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SightBeyond Transit: An iBeacon-Powered Outdoor Bus Navigation Aid for Independent Mobility of the Visually Impaired

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Abstract - People impaired visually have a lot of problem in using public transportation. This is because they do not get the help they need to navigate bus stops and buses. Most navigation system uses the Global Positioning System (GPS), which is not accurate and needs a constant internet connection. Many systems which are made to help are worn on body. Are not very comfortable, which makes them hard to use. This Research is about a system called SightBeyond Transit. It is a navigation aid for people who are blind or have low vision. It uses iBeacon technology to give real-time audio instructions t. The system has Bluetooth Low Energy beacons at bus stops and on buses. A smartphone app detects these beacons. Uses the signal strength to figure out how far away the user is. The system tells the user when a bus is arriving, what route it is on and when they are getting close to their stop. This helps the user to be more independent and confident when using transportation. The system uses Bluetooth Low Energy, which means it does not use a lot of power and is very reliable. It also does not need a satellite signal or a constant internet connection.

Key Words: iBeacon-Based Navigation, Smart Bus Guidance System, Independent travel, Bluetooth Low Energy (BLE) Technology, Voice Guidance.

1. INTRODUCTION

Being able to move is very important for people to participate in society go to work, and get an education. However, people face a lot of challenges when using public buses. Most digital displays and navigation apps are designed for people who can see, which makes them hard or impossible for people who are visually impaired to use.

Public transportation systems usually show arrival times and route details on screens, which helps people, but not those who are blind or have low vision. While there are navigation apps for smartphones, they have a lot of problems. For example, they are not very accurate in areas they do not work well near big buildings, and they need a stable internet connection.

Recent studies have shown that Bluetooth Low Energy beacon technology can provide reliable navigation. SightBeyond Transit is a solution to these problems. It focuses on helping impaired people at the most important parts of their journey like, finding the right bus stop, getting on the right bus, tracking their route, and getting off at the right stop.

2. SYSTEM DESCRIPTION

SightBeyond Transit has three main components:

1. BLE iBeacon Devices
2. Smartphone Mobile Application
3. Cloud/Local Database for Route Mapping

BLE iBeacons are set up at bus stops and on buses. Each beacon transmits a unique ID that includes:

1. Universally Unique Identifier (UUID)
2. Major value (Bus Stop or Route Category)
3. Minor value (Specific Bus Stop or Bus ID)

The mobile app continuously scans for nearby BLE signals. When it detects a beacon, it retrieves its ID and checks it against stored route and stop information in the database. Based on the matched data, the app provides relevant navigation instructions using text-to-speech (TTS) audio output.

The system operates in three stages during travel:

1. It tells the user where they're
2. It tells the user when a bus is coming and what route it is on
3. It tells the user when they are getting close to their stop

The app is designed to be very simple and easy to use with big buttons and voice commands.

3. WORKING METHODOLOGY

SightBeyond Transit works by detecting how close the user is to a beacon using Bluetooth Low Energy.

A. Beacon Broadcasting:

Each beacon regularly broadcasts BLE advertisement packets at set intervals. These packets contain the UUID and major and minor identifiers. In short, each beacon sends out a signal at intervals. This signal includes the ID of the beacon.

B. Signal Detection and RSSI Analysis:

The smartphone scans for nearby BLE signals and checks the Received Signal Strength Indicator (RSSI). RSSI helps estimate how far the user is from the beacon.

1. Stronger RSSI means the user is closer.
2. Weaker RSSI means the user is farther away.

Though RSSI can vary due to environmental factors, filtering methods are used in the data processing system to reduce interference. Or in other words, the app scans for these signals and checks how strong they are. This tells the app how far the user is from the beacon.

C. Data Processing:

The app takes the information from the beacon like beacon ID, Matches it with the route information in the database. It then gives the user audio instructions about what to do.

D. Audio Guidance:

The app tells the user things like "You're at Central Bus Stop" or "Bus number 121 is coming" as well as “Merry Weather Station is coming, be ready to get off the bus”.

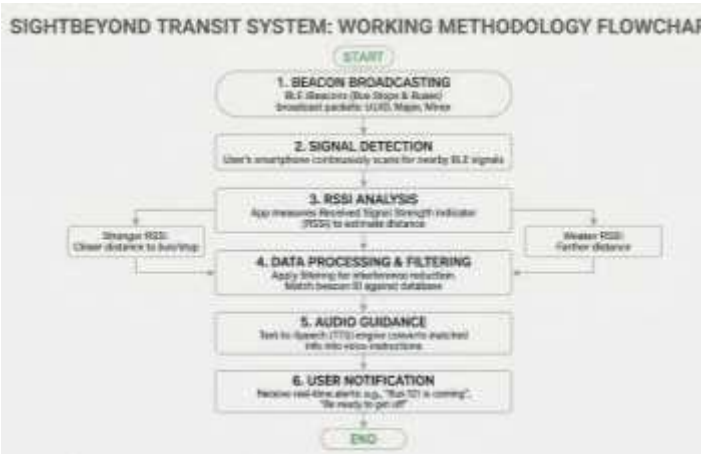

Fig -1: Workflow

4. TECHNOLOGIES USED

A. Bluetooth Low Energy (BLE)

BLE works in the 2.4 GHz ISM band, designed for low power wireless communication. It supports both connection-oriented and connectionless communication.

It is perfect for this system because it is reliable and does not need a lot of energy.

BLE beacons broadcast signals in advertising mode, allowing smartphones to detect them passively.

B. iBeacon Protocol

The iBeacon protocol is a way of formatting the signals that the beacons send out. This makes it easy for the app to understand the information and give the user instructions. Each packet contains:

1. 128-bit UUID
2. 16-bit Major value
3. 16-bit Minor value

This structured identification allows exact mapping of locations to digital information.

C. RSSI (Received Signal Strength Indicator)

RSSI is a way of measuring how strong a signal is. It can be affected by things like buildings and other people. The app uses special techniques like signal averaging and threshold filtering to make it more accurate.

D. USSD (Optional Integration Concept)

USSD is a way of sending information over a network without needing internet. It could be used in the future to make the system work with phones.

E. Text-to-Speech (TTS) Engine

The app uses a text-to-speech engine to turn the instructions into audio. This makes it easy for the user to understand what to do.

Fig -2: ibeacons

Fig -3: Mobile Application

5. SYSTEM ARCHITECTURE AND MODULES

The system has four functional parts:

1. Beacon Detection Module: Responsible for scanning and detecting BLE signals, measuring RSSI, and identifying the strongest nearby beacon.
2. Data Processing Module: Maps beacon IDs with stored bus route details and filters out irrelevant signals.
3. Audio Guidance Module: Converts navigation instructions into clear audible alerts using TTS.
4. Mobile Interface Module: Offers a simple, accessible interface with large buttons and voice command options.

6. ADVANTAGES OVER GPS-BASED SYSTEMS

SightBeyond Transit is better than GPS-based systems in following ways:

1. It does not need satellite signals.
2. It works with or without internet.
3. It is very accurate at close range.
4. It is lightweight and easy to use.
5. It does not need a lot of infrastructure.

GPS is not very accurate at close range, making it difficult to identify bus stops. SightBeyond Transit uses Bluetooth Low Energy, which is much more accurate.

Features	**GPS-Based Systems**	**Proposed BLE System**
Short-range accuracy	Limited	High
Bus-level identification	Not supported	Supported
Real-time boarding confirmation	No	Yes
Energy efficiency	Moderate	High
Context-aware proximity alerts	Limited	Available

Table -1: Comparison with GPS-Based Systems

7. LIMITATIONS

SightBeyond Transit has some limitations:

1. It needs a Bluetooth-enabled smartphone.
2. The beacons placement should be in accurate and perfect spot.
3. The signal strength can be affected by things like buildings.
4. It is for outdoor and bus-level navigation.
5. It needs an initial investment to set up.

6. Indoor navigation in large bus stations is currently not in scope.

8. FUTURE ENHANCEMENTS

In the future the system could be improved by:

1. Using AI-based RSSI filtering and intelligence to make the signal strength more accurate.
2. Integrating with smart city systems.
3. Adding real-time bus tracking.
4. Adding multilingual voice options.
5. Using vibration-based feedback.
6. Using solar-powered beacons.

10. CONCLUSIONS

SightBeyond Transit offers a practical, scalable, and affordable assistive navigation solution for visually impaired individuals using public buses. By using Bluetooth Low Energy and iBeacon technology, it provides real-time, accurate audio guidance without relying on satellite signals or steady internet access.

The system helps people be more independent, safe and confident. It also supports the development of transportation that includes everyone.

It helps with parts of travel like Knowing where to stop, Choosing the bus, tracking your journey, and getting alerts when you arrive.

By using BLE to detect how close you are, with RSSI and making the app work well for everyone, SightBeyond Transit helps make cities smarter. These cities focus on making sure everyone can move around easily and be included in society.

SightBeyond Transit supports the development of cities that focus on mobility equity and social inclusion.

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