이동망에서 결함 허용 위치 관리를 위한 포인터 포워딩 방법

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요 약

개인 통신 서비스에서 주된 당면 문제중의 하나는 위치를 자주 이동하는 많은 이동 단말기들의 위치를 찾는 것이다. 이러한 시스템 연산을 위치 관리라 한다. 이 작업은 복잡한 신호처리 트래픽과 데이터베이스 질의를 요구한다. 위치 관리의 효율성을 향상시키기 위하여 다수의 정책들이 제안되었다. 제안된 정책들은 이동 단말기의 현재 위치를 저장하기 위하여 위치 레지스터 데이터베이스를 사용한다. 그러한 위치 데이터베이스에 고장이 발생하면 위치 레지스터 데이터베이스의 고장에 대하여 취약하다. 이 논문에서는 위치 레지스터들의 고장을 허용하는 분산 홈 위치 레지스터를 갖는 결함 허용 포인터 포워딩 방법을 제안한다. 제안하는 방법의 성능은 시뮬레이션로 분석적으로 평가하고, Biaz의 우회 포워딩 정책, 두 개 경로 포워딩 정책과 성능을 비교한다.

A Pointer Forwarding Scheme for Fault-tolerant Location Management in Mobile Networks

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ABSTRACT

One of the main challenges in personal communication services(PCS) is to locate many mobile terminals that may move from place to place frequently. This kind of system operation is called location management. This task entails sophisticated signaling traffic and database queries. Several strategies have been proposed to improve the efficiency of location management. These strategies use location register databases to store the current locations of mobile terminals, and are vulnerable to failure of the location register databases. In this paper, we propose a fault-tolerant pointer forwarding scheme with distributed home location register in order to tolerate the failure of location registers. The performance of the proposed scheme is evaluated analytically by simulation, and is compared with Biaz's bypass forwarding strategy and two-path forwarding strategy.

키워드 : PCS 시스템(PCS Systems), 이동성 관리(Mobility Management), 결함-허용 위치 관리(Fault-Tolerant Location Management)

1. Introdutcion

In Personal Communication Services(PCS), a user is able to receive calls at any location in the PCS service area. To provide this service at any time and in any place, provisions must be made to be able to locate a mobile terminal whenever a call is to be delivered. This is achieved by using an appropriate location management strategy. Location management consists of location searches and location updates. A location search occurs whenever a host wants to communicate with a mobile host whose location is unknown to the requesting hosts. A location update occurs whenever a mobile host changes its location. Typical algorithms for location management are strategies that are on the basis of Interim Standard 41(IS-41) or pointer forwarding methods.

The mobility management strategies in IS-41 are two-level strategies in which they use a two-tier system with home and visited databases. When a user subscribes the services to a PCS system, a record is created in the system database called Home Location Register(HLR). When a mobile user visits new Registration Area(RA), a temporary record for the mobile user is created in the Visitor Location Register(VLR) of the visited system, and the HLR is updated with the new VLR address. Accordingly, future calls to the mobile terminal can be delivered correctly to the new location. In this scheme, considerable signaling traffics must be sustained to keep the HLR updating with the current mobile terminal location. The rapid growth in PCS incurs increasing loads on the databases and network

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signaling resources [1, 2]. Forwarding strategy is used for the users who move frequently, but receive calls relatively infrequently. The forwarding scheme avoids the update of the HLR by setting a pointer from the previous VLR to the new VLR. This strategy reduces the load on the signaling network between the VLR and the HLR, and also avoids the update of HLR database. However, this scheme is more vulnerable to failure in comparison with IS-41. In IS-41 scheme, failure-free operations in the HLR and the VLR of the current callee are required for successful call delivery. In forwarding scheme, failure-free operations in intermediate VLRs are also required for successful call delivery [1, 3].

In this paper, a Fault-Tolerant Pointer Forwarding scheme with Distributed Home Location Register(FT-PFDHLR) is proposed to tolerate the failure of location registers. The performance of proposed scheme is evaluated through an analytical model and a simulation, and is compared with the Bypass Forwarding Strategy(BFS) and the Two-Path Forwarding Strategy(TPFS) proposed by Biaz [4, 5].

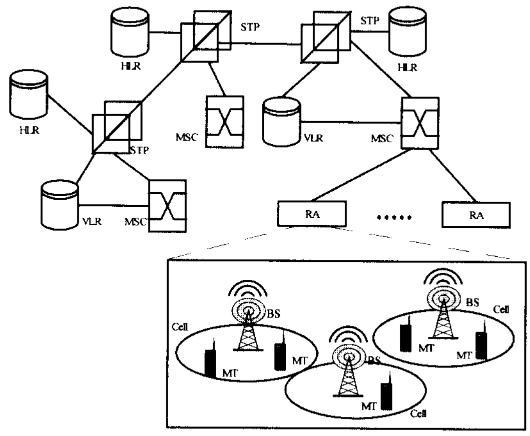
This paper is organized as follows : Section 2 presents a broad architecture of the PCS. Section 3 summarizes related works. Section 4 describes the proposed FT-PFDHLR scheme. Section 5 evaluates the performance of the proposed scheme through an analytical model and a simulation. Finally, Section 6 offers concluding remarks.

2. PCS Architecture

The PCS architecture consists of two networks such as a Public Switched Telephone Network(PSTN) and a signaling network. The PSTN is the traditional telephone system carrying voice, while the signaling network, meant for management purposes, uses the Signaling System no. 7 (SS7). For location management, the signaling network has two purposes :

- to track the location of the mobile terminals (registration/deregistration), and
- to provide information to the PSTN switches to establish a circuit between a calter and a mobile callee.

(Figure 1) represents a systematic view of the PCzS architecture. The Mobile Terminals(MT) access to the PSTN through base stations using wireless links. The area covered by a base station is called as a cell. A set of close cells geographically is defined as a Registration Area(RA). All mobile terminals roaming in a registration area have a record in a database called as a Visitor Location Register(VLR). A VLR is responsible for recording in a group of RAs. Each mobile terminal is registered permanently to a Home Location Register(HLR). The HLR keeps the user profile and the information needed to locate the mobile terminal. Networks are interconnected by way of SS7 that is used as a transport mechanism for call control and database transactions. The Mobile Switching Center(MSC) is a central office, which provides the call processing and channel setup function. For subscriber tracking and locating, network elements such as Signal Transfer Points (STP) and location registers are used. The STP performs message routing and other SS7 functions [6].



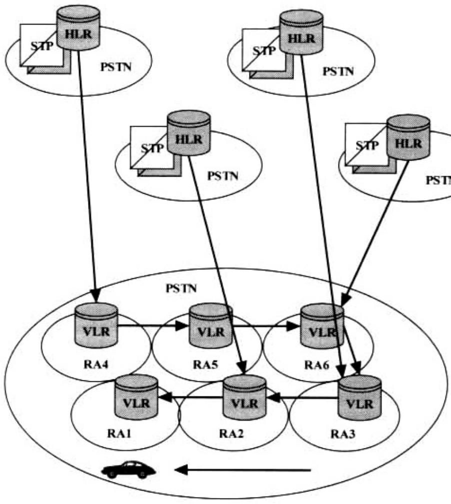
(Figure 1) Architecture of a PCS

3. Related Work

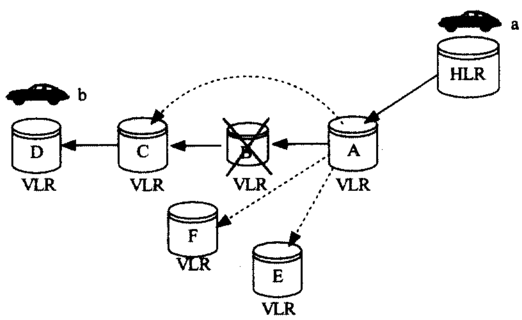
Lin [7] proposed Pointer Forwarding with Distributed HLR(PFDHLR) scheme that integrates the concept of distributed HLRs with pointer. In PFDHLR, the HLRs are distributed in remote PSTNs. A natural location for a distributed HLR is near by the STP. The HLRs may point to different VLRs where the portable visited previously (see (Figure 2)). After the *find* operation, the pointer of the distributed HLR is updated.

To address the lack of fault tolerance, two simple variations to the forwarding scheme were proposed by Biaz [4, 5]. The first scheme is based on the idea of maintaining two paths from the home location register to the last VLR. The second scheme is based on the knowledge of the neighbors of the faulty VLR. When a VLR on the forwarding pointer chain fails, the first scheme, called Bypass

Forwarding Strategy(BFS), attempts to bypass the faulty VLR by forwarding a request to all its neighbors. In the BFS, the chain length is limited to less than some value K. (Figure 3) shows the *find* operation for a VLR failure in BFS.

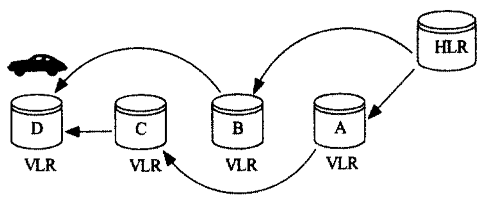


(Figure 2) PFDHLR(the registration operation)



(Figure 3) Find operation for a VLR failure

In the second scheme, called Two-Path Forwarding Strategy(TPFS), two independent paths from the MT's HLR to its current VLR are established. If a *find* operation fails due to loss of a pointer (due to VLR failure) along with the path, the HLR will start again with another path. As these two paths do not share an intermediate VLR, single intermediate VLR failure can be tolerated. In the TPFS, the forwarding pointer chains are compressed when

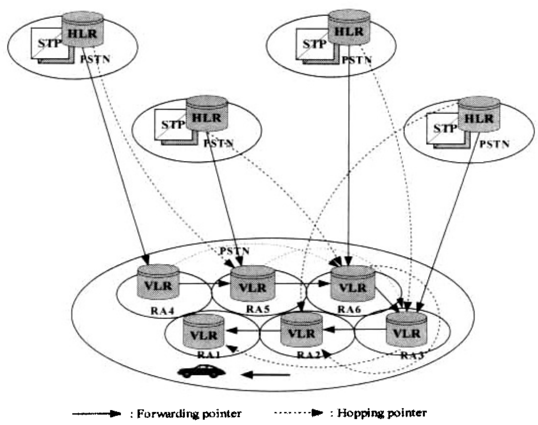


(Figure 4) Pointer update for *move*

the first chain followed by the HLR becomes of length K'. Accordingly, if the chain length of two schemes is limited to the same number of *moves* (K), K' is $K/2$. (Figure 4) shows pointer update for *move* in TPFS.

4. FT-PFDHLR

In this paper, we propose a novel pointer forwarding scheme that we refer to as FT-PFDHLR and that tolerates not only the failure of HLRs but also the failure of VLRs in the chain of pointers forwarding from the first VLR to the current VLR covering a MT. This scheme is designed on the basis of Lin's PFDHLR. (Figure 5) shows the configuration of FT-PFDHLR. Similarly to PFDHLR, HLRs are distributed in remote PSTNs. The HLRs may point to different VLRs where the portable visited previously. Unlike PFDHLR, location registers(LR) have two data structures : a forwarding pointer and a hopping pointer to maintain the location information of MTs. When a MT enters a new RA covered by a new VLR, late two VLRs store the location information of the MT(*update* operation). The forwarding pointer of old VLR is established from the old VLR to the new VLR, and the hopping pointer of former VLR of old VLR is established from the former VLR to the new VLR. If the former LR of old VLR is HLR, the hopping pointer of the HLR is established from the HLR to the new VLR.



(Figure 5) FT-PFDHLR

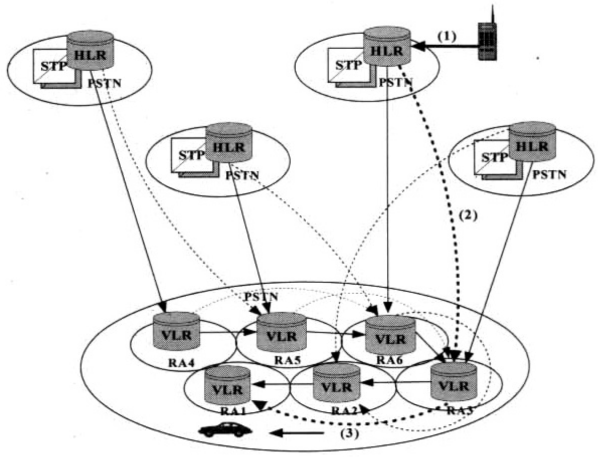
(Figure 6) shows the detailed procedure for the location update operation of FT-PFDHLR.

When a call is issued to a MT, the hopping pointers are traced to find the actual location of the portable (*find* operation, see (Figure 7)). So, the VLRs on hopping pointer chain will be queried until the current VLR covering the

MT. If the hopping pointer of the queried VLR on the chain is null, the VLR continuously traces the current VLR using the forwarding pointer.

```
FwdUPDATE()
{
    The MT detects that it is in a new RA ;
    The MT registers at the new RA/VLR, passing ID of
      former RA/VLR ;
    The New VLR deregisters the MT at the old VLR ;
    The forwarding pointer of the old VLR is created
      point to the new VLR ;
    The old VLR sends ACK msg and user's services
      profile to the new VLR ;
    The old VLR send HopUPDATE(ID, newVLR) msg to
      the former VLR of old VLR ;
}

/* When the VLR receives the HopUPDATE msg from the
    latter VLR */
HopUPDATE(ID, newVLR)
{
    The hopping pointer of the VLR is created
      point to the newVLR ;
    The VLR sends ACK msg to the latter VLR ;
}
```

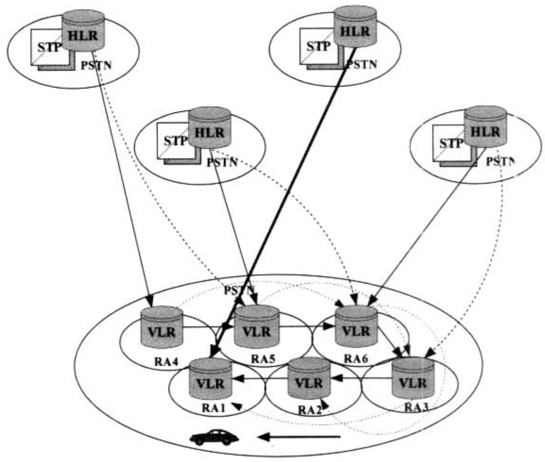
(Figure 6) Location Update Procedure of FT-PFDHLR



(Figure 7) FT-PFDHLR(the *find* operation)

After the *find* operation, the forwarding pointer of the HLR is updated as shown in (Figure 8) (*find update* operation). To reduce *find update* cost, we define a *find length*, as the number of forwarding pointers from the first VLR to the current VLR covering the destination MT (For the destination MT, the number of *moves* since the last find update). After a *find* operation, if the *find length* is less than some integer, *find length threshold* (L), then the *find update* operation is not performed, otherwise the location registration (*find update*) operation is performed in HLR.

(Figure 9) shows the detailed procedure for the location find operation of FT-PFDLHR.



(Figure 8) FT-PFDHLR(after the *find* operation)

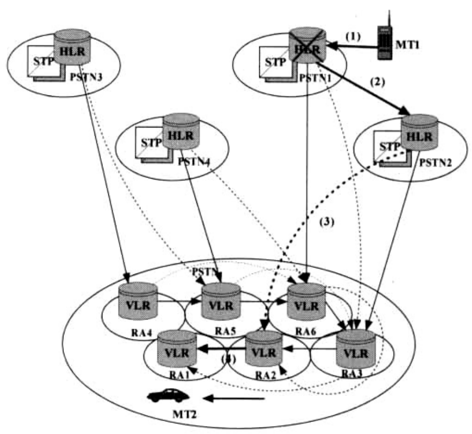
```
LocFIND()
{
  A call to PCS user arrives from a particular PSTN;
  The HLR of the PSTN is queried ;
  If (the hopping pointer of the callee ID of
      queried HLR is null) {
    The HLR responds to caller's switch with the first
      VLR that is pointed by the forwarding pointer ;
    k = 0 ;
  }
  Else {
    The HLR responds to caller's switch with the first
      VLR that is pointed by the hopping pointer ;
    k = 1 ;
  }
  Caller's switch queries the first VLR ;
  While (queried VLR is not callee's current VLR) {
    If (the hopping pointer of queried HLR is null) {
      VLR queries next VLR in forwarding chain ;
      k = k + 1 ;
    }
    Else {
      VLR queries next VLR in hopping chain ;
      k = k + 2 ;
    }
  }
  Callee's current VLR sends user location to HLR ;
  HLR sends user location to caller's switch ;
  If (k >= L) /* L is a find length threshold */
    basicUPDATE() ;
}

basicUPDATE()
{
  The current VLR covering the callee's MT sends a
    registration msg to the caller's HLR ;
  The forwarding pointer of the HLR is created
    point to the current VLR ;
  The hopping pointer of the HLR is setting by null ;
  The HLR sends a registration cancellation msg to the old VLR ;
  The old VLR sends a cancellation confirm msg to the HLR ;
}
```

(Figure 9) Location Update Procedure of FT-PFDHLR

4.1 HLR Failure

In FT-PFDHLR, the location information of a MT is distributed in HLRs and HLRs may point to different VLRs those are visited previously. When the HLR that received location request from a MT is fault, the HLR can't forward the request because all pointers are lost. Therefore, the STP having the faulty HLR forwards the request to one of the neighbor HLRs.

(Figure 10) shows fault-tolerant processing for a HLR failure. In this figure, the STP of PSTN1 receives a call request from local MT1 to remote MT2, and the HLR of PSTN1 fails. Then the STP of PSTN1 will not get a positive acknowledgement to its request. In this case, the STP will forward the request to the HLR of neighbor STP in PSTN2. The neighbor HLR will forward the request to the VLR of RA2 along with the hopping pointer, and the VLR of RA2 will pass the request to the VLR of RA1 that covering the MT2 along with the forwarding pointer. Therefore, the call will be delivered even if HLR fails.

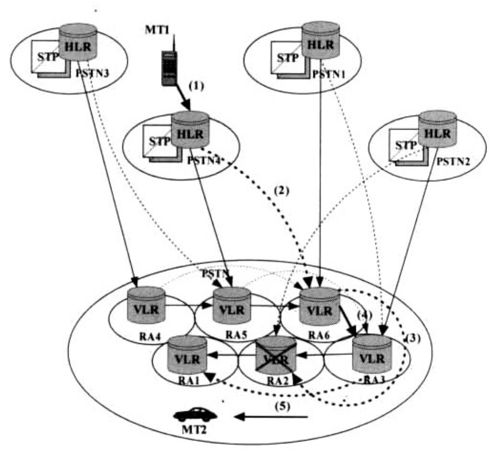


(Figure 10) Fault-tolerant processing of FT-PFDHLR for HLR failure

4.2 VLR Failure

If an intermediate VLR on the chain of hopping pointers fails during a call request, the previous VLR having the hopping pointer that points to the faulty VLR will forward the request to another VLR along with the forwarding pointer. Then the VLR will forward the request using the hopping pointer until it gets the current VLR covering the destination MT.

(Figure 11) shows fault-tolerant processing for VLR failure. In this figure, the STP of PSTN4 receives a call request from local MT1 to remote MT2, and the VLR of RA2 fails. Then the VLR of RA6 will not get a positive acknowledgement to its request. In this case, the VLR will forward the request to the VLR of RA3 using the forwarding pointer, the VLR will forward the request to the VLR of RA1 that covering the MT2 along with the hopping pointer. Therefore, the call will be delivered even if VLR fails.



(Figure 11) Fault-tolerant processing of FT-PFDHLR for VLR failure

5. Evaluation

In this section, we evaluate the performance of FT-PFDHLR through an analytical model and a simulation.

5.1 Analytical Model

The metric used for performance evaluation of FT-PFDHLR is the total costs for location management. The following terminology is used in the analysis :

- N = the number of PSTNs in a PCS system.
- k = for a caller host, this is the length of a forwarding pointer chain from the first VLR to the current VLR covering the destination host.
- γ = average number of calls per registration area crossing(call-mobility ratio).
- δ = the cost of traversing a pointer from a VLR to another.

To simplify the performance evaluation, we make the following simple cost estimation.

- The cost of sending a message from the source MT to the HLR and the cost of sending message from the HLR to the first VLR are normalized to 1.
- Since the old and the new VLRs are likely to be next to each other, it is reasonable to assume $\delta << 1$.

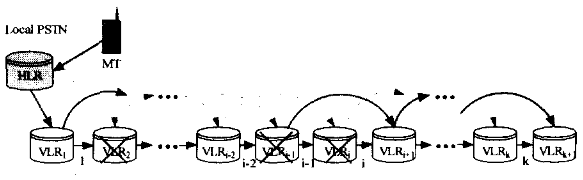
The total costs can be evaluated by $C_{total} = \frac{1}{\gamma} C_{update} + \gamma\{(1-P_f)C_{find} + P_f C^f_{find} + C_{find\_update}\}$, where C_{update} is the cost of an update operation, C_{find} is the cost of a find operation, C^f_{find} is the expected cost for a find operation in the presence of a VLR failure, C_{find_update} is the cost of an update operation after *find* operation, and P_f is the probability that a VLR on the forwarding pointer chain is faulty in a find operation, where C_{update} is 2, and C_{find_update} is 1. Equation (2) is the C^f_{find} of FT-PFDHLR.

- FT-PFDHLR :

$$C^f_{find} = 2 + \frac{1}{k}\left(1 + \lceil \frac{k}{2} \rceil \delta\right) + \frac{k-2}{2k}\left(\lceil \frac{k}{2} \rceil + \frac{3}{2}\right)\delta + \lceil \frac{k}{4} \rceil \delta \quad (1)$$

$$= 2 + \frac{1}{k} + \left\{\lceil \frac{k}{2} \rceil + \frac{3}{2}\left(\frac{1}{2} - \frac{1}{k}\right)\right\}\delta \quad (2)$$

(Figure 12) shows the failure of three different VLR locations on the forwarding pointer chain and recovery processes from these VLR failures. We can make Equation (2) from (Figure 12). The first term of Equation (1) represents the cost to access the first VLR on the hopping pointer chain, the second term represents the average find cost in the case of presence of VLR_2 failure that is the first VLR on the hopping pointer chain, the third term represents the average find cost in the case of the failure of VLR_i that is intermediate VLR on the hopping pointer chain, and the fourth term represents the average find cost in the case of the failure of VLR_{i-1} that is skipped by hopping pointer (see (Figure 12)).



(Figure 12) Fault-tolerant processing for the VLR failure of three different locations

The C^f_{find}s of other fault-tolerant schemes are as follows :

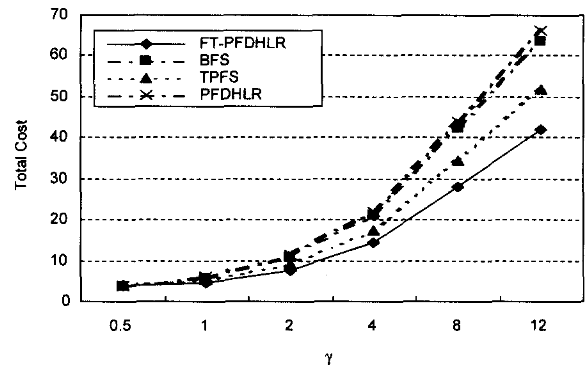
- BFS :

$$C^f_{find} = 3 - \frac{1}{N} + \frac{5}{k} + \left\{k + 5\left(1 - \frac{1}{k}\right)\right\}\delta$$

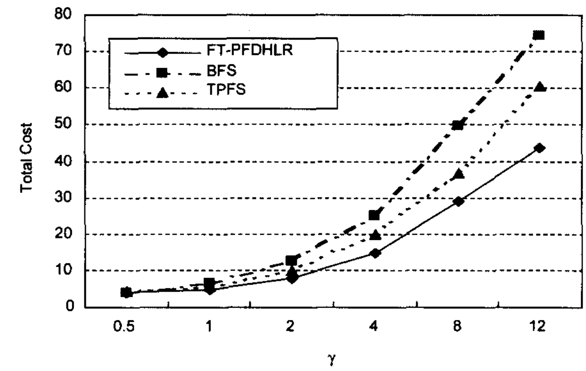
- TPFS :

$$C^f_{find} = 3.5 - \frac{1}{N} + \left\{\lceil \frac{k}{2} \rceil + \lceil \frac{k+1}{8} \rceil\right\}\delta$$

In case that P_f = 0.0(failure-free), the comparison between the total costs of location management schemes and call-mobility ratio is shown in (Figure 13). From the results of the performance evaluation, we know that the performance of FT-PFDHLR is better than that of other strategies.



(Figure 13) Total costs with N=5, K=7, L=7, k=5, δ=0.5, and P_f=0.0



(Figure 14) Total costs with N=5, K=7, L=7, k=5, δ=0.5 and P_f=0.3

In case that P_f = 0.3, the comparison between the total costs of fault-tolerant location management schemes and call-mobility ratio is shown in (Figure 14). From the results of the performance evaluation, we know that the performance of FT-PFDHLR is better than that of other fault-tolerant strategies.

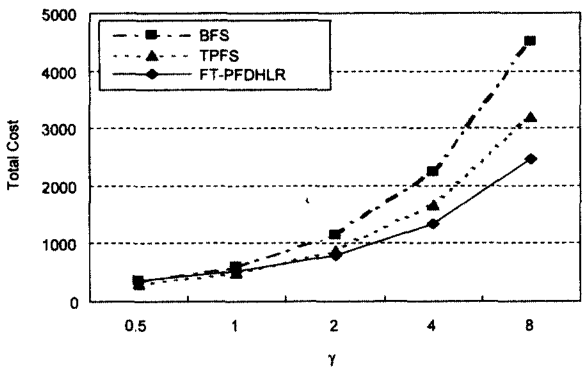
5.2 Simulation

We have evaluated the performance of FT-PFDHLR scheme through simulation. The simulation parameters are shown in <Table 1>, where source MT represents the MT that issues a call request. We assume that the PSTN location of a source MT is generated randomly from 1 to N. Under such this simulation environments, we compute the total costs for location management according to call-to-mobility ratio until the number of location updates is 100 times.

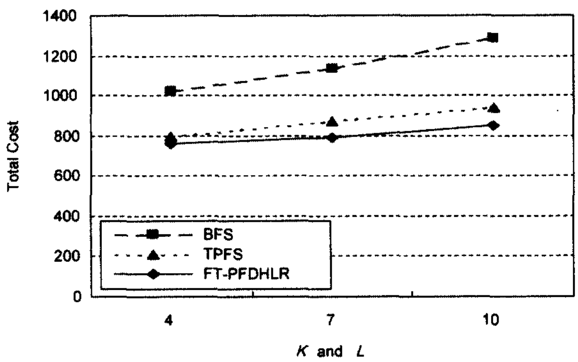
〈Table 1〉 Simulation parameters

Parameter	Data value
Number of PSTN (N)	5
Failure probability (P_f)	0.3
Number of location updates	100
Initial chain length of forwarding pointers (k)	Random (2, 4)
Find length threshold (L)	7
Chain length limit (K)	7
The PSTN location of a source MT	Random (1, N)

(Figure 15) shows the performance of fault-tolerant location management schemes through the simulation. The result is similar to the analytical model. In case that call-to-mobility ratio is less than 1.0, it is known that the performance of FT-PFDHLR nearly equals to that of other schemes. In case that call-to-mobility ratio is greater than 1.0, it is known that the performance of FT-PFDHLR is better than that of other schemes.



(Figure 15) Total costs by a simulation



(Figure 16) Total costs over K and L values with $\gamma=2$

(Figure 16) shows the total cost for location management over K and L values under the assumption that the chain length limit (K) and find length threshold (L) have the same value. From (Figure 16), we know that the proposed FT-PFDHLR has better performance than that of other schemes regardless of K and L values. Specially, as K and L values increase, the FT-PFDHLR performance is better.

6. Conclusion

Typical algorithms for location management are strategies that are on the basis of IS-41 or pointer forwarding methods. In IS-41 scheme, failure-free operations in the HLR and the VLR of the current callee are required for successful call delivery. In forwarding scheme, failure-free operations in intermediate VLRs are also requires for successful call delivery.

In this paper, we propose the FT-PFDHLR that tolerates not only HLR failures but also VLR failures. The FT-PFDHLR is able to tolerate multiple failures of HLRs and VLRs as long as no two consecutive VLRs in the forwarding chain fail. In case of both failure-free and failure, the results from an analytical model and a simulation show that the performance of FT-PFDHLR is better than that of other location management strategies.

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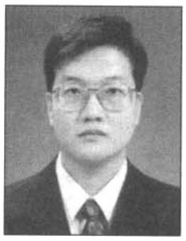

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