# Modified HLR-VLR Location Management Scheme in PCS Network

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## ABSTRACT

This paper proposes a modified version of conventional HLR/VLR scheme for improving the location management in PCS network. The conventional HLR/VLR scheme suggests that when a mobile terminal (MT) moves from one LA to another LA which is served by different VLR, it registers itself with new VLR along with HLR, at the same time HLR deregisters the mobile terminal from the old VLR and acknowledges the receipt of the message to new VLR. The modified version proposes that there is no requirement of deregistering of mobile terminal from old VLR at the same time when MT registers at new VLR and so message transmission cost and database overload can be reduced. Numerical analysis is done for both conventional and modified version and compared together. The numerical results are promising and a significant total cost reduction is obtained with proposed scheme.

## Keywords

Location Management, Mobility Management, PCS, HLR/VLR approach, deregistration.

## 1. INTRODUCTION

Cellular communication has been experiencing a rapid growth in recent years. Since its introduction in the early 1980s, cellular communication has been evolving from a costly service with limited availability toward 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 communications services (PCS), which can support a larger mobile subscriber population while providing various types of services unavailable to traditional cellular systems. The introduction of different types of services and the establishment of new service providers will result in an unprecedented predicted growth in the number of mobile subscribers. In the research arena, a large number of studies are being performed for better services. These research efforts range from the development of location management schemes, to the design of multiple access and channel allocation schemes, to the design of PCS network architectures. In this paper, we focus on surveying the location management mechanisms in PCS systems. In ordinary wire line networks, 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 it 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. In contrast, PCS networks support mobile terminals 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. A location-tracking mechanism is needed for effective delivery of incoming calls. The current methods IS-41, GSM for location management [1-3] require each MT to report its location to the network periodically. The network stores the location information of each MT in location databases, and this information is retrieved during call delivery. Current methods for location management employ centralized database architecture, while tracking and searching of MTs involve the transmission of signaling messages among various components of a signaling network. As the number of mobile subscribers increases, this scheme will become inefficient, and new improved schemes that can effectively support a continuously increasing subscriber population are needed.

### 1.1 Location management

In PCS, location management enables the network to determine the Mobile terminal current LA for call delivery. It is a two-phase process implying location update and location search. Location update occurs when the MT enters a new LA and notifies the network of its new location. Location search occurs when an MT is called; in which case the network database is queried in order to determine the Mobile terminal current LA. Currently, there are two commonly used standards for location management: Interim Standard-41 (IS-41) [1,2] and the Global System for Mobile (GSM) [3], [11]. Both standards employ a two-level database architecture consisting of one Home Location Register (HLR) and many Visitor Location Registers (VLRs), referred to as HLR/VLR(s) architecture in this study and shown in Fig. 1[4]. In this architecture, the HLR serves the entire network and is considered the centralized database of the network. It permanently stores the location profile and subscriber parameters of its assigned MT. The VLR serves one or more LA and stores all the relevant parameters of the MTs that roam within the LA that it controls. The VLR is usually collocated with an MSC. In order to deliver the calls correctly we need to maintain the location management.

Looking at the need of efficient location management, this paper attempts to propose a modification in conventional HLR/VLR scheme so that location management cost can be reduced.
The remaining part of this paper has been organized as follows. Section II gives an overview of conventional HLR/VLR scheme used in IS-41 and GSM, section III sheds light on proposed modified of HLR/VLR scheme. A comparative analysis has been carried out in section IV which is followed by results in section V and conclusion in section VI.

## II. CONVENTIONAL HLR/VLR SCHEME

This section describes existing standard of location management followed by the approaches evolved to overcome drawbacks of existing standard.
The two popular standards currently used are GSM and IS-41. They make use of two types of Registers, home location register (HLR) and visitor location register (VLR), to store the location

information of the mobile terminals. Fig. 1 shows the basic architecture under this two-level hierarchy[13].

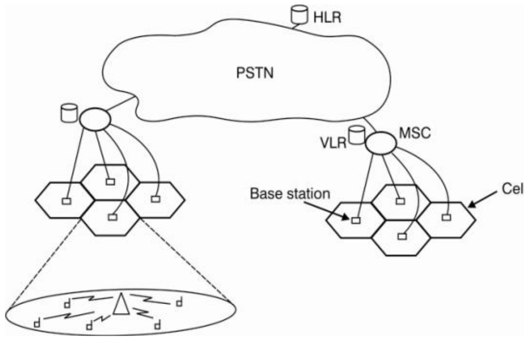


Fig. 1: The Standard PCN architecture

The HLR stores the user profiles of its assigned subscribers. These user profiles contain information such as the type of services subscribed, the quality-of-service (QoS) requirements and the current location of the mobile terminals. Each VLR stores replications of the user profiles of the subscribers currently residing in its associated LA. In order to effectively locate a mobile terminal when a call arrives, each mobile terminal is required to report its location whenever it enters a new LA. This reporting process is called location update. On receiving a location update message, the MSC updates its associated VLR and transmits the new location information to the HLR. We call this register update process as location registration. The HLR will acknowledge the MSC for the successful registration and it will also deregister the mobile terminal at the VLR of old LA. In order to locate a mobile terminal for call delivery, the HLR is queried to determine the serving MSC of the target mobile terminal. The HLR then sends a message to this MSC which, in turn, will determine the serving base station of the mobile terminal by paging all cells within its associated LA.

This location tracking scheme requires the exchange of signaling messages between the HLR and the new and old MSC's whenever the mobile terminal crosses an LA boundary. This may result in significant traffic load to the network especially when the current location of the mobile terminal is far away from its HLR and the mobile terminal is making frequent movements among LA's. Besides, the HLR may experience excessively high database access traffic as it is involved in every location registration and call delivery. This may result in increased connection set up delay during periods of high network utilization.

The major steps of the IS-41 location registration scheme are as follows (Fig 2)[13].

**Step 1:** The mobile terminal moves into a new LA and sends a location update message to the nearby base station.
**Step 2:** The base station forwards this message to the new serving MSC.
**Step 3:** The new MSC updates its associated VLR, indicating that the mobile terminal is now residing in its services area and sends a location registration message to the HLR.

**Step 4:** The HLR sends a registration acknowledgment message to the new MSC/VLR together with a copy of the subscriber's user profile.

**Step 5:** The HLR sends a registration cancellation message to the old MSC/VLR.

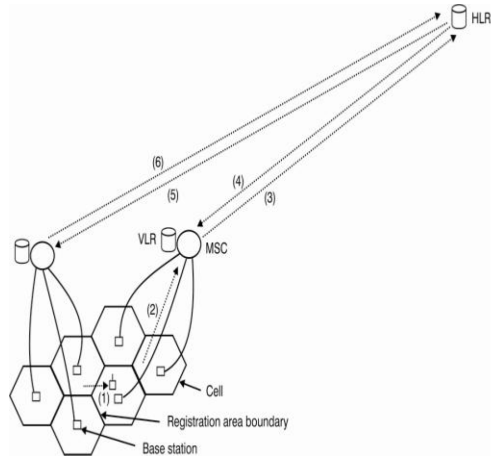


Fig 2: Location registration

**Step 6:** The old MSC removes the record for the mobile terminal at its associated VLR and sends a cancellation acknowledgment message to the HLR.
The IS-41 call delivery scheme is outlined as follows (Fig. 3)[13].

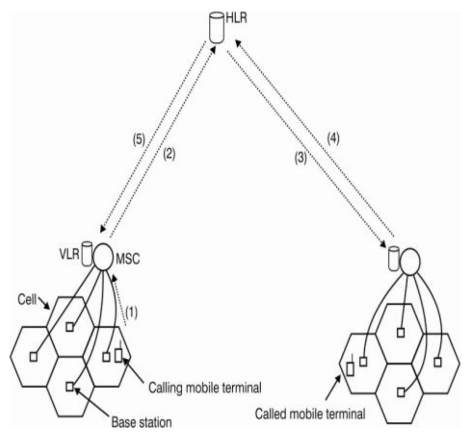


Fig 3: Call delivery

**Step 1:** The calling mobile terminal sends a call initiation signal to its serving MSC through the nearby base station.
**Step 2:** The MSC of the calling mobile terminal sends a location request message to the HLR of the mobile terminal.
**Step 3:** The HLR determines the current serving MSC of the called mobile terminal and sends a route request message to this MSC.
**Step 4:** The MSC determines the cell location of the called mobile terminal and assigns a temporary location directory number (TLDN) to the called mobile terminal. The MSC then sends this TLDN to the HLR.
**Step 5:** The HLR sends the TLDN to the MSC of the calling mobile terminal. The calling MSC can now set up a connection to the called MSC through the PSTN.

## III. MODIFIED HLR/VLR SCHEME

In the conventional HLR/VLRs scheme, the network database HLR is consulted during the processing of an incoming call. Conversely, the

HLR is updated as the MU moves to a new LA and is serviced by different VLR within the network. Querying the HLR every time a location search or a location update is performed results in tremendous strain on the use of the network resources due to the signaling traffic and database access load. This may significantly degrade the performance of the network with today's high number of subscribers. Reduction of signaling and database access traffic constitutes a growing research issue. Several strategies have been proposed [4-10][12-19].

In conventional approach when a MT moves from one LA to another LA, which are served by different VLRs, for registration of MT at new VLR a signal message is transferred to HLR from it, which sends a signal message to old VLR to deregister the MT and upon getting an acknowledgement of deregistration from old VLR, HLR acknowledges to new VLR for registration. This deregistration method is referred to as *explicit deregistration*[20]. The explicit deregistration scheme may produce significant signaling traffic in the network and require many accesses to the database involved. Due to the increasing number of mobile subscribers, the access rate to the HLR and the VLRs is expected to be very high and the databases could possibly become the bottle-neck of the future mobile systems. In [21,22], *implicit deregistration* and *timeout/polling deregistration* were proposed to reduce signaling traffic and database load due to deregistration. But the comparative study done by Z. Mao [20], it has been found that by using group deregistration strategy deregistration cost can be reduced significantly. Since this strategy reduces the cost of message transferring as well as database operation which will ultimately reduce total cost of location management.

In modified HLR-VLR scheme we try to ignore explicit deregistration message to old VLR and its acknowledgement to HLR. So when new VLR finds a new mobile unit it simply send a message to HLR which acknowledges the new VLR to register it. So signal no. 5 & 6 of fig. 2 can be avoided.

## IV. PERFORMANCE ANALYSIS

An analytical model to evaluate the performance of the conventional HLR/VLR architecture [9] and a comparison of the same is made with the modified HLR/VLRs. In this analysis, a hierarchical tree of R layers is used, as shown in Fig. 4 [9]. The layer R contains the root node and the layer 1 contains the leaf nodes. A database is installed on each node of the tree and the MTs are assigned to the leaf nodes. In the HLR/VLRs scheme, the network database, HLR, is situated on the only node of layer R and the VLRs are installed on the leaf nodes. The following terms are used in performance analysis:-

- $\mathbf{m}_{x,y}$ Layer of the closest common node to LA x and LA y.
- **p** Probability that the MT move is intra-VLR.
- **q** Probability that the called and the calling MTs are served by the same VLR.
- **n** New LA of the MU.
- **a** Old LA of the MU.
- **s** LA of the calling unit (source).
- **d** LA of the called MU (destination).

P($\mathbf{m}_{x,y}$=i) is defined as the probability that the closest common node to LA x and LA y is in layer i. This probability can be given by the following equation.

$$P(m_{a,n}=i) = \begin{cases} p(1-p)^{i-1} & \text{for } i = 1,2\ldots\ldots\ldots..R-1 \\ (1-p)^{i-1} & \text{for } i = R \end{cases} \quad \textbf{(1)}$$

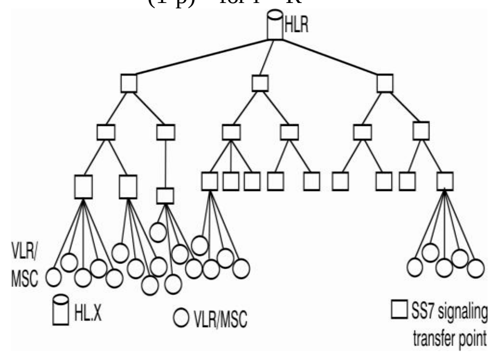


Fig. 4: HLR/VLR architecture

$$P(m_{s,d}=i) = \begin{cases} q(1-q)^{i-1} & \text{for } i = 1,2\ldots\ldots\ldots..R-1 \\ (1-q)^{i-1} & \text{for } i = R \end{cases} \quad \textbf{(2)}$$

We furthermore denote the costs of various operations used in this analysis as follows:

**T** (i, j): Cost of transmitting a message over a link between two adjacent layers i and j.
$\mathbf{C_m}$(i): Cost of accessing or updating a database in layer i.
$\mathbf{M_{HLR/VLR}}$: Estimated cost of a location update in the conventional HLR/VLRs scheme.
$\mathbf{M_{modified\ HLR/VLR}}$: Estimated cost of a location update in the modified HLR/VLRs scheme.
$\mathbf{R_{HLR/VLR}}$: Estimated cost of a location search in the conventional HLR/VLR scheme and modified HLR/VLR scheme.

The estimated cost of the location update of the HLR/VLRs architecture is as follows:

$$M_{HLR/VLR} = P(m_{a,n}=1)\times C_m(1) + \sum_{i=2}^{R} P(m_{a,n}=i)\times\{2C_m(1)+C_m(R)+4T(1,R)\} \quad \textbf{(3)}$$

The first part of Eq. No. 3 is the cost of location update in intra-VLR move. The second part illustrates the scenario after an inter VLR move. T (1, L) = T (1, 2) + T (2, 3) +…+ T (L-1, L) is equal to the cost of traversing links between a node of layer 1(i.e., VLR) and the node of layer R (i.e., where an HLR is located). This cost is multiplied by 4 because, when a signaling message is sent from a VLR to the HLR, the latter sends a similar message to the old VLR. By adding the cost of the acknowledgment from the old VLR to the HLR and then from the HLR to the current VLR, we can justify the 4T (1, L). For comparison purposes, we need the costs of the modified HLR/VLRs scheme, which is as follows:-

$$M_{modifiedHLR/VLR} = P(m_{a,n}=1)\times C_m(1) + \sum_{i=2}^{R} P(m_{a,n}=i)\times\{C_m(1)+C_m(R)+2T(1,R)\} \quad \textbf{(4)}$$

The first part of above Equ. No. 4 is same as previous one, the second part illustrates the scenario after an inter VLR move. T(1, L) is estimated in same manner but this cost is multiplied by 2 because, we are not sending any request to old VLR for deregistration separately nor receiving any acknowledgement.

The estimated cost of the location search procedure of the conventional HLR/VLRs scheme and modified HLR/VLR scheme remains the same as deregistration process is not at all affecting the cost of location search.

$$R_{HLR/VLR} = \sum_{i=1}^{R} P(m_{s,d} = i) \times \{C_m(1) + C_m(R) + 4T(1,R)\} \qquad \textbf{(5)}$$

## V. RESULTS

The numerical values of both the schemes i.e. conventional HLR/VLR and modified HLR/VLR schemes are evaluated and compared in this section. In this analysis it is assumed that the database access cost in layer *i* is equal to *i*, the cost of crossing a link between layer *i-1* and layer *i* is equal to *i*. Fig. 5 shows the performance of the analyzed scheme with *R=5.* In the figure users are classified with respect to their moves. When *p* (probability value that MU move is intra VLR) is very small (i.e. the mobile unit moves are not local), the modified HLR/VLR scheme outperforms the conventional one. When *p* increases, a significant cost reduction is obtained with the proposed scheme. When *p*=1, the performance of both the schemes are equal. This is normal situation since when *p*=1 the MTs move are always local.

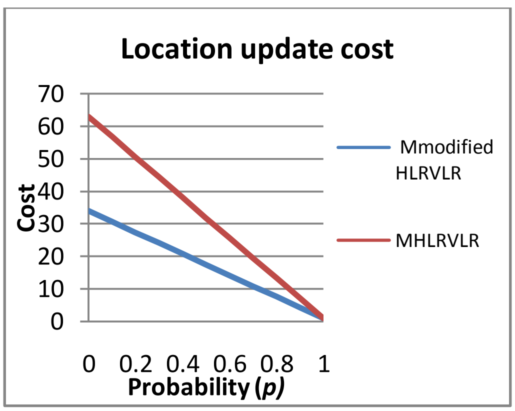


Fig. 5: location update cost

A similar analysis is conducted on the location search procedure. Users are classified by their location when processing an incoming call. Fig. 6 shows the performance of location search procedure when R = 5. In this case it is observed that both the scheme have the same cost as the deregistration strategy is not effecting location search cost.

Based on the analysis done above we can conclude that the performance of location management scheme is highly dependent on users' mobility and incoming call characteristics. Further we have investigated the class of users for which the proposed scheme yields a net reduction in signaling traffic and databases loads. We classify users by their Call-to-Mobility ratio (CMR), which is defined as the ratio between the average number of calls to an Mobile unit per unit time and the average number of times this Mobile unit changes LAs per unit time (i.e., incoming call rate/mobility rate). Then it follows that:

$$\mathbf{CMR=\lambda/\mu} \qquad \textbf{(6)}$$

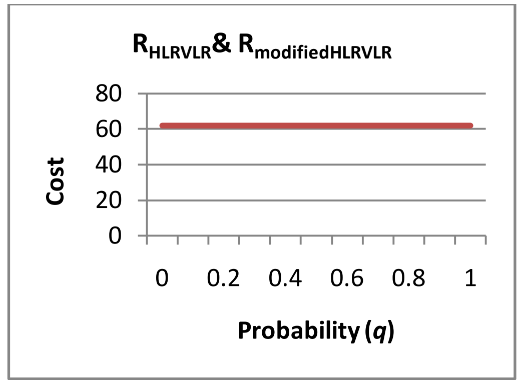


Fig. 6: location search cost

Where, λ=Incoming call rate, μ=Mobility rate
Let $C_{\text{modified HLR/VLR}}$ be the total cost of call in the modified scheme and $C_{\text{HLR/VLR}}$ be the total cost in the HLR/VLR scheme.
Then

$$C_{\text{modified HLR/VLR}} = \mu M_{\text{modified HLR/VLR}} + \lambda R_{\text{modified HLR/VLR}} \qquad \textbf{(7)}$$

$$C_{\text{HLR/VLR}} = \mu M_{\text{HLR/VLR}} + \lambda R_{\text{HLR/VLR}} \qquad \textbf{(8)}$$

Finally, the total relative cost of the modified location management scheme as the ratio of the total cost per unit time for the modified scheme to that of HLR/VLRs architecture. These costs can be derived from equations (7) & (8).

$$\frac{C_{\text{modified HLR/VLR}}}{C_{\text{HLR/VLR}}} = \frac{M_{\text{modified HLR/VLR}} + CMR * R_{\text{modified HLR/VLR}}}{M_{\text{HLR/VLR}} + CMR * R_{\text{HLR/VLR}}}$$

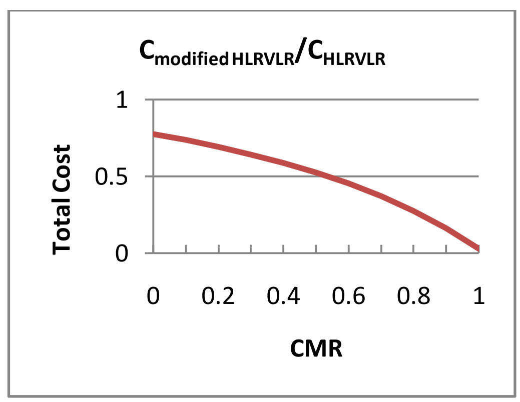


Fig. 7: Total cost of location management

Fig. 7 shows the total relative cost of the modified scheme and the conventional schemes plotted against CMR using various values of *p*, *q*, The CMR value varies from 0 to 1.

## VI. CONCLUSION

By the analysis done in the last section it is observed that the proposed modified HLR/VLR scheme is better than the conventional one as the signaling cost and database updation cost is significantly reduced by using group deregistration strategy for location update only. Since total cost consist of location update and location search so total cost is also reduced in modified HLR/VLR scheme. So it can be concluded that proposed modified version of HLR/VLR performs better than the conventional schemes for location management. We have tried to elaborate all the possible scenario of location update and search procedure and given an analytical analysis to study the performance of the modified HLR/VLR scheme and compared it with conventional HLR/VLR.

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