Information, Communication and Localization environment for Travelers with Sensory Disabilities in Public Transports

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***Abstract*—Despite the progress of information, localization and communication technologies (ICT), traveler information is still very difficult to access for people with sensory disabilities (visual or auditory) during their journeys in urban public transports. Through the experience gained in the French research project INFOMOVILLE, this paper presents the main aspects that are to be considered for the wide deployment of transport information systems accessible to sensory impaired persons. It considers different points of view: technical questions (information, communication, localization, energy), ergonomics, economics, legal and normative context.**

I. Introduction

The current signage in public transports is still very difficult to use for people with sensory disabilities. Besides, when changing mode of transport and at points of interconnection, travelers, even without sensory impairments, are often faced with interruptions in the information chain along their trip.

Transports are characterized for sensory impaired travelers by a high degree of uncertainty. Surface transports, busses in particular, are the more challenging because of the great diversity of possible configurations and situations. The amount of information necessary and available for a journey is very important. Information specific to transport is only a part of it but its importance is increased in some steps (localization of a stop, choice of a route, waiting at a stop, perturbations). Travelers realize several tasks more or less unconsciously and ask themselves many questions, such as for example: are there stops around me? Where are they? What are the lines serving this stop? What are the stops on this route? What are the schedules? What is the number of the approaching vehicle? What is happening is there a perturbation? This stop has been suppressed because of works, is there another way to reach my destination?

This list of tasks or questions is still more important at connection links when changing mode of transport (e.g. from bus to tramway, or from subway to bus). In that case, the person has to successively move in areas dedicated to transports and walk in urban areas that are not dedicated to transports.

Different traveler information systems deliver some part of the necessary information. But most of the time, the presentation of information is not appropriate for people with sensory impairments, e.g. graphical displays are not accessible to visually impaired persons (VIP) and auditory alarms are inefficient for visually impaired persons (AIP). It is often insufficient and the continuity of information is not maintained all along the trip.

VIPs may be uncertain or unaware of some or all of this information especially when they are in unfamiliar sites or when they are alone. AIPs continuously fetch visual information to prevent the occurrence of a potential hazard or avoid to be obliged to request information to another person which is difficult for them.

There are relatively few research projects working on improving information of AIP in public transports [1]. Yet, the design of a system well adapted to AIP, would certainly be a design useful for all.

For VIP, many international research projects have proposed different partial solutions and tested several approaches that can contribute to the design of assistive systems for the mobility of blind people in public transports, e.g. [2], [3], [4], [5], [6], [7], [8]. In France, for example, the DANAM project [9] focuses on mobility in subways using dead reckoning module assisted by sensors; The BlueEyes project uses Bluetooth technology for localization and guidance in subways. But up to now, systems that are actually deployed are most of the time elementary systems using remote controls to trigger some kind of vocal information. They are useful but insufficient. However, some new equipments are beginning to be installed by transport operators (e.g. The “IDV metro” is a dynamic traveler information system for subways installed by the French transport authority SYTRAL in Lyon; it offers a free service to VIP by sending vocal travel information on user mobile phones by Bluetooth).

There are many aspects to take into account for the wide deployment of transport information systems accessible to sensory impaired persons. In this paper, we will try to give a general view and we will consider different aspects: technical

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questions (information, communication, localization, energy), ergonomics (analysis of activities, man machine interface, evaluation), economics, legal and normative context. We will base our reasoning on the experience gained during the French research project INFOMOVILLE.

After this introduction, the second section of the paper presents the project INFOMOVILLE. The third one discusses economical aspects (including energy) and legal and normative context. The fourth section addresses technical questions including energy consideration.

II. The INFOMOVILLE Project

The INFOMOVILLE project aims to design a real time information, communication and localization environment for improving the mobility of travelers with visual or auditory disabilities in Public Transports. The project is supported by French National Research Agency (ANR) in the frame of the PREDIT research program on land Transport. The project is conducted by 4 complementary partners: ESIEE, LUMIPLAN, Ergonomos and Inerec. ESIEE is a center for higher education and research in information and communication technology. LUMIPLAN is a company designer of information products and services in transports. Ergonomos and Inerec are organizations specialist of ergonomics.

It follows the "RAMPE" project [10], [11] in which the team designed and implemented an interactive system for assistance and auditory information of blind people in bus networks. The "RAMPE" project was focused on the approach of a bus stop and the delivering of useful information before entering a vehicle. INFOMOVILLE considers various extensions of the RAMPE project, in particular:

- Extension to different kinds of transports: bus, tramways …
- Potential users: not only VIPs but also AIPs.
- Ergonomics and MMI development.
- Technological aspects: integration in the system of localization techniques, support of different kinds of connectivity (WiFi, Bluetooth ...), use of the SIRI protocol for information exchanges.

First, an analysis of people trips in public transport was carried out in the city of Lyon with a multimodal transport scenario and 3 different populations: visually impaired, auditory impaired and without sensory impairment (WIP).

This analysis of activities has allowed explaining the mechanisms of orientation, navigation and information acquisition for the three populations. It identified the difficulties and needs of each population.

By formalizing trips in four spatial zones and the diffusion of information in three temporal levels [11], we have located in space and time the requirements in information.

We have designed a system that helps users during their trips to know the existence of stops around them, to identify these stops, to localize them, to be oriented towards them. It contributes to maintain the continuity of information along the trip.

Our methodology can be summarized by the following steps:

- Analysis of the end to end traveler's journey.
- Analysis of the traveler's activity and needs all along his journey.
- Analysis of the environment structure and of the role of information along the journey.
- Analysis of potential technologies (hardware and software).
- Development of prototypes with a special care to man machine interface (MMI).
- In situ experimentation and evaluation in partnership with transport authorities.

A. *Description of the INFOMOVILLE System*

The INFOMOVILLE system consists of two parts: handheld user devices (smartphones or PDA) and fixed equipments (latter called base station) installed at stops places or in connection links. Base stations (BS) are connected to the traffic management and traveler information system (SAEIV).

The user device can be a mobile phone or a PDA. The system relies on a data driven application embedded in the user device. It receives information from BS. This intelligent application is adapted to the user disability. It communicates via WiFi with the BS. WiFi technology is used not only for communication [12] but also for localization purposes using a radio-fingerprint technique [13] and GPS. The system can handle complex situations such as multi-stops sites or multiple lines stops.

An original software development framework for the design of auditory applications has been developed. Figure 1 illustrates components of the software application.

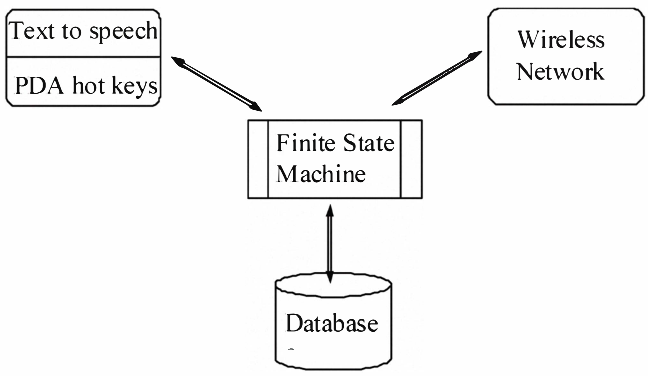

Fig. 1 Components of the software application

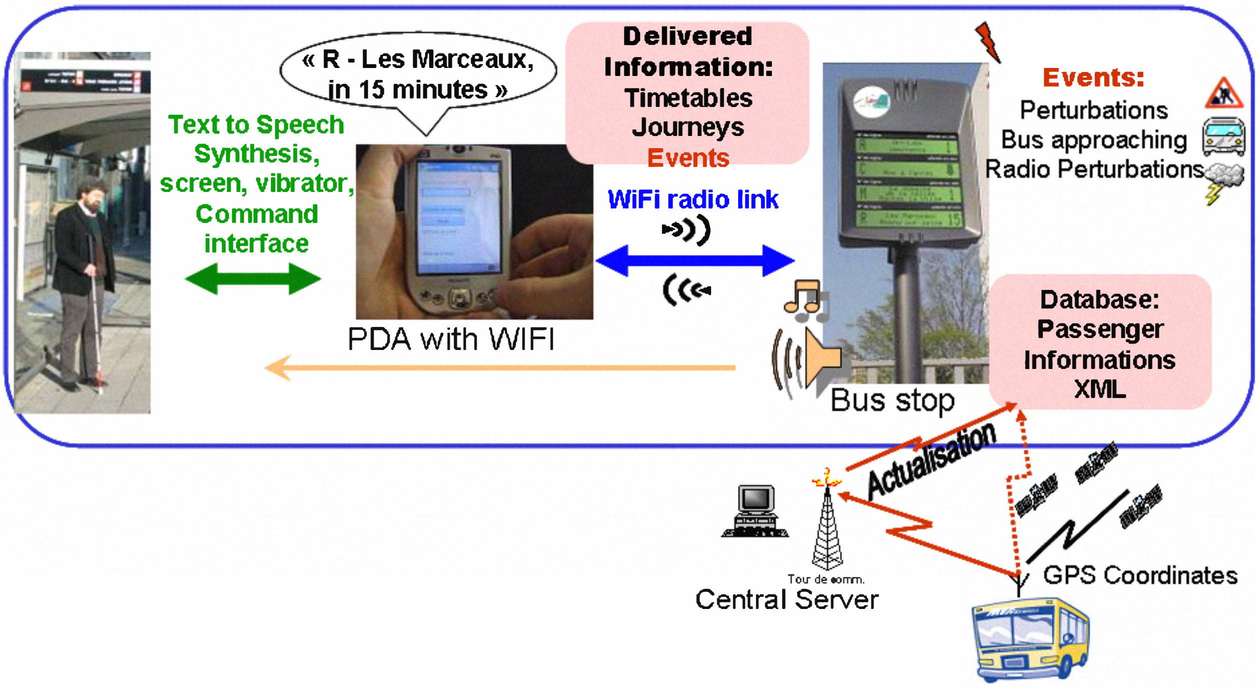

Fig. 2 Description of the INFOMOVILLE system

Figure 2 indicates the different components of the INFOMOVILLE system and their connections.

Figure 3 shows the principle of the software development framework for the design of auditory applications.

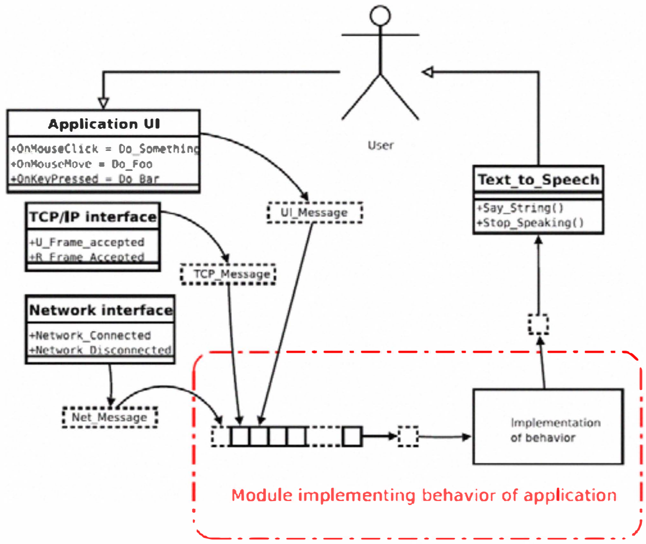

Fig. 3 Principle of the software development framework for the design of auditory applications.

Base stations are equipped with speakers and a flash light that VIP and AIP users can activate in order to help them to find the position of the stop.

A particular attention was paid to the design of man-machine interface and management priorities in the system for real-time information. Two human-machine interfaces have been designed:

- The auditory interface for VIP is based on a text to speech synthesis and a command interface using the phone keys that are dynamically reprogrammed for intuitive operation.
- The interface for AIP is primarily visual. It uses the screen to display static or animated text, images or maps. The cell phone vibrator is used for warning or alarm. The command interface uses the keys and the device screen.

The system INFOMOVILLE provides structural information (identification of stops, routes, timetables,), temporary information (schedule changes, temporary perturbations ...), immediate information (vehicle approaching, delay, other real-time disturbances or events ...) as well as contextual information.

In addition to this information purely related to transports, the system transmits local geographical data (e.g. maps with stops location).

The system integrates the new ITS protocol SIRI (Service Interface for Real Time Information). SIRI is used for exchanging information between BS and central server of traveler information as well as for exchanging information between user devices and BS.

B. *Experimentation*

The RAMPE system was experimented in situ with 23 blind users in collaboration with SYTRAL (Syndicat mixte des transports pour le Rhône et l'agglomération Lyonnaise) in Lyon in April 2007 [14], [15]. We have evaluated the relevance and usability of the system in a normal or disturbed situation. The results were taken into account for the design of the second version of the system.

Fig. 4 is a photo taken during the RAMPE experimentation.

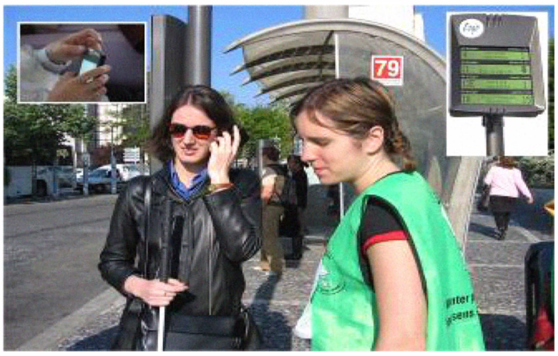

Fig. 4 Photo of the experimentation in Lyon

The testing of INFOMOVILLE is ongoing in Lyon (in April-May 2010) with 3 groups of users: VIP, AIP, WIP.

The system is tested on a multimodal route including a relatively complex multimodal area of interconnection links. The issues will cover both the fetching of transport related information, the management of the transport mode changes and the use of guidance local information.

III. Economical Aspects, Legal and Normative Context

Among the possible obstacles or difficulties to the development of widely deployed efficient assistive systems are the economics and energetic aspects:

- Cost of equipments for transport authorities and operators,
- Cost of maintenance for transport operator,
- Cost of user equipments,
- Energy,
- Definition of an adequate economical model,

The cost for the equipment of a city with intelligent transport base stations in bus, tramway and subway networks may be important. Maintenance of equipments dedicated to sensory impaired persons is crucial; otherwise the system may become unusable. For example, some kinds of localization techniques require calibration of the area where they are implemented. The maintenance of this calibration may be an obstacle in practice.

The cost of user equipment was a strong limitation a few years ago, but the use of smartphones is increasing very fast and their cost should decrease and become affordable for more people.

In general, the use of generic technologies (e.g. smartphone, PDA, WiFI, 3G) not dedicated to a limited population helps to maintain low costs and to facilitate the future deployment of the system with an approach of design for all.

Another key factor is energy for power supply of the base station. In a city such as Lyon, there are approximately 800 bus stops. A part of them (but not all of them) are already equipped with electronic display for travel information and they are connected to some kind of power supply. But this source of energy is not always very important (some stops use solar panels) and a non negligible part of the stops are not connected to any power supply.

The economical model for systems taking into account the needs of VIP and AIP is not easy to build because the number of concerned persons is limited and only some of them can afford to pay for such a service. But since a few years, new laws have been published in Europe and several countries outside Europe that make mandatory the accessibility of transport information.

More generally, in Europe, the legal and normative context is favorable:

- For example, the French law of February 2005 for the equality of rights and social participation of the disabled proposes a timetable for the implementation of all necessary measures to ensure a right of access to public transport and urban mobility.
- The Working Group GT7.3 on Standardization of SIRI has begun to address accessibility issues and extensions dedicated to the disabled.
- The European “Inspire” directive establishes an infrastructure for spatial information including a theme on transport networks. It creates a framework for spatial information to be collected, stored, manipulated and made available in a standardized electronic environment to facilitate sharing of information by public sector organizations, commercial enterprises and citizens

IV. Technical Aspects

Some of the scientific and technical issues are:

- Information Management (production, structure, presentation) for transport and geographical data.
- Communication between phones and BS with low power consumption and sufficient range and robustness in urban environment. Communication between BS and SAEIV server and potentially between BS and localization server. Communication between vehicle and SAEIV Server and between vehicle and BS which allows precise real-time information on arrival of a vehicle. And potentially communication between BS.
- Localization (precision, speed, robustness, maintainability) and guidance. Continuity of indoor and outdoor localization.
- Ergonomics of the multimodal MMI: the challenge is to develop a sophisticated query and communication interface (auditory, vocal, visual, and tactile) able to absorb the increase of information without significantly increasing the complexity of use.
- Robustness of the software application embedded in the user device to ensure its usability in a disturbed and potentially dangerous environment. It must take into account the hazard of the environment (radio link quality, acoustic surrounding noise, user’s distance to a stop, mobility of the user …) and treat them not to confuse the user,
- Taking into account heterogeneity of infrastructure configurations and traveler information systems.
- Portability of software developments on different user devices (smartphones and PDA).

- Hardware abstraction layer decoupling physical characteristics of the user Design of robust localization techniques able to position users in dense urban environments inside and outside buildings without discontinuity.

A. Information

1) Transport Information and SIRI

An important question is the existence of up-to-date multimodal transport information and protocols to access to this information.

SIRI (Service Interface for Real-Time Information) is a European standard (CEN / TS 15531) which aims to provide mechanisms for real-time dialogue for exchanging traveler information. Today, SIRI protocol is mainly seen as a protocol tool allowing an internal dialogue in the traveler information system. The tools provided by SIRI can also be used to allow user devices to access traveler information.

SIRI protocol provides two mechanisms for dialogue: a query-response mode in which the client executes a query and receives a response from the server and a subscription mode in which the customer has subscribed for such information and can receive it following two approaches without having to query. The two approaches of the subscription mode are the “push mode” in which the subscriber client receives the updated information and the "notification mode” in which the client only receives an event for the notification of update. It must then make a request to retrieve information.

SIRI protocol structures the different types of request (services) according to three main focuses: on the line, on the stop, on the vehicle.

- The services focused on "line" are "Production Timetable" and "Estimated Timetable" which correspond to planned and updated schedules.
- The service focused on "vehicle" is "Vehicle Monitoring" which allows the location of a vehicle in its route.
- The service focused on "stop" are "Stop Timetable" and "Stop Monitoring" which provide information related to a stop (lines, arrivals and departures).
- A fourth type of services focuses on the management of connections ("Connection Timetable Delivery” and “Connection Monitoring”).

In France, STIF (Syndicat des Transports d'Ile de France) has specified a profile for the early stages of deployment that is based solely on a request-response protocol and uses the service "Stop Monitoring". It also provides the use of the service, not listed above, "General Message" which aims to provide a forum for the exchange of free information; free or not already specified by an existing SIRI service.

The developments undertaken within the project INFOMOVILLE therefore have implemented the services offered by this protocol as part of a user application for real-time traveler information. In the previous project (RAMPE), the transmission of real-time traveler information was based on proprietary protocol. The deployment of a standardized interface is an important issue for a project such as INFOMOVILLE firstly because it allows to open access to the service offered by the BS to other user devices and secondly because it allows the INFOMOVILLE user device to connect to other information points than INFOMOVILLE BS.

For example, the dialogue structure between user devices and the BS implemented in RAMPE comprised 4 phases:

- Detection of the stops in the vicinity of the user and selection of one of these stops. This selection is achieved by a WiFi association and a DHCP negotiation to insert the user device into the LAN (Local Area Network) of the BS.
- Assistance to orientation and guiding. In this phase, the user device sends command frame to the BS using TCP protocol in order to activate the BS loudspeaker and make it play an audio beacon used for spatial localization purposes.
- Downloading of the database using a proprietary XML structure linked to the stop. This query uses HTTP-GET protocol and allows downloading all the traveler information theoretical or recalculated: lines, composition of these lines (stops on routes), interconnection links and arrival time at the stop for the different lines.
- Broadcasting by the BS of asynchronous or "urgent" messages: arrival of a vehicle, disturbance ... This dialogue phase uses the UDP protocol in broadcast mode.

The adoption of SIRI Protocol in the INFOMOVILLE system to implement services similar to those proposed by the RAMPE system posed the problem of projecting them on the services offered by SIRI. The services offered by INFOMOVILLE are based on the one hand on downloading from the BS information on the lines and schedules at a given stop and on the other hand on the broadcasting by the BS of real-time traveler information that the user cannot know a priori and for which he cannot make a request.

The acquisition of the complete information about a stop (theoretical or recalculated) can use the "Stop Monitoring" service of SIRI specified in the STIF profile as soon as the SIRI stop identifier is known by the application in the user device. On the other side, the broadcasting of real-time information, whose existence is not known in advance, cannot fit in a request-response pattern. It needs a subscription. But it is not currently supported by the STIF profile. The knowledge of the SIRI stop identifier and of contextual information related to the stop (geo-referenced map, GPS coordinates of the different stops present on a site) can be defined in the structure of a "General Message" query performed by the user device when connecting to the stop.

The management of urgent messages such as: arrival of a vehicle, announcing perturbation, and so on could be part of a scheme using the services offered by specific "General Message" that would be delivered on subscription, this subscription being considered as implicit when the user device requests the SIRI identifier of a stop.

The use of the SIRI protocol for a system such as INFOMOVILLE is an important step towards interoperability of traveler information systems.

In INFOMOVILLE, we use the new e-dilyc multimodal dynamic information system of SYTRAL. It offers theoretical timetables plus real-time information for bus, tramway, and subway networks in Lyon. The data exchanges are based on SIRI, web services and XML streams. The same database is used by another French project MOBIVILLE [16] where the service is accessed by a user with a mobile phone with an internet connection and a GPS.

2) Geographical Local Information for Guidance

The INFOMOVILLE system can communicate local guidance information between two local transport stops with indication suited to specials needs of sensory disabled persons. This guidance information uses an XML format and is communicated to the mobile phone via a SIRI general message. It is specific to a local area around each stop.

If localization means are available, this local information is delivered in consideration with the precise position of the user. Otherwise the guidance information simply describes step by step how to go from one stop to another in the proximity of the user.

B. Communication

Different communication and network technologies can be envisaged for such applications with different constraints depending on the considered link. The different links are:

- The communication between phones and transport information databases; this can be established whether directly by some cellular connection or indirectly via the BS using a wireless connectivity between phones and BS. The second solution is more secure for the information providers. It has also the advantage of being a localization indicator without any other localization means. For INFOMOVILLE, we have chosen a WiFi link between phones and BS. But it requires that WiFi access points (AP) be installed in BS which is not always possible depending on the type of power supply available in the BS. This link allows the phone to access to transport and local geographical information via the BS. It also allows blind users to remotely activate loudspeakers integrated in the BS that can play a chime to help the user to situate the position of the stop. We chose WiFi in preference to Bluetooth because of its longer range in outdoor environment and of its shorter connection times. A special care must be taken to minimize the power consumption and the robustness of this link in urban environment.
- Communication between BS and information server and potentially a localization server; this link can be done by different classical communications means. For INFOMOVILLE we use a 3G connection. It accesses the distant e-dilyc transport information server when the BS receives a SIRI request from a user. It also accesses a distant localization server based on WiFi radio fingerprints.
- Communication between vehicle and BS; this link allows precise real-time information on arrival of a vehicle. It is an important link in order to be able to provide to blind people the information on the identity of an approaching bus. This link exists in some cities. In Lyon for example, it is currently provided by Mobiloc which is a service operator for radio-localization and supervision of fleet of vehicles.
- Communication between vehicles and SAEIV Server using TETRA, or other systems such as GPRS or 3G links.
- Potentially communication between BS. This communications can be achieved by a wired or a wireless network. This connection between BS can help to relay a link between a user and a BS too distant from the user to be directly accessible by WiFi.

C. Localization and Guidance

Localization and guidance may be useful for people with sensory impairments while moving in transport networks. We can distinguish indoor (e.g. subway underground corridors, train stations), outdoor situations (e.g. bus or tramway networks) and hybrid situations at connections between different transport modes (e.g. from subway to bus). Localization and guidance is particularly useful in outdoor and hybrid situations because of the complexity and uncertainty of the environment and of the discontinuity or even interruption of the transport signage.

The Global Positioning System (GPS) is very widely available for outdoor localization and GPS receivers are more and more often included in smartphones. However, it is not suitable for some specific environments, such as indoor and the acquisition of satellites signals may necessitate some minutes when starting the receiver.

Localization technology based on WiFi radio waves (WiFi Positioning System WPS) using radio fingerprint statistical methods [17] offers an alternative approach. It can be used indoor and outdoor. One of the drawbacks of this method in comparison with GPS is that it necessitates a calibration of the site before using the system and it has to be maintained in order to check that the WiFi radio map of the environment has not changed too significantly.

In INFOMOVILLE project, we have tested both GPS and WPS technologies. WiFI technology is used both for communication and localization purposes. We used Ekahau WPS RTLS (real time localization system) system. The indoor results are very satisfactory. For localization purposes, the Ekahau client software is installed in the phone. It periodically transmits to a distant Ekahau localization server, a parameter of data representing indicators of the received power strength from surrounding Wifi access points with the MAC addresses of these AP. The Ekahau server estimates the phone position using a previously recorded radio map of the area and statistical methods. It then returns to the phone its estimated position. The number of necessary WiFi access points is quite limited for an indoor localization precision sufficient for a pedestrian and the type of envisaged services. But for a typical square area of 100 m^2 using 3 access points installed in 3 BS (bus stops) approximately 2 m high, the outdoor results are not as precise as GPS ones. And the robustness is also inferior to that of GPS. The refreshing period of localization is also a bit too slow (typically 10s).

Even if no localization mean is available, the INFOMOVILLE system can communicate to users guidance information between two transport stops.

V. Conclusions

The development of information and communication technologies including mobile communications and positioning systems, and the miniaturization of consumer electronics make it possible to design new systems and services to improve the autonomy and mobility of sensory impaired people in cities.

In several countries, the legal and normative context is favorable. But there remain economical, technical and ergonomics questions to be considered.

In this paper we have presented the main aspects that are to be considered for the wide deployment of transport information systems accessible to sensory impaired persons with the example of the French research project INFOMOVILLE. INFOMOVILLE is a new interactive system for auditory, visual and tactile information, for the mobility of persons with sensory disabilities in public transport. It uses a real-time application embedded on mobile phones and takes profit of different technologies to provide relevant information at the right time. The choice of specific technologies: telephone, WiFi, SIRI, should facilitate the deployment of the system and allow interactions with other services.

The experiments provided in situ in April-May 2010 will evaluate the system with subjects with sensory impairment. It will also assess the performance of the localization technique using WiFi radio footprint and GPS in urban environments.

The development of new databases and standards for dynamic multimodal traveler information such as SIRI is a critical point. INFOMOVILLE is one of the of the first user applications using SIRI protocol.

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