Network Architecture for Personal Mobility

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ABSTRACT

In this paper we discuss personal mobility on the wireline network. The components of personal mobility are identified and abstract characterisations of the services are described. We suggest several different architectures for realizing personal mobility. Finally, we present our approach to modelling and analysing these architectures, complete with the results obtained by applying these techniques.

1 INTRODUCTION

Mobility-related services range from being able to keep the existing telephone number when moving premises to the ability to make or receive calls while on the move. Many of these services are already being offered to customers of cellular networks, but unfortunately, this approach is not without its problems: The proliferation of standards and incompatibility of networks mean that there are severe restrictions to the area in which one can freely roam. The limited bandwidth available constrains both the number of subscribers these networks can support and the kind of services that can be offered to the subscribers.

In this paper, we consider the alternative approach of offering personal mobility services to customers on the wireline network. The success of recently-introduced services confirms that the services are meeting real customer requirements. The next sections examine the requirements for a wireline personal mobility service and architectures for its wide-scale introduction.

2 PERSONAL MOBILITY

From the user's point of view, there are different kinds of mobility-related services. The usual classification of mobility related services (e.g. in [1]) are in terms of:

- personal mobility - the ability of a user to make and receive calls from any terminal e.g. by using personal numbers;
- terminal mobility - the ability of a user to make and receive calls on the move by using a portable cellular phone;
- service mobility - the ability of a user to access all the subscribed services from any terminal.

In this paper, we focus on personal mobility services on the wireline network. We see personal mobility as a combination of:

- Number portability - the ability to have incoming calls re-directed to a customer's current location;
- Billing portability - allowing a customer to make calls from any phone, but have them charged to his/her own telephone account (e.g. telephone charge cards);
- Service portability - allowing a customer to access his/her own services from any phone.

2.1 Abstract Characterization of Personal Mobility

Personal mobility can be characterized by considering the basic components of a telephone connection:

- Physical address - the physical location of the socket;
- Number in - the directory number to be dialled by other telephone users;
- User id - identification of the (primary) telephone user;
- Billing account - to be charged for outgoing calls;
- Services-in profile - services associated with incoming calls;
- Services-out profile - services associated with outgoing calls.

We note that the outgoing number might actually be based on the billing account or the user id, depending upon the actual usage (e.g. calling line identity should give the user id).

For a basic POTS telephone connection the physical address is a line card connection; the number in, user-id, billing account and service profiles are all associated with the single telephone number.

Number and service portability for incoming calls is illustrated in Figure 1. For incoming calls, portable numbers must be translated to the physical address of the new location (in this case, address 2). The services- in profile is required to allow subscribers to access their services for incoming calls, e.g. user 1 may have subscribed to the

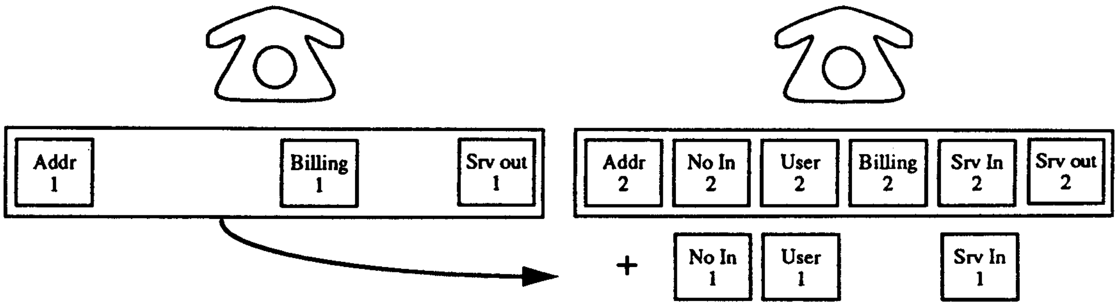

Figure 1 - Number & Service Portability

Calling Line Identity service and wishes to have this present for all incoming calls, no matter what the current location.

3 ARCHITECTURES FOR PERSONAL MOBILITY

This section examines possible architectures for provisioning personal mobility services on a wide-scale. Section 4 presents a basic analysis of these architectures to show their suitability to the number portability problem.

3.1 Functional Entities

All of the architectures that we have considered use location registers for storing information about customers' current geographical locations and about the services that they have subscribed to. These location registers have been split into two functional entities:

- Global Location Register (GLR):

  The GLR is a single logical database. Each subscriber will have an entry in the database that includes their service profile and their last known location. The GLR may be partitioned by the subscriber number (i.e. the called telephone number) to allow the database to be physically distributed. There may also be multiple copies of the GLR, though this would require a more complex update procedure as the multiple GLRs need to be consistent with each other.

- Local Location Register (LLR):

  The LLR is simply a cache of a subset of the GLR database. The exact contents of the LLR will depend upon the caching strategy (discussed below).

  A switch will use the LLR as the first point of lookup for a given portable number. If the LLR does not contain the number, the LLR will forward the request to the GLR. In this way, a good caching system will greatly reduce the load on the GLR.

3.2 Single Global Location Register (GLR)

The single GLR architecture adopts the simplest approach - that is to have a single physical GLR and pass all lookup requests to this database. LLRs are not required in this scheme and all requests to the portability service will require a lookup in the central GLR. For example, a call to a portable number will be passed from the CO (central office) to an SSP (Service Switching Point) where a *send routing information* message is sent to the GLR on the signalling network. This will return the called subscriber's current location.

This scheme is suitable for low volume usage for identifiable portable numbers e.g. for the recently introduced 700 numbering scheme. While it is an economical architecture to set-up, its scalability is very limited. In addition, if the system is used for existing numbers, there is an issue concerning local calls. In this situation, the CO would route the call as a local call, bypassing the SSP and the subsequent GLR lookup. To ensure that local calls to a portable number are handled correctly, a suitable scheme must be employed.

3.3 Partitioned GLR

In this architecture the GLR is split into a number of databases, partitioned by the subscriber's number, each database handling all events related to its contained subscriber base. A call to a portable number will be routed to the appropriate GLR, which requires a fixed mapping from the subscriber's number to a GLR partition.

This scheme offers better scalability than the single GLR; as new GLRs can be added as required. However in the long term, the fixed mapping can cause inefficient distribution of numbers as people permanently relocate to new areas.

3.4 Cached GLR

In this architecture (shown in Figure 2), LLRs are used to provide caching for portable numbers, avoiding the need to always perform the number translation at the GLR. The GLR may also be partitioned, though a single GLR is an alternative arrangement that may be suitable for highly-successful caching strategies.

Calls to a portable number will use the nearest LLR to perform a lookup of the subscriber's current location. If the lookup is unsuccessful, the LLR will request the

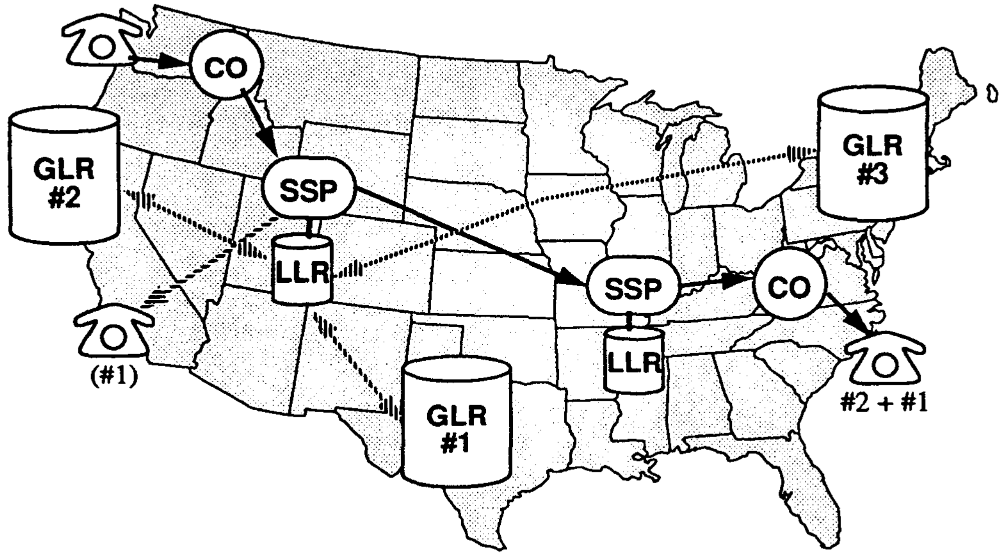

Figure 2 - Cached GLR

lookup from the appropriate GLR. In either case, the LLR returns the translated number to the SSP for call completion.

This architecture can be grown to meet the required demand, providing good scalability. However, the success of the architecture is very dependent upon the success of the caching strategy used by the LLRs. Possible caching strategies are discussed in the next section.

3.5 Caching Strategies

Physical Proximity:

A physical proximity cache contains the numbers of the subscribers who are currently within the geographical area covered by the LLR. This strategy works well if most calls are within the local area and has the advantage that the subscriber's information is only stored in two places - the GLR and the current LLR (for location changes, this provides for a simple update mechanism). However, inter-area calls will always require a lookup in the GLR.

Frequently Called Numbers:

Numbers that are frequently called from within the local area are cached, no matter where the destination of the call may be. This scheme performs better for inter-area calls as these numbers may now be in the cache. However, the update mechanism (for a subscriber's new location) is more complex as the subscriber's profile may be in several LLRs as well as the GLR. The cache also needs to be sufficiently large to ensure a high percentage of cache hits. If the majority of calls are to a few numbers, then this is easy to achieve. However, if calls to portable numbers are more distributed, a larger cache would be required.

Suggestion Cache:

The suggestion cache is allowed to be out-of-date i.e. it need not be updated if a subscriber moves to a new location. While this simplifies the update process, it requires a check to the GLR for every lookup to ensure accuracy and may not provide any benefits of using a cache.The scheme is only viable if the GLR lookup (for checking) can be piggy-backed onto other signalling.

3.6 Other Approaches

In [5], a more radical architecture based on very high bandwidth communication between the network elements is described.

Approaches to interworking of personal and terminal mobility are described in [2],[3] and [4].

4 TRAFFIC ANALYSIS

With the different architectures for implementing number portability, it is necessary to have a way of evaluating them. In this section, we first discuss briefly our information modelling approach and then we describe its application in deriving the load on the network elements and links for the proposed architectures.

4.1 Modelling techniques

We see traffic analysis as taking as input information about the network, the protocol and usage and generating as output information about the network element and link load.

The **network model** contains information about the network elements, e.g. number and type of switches, databases etc., and their interconnections. The network model can be specified at different levels of abstraction.

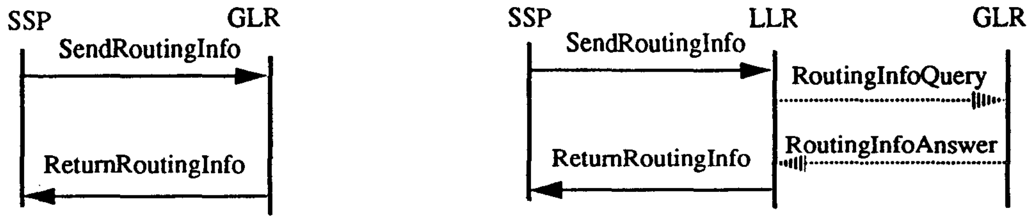

Figure 3- Signalling flow for Call-Setup in architectures 1, 2 (left) and 3 (right)

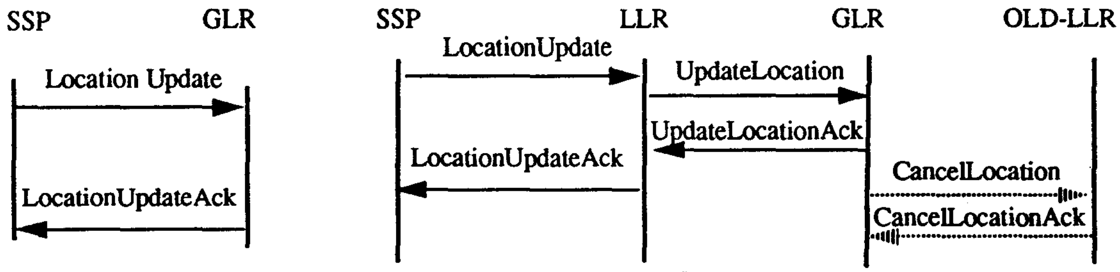

Figure 4- Signalling flow for Registration in architectures 1, 2 (left) and 3 (right)

- the **abstract system level** views the system as a single abstract entity providing various network services such as call-setup, registration etc.
- the **functional level** views the system as a composition of different functional entities such as number translator, switching system etc.
- the **logical entities level** maps the functions into logical entities. In our example, the number translation function has been split between a GLR and an LLR.
- the **physical level** implements the logical entities in physical network elements. A single physical element can contain multiple logical entities and vice versa.

The **protocol model** contains two different types of information:

- the signalling diagrams describe the signalling events which take place between the network elements in order to implement the network functions.
- the protocol stack model describes how the information exchanged at the application level is mapped down to the physical level before being transmitted. This model allows the estimation of the physical transmission capacity.

The **usage model** contains information about the subscribers and is used to determine the service demand. It can be at two different levels of refinement:

- the coarse granularity only contains the number of subscribers to the different services, and their average daily behaviour;
- the fine granularity refines the above information by taking into account different user profiles (business, domestic), the geographical variation (rural, town, cities) and the temporal variation (time of the day, day of the week). This information is useful to determine the peak demand.

4.2 Comparative analysis

This section describes the comparison of the proposed network architectures using our traffic analysis approach.

We assume that the network contains 1000 tandem switches. Arch. 1 refers to the single GLR approach, Arch. 2 refers to the partitioned approach, and Arch. 3 to the local caching approach.

For Arch. 2 we assume that there are 20 GLRs. For Arch.3 we use the physical proximity caching strategy and assume that there are 20 GLRs and 100 LLRs.

We have used simple protocols for the location update and location request procedures, and assume that SS7 is used for the transport of signalling messages. Our estimate of the message size at the physical level is 100 Bytes for short messages and 200 Bytes for long messages. (The signalling protocols are shown in Figure 3 & Figure 4).

For the usage model, we have assumed a 200 million subscriber base, with 20% penetration for the mobility service. We assume that the service is provided to existing numbers, i.e. all dialled numbers would need to be translated, even for non-subscribers. The peak hour traffic is taken to be about 20% of the total traffic in the day.

The last relevant assumptions are that databases contain 300 bytes per subscriber and that the physical proximity strategy gives a 80% cache hit rate and 20% inter-LLR location updates.

Table 1 summarizes the general results on the requirements for the various network elements with the peak

	GLR Arch. 1		GLR Arch.2		GLR Arch. 3		LLR Arch. 3	
Database Read/s	23K	(110K)	1150	(5500)	230	(1100)	230	(1100)
Database Write/s	6K	(28K)	300	(1400)	60	(280)	15	(70)
Total Read + Write	29K	(138K)	1450	(6900)	290	(1380)	245	(1200)
Database size	12 GBytes		600 MBytes		3000 MBytes		600 MBytes	

Table 1 - Network Element Requirements

	SSP-GLR Arch. 1		SSP- GLR Arch. 2		SSP-LLR Arch. 3		LLR- GLR Arch. 3	
Call traffic (kb/s)	37	(178)	1.9	(8.9)	37	(178)	4	(18)
Registr. traffic (kb/s)	2	(9)	0.1	(0.5)	2	(9)	1	(5)
Total Traffic	39	(187)	2.0	(9.4)	39	(187)	5	(23)

Table 2- Traffic Load on Interfaces

load between parentheses. Table 2 shows the traffic load on the various interfaces.

It appears from this preliminary analysis that full number translation is technically feasible. Architectures 3 can best support the required traffic although there are stringent requirements on the load of the network elements.

The results also show that the communication bandwidth is not a problem - an SS7 based system would be sufficient. In our analysis, we assumed direct connections of the network elements. Our results show that this is not necessary. The next step would be to refine the analysis by taking a particular network topology for interconnections. Further study on network performance and traffic delays using stochastic methods is also required.

5 CONCLUSION

The main focus of the paper was on personal mobility on the wireline network. We identified the different components that make up this service, namely number portability, billing portability and service portability. We examined three possible architectures for personal mobility: a single global location register (GLR); a partitioned GLR; and a partitioned GLR with local caches. The relative merits of these architectures were briefly discussed.

Our approach to model and compare these alternatives was then presented. Information about the network, the protocol and the usage are used to derive the load on the network elements and links. A somewhat surprising result from the preliminary analysis was that the local caching approach could be scaled up to support full number translation, i.e. the translation of every dialled number to physical address for subscribers and non-subscribers alike. Furthermore, it is noted that, from the capacity point of view, an SS7-like mechanism for the transfer of signalling messages would be adequate. Finally, different ways of improving the analysis were described.

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