AN ARCHITECTURE FOR CONTEXT-SENSITIVE TELECOMMUNICATION APPLICATIONS

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Abstract: Nowadays, everybody utilizes information from different sources and services from various providers. However, one must know how to find the interesting information and how to access services. Wouldnt it be better if information and service access could adapt to the user and his interests? This approach is the central point of the ubiquitous computing research. And the adaptation is done based on the current context describing the user and his equipment. Although there are many projects that claim to be context sensitive, a general architecture for context-sensitive applications has not yet been introduced. This paper closes this gap and describes an architecture that has been developed for assisting handicapped tourists during their holidays in the Thuringian Forest. However, this architecture can easily be generalized for any context-sensitive telecommunication application, because it gives a well-defined and flexible model for context information and defines several processes to gather, transfer, process and apply context information.

1 INTRODUCTION

Information has become inestimable goods in today's society. With the rise of the Internet, information can easily be retrieved from any computer connected to the network, and when using mobile communication technologies, access to information is possible at any time and from any place. However, information is always linked to the person who supplies them, and not to the person who would like to have access to them. An obvious example is trying to find information in the Internet: one normally uses an Internet search engine, gets thousands of entries matching the specified keywords, and has to eliminate all the entries that do not contain the desired information. Thus, information that is well suited for the person trying to retrieve them is desirable.

Ubiquitous computing is an approach to alleviate the access to information by supplying user interfaces that do not rely on traditional computing technique. In a ubiquitous computing environment, the user interacts with the contained components in a rather common way without having to become accustomed to new interfaces. The technologies weave themselves into the fabric of everyday life until they are indistinguishable from it (Dey, 2001). The interface to the environment, hence, adapts to the persons wanting to utilize it. And to carry this idea one step further, not only the interface but also the information exchanged through this interface must be adapted to the desires of the user.

This personalization of services and information is usually directly coupled with the collection and usage of context information. In order to collect, transmit and process context information, they must be modeled and described in a formally defined language (Debes et al., 2005). Then, they are used to adapt services and information to the user.

Although context-sensitivity is application independent, it is easier to start with a certain application to define specific context information. In our project, we are working on a system aiding handicapped tourists on their holidays in the Thuringian Forest (TAS, 2005). We want to provide them with barrier-free access to any service and information they desire. Thus, context-sensitive services play a major role in this project. The tour planned for the tourists must be adapted to their abilities and handicaps. Furthermore, the tourist is provided with services and information which are optimized to the current context. Service providers are able to store their offers and services, or at least information about their ser-

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vices and where these services are accessible, in a central database. Furthermore, this database contains a detailed map of the according tourist area. The subscriber is now able to access information about navigation, routing and additional useful information (opening hours, sights, shopping possibilities etc.). The architecture of TAS enables the seamless integration of new services and the exploitation of innovative context information. Communication is conducted through existing networks, which are connected with the Internet. The basic ideas are described in more detail in (Debes et al., 2003).

The paper is structured as follows. In the next section, several recent and current projects and systems are introduced that have the same scope as the architecure described in section 3. There, we show how context information are gathered, transported to the central server, analysed and used for adapting services and information offers. Finally, section 5 will summarize the paper and give an outlook on future work.

2 RELATED WORK

Context-sensitive systems have emerged in different areas of today's life. However, the term "context" is treated differently in the literature. Furthermore, on one hand a number of authors use a definition considering quite concrete properties which is directly related to a considered object. On the other hand, one finds quite general definitions in the literature but which are only valid for special application cases.

Nevertheless, in our opinion the definition of A. Dey and G. Abowd is the most appropriate. They state that context defines a subset of a physical or conceptual status, which is of interest to a certain entity. Their definition includes the complete range of context in such a universal way that it can be applied to very different applications. Dey and Abowd propose the following definition (Dey and Abowd, 2000):

> Context is any information that can be used to characterize the situation of entities (i.e. whether a person, place or object) that are considered relevant to the interaction between a user and an application, including the user and the application themselves. Context is typically the location, identity and state of people, groups and computational and physical objects.

Projects, which are related to context-sensitivity, are numerous so the following list of projects cannot be complete. Therefore, we focus our list on projects in the area of navigation and localization, since localization information belongs to the most important type of context information (Hazas et al., 2004). Nevertheless, this list shall provide a general impression of the importance of this research.

- The aim of the *Lancaster Guide* project is to investigate the provision of context-sensitive mobile multimedia computing support for city visitors. In essence, the project will develop a number of hand-portable multimedia end-systems which will provide information to visitors as they navigate an appropriately networked city (Davies et al., 2005).
- The project *REAL (Resource-Adaptive Localization)* was done at the Universität des Saarlands in Saarbrücken, Germany. It utilizes GPS navigation for outdoor movements and localization based on infrared technologies indoors. The system reacts on the situation the user is in and, thus, adapts to the user context (Baus et al., 2002).
- The project *DRISHTI* from the University of Florida in Gainesville focused on a navigation system for visually impaired and disabled persons in indoor and outdoor areas (Helal et al., 2001).
- At the Technische Universität Vienna, the project *LoL@ (Local Location Assistant)* implements a prototype that offers several services over UMTS. Being a mobile GIS application, these services consist of map- and position-dependent multimedia information. Routes through the town center of Vienna are calculated, which allow multimedia interaction, an electronic travel diary and information about the main points of interest (Umlauft et al., 2002).
- Keidl and Kemper from the University of Passau propose a context framework that facilitates the development and deployment of context-aware adaptable web services. This framework led to the ServiceGlobe system, which is an open and distributed web service platform (Keidl and Kemper, 2004).

However, we still have not found a general architecture for implementing context-sensitive telecommunication applications. Combining all the experiences of the projects we have investigated, we came to the general architecture described in the next section.

3 THE PROPOSED ARCHITECTURE

This section introduces the architecture developed for the TAS system. Figure 1 gives an overview of this architecture. It can be roughly separated into four views:

1. The *INPUT* view is concerned about collecting context information.
2. The *PROCESSING* view deals with analyzing and applying context information.

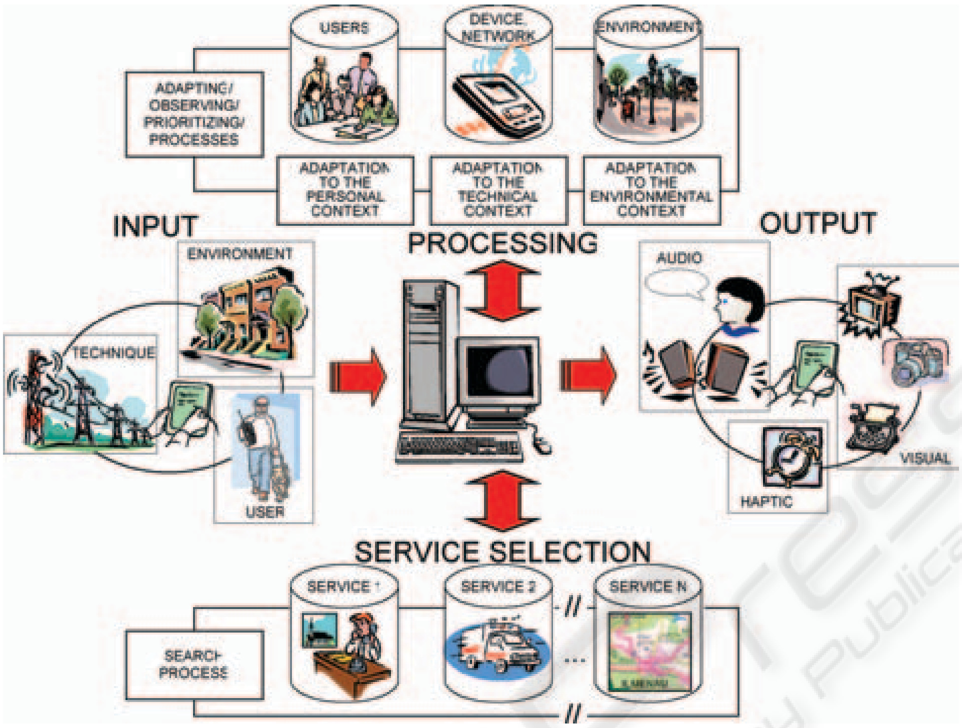

Figure 1: An overview of the introduced architecture.

3. In order to select a service appropriate for the given context, a third view called *SERVICE SELECTION* was created.
4. Finally, the service and/or information required by the user must be presented according to the current context, which is done in the *OUTPUT* view.

Thus, context information must be gathered, transmitted, analyzed and applied to the selection and presentation of information and services. The following subsections detail these specific tasks.

3.1 Gathering Context Information

Gathering context information (describing the *INPUT* view) can be accomplished differently. For the TAS architecture, three options are taken into account. The first option, called *explicit feedback* is based on directly interrogating the user for context information. This can be done either by a direct interview or by a questionnaire the user has to fill out. This method is very accurate and results in dependable context information. However, the user has to take some time to complete the questionnaire or the interview and is thus distracted from the activities he wanted to do, which might lead to discontent. Furthermore, there is the risk of asking too much of the user so that he might not be willing to answer any further questions. Thus, explicit feedback should only be applied if few and clear questions can be formulated that lead to well defined but rather invariant context information.

The second option, according to the first option named *implicit feedback* (Poslad et al., 2001), tries to extract context information from observing user interactions with the equipment he utilizes. Thus, whenever the user asks for certain services of information, the systems logs these requests and tries to classify them. When a certain class is requested more often than others, it looks like the user is interested in this special kind of service and the system tries to organize information and service offers accordingly. Especially for advertisements, this kind of feedback is very useful. The user is not directly involved in establishing the context and thus not molested like in the explicit feedback method. However, the correctness of the information cannot be proven, though it is rather likely that the derived context information align with the user preferences and interests, especially if this logging process can be done over a quite long period of time.

Furthermore, in our system, a third option of gathering context information has been implemented. This option is based on sensing the environment of the user and collection these sensor information, which was implemented by several other projects as well, e.g. in the *Context Toolkit* (Salber et al., 1999). Therefore, we call this option *sensory feedback*. Sensors may be attached to the users themselves (e.g. to estimate the physical conditions), to the mobile equipment (e.g. to measure the ambient temperature) or in the close vicinity to the user (e.g. for information about weather conditions). Additionally, these sensors can be complemented by special actors. A rather prominent example is using RFID technology (Radio Frequency IDentification). The environment is equipped with several RFID tags and the user equipment is augmented with an RFID reader. This reader can receive the answers sent out by RFID tags which contain the tag's identification. With this identification, the actual position of the user can be accurately determined and thus GPS localization can be improved.

It is quite obvious that all three options for gathering context information must be combined and implemented to build up a comprehensive model of the actual user context. Thus, our system starts with interviews and questionnaires in the explicit feedback phase. Then during the user's stay, the context is being amended by implicit and sensory feedback.

3.2 Transmitting Context Information

All context information must then be transmitted to a central server for evaluation. Therefore, the TAS architecture must be detailed, which is depicted in figure 2.

The heart of this architecture is the TAS headquarter, where a central server is located that is responsible for processing the context information. It is connected to the Internet via an Internet service provider and it incorporates ISDN router so that a direct dial-up connection via the telephone system is also possible. This option was implemented, because the TAS architecture also provides barrier-free access to services or information by information terminals specially designed for handicapped persons by "*systems engineering ilmenau sei*", one of the cooperation partners in the TAS project. These terminals provide information via a web interface accessible through a touch screen, which is adjustable in three dimensions.

Users can also get information (and pass their context information) using their PC at home or in an Internet cafe. But the main focus of the TAS project is on users on their way through the Thuringian Forest. Since the users are mobile, the transport of context information from the mobile user equipment should rely on wireless technology. The TAS system does not restrict information transport to certain networking technologies. It rather is open for any current or even evolving mobile communication technology.

Currently, the mobile equipment can use Bluetooth, Wireless LAN (according to IEEE 802.11), GSM, GPRS or even UMTS to transfer the collected sensor information to a central server. This flexibility could be achieved by using the Internet Protocol as a basis for information transport. Utilizing a special handover mechanism (Evers, 2004) the mobile equipment always chooses the best available communication network to send the context information. Furthermore, this mechanism allows a seamless handover between different network technologies. Thus, if the user started to communicate in a Wireless LAN and left the radio coverage of this WLAN, the mobile equipment would change to another network, e.g. GPRS. Although the mobile equipment would then receive a new Internet address, ongoing communication would not be interrupted. This is accomplished by using a proxy architecture based on the SOCKSv5 standard (Leech et al., 1996).

3.3 Analyzing Context Information

Once context information have arrived at the central server, they must be analyzed and evaluated, the subject of the *PROCESSING* view. The essence of all the transmitted information is then stored in a data base, which is constantly being updated. Thus, a concise data base model for context information is required. In the TAS project, the following three types of context information are distinguished: user context, technical context and environmental context.

3.3.1 User context

According to (Cheverst et al., 2000), user context comprises all information that are directly connected to a specific person. In our project, the following information are important:

- *User data*
  This item contains all information about a user, which can be further subdivided into his personal data (name, given name, date of birth, home address, visiting address, etc.), his interests (hobbies, relevant news, etc.) or his preferences (e.g. about food or telecommunication service provider). Furthermore, user data may be enhanced by logged user activities as described in section 3.1.
- *Group membership*
  For helping handicapped tourists on their holidays, it is useful to know, whether they are accompanied by other persons or whether they are on their own.
- *Physical status*
  Since the system should be useful for physically handicapped persons, this person's context partially consists of information about sensor data describing the health status, like heart frequency, blood pressure, body temperature and alike, the

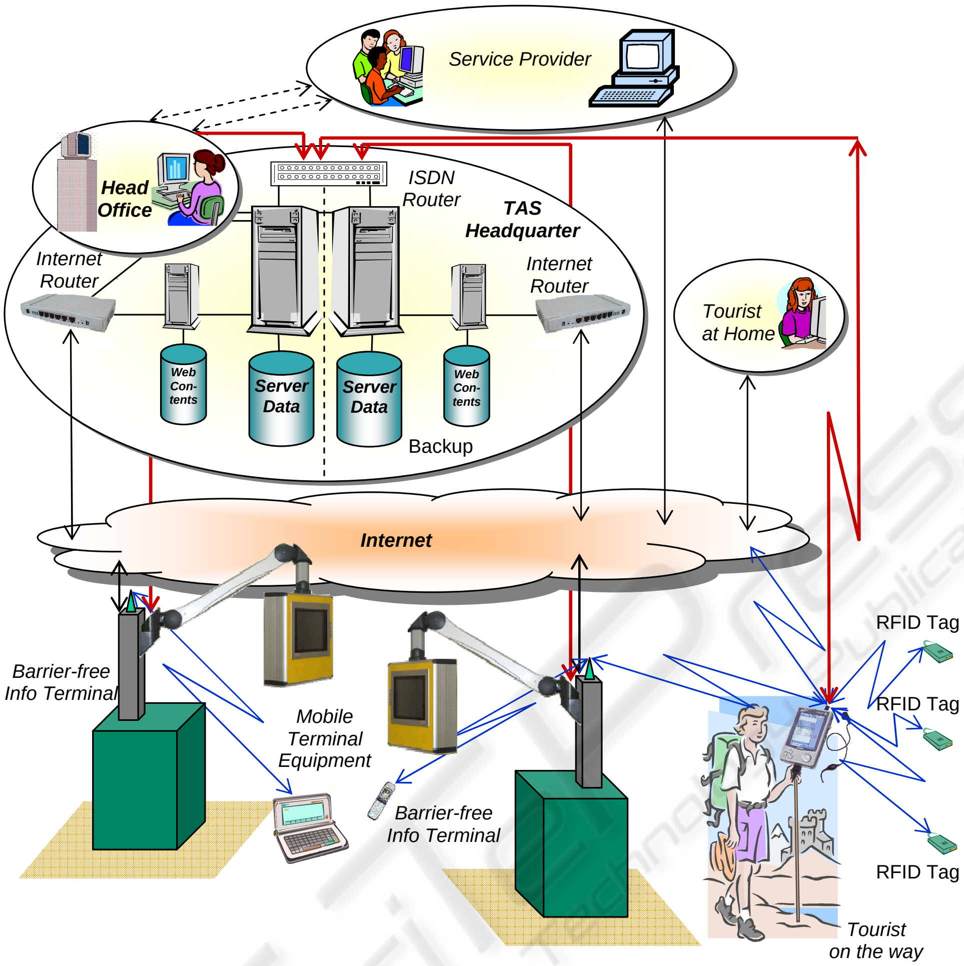

Figure 2: The communication infrastructure of TAS.

emotional or mental state, the speed of motion or the current physical activity.

- *Handicap*
  Finally, kind and degree of the person's handicap must be stored in the context information data base.

3.3.2 Technical context

Technical context describes the user equipment and the technical communication infrastructure that is or can be used. Thus, the context information database contains the following information:

- *User equipment*
  User equipment is described by its type (PDA, mobile phone, laptop, etc.), its grade of mobility, its display characteristics (size, resolution, color, etc.), its input features (e.g. number of hardware buttons), its audio capabilities, its speech recognition and synthesis features or its battery status.

- *Technical environment*
  For the technical environment, especially the available communication networks with their communication capabilities are recorded.

3.3.3 Environmental context

Finally, all other context information come from the environment. According to (Schmidt-Belz et al., 2002), this group of context information consists of

- *Time*
  The entry "time" has many different facets. Of course, the current time is necessary to characterize the context entries. Furthermore, time also relates to specific objects in the environment (just like opening hours of a museum or the remaining time in a public swimming pool). Thus, time must be specified using a type "entry".

- *Localization*
  Another very important information is the current

position of the user. Firstly, it is distinguished whether the person is inside a building or outside. According to this information, coordinates give the current position, e.g. GPS data, recently received RFID tag or alike.

- *Orientation*
  A very valuable enhancement to the localization part of the environmental context is the orientation of the user, which may be derived from different sensors like head-mounted displays or GPS receivers. Thus, the different information sources must be taken into account in this context entry.
- *Environment*
  Rather general is the last entry that describes information about the environment like weather conditions, road conditions, or other travel information.

3.3.4 Data base entry for context information

As described earlier, the processed context information is stored in a data base. Therefore, we defined the data base structure as shown in table 1.

This database entry is then used to adapt information and services for the concerning user.

3.4 Applying Context Information

Once context information is stored in the data base, the next view called *SERVICE SELECTION* is responsible for utilizing them to choose and adapt services and information.

In this view, three kinds of interaction are distinguished. In the *user driven interaction*, the user explicitly requests a certain service or some actual information. According to the stored context information, the service provider is chosen, which fits best for the requirements of the user. A simple example might be that the user on his way through the Thuringian Forest would like to know the way to the nearest restaurant. Being a vegetarian (which is of course stored in the context information data base), he certainly would be very annoyed if the system would choose a restaurant serving only a very restricted selection of vegetarian food. Moreover, according to the “time” information the system checks whether the restaurant is open and ready to serve some food. In a second step, the user interface for this service is adapted to the user preferences and the current technical environment. Thus, if the user is impaired of seeing, an acoustical presentation of the route to the restaurant should be preferred to a simple textual one, if the user equipment provides an acoustical output device. And in alignment with the current networking technology the user can communicate over, the information is coded to achieve minimum delay and cost.

The second kind of interaction is the *server driven interaction*. This is started whenever the context information is changing beyond a given threshold. As described in section 3.1, context information is being collected and updated constantly. Hence, the server might notice a change of context the user should be informed about. For example, a user has requested a route to a certain point of interest and received a route. Then, sensors notify about changing weather conditions, which means a storm is on its way. Thus, the system sends out a warning that the walk to the chosen point of interest would become quite unpleasant and suggests another point of interest according to the user’s interests.

The third kind of interaction is finally the *user equipment initiated interaction*. As user equipment also contributes to the context information, it also may observe the context state. Whenever critical conditions occur, e.g. the battery is quite low or the heart frequency drops below a given threshold, it may initiate interaction with the user, the TAS headquarter or with other persons the user is in a group with. This helps to initiate emergency actions when a user gets lost or when his health state requires immediate countermeasures.

4 IMPLEMENTATION

The TAS system is currently being implemented. Prototypes have been set up and demonstrated. In March 2005, the system will run in Georgenthal, a village in the Thuringian Forest, where special installations for handicapped persons already have been put up.

During all the project time, the team members cooperated with several associations for handicapped persons to be able to understand their special needs and requirements. Nevertheless, we found out early that handicapped persons will never rely on technical equipment only. Although we tried to increase reliability as much as possible, simple technical events like low battery, unavailable GSM coverage or inaccurate GPS positioning prevent the system from being totally reliable. Therefore, we think of TAS as being an assisting system that simplifies the holidays for handicapped tourists in the Thuringian Forest.

5 CONCLUSION

Within this paper, we presented the TAS system and focused on the context-sensitivity of the system. We showed how context information is gathered, transmitted, processed and applied. We have developed a comprehensive and flexible data base scheme for stor-

Table 1: Example of a data base entry

PERSONAL CONTEXT	**USER DATA**	PERSONAL DATA	ID	***0176***
			name	***Anna***
		INTEREST	hobby	***music***
			current interests	***shopping***
	GROUP	MEMBERSHIP	individual person	***x***
			group	---
	STATE	HEALTH STATE	heart frequency (strokes/minute)	***70***
			blood pressure (mmHg)	***120/80***
			body temperature (°C)	***36,2***
			sugar content (mg/dl)	---
		SPEED OF MOTION	slow	---
			normal	***x***
			quick	---
	HANDICAP		type	***seeing hindrance***
			degree (%)	***50***
TECHNICAL CONTEXT	**EQUIPMENT**	TYPE		***Pocket PC***
		MOBILITY	fixed	---
			mobile	***x***
		DISPLAY	resolution (dpi)	***240x320***
			colour	***monochrome***
		HARDWARE BUTTONS	number	***4***
			emergency call	***x***
		AUDIO OUTPUT		***x***
		SPEECH SYNTHESIS		***x***
		BATTERY	state of battery (%)	***30***
			operating time remaining (minutes)	***35***
	TECHNICAL ENVIRONMENT	NETWORK	ISDN	---
			GSM/ GPRS	***x***
			WLAN	---
ENVIRONMENTAL CONTEXT	**TIME**	KIND	available time (hours)	***2,5***
		TYPE	date	***15.12.2004***
			hour	***08:30:46***
	LOCALIZATION	PLACE	outside of buildings	***x***
			within buildings	---
		KIND OF DATA	GPS	***10°56´22´´eL 50°40´57´´nW***
			GSM	---
			RFID-data	---
	ORIENTATION	BEARING KIND	direction	***north***
			coordinates	---
	ENVIRONMENT	WEATHER	temperature (°C)	***10***
			weather conditions	***rain***

ing and updating context information and considered different sources of context information.

With context information, services and information provided to users can be adapted and filtered according to the user's interests and preferences. However, one often experiences that smart applications rapidly start to annoy the user because they do not allow him to directly influence the way the application works. We therefore will closely investigate the effect of our adaptation on the user and try to find out how content he or she is with the system. As we do not assume that the user of our system is a computer expert, we will have to do many interviews to come to reliable statements about the acceptance of the system.

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