The Role of Semantic Locations for Mobile Information Access

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Abstract: The concept of symbolic or semantic locations significantly simplifies the development of several applications that access location information in mobile scenarios. This paper motivates the idea of semantic locations and presents the Nimbus framework, which was designed and realized to support developers of location-based applications and services. Nimbus considers the requirements of clients in mobile environments. It is based on a decentralized and self-organizing runtime infrastructure and thus highly scalable and accessible for mobile users.

1 Introduction

Applications or services which take into account the current location will become increasingly popular in the future. Especially mobile phone providers expect a huge market for such services [UM00]. Typical applications answer questions like "Where is the nearest hotel?", serve as electronic city guides or provide location-dependent emergency services. Currently, the development of such applications is still cost-intensive due to the heterogeneity of position information and location data [Ro02, Ro04].

Often, location based services need symbolic location information (so-called *semantic* locations) that carries semantics about the location, but most positioning systems only provide *physical* locations such as 51º22.634 North, 7º29.694 East. Physical locations are not useful for most users, whereas semantic locations [Le98, Pr00, SA94] have a certain meaning for users or applications. Typical semantic locations are "Campus, University of Hagen" or "City centre of Paris". Note that physical locations can be considered as a single point in space, whereas semantic locations usually cover areas. Semantic locations can be of different types, e.g., locations with a political meaning (countries, states or cities), geographical locations (mountains, rivers or forests) or temporary locations (construction zones or fairs). As a great benefit, semantic locations that are built according to a well-defined name space can easily be used as a search key for traditional databases, tables or lists.

The role of semantic location information is discussed with the help of an example:

Fig. 1 shows a location-based bus planner. The user simply selects the destination (fig. 1, left) and the application computes the appropriate time table for the selected destination, while taking into account the current time and location (fig. 1, middle). After boarding the bus, the planner supervises the current location and informs the user when to exit (fig. 1, right). This application is not primarily interested in the physical coordinates of the user's current location, but wants to know at which bus station the user is waiting. In this context, locations such as "Bus Station at the Central Railway Station" are typical semantic locations.

Fig. 1: The location-based bus planner

As many positioning systems produce physical location information, the application or service often perform a mapping of physical coordinates to the respective semantic location (in the example: the bus station) internally. If this mapping operation is separately integrated into multiple applications, this causes an undesired code overhead. In addition, this mapping requires geo data that the service provider has to collect and administrate. This can be an expensive task.

As a solution, the Nimbus framework was designed and realized to encapsulate all functions related to positioning and mapping to semantic locations. The framework provides semantic location information according to a predefined name space, thus semantic locations can easily be used to look up spatial data in traditional databases. The mapping between physical and semantic location information is provided by a decentralized federation of *location servers*. Local information is entered and administered at a local server.

2 Semantic Locations in the Nimbus Framework

To support developers of location-based services we created the Nimbus framework. Nimbus provides a common interface to location data and hides the position capturing mechanisms. To achieve an optimal flexibility, it provides physical coordinates as well as semantic information about the current location. With Nimbus, mobile users can switch between satellite navigation systems such as GPS, positioning systems based on cell-phone infrastructures, or indoor positioning systems without affecting the location-based service. Nimbus is based on a self-organizing infrastructure, thus flexible and easy to extend.

Fig. 2 (left) shows the data flow in the Nimbus framework. We assume that the positioning systems are either attached to the mobile client or location information provided by a tracking system can be accessed by the mobile client via a wireless network.

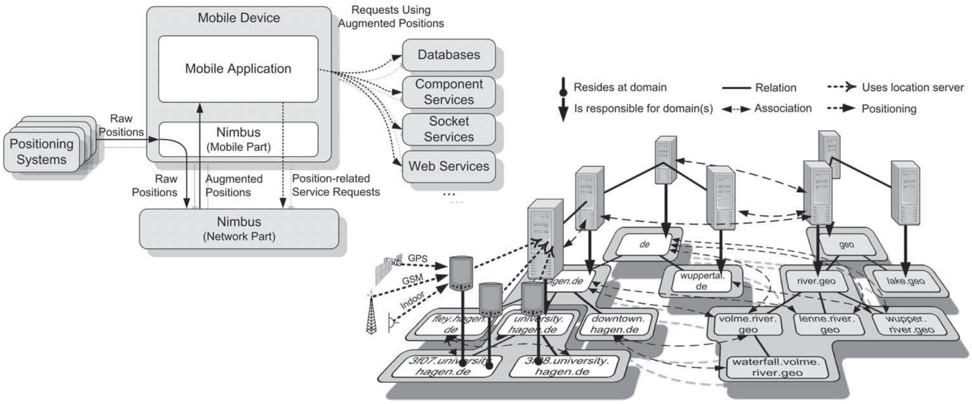

Fig. 2: Data flow and Nimbus architecture

The Nimbus framework has a mobile part installed on the mobile system and a network part providing information about the location. The mobile part receives raw positions and requests an augmentation service from the network part. As a result, the mobile client receives globally unique physical and semantic location information, which can be easily processed by the application. As the semantic locations are strings that follow a predefined name scheme, they can easily be used for direct queries in database tables and lists and can be parts of file names. Besides the main function of augmenting locations, Nimbus provides several services strongly related to location-based services such as geocasting services [Ro03a].

From the conceptual view, Nimbus contains two important parts:

- The *location model* structures the space and relates physical to semantic locations. It models locations with so-called *domains* that represent both physical and semantic aspects of locations. Domains are logically linked to each other by *relations* and *associations* and form higher structures called *hierarchies*. The specific structure of hierarchies enables an efficient execution of mapping operations between physical and semantic locations [HR04, Ro03b]. The correctness of these operations is formally proved [Ro05].

- A *runtime infrastructure* (fig. 2 right) with its servers effectively stores the location data and is able to run the required algorithms in a decentralized manner. Domain data are directly available in the formal location model, but the domain access via a network has to be considered in a decentralized environment. The efficiency of the distributed algorithm is presented with the help of several simulations [Ro05].

The decision for a distributed storage of semantic locations has different reasons. First, a single database would be a bottleneck for a huge number of potential clients.

Second, mobile users who access domain data want to connect to the responsible server over low distances (in terms of network as well as geographically). Finally, information about local domains is usually available locally and is difficult to administrate in a central database. To address problems in the distributed, mobile scenario, the Nimbus Framework contains a number of mechanisms:

- A decentralized lookup mechanism allows a client to lookup the location server, responsible for the local area and in addition interconnects the servers that are logically linked. The lookup mechanism does not require any central instance and considers the low bandwidth of current wireless connections.

- An advanced caching concept additionally reduces network traffic and allows the mobile client to perform the resolution task while it is disconnected for a certain time. Computational demanding geometric operations are not executed on the client's site.

3 Evaluations

The Nimbus framework is completely implemented and works well. To show the effectiveness, a number of performance experiments were conducted to examine response time, scalability and network traffic. To get realistic results, the experiments used 8000 domains imported from the German land survey office (fig 3 left) that represent the area of Hagen.

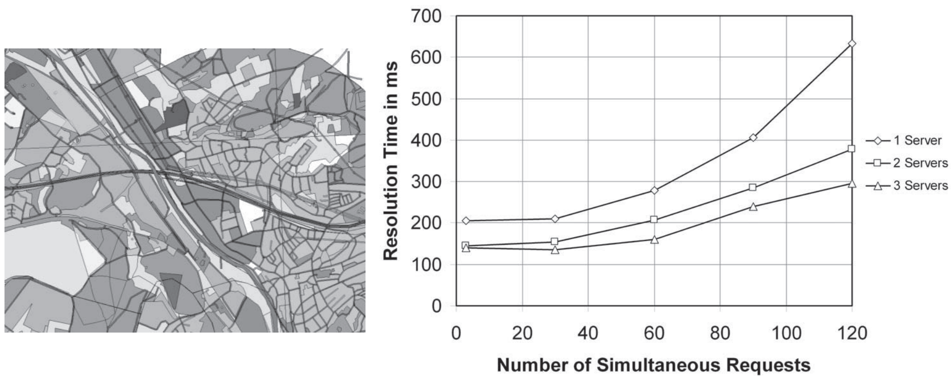

Fig. 3: Average resolution time for simultaneous requests

The most important result is presented in fig. 3 (right). A number of clients periodically perform a mapping between physical and semantic locations. The experiments were conducted for 1, 2 and 3 servers. All caches were switched off. Once receiving a semantic resolution result, the next request is sent without any delay. This causes a high load to the servers. It is important to note that in reality significantly more users per location server are needed to cause a specific load.

This experiment shows the scalability of the Nimbus approach. Using more than one location server, the load caused by different users is distributed. As expected, the approach is scalable: the use of more location servers results in a more flat curve.

4 Conclusion

We strongly believe that semantic locations will play a major role in future location-based application scenarios. We implemented a number of sample applications on top of the Nimbus framework to motivate the strength of the concept, e.g., a tourist guide and a friend finder application. With the help of the powerful Nimbus infrastructure, the development of such applications was significantly simplified.

Current domains are public and static. A future goal is to include mobile, private, secret and fuzzy defined domains in the concept. In addition, the way to enter domain data will be extended. Whereas domains are currently either entered manually or imported from a land survey source, a completely different approach is conceivable, where *users* are responsible for entering the domain data. As a consequence, the framework has to deal with incomplete and partly wrong domain data, but an ideal framework jointly supports authorized and user-entered domain data.

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