한국통신학회논문지 '05-1 Vol 30 No 1A

# 사용자 성향에 기반한 이동 멀티캐스트 기법

정회원 성 수 련* 학생회원 전 진 영* 서 유 화* 정회원 신 용 태*

# Mobile Multicast Method using the User Pattern

Sulyun Sung* Jinyoung Jeon* Yuhwa Seo Yongtae Shin

## 요 약

본 논문은 사용자의 이동 패턴에 기반한 효율적인 이동 멀티캐스트 기법을 제안한다  본 논문은 멀티캐스트 서비스를 받기 위해 소요되는 전체 지연 시간을 줄이기 위한 방법으로 이동 노드의 반복적인 이동 성향을 정의한다 정의된 이동 성향을 바탕으로 지역의 범위에 속하는 외부 에이전트들은 멀티캐스트 라우팅 트리를 활성화된 상태로 유지함으로 이동 노드가 재방문 했을 경우 지연 없이 멀티캐스트 서비스를 즉시 받을 수 있다. 수학적 분석 모델을 이용하여 제안된 방안의 성능을 증명하며, 분석 결과는 제안된 방식이 기존의 연동방식 보다 전체 처리 비용과 서비스 지연 시간 측면에서 우수하다는 것을 보여준다

Key Words mobile IP, Multicast, User patter

## ABSTRACT

This paper presents an efficient mobile multicast method using the user pattern We exploit the repetitive movement pattern of mobile node to reduce the total number of experience of graft and join procedure We defined the locality scope by a movement pattern While the network is included in the locality scope, the network should maintain a multicast tree even when the mobile node moves to the other network. In this way, the mobile host can receive a multicast service without a delay when it moves to the network in the locality scope later We compare our scheme with existing schemes under the total signaling cost and the service delay time by using a discrete analytical model for cost analysis Analytical results demonstrated that the total signaling cost and service delay time was significantly reduced through our proposed scheme.

## Ⅰ. Introduction

The next generation internet will focus on a service of the high-speed network and real-time multimedia

The mobile computing technology and multicast is required for this service Mobile IP allows a mobile node to move amongdifferent networks without a disconnection of an established session. A multicast supports the source conservation by transferringone copy of data instead of transmitting information to each receiver separately But, the existing IP multicast doesn't consider a mobility of host and IETF Mobile IP doesn't consider a multicast service either Most of the existing mechanism can be classified into bidirectional tunneling and remote subscription. In the aspect of routing efficiency and originality, the remote subscription is superior to the bidirectional tunneling except a delay resulted from the graft and join If the delay problem can be solved, it will be a better mechanism than any other ones.

---

* 숭실대학교 컴퓨터학과 통신연구실(ssl@cherry ssu ac kr)

논문번호. KICS2004-07-083, 접수일자 2004년 7월 6일

※본 연구는 숭실대학교 교내 연구비로 수행되었습니다

The way to reduce a delay is classified two methods One is to reduce the real delay time. The other is to reduce the number of experience of delay But, the former depends on the existing multicast mechanism, for example, IGMP or DVMRP ([4][5]) Therefore, if we intend to reduce a real delay time, we have to modify many parts of existing mechanism So, we will choose the latter case, which is to reduce the total number of experience of delay. By reducing the total number of experience of delay, we solve the problem of the remote subscription and provide an efficient multicast service in mobile environment.

We exploit the movement pattern of mobile node to reduce the total number of experience of graft and join. We define the locality scope by a movement pattern While the network is included in the locality scope, the network should maintain a multicast tree. The mobile host can receive a multicast service without a delay when it moves to the network in the locality scope In this way, we intend to reduce the total number of the graft and join case and provide an efficient multicast service in a mobile environment

The rest of the paper is organized as follows Section 2 introduces a new mobile multicast method using the user pattern Section 3 evaluates the performance and compares proposed method with the existing protocols Section 4 demonstrates the performance improvement of our scheme over the existing scheme, using a total signaling cost and a service delay time Finally, we conclude this paper in Section 5.

## Ⅱ. Mobile multicast method using the user pattern

### 1 Overview

The total delay resulted from join and graft can be reduced by using the user pattern The user pattern means the repetitive movement pattern of mobile node The HA defines the locality scope by a movement pattern The elements in the locality scope are the group of a recently visited network The HA maintains the locality information by the specified scope This paper basically uses a remote subscription If there is an established multicast tree, the mobile node can receive the multicast packet without a delay We use a locality of movement to increase the above case.

When the mobile node moves to the other network and the HA receives a registration request message from a FA, the HA sends to a mobile node a locality information in the registration response message After receiving the registration response message, the FA manages the locality information and maintains the multicast routing tree without a prune until it receives a deletion notification message, defined newly in this paper While the FA maintains the multicast routing tree, the mobile node can receive the multicast service without a delay at any time of returning to the foreign network In other words, when the mobile node moves to the networks included in the locality scope, since the networks maintain a multicast routing tree, the mobile node can a multicast service without a delay In this way, we can reduce the total service delay by a graft and join procedure.

### 2 Definition of the user pattern

This paper defines the user pattern as a repetitive movement pattern of a mobile node. This user pattern can be explained with a case of one professor He spends most of his time in home, school and company In other words, the professor's movement does not get out of the restricted location. In other words, his movement pattern is repetitive and restricted We can say that the location where has ever been visited inclines to be re-visited by one. By using this feature, we will define the user pattern with a refined form, locality scope if we assume that n is the number of network in advance, we can say the definition of locality scope for n, G = {n1, n2, n3, n4}

### 3 Method description

In this mechanism, the locality scope is defined as a group of FA by the specified network number In other word, for n, the group of locality scopecan be explained as G = {FA1, FA2, FA3, FA4}. The size of G is determined by the n and specified by HA. The HA has an information of group G in the form of cache. After processing a registration response message, the HA update the cache by using a locality information. Figure 1 shows a total procedure of the proposed mechanism.

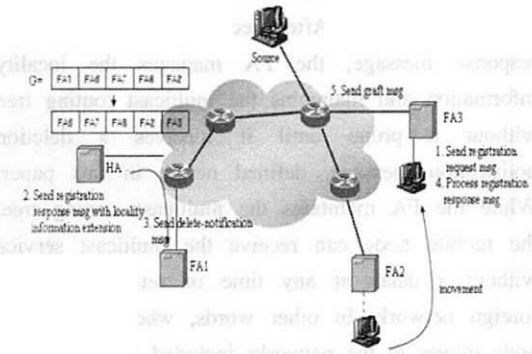

Fig 1. The total procedure of the our mechanism

### 3.1 Operation of HA

After receiving a register request, the HA send a register reply message with a locality information message to a mobile node. After sending a register reply message, the HA update a cache of the localityinformation. At this time, if the room in the cache is full, the HA should discard the existing FA in the cache. The cache management waydepends on a policy. As soon as the HA discard one FA entry, it sends a delete notification message to the correspondent FA. When the FA receives this message, if the mobile node is the last one to receive the packet of the correspondent multicast group, it can prune the existing multicast routing tree to which the mobile node is joined.

```
Algorithm operation_by_HA
Variables
bindingi= set of binding information for mobile host i
locality_infoi = the group of network visited by the mobile node for the specified number of network
Initiallybinding = nil
upon receiving reg_requestj from MHi:
    update bindingi ;          /* create bindingi */
    if locality_infoi = Full then
        remove FAi from locality_infoi ;
        send delete_notification to FAi ;
    add FAi to locality_infoi ;
    send reg_reply to FAi
```

### 3.2 Operation of FA

When the FA receives the register reply message, it processes a localityinformation message. The FA maintains a locality table. In the localitytable, the FA maintains the list of mobile node using a proposed method in this paper. After receiving a register reply message, the FA adds the mobile node to the locality table. If the mobile node has a multicast group to join, it can send an IGMP response message to the FA. When the mobile node moves to the other network, the mobile node sends a leave message to the FA. Although the FA receives the leave message, the FA should not prune the multicast routing tree until it receives a deletion notification message, which is different from the existing IGMP mechanism. To this, the FA should maintain the multicast routing tree by sending an IGMP response message to itself instead of the MN.

In this way, if the mobile node re-visits the FA that still maintains the multicast routing tree later, it can receive the multicast service without delay. Sincethe mobile node inclines to move into the limited region, this way can reduce the total number of experience of such a delay.

```
Algorithm operation_by_FA
Variables
visitor_listi= set of mobile host i visited to the FA
locality_tablei = set of mobile host i using a proposed method
membersj = set of host ids for multicast group j
Initially visitor_listi = nil, members = nil
  upon receiving reg_replyi from HA ;
      update visitor_listi ;
      if existlocality_info_extension then
          add MHi to locality_table i ;
  upon receiving Joinj from MHi
```

```
      if membersj = nil  then
         send Graft to MRj
         add MHi to membersj  ;
   upon receiving leavej from MHi
      if MHi ? locality_tablei  then
         hold Multi_tree until receive
                  delete_notification ;
      else
         send Prune to MRj  ;
      update membersj
```

## Ⅲ. Performance evaluation

In this section, we derive the cost function of registration cost and multicast packet delivery cost of our scheme, a remote subscription and bidirectional tunneling The total processing cost in a registration and multicast packet delivery is considered as the performance metric. In addition, we calculate a service delay time of three mechanisms We do not take the periodic binding updates that a MN sends to it's HA or FA to refresh their cache into account

### 1. Processing cost

The processing cost is composed of the registration cost and the packet delivery cost In this section, we define the each cost reflecting a various circumstance.

#### 1 1 Registration cost

This registration cost includes a cost to register at the FA and a cost to join and graft to a multicast routing tree We define the following parameters for registration cost in the rest of this paper:

$C_{fm}$ The transmission cost of registration update between the FA and MN

$C_{fh}$: The transmission cost of registration update between the FA and HA

$C_{jfm}$: The transmission cost of IGMP join message between the FA and MN

$C_{jfh}$: The transmission cost of IGMP join message between the HA and FA

$a_h$: The registration processing cost at the HA

$a_f$ The registration processing cost at the FA

$a_j$: The IGMP join message processing cost at the FA and HA

$M_g$: The graft message processing cost at the FA and HA

If the MN moves to the network which has not been joined to the multicast group, the registration cost of MN can be calculated as:

$$Cnot\_m=2af+ah+2Cfm+2Cfh+Mg+aj+fm \tag{1}$$

If the MN moves to the network which has been joined to the multicast group, the MN does not need a multicast join procedure The registration cost of this case can be calculated as.

$$Cm=2af+ah+2Cfm+2Cfh \tag{2}$$

Additionally, we define the registration cost of remote subscription mechanism as.

$$CHA=2af+ah+2Cfm+2Cfh+Mg+aj+Cjfm+Cjfh \tag{3}$$

Let lfm be the average distance between the FA and the MN in terms of the number of hops, lfh be the average distance between the FA and the HA. We assume that the transmission cost is proportional to the distance and the proportionality constant is U. Thus Cfm, Cfh can be expressed as lfmU, lfhU Since the transmission cost of the wireless link is generally higher than that of the wired link, we suppose that the transmission cost over the wireless link is times higher than the unit distance wired line transmission cost and the transmission cost of IGMP join message is q times lower than the one of registration update message. Then the above two registration costs can be expressed as:

$$Cnot\_m=2af+ah+Mg+aj+(2lfh+2+pq)\delta U \tag{4}$$

$$Cm=2af+ah+2(lfh+p)\delta U \tag{5}$$

$$Ch=2af+ah+Mg+aj+(2lfh+2+pq+qlfh)\delta U \tag{6}$$

Assume each MN may move randomly among N subnets and the locality table includes k subnets.We model the movements of a MN as a discrete system Define a random variable M so that each MN moves out of a locality group at move m. At movement 1, a MN may moves to either subnet 1, 2, or N At movement 2, the MN may move to any of the other N-1 subnets We assume that the MN will move out to the other N-1 subnets with equal probability, $\frac{1}{N-1}$ The MN should re-join to the multicast group until the locality table is filled totally, until the network number which the MN moves to is k. Therefore, in the case of m<k, the MN should join to the multicast group at each movement In the case of m>k, the probability of moving out of locality group, the probability of performing a multicast join procedure at movement m is

$$P^{m} = \frac{N-k}{N-1} \cdot \left(\frac{k-1}{N-1}\right)^{m-2} \text{ where } k < m < 8 \tag{7}$$

The expectation of M is like followings:

$$\mathrm{E}[\mathrm{M}] = \sum_{m=k}^{\infty} \mathrm{m}P^{m} = 1 + \frac{N-1}{N-k} \tag{8}$$

Assume that the average sojourn time in each subnet within a regional network is Tf In our mechanism, when the MN moves inside of the locality group, it does not need a group join procedure We exclude the case that the FA has already joined to the specific multicast group. Therefore, the average registration cost of our scheme is:

$$C_{Ours} = \frac{\mathrm{E}[M]C_{m} + (k+1)C_{not\_m}}{(k+\mathrm{E}[M])T_{f}} \tag{9}$$

In the remote subscription, whenever the MN moves to the other subnet, it should join the multicast group to which it wants to join. Therefore, the average registration cost of a remote subscription is

$$C_{FA} = \frac{(\mathrm{E}[M] + k + 1)C_{not\_m}}{(k+\mathrm{E}[M])T_{f}} \tag{11}$$

In the bidirectional tunneling, the MN should join the multicast group through the HA. Therefore, the average registration cost of a bidirectional tunneling is

$$C_{HA} = \frac{(\mathrm{E}[M] + k + 1)C_{h}}{(k+\mathrm{E}[M])T_{f}} \tag{12}$$

### 1 2 Packet delivery cost

The packet delivery cost includes the transmission and processing of multicast packet We define the following parameters for a packet delivery cost in the rest of this paper:

$T_{hf}$ The transmission cost of multicast packet between the HA and FA
$T_{fm}$: The transmission cost of multicast packet between the FA and MN
$U_h$ The multicast packet processing cost at the HA
$U_f$ The multicast packet processing cost at the FA

The cost for packet delivery procedure of our scheme, a remote subscription and a bidirectional tunneling can be expressed as:

$$C_{ours-PD} = \mathrm{Tfm+Uf} \tag{13}$$

$$C_{FA-PD} = \mathrm{Tfm+Uf} \tag{14}$$

$$C_{HA-PD} = \mathrm{Thf+Uh+Uf} \tag{15}$$

We assume the transmission cost of delivering data packets is proportional to the distance between the sending and the receiving mobility agent with the proportionality constant D. Then Thf, Tfm can be expressed as lhfD, lfmD Assume on average there are MNs in a subnet. Therefore, the complexity of the HA registration list lookup and FA visitor list lookup is proportional to
We define the multicast packet processing cost at the FA and HA as:

$$U_{h} = U_{f} = \lambda_{a}(\alpha\omega + \beta\log(w)) \tag{16}$$

where a is the packet arrival rate for each MN, and are weighting factor of visitor list or registration list and routing table lookups In this case, the packet delivery cost of three mechanisms is evaluated as·

$$C_{ours\text{-}PD} = C_{FA\text{-}PD} = \lambda_a(\alpha\omega + \beta\log(w)) + \rho\delta_D \qquad (17)$$

$$C_{HA\text{-}PD} = 2\lambda_a(\alpha\omega + \beta\log(w)) + (l_{fh} + \rho)\delta_D \qquad (18)$$

### 1 3 Total processing cost

The total processing cost is calculated bya sum of the registration cost and the packet deliverycost. Based on the above analysis, we may get the total processing cost function as

$$C_{()-TOT}(k, \lambda_a, T_f) = C_{()-R} + C_{()-PD} \qquad (19)$$

### 2 Service delay time

After the mobile node moves to the other network, it experiences a delay from the registration procedure to the receipt of multicast service The total delay D is composed of to $\tau_s$ the time of searching a new agent, $\tau_R$ the time of registration, $T_M$ the time of graft and join to multicast routing tree, Tthe time to tunneling and Tm transmission time of multicast packet We calculate a total delay *until the movement m. We suppose that the packet* arrives λ at the rate of in the each subnet By using these variables, we can define the delay of our scheme, bidirectional tunneling and remote subscription as (20), (21), (22)

$$D_{ours} = (k+1)(\lambda T_m + \tau_s + \tau_R + M) + E[M](\lambda T_m + \tau_s + \tau_R) \quad (19)$$

$$D_{FA} = (E[M]+k+1)(\lambda T_m + \tau_s + \tau_R + \delta M) \qquad (20)$$

$$D_{HA} = (E[M]+k+1)(\tau_s + \tau_R + \delta T) \qquad (21)$$

## Ⅳ. Analytical Results

In this section, we demonstrate the performance improvement of our scheme over the existing scheme, using an above a total signaling cost and a service delay time. Since the total number of subnets that MNs access through wireless channels *is limited, we assume w=30 For our evaluation,* lfh, lfm is fixed numbers If not, signaling packets may take different paths each time according to the traffic load and routing algorithms at each mobility agent Thus, lfh, lfm, vary within a certain range An MN may use the TTL field in packet headers to get the number of hops packets travel.Since the TTL field in IP header is usually initialized to 32 or 64, the upper limit on the number of hops through which a packet can pass is 32 or 64, we assume lfh= 20, lfm = 5 Table 1 lists some of the parameters used in our performance analysis. In the simulation, we used same parameters in Table 1

Table 1 Parameters for performance analysis

| | | |
|---|---|---|
| Pkt process cost | $a_h$ | 25 |
| | $a_f$ | 10 |
| | $a_j$ | 5 |
| | $M_g$ | 15 |
| Message factor | q | 0 7 |
| Distance cost unit | $\delta_U$ | 0 1 |
| | δD | 0 05 |
| Weight | α | 0 3 |
| | β | 0 7 |
| Number of MN | ω | 15 |
| Wireless Factor | ρ | 10 |

*First, we compare our scheme with the existing* schemes by using the call-to-mobility (CMR) We define the call-to-mobility as the ratio of the packet arrival rate to the mobility rate, CMR=aTf We assume that the average values of residence time in each subnet and packet arrival rate of all the MNs are the same. When the CMR is low, the mobility rate is higher than a packet arrival rate In other words, the registration update cost dominates a total processing cost.

[Fig 2] shows the total processingcost as a function of CMR for the threeschemes when the arrival rate and residence time increase at the same

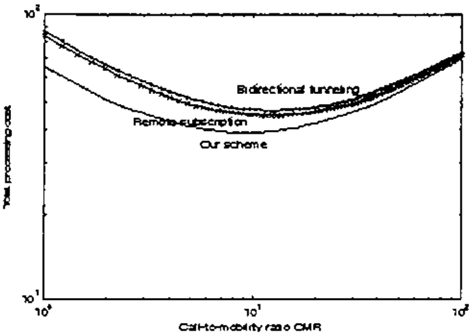

Fig 2 Comparison of total processing cost based on the CMR

time When the CMR value is low, because the higher mobility rate results many registrations in existing scheme, our scheme performs far better than the existing scheme In the experiment, the locality table size is k=10. In [Fig. 2], the three bluelines show simulation results In the simulation, our scheme can save a total signaling cost to 11%, 12.5% compared to a remote subscription, a bidirectional tunneling

In the second experiment, we assume that the residence time of users follows an exponential distribution, like

$$f_1(T_f) = \frac{1}{\overline{T}_{f1}} e^{-T_f/\overline{T_{f1}}} \quad , \quad \text{Tf=0} \qquad (22)$$

Let the packet arrival rate a be the fixed number, a=10 and the average residence time $\overline{T}_{f1}=10$ [Fig 3] shows the comparison of total processing cost under an exponential distribution of user movement pattern

Therefore, the total processing cost of our scheme and existing schemes are.

$$C_{TOT} = \int_0^{\infty} f_1(T_f) C_{()\text{-}TOT}(k=10, \lambda_a, T_f)) dT_f \qquad (23)$$

Although the performance improvement of our scheme is not large under the user residence time of above 102, our scheme shows a high performance in the most user residence time.

At this time, we assume that the residence time

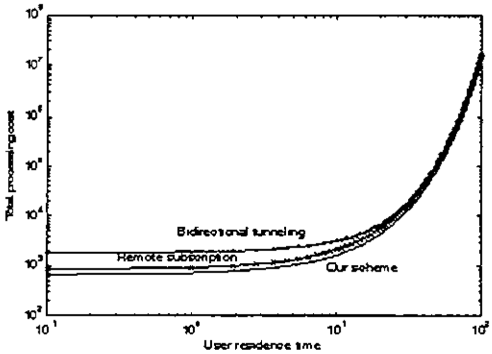

Fig 3 Comparison of total processing cost under user with an exponential distribution

of user follows a Gaussian distribution:

$$f_2(T_f) = \frac{1}{\sqrt{2\pi\sigma}} e^{-(T_f-\overline{T}_{f2})^2/2\sigma^2} \quad , \quad \text{Tf=0} \qquad (24)$$

$$C_{TOT} = \int_0^{\infty} f_1(T_f) C_{()\text{-}TOT}(k=10, \lambda_a, T_f)) dT_f \qquad (25)$$

Let the packet arrival rate be the constant and the

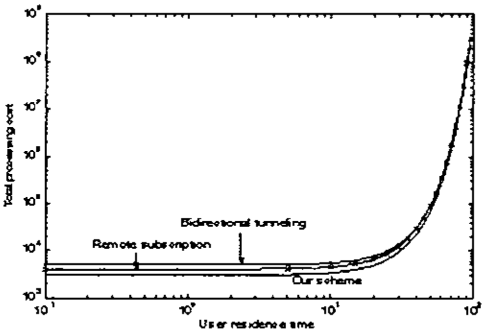

Fig 4 Comparison of total processing cost under user with a Gaussian distribution

average residence time $\overline{T}_{f1}=10$.

[Fig. 4] shows the comparison of total processingcost under a Gaussian distribution of user movement pattern Because the long residence time makes a multicast join procedure not happen frequently, the total processing cost of our scheme is lower than the existing schemes to the some extent.

We assume that the residence time of users is fixed number, Tf=1 and the arrival rate changes

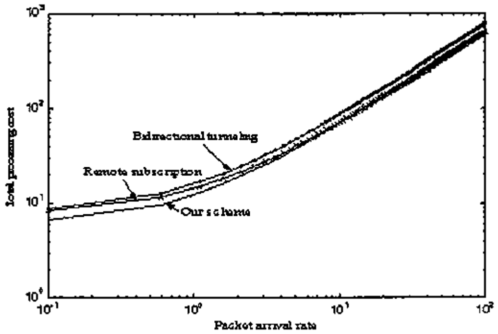

Fig 5 Comparison of total processing cost under packet arrival rate

[Fig 5] shows the total signaling cost of our scheme and existing scheme as a function of a packet arrival rate under a mean residence time=1. When the packet arrival rate is high, the signaling cost of our scheme is almost as same as one of it But, when the packet arrival rate is low, we can save a total processing cost to the about 13% This is resulted from what the packet processing cost excesses a registration cost The higher packet arrival rate, we can save the less processing cost to be compared with the existing scheme.

The average packet arrival rate is $\bar{\lambda} = 10$ . The packet arrival rate follows a Gaussian distribution where = 20

$$f(\lambda) = \frac{1}{\sqrt{2\pi\sigma}} e^{-(\lambda-\bar{\lambda})^2/2\sigma^2} , \qquad (26)$$

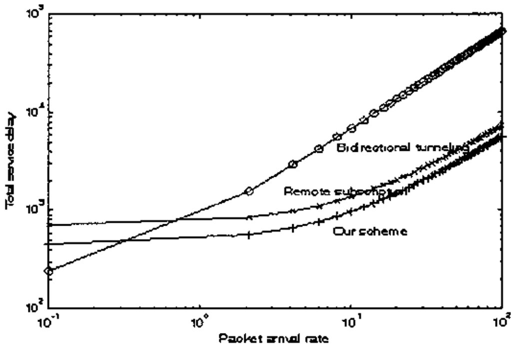

Fig 6. Comparison of total service delay under packet arrival rate

The figure 6 shows total service delay of three mechanisms. Because there is no need a new join and graft to the multicast tree but a tunneling delay exists in the bidirectional tunneling mechanism, when the packet arrival rate is low, the bidirectional tunneling is more efficient than two mechanisms But, our scheme has the lower delay in the high packet arrival rate. Our scheme can reduce a 17% delay time than a remote subscription and maximum 75% delay time than a bidirectional tunneling

## V. Conclusion

The IETF Mobile IP provides two approaches to provide multicast in mobile environment, which are remote subscription and bi-directional tunneling. The former always provides an optimal route but it has a delay resulted from join and graft. The latter provides a transparency to the multicast host but it has a not-optimal route. We used a remote subscription in the aspect of routing efficiency. We exploited the movement pattern of mobile node to reduce the total number of experience of graft and join We defined the locality scope by a movement pattern While the network is included in the locality scope, the network should maintain a multicast tree In this way, the mobile host can receive a multicast service without a delay when it moves to the network in the locality scope

By using a discrete analytical model for cost analysis, we compare our scheme with existing schemes under the total signaling cost and the service delay time Analytical results demonstrated that the total processing cost and service delay time was significantly reduced through our proposed scheme

## REFERENCE

[1] C. Perkins, "IP Mobility support," Internet RFC 2002, Oct. 1996.

[2] G. Xylomenos and G Polyzos, "IP Multicast for Mobile Hosts," IEEE Communications Magazine, Jan. 1997.

[3] Harrison, T.G., Williamson, C.L. mackrell, and Bunt, R. B, "Mobile Multicast (MoM) protocol: multicast support for mobile hosts," In Proc. 3rd Annual ACM/IEEE conf. Mobile Comp and Networks, 26-30 September, pp. 151-160.

[4] Fenner, W., "Internet group management protocol, Version 2," RFC 2236.

[5] Pusateri, T., "Distance vector multicast routing protocol," Internet Draft, 1999.

[6] G. Cho, L.F. Marshall, An efficient location and routing scheme for mobile computing environment, IEEE J. Select. Areas Commun. 13 (5) (1995) 868-879.

[7] R. Jain, et al., A caching strategy to reduce network impacts of PCS, IEEE J. Select. Areas Commun. 12 (8) (1994) 1434-1444.

[8] V. Chikamane and C. L. Williamson, "Multicast Support for Mobile Host using Mobile IP: Design Issues and Proposed Architecture," ACM/Baltzer Mobile Networks and Applications, 1998, pp.365-379.

[9] S. Deering, "Host Extensions for IP Multicasting," Internet RFC 1112, Aug, 1989.

[10] Ajay Bakre and B.R. Badrinath, "I-TCP: Indirect TCP for mobile hosts," Tech. Report DCS-TR-314, Computer Science Depart-ment, Rutgers Univ., Piscataway, N.J., 1994.

[11] Ramon Caceres and Venkata N. Padmanabhan, "Fast and Scalable Handoffs for wireless internetworks," ACM Mobicom '96, November 1996.

[12] Cheng Lin Tan, Stephen Pink, and Kin Mun Lye, "A Fast Handoff Scheme for wireless networks," WoW-MoM '99, 1999.

[13] Kuang-Hwei Chi, Chien Tseng and Ting-Lu Huang, "A framework for Mobile Multicast using Dynamic Route Reconstructions," the computer journal, vol. 42, No. 6, 1999.

**성수련(Sulyun Sung)** 정회원

2000년 2월 : 숭실대학교 컴퓨터학과졸업

2002년 2월 : 숭실대학교 컴퓨터학과 석사 졸업

2002년~현재 : 숭실대학교 컴퓨터학과 박사과정

<관심분야> Ad-hoc/Sensor Network, Mobile IP, Multicast, QoS

**전진영(Jinyoung Jung)** 학생회원

2003년 2월 : 숭실대학교 컴퓨터학과졸업

2003년~현재 : 숭실대학교 컴퓨터학과 석사과정

<관심분야> Ad-hoc/Sensor Network, Mobile IP, Multicast, QoS

**서유화(Yuhwa Seo)** 학생회원

2003년 2월 : 숭실대학교 컴퓨터학과졸업

2003년~현재 : 숭실대학교 컴퓨터학과 석사과정

<관심분야> Ad-hoc/Sensor Network, Mobile IP, Multicast, QoS

**신용태(Yongtae Shin)** 정회원

한국통신학회논문지, 제29권, 제 2C호 참조