Front. Electr. Electron. Eng. China 2009, 4(1): 24–30
DOI 10.1007/s11460-008-0065-8

RESEARCH ARTICLE

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Difference-less mobility management network

Abstract Core system technology is a key factor in the next generation network (NGN). A difference-less mobility management network is proposed to better support the mobility of an IP multimedia subsystem (IMS). This kind of network can provide good service and user mobility, enabling local user access to the network anywhere. User location management and session creation are analyzed. The results show that under this network architecture, the cost of the user location registration and session creation is lower than that of the home control model employed by the IMS.

Keywords difference-less mobility management network, location management, session, IP multimedia subsystem (IMS)

1 Introduction

Service mobility is indispensable for a mobile network, which means that accessibility does not depend on the access point of the subscriber. It focuses on how to serve users, i.e., the network service control model. Currently, the mobile network utilizes roaming or home network control to provide service mobility. Under this service control model, the receiver's home must be visited first to obtain its location information before routing the signal to the caller, which makes the roaming user follow a long signaling process when creating a session.

With the further development of telecom networks, the service has become richer with IP multimedia subsystem (IMS) and next generation network (NGN) use and widened the service gap. However, the present service control model does not meet new requirements. Therefore, this paper is devoted to finding a new model to support network mobility. It supports difference-less mobility management, which provides service mobility flexibility as well as enhances personal mobility.

2 Service control network architecture

The general design of the architecture is as follows: the location information can be obtained by contiguity. The user's profile moves in the network with changes to the network access point. The user's service access changes according to its network access point.

Figure 1 shows the architecture of the service control network. The user equipment (UE) logs on to the service network through the access network. Introduction to the network elements is as follows.

1) Service control network

The service control network is a concept opposed to the user access network at the service providing level. It is fundamental to the network as a whole to serve all subscribers, including selecting service node for he subscriber, migrating the user's data, managing the subscriber's location, authentication and authorization, and publishing a new service. The access user or terminal considers it as a server that provides service. The user is only concerned with the service itself rather than the location of the server.

2) Boundary node

The boundary node lies between the service control network and the access network, through which the user accesses the service control network. The boundary node plays the role of service control node and location management node at the user's place – it will authenticate and authorize the user for the service control network. It functions as the user registrar and is responsible for authentication between the user and the network to ensure that the user has legal right to the service. It selects the service node for the user, routes the signal to this service node and assigns the most suitable service provider to the user. For different services there may be different service nodes for the same user. The boundary node is in charge of finding the receiver's location and service node and then rout-ing the signal to the right location.

3) Service node

The service node is responsible for controlling the service, including signal routing and controlling, controlling media streaming and authorizing the user.

Translated from *Journal on Communications*, 2007, 28(7): 1–7 [译自: 通信学报]

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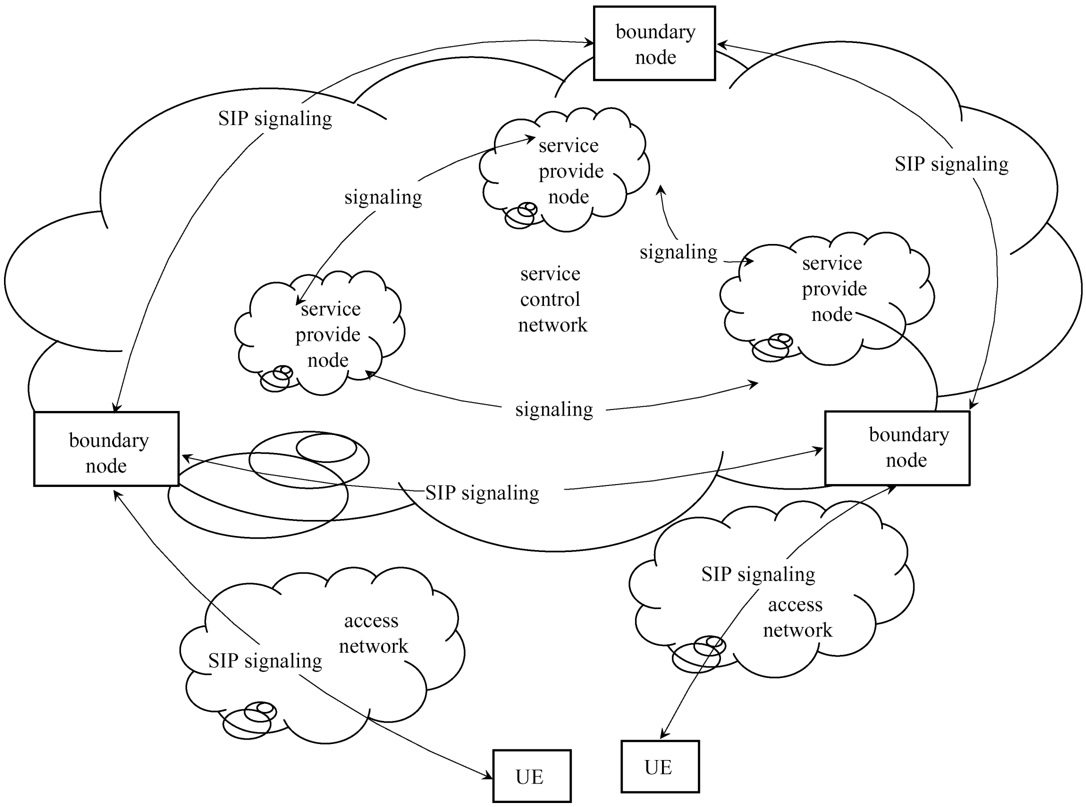

Fig. 1 Service control network architecture

This node does not have to be single element and can be a sub-network such as S-CSCF (session control function) and application server (AS) in the IMS. There are controlling nodes and application providing nodes, which vary in different service control networks. All elements in the sub-network are trustworthy since the boundary node takes responsibility for authentication and security assurance. With a changing access point, the element in the control network serving as a resource is assigned to the user. The service topology and information of the user's location are stored in the network. Any user's access location and service node can be found from any boundary node. When the user selects a service, a request sent to the boundary node can be routed to an appropriate service node according to the service topology. Therefore, the user accesses the service control network from any access network similar to accessing the service network from his home network. This gives the user a difference-less service access experience. Since all users access the network in the same way, it is called a difference-less mobility management network.

3 Location management

With a change in the access point, the user's data move in these boundary nodes. However, two problems emerge.

1) Jounce: the user's data move between two nodes frequently.

2) Useless movement: the user's data move into boundary nodes B, but no session occurs before this user moves out of boundary B. Thus, the cost of the user's data movement is wasted. Many methods are proposed to decrease the location management cost. In Ref. [1], a link method to reduce the location registration cost is given. In Refs. [2–4], three-level location management to reduce this cost is employed.

The location registration process of the service control network is simpler than that of the traditional network. The user regards the whole service control network as its registrar. When the user finds its location changed, it initiates a location registration process. The serving boundary node records the location and service information of the user, then requests authentication data from the network, as shown in Fig. 2.

The user moves from boundary node 1 to node 4 and no session occurs. The user data is still stored in boundary node 1. But once there are application data sending to the user, the user data will be downloaded into node 4 from node 1. The registration process is shown in detail as follows:

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//registration process
If (user enters into a new network)
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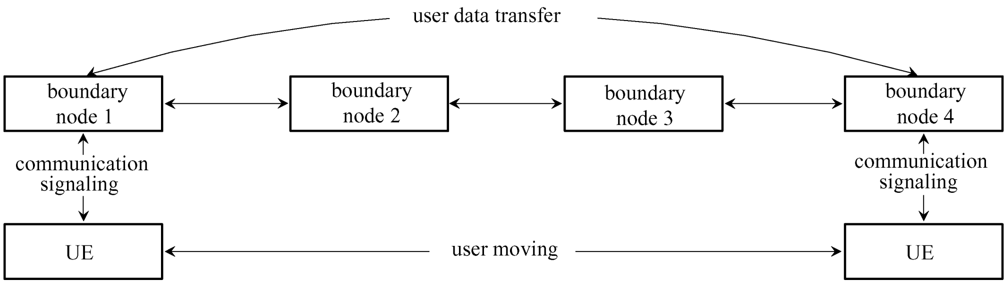

Fig. 2 Location registration procedure under service control network

user registers its location (network route the registration signal to the new boundary node);

//the process on boundary nodes

According to the information in the signal, request the nodes where the user data reside to authenticate the user;

If (! Passes the authentication)

return the failure information to the user;

Else

record the location of the former data residing nodes;

send location update request to the former nodes;

download authentication information and save it in user data;

map suitable service nodes for the user;

return success information/message to user;

ENDIF

//process in the middle boundary nodes

Receive a location update request from some boundary nodes;

Authenticate the request;

If (Passes the authentication)

update the location information in the user data;

return the update result with location of the residing boundary nodes;

Else

return the rejected request with the reason;

ENDIF

//after accessing the new boundary nodes, the first application data arrive;

New boundary nodes down load the user data from the data residing boundary nodes;

Send de-registration request to the former access boundary nodes;

//the location de-registration process

Boundary nodes receive the de-registration request;

Authenticate the request;

If (Passes the authentication)

delete the user data;

if this node is not an end, send the de-registration request to its former;

Else

return the rejected request with the reason;

ENDIF

3.1 Cost analysis of registration and session creation in home service control model (IMS)

A user needs to register on the home network via P-CSCF in the visited region. The session signal must pass the home S-CSCF to access the user's service, as shown in Figs. 3 and 4. Figure 3 is the case of a home network control model in IMS, while Fig. 4 is the signaling path of session creation.

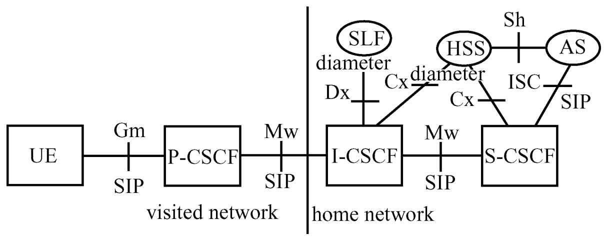

Fig. 3 Home service control model of IMS

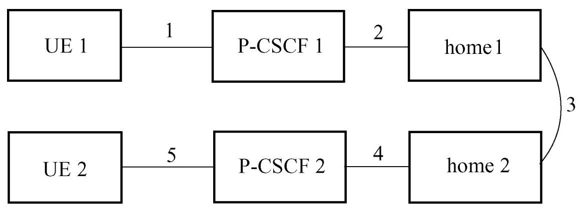

Fig. 4 Signaling path of session creation under IMS home service control model

Here are some parameter sets for convenience of analysis. C_{up} is the transfer cost from UE to P-CSCF; C_{ph} is the transfer cost from P-CSCF to the home network; P_p is the process cost in P-CSCF; R is the cost of updating location in the IMS; P is the cost of dealing with signaling in IMS. Suppose u is the cost of one skip in the fixed network. Since the transfer cost of the wireless link is much higher than that of the wire link, assume that the former is m times the latter. Suppose the length of the path between the caller and receiver is n, the even roaming length of the user is n. The roaming length is the skip number between the home network and the visited network. Assume that roaming possibility of the user is α and the call possibility between different location domains is β, then

$$C_{\text{up}} = mu,$$
$$C_{\text{ph}} = (\alpha n + (1-\alpha))u, \quad (1)$$
$$C_{\text{hh}} = \beta nu.$$

The interval between the two registers when they refresh is T, the moving frequency of the user is γ, and $\eta = 1/(\gamma T)$ represents the ratio between the user's moving interval and the register refresh interval. If only a single path signal is considered, the register cost under the home service control model is

$$C_{\text{R\_H}} = (C_{\text{up}} + P_{\text{p}} + C_{\text{ph}} + R_{\text{i}})\left(1 + \frac{1}{\gamma T}\right) = \left(mu + P_{\text{p}} + (\alpha n + (1-\alpha))u + R_{\text{i}}\right)(1+\eta). \quad (2)$$

It can be seen from Figs. 3 and 4 that the session creating cost under the original location management $C_{\text{S\_H}}$ is

$$C_{\text{S\_H}} = 2C_{\text{up}} + 2C_{\text{ph}} + C_{\text{hh}} + 2P_{\text{p}} + 2P_{\text{i}}. \quad (3)$$

According to Eq. (1), Eq. (3) can be rewritten as

$$C_{\text{S\_H}} = 2mu + 2(\alpha n + (1-\alpha))u + \beta nu + 2P_{\text{p}} + 2P_{\text{i}} = 2(m + \alpha n + (1-\alpha))u + \beta nu + 2P_{\text{p}} + 2P_{\text{i}}. \quad (4)$$

3.2 Registration cost of difference-less service control network

There are two different procedures: the user location changing without and with a session occurring. It is defined as follows:

L: the location registration cost;
R: the cost of a path link deleted in one node;
R_{l}: process cost in boundary nodes for registration;
M: the cost of user data movement;
ρ: user's call and move ratio (CMR);
$\alpha(i)$: the possibility user passes through i location domains in a session interval.

Thus, the whole location registration cost is $C = Li + Ri + M$, and the even cost of location registration is:

$$C = \sum_{i=1}^{\infty}(Li + Ri + M)\alpha(i) = \frac{L+R}{\rho} + M(1-\alpha(0)). \quad (5)$$

If the arrival ratio is λ, the average time a user stays in one location domain is $1/\mu$, $\rho = \lambda/\mu$. The user's motion observes a negative exponent distribution. Since the account of the motion observes a Poisson distribution, $\alpha(0) = \mathrm{e}^{-1/\rho}$ and Eq. (5) can thus be changed into:

$$C = \frac{L+R}{\rho} + M\left(1 - \mathrm{e}^{-\frac{1}{\rho}}\right). \quad (6)$$

Location registration occurs locally, although the authentication signal needs routing to the last registration nodes. Hence there will be several signaling interactions that lead to a huge signaling cost. Therefore, we set L to 2. R is a process in one node to delete the path link with simple data and signaling interaction, thus it is set to 1. M is the moving cost of the user's data. With an increase in the number of applications, the scale of the user data becomes large. The user data move directly between the nodes where the data stay and the user's current boundary node. Therefore, the maximal path length between the two nodes is the diameter of the network. However, the path length bears a limited relationship with the number of movements during one session interval. According to the importance of the traffic in the analysis, M is set to [1.2, 2].

Figure 5 shows the changes of the cost of location registration to the CMR with different M values. The change of M has little effect on the cost, unless the user movement brings heavy traffic to the system. The figure demonstrates the case when the user data movement cost is 5 times the location registration cost without such movement. In this case, the whole cost increases slightly. For the user with small CMR the cost is significant, but since there are few sessions in this case, the user data seldom move. For the user with large CMR, the location registration cost hardly changes. Consequently, the user data movement contributes slightly to the location registration cost as a whole.

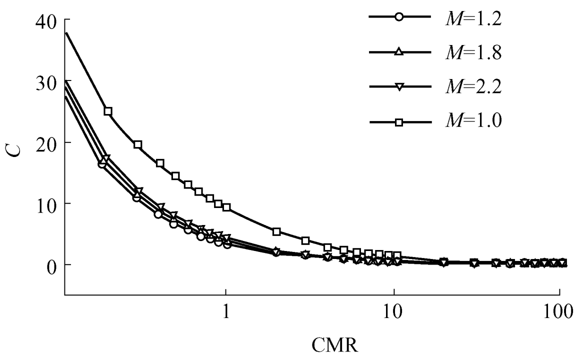

Fig. 5 Location registration cost

The average registration cost in the home service control network is described by Eq. (2). The procedure of location management in the new service control network is shown in Fig. 2. In the new network, the user just registers in the local location domain and the boundary node functions as the registrar. The average registration cost in the new network is described as

$$C_{\text{R\_no}} = (C_{\text{up}} + P_{\text{p}} + R_{\text{i}})\left(1 + \frac{1}{\gamma T}\right) = (mu + P_{\text{p}} + R_{\text{L}})(1+\eta).$$

For the existing network, the signaling cost is given and transfer time in a link and process time in a node are fixed. However, since the ratio of the roaming user and the long-distance call is variable, we give the following assumptions shown in Table 1.

Table 1 Parameter weight in system cost

parameter	value
P_p	15
P_i	20
u	1
β	0.25
R_i	30
R_l	25
m	10

Suppose one skip transfer cost (u) in the fixed network is 1. Since the wireless channel is much lower than the wire channel, the transfer cost of the wireless interface is much higher than that of the wire interface. Thus, m is assumed to be 10. The process cost in P-CSCF (P_p) includes SIP compression and decompression, making the cost huge. We set it to 15. P_i includes the process cost of I-CSCF and S-CSCF. Since the element needs interaction with home subscriber server (HSS), it is bigger than P_p, and set to 20. R_i is the cost of the registration on the core network, which possesses more interactive signaling processes, and is therefore bigger than P_i and set to 30. The registration cost that occurs in boundary nodes is close to the registration cost of the IMS home register (R_i). The registration process in a new network involves fewer nodes than that of the original network, and thus $R_l < R_i$ and R_1 is supposed to be 25. According to the published data, in the fixed network the long-distance session accounts for 25% of all sessions. Estimated by personal communication rules, mobile communication has a similar case. When the network convergence is realized, the ratio of the long-distance session will not change much. Consequently, the long-distance ratio (β) is assumed to be 25%. The ratio of the roaming user is relatively significant. However, social development makes the roaming ratio increase as people communicate frequently. Given that α falls in [5%, 20%] and the average length between the caller and receiver is within [4, 10].

Figure 6 illustrates the relationship between C_{R_H} and C_{R_no}, showing that registration cost in the new network is smaller than that in the original network. When registration frequency becomes larger, the advantage of the new network becomes clearer.

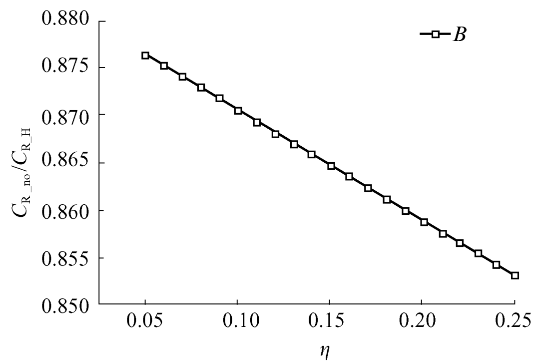

Fig. 6 Comparison of registration cost between new and original networks

4 Session creating procedure

The session creating procedure is a signal routing process. If the session creating signals can be routed directly to the service node of the caller, the service node of the receiver and the receiver terminal, the session should be created, otherwise it fails. The procedure involves several network nodes, i.e., the caller terminal, caller's boundary nodes, caller's service nodes, receiver service node, receiver boundary node and receiver terminal. The whole procedure is illustrated in Fig. 7.

User A sends a session creating request to the service control network. When the boundary node receives the request, it routes the request to A's service node according to the information in the request. If A's service node

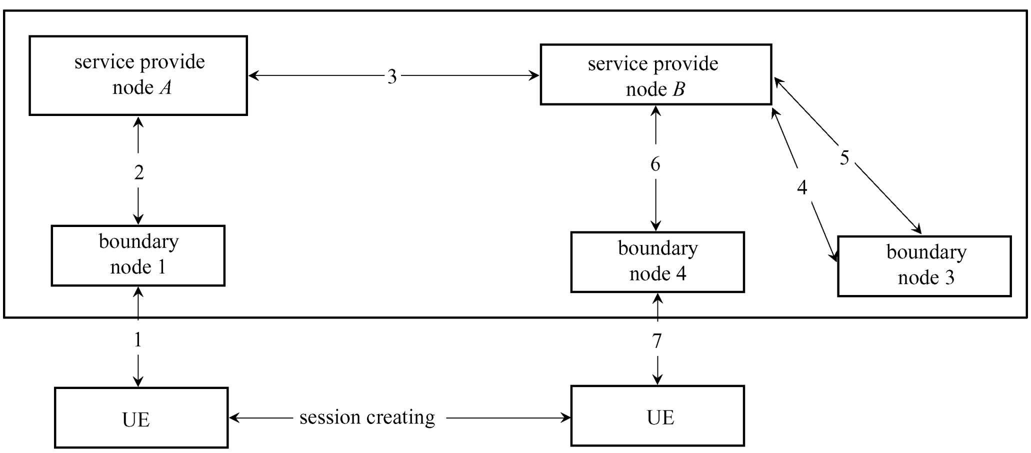

Fig. 7 Session creating procedure

accepts the request, it will execute the service control function and find user B's service node and the location of user B. A's service node sends the request to B's service node with the location of B. If B's service node accepts the request, it sends the request to B according to the location information in the request. B's boundary node gets the request and then sends it to B. If it finds that B is not in the local network, the request will be forwarded to the right location.

The key to the procedure consists in the caller's service node obtaining the location information of the receiver. It is solved when the location information is gained in the boundary nodes and as a session parameter sent to A's service node.

4.1 Finding receiver's information

During the session creating procedure, the signal can be transferred from the caller to the receiver only after getting the receiver's location and its service node, i.e., there is an addressing procedure. This procedure finds the receiver's location as well as service information, including the service node and the user data, and then stores the information in the boundary node.

Because user data must be obtained from the boundary node and only one copy of the data is stored in the network, it is required that the user data can be obtained from any boundary node.

The user data can be stored in a distributed database or P2P network for sharing [5,6]. Since data query path length in a P2P network may be more than 1, data caching is employed to speed up the query. The query procedure is as follows:

1) Finding the receiver's location from the local cache.
2) If found, user's location information is returned.
3) Otherwise, search the user location information using the P2P model.
4) Store the new data in the local cache.

4.2 Cost analysis of session creation

Only the session creating signal from the caller to the receiver rather than the response signal is discussed in this section for simplicity. According to the session creating procedure, the cost includes signaling transfer cost, location finding cost and process cost in service nodes. For the high speed of the backbone network, the cost mainly belongs to nodes.

It is assumed that:

L: process cost in boundary nodes;
R: location finding cost;
S: process cost in service nodes;
R_e: redirecting cost;
M: link transfer cost;
μ: hit ratio of caching;
M_{L-S}: traffic cost from boundary node to service node;
M_{S-L}: traffic cost from service node to boundary node;
M_{S-S}: traffic cost between service nodes;
M_{Re}: traffic cost for searching the user's location information.

According to Fig. 7, the process cost for session creation is

$$\begin{aligned} C &= L + R + S + S + L + (1-\mu)(R + R_e + S + L) \\ &= (3-\mu)(L+S) + (2-\mu)R + (1-\mu)R_e. \end{aligned} \tag{7}$$

Because the path is symmetrical, L−S has the same length as S−L, i.e., $M_{L-S} = M_{S-L}$. Thus the network traffic cost is

$$\begin{aligned} C_T &= M_{L-S} + M_{S-S} + M_{S-L} \\ &\quad + (1-\mu)(M_{L-S} + M_{S-L} + M_{Re}) \\ &= 2(2-\mu)M_{L-S} + M_{S-S} + (1-\mu)M_{Re} \\ &= 2(2-\mu)u + \beta n u + (1-\mu)M_{Re}. \end{aligned} \tag{8}$$

The hit ratio of location caching will be higher than 0.3 when the user's CMR $>$ 3. Whether data can be cached depends on the user's CMR, while the data's caching state accord with the fact. Thus, the real cost is lower than that described by Eqs. (7) and (8).

For convenience, the parameters in Eqs. (7) and (8) are interpreted. The work done in the boundary node includes authenticating, authorizing, selecting the service node and forwarding the signal. Since selecting the service node is only simple mapping, its cost can be omitted. Its place is similar to P-CSCF. L is set to 15 (similar to P_p). Since retrieving the receiver's location information is mainly processed in the local node by local caching, and the retrieving occurs in the local database or even in a memory database, the process cost is very small. Therefore, R is close to 1.5. The process cost of the service control is similar to P_i, while a little is taken over to the boundary node. Thus, it is smaller than P_i and S is set to 18. The redirection cost includes parts, retrieving the location and forwarding the signal. Therefore, R_e is set to 2. M_{Re} is traffic in the location retrieval. For location caching, the hit ratio of local retrieval is higher than 0.8. If it cannot be found locally, a global search should be conducted. Suppose the average length of the network is n. Since the data with the location retrieving signal is less than that with the session signal, assume that the former is half of the latter, that is, $M_{Re} = 0.2 \times 0.5n = 0.1n$.

Figure 8 shows a comparison of the session creating cost between the new and original network. In the original network the process cost just involves the caller's access node (P-CSCF) and home service node of the caller and the receiver (S-CSCF). The process cost in one node is a constant. Under the former assumption and the analysis the process cost is 70 units. According to Eq. (8) we have Fig. 8. With an increase of the caching hit ratio the process cost is less than that in the original network by 6 units.

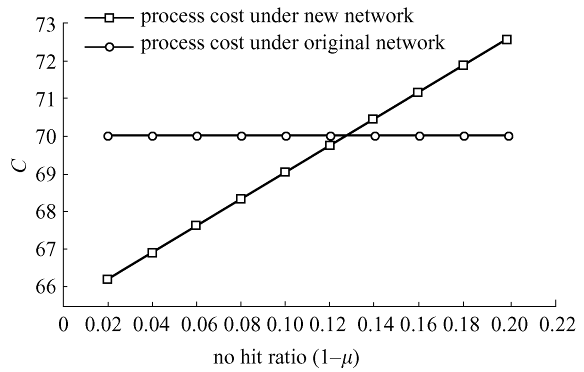

Fig. 8 Comparison of process cost between new and original network

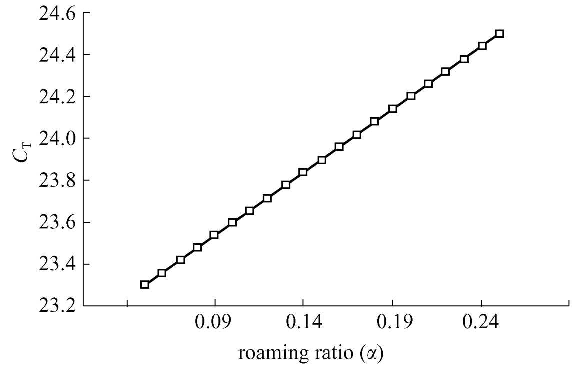

Fig. 10 Traffic cost of session creation in original network

Figures 9 and 10 are traffic costs in the new and original networks. Figure 9 shows that with an increase of the caching hit ratio, the traffic cost can reach around 23.0 units. Figure 10 shows that with an increase of the roaming ratio, the traffic cost increases in the original network. In the best case of non-roaming it can be about 23.3. But in fact this case in the mobile network is rare. The traffic cost from the UE to the network is the largest and assumed to be 20 units. Therefore, a significant improvement can be achieved by only reducing 1 unit.

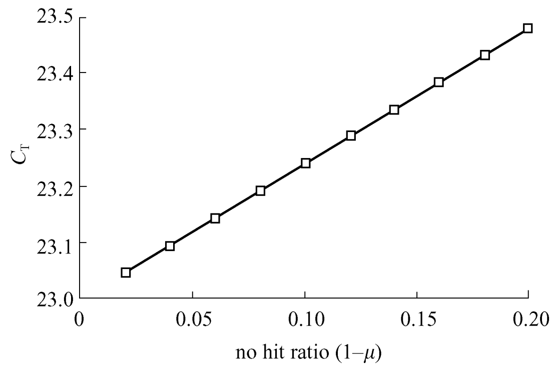

Fig. 9 Traffic cost of session creation in new network

5 Conclusions

A service control network (the difference-less mobile network) is proposed to implement total network mobility and enhance personal mobility. Under this system the user accessing the network from anywhere can get their subscribed service in contiguity, which provides personal and service mobility well.

Any user's location information can be retrieved from any boundary node correctly and fast. This is the key factor contributing to the networks high performance, which is worthy of further studies. The service topology finding and the service delivery are also important. Although currently it is hard to implement such a network and the solution is not perfect, network trends, especially for convergence networks such as an IMS network, show that it is possible to use this service control model.

Acknowledgements This work was supported by the National Science Fund for Distinguished Young Scholars (No. 60525110), the National Basic Research Program of China (Nos. 2007CB307100, 2007CB307103), the Program for New Century Excellent Talents in University (No. NCET-04-0111), the Development Fund Project for Electronic and Information Industry (Mobile Service and Application System Based on 3G).

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