A Simple Swap Technique and Enhanced GTT Location Database Management Scheme

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***Abstract*-In this paper, we have proposed a location update scheme by applying swap technique and enhanced GTT in STP. This scheme achieves significant improvement in signalling costs compared to other location update schemes. This paper presents the details of this scheme and provides comparison results with other location database management schemes. The performance results clearly indicate that our proposed scheme is far superior to most other schemes and provides a 15-50% reduction in signalling cost when compared to GSM. The novelty of the proposed scheme is that it provides considerable reduction in signalling cost, and at the same time it is very simple and easy to implement.**

I. INTRODUCTION

The major goal of location management in Mobile Networks is to track the locations of the roaming Mobile Terminals (MTs) in a cost-effective way. Location registration (or update) and call delivery (or terminal locating) are the two basic operations of location management. Location update occurs when an MT moves from one Location Area (LA) to another. This procedure involves the updating of location databases when the latest MT location information is available. Call delivery procedure involves the querying of location databases by the network to locate a MT when an incoming message arrives for the MT. The protocols implemented in the current mobile networks are ETSI GSM MAP [1] and EIA/TIA IS-41 [2]. The two-level database strategy, namely Home Location Register (HLR) and Visitor Location Register (VLR), is applied in the current standards to track the roaming MTs.

For the past decade, mobile users have been increasing exponentially and it is predicted to continue so for another decade or so. Due to much higher mobile users density in the future mobile systems, the volume of signalling traffic for real-time updating and querying the location database will be extremely high [3,4]. The location database eg. HLR may become the bottleneck of the mobile network. Efficient methods for reducing the signalling traffic and databases transaction in a network to locate the mobile users are therefore required.

The functions in location management can be divided into two categories: Location Database Management (LDM) and Location Area Management (LAM). LDM involves database query and update above the MSC/VLR level, which concerns the database architecture and signalling network eg. SS7. LAM involves study of the location update rate and paging cost at lower level of the network architecture ie below VLR/MSC. This paper addresses efficient mechanisms for LDM only. In [5], the authors have proposed a BSC based LA scheme and applied overlap macro-cell concept for efficient LAM.

Generally, the proposed schemes in LDM research can be classified into two groups: centralised database architecture and distributed database architecture. The centralised database approaches [6-12] are based on the two-level database strategy applied in the current standards and try to enhance the performance of location database management with minimal changes in the existing database network architecture.

In [13], a fully distributed location database strategy was proposed for location registration. Each database in the tree structured architecture records the location information of the MTs that reside in its coverage area. Results show that the size of each database will be reduced by almost 50%, but this scheme may cause longer call set-up delay due to the number of databases involved and the numbering plan needs to be changed to a location-dependent plan.

In this paper, we have proposed a *swap* in VLRs for LDM. Implementation of this scheme requires two database storage, primary and secondary. The secondary storage can be any reasonably priced storage mechanism. The essential information for quick retrieval will be stored in the primary database. As only the essential information is stored in the primary database, very quick and efficient retrieval of this information is possible, thereby saving time and database processing. Depending on the users daily or regular movement routines the VLR will decide to swap the users information between the primary and secondary databases. In this paper, we also proposed an enhanced GTT (global title translations) scheme for LDM. In intelligent network, the STP GTT table look up technique will determine where the appropriate SCP is located and what specific database needs to be accessed within that SCP. The GTT function at STP has been applied in our study to translate the MT number to a location pointer. Results show that the proposed scheme outperforms GSM, pointer forwarding and local anchoring schemes.

II. LOCATION DATABASE MANAGEMENT

Fig.1 illustrates the signalling architecture for LDM. The MSC and VLR are assumed to be co-located or to be integrated into one component, therefore the SS7 signalling cost between MSC and VLR is ignored. According to Fig. 1, each network element is connected to the other through SS7

STP and also assumes that the HLR is connected via the remote-signalling network. Temporary Mobile Subscriber Identity (TMSI) used in GSM is applied in this study for performance study of different LDM approaches. TMSI is an alias for International Mobile Subscriber Identity (IMSI) and is assigned by the VLR during the inter-VLR location update. Because IMSI is the unique user identity that identifies mobile user's HLR, in the location update procedure the new VLR has to retrieve the IMSI from the old VLR first. For performance comparison purposes, we assumed that TMSI concept is applied to all of the LDM approaches. The LDM consists of location database update and call delivery. Location database update involves the database update to record the roaming MT's current location. Call delivery involves the database query to deliver the incoming messages to the called MT.

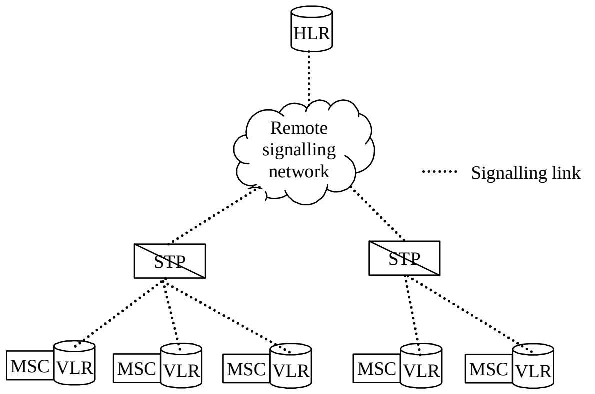

Fig. 1 Reference signalling network architecture

A. Location Database Management

1) GSM Location Database Update

In this section the GSM LDM is briefly explained, as this mechanism will be used as the base for evaluating the other schemes. Fig.2 shows the simplified location database update procedure for GSM network. IMSI is the unique user identity that identifies the MT's HLR. A brief description of the location procedures is as follows.

1 When a MT moves to another VLR coverage area, a location update request message is sent from the MT to the new VLR (VLR_{new}). The VLR_{new} then sends a location update request message to the previous VLR (VLR_{old}) with MT's TMSI.
2 According to the TMSI, VLR_{old} then responds and sends the MT's IMSI with authentication parameters and user/service profiles to the VLR_{new}.
3 VLR_{new} informs HLR the MT's new database location by sending a location update request message.
4 HLR sends a location update response message back to the VLR_{new} and also send a location cancellation request message to the VLR_{old} to delete the obsolete information about the MT.
5 A location cancellation response message is sent from VLR_{old} to HLR.

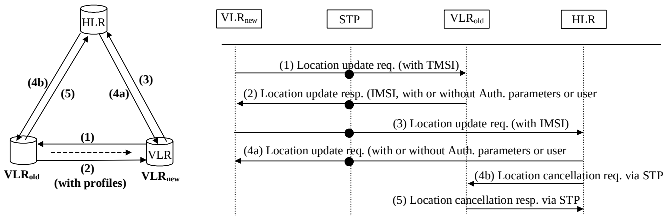

Fig. 2 GSM Location update procedures

2) Pointer Forwarding Location Database Update

Pointer forwarding location database update approach was proposed in [8,9] to improve the scheme adopted in IS-41. In this paper we modified it for GSM to enable comparative studies. One of major differences between IS-41 and GSM is that GSM applied a TMSI instead of IMSI in the air interface transmission. Fig. 3 illustrates the modified pointer forwarding approach for LDM. Fig. 3A shows the location database update procedure between VLR_{new} and VLR_{old} when both VLRs are connected to the same STP. A pointer is set-up from the VLR_{old} to VLR_{new}, the current VLR. The authentication triplets and user/service profile are transmitted from VLR_{old} to VLR_{new}. No communication with HLR is necessary in this situation. In the pointer forwarding approach, the incoming call set-up delay will increase when the pointers chain length increases. Therefore a maximum length, *k*, was introduced [8]. Fig. 3B shows the case of when the MT makes frequent movements and the pointers chain length from the anchor VLR (VLR_A) to the current VLR exceeds the threshold value (*k*). The VLR_{new} will send a location database update request to the pervious VLR, VLR_{old}. VLR_{old} will then respond to VLR_{new} with user information. VLR_{new} sends a location update request to HLR to update the MT's location information. A location cancellation request is sent by the HLR to VLR_A to erase the location pointer. Pointer cancellation requests will then follow the pointer chain to delete the pointers that are in the pointer forwarding chain. In the case of inter STP update when the MT moves into a new VLR that is connected to another STP, the location database procedure is similar if TMSI is used.

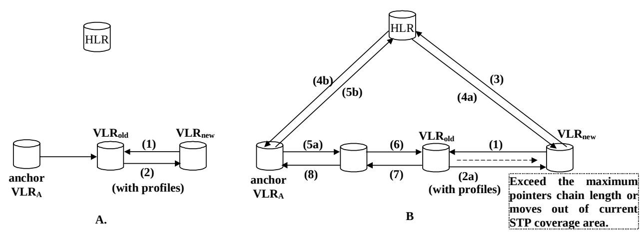

Fig. 3 Location update for pointer forwarding approach

3) Local Anchor Location Database Update

Local anchor database update approach was proposed in [12] to improve the scheme adopted in IS-41. In this paper, this scheme has been adopted to GSM to help conduct comparative studies. In the local anchor approach, a local anchor is assigned when a MT moves into a new VLR that is connected by another STP. This scheme is very similar to the pointer forwarding approach. Instead of setting up a pointer from the previous VLR to the current VLR, a pointer is set up from the local anchor VLR to the current VLR, VLR_{new}. Fig. 4 illustrates the location update procedures using the local anchor scheme. Fig. 4A shows the location database update within the same STP. A location update request message is sent from VLR_{new} to VLR_{old}. VLR_{old} responds to the request with user information. VLR_{old} also send a location change (pointer update) request message to inform the local anchor VLR, (VLR_{LA}), of the MT's current location. After receiving location change response from VLR_{LA}, VLR_{old} erases the information in its database. Fig. 4B shows the situation when a MT moves out of the current STP coverage area. In this case, the VLR_{new} will first retrieve the MT's IMSI and user information from VLR_{old} and then send a location update request to the HLR informing the HLR of the MT's current location for delivery of future incoming calls. HLR then sends a location cancellation request to VLR_{LA} to erase the location pointer from VLR_{LA} to VLR_{old}. After the inter STP location update procedure VLR_{new} becomes the new local anchor.

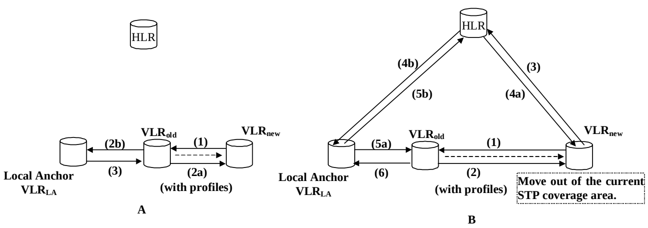

Fig. 4 Location update for local anchor approach.

4) Swap Technique and GTT Based Update

In the proposed swap approach, we have divided the conventional location database (VLR) into two parts: current and history database. The current database records the user/service profiles of the MTs that are currently residing in the VLR coverage area and is in the primary storage. The history database is stored in the secondary storage. The history database records the profiles of the MTs that visited the VLR previously in a certain period. The swap technique is used to exchange information between the primary and secondary databases. It is necessary for the MT to have a list of all VLRs that have the MT's user information in their secondary storage.

In the conventional mobile network (e.g. GSM, IS-41), the location-updating procedure will update the profiles at VLR_{new} and then the profiles at VLR_{old} will be deleted. In our approach, instead of erasing the user profiles at $VLR_{old,}$ the user information will be swapped from the primary database to secondary database. The user information will be erased only based on the mobility patterns and the timers. By using the swap technique at VLR, the signalling traffic for user profile download will be reduced significantly. The LDM using swap concept is illustrated in Fig. 5. The *swap* scheme is especially efficient for userswith regular daily routine, for example, those who daily commute from home to office (or office to home).

In the intelligent network, the STP GTT table look up will determine where the appropriate SCP is located and what specific database need to be accessed via that SCP. The GTT function at STP has been enhanced in our study to use the MT identity to provide a location pointer. This location pointer points to the VLR in which the MT is currently residing. In conjunction with the STP GTT table look-up, the swap algorithm applied at location databases can further reduce the total signalling traffic for LDM.

Fig. 5A illustrates the location database update within one STP. From the broadcast signalling message, which includes VLR identification, the MT detects that it has moved into a new VLR. The MT will then check if the new VLR is in its list of VLR's which are supposed to have the MT's informatio in its secondary database. If the check is positive the MT will send a location update request to VLR_{new} as shown in Fig. 5A. An extra bit is added in this request message to inform VLR_{new} that this VLR has the MT's information in its secondary storage. VLR_{new} will then send a location update request with TMSI to VLR_{old} via STP. The VLR_{old} will respond back with MT's IMSI and swap the user information from primary storage into secondary storage. Using the IMSI, the VLR_{new} can then swap the user information from its secondary to primary storage. During the signalling exchange between VLR_{new} and VLR_{old}, the GTT at STP for the MT will be updated. If the MT finds that the VLR_{new} is not in the swapped VLRs list, then the location update procedure is similar to GSM. The only difference is that the enhanced STP GTT is applied in our approach. The location pointer is updated at STP GTT not at HLR for the intra STP update situations.

Fig. 5B illustrates the inter-STP location update where the VLR_{new} has swapped user information in its secondary database. The location update procedure is similar to GSM except that two STP GTT entries are to be deleted/updated. No profile transmission between VLRs is required. In case the MT detects that the VLR_{new} is not in its swapped VLRs list, the location update is same as GSM except that two extra STP GTT entries are deleted/updated.

B. Call Delivery

1) GSM Call Delivery

Fig.6 shows the simplified call delivery procedure for GSM network. The GSM approach is used as a base for comparison. A brief description of location procedures is as follows.

1. When a call is initiated, the calling MT sends a call initiation message to its serving $MSC/VLR_{calling}$ and the $VLR_{calling}$ then sends a location request to the MT's HLR based on the called MT's MSISDN (Mobile Subscriber ISDN number).
2. HLR sends location request to the MSC/VLR_{called} in which the called MT is residing, to retrieve the called MT's MSRN (Mobile Subscriber Roaming Number).
3. MSRN is sent back from VLR_{called} to HLR
4. HLR forwards the MT's routing information to the $VLR_{calling}$, a call then can be set up between $MSC/VLR_{calling}$ and MSC/VLR_{called} based on the MSRN.

2) Pointer Forwarding and Local Anchor Approaches

Fig. 7 illustrates the call delivery procedure in pointer forwarding approach. The call delivery procedure is similar to GSM, but extra call set up delay is excepted due to the forwarding pointer tracing between VLR_A and VLR_{called}. Fig. 8 illustrates the call delivery procedure in local anchor approach. Because the maximum pointer chain length is always to be one in this approach, therefore the average call set up delay is less than pointer forwarding approach.

3) Swap and Enhanced STP GTT Approach

Fig. 9 illustrates the call delivery procedure in the proposed enhanced STP GTT approach. Fig. 9A shows that $VLR_{calling}$ and VLR_{called} are connected to the same STP. In this case, HLR is not involved as this is a local STP call delivery. The call will be set up faster and also the signalling traffic will be reduced in the network. The enhanced GTT can also be used for the calls that are initiated from the Local Exchanges (LEs) of the fixed networks. It is not necessary for the LE to request MT's location information through Gateway MSC (GMSC) and HLR as conventional call delivery procedures do.

Fig. 9B illustrates the call delivery procedure when $VLR_{calling}$ and VLR_{called} are not connected to the same STP. When a call is initiated at $VLR_{calling}$, the $VLR_{calling}$ sends a location request signal with called MT's MSISDN to STP2. STP2 uses the GTT to translate MT's MSISDN to MT's HLR identity/address. HLR then sends a location request to VLR_{called} via STP1 GTT. Finally, the VLR_{called} responds to the location request with MT's MSRN to $VLR_{calling}$ through HLR. A call is then set up between $MSC/VLR_{calling}$ and MSC/VLR_{called} based on the MSRN.

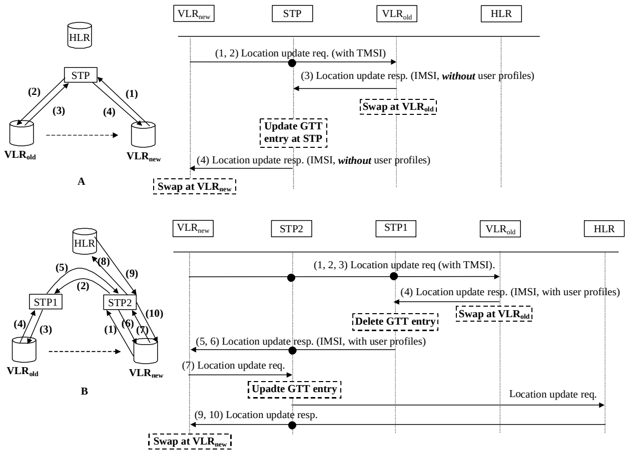

Fig. 5 Location update procedure using Swap technique

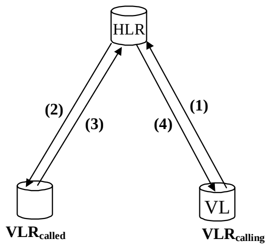

Fig. 6 GSM call delivery procedures

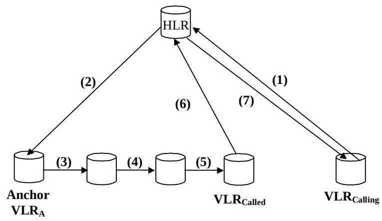

Fig. 7 Call delivery for pointer forwarding approach

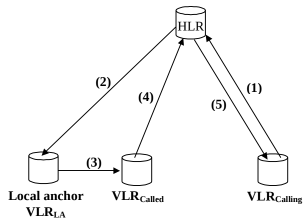

Fig. 8 Call delivery for local anchor approach

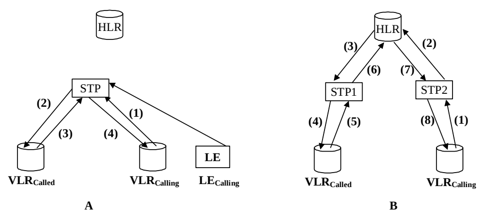

Fig. 9 Call delivery procedure for enhanced STP GTT approach

III. Analytical Approach For LDM Performance

In this section, we compare the different scheme for LDM namely the Pointer Forwarding, the Local Anchor and the proposed Swap technique. To evaluate the signalling cost for LDM, costs are assumed for each network element and signalling links between them. Notations and associated cost are as follows.

Link costs:

- R: costs to route a message by the remote signalling link (STP ↔ HLR).
- L: costs to route a message by the local signalling link (VLR ↔ STP).

$R^\#$, $L^\#$: links cost including not only transmission for normal signalling messages but also the user/service profiles.

Database costs:

- H: cost of a query or update to HLR.
- V: cost of a query or update to VLR.
- V^*: cost of swap processing in VLR.
- S: cost of STP routing processing.
- $S^\wedge$: cost of STP GTT look up table processing (delete/update).

C_{VL} is the signalling link cost for sending a signalling message from one VLR to another VLR through local STP. C_{VR} is the signalling link cost for sending a signalling message from one VLR to another VLR through remote signalling network. C_{VH} is the signalling link cost for sending a signalling message between VLR and HLR. These cost are calculated as follows.

$C_{VL} = L + S + L$; $C_{VL}^\# = L^\# + S + L^\#$; $C_{VL}^\wedge = L + S^\wedge + L$

Where $C_{VL}^\wedge$ is C_{VL} + cost of STP GTT table update and $C_{VL}^\#$ is C_{VL} + cost of extra user profile download in the signalling link;

$C_{VR} = L + S + R + S + L$; $C_{VR}^\wedge = L + S^\wedge + R + S^\wedge + L$

Where $C_{VR}^\wedge$ is C_{VR} + cost of STP GTT table update

$C_{VH} = L + S + R$; $C_{VH}^\# = R^\# + S + L^\#$; $C_{VH}^\wedge = R + S^\wedge + L$;

Where $C_{VH}^\wedge$ is C_{VH} + cost of STP GTT table update and $C_{VH}^\#$ is C_{VH} + cost of extra user profile download in this signalling link;

A. Location Update Signalling Costs

Provided below are the costs calculated for the different location update mechanisms, including GSM. For each mechanism the costs for location update when the MT is moving within the same STP and when it moves across different STPs is given. For the proposed swap and enhanced STP GTT scheme, costs under the two options of the new VLR being listed and not listed in the MT's VLR list are considered. While estimating the final costs as given in the table, the probability of inter STP movement is also taken into consideration.

1) GSM:

- Intra-STP VLR update

$$C_{GU1} = V_{new} + C_{VL} + V_{old} + C_{VL}^\# + V_{new} + C_{VH} + H + \begin{cases} C_{VH} \\ C_{VH} + V_{old} + C_{VH} \end{cases}$$

- Inter-STP VLR update

$$C_{GU2} = V_{new} + C_{VR} + V_{old} + C_{VR}^\# + V_{new} + C_{VH} + H + \begin{cases} C_{VH} \\ C_{VH} + V_{old} + C_{VH} \end{cases}$$

Signalling cost following curly parenthesis indicate that the signals related to these costs can proceed in parallel.

2) Pointer Forwarding:

- Intra-STP VLR update

$$C_{PFU1} = C_{m<k} = V_{new} + C_{VL} + V_{old} + C_{VL}^\# + V_{vew}$$

$$C_{PFU2} = C_{m=k} = V_{new} + C_{VL} + V_{old} |+ C_{VL}^\# + V_{new} + C_{VH} + H + \begin{cases} C_{VH} \\ C_{VH} + V_A + \begin{cases} (k-1)(V + 2C_{VL}) \\ C_{VH} \end{cases} \end{cases}$$

- Inter-STP VLR update

$$C_{PFU3} = V_{new} + C_{VR} + V_{old} + C_{VR}^\# + V_{new} + C_{VH} + H + \begin{cases} C_{VH} \\ C_{VH} + V_A + \begin{cases} l(V + 2C_{VL}) \\ C_{VH} \end{cases} \end{cases}$$

where l is the average chain length

3) Local Anchor approach:

- Intra- STP VLR update

$$C_{LAU1} = V_{new} + C_{VL} + V_{old} + \begin{cases} C_{VL}^\# + V_{new} \\ C_{VL} + V_{LA} + C_{VL} \end{cases}$$

- Inter-STP VLR update

$$C_{LAU2} = V_{new} + C_{VR} + V_{old} + C_{VR}^\# + V_{new} + C_{VH} + H + \begin{cases} C_{VH} + V_{LA} + C_{VL} + V_{old} + C_{VL} \\ C_{VH} \end{cases}$$

4) Swap and Enhanced STP GTT Approach:

4.1) VLR_{new} is in the Swap list recorded in the MT

- Intra-STP VLR update

$$C_{WU1} = V_{new} + C_{VL} + V_{old}^* + C_{VL}^\wedge + V_{new}^*$$

- Inter- STP VLR update

$$C_{WU2} = V_{new} + C_{VR} + V_{old}^* + C_{VR}^\wedge + V_{new}^* + C_{VH}^\wedge + H + C_{VH}$$

4.2) VLR_{new} is not in the Swap list recorded in the MT

- Intra-STP VLR update

$$C_{WU3} = V_{new} + C_{VL}^\wedge + V_{old} + C_{VL}^\# + V_{new}$$

- Inter-STP VLR update

$$C_{WU4} = V_{new} + C_{VR} + V_{old} + C_{VR}^\# + V_{new} + C_{VH} + H + \begin{cases} C_{VH}^\wedge \\ C_{VH}^\wedge + V_{old} + C_{VH} \end{cases}$$

We assume that the probability of inter STP movement is P_s, the probability of a VLR being in the MT's swap list is P_w, Let the maximum pointer chain length be k for the Pointer forwarding approach. Table 1 shows the average costs for the above four schemes.

TABLE I
AVERAGE COST FOR LOCATION DATABASE UPDATE

	Average cost for location database update
GSM	$C_{GU} = (1-P_s) \cdot C_{GU1} + P_s \cdot C_{GU2}$
Pointer forwarding	$C_{PFU} = (1 - P_s) \cdot [(k-1) \cdot C_{PFU1} + C_{PFU2}]/k + P_s \cdot C_{PFU3}$
Local anchor	$C_{LAU} = (1 - P_s) \cdot C_{LAU1} + P_s \cdot C_{LAU2}$
Swap and enhanced GTT	$C_{WU} = P_w \cdot [(1-P_s) \cdot C_{WU1} + P_s \cdot C_{WU2}] + (1-P_w) \cdot [(1-P_s) \cdot C_{WU3} + P_s \cdot C_{WU4}]$

B. Call Delivery Signalling Costs

Provided below are the costs calculated for the different call delivery mechanism, including GSM. For each mechanism the costs for call delivery under various applicable options are given. We calculated the call delivery cost until the $VLR_{calling}$ has the MSRN.

1) GSM:

$C_{GD} = V_{calling} + C_{VH} + H + C_{VH} + V_{called} + C_{VH} + H + C_{VH}$

2) Pointer Forwarding:

$C_{PFD} = V_{calling} + C_{VH} + H + C_{VH} + V_A + l\ (2C_{VL} + V_{called}) + C_{VH} + H + C_{VH}$

where l is the average chain length.

3) Local Anchor:

- Called MT is in VLR_A

$C_{LAD1} = V_{calling} + C_{VH} + H + C_{VH} + V_A + C_{VH} + H + C_{VL}$

- Called MTs is not in VLR_A

$C_{LAD2} = V_{calling} + C_{VH} + H + C_{VH} + V_A + C_{VL} + V_{called} + C_{VH} + H + C_{VH}$

4) Swap and Enhanced GTT Approach:

- Calling MT and called MTs are in the same STP

$C_{WD1} = V_{calling} + C_{VL} + V_{called} + C_{VL}$

- Calling MT and called MTs are not in the same STP

$C_{WD2} = V_{calling} + C_{VH} + H + C_{VH} + V_{called} + C_{VH} + H + C_{VH}$

Assume the probability of called MT located in anchor VLR is P_a, the probability of calling and called users located in the different STP is P_r. Table II shows the average call delivery cost for above four schemes.

TABLE II
AVERAGE COST FOR CALL DELIVERY

	Average cost for call delivery
GSM	C_{GD}
Pointer forwarding	C_{PFD}
Local anchor	$C_{LAD} = P_a \cdot C_{LAD1} + (1-P_a) \cdot C_{LAD2}$
Swap and enhanced GTT	$C_{WD} = (1-P_r) \cdot C_{WD1} + P_r \cdot C_{WD2}$

VI. NUMERICATL EXAMPLES AND PERFORMANCE COMPARISON

Table III gives four sets of data for different signalling element and link costs and mobility parameters. Set 1 takes all the network elements and signalling links into account. Set 2 assumes the signalling links costs are small and are ignored, and the database costs dominate the total cost. Set 3 assumes the databases costs are small and are ignored, the signalling links costs dominate the total cost. Set 4 changes P_r from 0.2 to 0.8 and P_w from 0.5 to 0.2. Fig. 10, 11, 12 and 13 show the performance graphs of set 1, 2, 3 and 4 respectively. In plotting the graphs in Fig. 10-13, Call-to-Mobility Ratio (CMR) [8,12] is applied. Here the relative cost is the average location database update cost normalised to location update costs in GSM. From Fig. 10-13, we find that the pointer forwarding and local anchor schemes outperform GSM for low values of CMR, ie higher MT movement compared to the number of incoming calls. But for high values of CMR the performance drops, indicating that these schemes are good only for those types of users who receive more calls but are less mobile. Compared to this, the proposed swap and enhanced GTT scheme always outperforms GSM. The location management costs averages to only about 50 to 85% of the cost compared to GSM. The range depends on the selection of the input parameters like P_w, P_r, etc. In the figures as all costs are normalised to the costs in GSM, the GSM cost can be seen as the thick line corresponding to the relative cost value of 1.

TABLE III
VALUES SETS FOR SIGNALLING COSTS AND MOBILITY PARAMETERS

	Set 1	Set 2	Set 3	Set 4
R	2	0	2	2
L	1	0	1	1
$R^\#$	4	0	4	4
$L^\#$	2	0	2	2
H	3	3	0	3
V	3	3	0	3
V^*	3	3	0	3
S	3	3	0	3
$S^\wedge$	3	3	0	3
P_s	0.3	0.3	0.3	0.3
P_r	0.2	0.2	0.2	0.8
P_a	0.2	0.2	0.2	0.2
P_w	0.5	0.5	0.5	0.2
k	3	3	3	3
l	(k-1)/2			

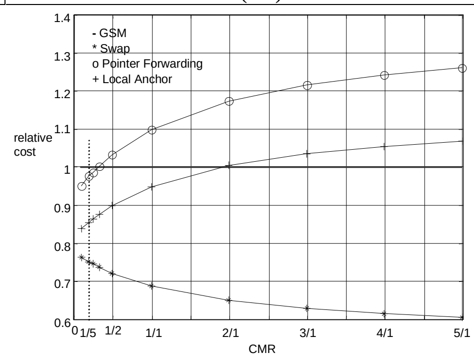

Fig. 10 LDM comparison, Set 1

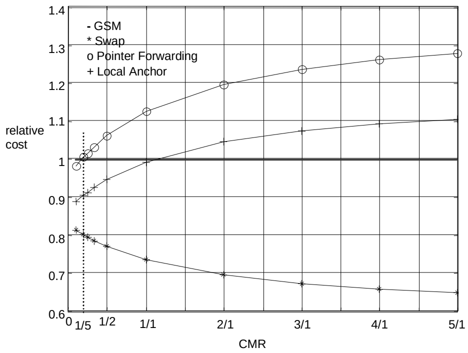

Fig. 11 LDM comparison, Set 2

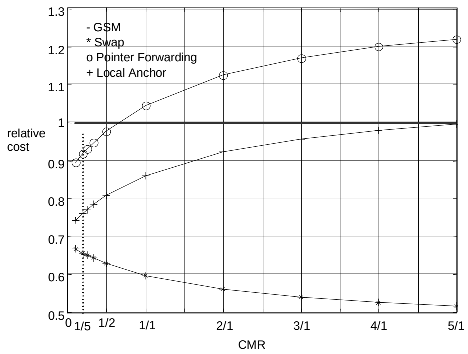

Fig 12 LDN comparison, Set 3

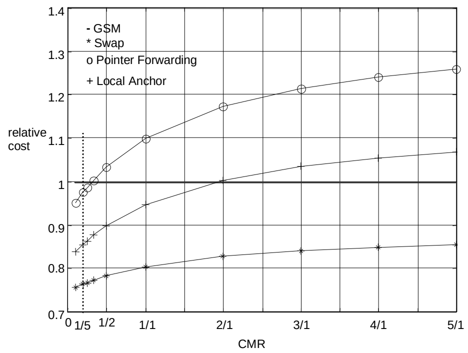

Fig. 13 LDM comparison, Set 4

VII. Conclusion

In this paper, we have proposed a new LDM strategy called *swap*. In conjunction with the enhanced STP GTT, the proposed scheme significantly reduces signalling costs. GSM, pointer and local anchor location database management schemes were selected for signalling cost comparison. Results show that the swap and enhanced STP GTT scheme always outperforms GSM by 15-50% depending on the input parameters. Pointer forwarding and local anchor schemes are only good for lower CMR. Furthermore, the proposed swap and enhanced STP GTT scheme are easy to implement and can work with other schemes.

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