CSE461

Introduction to Robotics

Group 04
Section: 03
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Bus Tracking System

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Table of Contents

Introduction

Time is arguably the most valuable human resource. How an individual spends their time not only has significant implications for their personal life, but it also has a direct correlation with numerous economic indicators. For the people of our country, daily transit is an area where a significant amount of time is wasted. Many economic reports suggest that we are losing a lot of money in people's time wasted in traffic congestion every year. Numerous efforts have been made to improve the situation but the progress has rather been slow. Most of the efforts come in building additional infrastructures but there hasn't been much incorporation of viable information technologies to the system which is rather disappointing given we are living in a world where technologies have already transformed many countries for the good. The idea we are presenting is a demonstration of the possibility of integrating technology to improve on the daily arduous transit life where endless sufferings are tolerated and massive time is wasted.

Idea and Features

We want to equip every bus with a tracking system. This tracking system would collect numerous valuable information which would serve the different end users according to their purposes. For an end user concerned with their transit, this system would provide them with active bus locations and vacancy status. For the owners of these transportations, they can see, with a reasonable level of accuracy, how many people are using their services. They can also better manage and plan the routes for their buses, anticipate congestion, identify profitable routes, monitor distance covered and fuel costs, monitor the driver's driving behavior etc. This may sound ambitious and it is but all of this is possible with the employment of some appropriate sensor. We will be using GPS sensors to track the buses, a counter system powered by the Pi camera equipped with computer vision software, a Raspberry Pi board, a usb cellular modem to connect to cellular network and a power supply. This project is more of a software challenge than hardware. With this project we want to demonstrate and verify the potential of IoT systems in transforming lives and increasing the efficiency of the transit industry.

Components

List of all the components used, their description and working principle

Raspberry Pi 4 Model B

A compact, single board computer boasting a 1.5GHz quad-core ARM Cortex-A72 CPU. Accommodates three memory options namely 2GB, 4GB and 8GB LPDDR4-3200 SDRAM. With dual-band 802.11ac wireless networking, Bluetooth 5.0, and Gigabit Ethernet, the Raspberry Pi 4 Model B offers a wide range of connectivity options.Has two USB 3.0 and USB 2.0 ports each. 4K 60FPS video output is supported via two micro-HDMI ports. Supports a wide range of operating systems which includes Raspberry Pi OS, Ubuntu and Windows IoT Core. Can be programmed with Python, C, C++, Java among others.

Raspberry Pi 15W (5V/3A) USB-C PSU

The official Raspberry Pi USB-C Power Supply is designed to power Raspberry Pi 4 Model B and Raspberry Pi 400 computers.

- 5.1V / 3.0A DC output
- 96-264Vac operating input range
- Short circuit, overcurrent and over temperature protection
- 1.5m 18 AWG captive cable with USB-C output connector

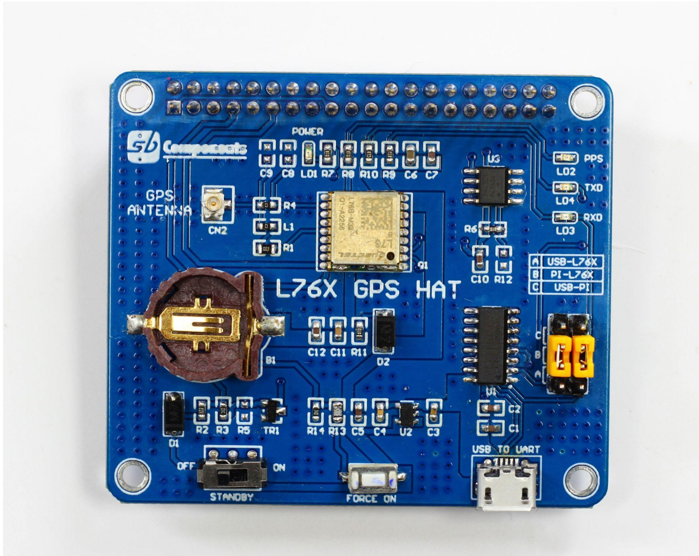
Raspberry Pi Camera Module 3

Comes with an improved 12MP IMX708 Quad Bayer sensor and features a High Dynamic Range mode. Ultra fast auto focus is standardized. Supports up to 120 degree angle of view. Other features include rapid phase detection autofocus, HDR mode up to 3 megapixels, and IR variants available.

Working Principle

The IMX708 Quad Bayer sensor uses the CMOS(Complementary Metal-Oxide-Semiconductor) technology to convert light into electric signals. When light falls on the sensor's photodiode, it generates a small electric current, which is then amplified and processed by the camera's image processing system. Apart from the image processing unit the module also includes an integrated lens, a serial communication interface. The lens focuses the light onto the sensor. The image processing hardware is a small circuit board which is responsible for processing the raw sensor data. The serial interface is used to communicate with the Raspberry Pi board. It is used for receiving the image or video data and also to control the camera.

SB Components GPS HAT for Raspberry Pi



The extremely compact and powerful GNSS module GPS HAT for Pi is a concurrent receiver module that integrates GPS with the BeiDou system. It's pin-to-pin compatible with Quectel's GNSS module L76 and can receive both GPS and BeiDou open service L1 signals at the same time. GPS HAT for Pi can acquire and track any mix of GPS and BeiDou signals thanks to its 33 tracking channels, 99 acquisition channels, and 210 PRN channels. When compared to utilizing simple GPS, enabling both GPS and BeiDou doubles the number of visible satellites, reduces the time to first fix, and improves positioning accuracy, especially in congested urban areas**.**

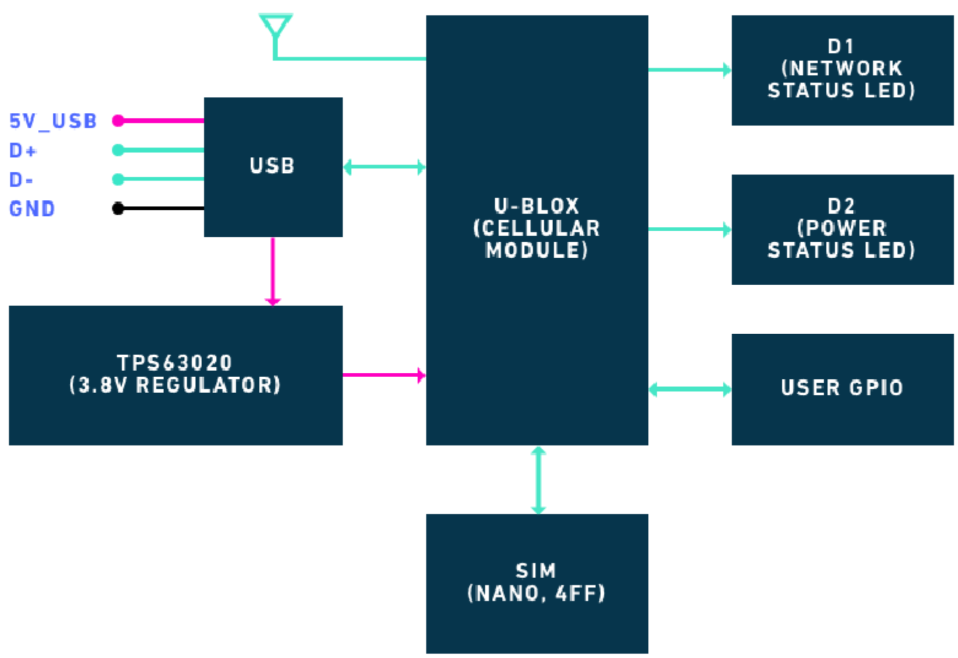
Working Principle

The L76 module is a concurrent GNSS (Global Navigation Satellite System) receiver with multiple GNSS systems. It provides simultaneous GPS, GLONASS, BeiDou, Galileo and QZSS open service L1 reception capability. At a given time, there are typically 24 GPS satellites orbiting earth. These satellites transmit signals to GPS receivers on earth. These signals contain information about the satellite's location and the exact time the signal was sent. The GPS receiver uses the time stamp information in the signal to determine the distance between the receiver and each visible satellite. The GPS receiver incorporates this distance information from at least four satellites in a process called trilateration which is used to determine the exact location of the GPS receiver on earth. Trilateration involves calculating the intersection point of three spheres, each centered on one of the three satellites, and with a radius equal to the distance between the receiver and each satellite. The intersection of these spheres gives the GPS receiver's location.

Hologram Nova

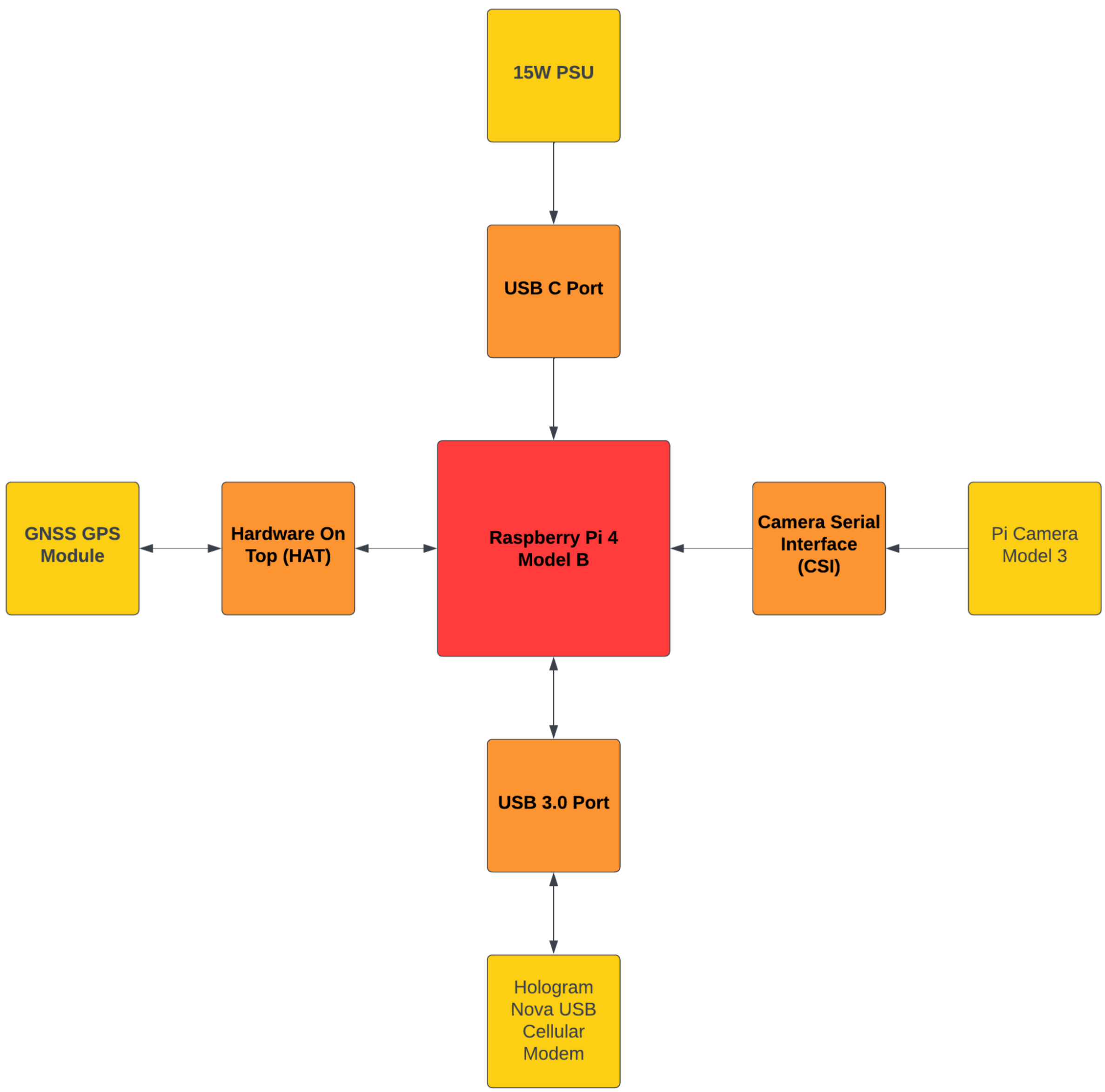
The Hologram Nova is a powerful cellular modem designed to provide reliable, low-cost connectivity for Internet of Things (IoT) devices.The Nova is a compact, plug-and-play device that can be easily integrated with a range of IoT devices. It supports 2G, 3G, and 4G LTE cellular networks and includes a SIM card that provides access to a global network of over 170 carriers.

Working Principle

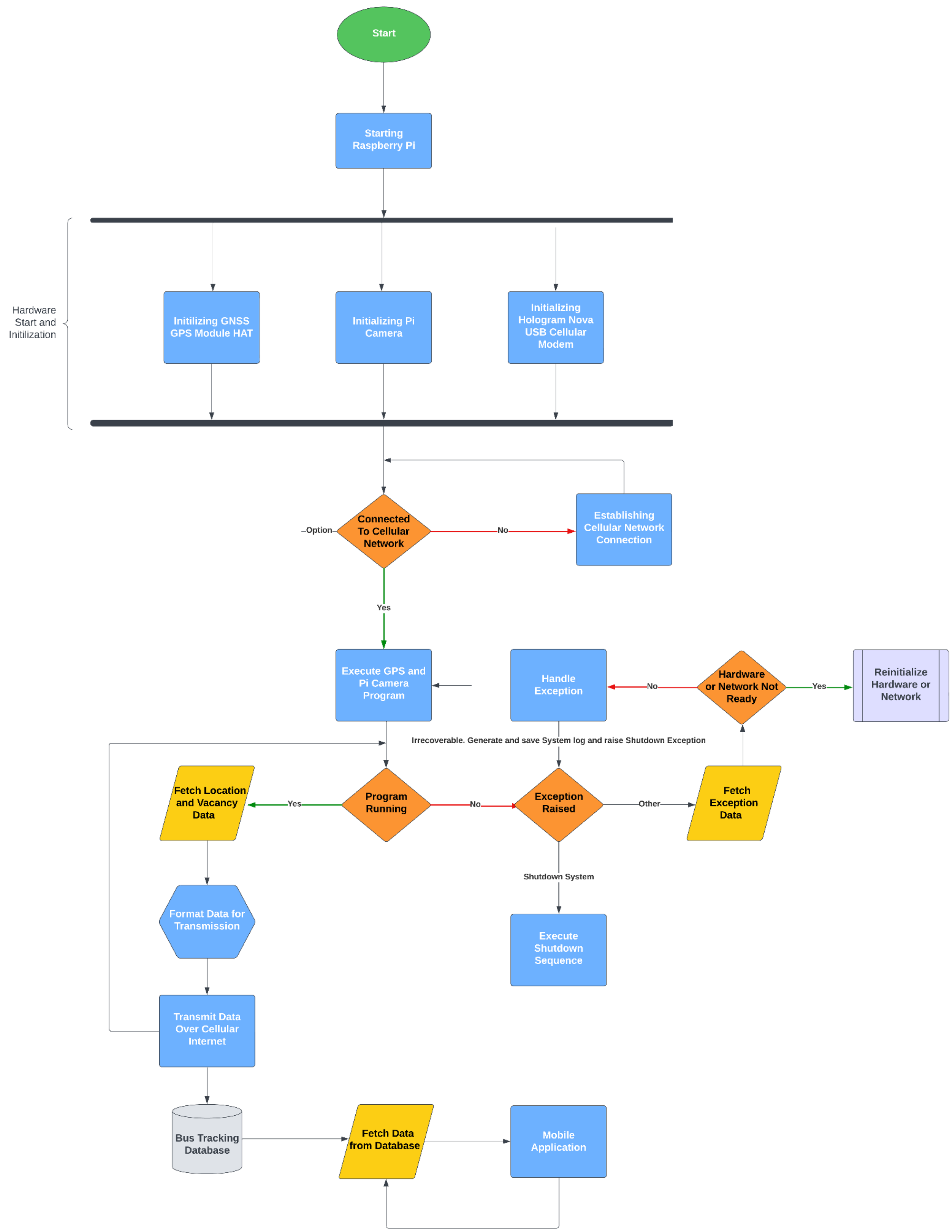


The U-BLOX cellular module is responsible for establishing connection to a cellular network. This modem communicates with the cellular network using radio waves, which are transmitted and received via the device's antenna. When the user is sending data, the data is first modulated to an appropriate digital format before being sent as a digital signal in the form of radio waves to a nearby cellular tower. The tower then forwards the data to the appropriate destination. When receiving data from a cellular network, the modem demodulates the digital signal and does some preprocessing before sending it to the user.

Connection Diagram



Data Flow Diagram



Result

Just as the system delivered on many areas, it also showed a lot of room for improvements. We were realistic with our anticipation of the results so we were eager more to validate our many hypotheses and also optimistic on the things we believed the system was capable of delivering. The GNSS module lived up to its mark. We tracked the vehicle successfully and were also able to plot its route throughout its travel. The GNSS module showed no issues with connectivity throughout our testing. The usb cellular modem also delivered. Although we didn't test the system where the cellular network is weak, the device ensured its performance under nominal conditions. The counter system based on the pi camera which incorporated opencv software, really highlighted the challenges of a project implemented in a mobile environment. The camera did an okay job while the bus was stationary, but it underperformed in rough terrains where the face detection algorithm suffered from blurry video data along with noise noise from other objects. We were able to mitigate the noise part by framing the camera in such a way that it only has a fixed range of view under the entry of the bus. We took measures for stabilizing the camera in bumpy roads although we didn't push further as we knew any efforts to stabilize a 25$ camera not engineered for heavy duty conditions would be counterproductive. As mentioned, reframing the camera properly and ensuring stability as much as we can, our testing data showed the counter accuracy was around 92 to 95 percent under desirable conditions which is extremely good for under constrained situations. Although, in such systems where the error aggregates, this is not reliable. Raspberry Pi, being a single computer on board with limited memory and clock, made use of all its resources. Therefore prolonged periods of usage showed indications of cpu throttling as the programs ran, especially given the heavy footprint of the computer vision enabled counter system program and all the data transmission that was taking place all at the same time asserted a persistent load on the board. But at the end, we were more than satisfied that the system at least worked with reasonable accuracy given our objective was to prototype this system to ensure its validity.

Use Case

The system is especially useful in places with high public transport demand, where commuters must save time and organize their travels more efficiently. In a densely populated urban area where public transportation is an important mode of transportation, the Bus Tracking System can be valuable. With such many commuters, it is critical to have a dependable and efficient transport system that can carry people throughout the city quickly and safely. A technological system called the Tracking System offers real-time information on the whereabouts and arrival times of public transit vehicles. It uses a GPS module and a cellular data network to pinpoint the bus's location and send that information to a centralized database. This system is very much helpful for the people who are going to the office and school can manage their time to reach their destination. This strategy is also helpful for commuters who need to plan their trips more effectively and save time in areas with high public transport demand. The Bus Tracking System can be useful in densely populated urban areas where public transit is a crucial mode of transportation. It is essential to have a trustworthy and effective transport system that can get people about the city swiftly and safely given the high number of commuters. Also, Bus owners are able to optimize their routes and scheduling thanks to the system's useful data, which resulted in lower fuel consumption and operating expenses.

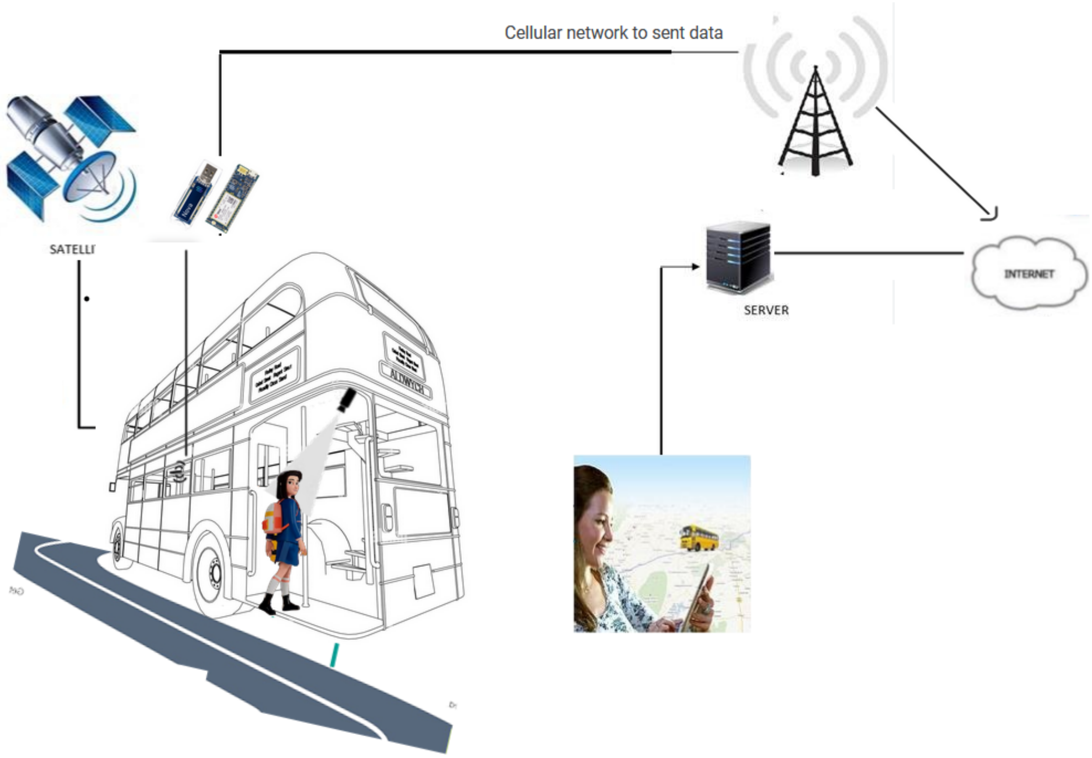
The Bus Tracking System, which includes a GPS module and cellular data connectivity, can function in a variety of environmental settings, but it would be most suited for use in moderate climates with temperatures between -10°C and 50°C and relative humidity levels between 20% and 80%. The system should be able to survive exposure to a variety of weather conditions, including rain, and strong winds, as it is intended to function outdoors. It would also need to be capable of withstanding electromagnetic interference, vibrations, and shock, all of which are frequent in transportation contexts. The strong and rugged SB Components GPS HAT for Raspberry Pi fitted into the Raspberry Pi, enabling it to function in challenging conditions. Moreover, No matter where the buses are, the Hologram Nova modem is made to enable cellular data access, which is necessary for sending data to the main database.

Analysis

Even though the Bus Tracking System can have a big impact on managing public transport, our analysis said that there are several issues that can make users lose faith in the system.

1. Technical Issues: Hardware parts of the system, like the GPS module and cellular network connectivity devices, could malfunction or have connectivity problems. These technical problems may weaken the system's accuracy and dependability by interfering with real-time tracking and data transfer.
2. Data Security: The system's database holds critical information regarding the location and operation of the bus fleet, leaving it vulnerable to data breaches and cyber-attacks. To ensure data security, the system must be developed with robust security mechanisms, such as encryption and authentication measures, to defend against unauthorized access and data theft.
3. User Acceptance: There may be some opposition or skepticism from passengers who may not believe the accuracy of the system's data, despite the fact that the system can give users of public transportation accurate and up-to-date information. The system must be created to be user-friendly and offer clear, concise information in order to overcome this difficulty and foster confidence in the system.
4. Maintenance: To keep them running at their best, the hardware parts and software programmes of the system need to be maintained on a monthly basis. Operators of the system must possess the knowledge and resources required for maintenance. If this isn't done, the system's performance could suffer or it could stop working altogether

2D Representation



Conclusion

The main objective of this project was to demonstrate the transformative potential of IoT technologies and the possibility of implementing such systems. This toy project was an attempt to show that it's a plausible system in the context of our country, it has great market potential and most importantly by developing this prototypical system it showed promise for industry grade production based on the state of the art manufacturing processes that would produce much more robust, efficient and accurate systems.