Performance Evaluation of PB-cache Scheme for Personal Communication Service Network

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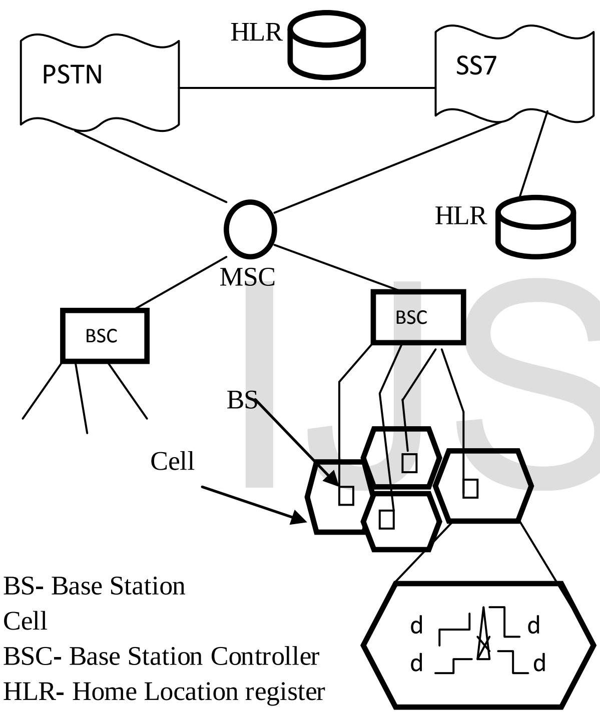
Abstract - In this paper forwarding pointer-based cache scheme (PB-Cache scheme) has discussed that reduces the signaling cost in PCS networks. In the conventional cache scheme, the cache information can effectively reduces the signaling traffic for locating called mobile. However, when the cache information is obsolete, it results in more signaling traffic than the IS-41. To solve this problem, the new location cache scheme called the PB-Cache scheme exploits a user's movement locality as well as call locality. Even if the cached information is not up-to-date, the called user can be found by tracing forwarding pointers starting from that VLR pointed in the cache instead of querying the HLR. Thus, the PB-Cache scheme can effectively reduce the frequent access to the HLR and the signaling traffic for location management. Moreover, it also distributes the signaling and database access load on the HLR to the VLR's. Analytical results indicate that the PB-Cache scheme significantly outperforms the other schemes when a user's (CMR) is high or the signaling traffic to the HLR is heavy.

Keywords: location management, forwarding pointer, cache, location registration, call delivery, personal communications service (PCS).

1. INTRODUCTION

Cellular Communication has been experiencing a rapid growth in recent year. Since its introduction in the yearly **1980s**, cellular communication has been evolving from a costly service with limited availability towards an affordable alternative to wired telephone service. This wide acceptance of cellular communication has led to the development of a new generation of mobile communication network called **Personal Communication system** (PCS), which can support a larger mobile subscriber population while providing various types of services unavailable to traditional cellular system. Personal Communications Service (PCS) networks provide wireless services to subscribers that are free to travel and the network access point of a mobile terminal (MT's) and changes as it moves around the network coverage area. A Location Management (LM) scheme, therefore, is necessary to effectively keep track of the MT's and locate a called MT when a call is initiated. There are two commonly used standards forLM: IS-41[1, 5-9] and GSM [1, 2,10 and 25]. Both are based on a two-level database hierarchy, which consists of Home Location Register (HLR) and Visitor Location Registers (VLR's).The whole network coverage area is divided into cells. There is a Base Station (BS) installed in each cell and these cells are grouped together to form a larger area called a Registration Area (RA). Location management is one of the most important issues in PCS networks. As the number of MT's increases, location management scheme under the IS-41 has gone through many problems such as increasing traffic in network, bottleneck to the HLR, and so on. To overcome these problems under the IS-41, a number of works have been reported. A cache scheme [12] was proposed to reduce the signalling cost for call delivery by reusing the cached information about the called MT's location from the previous call. When a call arrives, the location of the called MT is first identified in the cache instead of sending query messages to the HLR. When a cache hit occurs, the cache scheme can save one query to the HLR and traffic along some of the signaling links as compared to theIS-41. This is especially significant when the call-to-mobility ratio (CMR) of the MT is high. However, a penalty has to be paid when there is "location miss" since the cache Information is not always up-to-date. In this paper, the enhanced cache scheme called PB-Cache scheme exploits a user's movement locality as well as call locality at the same time, thereby reducing the access to the HLR and the signaling traffic for location management throughout the networks. In ordinary wireless network, such as the telephone network, there is a fixed relationship between a terminal and

its location. Changing the location of a terminal generally involves network administration, and cannot easily be performed by a user. Incoming calls for a particular terminal are always routed to its associated location because there is no distinction between a terminal and its location. Contrast, PCS network support mobile terminals (MTs) that are free to travel, and the network access point of an MT changes as it moves around the network coverage area. As a result, the ID of an MT does not implicitly provide the location information of that MT.
Fig1. Demonstrate the general architecture of a PCS Network. It can be seen in Fig.1 that a number of base station controller (BSC).



BS- Base Station
Cell
BSC- Base Station Controller
HLR- Home Location register
MSC- Mobile Switching Center
PSTN- public switching telephony network
SS7- Signal system number 7

Fig 1: PCS network architecture

2. SCHEMES OF CENTRALIZED DATABASE ARCHITECTURE:

2.1 Per-user Location Caching Strategy: This reduces the volume of signaling and database access traffic for locating an MT by maintaining a cache of location information at a nearby STP [12, 15]. Whenever the MT is accessed through the STP, an entry is added to the cache which contains a mapping from the ID of the MT to that of its serving VLR. When another call is initiated for an MT, the STP first checks if a cache entry exists for the MT. If no cache entry for the MT exists, the IS-41 call delivery scheme described earlier is used to locate the MT. If a cache entry exists, the STP will query the VLR as specified by the cache. If the MT is still residing under the same VLR, a hit occurs, and the MT is found. If the MT has already moved to another location which is not associated with the same VLR, a miss occurs, and the IS-41 call delivery scheme is used to locate the MT. demonstrates the operation of per-user location caching. When a call is initiated from MT 1 to MT 2, as indicated, the system can locate MT 2 by using the cached information at STP1. As a result, MT 2 is successfully located without querying the HLR of MT 2. As compared to the IS-41 scheme demonstrated in per-user location caching allows the STP to locate the VLR of the called MT after only one cache database lookup. This is true, however, only when the cached location information of the called MT is valid (a hit).The cost of per-user location caching is higher than the IS-41scheme when a miss occurs. Based on the system parameters, the minimum hit ratio required to produce a performance gain using per-user location caching needs to be determined. In the authors define the local call-to-mobility ratio (LCMR) as the average number of calls to an MT from a given originating STP divided by the average number of times the User changes VLR per unit time. The minimum LCMR necessary to attain the minimum hit ratio is obtained. In order to reduce the number of misses, it is suggested in that cache entries should be invalidated after a certain time interval. Fig.2 demonstrates the operation of per user location caching.

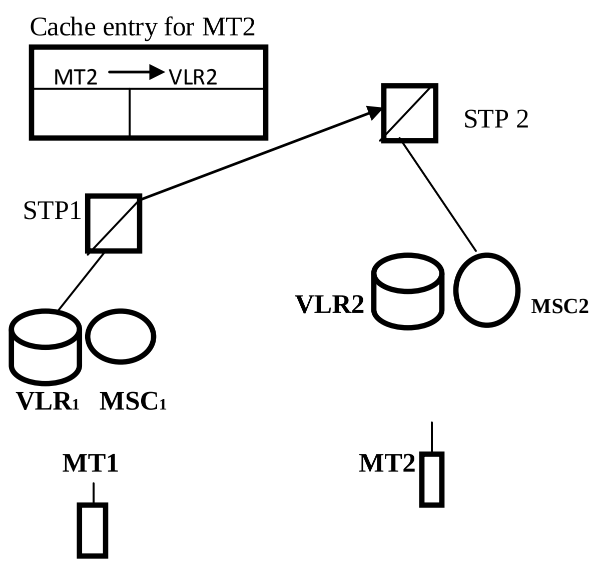


Fig 2: Per-User Location Caching Scheme

2.2 Pointer Forwarding Strategy: This strategy instead of reporting a location change to the HLR every time the MT moves to an area belonging to a different VLR[18,19], the reporting can be eliminated by simply setting up a forwarding pointer from the old VLR to the new VLR. When a call for the MT is initiated, the network locates the MT by first determining the VLR at the beginning of the pointer chain and then follows the pointers to the current serving VLR of the MT. To minimize the delay in locating an MT, the length of the pointer chain is limited to a predefined maximum value, *K*. When the length of the pointer chain reaches *K*, additional forwarding is not allowed, and location change must be reported to the HLR when the next movement occurs. Pointers are set up from VLR 1 to VLR 2 and from VLR ***2*** to VLR 3 as the MT moves from MSC 1 to MSC2 and from MSC 2 to MSC 3, respectively. For *K* = 2, the pointer chain cannot be extended any further. An additional movement from MSC 3 to MSC 4 will result in a location registration at the HLR. It is demonstrated that, depending on the mobility and call arrival parameters and the value of K, this scheme may not always result in a reduction in cost from the original IS41 scheme. Fig.3 demonstrates the operation of Pointer Forwarding.

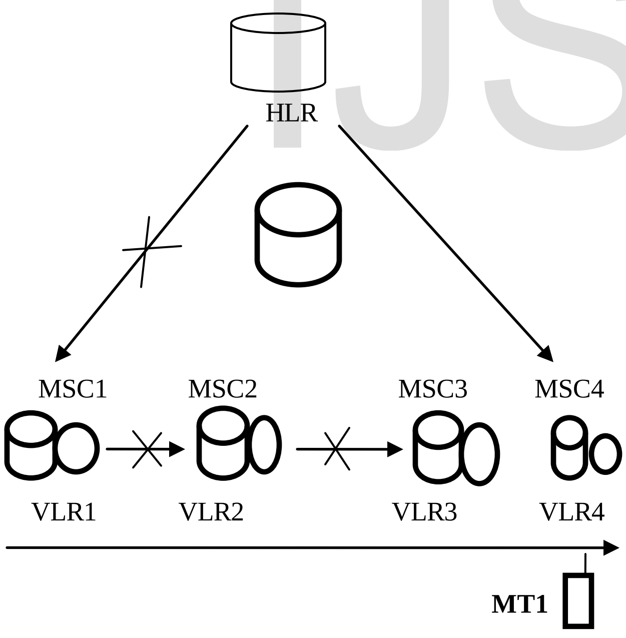


Fig: 3 Pointer Forward Strategy

2.3 Local Anchoring Scheme: It reduces the signaling traffic due to location registration by eliminating the need to report location changes to the HLR [21, 22]. A VLR close to the MT is selected as its local anchor. Instead of transmitting registration messages to the HLR, location changes are reported to the local anchor. Since the local anchor is close to the MT, the signaling cost incurred in location registration is reduced. The HLR keeps a pointer to the local anchor. When an incoming call arrives, the HLR Queries the local anchor of the called MT which, in turn queries the serving VLR to obtain a routable address to the called MT. the local anchoring scheme, The authors introduce two schemes for selecting the local anchor for an MT: static and dynamic local anchoring. Under static local anchoring, the serving VLR of an MT during its last call arrival becomes its local anchor. The local anchor is changed when the next call arrival occurs. Static local anchoring completely eliminates the need to report location changes to the HLR. Dynamic local anchoring changes the local anchor to the serving VLR when a call arrives. However, the network also makes a decision whether the local anchor for an MT should be changed to the new serving VLR based on the mobility and call arrival parameters.

2.4 User Profile Replication Scheme: It replicates user profiles at selected local databases [17]. When a call is initiated for a remote MT, the network first determines if a replication of the called MTs user profile is available locally. If the user profile is found no HLR query is necessary, and the network can locate the called MT based on location information available at the local database. Otherwise, the network locates the called MT following the IS-41 procedure. When the MT moves to another location, the network updates all replication of the MT user profile. This result in higher signaling overhead for location registration. Depending on the mobility rate of the MT and the call arrival rate from each location it reduces the signaling and data base access overhead for LM

3. FORWARDING POINTER-BASED CACHE SCHEME

In Fig.4 shows an illustrative example of locating the MT under the PB-Cache scheme [19]. The VLR1 represents the calling VLR associated with the RA the caller resides. We assume that the cache information exists in the MSC1 and the cache entry for the called MT (MT1) currently points to the VLR1. Let's considering that the MT1 has moved from the RA associated with VLR1 to the RA associated with VLR2 after the last call arrived. Then, the current location of the MT1 is the RA associated with the VLR2. When the next call arrives, the MSC0 first queries the pointed VLR, that is, VLR1. In this case, since the existing cache scheme has to perform the call delivery procedure of the IS-41 after an unsuccessful query for the cache, it results in the waste of the signaling traffic as compared to the IS-41. However, under the PB-Cache scheme, even if the cache information is obsolete, it traces the pointer chain without querying the HLR until the current location of the called MT is found within the maximum pointer chain length of *K*. So, the saving of one query to the HLR and traffic along some of the signaling links can be obtained. Note that the pointer chain length has to be limited due to the maximum pointer setup delay requirement. , we assume that the maximum pointer chain length, denoted by *K*=1. Therefore, unless the MT1 moves into the RA associated with the VLR3, it can be found through both cache and forwarding pointer information without querying the HLR.

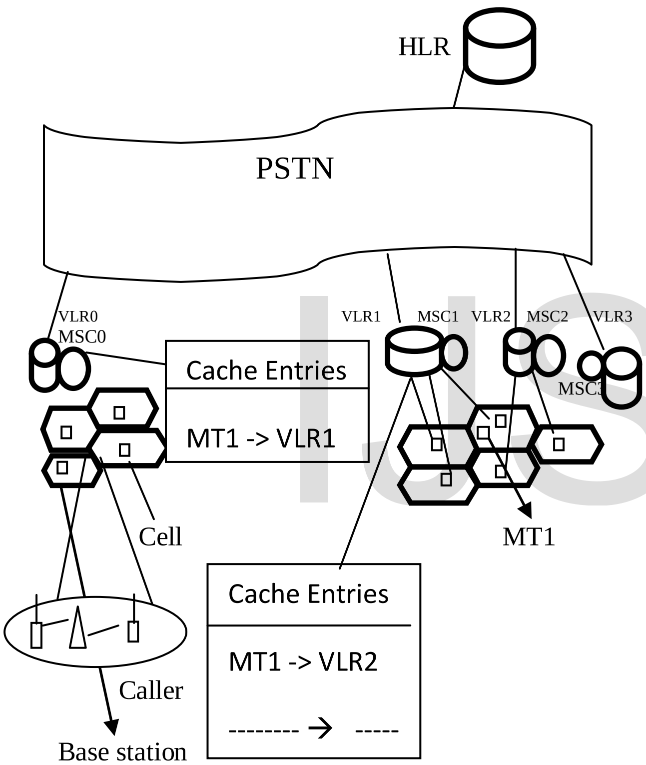


Fig 4: An example of locating an MT under The PB-Cache scheme

3.1 Location Registration:-

Compared with the IS-41, most procedures for location registration under the PB-Cache scheme are exactly the same as those of the IS-41 except that the forwarding pointer is additionally set up between the two VLR's.

3.2 Call Delivery:-

Most procedures for call delivery under the PB-Cache scheme are almost the same as those of the cache scheme except that the called MT is traced through the pointer chain length of *K*. When the cache information is obsolete, the pointer chain is traced to find a called MT starting from the VLR pointed in the cache. If the called MT is located within the pointer chain length of *K* from that VLR, it can be found without querying the HLR. Describes the procedures for a cache hit under the PB-Cache scheme. The cache hit under the PB-Cache scheme contains two situations: One is the situation that the cache information is correct. Thus, the called MT is found after the only one query to the pointed VLR. The other is the situation that the cache information is not correct. In this case, after querying the pointed VLR, the called MT is found by tracing through the pointer chain length of *K*. The cache miss under the PB-Cache scheme occurs when the called MT is not found even if the forwarding pointer chain has been traced until the length of *K*. After this, the same call delivery procedure as that of the IS-41 is performed. In this case, the current location of the called MT is transmitted from the HLR to the calling VLR together with the cache update request message

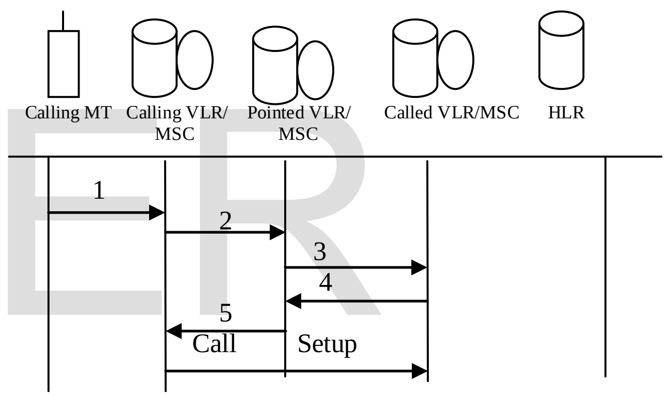
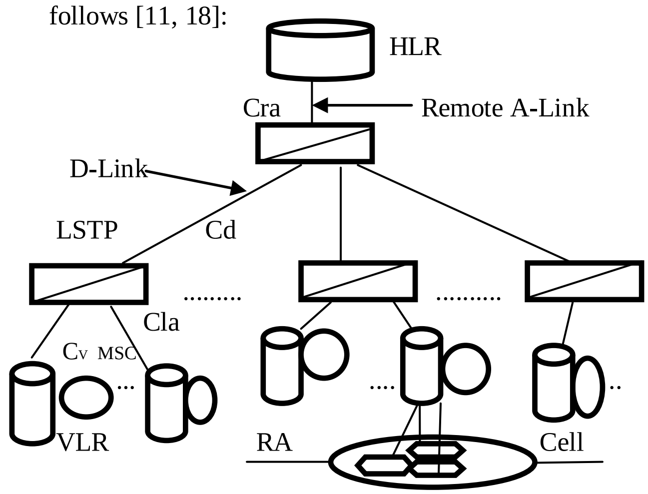


Fig 5: Call Delivery under PB-Cache (Cache Hit)

4. PERFORMANCE MODELING

Basic Assumptions and Parameters: The basic assumptions for the performance modelling are as follows [11, 18]:



Cla	Cost of Sending a Signalling message through the local A-link
Cd	Cost of sending a Signalling message through the D-link
Cra	Cost of Sending a signalling message through the remote A-link
Cv	Cost of a query or an update of the VLR
Ch	Cost of query or an update of the HLR
m	Probability (Any movement or searching by a user is within its current LSTP area)
t	Probability (VLR pointed in the calling MSC's cache is the VLR within the sameLSTP area)
j	Length of pointer chain traced until the MT is found ($0 < j \leq K$)
k	Maximum allowable length of pointer chain which can be traced to locate the MT
q	MT's CMR
p	Cache hit ratio under the PB-Cache scheme
$\overline{p}$	Cache hit ratio under the cache scheme

4.1 Analytical Model for Location Management Cost:-

In our analytical model, the signaling and database access costs are used to measure the performance of both the PB-Cache scheme and the cache scheme. These costs are associated with the delays needed to perform the signal transmission and database Update query. For the analytical model, we also assume that there are *q* call arrivals for an MT between two RA crossings. Based on these assumptions, we derive location management cost for the IS-41, the cache scheme, and the PB-Cache scheme, respectively.

4.1.1 Location management cost under the IS-41:-

The Signaling Cost for LR(UNC_{IS}) and for call delivery (SNC_{IS}) are $4(C_{la}+C_d+C_{ra})$

Total Signaling Cost(NC_{IS}) $=UNC_{IS}+qSNC_{IS} = 4(1+q)(C_{la}+C_d+C_{ra})$ ... (1)

The Database Access Cost for LR (UDC_{IS}) and call delivery(SDC_{IS}) are $(2C_v+C_h)$

Total Database Access Cost (DC_{IS}) $= UDC_{IS} + qSDC_{IS} = 2C_v+C_h + q(2C_v+C_h)$ ... (2)

Total Cost(TC_{IS}) $= NC_{IS}+DC_{IS}$

$= 4(1+q)(C_{la}+C_d+C_{ra}) + 2C_v+C_h + q(2C_v+C_h)$ ..(3)

4.1.2 Location management cost under the cache scheme:-

The signaling cost for location registration Under the cache scheme is the same as that Of the IS-41. Thus, the Signaling Cost for LR is same as that of IS-41(UNC_{Ca})$=UNC_{IS}=4(C_{la}+C_d+C_{ra})$ ....(4)

Signaling Cost for Call Delivery $(SNC_{Ca}) = pSNC_{CaH} + (1-p)SNC_{CaM}$ …..(5)

SNC_{CaH} = signaling cost for call delivery where a cache Hit occurs

SNC_{CaM} = signaling cost for call delivery where a cache Miss occurs.

$SNC_{CaH}= 4C_{la}+ 4(1-t)C_d= 4[C_{la}+ (1-t)C_d]$ …..(6)

$SNC_{CaM}= 4[C_{la}+ (1-t)C_d] + 4(C_{la}+ C_d+ C_{ra})$ …(7)

Thus,above equation can be written as-

$SNC_{Ca} = 4[C_{la}+ (1-t)C_d] + 4(C_{la}+ C_d+ C_{ra})(1-p)$

Total signaling Cost(NC_{Ca})= $UNC_{Ca} + qSNC_{Ca} = 4(C_{la}+ C_d+ C_{ra}) + q\{4[C_{la}+ (1-t)C_d] + 4(C_{la}+ C_d+ C_{ra})(1-p)\}$

DBA Cost for LR is $UDC_{Ca} = UDC_{IS} = 2C_v + C_h$

DBA Cost for Call Delivery is $SDC_{Ca} = p\,SDC_{CaH} + (1-p)\,SDC_{CaM}$ .....(8)

SDC_{CaH} = DBA cost for call delivery where a cache Hit occurs,ie, $= 2C_v$ .....(9)

SDC_{CaM} = DBA cost for call delivery where a cache Miss occurs $=3C_v+C_h$ ......(10)

putting these valus in above eq.(8) we get-

$SDC_{Ca}= pSDC_{CaH}+ (1-p)SDC_{CaM}= 3C_v+ C_h- p(C_v+ C_h)$

Total Database Access Cost(DC_{Ca}) is $= UDC_{Ca} + qSDC_{Ca} = 2C_v+ C_h+ q[3C_v+ C_h- p(C_v+ C_h)]$

Total Cost (TC_{Ca})$= NC_{Ca}+ DC_{Ca} = 4(C_{la}+ C_d+ C_{ra}) + q\{4[C_{la}+ (1-t)C_d] + 4(C_{la}+ C_d+ C_{ra})(1-p)\} + 2C_v+ C_h+ q[3C_v+ C_h- p(C_v+ C_h)]$

4.1.3. Location Management Cost under PB-Cache Scheme:-

Signaling Cost for LR $(UNC_{PB}) = UNC_{IS}+ S_N= 4(C_{la}+ C_d+ C_{ra}) + 4[C_{la}+ (1-m)C_d]$

S_N= additional signaling cost for setting up Forwarding pointer between the VLR's.

Signaling Cost for call delivery $(SNC_{PB})= pSNC_{PBH}+ (1-p)$

SNC_{PBH} = signaling costs for call delivery when a cache hit occurs.

SNC_{PBM} = signaling costs for call delivery when a cache miss occurs

To quantify j, we assume that on average $j= K/2$

$SNC_{PBH}= 4[C_{la}+ (1-t)C_d] + 2K[C_{la}+ (1-m)C_d]$

$SNC_{PBM} = 4[C_{la} + (1-t)C_d] + 4K[C_{la} + (1-m)C_d] + 4(C_{la} + C_d + C_{ra})$

Therefore, $SNC_{PB} = 4(C_{la} + C_d + C_{ra})(1\text{-}p) + 2K(2\text{-}p)[C_{la} + (1-m)C_d] + 4[C_{la} + (1-t)C_d]$

Total Signaling Cost(NC_{PB}) $= UNC_{PB} + qSNC_{PB} = 4(C_{la} + C_d + C_{ra}) + 4[C_{la} + (1-m)C_d] + q\{4(C_{la} + C_d + C_{ra})(1\text{-}p) + 2K(2\text{-}p)[C_{la} + (1-m)C_d] + 4[C_{la} + (1-t)C_d]\}$

DBA cost for location registration (UDC_{PB}) = $UDC_{IS} + S_D = 4C_v + C_hS_D$

DBA cost for call delivery (SDC_{PB})= $pSDC_{PBH} + (1-p)SDC_{PBM}$

Let j=K/2, the

DBA cost when a cache Hit occurs $SDC_{PBH} = (K+2)Cv + Ch + Cv = (K+3)Cv + Ch$

DBA cost when a cache Miss occurs $SDC_{PBM} = (K+2)C_v + C_h + C_v = (K+3)C_v + C_h$

$SDC_{PB} = = pSDC_{PBH} + (1-p)SDC_{PBM} = (K+3)C_v + C_h - p[(K/2+1)C_v + C_h]$

Total Database Access Cost(DC_{PB}) = $UDC_{PB} + qSDC_{PB} = 4C_v + C_h + q\{(K+3)C_v + C_h - p[(K/2+1)C_v + C_h]\}$

Total Cost(TC_{PB}) $= NC_{PB} + DC_{PB}$

$= 4(C_{la} + C_d + C_{ra}) + 4[C_{la} + (1-m)C_d] + q\{4(C_{la} + C_d + C_{ra})(1\text{-}p) + 2K(2\text{-}p)[C_{la} + (1-m)C_d] + 4[C_{la} + (1-t)C_d]\} + 4C_v + C_h + q\{(K+3)C_v + C_h - p[(K/2+1)C_v + C_h]\}$

The Total Cost Under PB-Cache Scheme is less than that of other two Schemes

4.2 Performance Analysis

We evaluate the performance of the PB-Cache scheme by comparing it with theIS-41 and the cache scheme based on the analytical model described in section [22]. Similar to [8, 15] we define the relative cost of the PB-Cache scheme as the ratio of the total cost for the PB-Cache scheme to that of the IS-41. A relative cost of 1 means that the costs under both schemes are exactly the same. In order to estimate m, we use the model of the called MT's mobility across LSTP areas (see [18] for more details). Then, the probability of intra-LSTP movement can be estimated to be approximately 0.87, and t is assumed to be 0.2.

4.2.1 Signalling Cost

We see that parameter sets 1 and 2 show the cases when the cost for sending a message to the HLR is relatively low. Parameter sets 3 and 4 show the cases when the cost for sending a message to the HLR is relatively high. As the number of the mobile users keeps increasing rapidly, parameter set 4 is especially expected to be the common case. Fig. 7 shows the relative signaling cost for both the cache scheme and the PB-Cache scheme when the parameter sets 2 and 4, as given in Table 2(a), are used. We can see that the PB-Cache scheme for $K = 1$, on the whole ,results in the lowest signalling cost as compared with other schemes.

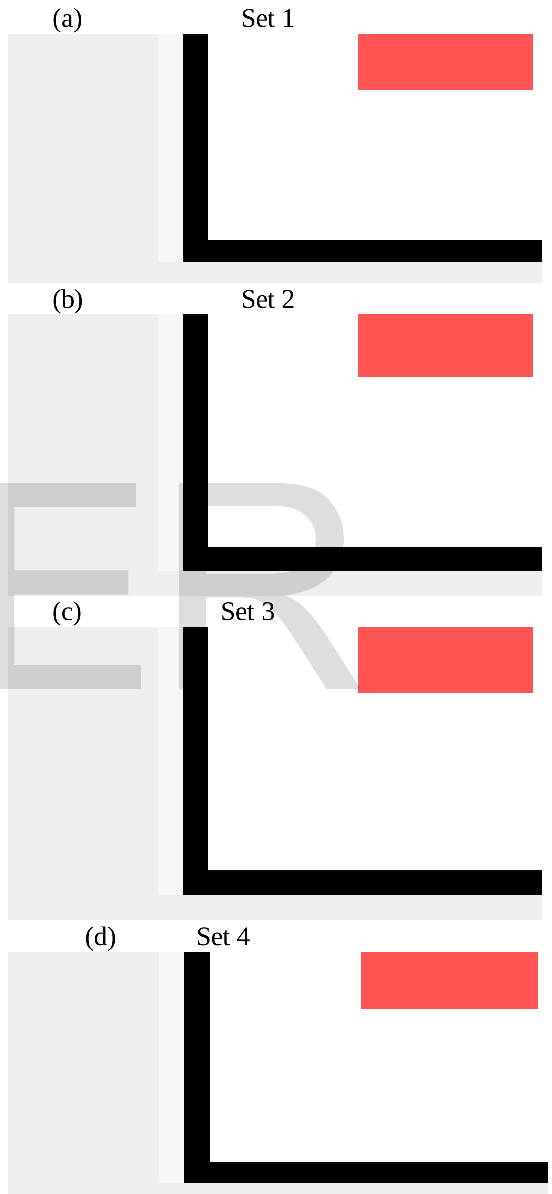
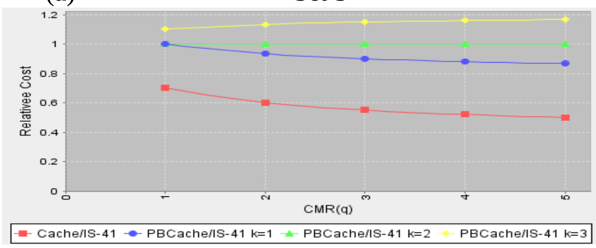


Fig7: Signaling Cost

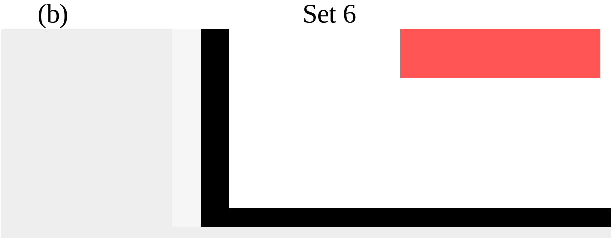
4.2.2 Database Access Cost

In the following, we evaluate the relative database access cost for both the cache scheme and the PB-Cache scheme when the parameter sets 6 and 7, as given in Table 2(b), are used. Note that in 8(c) the situation offsets the additional database access cost incurred by tracing more VLR queries against fewer HLR queries, and this will be more apparent as the cost for accessing HLR will become higher

(a) Set 5



(b) Set 6



(c) Set 7

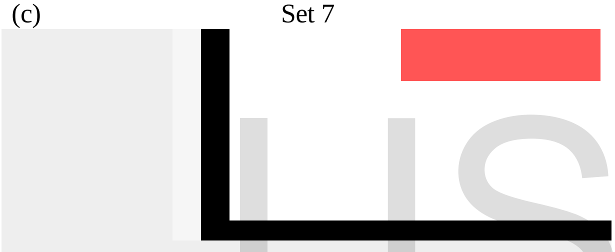
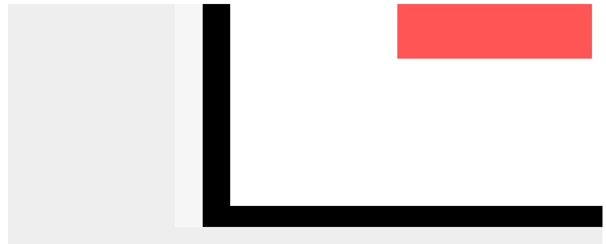


Fig 8: Database Access Cost

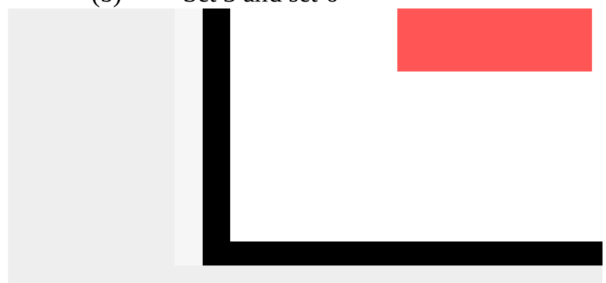
4.2.3 Total Cost

We compare the total cost of the PB-Cache scheme with that of the IS-41 and the cache scheme. We can see that the PB-Cache scheme for *K* = 1, on the whole, results in the lowest total cost compared with other schemes. For high CMR, the reduction in the total cost of the PB-Cache scheme is very significant when the cost for accessing to the HLR is relatively high (Fig. 9(c)). However, when *Cra and Ch* are relatively low (Fig. 9(a)), the reduction in the total cost of the PB-Cache scheme for *K* = 1 is almost the same as that of the cache scheme. These results may be expected because the PB-Cache scheme tries to reduce the number of messages going to the HLR by searching the MT based on the VLR pointed in the cache. Thus, the decision of the appropriate maximum pointer chain length is essential to improve the performance of the PB-Cache scheme.

(a) Set2and5



(b) Set 3 and set 6



(c) Set 4 and set 7

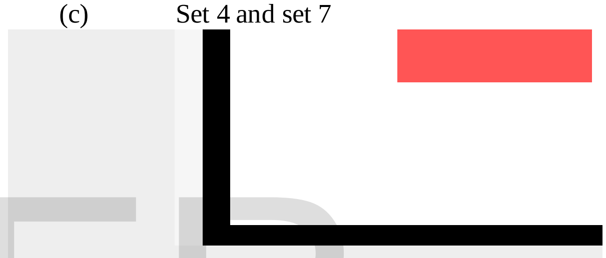


Fig9. Total Cost

Table 2: Cost Parameter sets

Set	Cla	Cd	Cra
1	1	3	3
2	1	3	5
3	1	5	7
4	1	5	10

(a) Signaling Cost

Set	Cv	Ch
5	1	3
6	1	4
7	1	5

(b) database cost

5. CONCLUSION

In this paper, PB-Cache Scheme is compared with cache and pointer forwarding scheme which reduces the signaling cost as well as database access cost thereby reducing the total cost. A caching strategy suits who receive calls more frequently(high CMR's) than change the PCS Registration Areas. But, pointer forwarding strategy in contrast, are suitable for users who move among the PCS Registration Areas frequently but does not receive the calls frequently (low CMR's). Also, the cache strategy reduces cost due to Call Delivery whereas, pointer forwarding attempts to reduce the cost of registration. Cache strategy are suitable for users who tend to revisit previous RA and tends to visit previously called RAs, i.e., to update the cached records resulting in higher *cache hit and valid ratios* whereas, pointer forwarding helps to reduce the penalty due to *cache hit but invalid ratios*. In the previous fig 7(a),7(b),7(c) and 7(d) the signalling cost in cache is higher than that of signalling cost in PB-cache, also, in the case of cache as the cost of cd and Cra is going high, the cost for exchanging signalling messages in going low but in PB-cache as the value of *K* is going high, the cost is also increasing while in case of database Access Cost as shown in fig. 8(a),8(b) and 8(c) the cost in PB-Cache is high than that of Cache. But at the same, as the cost of *ch* is increasing the cost of database access is decreasing. Thus, we need to keep the value of *K* as minimum i.e., equal to 1.Hence the PB-cache scheme reduces the Database load and signaling load on the HLR to VLR.

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