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Network Design for IN-based Location Management

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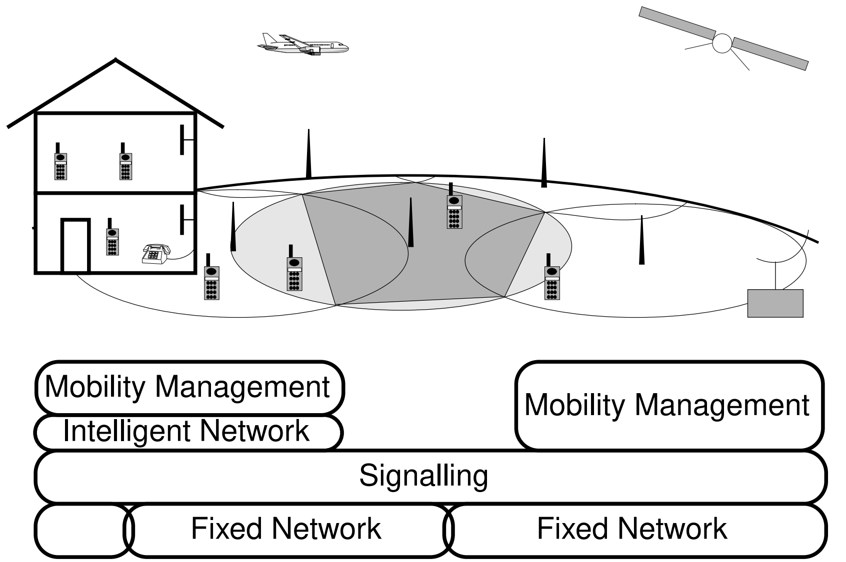
After a short introduction, we will present a user model that covers those aspects of mobility and call behaviour of a user which seem to be relevant for efficient data management and network design. Next, we will examine how mobility management can be realized in an intelligent network environment and will compare two data distribution mechanisms. Finally, we will investigate how mobility management, taking into account the user behaviour, will perform in an multi-network-operator environment, and from this we will draw the conclusion that a common distributed database should be part of a good network design.

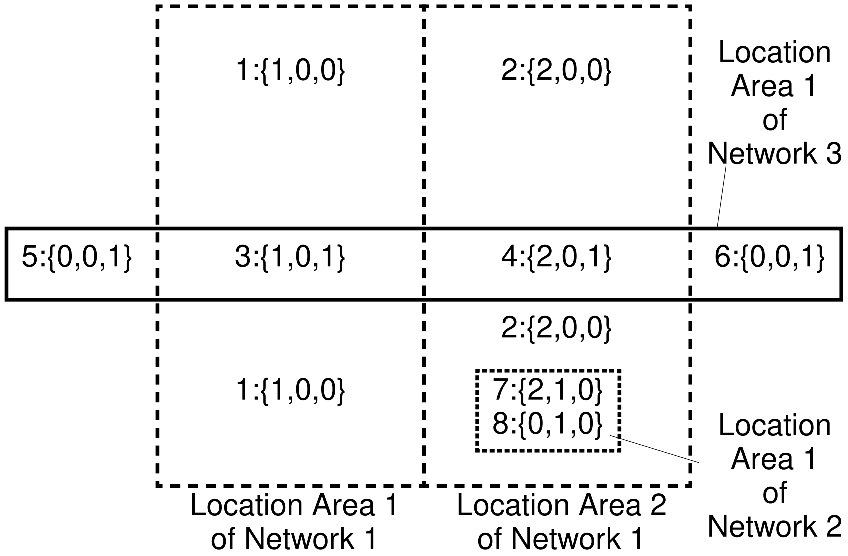
Introduction



Personal Communications Services shall enable communication between parties irrespective of their geographic location and network-access technology. These services will be provided by a multitude of service providers and network operators. Subscribers will roam (possibly using multi-mode personal communicators) between several independently operated networks including private and public wireline and cordless networks, cellular networks and satellite systems. Each network usually only provides limited coverage and is optimized for specific environments. Several networks together can provide anytime and anywhere communications at reasonable cost.

The Intelligent Network (IN) concept seems to be appropriate to enable the provision of these new personal communications services. A high load is expected to be put on the IN databases and on the supporting signalling network by those services. Network topology, database location and data management techniques in conjunction with user behaviour determine total network cost, resource efficiency and performance. Network design should minimize network cost while meeting performance and management requirements. In order to derive the offered load to the network, user behaviour models are needed.

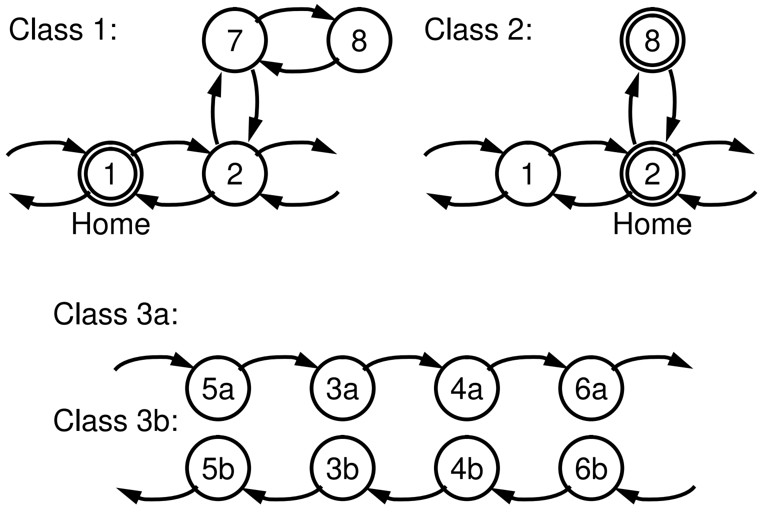
The User Model: Mobility



Invocation of service logic and database operations usually are triggered by user behaviour. The movement of a user may result in a location update either within one network from one location area to another location area or between different networks (e.g. from a cellular network to a private in-house cordless network.). When a call is placed towards a user, the call set-up scenario depends on the origin of the call and on the home and current location of the called party. The call behaviour of the involved parties tends to depend on their current location.

From the network point of view the relevant aspects of user location can be expressed in terms of location areas. At a given geographic location a user has the possibility of registering with one or several networks. In each network the user is assigned to a (possibly user-specific) location area. We define several classes of users. For each class there exist one or several home location areas; up to a maximum of one per network. The location of a user is described by its registration state which is the set of location areas a user is registered to. Between two registration states a geographic distance can be defined. The mobility of the users of a specific class is defined by the different registration state probabilities (which might be dependent on their geographic distance from the home locations, compare [Eynard]) and the transition rules between the states.

State Transition Diagrams

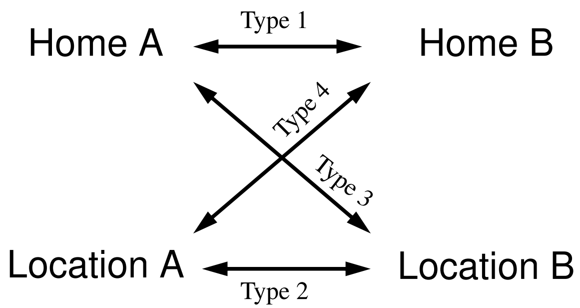


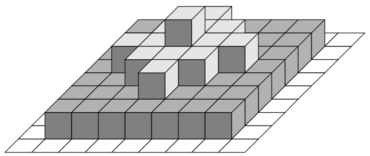
The sojourn time of a customer in a registration state is assumed to be negative-exponentially distributed. The transition rates can be derived from the state probabilities, a neighbourhood matrix and conditions like time-reversibility. From this follow the mean sojourn times of a customer in the different states.

Let us consider an example. We assume three different networks: Network 1 is cellular (e.g. GSM), Network 2 is in-house (e.g. DECT), Network 3 is part of a railway phone system.

We can identify in a small geographic area eight possible registration states. State transition diagrams for three arbitrarily chosen classes of users are shown. Class 1 has a high probability of being in state 1 and can register with several networks. Class 2 has a high probability of being either in state 2 or in state 8 and registers only with one network at a time. Class 3 customers travel on a railway system in one of two directions.

The User Model: Calls





Distance Dependent
Traffic Matrices

For the call activity of a user class, the geographic distances which are defined between the registration states are (independent of the networks) of importance. The according traffic matrix can be defined dependent on these geographic distance matrices.

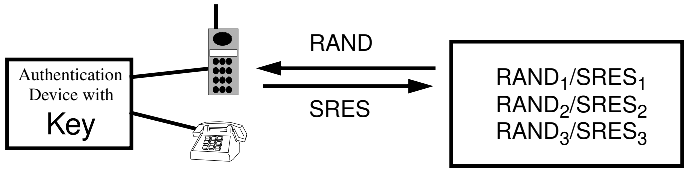
We identify four types of calls:

- **Type 1** calls from parties whose home location is “close“ to the home location of the B party.
- **Type 2** calls from parties whose current location is “close“ to the current location of the B party
- **Type 3** calls from parties whose home location is “close“ to the current location of the B party.
- **Type 4** calls from parties whose current location is “close“ to the home location of the B party.

It is obvious that the resulting traffic matrices are dependent on the mobility model. In order to simplify the model, we limit it to the type 1 and type 2 calls which seem to be sufficient to enable us to derive realistic traffic matrices.

Mobility Management Procedures

- User Authentication:



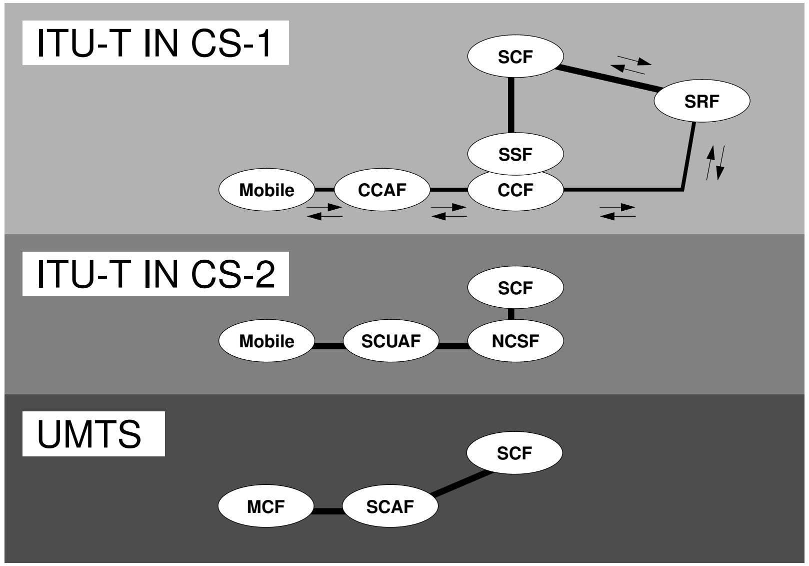
- Location Update: Usually with temporary ID
- Call Setup

We focus on three representative mobility management procedures:

- User Authentication
- Location Update
- and Call Setup

User Authentication is performed by sending an input challenge RAND to the subscriber whose SIM card (or similar device) within the personal communicator computes a signed result (SRES) using a cryptographic algorithm and his secret key. Service logic needs to have access to RAND-SRES pairs which are provided by an authentication centre. Usually, a vector with several of these pairs is produced. Each pair is used only once and the vector with the unused pairs is usually kept near the location of a subscriber. A Location Update is preceded by a User Authentication and might include a transfer of the authentication vector.

Information flow between Mobile and SCF



These procedures put requirements on the Intelligent Network architecture and functionality. Part of the mobility management related functionality has to be located with the user. In the UMTS standardization process the Mobile Storage Function (MSF) and the Mobile Control Function (MCF) are identified.

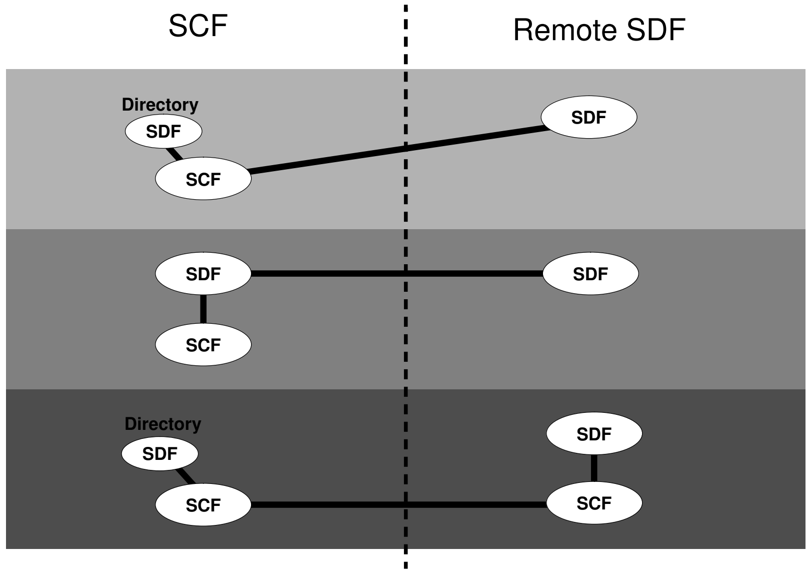
There is a need for information flow between MCF and Service Control Function (SCF). In the ITU-T IN CS-1 this cannot easily be achieved. A possibility would be via CCF, SSF and SRF (involving call handling and possibly some inband signalling), which is very inefficient.

Non-call associated service invocation and information flow is needed.

In ITU-T IN CS-2 drafts this is done via Service Control User Agent Function (SCUAF) and Non-Call Service Function (NCSF).

In UMTS a Service Control Agent Function (SCAF) has been defined.

SCF - Remote SDF Relationships



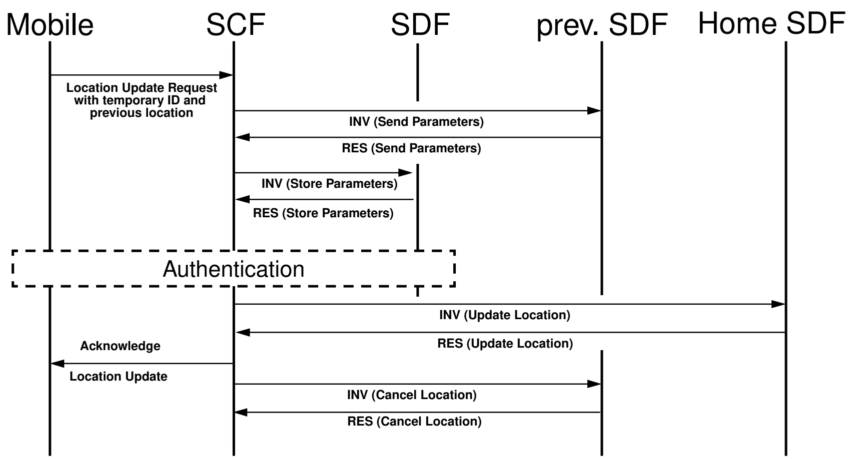
In ITU-T IN CS1 only SCF-SDF relationship exists. We will show how a GSM-like mobility management can be realized based only on SCF-SDF relationship.

If SCF-SCF and/or SDF-SDF is present, this can be done more efficiently. Usually, there exist two approaches.

In the first approach SDF-SDF relationship is used to hide data location to the SCF (data distribution transparency).

In the second approach, which is not contradictory but rather complementary, SCF-SCF relationship is used to access remote SDFs. Part of the service logic, which might include complex interaction with the remote SDF, is performed in the remote SCF.

GSM-like Location Update

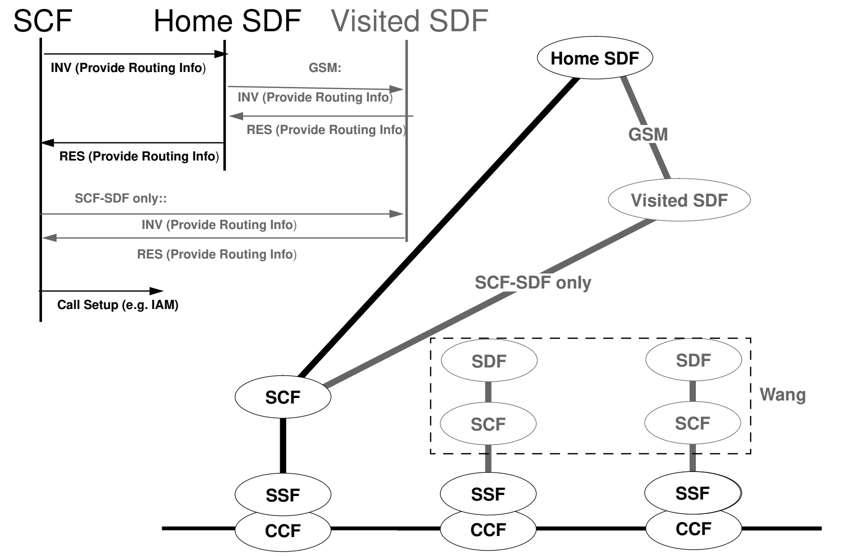


In the following we will take a closer look at the different location management procedures in the IN environment (and at their possible impact on network design).

If the authentication vector is present, user authentication only requires local action. SCF and SDF should be placed close to the user. In GSM, they are placed in the VLR. Once in a while a new authentication vector has to be retrieved from the authentication centre, which could be placed near the home location of the user. In case of a location update, the authentication vector is usually accessed at the previous location, especially when temporary identifiers are used.

The purpose of a location update is two-fold. The main purpose is to enablethe network to find the user in case of an incoming call. The second is to assure that the location of user data like e.g. the authentication vector can be optimized according to the user‘s location, i.e. user data could be transfered from the SDF at the previous location to the SDF at the current location of the user. A GSM-like location update which only makes use of SCF-SDF relationships is shown.

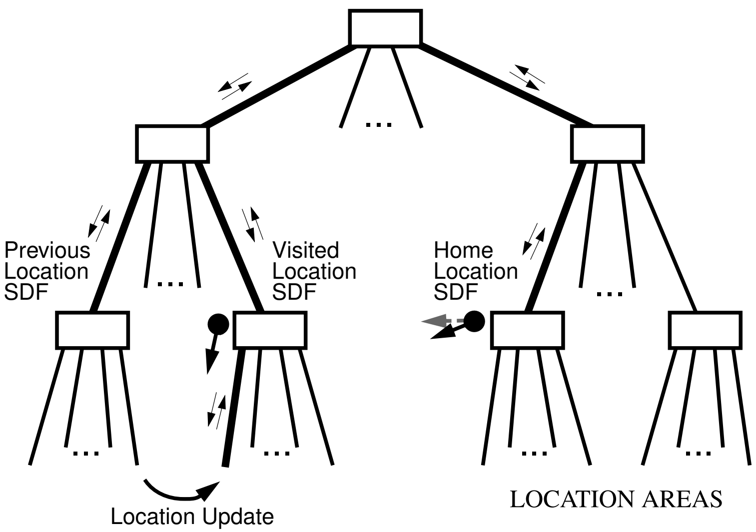
Different Call Setup Scenarios



Call set-up fits perfectly into the traditional Intelligent Network concept. When a connection is set up, routing decisions have to be taken at several points along the path. The retrieval of routing information is one of the main applications of current IN implementations. Routing information can be retrieved before the connection setup (like to some extend in GSM) or during connection setup at several switching points, like e.g. in [Wang].

In GSM routing information is provided by the node at the visited location on a call per call basis [Mouly]. Alternatively, this information could be provided on a registered location basis by the visited location node at location registration and kept in the home SDF. This increases dramatically the consumption of Roaming Numbers but reduces signalling and call setup delay, since routing information can be retrieved directly from the home SDF.

Data Distribution: GSM-like

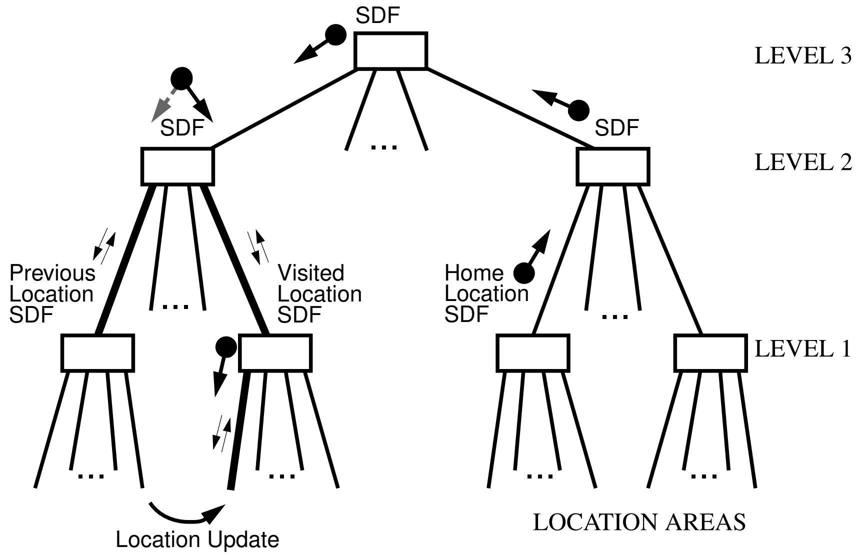


The previously shown scenarios assumed data distribution similar to the GSM HLR-VLR hierarchy. SCF is located close to the network access, often together with an SDF which stores data of the users registered to location areas served by this SDF. In addition several SDFs in the network are “home SDFs“. Each subscriber is associated with exactly one home SDF, where e.g. the address of his current visited SDF is stored.

When signalling is assumed to be cheap, this is a good design, since the number of database transactions is kept small and delay is tolerable. This is also scalable, since the number of home SDFs can be adapted to the number of subscribers and the expected call setup and location update rates. Home SDFs can be placed close to the home location of a user, if call and mobility behaviour exhibits some locality.

In this context first priority should be placed on reducing the location update rate (without augmenting paging cost), which saves also costly bandwidth at the radio access, instead of optimizing the handling of location updates in the fixed network.

Distributed Database according to [Wang]



With the expected reduction of location area size and increase of location update rates, due to smaller cells and multi-network-operator environments, signalling cost might no longer be neglectable. Several distributed database architectures have been proposed, which usually reduce signalling in exchange for increased processing cost and overall database size.

[Wang] proposes an IN-based approach where calls are routed in a hierarchical manner. At each level of the hierarchy a routing decision has to be taken. If no other information exists, calls are routed towards the home location of the called user. If the called user is registered with another location, each node in the hierarchy which has to deviate the call keeps a “deviation pointer“ associated with the called user.

This approach minimizes call setup cost of calls between users who are located close to each other, and location update cost if the user moves locally, even when he is far away from his home location.

On the other hand, call setup might involve several database queries, routing is tied to the database structure, and users who roam far away from their home location produce several database entries.

Comparison with high locality (95%)

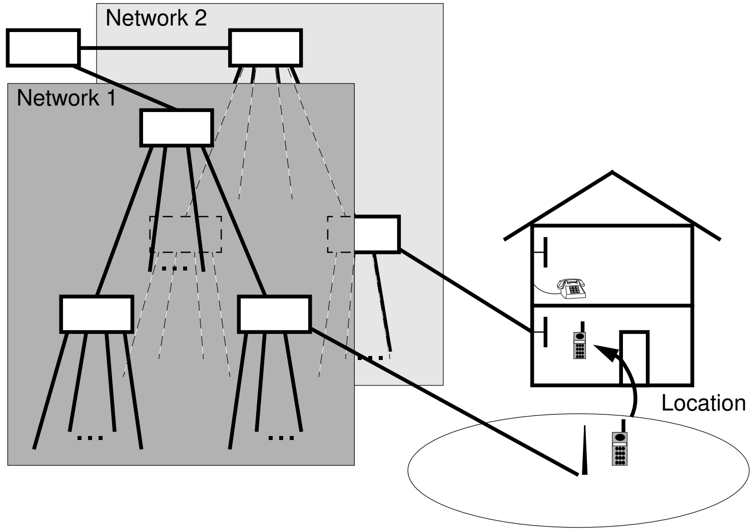
Comparison of [Wang] with GSM-like MM	Overall Signalling	Signalling above Level 1	Database Transactions
Location Update Cost	- 42%	- 72%	+ 0%
Call Setup Cost	- 31%	- 40%	+ 11%

Like other distributed database architectures, this approach exploits locality of user behaviour in terms of calls and movement. [Wang] assumes that users stay 95% of the time within the coverage area of their home SDF, 5% of the time they have an entry in a level 2 SDF, and 0.5% of the time an entry in the level 3 SDF.

If we assume the same kind of locality for calls, which we assume to be type 2 calls (see Call Model), and some locality for the movements between location areas, we find, that this approach reduces signalling load moderately without significantly rising the number of database transactions compared to the GSM-like mobility management presented above.

In numbers: Location update signalling cost is reduced by 42% (72% above level 1) in terms of signalling messages × distance (according to [Wang]) and call setup signalling cost is reduced by 31% (40% above level 1).

Multi-Operator Environment



True Personal Communication Services include (frequent) roaming between different access technologies and network operators. Since there is usually some separation between the networks of different operators, a small geographic move, e.g. entering a building or getting on a train, might result in very costly mobility management procedures.

We assume that each subscriber is always registered with exactly one network. In case of a location update the authentication vector is retrieved from the previous location, which is usually at least as costly as retrieving it from the home SDF. In this context, network specific authentication procedures might save some signalling.

Another possibility is to allow multiple-registrations. The mobility management in each network could be viewed separately. Call setup might become more costly, since either the user has to be searched sequentially in the different networks which increases call setup delay, or the user is searched in parallel in several networks which increases signalling load.

Comparison with low locality (50%)

Increase due to low locality (GSM-like MM)	Overall Signalling	Signalling above Level 1	Database Transactions
Location Update Cost	x 13	x 22	x 1.5
Call Setup Cost	x 8	x 10	x 1

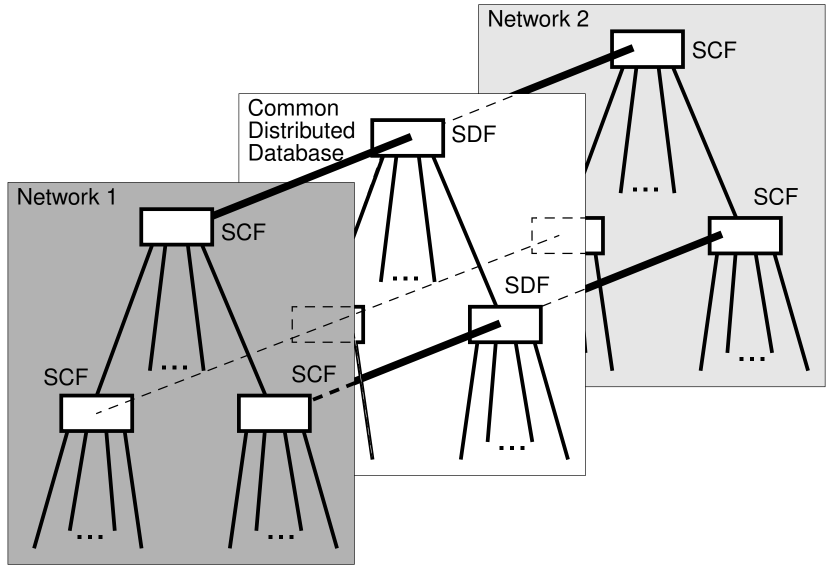
Comparison of [Wang] with GSM-like MM	Overall Signalling	Signalling above Level 1	Database Transactions
Location Update Cost	- 32%	- 34%	+ 20%
Call Setup Cost	- 39%	- 40%	+ 110%

If we take the above presented example and diminish locality in terms of calls and movement - which somehow models a mull-operator environment - but without increasing the location update rates (which might increase as well in a multi-operator environment), we find, that signalling increases dramatically in both approaches (GSM-like and [Wang]), and that the [Wang] approach is still only moderately better in terms of signalling cost, but requires more database transactions.

Table 1 shows the increase of signalling and database transactions for the GSM-like mobility management due to lower locality (50% instead of 95%) and the higher probability of location updates between location areas under different SDFs (50% instead of 1%).

Table 2 compares the [Wang] approach to the GSM-like approach under these changed conditions.

Common Distributed Database



We conclude that a multi-operator environment which does not reflect locality of user behaviour in its data management produces a large amount of signalling load and might not be able to fulfil performance requirements.

We propose a common distributed database which is shared by several networks and is able to exploit the geographic locality of user behaviour. An Database than manages location information of users within a specific **geographic** area and not only within a network-dependent location area. The separation of telecommunication network and distributed database is well supported by the IN concept, which enables separation of Service Control Functions (SCF) and Service Data Functions (SDF).

In addition, multiple-registrations can easily be handled in a common database, and, if there is a separation of routing information retrieval and call setup, service logic can than decide, over which networks or access technologies two parties are to be connected.

References

[Eynard] Eynard, C. et al., *A Methodology for the Performance Evaluation of Data Query Strategies in Universal Mobile Telecommunication Systems,* IEEE JSAC Vol.13, No.5, 1995

[Mouly] Mouly, M. and M.-B. Pautet, The GSM System for Mobile Communications, published by the authors, Palaiseau, 1992

[Wang] Wang, J.Z., *A Fully Distributed Location Registration Strategy for Universal Personal Communication Systems,* IEEE JSAC Vol.11, No.6, 1993