Potentials and Requirements of Mobile Ubiquitous Computing for Public Transport

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Abstract: Public transport plays an important role in our society which is characterized by mobility, individuality, comfort and ecological constraints. It is common opinion that public transport offers a high level of comfort but lacks individual flexibility compared to individual transport. While navigation systems and other context-aware services enhance the feeling of self determination for car drivers, no comparable means for customers of public transport are currently available. In this paper we show that ubiquitous computing can supply customers of public transport with convenient attendance and flexibility. We describe typical scenarios, carve out general and technical requirements, and sketch a solution for a concrete implementation example. Our findings give evidence that ubiquitous computing can leverage public transport for both customers and providers.

1 Motivation

Customers typically perceive public transport as comfortable and safe but unreliable, inflexible and limiting their self-determination compared to individual transport. A recent study in Germany found (cf. [ZM+05], p. 89), that the more mobile passengers are the more they avoid public transport even for long distance trips. The same study carved out that people in particular demand better support for changing connecting transport services (cf. [ZM+05], p. 108). In this paper we show how mobile ubiquitous computing can enhance flexibility and self-determination in intermodal public transport. Existing infrastructures[1] allow for realizing ubiquitous systems with new services beneficial for both the customers and the operators with only minor efforts.

The rest of this paper is structured as follows. In section 2 we describe different use cases in brief. In section 3 we conclude a set of general requirements and map them to

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[1] E.g. the German DB already invested about 200 Mio Euro during the last years to set up a dynamic information system (cf. [Ec03]) for actual traffic times. This is a valuable infrastructure that can be used to deliver this information to the passengers when they need it. Hence, it is a crucial part of our replanning scenario.

the scenarios. Section 4 details the trip replanning scenario. We concretize the requirements needed, sketch a technical solution and discuss drawbacks and potential enhancements. In the final section we summarize our findings and envision future work.

2 Use Cases for Mobile Support in Public Transport

This section discusses some use cases highlighting valuable benefits for public transport customers. We point out that benefits can be achieved with relatively little effort in addition to already existing infrastructure like real-time data of train connection.

Trip Replanning. Even good planned trips often are subject to change. Among the diverse causes for replanning are customer-driven replanning (either on a station or while traveling) and operator-driven replanning. For the latter we distinguish unforeseen changes (e.g. due to lateness or machine failure) and foreseen changes (e.g. delay due to construction work or additionally scheduled connections). In section 3 we describe a concrete replanning scenario and sketch potential technical solutions.

Door to Door Navigation. Travelers in particular worry about intermodal trips, i.e. trips combining different traffic means. Difficulties in changing connections or navigation on large stations in limited time play an important role for travelers and let many of them feel reluctant to choose public transport. A personal system (not only on public screens but on the owner's mobile device) which seamlessly guides travelers along their complete journey increases their comfort and reduces their concerns against using public transport. Personalized information can support different passenger groups adequately[2].

Context-Sensitive Tourist Guide (and other value-adding services). Beside objective and rational criteria like travel time or price, subjective sensual criteria play an important role in people selection of traffic means. Dick describes in [Di04] the event character of journeys as an important for the acceptance of public transport. We believe that ubiquitous computing can help to attain such an event character, e.g. by supplying travelers with rich tourist information[3] along their way.

3 General Requirements

In this section we present a set of general requirements that apply for ubiquitous and mobile computing in the area of public transport. At the end of section, we show how they are related to the scenarios we defined in the previous section.

Spontaneous and reliable access to information (SRI) is an important general demand; for public transport even more than for individual transport, since you can not stop and

[2] E.g. business passengers need other navigation information than elderly people or families.
[3] Examples are: multimedia information about stories of the landscape, towns or buildings that are visible during the ride, historical facts or technical details etc.

think for a while. Furthermore, internet connection is often limited and unreliable.

Access to dynamic real travel information (DTI) is needed in addition to the connection schedule as replanning often occurs due to deviation from schedule (e.g. scenario two). Usually, this information is readily available for trains, subways and many buses (cf. [EC03], [MD01]) and accessible via web browsers.

Situation detection (Context Sensing & Interpretation) (SD) is crucial to supply passengers with adequate information and functionality. In general it is achieved by sensing various context data and interpreting it to assess the current user's situation. Most important is location detection, but the spectrum is broad. Further examples are the type of travel, user preferences, the personal trip plan, time, and location. The interpretation step applies some kind of reasoning and is in general very difficult (cf. in [KA03] case-based reasoning is applied). We assume that many scenarios in the area of public transport are comparatively easy, since many situations of passengers can be predefined.

Proactivity (PA) relieves passengers from continuously interacting with their device. The system actively provides them timely with relevant data or functionality. A cornerstone of proactivity is the ability to predict what will be important for the user in the next future. In general this is a very difficult task involving stochastic reasoning or automated learning techniques. Laasonen describes in [La05] an approach to route prediction based on GSM cell information and other context data. In the context of public transport predicting the passenger's route is easier. Longer trips are usually planned and the traveler's situation can relatively easy and reliably be extrapolated in time. Proactive context determination will enable timely delivery of diverse information and personal profiles can adjust it to the individual traveler. Nevertheless, it remains a challenging task, since other context data have to be taken into account too.

Adequate user interaction (AUI) is crucial for acceptance and usability. In certain situations user interaction should be minimized (e.g. in our trip planning scenario cf. section 4) while other situations rely heavily on user interaction. The user interface remains a scarce resource. Hence, user interface should adapt to the context and possibly share the available space and interaction modes (cf. [BK07]).

Dynamic software adaptivity (DS) supplies the users with context-sensitive functionality integrated in their common environments and tools. This is a key to user acceptance. There are diverse levels of adaptivity like parametric variation, extension (e.g. by plug-ins), and complete reconfiguration on some level of components. In the research project context-sensitive intelligence[4] we develop a framework for less-anticipated context-driven adaptation of software (cf. [MRC07], [MR+07], [RSC06]). Personalized tailoring of information selection workflows for the context-sensitive tourist guide is of equal interest (cf. [AK07]).

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[4] Context-Sensitive-Intelligence is a research project carried out by the group on Software Architecture and Middleware at the University of Bonn and funded by the Deutsche Telekom Laboratories.

Table 1 maps[5] the uses cases (cf. section 2) to general requirements:

Scenario	Arising General Requirements (level of importance)					
	SRI	DTI	SD	PA	AUI	DSA
Trip Replanning	high	high	mid	low	high	low
Door to Door Navigation	high	low	high	high	mid	high
Context-Aware Tourist Guide	low	mid	high	high	high	high

Table 1: Mapping use cases to general requirements

4 A Concrete Scenario – Trip Replanning

This section details the trip replanning scenario. Assume, you are on a business trip. Your travel plan schedules changing trains in Dortmund where you have to wait 45 minutes for your connecting train. Assume further, an earlier train leaving Dortmund to your destination is delayed by 20 minutes, so that you can catch it unexpectedly. Typically you will not get this information timely, and miss the chance to reach your destination faster than originally planned. Our system will receive the real travel time of this train early enough to point you to that opportunity, thus suiting the demands for proactivity (PA). This scenario can theoretically be accomplished with today's customary mobile devices with internet access. Nevertheless, we think that the current level of support does not suffice and that ubiquitous computing is necessary to let you take the opportunity of beneficial replanning. In the following we discuss the deficiencies of the current situation and suggest leveraging the use case.

At the beginning of an intermodal travel, the passenger typically uses the operators routing algorithm via a web interface and determines the details of his travel plan. This travel plan rests upon static schedule data. Today, such travel plans are not reified. We suggest to persist the plan data synchronously[6] on both the passenger's mobile device and the carrier's system (cf. step 'a' in fig. 1 and 2).

Operator-driven replanning depends on monitoring dynamic real traffic data and noticing relevant deviations from schedule. Today, the passenger is responsible for monitoring[7] (pull mode) and needs actively to adjust his travel route by planning again. Here we see two main drawbacks. First, passengers do not want to monitor traffic data manually. Second, even with client-side automated monitoring they still rely on a good internet connection which is not guaranteed on the ride. Hence, neither demand for both quick and reliable information access (SRI) nor the requirement of an adequate user interface over the complete workflow (AUI) is accomplished. Therefore, we suggest an

[5] Due to space limitations, we chose to omit details here.

[6] Keeping both copies of a travel plan (on the user's device and on the operator's system) synchronized is not an issue, since there is only one way to edit the data: by using the operator's planning service.

[7] Access to dynamic real traffic data is usually provided by the operators. Examples of such systems are: the RIS system of German DB providing real time information for most stations and connections [Ec03] and bus observation systems like MyBus [MD01] or NextBus (cf. http://www.nextbus.com).

architecture enabling continuous monitoring and notification without user interaction (cf. fig. 2). The individual travel plan of the passenger is registered for relevant changes against the dynamic traffic data base (cf. step 'b' in both figures). Update propagation algorithms can be applied to efficiently conclude which plans are affected by a given traffic event and provide automated access to dynamic traffic information (DTI). In case replanning is needed, it is performed on the operator's side and the resulting alternative travel plans are delivered to the passenger's device.

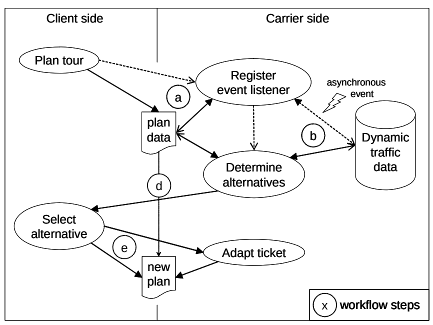

Figure 2: Course of action for operator-driven replanning

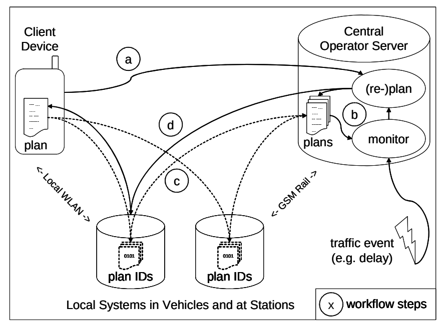

Figure 3: Proposed system architecture for operator-driven replanning

Delivering travel plan updates from the operator to the passenger's mobile device could be approached through direct connections via internet or SMS. But this either presumes the user to be "always on" or disintegrates his interaction mode and is uncomfortable. Hence, we suggest an indirect way via the passenger's current vehicle (cf. step 'd' in both figures). The two communication steps rely on stable techniques as GSM Rail[8] and local WLAN[9] as shown in figure 2. Therefore the user's instance of the travel plan is tracked through the transport system (cf. step 'c' in fig. 2) by sensing whenever the passenger enters or leaves a vehicle or station[10] (cf. requirement SD). Privacy issues are not affected, since only the anonymous travel plan itself is tracked which is neither bound to a specific device nor to a person. Diverse tracking technologies exist which must be considered in detail in future work, e.g. RFID, NFC, and Bluetooth.

Finally, when the passenger has been informed about replanning alternatives, the system should not demand explicitly selecting an alternative, but instead implicitly perceive his decision (cf. requirement AUI) by further tracking his positions (cf. step 'c' in fig. 2). An optional ticketing functionality could be a convenient extension of the sketched workflow (cf. step 'e' in fig. 1).

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[8] Details about GSM Rail can be found at the GSM-R homepage at http://gsm-r.uic.asso.fr
[9] A Heise article describes current plans for extending WLAN support in ICE trains of German DB, cf. http://www.heise.de/newsticker/meldung/57558
[10] Currently, some projects to track passenger's location based on GSM/UMTS cells or NFC are carried out, e.g. Ring&Ride or Travel&Touch, cf. http://www.heike-scholz.de/2007/03/19/nfc-bewegung-im-deutschen-markt-fr-mobile-ticketing/

5 Outlook

This paper gives evidence that ubiquitous computing can provide beneficial improvements for customer support in the area of public transport. We derived a set of general requirements and discussed how they can be tackled in the scenario of trip replanning. Therefore we sketched a system architecture and service workflow. In order to continue these ideas, business models have to be elaborated, market analyses and usability studies have to be carried out, the architecture needs to be adjusted to the operator's concrete infrastructure, and different end-user platforms must be considered. For many details[11] we already see migration paths from currently established systems to the vision of a more convenient intermodal public transport.

6 References

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[11] E.g. the indirect delivery of data from the operator to the passenger by tracking his travel plan can be intermediary replaced by a simple SMS-based notification.