Catching the Right Bus - Improvement of Vehicle Communication with Bluetooth Low Energy for Visually Impaired and Blind People

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Abstract. Visually impaired and blind people have major difficulties in locating and communicating with public transport vehicles due to their restriction of vision. They must rely on other people's help or technical supports. In this paper we show how direct communication with the bus driver via Bluetooth Low Energy (BLE) is possible. A person with visual restriction is able to send and receive messages via an accessible smartphone app directly to the bus driver. With the help of the suggested system traveling with public transport gets easier and the person's independent mobility is improved.

Keywords: Blind · Public transport · Bluetool low energy · Vehicle communication

1 Introduction

Independent mobility is an important life issue but when it comes to visually impaired or blind people this implicitness gets a different perspective. In fact, visually impaired or blind people have to rely on public transportation in order to travel from one place to another. However, their journey is often accompanied by several obstacles such as several heavy traffic, noisy environment or indoor navigation at subway stations. Another but rather critical aspect is the restricted communication between a bus driver and a traveler, respectively the public transport systems and a smartphone. Normal-sighted people usually do not have difficulties to look for a bus or tram heading in the right direction, to read departure times from info screens or just signal a bus driver to get a lift. Visually impaired and blind people, however, have major difficulties in communicating and locating their needs due to their Visual restriction.

This research discusses several improvements for the communication between a vehicle and a smartphone to better support visually handicapped people while using public transport. The main contributions are quick communication setups employed by Bluetooth Low Energy (BLE) technology, an optimized user experience for smoother app interactions and finally the use of iOS devices which are quite popular among people suffering from visual impairment.

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2 Related Work

In recent years, there has been substantial research in the support of visually impaired and blind people in terms of public transport. Common problems these people face, are the appropriate routing on footpaths for pedestrians [3,6] the support of orientation and localization within buildings [8,11] as well as the orientation at intersections on heavy traffic roads [4]. These are significant situations demanding general guidance and support, in particular for people with visual impairment [5,9]. In this setting, the communication with vehicles is crucial in order to facilitate independent travelling [2,10]. Last, but not least an interactive, multimodal and intuitive user interface [1,7] is essential for the acceptance of any supporting system.

3 Catching the Right Bus

For every person using public transport it is essential to catch the right vehicle. Visually impaired and blind people need help form others or from technical solutions to find the suitable bus or tram. Technical systems need a communication channel from the vehicle directly to the person's device.

3.1 Existing System

The previous research project NAVCOM [2] aimed at facilitating the communication between smartphones and public transport vehicles with the use of WLAN. The connection between the internal bus system communication (IBIS system) and a standard smartphone was established via WLAN and relevant information was transmitted wirelessly as shown in Fig. 1.

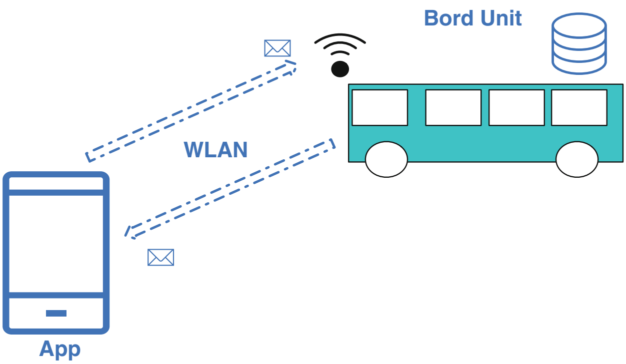

Fig. 1. The NAVCOM architecture build on WLAN communication between the public transport vehicles and the smartphones.

Despite its first success, some limitations occurred: Firstly, the time to establish a consistent connection with a bus driving by and a blind person's smartphone took too long. Secondly, the API, needed to program the WLAN components, was not available on the iOS platform.

3.2 Improved Approach

In the project at hand, we enhanced the existing NAVCOM system in following ways:

- **Communication with the bus on-board-unit:** BLE (Bluetooth Low Energy) inner workings allow usage of radio frequency signals in a quite different way than WLAN. It can be configured to constantly emit or receive signals without draining batteries. Above all, the connection time of this wireless communication standard is much faster than WLAN, which is crucial in specific traffic situations. It is possible to exchange information even with a bus moving at high speed. Furthermore, this standard is supported by all vendors and allows the usage of various apps on both popular smartphone platforms, iOS and Android.

  Visually impaired and blind people need the following important functions: getting the driver's attention when entering or leaving the bus. So the driver can help to get on/off the bus. If there is just a display of the next station, then the request of the next station is also an important feature. The BLE signal strength can be used to check the distance to the bus, while the entering of the bus (Fig. 2).

  In the future every bus should be accessible. Therefore this has to be defined as a standard. In the serial IBIS system every producer implemented the system in a different way. It was not possible to produce a solution for every customer. Now we have a European standard ITxPT[1] and a German IP-KOM-ÖV standard[2] which work with ethernet network. The European project aim4it[3] focuses on the accessibility of the standard. However it will take 10–20 years that the public transport providers change to the new standard.
- **Navigation:** One of the most essential part for independent traveling of visually impaired people is to choose a viable route without too many obstacles. We optimized route selection by a suitable configuration of an Open Street Map (OSM) routing server, which prefers paths meeting the needs of visually handicapped users' such as finding appropriate pedestrian areas, avoiding roads with heavy traffic or dangerous tracks [3].

  The accuracy of the GPS position can be weak and additional information about the surroundings can improve the navigation. Blind people can verify the route, when the know the side of the wall or the street. Then they also know on which sidewalk of the street they walk. Most of the navigation systems

[1] http://itxpt.org.
[2] https://www.vdv.de/ip-kom-oev.aspx.
[3] http://www.ways4all.at/index.php/de/aim4it.

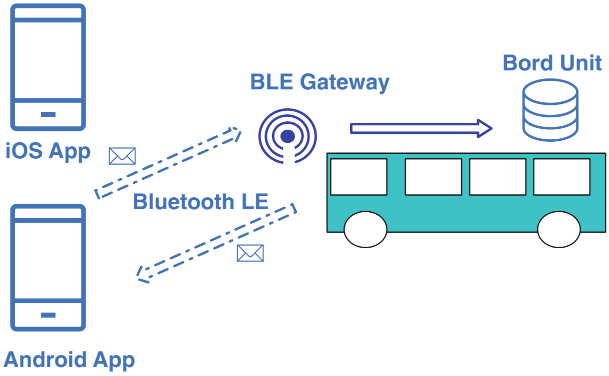

Fig. 2. The BLE architecture allows also access to iOS smartphones.

have been developed for outdoor navigation. A two-dimensional model was sufficient for the most cases. There are new challenges in indoor navigation. Especially public traffic stations can be tricky. The stations are distributed over several levels. Here a tree-dimentional model is more appropriate.

However indoor navigation is a difficult task. Some of the designers, try to make it a simple as possible. I.e. the Vienna public transport company use an interesting approach with routing information static texts for every subway station and each platform. Visually impaired users can step through the segments of a route.

– **Accessible User interfaces:** In the last years many users suffering from impaired vision have switched to modern smartphones. The improvements of the built-in accessibility features, such as Android Talkback, allow visually impaired people to use their smartphones for more daily needs. The NAVCOM system – a previous implementation of the authors – allows speech output [7]. In the current phase many further improvements are in development. One example is the user interface which can be replaced with different appearance to support users with different forms of visual restraints, extending and augmenting the built-in accessibility features (see Fig. 3).

4 Evaluation

To evaluate the improvements of the supporting system we conducted an empirical study with four visually impaired users. The evaluation was performed in the final project meeting on 15.12.2014 in the area of the public transport station (Praterstern) in Vienna. The testgroup got prepared smartphones (Android based phones with the reinstalled vehicle communication app and enabled screenreader Talkback) and were asked to perform following tasks (see Fig. 4).

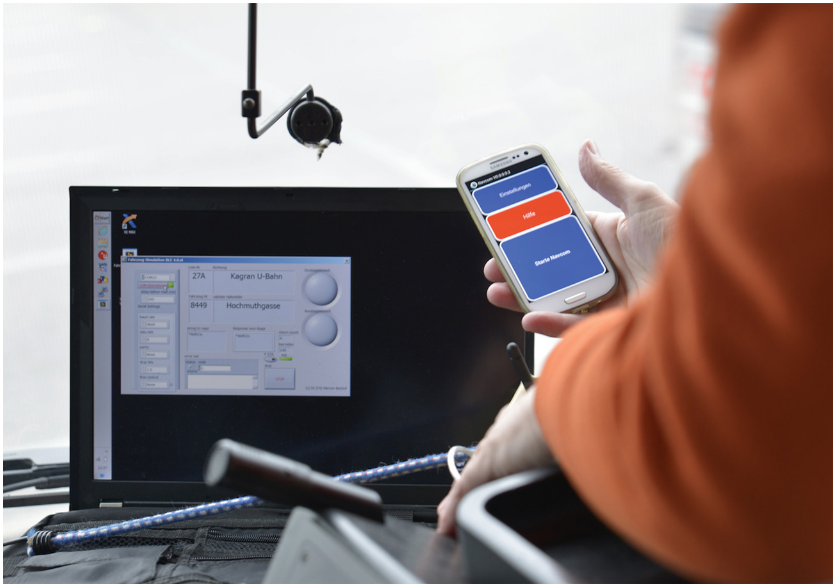

Fig. 3. The user interface of the app and the bus driver display.

Table 1. Data of user evaluation

User	Age	Visual impairment	Usage of public transport	Smartphone	Feedback	Suggestion
1	53	none	daily	iPhone	proof of concept works, but needs improvement	more stability
2	57	blind since age of 9	daily	2 PMON	some technical problems	nix
3	60	became blind in the age of 40	daily	Samsung Galaxy Active	search for available vehicles too long	more information about the next stop
4	48	strong partial visual impairment	rarely	iPhone	connection to vehicle is not reliable, but works great after connection	focus on relaiability of the connection

- Sending an boarding request
- Getting information about the next stations on the bus
- Sending an alighting request

With the support of thinking-aloud tests and an additional questionnaire the following findings were generated.

Firstly, the user interface of the implemented prototype is intuitive and simple enough to be used even in stressful situations. The communication works well due to the Bluetooth low energy technology. Only in situations with heavy concurrent usage the reliability of the overall system is not sufficient as users experienced drop offs. The test users gave also critical feedback about the systems relaiability. The time to connect to the vehicle was too long, but afterwards the connection was stable (details are available in Table 1).

Fig. 4. Test users sending request to bus.

5 Conclusion

The proof of concept to use BLE for public transport vehicle communications was successful. According to the statements of the visually-impaired test users, the usage of the smartphone in terms of usefulness and accessibility was feasible. They were able to perform the tasks required in a reasonable time frame. Some problems still occurred with too many simultaneous connections (more than 20). A possible solution for this would be to change to the BLE advertisement mode. This would mitigate overload on the server side and might be worth considering in upcoming versions of the software.

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