거대한 PCN 망에서 HLR의 오버헤드 트래픽을 줄이기 위한 분산위치관리 기법

이 동 춘† · 김 점 구†† · 조 석 팔†††

요 약

본 논문에서는 거대한 PCN망에서 HLR의 오버헤드 트래픽을 줄이기 위한 분산위치관리기법을 제안한다. 제안된 기법은 수학적 분석과 시뮬레이션 분석을 통하여 복제하는 위치 정보가 작은 PCN망에서도 효율적이고 적합하다는 것을 보여준다. 또한 위치관리의 오버헤드 트래픽은 더욱 줄이기 위하여 계층환경으로 구성하여 거대한 PCN망의 규모로 확장할 수 있다. 분석 결과를 통해서 제안된 분산위치관리기법이 표준 IS-41기법 보다 우수하다는 것을 보인다.

Distributed Location Management Scheme for Reducing Overhead Traffic of HLR in Large Personal Communication Networks

Dong Chun Lee† · Jeom Goo Kim†† · Sok Pal Cho†††

ABSTRACT

In this paper we describe a distributed location management scheme to reduce the bottleneck problem of HLR in Large Personal Communication Networks (LPCNs). Using analytical modeling and numerical simulation, we show that replicating location information is both appropriate and efficient for small Personal Communication Network (PCN). Then, we extend the scheme in a hierarchical environment to reduce overhead traffic and scale to LPCNs. Through extensive numerical results, we show the superiority of our scheme compared to the current IS-41 standard scheme.

키워드 : 분산위치관리(Distributed Location Management),거대한 PCN망(LPCN), 성능분석(Performance Analysis)

1. Introduction

One of the challenging tasks in a PCN is to efficiently maintain the location of PCN subscribers who move around freely with their wireless unit called mobile host in North America, Telecommunications industry Association's Interim Standard IS-41 [1], [2] is used for managing location information of subscribers and enabling them to send and receive calls and other services such as message service and data service.

In a PCN [3], every subscriber is registered with a home network, the Home Location Register (HLR) of which maintains the subscriber's current physical location. In IS-41 standard scheme, this physical location is the ID of the Mobile Switching Center (MSC) currently serving the subscriber. If the subscriber has roamed to another region then he/she has to register with the Visitor Location Register (VLR) that covers the new region. During registration, the VLR will contact the subscriber's HLR, and the HLR will update its database to reflect the new location of the subscriber. If the mobile has registered with some other VLR before, HLR will send a registration cancellation message to it. Thus, HLR is a critical entity in the IS-41 location management system. There are many disadvantages to have a centralized location management scheme (bottleneck problem) such as the scheme used in IS-41 scheme.

A number of works have been reported to reduce the bottleneck problem of the HLR. In [23], [24], a Location Forwarding Strategy is proposed to reduce the signaling

† 정 회 원 : 호원대학교 컴퓨터학부 교수
†† 종신회원 : 남서울대학교 컴퓨터학과 교수
††† 정 회 원 : 성결대학교 컴퓨터학부 교수
논문접수 : 2001년 10월 16일, 심사완료 : 2001년 11월 8일

costs for location registration. A Local Anchoring scheme is introduced in [14], [17]. Under these schemes, signaling traffic due to location registration is reduced by eliminating the need to report location changes to the HLR. Location Update and Paging subject to delay constraints are considered in [20]. When an incoming call arrives, the residing area of the terminal is partitioned into a number of sub-areas, and then these sub-areas are polled sequentially. While increasing the delay time needed to connect a call, the cost of location update is reduced. Hierarchical database system architecture is introduced in [16]. A queuing model of three-level hierarchical database system is illustrated in [22]. These schemes can reduce both signaling traffics due to location registration and call delivery using the properties of call locality and local mobility. A User Profile Replication scheme is proposed in [18]. Based on this scheme, user profiles are replicated at selected local databases. If a replication of the called terminal's user profile is available locally, no HLR query is necessary. When the terminal moves to another location, the network updates all replications of the terminal's user profile.

In this paper, we propose this distributed location management scheme. In order scale to LPCN, we extend our scheme by organizing the Location Registers (LRs) hierarchically so as to reduce the cost of updating location information.

The paper is organized as follows. Section 2 and Section 3 analyze our location management scheme for non-hierarchical network and compares it to the IS-41 scheme. Performance analysis in non-hierarchical network is presented in Section 4. Section 5 extends our scheme to hierarchical networks. Section 6 analyzes this hierarchical extension and numerical results are then presented in Section 7. Section 8 concludes the paper.

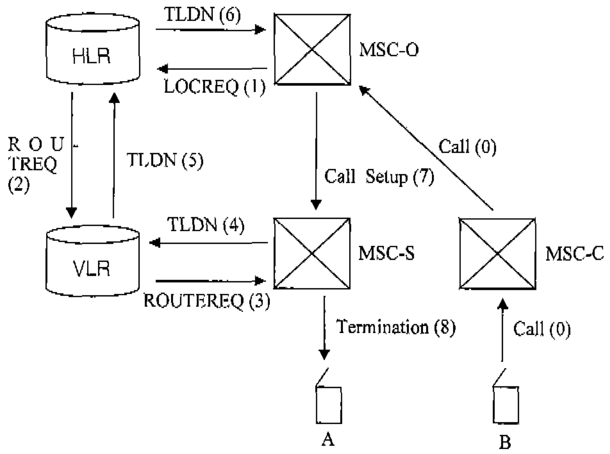
2. IS-41 Standard Location Management

In IS-41 scheme [1], an incoming call is routed to the called subscriber as follows. The dialed call is received by the MSC in the home system. This MSC is called the originating MSC. If the mobile host is currently being served by the originating MSC (i.e. the mobile host is not roaming), then this MSC queries the HLR to obtain the registration status and feature information of the mobile host. After receiving the response from the HLR, the originating MSC pages the mobile host. When the mobile host responds (i.e. subscriber accepts the call by pressing the proper button), the originating MSC sets up the circuit to terminate the call to the mobile host.

(Fig. 1) shows how a call is delivered to a roaming mobile host. As before, when a call to a mobile is dialed, the call is first routed to the originating MSC. The originating MSC then sends a location request message to the HLR to find out the current location of the mobile. The HLR, in turn, sends a route request message to the VLR that is currently serving the mobile. The VLR then sends a route request message to the MSC that is currently serving the mobile. The VLR then sends a route request message to the MSC that is currently serving the mobile. The serving MSC creates a Temporary Location Directory Number (TLDN) and returns it to the VLR. The TLDN is then passed back to the originating MSC through the HLR. The originating MSC then routes the call using this TLDN. When the serving MSC receives the call routed using the TLDN, it pages the mobile host. If the mobile responds, then the call is terminated at the mobile.

Thus, HLR is a critical entity in the IS-41 location management system. There are many disadvantages to have a centralized location management scheme such as the scheme used in IS-41 scheme. One disadvantage is that every location request as well as location registration are serviced through an HLR, in addition to the HLR being overloaded with database lookup operations [4], the traffic on the links leading to the HLR is heavy. This, in turn, increases the time required to establish a connection to a mobile host. Another disadvantage is that any HLR system failure causes all mobiles registered with the HLR to be unreachable even though mobiles may be roaming and away from the HLR region. Thus, HLR is a single point of failure in the network.

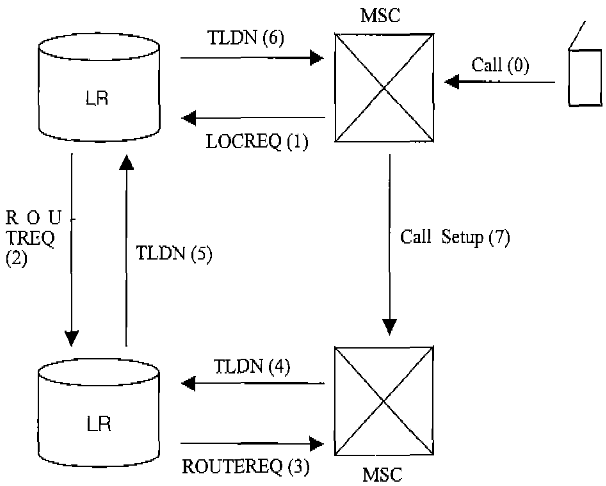
There is also another disadvantage which is generally referred to a tromboning problem. Consider the situation depicted in (Fig. 1). The subscriber A's home MSC is MSC-O, and A is currently roaming and being served by MSC-S, makes a call to the local exchange carrier. But, MSC-O (the home MSC of A) is geographically far away from both MSC-C and MSC-S and connected to them by a long distance carrier. Routing the call from B to A involves two long distance legs, one between MSC-C and MSC-O, and the other between MSC-O and MSC-S. The latter leg is used twice, first to obtain the TLDN, and then to provide the voice/data connection.



(Fig. 1) Call Delivery in IS-41 standard scheme

3. Distributed Location Management

We present a novel approach for efficient location management by distributing the location information across Location Registers (LRs). These LRs replace the centralized VLR s and HLRs which are found in current PCN. Thus, a unique feature of our proposed scheme is availability (fault-tolerance) by not having the concept of "home." Since there are no HLRs or VLRs in this system, each LR maintains the location information of not only the mobiles that are local to it, but also of other mobiles in the network. That is, the location information of all mobile hosts is fully replicated in all the LRs. The LRs are distributed throughout the network. An LR may serve one or more MSCs just like the VLR in the PCN architecture. An LR/VLR could also co-exist with an MSC, and serves only that MSC. LRs function as both the location registry for the local mobile hosts as well as the lookup directory for the location of other mobile hosts. The type of location information maintained for a mobile host depends on whether the mobile is local to the LR or not. For local mobile hosts and mobile hosts that are not local, LR maintains the id of the LR where the mobile host currently resides. When a mobile registers with an LR, the new location information is disseminated to all other LRs in the network. This dissemination is carried out in parallel through the whole network so that the new location is very quickly updated at all LRs. When a call request arrives at the local LR, this LR can directly contact the serving LR (cf. (Fig. 2)), thus avoiding the tromboning problem presents in the current IS-41 standard. We analyze this distributed location management scheme. In order to scale to LPCNs, we extend our scheme by organizing the LRs hierarchically to reduce the cost of updating location information.



(Fig. 2) Call Delivery in our distributed location management

4. Performance Analysis for Non-Hierarchical Distributed Network

In this section, we analyze our proposed distributed location management scheme and compare it with that of the IS-41standard scheme. For simplicity, it is assumed that there is only one MSC per service area, and the LR/VLR is collocated with the MSC. Thus, we use LR to indicate an MSC/LR combination, and VLR to indicate MSC/VLR combination. In both schemes (fully replicated and IS-41 standard), the total cost consists of Update cost and Location Tracking cost (Find cost). The Update cost covers all the costs involved in mobile host registration and location update. In the case of distributed location management, Update cost also includes the cost involved in the dissemination of location information. The location tracking cost covers all the costs involved in terminating a call to mobile host. In the case of IS-41 standard, Location tracking cost consists of all the costs involved in the call termination as depicted in Figure 1. However, since we have assumed that VLR is co-located with the MSC, Location tracking cost basically consists of the cost of signaling between originating area VLR and HLR, and of signaling between HLR and serving VLR. In order to compare the cost efficiency of our distributed scheme and the IS-41 scheme, we use the expected total cost incurred for a mobile host while it is in a single LR (or VLR) service area as the comparison metric. The total cost includes the

Update cost incurred for registering the mobile host when it moved into the LR (or VLR) service area, and the Location tracking cost incurred for every call terminated to the mobile host while it is in this service area and before it moves to another service area.

In IS-41scheme, Update involves the new VLR registering the mobile host with its HLR, and the HLR sending registration cancellation to the old VLR. Hence the Update cost, $C_{Update\ IS\text{-}41}$ is given by :

$$C_{Update_{IS41}} = Cost(VLR_{New} \leftrightarrow HLR) + Cost(HLR \leftrightarrow VLR_{old}) \quad (4.1)$$

Assuming the time to register with the HLR is very short (i.e. the probability that a location request to the HLR falls during the registration time is negligible), the Location Tracking cost, $C_{Lacation\ tracking}{}_{IS-41}^{roa\min g}$ of a roaming mobile is given by (cf. Fig 1) :

$$C_{Location\,tracking}{}_{IS41}^{roam} = Cost(VLR_{Caller} \leftrightarrow VLR_{orig}) + Cost(VLR_{orig} \leftrightarrow HLR) + Cost(HLR \leftrightarrow VLR_{callee}) \quad (4.2)$$

and for a non-roaming mobile host, the Location Tracking cost, $C_{Lacation\ tracking}{}_{IS-41}^{non-roa\min g}$ is given by :

$$C_{Location\,Tracking}{}_{IS41}^{non-roam} = Cost(VLR_{caller} \leftrightarrow VLR_{orig}) + Cost(VLR_{orig} \leftrightarrow HLR) \quad (4.3)$$

Here, VLR_{caller} is the MSC/VLR where the call is generated, VLR_{orig} is the home MSC/VLR of the mobile host, and VLR_{callee} is the MSC/VLR that is currently serving the roaming mobile host.

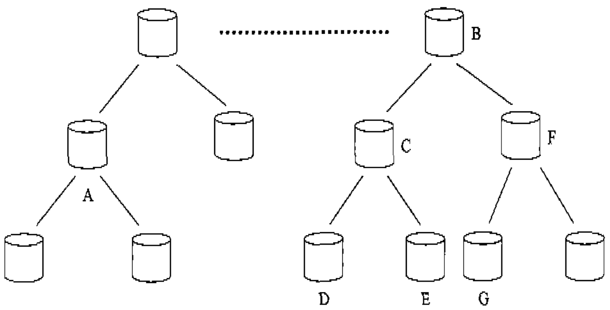
5. Hierarchical Location Management

Our distributed location management scheme requires that new location information about all mobiles be disseminated to all the LRs in the network. As the size of the network grows, location information dissemination not only consumes a significant portion of the network bandwidth but also consumes significant portion of LR resources to process large number of update messages. In addition, the gain of employing full dissemination diminishes with the size of the network. That is, for a large network, it is impractical to have a location management scheme based on full location information dissemination. Full location information dissemination can be avoided by logically arranging LRs in a hierarchical fashion-a tree structure as in [10] or a cluster-super cluster arrangement as in [11]. The idea here is to divide the LRs into hierarchy of clusters, and confine location information dissemination to within the clusters as much as possible. This section analyzes the performance of our distributed location management in a hierarchical environment and assesses its applicability and benefits. Our scheme is different form other hierarchical schemes (e.g., [6]) in that its goal is not only to reduce the overhead of location management, but also to uniquely provide high availability through (selective) replication of location information.

5.1 Proposed Hierarchical Location Management

(Fig. 3) shows the conceptual arrangement of the LRs in a hierarchical network under our proposed scheme. The proposed approach uses a distributed location management. The mobile hosts are not associated with a home location register like in IS-41standard. Each LR maintains the location information of the entire mobile that are currently being served in the sub-tree rooted from the LR. It also maintains the location of the mobiles that belong to the sub-tree rooted from its sibling LRs. Note here that the sub-tree rooted from a leaf node contains only that leaf node. If a mobile host is being served by one of the descendants of an LR, then the LR maintains the ID of its immediate child LR, whose sub-tree contains the mobile host, to track the mobile host. Referring to (Fig. 3), if a mobile host is in the service area of LR D, then location information in LR C for the mobile host would point to LR D, but the location information in LR B for the same mobile host would point to LR C. For the mobile hosts that reside in the sub-tree of a sibling, the LR maintains its sibling's ID to track the mobile host. That is, location information in LR F for that mobile host served by LR D would be LR C. This way the location information of a mobile host is only maintained by the following LRs : serving LR of the mobile host, sibling LRs of the serving LR, ancestor LRs of the serving LR, and sibling LRs of the ancestors. That is, location information of the mobile host being served by D is maintained only in the LRs D, E, C, F, B, and so on. LRs A and G do not maintain the location information for that mobile host.

Tracking the LR serving a mobile host involves traversing the LR tree hop-by-hop until the serving LR is reached. If the location entry for a mobile host does not exist in an LR, then the tracking request is reached. That LR forwards the tracking request to the LR pointed to by the location information. Here, location tracking traverses laterally. From there, it traverses downwards until the LR currently serving the mobile host is reached. For example, if G were to track the LR of a mobile host being served by D, G forwards the tracking request to F. F forwards the request to C, which forwards it to D. This information is returned back to G.



(Fig. 3) Conceptual diagram in the hierarchical arrangement

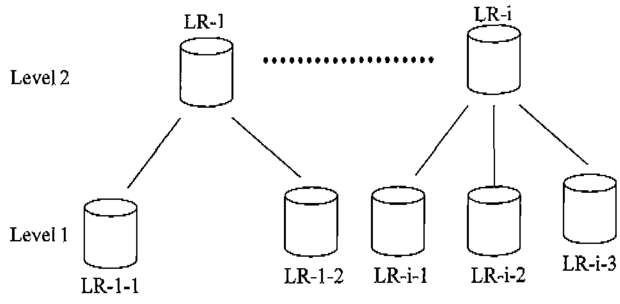
5.2 Registration and Location Update Algorithm

Mobile hosts identify their current LR by the periodic beacon message broadcasted by the base stations. If the mobile host receives a beacon message with a different service area than its currently registered service area, it registers with the new LR serving the area. The registration message contains the id of the mobile host. This registration message is propagated to the serving LR of the area. Upon receiving the registration message, in addition to sending registration confirmation back to the mobile host, the LR also sends a location update message to other LRs in the dissemination list. The dissemination list of an LR contains its entire sibling LRs and the parent LR.

6. Performance Analysis for Hierarchical Distributed Network

We try to answer the question of when our hierarchical location management system is cost efficient compared to IS-41standard and the non-hierarchical distributed location management evaluated in Section 4. Here we analyze a two-level hierarchy as shown in (Fig. 4). Note here that this analysis can be extended in a straightforward way to higher levels of hierarchy as well.

Now, if a mobile host moves across level-1 LRs belonging to the same level-2 LR, henceforth called level-1 move,



(Fig. 4) Conceptual diagram in a two-level hierarchical arrangement

then the cost of updating the move is the cost of distributing the location update to all the LRs in that cluster only. We assume location updates to other LRs using flooding as in Section 4 ; they can be efficiently disseminated to all the LRs in the dissemination list over a spanning tree rooted at the new level-1 LR that is currently serving the mobile host. Then the Update cost, $C_{Update\ H\text{-}level\ 1}$ is given by :

$$C_{Update_{H\text{-}level1}} = C_{level1} \times (M_{level1} - 1) \tag{6.1}$$

Here, C_{level1} is the average cost of the link connection two adjacent level-1 LRs, and M_{level1} is the average number of LRs in a level-1 cluster.

If a mobile host moves across level-2 LRs, henceforth called level-2 move, then the cost of updating the move is the cost of distributing the location update in the new cluster plus the cost of updating all the level-2 LRs to point to the new level-2 LR plus the cost of distributing "delete" message to all the LRs in the old cluster. Then the Update cost, $C_{Update\ H\text{-}level2}$ is given by :

$$C_{Update\ H\text{-}level2} = 2 \times C_{level1} \times (M_{level1} - 1) + C_{level2}(M_{level2} - 1) \tag{6.2}$$

Assuming $P_{local\text{-}move}$ is the probability that a mobile host move is across the LRs in level-1, the Update cost, $C_{update\ H}$ in the hierarchical system is by :

$$C_{Update\ H} = P_{local\ move} \times C_{Update\ H\text{-}level1} + (1 - P_{local\text{-}move}) \times C_{Update\ H\text{-}level2} \tag{6.3}$$

The location tracking cost of a mobile depends on whether the call is from a mobile host in the local cluster or not. The location tracking cost, $C_{Location\ tacking\ local\text{-}call}$ for a call from a local cluster is given by :

$$C_{Location\ tacking\ local\text{-}call} = Cost\ (LR_{caller} \leftrightarrow LR_{callee}) = Cost\ (LR_{local} \leftrightarrow LR_{local}) \tag{6.4}$$

If the call is from a mobile in another cluster (henceforth called a remote-call), then the calling party LR (a.k.a. LR_{caller}) needs to contact its parent LR ($LR_{caller-level2}$) to track the callee. $LR_{caller-level2}$ will contact the callee level-2 LR ($LR_{callee-level2}$), which in turn will contact the currently serving LR of the callee (LR_{callee}). Hence the location tracking cost, $C_{Location\ tracking\ remote-call}$ tracking of a remote-call is given by :

$$C_{Location\ tracking\ remote-call} = Cost(LR_{caller} \leftrightarrow LR_{caller-level2}) + Cost(LR_{caller-level2} \leftrightarrow LR_{callee-level2}) + Cost(LR_{callee-level2} \leftrightarrow LR_{callee}) \quad (6.5)$$

Let $P_{local-call}$ be the probability that the call that arrived is from a mobile in the local cluster. Then the location tracking cost, $C_{Location\ tracking\ H}$ in the hierarchical network is given by :

$$C_{Location\ tracking\ H} = P_{local-call} \times C_{Location\ tracking\ local-call} + (1 - P_{local-call}) \times C_{Location\ tracking\ remote-call} \quad (6.6)$$

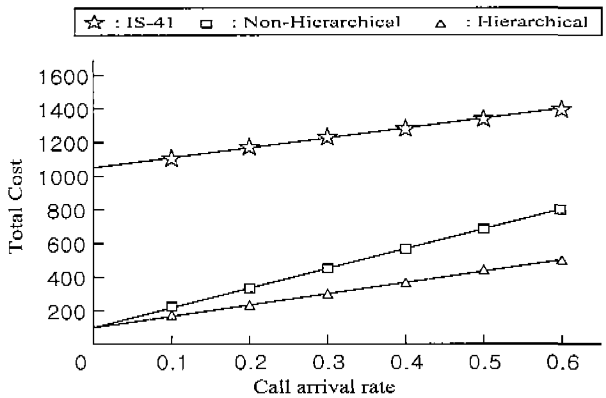
Following the same method of analysis as in Section 4, given λ is the call arrival rate to a mobile and $1/\mu$ is the mean of the (exponentially distributed) residence time of the mobile in a service area, the total cost, $C_{total\ H}$ of the location management in the hierarchical network is given by :

$$Cost_{total\ H} = C_{Update\ H} + \text{Expected num. Calls per move} \times C_{Location\ tracking\ H} = C_{Update\ H} \times \frac{\lambda}{\mu} \times C_{Location\ tracking\ H} \quad (6.7)$$

7. Numerical Results for Hierarchical Distributed Network

We consider a mesh topology. If the total number of LRs in the network is N_{LR}, and the number of clusters is N_c, then the average number of LRs in a cluster is N_{LR}/N_c. The level-2 LR is placed along with the level-1 LR at the center of the cluster. If there is no single center LR, then the level-2 LR co-locates with one of the four center LRs. Assuming the cost of the link connecting two adjacent LRs is proportional to the distance between the LRs, parameters C_{level1} and C_{level2} are related by $C_{level2} = \sqrt{N_{LR}/N_c}\ C_{level1}$. The cost between any of the level-1 LR and its level-2 LR is given by $1/2\sqrt{N_{LR}/N_c}\ C_{level1}$ for large values of $\sqrt{N_{LR}/N_c}$ (greater than 4). <Table 1> summarizes values of the parameters involved in the equation for total cost. In the following numerical results, C_{level1} is taken to be 1, $P_{local-move} = 90\%$ and $P_{local-call} = 1/N_c$.

(Fig. 5) shows the total cost versus call arrival rate for IS-41 scheme, our non-hierarchical distributed and hierarchical distributed schemes. Both distributed schemes implement full dissemination over a spanning tree rather than by flooding. The two-level hierarchical distributed scheme performs the best.



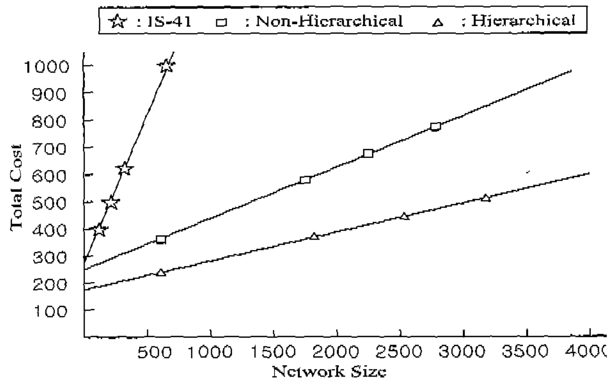
(Fig. 5) Total cost in a non-hierarchical networks

(Fig. 6) illustrates how hierarchical distributed scales compared to non-hierarchical distributed scheme and IS-

<Table 1> Cost Assumptions and parameters for hierarchical network

Parameter	Value	Comment
N_{LR}	N_{LR}	Total number of LRs
Nc	Nc	Number of clusters
C_{level1}	C_{level1}	Cost of the link connecting adjacent level-1 LRs
C_{level2}	$\sqrt{\frac{N_{LR}}{N_c}}\ C_{level1}$	Cost of the link connecting adjacent level-2 LRs
Cost ($LR_{local} \leftrightarrow LR_{local}$)	$1.33(\sqrt{N_{LR}/N_C/2})\ C_{level1}$	Average cost between any two level-1 LRs
Cost ($LR_{caller} \leftrightarrow LR_{caller-level1}$) Cost ($LR_{callee} \leftrightarrow LR_{callee\ level2}$)	$1/2\sqrt{N_{LR}/N_c}\ C_{level1}$	Average distance between the level-1 LR and its parent LR
Cost ($LR_{caller\ level2} \leftrightarrow LR_{callee-level2}$)	$1.33(N_c/2)\ C_{level2}$	Average cost between two level-2 LRs

41 scheme as the network size increases for $\lambda = 3$ and $\mu = 0.1$. The network size is varied from 50×50 to 200×200, where number of clusters Nc equals to 10, 20, 30, and 40, respectively. The results suggest that our hierarchical distributed scales much better than IS-41 scheme.



(Fig. 6) Total cost in hierarchical networks

8. Conclusions

As shown by analytical and numerical performance analysis, our distributed location management scheme is more suitable than IS-41 standard management. The distributed location management not only reduces the overall system cost, but also reduces the call establishment latency and increases the availability of the system. The hierarchical implementation of our distributed scheme allows for scaling to LPCNs while still providing high availability.

Our distributed location management scheme is general and can make use of other scalability and fast location lookup techniques [13], besides hierarchically organizing the location registers, For example, location information can be disseminated only to most frequent callers, who can cache it in memory to speed up their location lookups. In our future work, we will investigate such extensions and study the tradeoffs between availability and cost/overhead.

References

[1] "Cellular Radio-Telecommunications Intersystem Operation," December, 1990.

[2] Michael D. Gallagher and Randall A. Snyder, Mobile Telecommunications Networking with IS-41, McGraw-Hill, Inc., 1997.

[3] Jan Thornier, Intelligent Networks, Artech House, Inc., 1994.

[4] C. N. Lo, R. S. Wolff, and R. C. Bernhards, "An Estimate of Network Database Transaction Volume to Support Personal Communication Services," pp.236-241, 1992.

[5] Harry Harjono, Ravi Jain, and Seshadri Mohan, "Analysis and Simulation of a Cache Based Auxiliary Location Strategy for PCS," Conference of Networks for Personal Communication, March, 1994.

[6] Joseph S. M. Ho and Ian F. Akyildiz, "Local Anchor Scheme for Reducing Location Tracking Cost in PCNs," IEEE/ACM Transaction in Networking, October, 1996.

[7] Sampath Rangarajan, Karunaharan Ratnam, and Anton T. Dahbura, "A Fault-Tolerant Protocol for Location Director Maintenance in Mobile Network," in Proc. of the 25th International Symposium on Fault-Tolerant Computing, June, 1995.

[8] Karunaharan Ratnam, Sampath Rangarajan, and Anton T. Dahbura, "An Efficient Fault-Tolerant Location Management Protocol for Personal Communication Networks," to appear IEEE Transactions on Vehicular Technology.

[9] "CSIM18-the simulation engine," Mesquite Software, Inc.

[10] J. Z. Wang, "A Fully Distributed Location Registration Strategy for Universal Personal Communication System," in IEEE Journal on Selected Areas in Communications. IEEE, Vol.11, pp.850-860, Oct. 1993.

[11] J. Westcott and G. Lauer, "Hierarchical Routing for Very Large Network," in Proc. of IEEE INFOCOM'84, 1984.

[12] K. Ratnam, I. Matta, and S. Rangarajan, "A Fully Distributed Location Management Scheme for Large PCS," Tech. Rep. BU-CS-1999-010, Computer Science Department, Boston University, Boston, MA 02215, August, 1999.

[13] K. Ratnam, I. Matta, and S. Rangarajan, "Analysis of Caching-Based Location Management in Personal Communication Networks," in Proc. of IEEE ICNP '99, 1999.

[14] I. F. Akyildiz, J, McNair, J. Ho, H. Uzunalioglu, W. Wang, "Mobility Management in Current and Future Communication Networks," IEEE Network, pp.39-49, Jul./Aug., 1998.

[15] R. Jain, Yi Bing Lin, C. N. Lo. and S. Mohan, "A Caching Strategy to Reduce Network Impacts of PCS," IEEE Jour. on Selected Areas in Comm., Vol.12, No.8, pp.1434-1445, 1994.

[16] C. -L. I, G. P. Plooini and R. D. Gitlin, "PCS Mobility management Using the Reverse Virtual All Setup Algorithm." IEEE/ACM Trans. Vehicle. Tech., pp.1006-1010. 1994.

[17] T. Russel, Signaling System #7, McGraw-Hill, 1995.

[18] J. S. M. Ho and I. F. Akyildiz, "Local Anchor Scheme for Reducing Location Tracking Costs in CNs," Proceeding of ACM MOBICOM'95, pp.181-194, Nov. 1995.

[19] J. Z. Wang, "A fully Distributed Location Registration Strategy for Universal Personal Communication Systems," IEEE Personal Comm., pp.42-50, First Quarter 1994.

[20] X. Qui and V. O. K. Li, "Performance Analysis of PCS Mobility Management Database System," Proceeding of USC

/IEEE Int'l Conf. Com. Com., and Networks, Sept. 1995.

[21] C. Eynard, M. Lenti, A. LOmbardo, O. Marengo, S. Palazzo, "Performance of Data Querying Operations in Universal Mobile Telecommunication System (UMTS)," Proceeding of IEEE INFOCOM '95, pp.473-480, Apr. 1995.

[22] Y. Bing Lin and S. -Y. Hwang, "Comparing the PCS Location Tracking Strategies," IEEE Trans. Vehicle. Tech, Vol.45, No.1, Feb. 1996.

[23] T. H. Cormen, C. E. Leiserson, R. L. Rivest, Introduction to Algorithms, MIT Press and McGraw-Hill, 1990.

[24] N. Shivakumar, J. Widom, "User Profile Replication for Faster Location Lookup in Mobile Environment," Proceeding of ACM MOBICOM'95, pp.161-169, Nov. 1995.

이 동 춘

e-mail : ldch@sunny.howon.ac.kr

연세대학교 컴퓨터과학과 공학박사

1989년~현재 호원대학교 컴퓨터학부 정교수

JPDC, JHSN, ETT, Performance Evaluation 국제 논문지 심사위원

관심분야 : 무선통신(IMT-2000,Wireless IP, Wireless ATM)의 위치관리(DB) 기법과 성능분석, 무선통신보안

김 점 구

e-mail : jgoo@nsu.ac.kr

1990년 광운대학교 전자계산학과 이학사

1994년 광운대학교 대학원 전자계산학과 이학석사

2000년 한남대학교 대학원 컴퓨터공학과 공학박사

1990년~1994년 (주) 제성 프로젝트 연구원

1995년~1998년 (주) 시사 컴퓨토피아 인터넷사업부장

1999년~현재 남서울대학교 컴퓨터학과 조교수

관심분야 : 정보보호, 컴퓨터네트워크, 무선통신

조 석 팔

e-mail : spcho@sungkyul.edu

1976년 광운대학교 전자통신과(공학사)

1987년 한양대학교 전자통신과(공학석사)

1992년 경희대학교 전자공학과(공학박사)

1976년 Control Data Corp. Computer SE.

1984년 삼성전자 정보통신 연구소 연구실장 (수석연구원)

1995~현재 성결대학교 컴퓨터 및 정보통신공학부, 정보통신전공 교수

관심분야 : 컴퓨터네트워크, 이동통신망, 통신보안