Assistive System for Enhancing Accessibility of Public Transport for People with Disabilities

Mizael Claudino Lins Silva
Federal Institute of Pernambuco
Caruaru, PE, Brazil
mcls6@discente.ifpe.edu.br

Bruno Bione
Aida Araujo Ferreira
Iona Rameh Barbosa
Gilmar Gonçalves de Brito
Vania Soares de Carvalho
Federal Institute of Pernambuco
Recife, PE, Brazil
babs@discente.ifpe.edu.br
(aidaferreira, ionarameh)@recife.ifpe.edu.br
(gilmarbrito, vaniacarvalho)@recife.ifpe.edu.br

Dalton Cézane Gomes Valadares
Federal Institute of Pernambuco (IFPE)
Caruaru, PE, Brazil
VIRTUS RDI Center
Federal University of Campina Grande
Campina Grande, PB, Brazil
dalton.valadares@virtus.ufcg.edu.br

Gutemberg G. dos Santos Júnior
VIRTUS RDI Center
Federal University of Campina Grande
Campina Grande, PB, Brazil
gutemberg@virtus.ufcg.edu.br

Kyller Costa Gorgônio
VIRTUS RDI Center
Federal University of Campina Grande
Campina Grande, PB, Brazil
kyller@virtus.ufcg.edu.br

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***Abstract*—Given the significant population growth in some regions, urban mobility faces challenges and demands innovative solutions. These solutions involve social inclusion, especially when considering improving the quality of life of people with disabilities. Within the Brazilian constitutional scope, the Statute of Persons with Disabilities claims to guarantee access to public transport with other people, identifying and eliminating any barrier. In this context of urban mobility and rights guarantee, this work proposes a system that aims to guarantee the safety and autonomy of people with disabilities when accessing public transport, compliance with the rights guaranteed in the constitutional sphere, and greater efficiency in the boarding process for both the driver of the collective and for the person with a disability. To achieve this, we implemented a prototype that establishes bilateral communication between people with disabilities and public transport (e.g., buses) to be strategically located to assist with autonomously and safely boarding. Communication is established with LoRaWAN technology, integrating the user, transport consortium, and public transport.**

***Index Terms*—Accessibility, LoRa, Public Transportation, Safe Boarding**

I. Introduction

Public transportation holds a significant place in people's lives as a means of commuting to work and school, among many other activities, and plays a fundamental role in the independence of its users. According to the Brazilian Institute of Applied Economic Research, 65% of the Brazilian population uses public transportation in the capitals [1]. Understanding the concept of persons with disabilities (PwD) is the starting point for developing technological tools, laws, and other initiatives to provide better living conditions for these individuals. According to the United Nations [2], "persons with disabilities" are those who have impairments of a physical, mental, intellectual, or sensory nature, which, in interaction with various barriers, can hinder their full and effective participation in society with other people.

The United Nations estimates that more than 1 billion people worldwide live with some form of disability [3]. Whether due to physical, mental, intellectual, or sensory impairments, PwDs require special attention from the Public Authorities, which must enable them to fully and effectively participate in society. Nonetheless, conventional urban public transportation systems globally, particularly in less developed nations, are typically tailored for the able-bodied populace and seldom account for the specific requirements of individuals with disabilities (PwDs) [4].

The National Health Survey of Brazil, conducted by the Ministry of Health in partnership with the Brazilian Institute of Geography and Statistics (IBGE, in Portuguese), revealed that, in 2019, 17.3 million people aged two years or older had one of the investigated disabilities (physical, auditory, visual, and mental), with 9.9% of them located in the Northeast of the country [5]. Article 2 of the Brazilian Federal Law No. 13,146/15 (Statute of Persons with Disabilities) defines accessibility as the possibility and condition of reaching for utilization, safe and autonomous, of spaces, furniture, urban equipment, buildings, transportation, information, and communication, including their systems and technologies, as well as other services and facilities open to the public [6].

Within the State of Pernambuco (Brazil), Law No. 14,789 (dated October 1, 2012), establishes the State Policy for Persons with Disabilities [7]. Through this policy, it became possible to conduct a registration of PwDs entitled to the Metropolitan Electronic Pass (VEM, in Portuguese), which allows PwDs to use the Public Passenger Transportation

System of the Metropolitan Region for free [8]. Currently, more than 38,000 PwDs use public transportation with VEM in the Metropolitan Region of Recife. The Consortium of Transportation (CT) for the Region of Recife has, as one of its main missions, facilitating, regulating, and overseeing the operation of public transportation users in the region. The CT records over 25,000 daily trips, totaling more than 1.5 million passengers. One of the greatest challenges faced by CT consists of developing and providing technological solutions that enhance the accessibility of these users, given the difficulty in obtaining financial resources, computational capacity, and a dedicated technical team for this purpose.

This work proposes an innovative solution for assisting the boarding of people with disabilities (PWDs) on public transportation, addressing a real-world problem that affects millions of people around the world. The solution is based on an Internet of Things (IoT) application using a microcontroller device that receives the PWD's request and sends it to a central. The central processes the request and forwards it to the vehicle on the requested line, in order to inform the driver about the boarding of a PWD at the specific stop. The communication between the device and the central is carried out using LoRa technology, which is suitable for sending small amounts of data over long distances. With the data collected by the central system, analyses can be performed to evaluate and apply other measures to improve the quality of public transportation. Indeed, the proposed solution has the potential to significantly improve the accessibility and convenience of public transportation, helping to ensure that the PWDs are able to board the vehicle safely and comfortably.

II. Background

A. LoRa Communication

LoRa (Long Range) is a wireless communication technology that can transmit data over long distances with low energy consumption. LoRa is especially useful in IoT applications, where small, low-power devices must send data over long distances, often in urban or rural environments. LoRa technology utilizes unlicensed radio frequencies and is known for its energy efficiency and ability to penetrate obstacles. It is ideal for remote monitoring, asset tracking, smart agriculture, and numerous other applications that require long-range communication with low cost and energy consumption [9].

LoRa is based on the LPWAN (Low-Power Wide Area Network) standard, which focuses on transmitting low amounts of data over long distances. Furthermore, this type of technology also focuses on saving energy during data transmission. Therefore, technologies like LoRa are ideal for many IoT applications, especially those that collect telemetry data, as devices are often located geographically scattered and far from the communication gateway [10].

B. Arduino

Arduino is an electronic prototyping platform that emerged in mid-2005 and was created to facilitate cost-effective prototyping so that users without knowledge of programming and electronics could develop their projects. This platform has the main objective of facilitating the process of creating and manufacturing prototypes, resulting in a low-cost product with the ability to detect possible projections, qualities, and flaws of the developed project.

Two categories unite the Arduino: software and hardware. The software concerns its development environment, such as the Arduino IDE, in which programming codes are inserted to be loaded onto the platform and enable the manipulation of sensors and modules of greater complexity, such as wireless connectivity, storage, among other modules. The hardware consists of a board with a microcontroller, communication ports, USB connection, power supply, and other devices to be integrated into the project circuit, joining sensors and other components through their communication ports that can be analog or digital, with the objective of sending or receiving electrical signals [11].

C. Related Work

The IoT has revolutionized the world by providing ubiquitous connectivity at the individual level and enabling real-time monitoring of user behavior. The rapid advancement of IoT devices and supporting technologies has opened up new possibilities for everyone, but its potential is even more pronounced for people with special needs, as anything and everything can now be connected. People with special needs, which often includes people with disabilities and the elderly, can benefit greatly from IoT technology, which is well-suited to helping them with their daily activities and thereby improving their quality of life [12].

Several IoT-based solutions were proposed over the years as a means to improve the accessibility and convenience of public transportation for PwDs. In 2017, a study conducted in Japan by TANAKA et al. presented a system that used a totem with an interactive tablet where passengers could request their bus line and see the arrival time on the screen [13]. The project initially used Wi-SUN technology, which has a shorter range and requires many signal repeaters, increasing the cost of maintenance and deployment. However, when LoRa technology was introduced for the same purpose, the number of repeaters required was reduced by 75%, making it a more cost-effective solution.

In 2019, SANDRU et al. [14] proposed a vehicle tracking system to reduce road pavement deterioration by managing heavy vehicle traffic flow. The system uses LoRa technology to track vehicles along their routes, evaluating the traveled path and notifying drivers if they enter unauthorized zones. Later, CABRERA et al. [15] presented a new intelligent transportation system using IoT to improve public transportation mobility. The proposed system uses LoRa communication to track public transportation fleets in order to integrate information and manage vehicles efficiently, optimizing traffic mobility.

In 2020, PODEVIJN et al. [16] presented an application that successfully improved LoRa geolocation systems without a significant increase in deployment and usage costs. The application used a digital compass in conjunction with LoRa technology to provide directional and location information for vehicles and people, resulting in improved accuracy. The proposed strategy achieved an increase in accuracy of 65%, 76%, and 82% for motor vehicles, bicycles, and walking, respectively. Despite a 10% increase in energy consumption, this approach is still 14 times more energy-efficient than a GPS system.

III. "Sigabem" Boarding Support System

The proposed solution, named "Sigabem" Boarding Support System, is based on IoT technologies, connecting people with disabilities and devices to a central transport system by a Lora Communication Link, assisting people with disabilities to board public transportation system. The solution consists of two devices: one at the bus stop and one in the driver's cockpit. The device at the bus stop allows people with disabilities to communicate with the driver to inform them of their desire to board. The device in the driver's cockpit alerts the driver that a person with a disability is waiting to board.

This system improves accessibility, autonomy, and safety during boarding. People with disabilities is able to choose their bus line in an accessible way, with the device equipped with Braille and speakers, providing bilateral communication. Additionally, sending data to the driver does not violate their operating procedures.

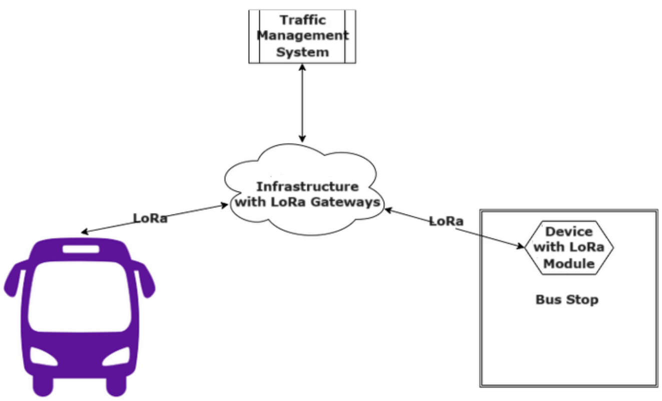

Fig. 1. Basic architecture and communication flow.

Figure 1 shows a simplified architecture of the proposed solution, illustrating the communication flow. A proof of concept of the solution was developed with a LoRa communication module and will be deployed at bus stops in the city of Recife. Through this device, people who need assistance boarding can signal their need to the traffic management system. The signal can be sent by pressing a button on the device, which sends the location of the bus stop. The signal is sent through a LoRa communication network with gateways geographically distributed throughout the city.

Upon receiving a signal from a device, the Traffic Management System will register the request and forward it to the driver on the route of the bus stop, notifying the driver to be attentive for the boarding of a PwD. Subsequently, there is an intention to enhance the device by providing some form of authentication that enables the identification of the PwD.

The LoRa technology will be used for communication between the devices located at the bus stops and on the vehicles. Communication between LoRa gateways and the Traffic Management System can use any available technology. LoRa technology enables long-distance data communication, reducing the number of access gateways required to cover a specific geographic area. With the proposed solution, the collected data can be used to assess the quality of service for individuals requiring assistance during boarding and to suggest improvements.

Initially, there must be available infrastructure with LoRa technology. The initial challenge is to provide infrastructure that covers the city's streets with bus stops. In addition to the possibility of deploying proprietary infrastructure, some companies in various cities in the country offer communication services with this technology.

Other applications can also benefit from gateways made available in the communication infrastructure. Furthermore, the devices, which will initially inform drivers that there is a PwD at a specific public transport stop, can add other functionalities that require sending a low amount of information, such as telemetry data (e.g., temperature and humidity). With the proposed system in use, some simple sensors can add functionalities to improve care for PWDs and the general public.

IV. Partial Results

To develop the proposed solution, we created the device prototype, consisting of the following components: display (Figure 2), speakers (Figure 3), matrix keyboard (Figure 4), and the LoRa shield (Figure 5). Each circuit component aims to optimize and make the routine of the target audience (i.e., PwD) more practical, accessible, and autonomous regarding the request to board public transport.

Fig. 2. Display.

Fig. 3. Speakers.

Fig. 4. Matrix keyboard.

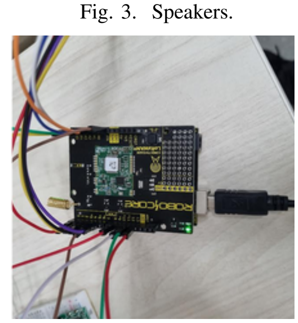

Fig. 5. LoRa shield.

As data output to the user, the solution contains a display and speakers to simultaneously inform the available lines at the bus stop via audio and video. As data input, the user will use the matrix keyboard, which helps to select the desired bus line based on the information displayed by the data output peripherals. These electronic devices are interconnected by a circuit on an Arduino board (Figure 6). It is programmed to execute all the processes involving each component mentioned above until sending the data, selected by the user, to the public transport monitoring center, through LoRa communication. These electronic components can be replaced in case of product improvements in the future.

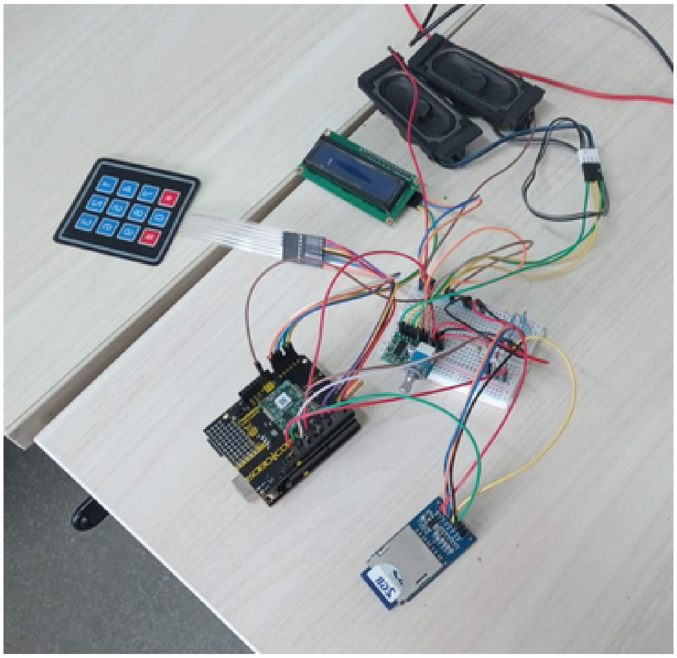

Fig. 6. Prototype with Arduino and integrated components.

Currently, the prototype is in its first version. We carried out several tests with the components separately and together, and all tests were executed successfully. We have also tested LoRa communication and are currently conducting tests to verify the loss of LoRa signal in a building environment with obstructions. The next step will be to develop a prototype of the traffic management system to receive data from devices at bus stops.

V. Conclusion

Given the population growth and the PwDs' difficulties in accessing public transport, this work described the proposal for a system to help boarding for this portion of the population. The system will use an IoT device to collect information about the bus line requested by a PwD at a given boarding point. The device will communicate this information to a central system through LoRa technology. The central system will process this information and forward its response to the PwD who requested boarding on the specific line and to the driver of the requested line's vehicle to inform the driver about the need to board that PwD at that location. As the central system will also store the data, analyses can be carried out on schedules, locations, and demands, with the aim of proposing improvements to the operationalization of the public transport service for these users.

The proposal is in the development phase, with a prototype of the device implemented. In future work, we intend to improve the prototype and conduct tests with public transport in the city of Recife. Besides, we will test the LoRa signal loss in an indoor environment, analyzing how it flows through some obstructions. We also plan to develop a central management system to get and analyze the devices' data.

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