무선 이동 망 환경에서 자원 예약 비용 성능 모델링

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Performance Modeling of Resource Reservation Cost in Wireless/Mobile Networks

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요 약

본 논문에서는 HMRSVP(Hierarchicl Mobile ReSource reserVation Protcol)[3,4]에서 확장된 새로운 이동 클러스 기반의 HMRSVP(MC-HMRSVP: Mobile Cluster based HMRSVP) 기법을 제안한다. MC-HMRSVP는 이동 호스트(MH:Mobile Host)가 현재 이동 에이전트(Mobile Agent) 지역에 도착할 경우 해당 지역은 active 예약을 하고 이웃한 MA는 passive 예약을 한다. 여기서 active MA와 passive MA 지역을 이동 클러스터(Mobile Cluster) 또는 가상 클러스터라 부른다. MC-HMRSVP는 또한 MH가 다른 MA로 이동하는 것에 관계없이 GMA(Gateway Mobile Agent) 기능에 의해 이동클러스터를 설정한다. 본 연구에서는 자원 예약 비용 관점에서 기존에 제안되어진 HMRSVP extension들과 성능 비교를 위해 단순한 재귀 방정식을 이용한 자원 예약 비용 분석 모델을 만들었다. 결과적으로 MC-HMRSVP 기법이 낮은 예약비용을 나타내는 것을 보았다.

ABSTRACT

We propose a new resource reservation scheme called MC-HMRSVP (Mobile clustering based-Hierarchical Mobile ReSource reserVation Protocol) that is an extension of HMRSVP[3,4]. MC-HMRSVP always establishes a virtual cluster called Mobile Cluster, which includes its immediately adjacent MA(Mobile Agent)s for passive reservation as well as the current MA for active reservation to which MH(Mobile Host) belongs. Our scheme also establishes the MC regardless of intra/inter region movement by GMA(Gateway Mobile Agent) function when a MH moves. To provide a general formulation on analyzing the performance in terms of reservation cost, we also model the resource reservation cost by using a simple recursive equation. Then, we show that our scheme decreases the reservation cost in comparison with the existing HMRSVP extensions.

I. introdution

Mobile ReSource reserVation Protocol (MRSVP)[2], as an extension to conventional RSVP, overcomes the impact of mobility on RSVP[1] by making advance resource reservations, namely passive reservations, in all subnets. Unfortunately, these excessive resource reservations may waste bandwidth and degrade the network performance. Hierarchical MRSVP (HMRSVP)[3], a modification to MRSVP, makes an advance resource reservation only when the handoff delay tends to be long. However, it may not be able to guarantee seamless intra region handoffs a wireless mobile support network size increases. Also, the pointer forwarding scheme[4] as an extension of HMRSVP, which makes an advance resource reservation only one-step forwarding in its path from an

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MH(Mobile Host). Although this scheme has a merit of decreasing the advance resource reservation cost, it also has the drawback of possibly a long active reservation path as the MH moves further away from its entry point.

In this paper, we proposed new HMRSVP extension, namely MC-HMRSVP, which make advance reservation path by using mobile clustering scheme. Here, we define the active MA(Mobile Agent) as the current MA to which the mobile belongs and passive MAs as the MAs that are immediately adjacent to the active MA. Such reservation regions are referred to as a mobile cluster (MC). Also, gateway mobile agent(GMA), which take care of several MAs, is performing the access point for tunneling with exterior network and manage a mobile cluster for a active MH with neighbor GMA. Therefore, a mobile cluster makes an advance reservation regardless of intra GMA movement and inters GMA movement.

To provide a general formulation on analyzing the performance in terms of reservation cost, we also model the resource reservation cost for each HMRSVP schemes by using a simple recursive equation and compare our scheme with the resource reservation schemes for the unicast and multicast cases in HMRSVP. Consequently, we show that our scheme decreases the reservation cost when the service rate is high and the handoff rate is high.

This paper is organized as follows. Section II summarizes the HMRSVP extensions. Section III describes the performance analysis model for calculating the resource reservation cost, which considers user mobility and service rate. Section IV provides numerical results. Finally section V concludes the paper.

II. HMRSVP Extension

Recently there have been some works addressing the problem of providing QoS to mobile hosts. In this section, we describe three schemes that are extended from the HMRSVP in order to resolve the impacts of MH's mobility on RSVP in mobile networks[4] and propose our scheme.

HMRSVPm represents an extension of HMRSVP using multicast scheme on the wireless Internet as shown in Fig. 1. The HMRSVPm makes an advance resource reservation (ARR) on all the branches of the tree topology from the sender under the multicast approach[4].

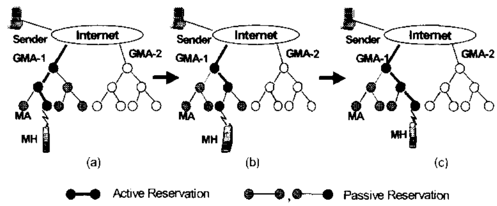


Fig. 1. Multicast based HMRSVP

HMRSVPu represents an extension of HMRSVP using unicast scheme on the wireless Internet. The HMRSVPu makes an ARR only two passive paths from a router or host to the two neighboring MA's of the current visited MA, in which the router or host is the least common ancestor of the two neighboring MA's[4].

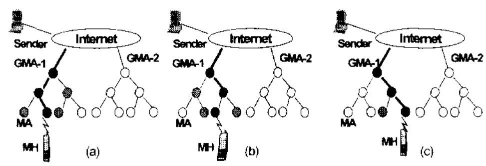


Fig. 2. Unicast based HMRSVP

The above suggested schemes includes the following problems:

- The seamless handoff guarantee problem regardless of the inter/intra region movement (HMRSVPm ,HMRSVPu)
- The excessive signaling overhead

(HMRSVPm)

In order to the above problems, we propose the MC-HMRSVP as followings:

HMRSVPmc makes advance resource a reservation for inter GMA as well as two passive paths from a router or host to the two neighboring belongs to a GMA. As shown in Fig. 3, the root node of binary network topology is GMA and the bottom nodes connected to a GMA are MAs. The determination of which MAis passive or active when a MH is originated is determined by GMA. GMA is responsible for performing the Mobile IP regional tunneling for all the mobile hosts in the subnet as HMRSVP.

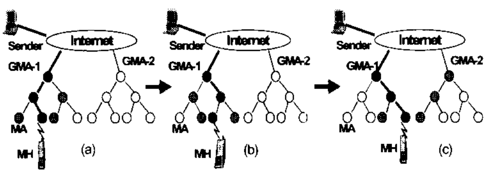


Fig. 3. MC based HMRSVP

In Fig. 3(a)-(b), MH is located in the predictive region for an intra region (or cluster) handoff. However, MH in (c) is located in the predictive MA for an inter region handoff. With these viewpoints, the decision of scope for an ARR is determined by the assumption of GMA function as follows:

- A number of MAs are grouped in one cluster called fixed cluster and these MAs are managed by GMA .
- GMA is an agent that represents one cluster and act by CoA (Care of Address) of all FA(Foreign Agent)s that exist on lower part. That is, act to all lower part MA tunneling point.
- GMA provides the functions of QoS mapping/inter-working between external Internet and wireless/mobile sub network. Here, external Internet can or cannot support RSVP protocol.
- We also assume the GMA can determine or maintain the scope of reservation, that is Mobile Cluster, for the ongoing MH under its own sub network, which is possible by sharing the sub network information of the neighboring GMAs as well as its own sub network. This assumption also implies that our scheme decreases the reestablishment cost for the new resource reservation when a MH handoff to the MA belonging to a neighboring GMA.

III. Performance Analysis

1. The Resource Reservation Cost

To provide a general formulation in terms of the resource reservation cost(RRC) per each MH in a MA, the wireless/mobile Internet environment is assumed to be a binary tree network topology as shown in Fig. 4. In this section, we consider the RRCs with those of the HMRSVPm, HMRSVPu and HMRSVPmc considering both direction of MH movement.

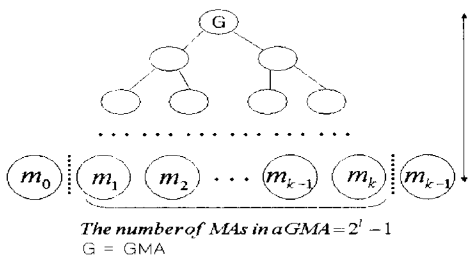


Fig. 4. Binary tree network topology connected a GMA

Referring to Fig. 4, we denote m_i as MAi for $\{0, 1, 2, \ldots, k-1, k, k+1\}$. A GMA consists of the set of MAs $\{m_{1,\ldots,}m_k\}$, which is symmetric. According to the location of the current MA, we also decide the inter/intra region movement for the ARR according to the outer or inner location of the GMA. Therefore, we can define

$\{m_k, m_1, m_k, m_{k+1}\}$ for inter movement and $\{m_2, \ldots, m_{k-1}\}$ for intra movement.

To describe this cost model, we define the following parameters:

l : The hierarchical network level of the binary tree.

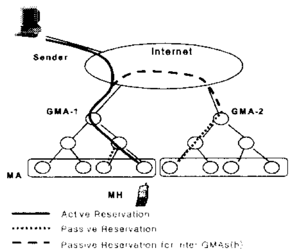
α : The resource reservation cost that the reservation path length is one between two neighboring nodes among the nodes branching from the root GMA to the bottom MAs.

θ : The ratio of the cost of a passive reservation path and the cost of active reservation path; θ can be referred to as reservation overhead($0 \le \theta \le 1$).

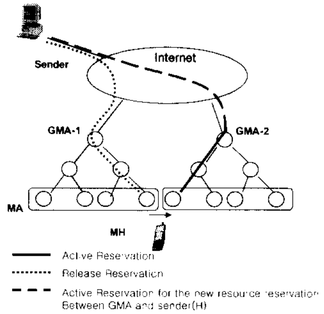
h : The ARR(Advance Resource Reservation) cost between the current GMA and the target GMA as shown in Fig. 5(a).

H : The new resource reservation (NRR) cost for reestablishment between the target GMA and HA (or CH (Correspondent Host)) when MH occurs in the inter-domain handoff as shown in Fig. 5(b). This cost depends on the state of core network (wired Internet)

$r_{i,j}$: The RRC of a MH, which is in MA j for j given its initial MA is i for i. HMRSVP extensions, r_{ij} depend only on j.



(a) The ARR cost (h)



(b) The NRR cost (H) for the reservation reset

Fig. 5. The depiction of the parameters (h, H)

● The Multicast-HMRSVP

Define r_{ij} is the RRC in MA j given its initial MA is i for $i, j = \{1, \ldots, k\}$.

In each scheme, the RRC r_{ij} for a MH consists of the active cost and passive cost as Eq. (1). This is referred in[4]

$$r_{i,j} = Cost_{active} + Cost_{passive} \qquad (1)$$

For HMRSVPm, the $Cost_{active}$ is $(l-1)\alpha$ and $Cost_{passive}$ is determined by the location of the MA movement as shown in Eq. (2, 3).

$$r_{ij} = \begin{cases} (l-1)\alpha + (2^l - l - 1) \cdot \theta \cdot \alpha, (2 \le i \le k-1) \text{ intra movement} & (2) \\ (l-1)\alpha + (2^{l+h} - l - 1) \cdot \theta \cdot \alpha, (i = \{1, k\}) \text{ inter movement} & (3) \end{cases}$$

Then we can obtain the column vector r_i with NRR as shown in Eq. (4). In this case, the ARR parameter(h) is not considered as following.

$$r_1 = \{r_{i,j}\} = \begin{matrix} (l-1)\alpha + (2^l - l - 1) \cdot \theta \cdot \alpha \\ \vdots \\ (l-1)\alpha + (2^l - l - 1) \cdot \theta \cdot \alpha \end{matrix} \qquad (4)$$

where $\mathbf{r}_i = \{r_{i,j}\} = \begin{bmatrix} (l-1)\alpha + (2^l + h - l - 1) \cdot \theta \cdot \alpha \\ (l-1)\alpha + (2^l - l - 1) \cdot \theta \cdot \alpha \\ \vdots \\ (l-1)\alpha + (2^l - l - 1) \cdot \theta \cdot \alpha \\ (l-1)\alpha + (2^l + h - l - 1) \cdot \theta \cdot \alpha \end{bmatrix}$ is a column vector and the matrix is used for the average reservation cost in a MA as shown in section 3.2

$$R^{(m)} = [r_1 \cdots r_k]^T \quad (5)$$

● The Unicast-HMRSVP

When the MH exists in the intra movement region, we obtain the maximum and minimum $r_{i,j}$ in the following Eq.(6, 7). This is referred in[4]

Maximum

$$r_{i,j} = (l-1)\alpha + l \cdot \theta \cdot \alpha \quad (2 \le i \le k-1) \quad (6)$$

Minimum

$$r_{i,j} = (l-1)\alpha + \theta \cdot \alpha \quad (2 \le i \le k-1) \quad (7)$$

Therefore, we obtain the $r_{i,j}$, in the following.

$$r_{i,j} = (l-1)\alpha + \theta \cdot \alpha \le r_{i,j} \le (l-1)\alpha + l \cdot \theta \cdot \alpha, \quad (2 \le i \le k-1) \text{ Intra movement} \quad (8)$$

where $\mathbf{r}_i = \{r_{i,j}\} = \begin{bmatrix} (l-1)\alpha + \theta \cdot \alpha \\ \vdots \\ (l-1)\alpha + l \cdot \theta \cdot \alpha \\ (l-1)\alpha + l \cdot \theta \cdot \alpha \\ \vdots \\ (l-1)\alpha + \theta \cdot \alpha \end{bmatrix}$ is a column vector and the matrix is used for the average reservation cost in a MA as shown in section 3.2

The RRC of HMRSVPu, $R^{(u)}$ is defined as

$$R^{(u)} = [r_1 \cdots r_k]^T \quad (9)$$

● The MC-HMRSVP

When the MH exists in the intra movement region, we obtain the maximum and minimum r_{ij} in the following Eq.(10).

$$(l-1)\alpha + 3\theta \cdot \alpha \le r_{i,j} \le (l-1)\alpha + l \cdot \theta \cdot \alpha, \quad (2 \le j \le k-1) \quad (10)$$

Also, $r_{i,1}$ and $r_{i,k}$ for inter-region movement are obtained with the ARR cost (h) between the current GMA and the target GMA when the MH expects the inter region handoff. Finally, we obtain $r_{i,j}$ as shown in Eq.(11).

$$r_{i,j} = \begin{cases} (l-1)\alpha + 3\theta \cdot \alpha \le r_{i,j} \le (l-1)\alpha + l \cdot \theta \cdot \alpha, \\ (2 \le j \le k-1) \qquad \text{intra movement} \\ (l-1)\alpha + (l+h+1) \cdot \theta \cdot \alpha, \\ (j = 1, k) \qquad \text{inter movement} \end{cases} \quad (11)$$

The RRC of HMRSVPmc, $R^{(mc)}$, is defined as

$$R^{(mc)} = [\mathbf{r}_1 \quad \cdots \quad \mathbf{r}_k]^T \quad (12)$$

where $\mathbf{r}_i = \{r_{i,j}\} = \begin{bmatrix} (l-1)\alpha + (l+h+1) \cdot \theta \cdot \alpha \\ (l-1)\alpha + 3\theta \cdot \alpha \\ \vdots \\ (l-1)\alpha + l \cdot \theta \cdot \alpha \\ (l-1)\alpha + l \cdot \theta \cdot \alpha \\ \vdots \\ (l-1)\alpha + 3\theta \cdot \alpha \\ (l-1)\alpha + (l+h+1) \cdot \theta \cdot \alpha \end{bmatrix}$ is a column vector and the matrix $R^{(mc)}$ is used for the average reservation cost in a MA as shown in section 3.2.

2 Mobility modeling the HMRSVP extensions

In this section, we design the mobility model for performance analysis, which is used for the calculation of the average resource reservation cost in each HMRSVP extension. We assume that the call service time of MH in a MA is exponentially distributed with the mean $1/\mu$ and the movement time inter-MAs are exponentially distributed with the mean $1/\mu_d$. Therefore, we can obtain the pdfs of $f_X(x) = \mu e^{-\mu x}$ and $f_D(\tau) = \mu_d e^{-\mu \tau}$.

Using these pdfs, we can derive the average resource reservation cost for each HMRSVP schemes when a MH is originated in a MA as followings.

● The Multicast-HMRSVP

Using Eq(1~5), we can obtain the average resource reservation cost for HMRSVPm ($C(i)$) as followings :

Case 1: $2 \le i \le k-1$

Let $C(i)$ be the average reservation cost for a MH in a MA. When the MH exists in the region of intra movement region, $C(i)$ is

$$C(i) = \int_0^{\infty}\int_0^{\tau} (x \cdot r_{i,j})\, f_X(x)\, f_D(\tau)\, dx\, d\tau + \int_0^{\infty}\int_{\tau}^{\infty} \left(x \cdot r_{i,j} + \frac{1}{2}(C(i-1) + C(i+1))\right) f_X(x)\, f_D(\tau)\, dx\, d\tau$$

$$= \frac{1}{\mu} r_{i,j} + \frac{\mu_d}{2(\mu + \mu_d)}(C(i-1) + C(i+1)) \quad (13)$$

for $i, j = \{1, \ldots, k\}$

Case 2: $i = 1, k$:

Similarly, using Eq.(5), we can evaluate the average reservation cost with the NRR inter GMAs as shown in Eq. (4.16)

$$C(i) = \frac{1}{\mu} r_{i,j} + \frac{\mu_d}{2(\mu + \mu_d)}(C(i-1) + C(i+1) + H \cdot \alpha) \; with NRR \quad (14)$$

● The unicast-HMRSVP

Using Eq.(6~9), we can obtain the average reservation cost for HMRSVPu

Case 1: $2 \le i \le k-1$

$$C(i) = \frac{1}{\mu} r_{i,j} + \frac{\mu_d}{2(\mu + \mu_d)}(C(i-1) + C(i+1)) \quad (15)$$

Case 2: $i = 1, k$

$$C(i) = \frac{1}{\mu} r_{i,j} + \frac{\mu_d}{2(\mu + \mu_d)}(C(i-1) + C(i+1) + H \cdot \alpha) \; with NRR \quad (16)$$

● The MC-HMRSVP

Using Eq.(10~12), we can obtain the average reservation cost for HMRSVPmc

Case 1: $2 \le i \le k-1$

$$C(i) = \frac{1}{\mu} r_{i,j} + \frac{\mu_d}{2(\mu + \mu_d)}(C(i-1) + C(i+1)) \quad (17)$$

Case 2: $i = 1, k$

$$C(i) = \frac{1}{\mu} r_{i,j} + \frac{\mu_d}{2(\mu + \mu_d)}(C(i-1) + C(i+1)) \quad (18)$$

Defining $R = \{R^{(m)}, R^{(u)}, R^{(mc)}\}$ and $C = \{C(1), \ldots, C(k)\}$, we obtained the simple recursive equations as shown in Eq.(15~18).

Also, let A be the average reservation cost of the all MAs in a GMAfor each HMRSVP extensions, $A = \{A_m, A_u, A_{mc}\}$.

Here, the A for each HMRSVP extensions can be obtained by the following matrix equations in Eq.(19).

$$\begin{bmatrix} -1 & \frac{\mu_d}{2(\mu+\mu_d)} & 0 & \cdots & 0 & \frac{\mu_d}{2(\mu+\mu_d)} \\ \frac{\mu_d}{2(\mu+\mu_d)} & 1 & \frac{\mu_d}{2(\mu+\mu_d)} & 0 & \cdots & 0 \\ 0 & \frac{\mu_d}{2(\mu+\mu_d)} & 1 & \cdots & \cdots & \cdots \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ \cdots & \cdots & \cdots & 1 & \frac{\mu_d}{2(\mu+\mu_d)} & 0 \\ 0 & \cdots & 0 & \frac{\mu_d}{2(\mu+\mu_d)} & 1 & \frac{\mu_d}{2(\mu+\mu_d)} \\ \frac{\mu_d}{2(\mu+\mu_d)} & 0 & \cdots & 0 & \frac{\mu_d}{2(\mu+\mu_d)} & 1 \end{bmatrix} \begin{bmatrix} C(1) \\ C(2) \\ \vdots \\ C(k-1) \\ C(k) \end{bmatrix} = \begin{bmatrix} \frac{r_1}{\mu} \\ \frac{r_2}{\mu} \\ \vdots \\ \frac{r_{k-1}}{\mu} \\ \frac{r_k}{\mu} \end{bmatrix}$$

$$M(k,k)\,C(k,1) = r(k,1) \quad (19)$$

Using Eq.(4.19), we finally obtain

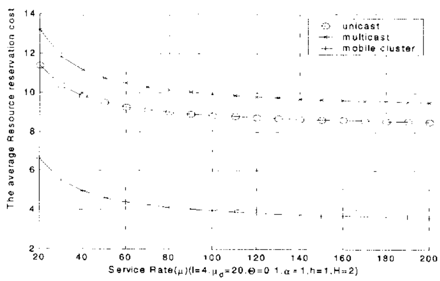
$$C = M^{-1} r \text{ and } A = \sum_{i=1}^{k} C(i)/k,$$

$$k: a \;\; number\ of\ MAs\ in\ a\ GMA \quad (20)$$

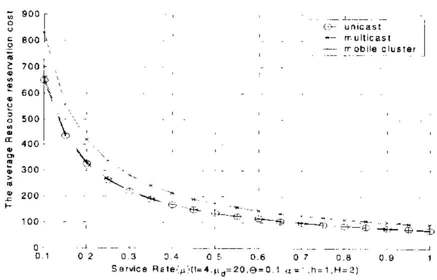
Ⅳ. Numerical Results

To compare the existing HMRSVP extensions with our MC-HMRSVP, we use the average reservation cost for the total MAs in a GMA with the following parameters: the layer size of binary tree (l)=0.1~1, service rate μ: 0.1~1 for long service time, 20~200 for short service time, handoff rate μ_d: 0.1~1 for long handoff time, 20~200 for short handoff time, α=1, θ=0.1~1, h=1 or 2, H=1~5.

In Fig. 6, we first examine the average reservation cost as increasing the service rate. As the service rate increase, the values of the A_m, A_u, A_{mc} have a tendency to decrease. In case of short service time, the A_{mc} there presents the lowest value among the HMRSVP extensions as shown in Fig. 6(a). In the results of case Fig. 6(b), the mobility of MH decrease as the service time decrease, therefore, the A_m and A_{mc} shows almost same tendency. This implies that the reservation cost for the MH has a significant influence by MH mobility.



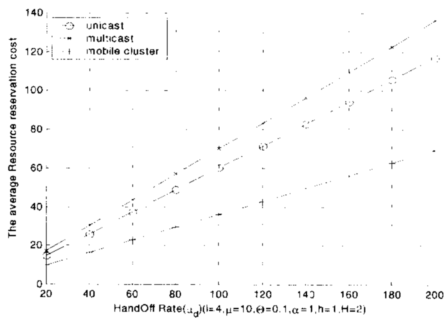
(a) In case of short service time $(1/\mu)$



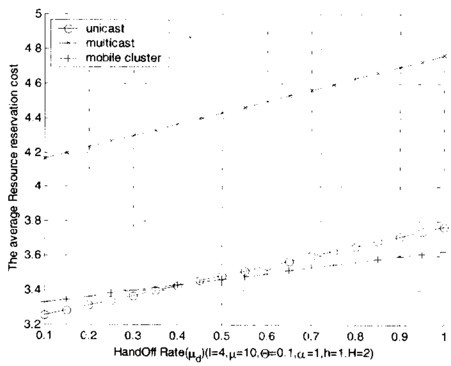
(b) In case of long service time $(1/\mu)$

Fig. 6. The average Reservation Cost vs. Service time.

In Fig. 7, we observe how the increase of handoff rate affects the reservation cost under the fixed service rate. Similarly, when the handoff rate is high, that is, the handoff time is small, the A_{mc}represents the lowest value among the HMRSVP extensions as shown in Fig. 7(a). When the handoff rate is small, the $A_u$and A_{mc}curves have a similar tendency as shown in Fig. 7(b). The reason of such a tendency is similar to the results obtained in Fig. 6.



(a) In case of short handoff time$(1/\mu_d)$



(b) In case long handoff time$(1/\mu_d)$

Fig. 7. The average Reservation Cost vs. HandOff time

In Fig. 8, we observe the A_m, A_u, A_{mc} by increasing the number of layer of the binary tree. In this result, the A_{mc} and A_u curves converge on the same point as the layer increase. This fact explains our scheme performs relatively well at a small network $(l \leq 5, k \approx 2^4)$ in comparison with HMRSVPu. The result of HMRSVPm shows the worst in a large size of network $(l \geq 5)$).

In this case, we can see the network size is a significant factor for the resource reservation.

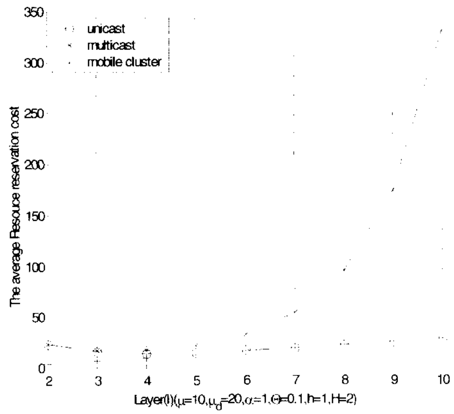


Fig. 8. The average reservation cost vs. Layer Size

In Fig. 9, we shows that the average res ervation cost of the A_m and A_u have a similar tendency as the penalty cost (H) increase. The NRR (new resource reservation) cost (H) is needed for the reestablishment path when a MH moves to the neighbor GMA and can be decided by the network reliability and network speed for the high-speed traffic transfer. In Fig. 10, the A_m is significantly higher than those of the A_u and A_{mc} showing the similar tendency as the reservation overhead (θ) incases.

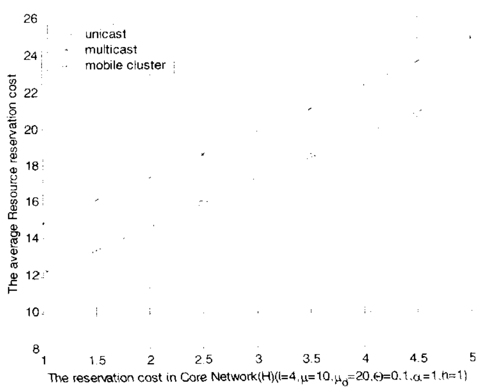


Fig. 9.The penalty cost (H)

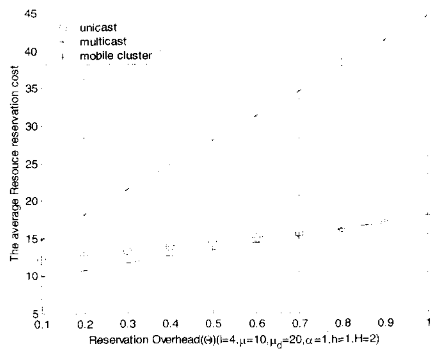


Fig. 10. The reservation overhead (θ)

V. Conclusions.

In this paper, we proposed a new reservation scheme called MC-HMRSVP, which is an extension of the HMRSVP[3,4]. In our results, we show that mobile cluster based HMRSVP performs well when the service rate is high and the handoff rate is high. This is because it performs advance resource reservation with the ARR cost (h) for the inter cluster movement as well as the intra cluster movement when MH handoff the neighbor MAs. We also identified that the NRR cost (H) for the reestablish path and the ARR cost (h) for advance resource res ervation inter clusters are the significant pa rameters for the resource reservation.

For the future, these two parameters will be studied in terms of the network capability of Internet and the performance issue of GMA. Also, a major problem of MC-HMRSVP will be its applicability in the current network infrastructure. It is required that relevant routers of the underlying network is aware of MC-HMRSVP, otherwise the control traffic will be very high and will even affect the best-effort performance.

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