韓國 컴퓨터情報學會 論文誌
第12卷 第5號, 2007. 11.

2007-12-5-2-2

이동 IP 망에서의 최적 이웃 스코프 값 기반의 위치 등록 방법

서 봉 수*

Optimal Neighbor Scope-Based Location Registration Scheme in Mobile IP Networks

Bongsue Suh *

요 약

이동 IP 네트워크에서 이동 단말의 망 접점의 잦은 변경은 네트워크에 오버헤드를 증가시킨다. 본 논문에서는 이런 문제를 해결하기 IP 지역 등록방법[1]에 동적인 스코프 값을 부여하는 계층적 방법을 제안한다. 만약 이동 단말이 스코프 값으로 정해진 이웃 영역내의 방문 에이전트 간을 이동할 경우에는 홈 등록을 수행하지 않고 지역적인 위치 등록만 실행한다. 제안하는 방법의 수학적인 분석과 수치적 비교를 수행하였으며, 결과적으로 최적화된 스코프 값을 이용한 계층적 구조의 제안 방법을 적용할 경우 표준의 이동 IP 프로토콜의 위치 등록 기법[2]에 비하여 뚜렷한 비용 감소 효과를 얻을 수 있다. 이는 영역 내에서의 이동시 지역 내 등록만으로 위치 등록을 완료하기 때문이다. 특히 홈 에이전트로의 신호 비용이 증가할수록 제안하는 방법이 더 유리함을 보여준다.

Abstract

The mobile terminal's frequent changes to the access point introduce significant network overhead in mobile IP networks. To solve this problem, we introduce a hierarchical structure with consideration given to the dynamic value of neighbor scope in IP regional registration[1]. When a mobile terminal moves within the neighbor given by the scope value, it makes registration locally without registration with its home agent. We analyze the algorithm mathematically and show the numerical results. As a result, optimization of the scope value for the localized registration under the hierarchical structure makes the proposed scheme outperform the standard mobile IP protocol[2]. This can be explained from the fact that there is only local registration for terminal's movement within the scope region. Moreover, as the signaling cost for home agent increases, the proposed scheme becomes more advantageous.

▸ Keyword : IP 지역 등록(IP Regional Registration), 최적 네이버 영역 값(Optimal Neighbor Scope), 모바일 IP(Mobile IP)

• 제1저자 : 서봉수
• 접수일 : 2007. 9.2, 심사일 : 2007. 10.1, 심사완료일 : 2007. 11.10.
* 공주대학교 정보통신공학부 부교수
※ 이 논문은 2004년도 안동대학교 학술연구조성비에 의하여 연구되었음

Ⅰ. 서 론

Mobile IP (Internet Protocol) supports a mechanism for terminal's roaming within the Internet [1][2][3]. A mobile terminal changes its point of access to the network without changing its IP addresses. This can be done by terminal's home agent(HA), foreign agent(FA), and the relating protocol between them.

However, the mobile terminal's frequent changes to the access point in mobile IP networks introduce significant network overhead in terms of increased delay, packet loss, and signaling [4][5][6]. This problem becomes more serious as the terminal's movement degree and the distance between the HA and the FA increase.

To solve this problem, there have been many algorithms and protocols. The Cellular IP protocol [6] provides the location management and handoff within the routing functions. The access terminals in Cellular IP network keep the hop-by-hop routing information to the mobile terminals by using the mobile-originated data packets. Hence, when a mobile terminal changes its access point and does not originate data packets, the routing information becomes invalid. In this case, IP paging will be made to deliver the mobile terminal-terminated data. When the access point of the mobile terminal is known from re-routing procedure, the location information is updated.

The HAWAII protocol [7] provides a separate routing protocol to handle the localized mobility. When a mobile terminal enters a new foreign domain, a new care-of-address is assigned and the home agent keeps this information. While the mobile terminal changes its access point within the given foreign domain, it does not change its care-of-address. Thus, the home agent gets involved for the movement between the foreign domains only.

Recently, in IP regional registration protocol [1], a new concept of foreign agent, called Gateway Foreign Agent (GFA), was defined in hierarchical manner to localize the registration made by mobile terminal's change of position. Since the care-of-address registered to home agent is the address of GFA, the home agent will not change mobile terminal's information when the mobile terminal changes foreign agent under the same GFA. For this purpose, the extensional aspects to the standard IP mobility, such as extended formats of agent advertisement message and registration message are proposed.

These protocols proposed so far have some common facts that they localized the registration under the foreign network to reduce the overhead caused by the signaling message, delay, and the processing load related to the home agent. However, the performance of these schemes can be increased by using information of the mobile terminal-specific characteristics. For example, the hop number from the home agent to the foreign agent, current traffic load on the network, and the movement trend of the mobile terminals can be used for optimization of the localized registration.

In this paper, we propose a localized registration scheme similar to [1]. The difference from [1] is that the proposed scheme uses the dynamic scope value to restrict the area of local registration. We show that the optimal size of the neighbor can be determined by making use of the mobile terminal's trend and its distance from home agent, which can reduce the expected registration cost significantly compared to the mobile IP protocol[2].

This paper is organized as follows. The proposed scheme based on the variable neighbor scope on the hierarchical structure is described in Section II. In Section III, the mathematical analysis and numerical comparison are carried out. Finally, in Section IV, conclusions are derived.

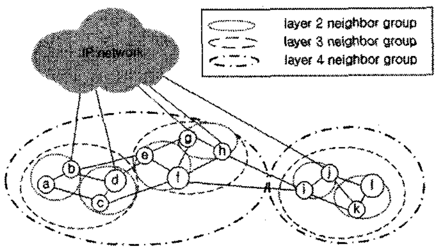

그림 1. FA들의 물리적 연결 상태
Fig 1. Physical connections between FAs

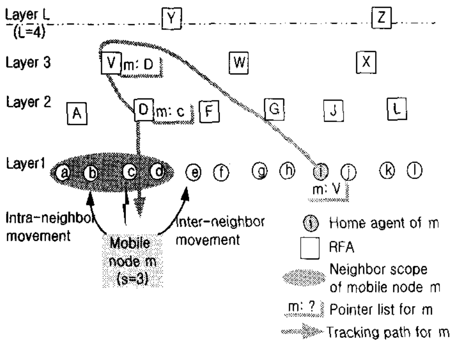

그림 2. FA들의 논리적 계층 구조
Fig 2. Logical and hierarchical structure of FAs

II. Proposed scheme for local registration

2.1 Registration information

An example of IP mobile networks consisting of a number of foreign agents (FAs) is shown in Fig. 1. The foreign agents on layer 1 are physically connected in arbitrary topology. A number of foreign agents are grouped into a layer 2 neighbor groups, which are depicted as the dotted eclipse. A representative foreign agent (RFA) is elected among the foreign agents within a layer 2 neighbor group. In the same manner, one of the foreign agents within a layer n neighbor group is elected as a layer n RFA. Any foreign agent can be an RFA of neighbor group of layer L.

A resulting hierarchical structure composed of the layer 1 foreign agent and their RFAs are shown in Fig. 2. The connecting lines among the foreign agents and RFAs are tunneling links made by the logical RFA election method.

According to the proposed scheme, a mobile terminal has a scope value (denoted by s) that restricts the area of its neighbor. The neighbor of a mobile terminal with s is composed of the foreign agents within mobile terminal's layer s neighbor group. For example in the Fig. 2, the neighbors of the mobile terminal m with s=3 are the foreign agents 'a', 'b', 'c', and 'd'.

When a mobile terminal moves first into a foreign domain, it performs home registration as in IP mobility protocol defined in [2]. The difference from the standard mobile IP protocol is that the home agent has the address of layer s RFA under which the mobile terminal resides, instead of mobile terminal's care-of-address. In addition to home registration, there occurs a local registration by the procedure that the foreign agent of a mobile terminal transmits the registration message up to layer s RFA.

As a result, the foreign agents from layer s RFA to layer 1 FA of the mobile terminal contain the linked pointer list for the mobile terminal. For example, we assume that a mobile terminal m with s=3 in Fig. 2 is residing under foreign agent 'c'. Then, the terminal 'i', the home agent of m, has the list of 'm:V'. And the terminal 'V' and 'D', the RFAs of m, have the pointer list as shown in the figure. The pointer list information makes the linked chain from the home agent to the layer 1 foreign agent of the mobile terminal.

2.2 Registration update

The pointer list is updated in minimum as the mobile terminal moves within its neighbor. When a mobile terminal moves between the foreign agents within its neighbor scope (we refer to this as an intra-neighbor movement), it does not perform home registration. Instead, it performs local registration as follows.

First, the mobile terminal sends a local registration message that contains the mobile's care-of-address, mobile's scope value, and the address of the previous foreign agent. Second, the new foreign agent assigns a new care-of-address to mobile terminal and forwards the registration message up to the higher RFA with the new care-of-address added. Finally, the message is transferred to the common RFA of the old foreign agent and the new foreign agent. The RFAs on above route update the pointer list so that their pointer list specifies the new tunneling link for the mobile terminal.

When a mobile terminal moves between the foreign agents of the different neighbor group (we refer to this as inter-neighbor movement), it performs home registration. The home agent updates the mobile terminal's information with the address of the new layer s RFA of the mobile terminal.

III. Performance evaluation

We note that the signaling load and delay increase considerably as the distance between mobile terminal's home agent and foreign agent increases. For this reason, each mobile terminal should be assigned an optimal neighbor scope respectively depending on the characteristics of the mobile terminal to minimize the expected registration cost. Our proposed scheme considers two factors to determine the optimal scope value: the mobile terminal's movement trend and the distance from the home agent.

3.1 Mathematical analysis

We evaluate the expected registration cost and determine the optimal neighbor scope value to minimize the cost. For the performance evaluation, we consider the following assumptions:

- The inter-FA movement of the mobile terminal where the common RFA of the old FA and the new FA is located on layer i is called layer i movement. The probability that a mobile terminal makes a layer i movement, pi, is given for i = 2, 3, … , L.
- Since the processing cost of a database is generally proportional to the logarithm of the number of stored objects, the processing cost at an FA or an RFA on layer i to update the pointer information for the local registration is proportional to alog N(i), where N(i) is the number of the mobile terminals registered at the agent of layer i and a is the proportional coefficient.
- As for the home registration, the unit processing cost at the HA is Hr.
- The unit signaling cost between the foreign network and the associated HA is Hs.
- We ignore the signaling cost among the agents within the mobile terminal's neighbor for the localized registration since the local registration is made within in a local area only.

According to the above assumption, Ca(s), the expected registration cost when a mobile terminal with scope s makes an intra-neighbor movement, can be derived as,

$$C_a(s) = \sum_{i=2}^{s} p_i \sum_{j=2}^{i} \alpha \log N(j). \quad \cdots (1)$$

We note that there is no cost factor relating to the home registration in Eqn. (1).

Ce(s), the expected registration cost when a mobile terminal with scope s makes an inter-FA movement, can be obtained as,

$$C_e(s) = \sum_{i=s+1}^{L} p_i \left\{ \sum_{j=2}^{s} \alpha \log N(j)_s + H_r + H_s \right\}. \quad \cdots (2)$$

From Eqn. (2), we see that Ce(s) is composed of the localized registration cost and the home registration cost. Then, the expected cost when a mobile terminal with scope s makes an inter-FA movement, denoted by CT(s), can be obtained as,

$$C_T(s) = C_a(s) + C_e(s). \quad \cdots (3)$$

Meanwhile, the expected registration cost of the standard mobile IP protocol [2], denoted by C1, can be simply obtained as,

$$C_1 = C_T(1) = H_r + H_s. \quad \cdots (4)$$

We define the cost reduction ratio as the registration cost of the proposed algorithm divided by that of the standard mobile IP protocol, denoted by CRR, can be simply obtained as,

$$CRR = C_T(s)/C_1 \quad \cdots\cdots (5)$$

표 1. 단말 이동 확률에 대한 세 가지 경우
Table 1. Three cases of movement probability of mobile terminal

Probability	Case I	Case II	Case III
p2	0.6	0.4	0.25
p3	0.2	0.3	0.25
p4	0.1	0.2	0.25
p5	0.1	0.1	0.25

3.2 Numerical results

For performance comparison and determination of the optimal scope value, we assume L = 5 and we consider three example cases of the different movement trends as shown in Table 1. Case I represents the movement trend of general case, where a mobile terminal makes the layer 2 movement relatively more frequently than others. Case II assumes that a mobile terminal makes an inter-FA movement more frequently for i = 2 and 3 than that of Case I. Case III assumes the case that might rarely occur, where a mobile terminal makes layer i movement with relatively higher value of i than that in Case I and II.

In addition, we make the following assumptions:

- a=1 and Hr= 5, whereas Hs varies from 1 to 10
- The number of mobile terminals cared by an FA is 10.
- For layer i, i 〉 2, the number of agents logically connected to a higher layer RFA is 10.

Fig. 3 shows the numerical results showing CRR versus Hs for the mobility trend of Case I. From this figure, we see that CRR decreases significantly as Hs increases. The decrement slope is steeper for the higher value of s. From this fact, we can expect that the higher value of s should be chosen for a mobile terminal that is further from its home agent. For Case I, we see that sopt, the optimal value of s to minimize C, can be achieved as follows: sopt = 2 for Hs 〈 4 and sopt = 3 for Hs〉 4.

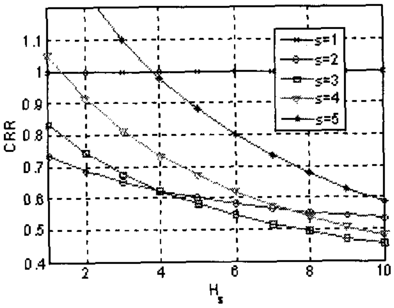

그림 3. Case I 에 대한 CRR 대 Hs 그래프
Fig 3. CRR versus Hs for Case I

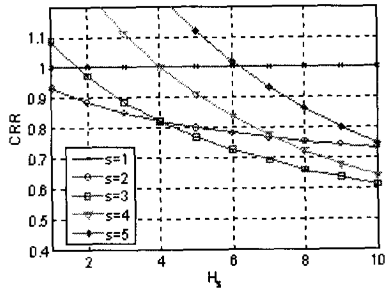

그림 4. Case II 에 대한 CRR 대 Hs 그래프
Fig 4. CRR versus Hs for Case II

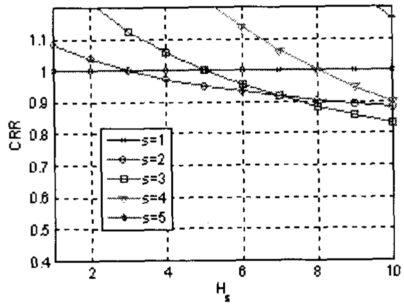

그림 5. Case III 에 대한 CRR 대 Hs 그래프
Fig 5. CRR versus Hs for Case III

Fig. 4 shows the numerical results for the mobility trend of Case II. CRR is relatively higher than that of Case I. This can be explained from the fact that possibility of making higher i layer movement increases which makes more frequent of home registration. From this figure, we see that sopt = 2 for Hs 〈 4 and sopt = 3 for Hs 〉 4.

Fig. 5 shows the numerical results for the mobility trend of Case III. From this figure, we see that sopt = 1 for Hs < 3, sopt = 2 for 3 < Hs < 7, and sopt = 3 for Hs < 7.

Table 2 summarizes sopt that minimize CRR depending on different values of Hs. for the three cases. We see that sopt increases as Hs increases. This means that it is advantageous to assign a higher scope value for a mobile terminal whose position is further away from its HA to minimize the expected registration cost. In addition, Case I has the relatively larger value of sopt than Case III, which means that the advantage from adapting optimal scope value becomes more apparent for the mobiles that have the mobility trend of making the layer 2 movement relatively more frequently (i.e., higher p2) than other movements cases.

표 2. 케이스별 Hs 에 따른 최적의 sopt 값
Table 2. sopt for three cases according to different values of Hs

Hs	Case I	Case II	Case III
1	2	2	1
3	2	2	1
5	3	3	2
7	3	3	2
9	3	3	2

IV. Conclusions

We have proposed a localized registration scheme to reduce the expected registration cost in mobile IP networks. The scope value can be dynamically determined by mobile terminal's characteristics such as the mobility trend and the distance from its home agent. When the IP networks support the proposed registration strategy in its extended form, the expected registration cost caused by the mobile terminal's movement between FAs can be dramatically reduced by adjusting the optimal scope value to each mobile terminal.

참고문헌

[1] E. Fogelstroem, A. Jonsson, C. Perkins, "Mobile IPv4 regional registration," RFC 4857, IETF (Internet Engineering Task Force), June 2007.

[2] C. Perkins, "IP Mobility Support", Internet RFC 2002, Oct. 1996.

[3] Y. J. Lee and I. F. Akyildiz, "A new scheme for reducing link and signaling costs in mobile IP," IEEE Trans. Computers, vol. 52, issue 6, June 2003.

[4] T. Poungkong and W. Benjapolakul, "A comparative analysis on signaling cost of mobile IP regional registration with paging support," IEEE Wireless Communications and Networking Conference, 2005.

[5] A. T. Campbell, J. Gomez, S. Kim, C.-Y. Wan, Z. R. Turanyi, and A. G. Valko, "Comparison of IP micromobility protocols," IEEE Wireless Commun, vol. 9, no. 1, Feb. 2002, pp. 72-82.

[6] A. G. Valko, "Cellular IP: a new approach to Internet host mobility", ACM SIGCOMM Comp. Commun. Rev., vol. 29, no. 1, 1999, pp.50-65.

[7] R. Ramjee, K. Varadhan, L. Salgarelli, S. R. Thuel, Shie-Yuan Wang, and T. La Porta, "HAWAII: a domain-based approach for supporting mobility in wide-area wireless networks," IEEE/ACM Transactions on Networking, vol. 10, issue 3, pp 396-410, June 2002.

저 자 소 개

서 봉 수

1993년 2월: 경북대학교 공학사

1995년 2월: KAIST 공학석사

1999년 8월: KAIST 공학박사

1999년 7월 ~ 2004년 2월: 한국전자통신연구원 선임연구원

2004년 3월 ~ 2005년 8월: 안동대학교 정보통신공학부 조교수

2005년 9월 ~ 현재: 공주대학교 정보통신공학부 부교수

관심분야 : 컴퓨터 네트워크, 통신 네트워크, WSN