Integrated Solutions and Services in Public Transport on Mobile Devices

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Abstract: Our society is characterised by individuality, comfort and mobility. It has been shown in many scientific studies that the mobile phone plays an important role in our living and working environment. While navigation systems in cars offer a high level of individuality, comfort and a high degree of integration with the car electronics, there are no comparable solutions and services available in public transport. In this paper, it is described that integrated solutions in public transport can improve the user needs in terms of flexibility and convenience. Although there are several individual mobile applications for rail information and ticketing available, an integrated and profile-based solution is hard to find on the market. We propose an integrative architecture that covers mobile trip planning, intelligent mobile ticketing and community solutions during the trip. This shows that our findings can enhance flexibility and comfort in public transport.

1 Motivation

In many situations, passengers feel comfortable when using public transport, but on the other hand, they feel inflexible and mostly not well informed about the actual trip information at changing points. It can also be detected that many customers are often annoyed when using the existing ticketing solutions, e.g. waiting at ticketing machines or queue at a counter. In most cases they are not so familiar with the complex handling of existing traditional and mobile ticketing solutions. Apart from the multifunctional mobile ticketing project Ring&Ride, which is introduced in the next sections, there are hardly any comparable technical solutions combining intermodal[1] mobile ticketing both for long and short-distance travel.[2] Intermodal mobile ticketing solutions can use location information, e.g. GSM, W-LAN, GPS or NFC, of mobile phones for reconstructing the route taken and calculating the corresponding fare. During the trip, it is a unique opportunity in public transport to provide passengers with information and entertainment/community offers, e.g. music, video, communities, travel guides.

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[1] Using short and long distance public transport on a trip, for example.
[2] The touch&travel project uses near-field communication (NFC) [Ba09].

A recent study in Germany [Zu05] found that the passengers would like to have better support concerning how to get to the station and when to change vehicles in public transport. Other studies [Vi08] pointed out that the market of mobile social communities will grow steadily until 2012. Almost 25% of mobile subscribers will use mobile social communities in 2012. The potential for advertising in mobile communities will also offer a huge opportunity for the operators in the next few years [Vi08]. During the trip, the passenger is responsive to "kill-time" offers. Typically, location-based services [Sa07; BI08] can support the passengers with the relevant information services they need in this situation. Beside the huge relevance of location-based information, personalisation of services [Fr06] also plays an important role in the mobile environment. A customer's information, e.g. saved travel plans, home address, costs aspects and sightseeing, can be used in an expedient manner for intelligent and integrated services.

Regarding the mobile device market, the prerequisites for an integrated solution are given. Most applications are implemented as a browser-based or a client-based solution on a mobile operating system. The market for smart phones[3] is growing, especially from 2007 to 2008, the number has risen by 28% [Ca09].

The paper is structured as follows: in section 2, we describe the trip planning scenario. The location-based mobile ticketing project Ring&Ride is introduced in section 3. Section 4 illustrates different aspects of infotainment/community in public transport that demand an open architecture capable to integrate third party services. Such an architecture is sketched in section 5. Finally, section 6 summarises this paper and gives an outlook to future work.

2 Trip Planning and Trip Management

In this section, the way a trip can be planned concerning departure and arrival details will be shown.

Technological developments and increasingly powerful mobile end devices with features like NFC or GPS can be linked with information systems (e.g. traffic and tourist). This opens up completely new travel planning possibilities and provides support during an intermodal trip. The expansion of mobile broadband networks allows for the provision of information on maps both with static and dynamic content at a high bit rate. The combination of these technologies and their integration into existing platforms creates increasingly intelligent services and supports the customer's satisfaction.

By providing travel details and making the position of the traveller known through location technologies, e.g. GPS or W-LAN, as well as the current time of departure of public transport[4] and necessary information such as maps and details about the trip can be shown.

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[3] For previous years see [Ca07].
[4] Dynamic travel data of most transportation companies is available but not integrated in most cases.

Making possible delays along the way, e.g. traffic jams or detours,[5] known, the traveller gets a reminder when he has to start his trip. While travelling to the station, the current travel plan is continuously compared with the dynamic traffic data and position of the user, and information about the current status is provided.[6] At the station, the user is informed about available parking spots and how public transport can be reached.

When getting on public transport, for example a train, the context-specific information such as navigation within the train, to find the seat reserved, the restaurant, the train crew or providing the restaurant's menu and much more, is adapted. In case of delays or connections, the traveller is informed in a timely manner, and another route may even be calculated and recommended. If trip replanning is needed, alternative routes are determined and the relevant information, e.g. dynamic traffic data or maps in stations, are provided to the passenger's device as well.[7]

At changing points, the traveller is guided along the way by in-house localisation and map navigation to the connecting public transport. Depending on the length of his stopover, further information, e.g. on museums or restaurants, can be provided as well. The traveller is then accompanied from the final station to the destination originally entered.

A high level of usability facilitates the acceptance of a service. Attention should also be paid to an easy installation on the customer´s device. An example of interactive handling is Apple's Appstore for downloading and installing as well as using the iPhone services. The user must not feel overwhelmed or even bothered due to a flood of information. Another benefit of adequate user interaction is the possibility of receiving relevant information either sent by the operator (push mode) or requested actively by the traveller (pull mode), a choice made by the user himself, depending on the situation, for example if making a connection becomes critical. Further important aspects are the user interface and interaction design for easy navigation through the service and clear presentation of the interface on a restricted display size of existing mobile devices. By integrating personal data, the trip can be tailored specifically to the traveller's needs. Preferences like reserving a window seat, the quickest or most convenient connections or an interesting entertainment program can be taken into consideration.

Currently, there are a number of applications for trip planning, e.g. Fahrplan (iPhone), ZugInfo (iPhone), FahrInfo VBB (iPhone), SBB Fahrplan (iPhone),[8] DB Railnavigator,[9] available on the market. Some of these applications include location features for determining the position of the traveler, but dynamic traffic data is currently integrated in an inadequate way.

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[5] http://www.adac.de/Verkehr/mobiledienste/default.asp or http://mobil.verkehrsinfo.de/

[6] A project at T-Labs was conducted by the University of Bonn which dealt with time management while traveling to a station. The status was shown as a green, yellow or red light, for example, depicting more than enough time to reach the station on time, being short of time, and not having enough time at all, respectively.

[7] For trip replanning see [MLE07].

[8] For applications for the iPhone, see http://www.apple.com/de/iphone/appstore/

[9] For DB Railnavigator, see http://www.bahn.de/p/view/buchung/mobil/railnavigator.shtml

Although delays of long distance vehicles (e.g. trains) are considered, dynamic traffic data for short distance (e.g. trams and underground) is currently missing in the applications above. Whereas some services use Google Earth to display the current trip, neither true, dynamic door-to-door navigation, trip replanning, intermodal mobile ticketing, personalization nor travel guides can be found in any of the services so far. For the system to plan the trip in its entirety, including trip replanning, it is necessary to have access to the transportation companies' dynamic traffic data on all the means of transportation required for the trip. In order to realize convenient and dynamic, real time door-to-door navigation in the above-mentioned scenarios, the user's position has to be continuously determined. Localisation is also important for status information regarding delays or time remaining to reach the desired means of transportation, for instance, or for providing environment-specific travel plans like historical buildings or cultural institutions.

3 Location-Based Mobile Ticketing

3.1 Ring&Ride overview

An example of a mobile ticketing project which uses location data for ticketing is the Ring&Ride[10] project [Lu08]. In contrast to most other mobile ticketing systems, Ring&Ride is based on the check-in/check-out concept, i.e. the customer has to take an action not only at the beginning, but also at the end of the trip. When starting, he dials a toll-free phone number and receives a ticket (SMS) that is valid for both long distance (Deutsche Bahn) as well as for short distance travel. At the end of the trip, the passenger dials the number again to signal that the trip has been finished. The customer's location is determined at the starting point and at the destination, but also during the trip at defined time intervals (cf. fig. 1). Therefore, the mobile phone has to be switched on during the whole journey to enable the system to record the location information. After the check-out call, the location data is transferred to a subsystem called "route tracing", which has access to infrastructure (public transport networks, i.e. bus and train stations, as a geo-coded database) and timetable data (schedule) and uses the combination of both together with the location data collected to determine the customer's route.

Depending on the positioning accuracy, often not just one, but several possible routes are found. Results have shown that most of the routes did not differ much; for example, they all matched the means of transport and lines available and only differed in the start or end stop, with a corresponding time shift [WS07]. The last steps in the Ring&Ride process are to calculate the corresponding fare and to send the customer an invoice.

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[10] The project was supported by the German Federal Ministry for Economics and Technology and carried out between 2005 and 2008 by Deutsche Telekom AG together with the Technical University Braunschweig, WVI GmbH, Deutsche Bahn AG and other public transportion companies based in Berlin.

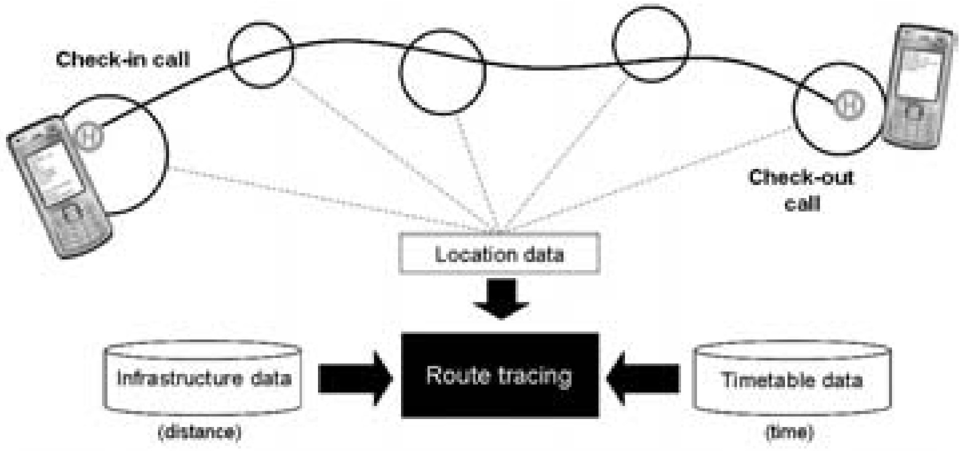

Figure 1: Location data (GSM) for a trip in Ring&Ride

The Ring&Ride idea has the following advantages: For customers, especially occasional and new ones, it means fewer restrictions and the possibility to take a trip spontaneously without any knowledge of tariffs or ticketing machines. Ring&Ride also supports the idea of intermodal public transport across Germany. For the transport companies, it would reduce ticket distribution costs (at least in the long run) by using existing infrastructure.

Two user interfaces were developed: the interactive voice response system (IVR) interface can be used by every type of mobile phone. The Ring&Ride application (for: Java or Windows Mobile) additionally provides route and pricing information (after the trip).

In Ring&Ride, different location technologies were used and compared. It is examined how the various location methods provide different qualities of location data during trips with different kinds of public transport vehicles and at stations. In particular, the quality of the calculated routes increased significantly using GPS or W-LAN location methods, even if they were only available for parts of the route. These findings can be helpful to optimize location methods to support all kinds of travel support use cases.

3.2 Location methods for travel scenarios

The location subsystem of the Ring&Ride system, which is the component responsible for collecting and integrating location information from different sources, hides the variety of possible location technologies from the other subsystems and uses the most suitable method for each situation. All location information is structured in the same way. A "position" consists of longitude and latitude (the centre of the radio cell), the accuracy (the radius of the cell) and a timestamp as well as the location technology used. First, only location data from GSM/UMTS mobile networks, provided by Deutsche

Telekom's PPGW[11], was used. In the second step, GPS and W-LAN localisation was added, but GSM was still used as a fallback solution whenever the other location technologies failed or were temporarily unavailable. The location subsystem was designed to be flexible and extensible for new location technologies: it would be possible to add GALILEO and NFC technologies without requiring major changes. Table 1 shows how the location technologies work in different situations on a trip. GSM/UMTS, GPS and W-LAN were tested in and around Berlin in Ring&Ride. The NFC technology is used in the Touch& Travel project by Deutsche Bahn [Ba09].

	GSM/UMTS	GPS	W-LAN	NFC
Distribution of mobile devices	Every device	Only modern devices	Only modern devices	Still few devices
Location cost	Depends on provider, contract	Only for data transmission	Only for data transmission	Only for data transmission
Quality of location	Cell radiuses vary from 200 m to several km	High precision (distance <50m)	Exact position (for fixed W-LAN router)	Exact position (for fixed NFC terminal)
Location at stations	yes	Problems in buildings and with roofs	Depends on existence of W-LAN routers	NFC terminals have to be installed
Location on trains	Mostly (some problems in tunnels)	Big problems in trains because modern glass windows obstruct "view" of satellite	No (even if W-LAN exists on train, it moves with train)	No (even if NFC terminal exists on train, it moves with train)
Location on underground	No[12]	No	Like for trains	Like for trains
Location on buses, trams	Yes	Yes (mostly)	Like for trains	Like for trains

Table 1: Comparison of different location technologies

3.3 Hybrid positioning

In the Ring&Ride project, we designed and used hybrid positioning strategies, i.e. the location subsystem uses whatever method is applicable in the situation to get the customer's location. We propose the following order to proceed whenever the application needs location data:

- Start with GPS due to high precision. If GPS is not available, try W-LAN.
- If neither GPS nor W-LAN works (e.g. on train), use GSM as fallback solution.
- NFC requires user interaction and the existence of NFC terminals. In situations where a customer uses NFC (like checking in for a trip with Touch&Travel), this location information should be included as well and override any other information because of its high precision.

11 PPGW is Deutsche Telekom's permission and privacy gateway, a trusted third party, neutral system platform which provides interfaces to 4 mobile network operators in Germany for GSM location conforming to German permission and privacy rules [EK06].
12 Even if people can telephone, the location may be wrong due to usage of repeaters in underground stations.

4 Infotainment/Community

The situation of public transport travellers offers a unique opportunity to supply them with information, entertainment or advertisements. During the trip, many travellers are idle for some time and responsive to ”kill-time“ offers. With travel information at hand, their situation can be characterised very precisely with respect to time and location. Furthermore, personal preferences could be obtained through the integration of community systems such as Facebook. This enables the transportation companies to provide their customers with specially-tailored infotainment offers.

Both data storage systems and content are already available in established and widely-used systems. DB AG, for example, already offers their customers a personalised system for *travel information*. Hence, detailed information about the travel schedule of a particular customer can be made available.

Many different *content* storage systems are at hand and are used by mobile stand-alone applications to retrieve location-specific information. Examples are AroundMe, WikiMe etc. for the Apple iPhone. *Personal preferences* that go beyond travel-specific data are maintained by an increasing number of people through diverse community systems such as Facebook, Xing, LinkedIn etc. We propose to provide the missing link between these systems by a RESTful architecture (cf. section 5) that brings the currently available information together and ease to provide user interfaces for the diverse mobile platforms.

Community support is not limited to use of existing data. On the contrary, we see at least two interesting forms of meaningful data generation caused by the travel: user generated travel information and automated presence information. User generated content and user generated links to existing content can be exploited to provide an increasingly rich and valuable set of location-specific offers. Geoinformation systems such as Google maps are already connected to location specific content such as user generated photos or mixed-media content in wikipedia. There is no big technical barrier to deliver multi-media content about a customer‘s route or destination while she is travelling.

For a growing number of people presence in diverse community system is a daily necessity. For microbloggers (such as Twitter users) the situation of travelling is certainly worth to inform friends about it. But also more serious users of community systems such as Xing are probably interested in updating their status online. An integrated travel system as we propose it in this paper could support personalised presence information by automated status updates.

5 Towards an Architecture for Integrated Travel Services

Fig. 2 shows how trip planning, mobile ticketing and third party services as info-tainment and community support can be integrated to yield a convenient and coherent service for travellers. We illustrate a proposed system architecture by focusing on four use cases: *plan trip*, *replan trip*, *select infotainment*, and *participate in community*.

We emphasise two requirements here: (1) both the traffic data service and all involved third party services must be easily accessible and integrable and (2) diverse mobile client platforms must be useable for the integrated service set.

State is crucial for trip planning in terms of timeliness of transport and resulting dynamic expected arrival time.[13] The data behind a trip plan changes dynamically during travel, e.g. a train gets delayed so that a certain connecting train will be missed. With the common session-based implementations (e.g. of the DB), trip plans are not persisted server-side. New travel situations can not be detected automatically, but must be perceived by the customer who manually has to create a new trip plan. Better support on the client side is difficult to implement (poll) and very special for each client platform.

Hence, we suggest to reify the customer‘s individual trip plan as a server-side resource as listing 1 exemplifies. We prefer a stateless client server communication for all trip planning functions to the common session-based connections. The state of the trip plan is therefore moved from the application to the resources.

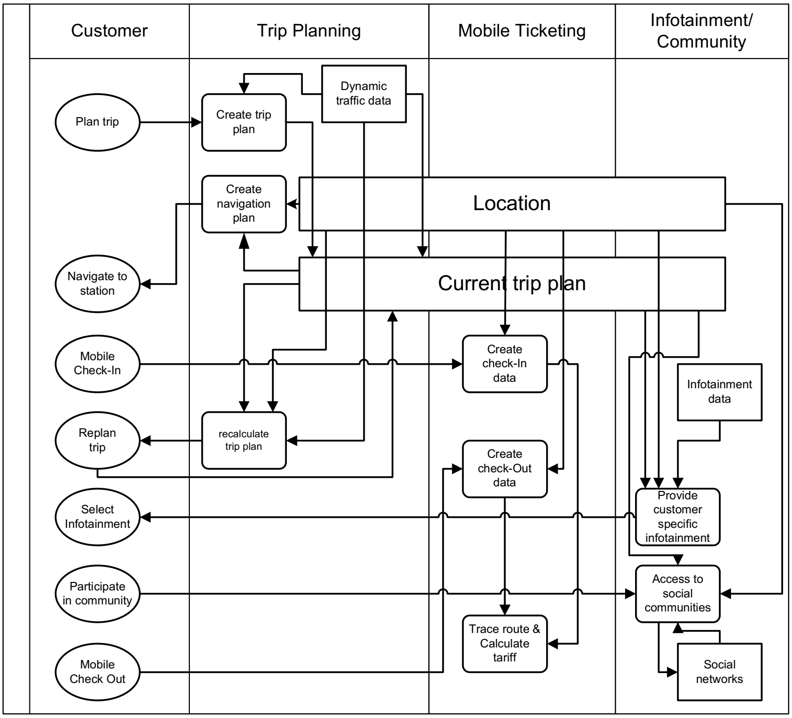

Figure 2: Illustration of trip planning, mobile ticketing and third party services

[13] E.g. users can keep each other informed about the status of their trip. As well as providing navigation information in cars, advanced TomTom navigation systems have a connection to cellular phones and can send information to TomTom servers when a car has stopped on the highway. Live traffic information (when multiple messages from the same road have to come within a certain timeframe) will suggest rerouting.

Our suggested architecture follows the REST[14] style [RiR07], i.e. each resource is addressable by an URI and accessed via the standard http methods GET, POST, PUT and DELETE. Resources are linked with each other. E.g. the XML sample for a trip plan resource links to other resources like stations, trains and the user's final destination.

In fig. 3 we sketch the suggested resource-oriented architecture. The resources are presented analogue to UML classes, e.g. `/tripplans` represents the set of all currently stored trip plans on the travel management server while `/tripplans/{id}` represents an individual trip plan as exemplified in listing 1 (with id = 0815). Each resource can be accessed by the standard http methods. E.g. calling POST with an appropriate set of parameters on `/tripplans` creates a new individual trip plan. Later on during the travel, this resource might be updated with dynamic traffic data or user triggered replanning by using the PUT method with appropriate parameters.

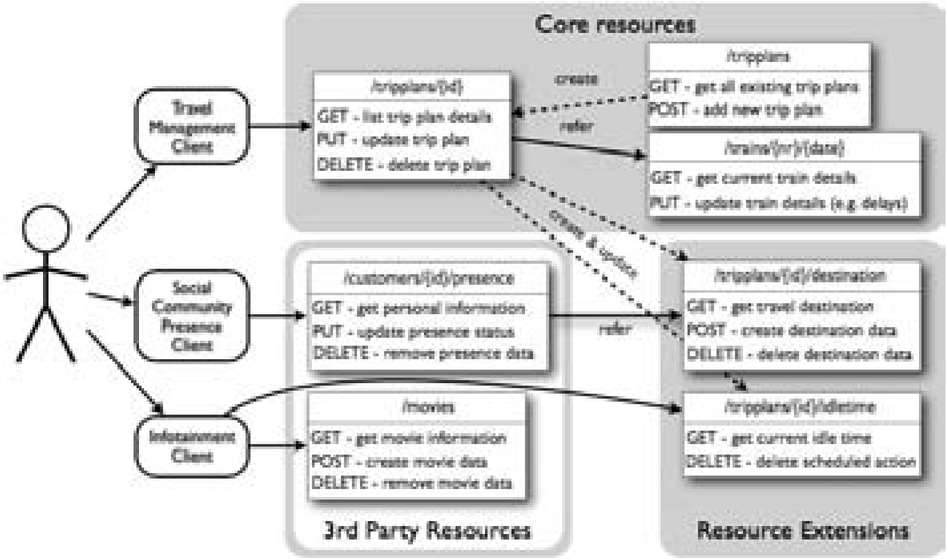

Figure 3: Sketch of resource oriented architecture

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[14] REST means representational state transfer and has evolved to a firm set of characteristics easing web-service interaction.

Hence, the trip plan is persisted on the server and accessible for reading and updating by simply using the resource URI and http methods. All client-server communication is atomic and state-less, so no session time outs will occur. Furthermore the direct access to resources provides a seamless integration with further information of the transport company. The trip plan is linked with train and station information and the like as shown in listing 1. To increase interoperability, special resources can extend the core set (cf. fig. 3). For example, the time until the traveller needs to take action again, e.g. to disembark, is modelled as a resource on its own. Calling GET on the resource `/tripplans/0815/idletime` retrieves the current idle time of the user. This allows a third party service to search automatically for movies with a maximum playtime by simply giving the URI to the idletime resource as search parameter. That could easily be integrated into a html page of the public transport company.

```
<TripPlan>
 <User><ID>0815</ID></User>
  <Dest><URI>
    bahn.de/tripplans/0815/destination
   </URI></Dest>
  <NextAction><URI>
    bahn.de/tripplans/0815/idletime
   </URI></NextAction>
 <Connection>
  <From><Station>
    <Name>Köln Hbf</Name>
    <URI>bahn.de/stations/koeln</URI>
   </Station>
   <Depart>2009.02.21_05:49</Depart>
  </From>
  <To><Station>
    <Name>Berlin Hbf</Name>
    <URI>bahn.de/stations/berlin</URI>
   </Station>
   <Arrive>2009.02.21_10:11</Arrive>
  </To>
  <With><Train>
    <Name>ICE 853</Name>
    <URI>bahn.de/trains/ICE853<URI>
  </Train></With>
 </Connection>
</TripPlan>
```

Listing 1: Abridged Trip Plan as XML

Resources can be represented in different formats, depending on the clients' demands. Hence, the same resources can be used by a web browser (receiving html) and e.g. an iPhone application (receiving xml). The selection is done using the standard accept meta data of the http call.

6 Outlook

In this paper, we show that integrated solutions in public transport consisting of trip planning, location-based mobile ticketing and infotainment/community services can enhance the customer´s satisfaction. We sketched an architecture how third party services (e.g. community and infotainment) can be integrated. In order to continue with these ideas, the proposed architecture needs to be adjusted to existing solutions (e.g. mobile ticketing). In the future, a prototype that covers trip planning, mobile ticketing and infotainment as well as community topics will be set up and implemented at different public transportation companies.

The integration of real-time information, infrastructure data and actual time table data will also be a necessary task, considering that “single-sign-on” functionalities (e.g. several public transportation companies) will enhance the usability and the comfort of the solution proposed above. Additionally, primary research for customer evaluation and acceptance tests should be considered in further work. Furthermore, business models have to be analysed and different end-user devices have to be considered.

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