1 Introduction

Mobility describes the situation in which users are away from their homes or offices and are on the way. In these situations, often information about the way, the surrounding, or the target is needed, such as street maps, close-by restaurants, or time to destination. The central aspect in this information provision is that it must be tailored to the current user context, mainly his actual location. Three technology directions nowadays allow to provide digital support here: mobile devices like mobile phones and personal digital assistants (PDA), wireless network technologies such as GSM and WLAN, and techniques to locate the user by GPS or GSM. Applications exploiting the user’s local position and providing a location-based selection of information about the spot and the surrounding are called location-based services (LBS). Prominent examples of such location-based services are navigation and routing systems that display position and directions on a map on the mobile device.

Location-based services rely on information that can directly be mapped to a real world location. This information, often encoded in points of interest (POIs) and geo-referenced map representations, can, in the broadest sense, be called “geodata”. Such geodata can then be mapped and displayed by a location-based application according to the user’s actual location.

To support the presentation of geodata on the mobile device, the question arises how the geodata is transferred to the mobile device. One way is to store all geodata needed beforehand “at home” on a memory card, like it is done by the map service Falk Navigator [1]. Another way is to retrieve the geodata via the available network infrastructure when being mobile. These networks will mostly be cellular networks with limited bandwidth (GSM). More powerful networks like wireless LAN (WLAN) are only available at a limited number of places (hotspots). In both cases another drawback is that the information has to be retrieved again by each single user. In addition, sending the same huge amount of data over and over again via point-to-point connections like GPRS or UMTS is likely to trouble the network and the content provider. A solution to this problem can be seen in the advent of broadcasting technology such as digital video broadcast (DVB), which allows to distribute high volume data to a large number of users simultaneously.

In this paper, we present broadcasting technology and the new DVB standard and investigate the special requirements of broadcasting geodata. We show how broadcasting of geodata can actually be integrated into mobile location-based applications, using our Niccimon platform as a development framework. The paper concludes with an outlook to upcoming broadcasting standards and future work in geodata broadcasting in the Niccimon project.

2 Using broadcast for geodata dissemination

2.1 Broadcast technology

Broadcast networks are point-to-multipoint based (like common television) in contrast to the above mentioned point-to-point networks. In this paper, we focus on wireless broadcast systems with only one transmitter. The advantage of broadcast networks is to deliver data simultaneously to a large number of users, whether there are ten or millions. This advantage, however, comes with higher costs concerning the organisation of broadcasted data. Furthermore, broadcasting in general is not well suited for the transmission of individual data, but it is possible to broadcast regionalised information.
Using this broadcast network while being mobile is especially challenging: power capacity, storage space, and processing power of the end devices are rather limited. In addition, mobile devices might not be continuously online, due to limited network coverage or power supply. These problems demand adequate solutions from client, network, and server side, to nevertheless enable the mobile user a trouble-free use of an application. Among the solution strategies to be considered are client-side caching, optimising the round time frequency for repeating the content, time slices, and content optimisation.

2.2 The broadcast standard DVB-T

Recently, digital video broadcast (DVB) [2], [3] has evolved as a standard for broadcasting digital television as well as data services. Terrestrial DVB (DVB-T) [4] is currently being installed in Germany, providing up to 11-15 Mbit/s for data channels. As a standard for high bandwidth point-to-multipoint communication, DVB-T is designed to transmit high volume data, to be used simultaneously by a large number of users.

A DVB-T network is built up by a number of cells. Each cell covers an area of up to 50 km in radius, which may be combined into single frequency networks (SFN). By single cells a service is regionalised automatically based on the DVB-T technology, which is an argument to have even smaller cells.

As shown in Figure 1 the data is organised for broadcast in carousels, which repeat their content periodically to give users the possibility to obtain programs or needed data on a regular basis. The carousel’s content may be changed by the Mediacaster on the run partly or totally. Round times are still a question to be answered depending on the type of data. Specific data should be available frequently like e.g. news, others might be interesting only for a short time such as weather forecasts. Large round times might cause long waiting times, e.g. if a user activates the broadcast reception just after the needed data was broadcasted. On the other side, regarding short round times, only a small amount of data could be broadcasted, which leads to the question of costs. A smaller amount of data will be interesting to fewer people, so less people will pay for it, though the costs of the transmission remain. This discussion shows, that the selection of geodata, especially map tiles, to be broadcasted by the carousel is crucial for the success of the geodata broadcasting and the applications relying on this information. Different, potentially contrary requirements should be met: the round times should be long enough to send the needed geodata and short enough such that users do not have to wait too long until they can receive the data they need; the map tiles should cover different map scale; the broadcasted bandwidth and data volume needed for an application using the geodata, the storage and processing capabilities of the end devices must be met.

2.3 Geodata for broadcast systems

Geodata is defined as “information that identifies the geographical location and characteristics of natural or man-made features and boundaries of the Earth. Geodata represent abstractions of real-world entities, such as roads, buildings, vehicles, lakes, forests, and countries.” [5]. In mobile information systems such geodata is mainly needed in order to generate maps which afterwards can be displayed and help the user to orientate him- or herself.
Basically, two different types of geodata for maps can be distinguished: vector data and bitmap data. Geodata provider usually use vector data to store their original geodata. As this data constitutes a high business value, it is unlikely that they want to publish it, which would be a consequence when using broadcast technology. Furthermore, vector data demands complex rendering on the end user device. In contrast, bitmap data can simply be visualised by the receiving system, with no further need to interpret the data. Therefore, in this paper we focus on broadcasting bitmap data.

To identify the broadcasted data correctly, they have to be geo-referenced. There are different ways to encode geo-references: the position information can be encoded in the bitmap file name. Another way is to use metadata entries within the bitmap file itself, as supported by bitmap formats like GIF using the comment area [6] or GeoTIFF [7]. Alternatively, it is possible to store the geo-referenced information in additional metadata files. As the latter format is the most flexible one, allowing to use different coordinate systems along with additional semantic description, we favour this approach.

3 Broadcasting geodata

For broadcasting geodata to mobile devices, several phases have to be considered. First, the geodata has to be processed and prepared for broadcast transmission. Next, the relevant data must be selected and transmitted, using a broadcast system like DVB-T. On the user end device, the broadcasted data has to be received and stored for future use. All received data has to be managed due to the limited storage capabilities of today's mobile devices. Finally, the geodata can be used by the system and presented to the user.

3.1 Processing and broadcasting geodata

To provide the mobile devices within a DVB-T cell with the appropriate geodata, only the geodata belonging to the cell area needs to be broadcasted. In order to cover this cell area with bitmaps, it is not reasonable to use a huge single file. Instead, the map is split up in many small uniform map tiles. There are two relevant parameters for this operation. On the one hand, the size of each tile is important for the processing capability of the end device. On the other hand, the number of the tiles is relevant for the transmitting broadcast system. An important goal of our work will be to find an optimal balance between these two parameters.

When using map data, users often want to change the scale of the displayed map. Therefore, different map scales of the same area must be broadcasted. To get an overview, a small map scale (e.g., 1 : 50 000) seems appropriate. When looking for detailed information, a large map scale (e.g., 1 : 2 500) is more useful. Nevertheless, it has to be considered that the map scale directly affects the number of broadcasted tiles. Though small scale map tiles typically have high data volume, only few of them are needed to cover an area. Large scales tiles, on the contrary, are small, but as one needs huge amounts of files to cover an area, they consequently represent a larger fraction of the overall data.

If alternative map scales of a designated target area would be broadcasted sequentially, the average latency until a needed map could be displayed would be quite long. The volume of the above mentioned two map scales would be approximate 160 MByte for an area covered by a single DVB-T cell, assuming tiles to be in JPG format at the size of 500x500 pixel with 72 dpi. Using the broadcast system with a designated transfer rate of 2 Mbit/s would already result in a round time about 11 minutes. This behaviour is neither desirable nor acceptable for the most common applications. Therefore, tiles have to be transmitted using an interleaved transmission scheme, based on a priority mechanism. This priority mechanism has to take several factors into account: The delay between choosing and displaying a map has to be kept to a minimum for the user. Furthermore, the available date rate has to be shared among all applications using the broadcast system, modifying the retransmission delay of all maps and especially overview maps, increasing the round time. Overview maps, which are needed more often, will receive therefore a high priority, whereas detailed and larger scaled maps will receive diverse priorities. Highly populated or frequently visited areas will get a high priority, whereas places of less interest will receive a low priority.
This altogether results in a well balanced broadcast list. To simplify the broadcast, geodata can be grouped into packages. Allowing to transmit lesser and larger files, which reduce protocol overhead. Based on this list of geodata or packages of geodata, the broadcast operator will be able to broadcast the geodata in an appropriate time.

In addition to the maps, the most common POIs, such as restaurants or sightseeing spots along with their extended information, can be broadcasted as well using the same priority mechanism.

### 3.2 Receiving geodata

In our application, only a certain fraction of broadcasted data is needed by each user at a specific time. Based on the current location and direction of the user, it is clear which map areas are relevant to the user. To identify a map tile, preceding the tile meta data is broadcasted, describing properties of the corresponding tile.

Relevant properties are: the coordinates of the area covered by a tile, the scale of a tile, the data format and the data size of a tile. By this information, it is possible to decide if a certain tile is relevant or not. If a tile is identified as not relevant, the mobile device can interrupt receiving data (based on the size of the tile) until the next meta data is broadcasted. Thus, the receiver does not have to listen constantly to the broadcasting channel.

Furthermore, receiving geodata over high speed broadcast networks can be troublesome for weak user end devices. The received data has to be processed and to be stored in the memory of the device. The performance of this process might be not good enough to cope with the transfer rate of the broadcast. In contrast to ordinary IP communication, there is no way to delay a data transfer or reduce the data rate in broadcast systems. In consequence, memory access and CPU speed can be a bottleneck while receiving tiles, resulting in a possible miss of data.

### 3.3 Managing and using broadcasted geodata

When receiving broadcasted geodata tiles, the mobile device has to correctly manage the data. The maps of the designated target area are, each map by its own, segmented into a number of uniform non intersecting tiles. When receiving such broadcasted tiles, the mobile device needs to decide which tiles are to be stored for future usage and which tiles can be ignored. This is an important process as the available memory on the used mobile device is limited. In order to avoid a critical memory overflow by storing too many tiles, only those must be fetched that will be needed/visualised in the near future. The relevant tiles are determined taking several factors of the current situation into account, namely the actual position of the user, her recent direction, and the current memory status of the device. This mechanism is strongly interwoven with the internal management process concerning the temporarily stored tiles and their disposal and will be explained in the following.

If a tile is stored, it is inserted into an internal spatial index structure managing all geodata. This index stores tiles for different areas as well as tiles of different map scales of the same area. Due to the user’s movement and the restricted memory, the stored tiles are constantly rated in order to dispose those tiles that are not needed anymore. The user’s actual position, together with her last direction vector is used to create high priority areas, for all map types stored in the spatial index. For each map scale, these priority areas differ in size, i.e., they get smaller the bigger the scale becomes. This fact is incorporated into the management by using smaller priority areas for large scaled maps. Two aspects justify this behaviour. First, users often use small scaled maps, covering large areas, to get an overview but demand detailed information only for small areas, using large scaled maps. The second aspect is related to the memory usage. When the same priority area, for instance an area with an 10 km diameter, would be used for all scales alike, one needs to consider 9 tiles (JPEG, 500x500 pixel with 72 dpi) at a 1:25 000 scale and 529 tiles at 1:2 500. Taking into account file number and individual file size (e.g., 20 - 30 kByte a tile) the huge amount of large scale map tiles would surely strain the memory management of a small mobile device. The different sizes of the priority areas can be depicted as a three dimensional "cone" (more precisely a set of stacked frustums) as shown in Figure 2.

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This "cone" is used by the spatial index structure to rate the corresponding tiles. Each tile that intersects or is enclosed by the appropriate conic section for each map type receives a high priority. All tiles that do not match this condition are removed from the index or are rejected when they are tested for insertion. In order to gain more flexibility, the diameters of the priority areas can be dynamically adapted for each map scale.

After the tiles are positively checked and inserted into the spatial index of the mobile GIS, they can be used. For instance, if the user moves or changes the scale of the map, new tiles may be used to update the visualisation. Those updated tiles are therefore fetched out of the spatial index for further processing. Due to two reasons a matching tile can be missing. It has not yet been broadcasted (due to the round time of the broadcast mechanism) or it has been removed out of the index beforehand (the system rated the tile as unimportant). In order to inform the user of the problem a message could be presented and an alternative action would be conducted. This could result in an incomplete visualisation, a proactive change of the map scale, or in disregarding the command.

Apart from the problems concerning the round time of the broadcast mechanism, the use of a broadcast system is completely transparent to the user. At present, we are implementing a prototypical geodata broadcasting system based on DVB-T and our Niccimon platform.

4 Geodata broadcast in Niccimon

In this section we describe how such a kind of service will be realised in the context of our Competence Center of Lower Saxony for Information Systems for Mobile Usage (Niccimon) [8], Germany.

The basis to integrate broadcasting of geodata into different application domains is the Niccimon platform. When developing mobile applications, e.g., mobile games [9] or tourist information systems [10], one of the central discoveries is that different applications often share similar basic application requirements. In our developments at the research centre, we identified different autonomous tasks and modules concerning location-sensing, location-visualisation, presentation of points of interest, etc. Based on these results, we developed a flexible, modular, and mobile platform, the Niccimon platform [11]. Following the mediator-wrapper-architecture approach, the Niccimon platform provides a mediator module which is governing, the per se autonomous, different wrapped applications treating the above mentioned topics. The integrated application modules cooperate with each other via distinguished interfaces provided by the mediator.

The interfaces provide access to functionality such as live cycle control, visualisation, network communication, and inter-component communication. This concept enables us to be flexible and powerful at the same time. There are different autonomous modules for map visualisation, POI
definition, acquiring location information, etc. as shown in Figure 3. Using these modules and interfaces, innovative mobile applications can rapidly be developed by reusing existing components and implementing the application’s particular tasks on top of these.

This platform has successfully been employed in different application domains, such as location-aware games [9] or mobile tourist guides [10], [12], [13]. In these applications, a location-based map visualisation has been a key factor for the user interface. However, the map data has either been locally stored on the mobile device or transferred via point-to-point networks, but so far has not been broadcasted.

The visualisation of the map data is realised by the GIS module of the Niccimon platform. It realises a 2D map presentation of the broadcasted map tiles and geo-reference POIs. This map visualisation supports basic functions like zooming, panning, selection, etc. As the most important information for a mobile user is that she can actually see where she is, the actual position of the user is displayed on the map. When the user moves around, this position information and other visualised aspects are continuously updated. Due to the environmental and inherent technical restrictions of localisation, the accuracy of the position information can vary. To display this fact, the visualised position icon is context sensitive and adapts itself (its visualisation) corresponding to the changing quality of the position information. Thus, the degree of the exactness is communicated to the user, which helps the user to recognise situations in which the system accidentally misplaces the user’s position on the map.

Figure 4 shows an example of this map visualisation of the Royal Herrenhausen Gardens in Hanover.

5 Applications using geodata broadcast

The functionalities of our Niccimon platform together with the intelligent broadcast of geodata over DVB-T allows to establish a basic service that can be used by a variety of location-based applications:

- Positioning, navigation, and routing services are best used with a map displaying position and direction.
- Tourist guides present the user a map of her surrounding area, and provides information about interesting sites like historical buildings or monuments.
- A city guide can contain information about facilities like restaurants, hotels, or public libraries. These POIs can be combined with further information like schedules for events or even booking functionality, e.g., for a concert.
- Specialised guides like pub, theatre, or shopping guides usually provide more restricted information, focused on specific areas and topics, adjusted to the needs of the vendors.
- Yellow pages can display their results on a map, including for example location-based paid-for advertising.
- Mobile location-based games can use geodata for game navigation and orientation, like the paper chase game described in [9].

We find different approaches today that address the provision of LBS in different application domains. In the automotive sector simple location-based services are already well established. Navigation systems provide the driver with driving directions and even additional information like restaurants etc. For pedestrians, the state of the art is less sophisticated. We also find research prototypes implementing LBS services like tourist and city guides (GUIDE in Lancaster [14], DeepMap in Heidelberg [15], or LoL@ in Vienna [16]), but so far only a few commercially available systems (e.g., O₂ [17]). These approaches have in common that they store the geodata on the mobile device and typically retrieve
it via point-to-point networks. However, until today there are no location-based applications making use of DVB-T for broadcasting geodata.

6 Conclusion and Perspective

In this paper, we discussed the use of DVB-T for broadcasting for the dissemination of geodata as a basic service for LBS applications. We shortly introduced broadcasting technology and its impact to the broadcasting of geodata. We presented the design of a service that takes into account the specific aspects of broadcasting geodata and existing broadcasting technology. This includes processing of the geodata for its broadcast, the management of and access to the broadcasted tiles on the client and the actual presentation on the mobile device. We presented the realisation of broadcasting geodata in the context of our Niccimon platform for mobile application development. First tests of our prototype will take place after the launch of DVB-T in Northern Germany in May 2004.

With broadcasting technology the distribution of geodata to a large number of mobile users becomes feasible and allows to support wide range of applications. Following first tests, we will elaborate on an optimal interleaving of geodata in different resolutions to support different types of applications with suitable round times and bandwidth.

The broadcast of geodata location-based applications that need both map data and information about geo-referenced points of interest allows mobile users to receive exactly that geodata that is both targeted at the current location and also up to date. The mobile access to geodata meets the limited storage capacity of mobile devices. With the launch of DVB-T we expect valuable results for the applicability of the approach and an optimisation of the loading of tiles into DVB carousel. Currently under specification, the upcoming DVB-H standard will adapt DVB to an even wider range of handheld devices, especially small and limited ones like mobile phones. As soon as the definition process is finished, we will start to migrate our solution from DVB-T to DVB-H.

References
