresponding multicast level.

For the equation (1), the bandwidth for each multicast traffic level is shown as

$$\Delta mB_{EF} = \sum_{\alpha=\alpha 1}^{EF_\alpha} \Delta mB_\alpha = \sum_{\alpha=\alpha 1}^{EF_\alpha} \frac{m\Psi_\alpha}{\sum \Psi} B_A \quad (2)$$

$$\Delta mB_{AF} = \sum_{\beta=\beta 1}^{AF_\beta} \Delta mB_\beta = \sum_{\beta=\beta 1}^{AF_\beta} \frac{m\Psi_\beta}{\sum \Psi} B_A \quad (3)$$

$$\Delta mB_{BE} = \sum_{\omega=\omega 1}^{BE_\omega} \Delta mB_\omega = \sum_{\omega=\omega 1}^{BE_\omega} \frac{m\Psi_\omega}{\sum \Psi} B_A \quad (4)$$

where $\sum \Psi$ is total weight sum, α means the session of traffic level EF, β is traffic level AF, ω means traffic level BE, and $0 < \frac{m\Psi_\alpha}{\sum \Psi}, \frac{m\Psi_\beta}{\sum \Psi}, \frac{m\Psi_\omega}{\sum \Psi} \le 1$.

The bandwidth consumed for multicast traffic level i to time period Δt_δ is given by

$$\Delta mB_{i(t_{\delta-1}, t_\delta)} = \frac{m\Psi_i}{\sum_{k=1}^{n} \Psi_k} B_A [t_\delta - t_{\delta-1}] \quad (5)$$

For particular multicast session that performs handovers in AR, the tunneling transmission traffic during time interval Δt_h (per each traffic level) is as follows.

$$\Delta mB_{EF\Delta t_h} = \frac{m\Psi_\alpha}{\sum \Psi} B_A \cdot \Delta t_h \quad (6)$$

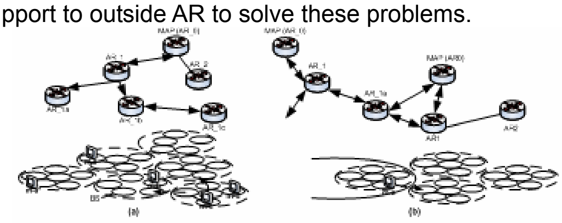
$$\Delta mB_{AF\Delta t_h} = \frac{m\Psi_\beta}{\sum \Psi} B_A \cdot \Delta t_h \quad (7)$$

$$\Delta mB_{BE\Delta t_h} = \frac{m\Psi_\omega}{\sum \Psi} B_A \cdot \Delta t_h \quad (8)$$

Therefore, if handover delay can occur, so traffic loss for particular multicast session occurs, then the loss as much as $\frac{m\psi_\alpha}{\sum \psi} B_A \cdot \Delta t_h$, $\frac{m\psi_\beta}{\sum \psi} B_A \cdot \Delta t_h$, $\frac{m\psi_\omega}{\sum \psi} B_A \cdot \Delta t_h$ can be occur as its maximum loss.

3.2 Multicast handover management for inter AR

The movement of mobile terminal to outside AR should perform LCOA binding or moreover RCOA binding because router is changed. For the mobile terminals which are using multicast services, the movement is much complicated and the management time is much large, because the multicast routing change occurs due to the movement to outside AR. Thus, the tunneling scheme suggested in above has a limitation such as the waste of link bandwidth or several routing steps, and has delay due to link reset at longer-distance than multicast handovers on inside AR. Therefore, our paper suggests advance subscription scheme for the fast multicast handover support to outside AR to solve these problems.



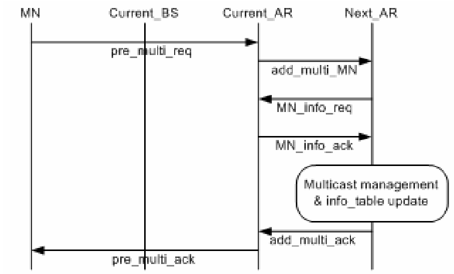
(Fig. 5) Multicasting routing change

The advance subscription scheme to outside AR means that if a mobile terminal moves to AR boundary cell, then it prepares multicast handovers by recording the information of corresponding terminal on advance subscription parts in information tables of next possible ARs. The first considerable subject for multicast handover to outside AR is the changed form and the changed routing intensity of AR depending on the terminal mobility. First, we have to consider AR changes of mobile terminal, whether it is change of local AR or change of AR in charge MAP.

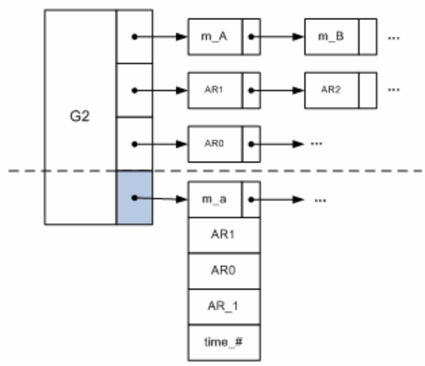
Movement to neighbored local AR – When a mobile terminal moves out its existing multicasting service area and goes into other AR management region, the multicast routing for the terminal should be changed. Because it is AR change rather than MAP change, the mobile terminal performs multicast handovers as it is performing LCOA binding for new AR.

Movement for MAP change – A mobile terminal which uses multicast services can move to other service management region from its MAP area. The movement requests MAP designation for new RCOA binding as well as local AR designation through LCOA binding.

Next, we will consider the changed routing intensity for multicast handovers. As we already explained, mobile terminals which take part in multicast have an effect. Fig. 5 shows the multicast routing for multicast handovers. Multicast routing change due to router exchange depends on whether multicast link that is being used in new AR or MAP region. If there are other mobile terminals belong in the same multicast group in the entering region, multicasting routing is already formed, therefore, it only needs information registration without routing change. However, there is no other mobile terminal belong in the same group, it should reset multicast routing. Fig. 5(a) describes the example situation that a mobile terminal enters to routing region and entering to new AR region. In this figure, if mobile terminal *m_c* makes multicast handover from *AR_1c* region to *AR_1b* region, there's no change for the multicast routing, and there is only the service change by registration in *AR_1b* for *m_c*. On the other hand, if the mobile terminal *m_c* moves to *AR_2* region from *AR_1c* region, multicast routing reset is not avoidable. As described in the figure, there is no link connection between *AR_2* and existing multicast routing. Thus, router *AR_2* performs multicast routing reset through the link connection to *AR*_0. In case of Fig. 5(b), a mobile terminal moves to other MAP region from its service MAP region. As explained in above, we should consider MAP changes as well as routing changes by local AR change in HMIPv6-based mobile network. Multicast routing should be reset by MAP designation as well as local AR designation in case of MAP change. For example, in the figure a mobile terminal, *m_a*, want to enter other local router *AR1* out of its local *AR_1a*. The mobile terminal *m_*a binds LCOA binding to *AR*1, RCOA binding to *AR0*, and sets the link for multicast services.

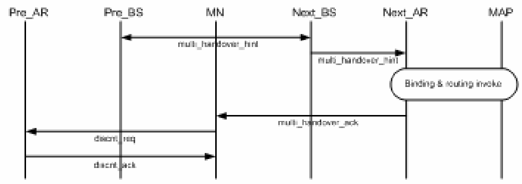


(Fig.6) Previous subscription for inter AR handover



(Fig.7) Multicast information table for the handover

If a mobile terminal moves to neighbored AR region, the management for the current routing as its changed part for the multicast routing intensity change should be considered. In Fig. 5(a), if mobile terminal *m_c* moves to other AR region, there is no difference in multicast routing because the terminal uses multicast services from current local router *AR_1c*. However if the mobile terminal *m_a* moves to other AR region, there is no more mobile terminal which uses multicast services in current AR region. In this case, the routing link between *AR_1*a and *AR_1* is deleted due to the multicast routing change. As you can see in this case, if a mobile terminal generates multicast handovers by going out its router service area (AR), the delay for the handover management is larger than the delay for the handovers in same AR. In addition, routing reset can occur due to the multicast link change, there is a limitation for the application of the link tunneling scheme that is for the BS change in AR. It is because bandwidth consumption can occur for multi- or long distance link due to the tunneling in case that the intensity change for multicast routing reset is serious, such as MAP changes. Therefore, this paper suggests advance subscription scheme for fast management of multicast handovers between ARs. The advance subscription scheme of mobile terminals which are using multicast services is shown in Fig. 6. As shown in the figure, when a mobile terminal enters into AR region boundary cell, then it requests information registration for advance subscription to AR which manages boundary cells. At first, the mobile terminal sends *pre_multi_req* message for multicast handover to AR through current BS. The AR received *pre_multi_req* message delivers *add_multi_MN* message to next AR for advance subscription of corresponding mobile terminal.



(Fig.8) Multicast handover for inter AR

After receiving the add_multi_MN message, the next AR is delivered the information of the mobile terminal (MN_infor_req and MN_info_ack message). The next AR received the mobile terminal information proceeds multicast routing computation in advance. For this process, the next AR makes a decision for MAP and local AR of the mobile terminal. The AR also searches rendezvous point with existing multicast routing, interacts an estimated path of the final multicast routing, and records it into advance subscription part in its multicast information table (perform multicast management & infor_table update). Fig. 7 shows an example of advance subscription part in multicast information table of the next AR. As shown in Figure 6(a), before mobile terminal m_a enters into AR1, the AR adds the advance information of the mobile terminal (information for terminal m_a, corresponding AR, MAP, rendezvous point, and information holding time) in advance subscription part of information table of AR1 through above process. After completion of information table update, the next AR announces the process result to current AR and the corresponding mobile terminal. The next AR also prepares multicast handover of the mobile terminal by delivering its table information to MAP. If the mobile terminal enters into the next AR, the next AR sets routing interacted in advance with MAP AR0 and keeps stable multicast services. The information in advance subscription part of the information table is updated by timer. When the information of particular mobile terminal is registered, the AR initializes its timer. The AR deletes the information by the timer to protect from too much information holding. The value of information holding time is registered in advance subscription part by measuring the estimated time in which the mobile terminal might enter into the next AR.

Fig. 8 shows the multicast handover process in case that a mobile terminal moves into the next AR. When the mobile terminal transmits hint message for multicast handover (multi_handover_hint message), the new BS delivers it to the next AR. The next AR received the multicast handover message defines MAP, and confirms RCOA, LCOA binding, and routing, which is defined in advance. The next AR also delivers the result to other group routers. If there's no advance subscription process, the AR should do too many steps and works such as setting for local AR and MAP, setting for multicast routing depending on the result, rendezvous point search, and so forth. Thus, through the advance subscription process, fast routing management can be acquired as you can see in Fig. 8. Mobile terminals deliver the multicast handover hint message to existing BS as well as new BS to release existing link. As we mentioned above, if there is no more multicast terminal in existing AR, then the multicast routing from existing multicast routing as well as the link between existing AR and the base station are released.

4. Performance analysis

We suppose that network environment is mobile network based on HMIPv6, and mobile terminals are available to use multicast services. Additionally, we will compare our approach with existing IGMP-based multicast approaches under remote subscription method [9]. For the performance analysis, multicast control signaling analysis is shown. The multicast control signaling time for multicast handovers on inside AR is given by

$$T_{\text{int}AR-IGMP} = T_{IGMPH} + T_{MR} \quad (9)$$

$$T_{\text{int}AR-TUNN} = T_{TUNNH} + T_{MR} \quad (10)$$

where $T_{intAR-IGMP}$ means the signaling time consumed in existing IGMP-based multicast control approaches, and $T_{intAR-TUNN}$ is control signaling time in our tunneling method. T_{IGMPH} also means the time consumed for IGMP message process, T_{TUNNH} is time for tunneling, and T_{MR} is time consumed for multicast link change. T_{IGMPH}, T_{TUNNH}, and T_{MR} are defined as follows

$$T_{IGMPH} = T_{DIGMP} + T_{bf} \quad (11)$$

$$T_{TUNNH} = T_{BSTP} + kT_{wsm} \quad (12)$$

$$T_{MR} = T_{MR} + nT_{wsm} + T_{BSP} + mT_{wrm} + T_{ARP/ack} \quad (13)$$

where T_{DIGMP} means the time interval between handover start time and IGMP message arrival, and T_{bf} is random backoff time. T_{BSTP} is processing time for tunneling signaling transmission, and kT_{wsm} is the time that the signaling is transferred successfully k-th times. T_{wsm} is signaling process time of the mobile terminal for multicast link change, nT_{wsm} is n-th signaling arrival time, and T_{BSP} is signaling processing time in BS received multicast link change. mT_{wsm} is defined as m-th signaling arrival time on cable line, and T_{ARP} is the time that process multicast link change for the mobile terminal and reply the result. Finally, k , m , and n mean the number of cases that signaling is transferred successfully.

Furthermore, we can get multicast control signaling time ($T_{interAR-IGMP}$ and $T_{interAR-PRER}$) for the movement to outside AR.

$$T_{\text{int}erAR-IGMP} = T_{IGMPH} + T_{BU/ack} + T_{mrer} \quad (14)$$

$$T_{\text{int}erAR-PRER} = T_{HOh\text{int}} + T_{BUiden/ack} + T_{mrinvoke/ack} \quad (15)$$

where $T_{interAR-IGMP}$ is signaling time that process multicast control method between ARs based on existing IGMP, and $T_{interAR-PRER}$ is processing time based on our advance subscription approach. $T_{BU/ack}$ is binding time for new AR and T_{mrer} is the time for multicasting re-routing. T_{HOhint} is the time for announcement for multicast handover, and $T_{EUiden/ack}$ and $T_{mrinvoke/ack}$ show the activation time for assigned binding and re-routing. These values are described as follows.

$$T_{BU/ack} = T_{LRCOAre} + T_{BU(MAP-AR)/ack} \quad (16)$$

$$T_{mrer} = T_{roure} + T_{upt} + T_{mre/ack} \quad (17)$$

$$T_{BUiden/ack} = T_{BUinvoke} + T_{ack} \quad (18)$$

$$T_{mrinvoke/ack} = T_{mrinvoke} + T_{ack} \quad (19)$$

where $T_{LRCOAre}$ is delivery time of binding request message, and RCOA and LCOA show binding processing time. T_{roure} is multicast re-routing request time, T_{upt} is multicast information table update time, and $T_{mre/ack}$ means re-routing processing time and request time.

[Table 1] System parameters.

Signaling propagation time		Signaling processing time	
Wired link	50μs	Mobile Terminal	5ms
Wireless link	0.12ms	BS	5ms
T_{bf}	100ms	AR	5ms
IP packet delay	10ms	Cell radius	100m

$T_{BUiden/ack}$ is assigned binding activation time, and T_{ack} is reply time for this. Finally, $T_{mrinvoke}$ is activation time for routing, and T_{ack} shows reply time after the activation.

If we suppose that T_{mh} is the time that a mobile terminal stays in handover area, and T_{mh} follows gamma distribution rule, then the probability density function for T_{mh} is shown as follows [12].

$$f_{T_{mh-gamma}}(t) = \begin{cases} \dfrac{\eta e^{-\eta t}(\eta t)^{\omega-1}}{\Gamma(\alpha)} & ,t \geq 0 \\ 0, t < 0 \end{cases} \quad (20)$$

where $\Gamma(\alpha)$ is the gamma function, where α is shape parameter for gamma distribution, and $\eta (= \sigma\alpha)$ is scale parameter of gamma distribution. The probability density function for the equation (19) is Erlang distribution when α is integer.

$$\Gamma(\alpha) = \int_0^\infty e^{-t}(t^{\omega-1})dt .$$

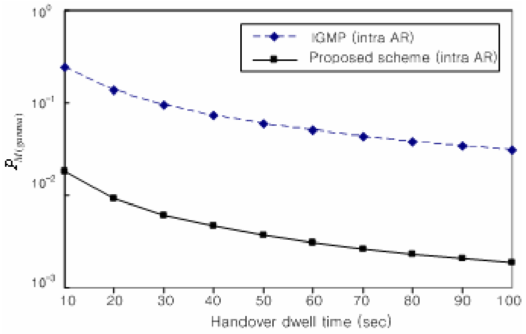
Hence, if multicast control signaling time for multicast handover is longer than the time that the terminal stays in handover region, it can make an effect to re-routing failure. Thus, when we suppose that multicast control signaling time follows the exponential distribution that has average T_{MS}, the probability of multicast re-routing blocking can be calculated as

$$\begin{aligned} P_{M(gamma)} &= \int_0^\infty e^{-t/T_{MS}} \cdot f_{T_{mh-gamma}}(t)dt \\ &= \int_0^\infty e^{-t/T_{MS}} \cdot \frac{\eta e^{-\eta t}(\eta t)^{\alpha-1}}{\Gamma(\alpha)}. \end{aligned} \quad (21)$$

Table 1 shows system parameters for performance analysis. We suppose that local router AR controls services through Diffserv QoS, and service class selection (EF – Expedited Forwarding, AF – Assured Forwarding, BE – Best Effort) is arbitrary random.

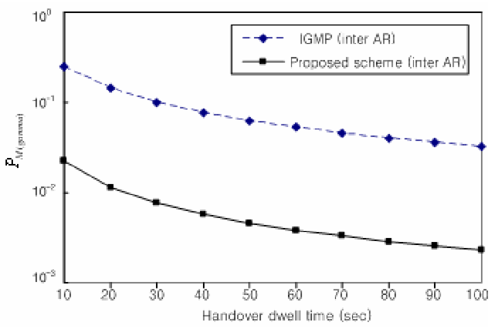
Fig. 9 shows the difference of $P_{M(gamma)}$ (in case of ω=1) between existing IGMP method and our tunneling method for the multicast handover inside AR. As you can see in the figure, $P_{M(gamma)}$ of our tunneling method shows much better performance. For example, if a mobile terminal stays in handover region for average 20 seconds,

$P_{M\,(gamma)}$ of IGMP method is 0.14, while $P_{M\,(gamma)}$ of our tunneling method is performance of 0.011.



$P_{M\,(gamma)}$

(Fig.9) Handover average dwell time versus (intra AR)

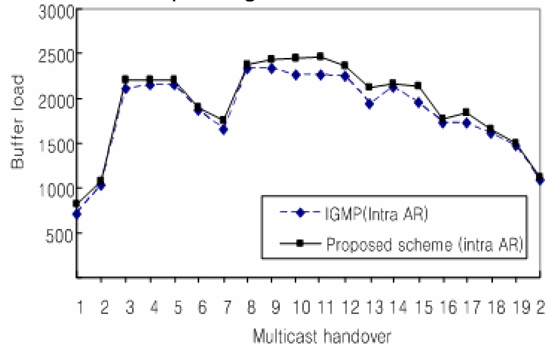


$P_{M\,(gamma)}$

(Fig.10) Handover average dwell time versus(inter AR)

Moreover, the result of existing IGMP method shows that it has more stable performance on around 0.03 as the handover stay time is longer, while the result of our tunneling method shows that the performance is increased to around 0.0018. Fig. 10 shows the performance comparison between existing IGMP method and our advance subscription method. Alike the above figure, if we suppose that the handover stay time is 30 seconds, then $P_{M\,(gamma)}$ of IGMP is 0.1, while the result of our advance subscription method is 0.0076. The total performance of $P_{M\,(gamma)}$ for multicast handover to outside AR is closed to 0.32 in case of IGMP, and 0.0023 in case of our approach, as the handover stay time is longer.

By the comparison between tunneling method and advance subscription method in Fig. 9 and 10, we can aware that tunneling method to inside AR shows 18~19% more good performance relatively. For example, when the handover stay time of a mobile terminal is 10 seconds, the performance is 0.022 in case of advanced subscription, and 0.018 in case of tunneling. The difference occurs because of the delay for multicast confirmation to outside AR such as binding or re-routing. Fig. 11 compares existing IGMP method and tunneling method for multicast handover depending on its buffer load. For this simulation, unicast and multicast traffic for mobile terminals occur through MMPP (Markov Modulated Poisson Process), and we suppose the movement speed of the mobile terminals is 5m/s. We also suppose that the output buffer size of AR, Diffserv router, is 5mbytes and output rate per second is 1Mbytes. We define the traffic transmission speed for mobile terminals is 192~32 kbps in EF class, and 64~32 kbps in AF class depending on the WFQ of each class.



(Fig.11) Multicast handover versus buffer load

The figure shows that the tunneling transmission between BSs inside AR doesn't make big effect on output buffer load than existing IGMP method. For example, the output buffer load in 5th multicast handover sampling is 2154 in case of existing IGMP method, and 2204 in case of tunneling method. It means that our approach can provide stable multicast services by fast multicast handover without big increase of buffer load for router.

5. Conclusions

In this paper, we propose multicast handover support approach in HMIPv6-based mobile network. Multicast handovers can divided into handovers inside AR and handovers outside ARs depending on the re-routing change density. We suggest tunneling method for multicast handovers inside AR, and advance subscription method for multicast handovers outside ARs. This hybrid method can support fast handovers without the traffic load increase of the corresponding router connected directly, and can prepare the handover delay time without frequent handovers inside AR. Through the simulation results, we showed that our approach supports more stable services rather than existing IGMP method. The multicast service support in the future will be an important service of mobile network, and we expect that our approach will be available technically and practically. Additionally, multicast management method for heterogeneous network will be considered.

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