Indian Institute of Technology Delhi, New Delhi

ELP305-Submission-1:

Project 2: SmartBus

Enhancing Intra-Campus Transportation at IIT Delhi

Requirements . Specifications

v0.1

TRIBE B

2 April, 2024

Document ID: 2024-04-02-335691

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Table 5: Design and Fabrication Team Members Details with IF < 1

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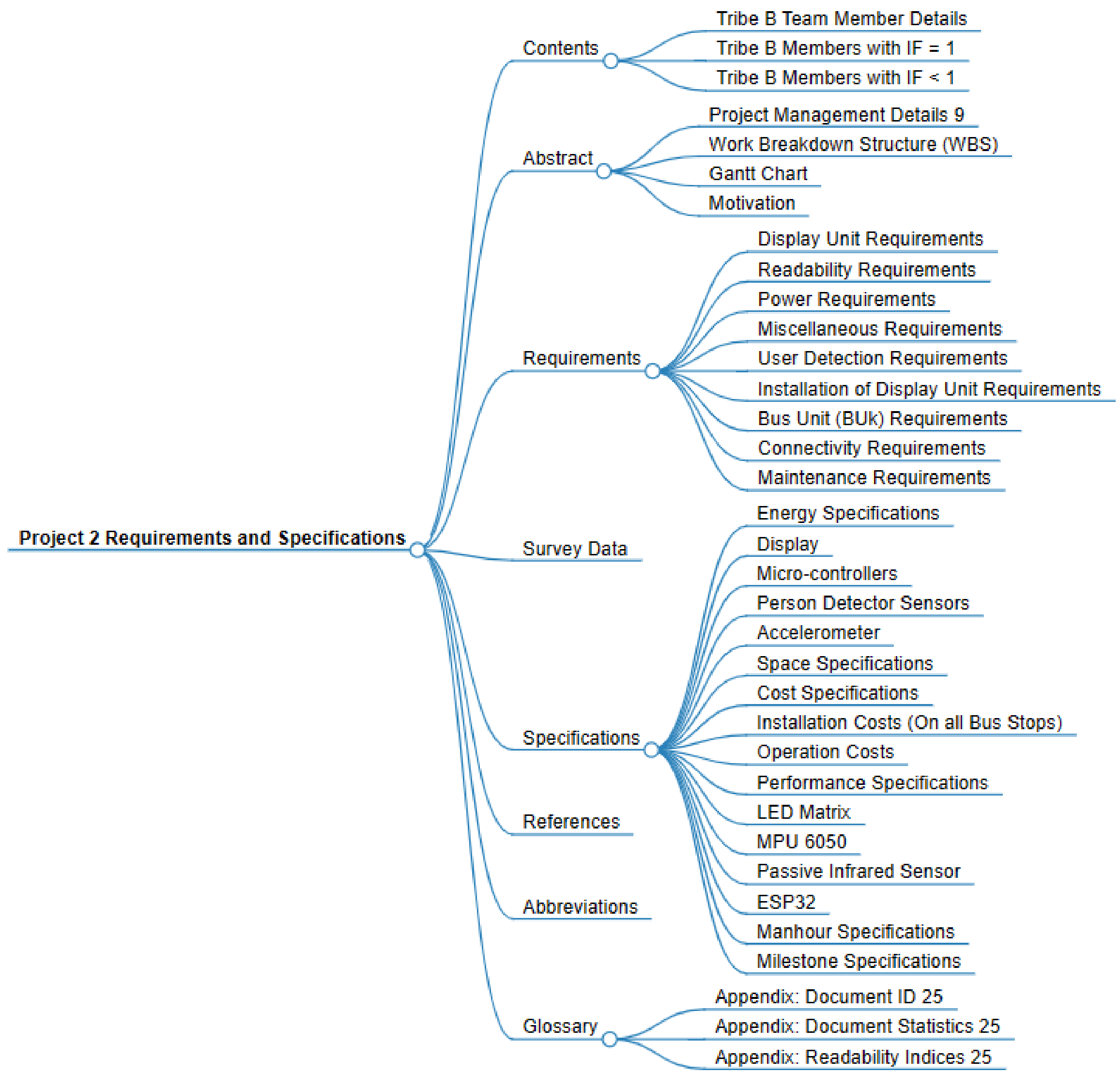

Figure 1: Document Outline Mindmap

Abstract

This project aims to address the need for real-time bus arrival information at designated stops within the IITD campus. Presently operating with two buses, serving endpoints at the East Campus Market and DMS TIFAC Building. However, buses lack visible labels, leading to uncertainty among waiting passengers regarding the next available bus. To alleviate this issue, a comprehensive solution incorporating display units at bus stops and bus-mounted units (BUk) has been proposed. These units provide bilingual information on the estimated arrival time of the next bus and the operational status of each bus, ensuring transparency and facilitating informed commuting decisions. The system's design encompasses considerations such as readability, connectivity, power management, and weather resilience, essential for seamless operation under diverse conditions. Furthermore, data logging capabilities enable performance monitoring and maintenance scheduling, ensuring sustained operational efficiency. Through the integration of advanced technologies and robust infrastructure, this project endeavors to optimize campus transportation, enhancing user experience and fostering a more reliable and intuitive commuting environment.

2 Project Management Details

2.1 Work Breakdown Structure (WBS)

A WBS is a project management system that breaks projects into smaller, more manageable components or tasks. It is a visual tool that breaks down the entire project to make it easier to plan, organize, and track progress and assigns each task a unique identifier and places them within a hierarchical structure that shows the relationship between each task and its related deliverables.

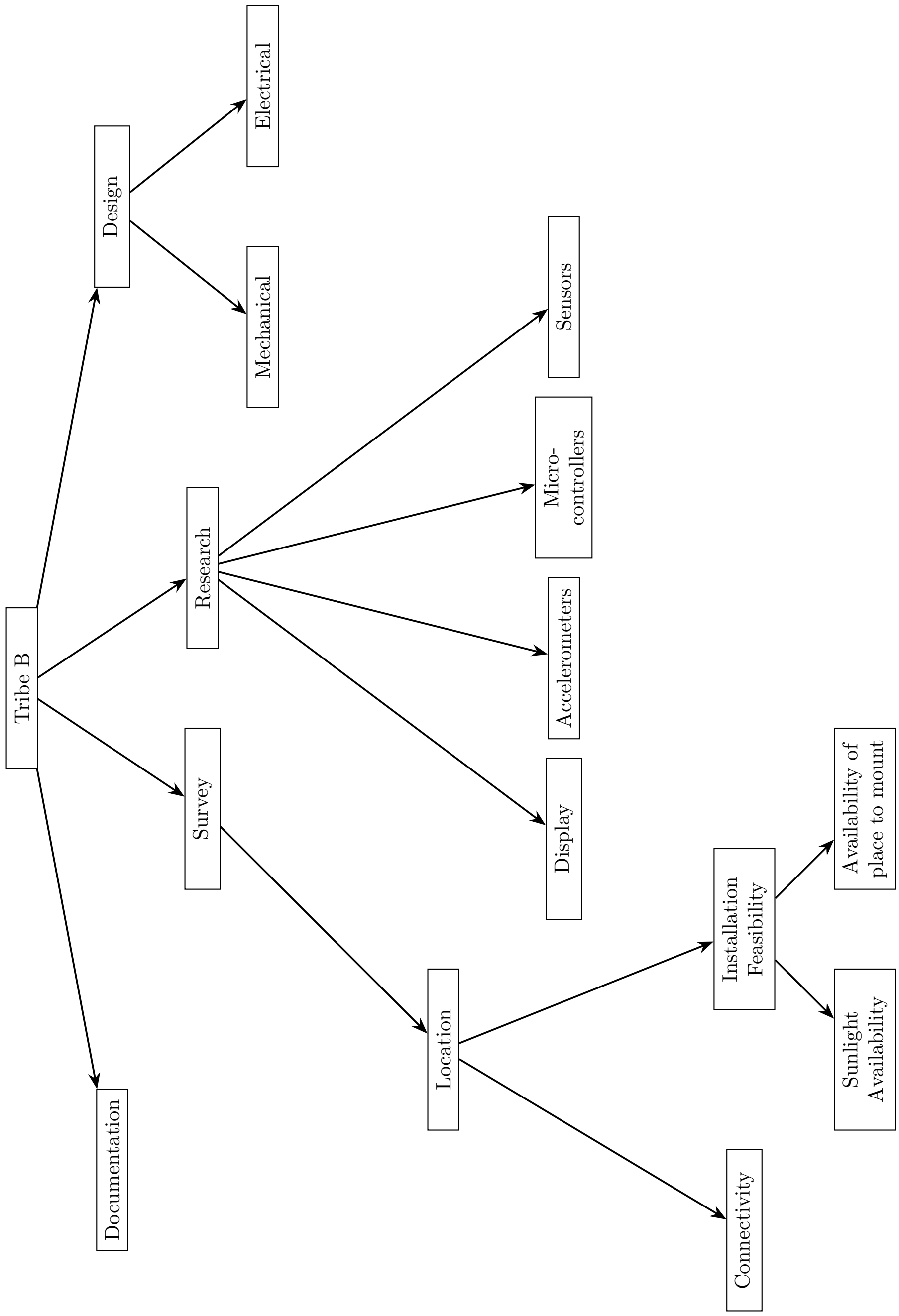

Figure 2: WBS

2.2 Gantt Chart

A Gantt chart is a type of bar chart that illustrates a project schedule. It lists the tasks to be performed on the vertical axis, and time intervals on the horizontal axis. The width of the horizontal bars in the graph shows the duration of each activity alongwith the start and finish dates of the terminal elements and summary elements of a project. It also shows the dependency relationships between activities.

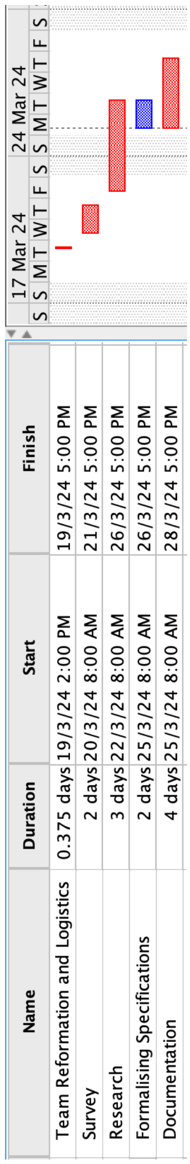

Figure 3: Gantt Chart

3 Motivation

Efficient transportation infrastructure is paramount within educational campuses, ensuring smooth mobility for students, faculty, and staff. However, existing intra-campus bus systems often lack essential features such as real-time arrival information[9], leading to inconvenience and uncertainty among commuters. This project aims to bridge this gap by addressing the pressing need for accurate and timely bus arrival information at designated stops within the campus.

The lack of visible labels on buses, coupled with staggered starting times, exacerbates the challenge for waiting passengers to predict the next available bus. Consequently, commuters face difficulties in planning their journeys effectively, leading to potential delays and frustration. By providing a comprehensive solution incorporating display units at bus stops and bus-mounted units (BUk), this project seeks to enhance the accessibility and reliability of campus transportation.

A review of existing literature underscores the significance of real-time transportation information in improving commuter satisfaction and overall system efficiency.Access to timely bus arrival information reduces perceived wait times, enhances commuter experience, and promotes the use of public transportation.

Furthermore, the integration of advanced technologies such as sensors for passenger detection, communication algorithms leveraging Bluetooth and WiFi protocols, and innovative display algorithms underscores the project's commitment to addressing contemporary challenges in campus transportation.

Through interdisciplinary collaboration and meticulous attention to design and functionality, this project endeavors to revolutionize campus transportation, fostering a more seamless and user-centric commuting experience for all stakeholders. By providing real-time bus arrival information, the system aims to optimize travel planning, reduce congestion, and promote sustainability within the campus environment. Ultimately, the motivation behind this research lies in enhancing the quality of life for campus residents and fostering a more efficient and reliable and intuitive transportation ecosystem.

4 Requirements

4.1 Display Unit Requirements

A display unit must be installed at every bus stop that gives the waiting passengers an idea of the time it will take for the next bus to arrive.

4.1.1 Readability Requirements

1. The italicized portion of the display may be pre-printed with only the actual time displayed in flashing/blinking mode. LCD displays with yellow back lighting can be used.

2. The display must be readable by a person with 6/6 vision standing at any point within 8 feet in front of the bus stop.

3. The display has to read 999 in case of any emergencies or unforeseen delays.

4.1.2 Power Requirements

1. The display unit in the stop must be battery powered and must work between 0700 and 1930 hours.

2. Outside these hours, it must self-power down and auto-restart the next day.

3. Solar power must be provided as an option. (Since bus stops are generally located in the shade, suitable nearest sun point has to be found for usage of solar power)

4.1.3 Miscellaneous Requirements

1. The reading on the display must be accurate to ±1 minute.

2. The Bus Stop unit has a white downward pointing LED which blinks with a 30% duty cycle during normal service.

3. In case of any unforeseen malfunction in the display unit, a stall period of 1 hour will be allowed to fix the issue.

4.2 User Detection Requirements

The presence of a waiting passenger standing for more than 30 seconds in any stop may optionally trigger a detector, and be used to inform (the single bicolor LED in the BUk starts blinking) the bus unit BUk that passengers are waiting. The passenger is detected automatically.

4.3 Installation of Display Unit Requirements

1. IP67 enclosures are to be used and will be provided by the lab. Four enclosures per Tribe for the DU unit will be provided - two to be used for the Route 1 bus stops and two for the other Route 2.

2. The display units should be difficult to steal and sell, this is to be ensured with mechanical fixation and placing it at an unreachable height.

4.4 Bus Unit (BUk) Requirements

1. It is mandatory for each bus to have a separate Bus Unit (BUk) (the 'k' in BUk refers to the kth bus).
2. The BUk must contain one bi-colour LED which can switch between red and green.
3. The colours that the unit display will follow the following protocol:
   (a) A red colour will indicate that the bus is out of service, and every stop on the route will display a suitable warning for waiting passengers.
   (b) A red LED which is also blinking is another combination, that is open to be used for flagging specific errors in design.
   (c) A green LED implies that the bus is functioning normally.
   (d) A green LED which is also blinking means that the passengers are waiting at at least one of the bust stops on the route.
   (e) Apart from this, a white LED is also available for use, but is up to the vendors' discretion.
4. The BUk is powered from the battery of the bus (primary power) and from a separate internal battery (secondary power). Primary power is available whenever the ignition is on or the when the engine has started. Secondary power is on at all remaining times. Switchover from primary to secondary power is automatic and without human intervention. A BUk cannot be turned off.
5. The BUk has a red toggle switch with positions 1 and 2 - pressing it to position 1 means that the bus is out of service.
6. The BUk is expected to be as compact as possible, and is to be placed on the dashboard of the bus along with the toggle button.
7. The BUk is also expected to keep the bus activity and travel logs for the past month.

4.5 Connectivity Requirements

1. Non-availability of cellular connectivity (like WiFi or GSM) should not interrupt the working of the system.
2. Occasional use of WiFi (IITD WiFi) is allowed.
3. The use of Bluetooth BLE is allowed in both BUk and the Display Units.
4. Any form of connectivity (wireless or wireless) which is legally allowed in India is allowed.

4.6 Maintenance Requirements

1. A digital interface to collect feedback from users and to allow the users to report errors is to be implemented.

2. Resources to perform daily maintenance of the display units and the bus units are available.

3. Metrics like logging start times, times at which the bus reach each stop and left that bus stop, and duration of out-of-service will be used as base metrics to evaluate efficiency and reliability of the bus service.

5 Survey Data

S. No.	Bus Stop Location	Latitude(°N)	Longitude(°E)	IITD Wifi Strength (dbm)
1	Shivalik	28.5480	77.1856	-65
2	Kailash	28.5442	77.1957	-78
3	Market	28.5428	77.1990	-65
4	Kumaon	28.5491	77.1849	-74
5	Aravali	28.5483	77.1840	-65
6	Karakoram	28.5473	77.1834	-75
7	Central Workshop	28.5441	77.1921	-70
8	Main building	28.5444	77.1928	-65
9	Bharti school	28.5448	77.1899	-73
10	IIT Hostpital	28.5455	77.1882	Poor connection
11	Nilgiri	28.5461	77.1829	-71
12	DMS	28.5428	77.1824	Poor connection
13	Rajdhani	28.5460	77.1868	Poor connection
14	Kalyan Mandap	28.5409	77.1981	Not Available
15	B-15 Gate 3	28.5404	77.1973	Not Available
16	Block B-18	28.5408	77.1961	Not Available
17	B-12 Bus Stop	28.5413	77.1951	Not Available

Table 6: Bus Stop Data

As part of the survey team tasked with evaluating the feasibility of installing WiFi hotspots powered by solar panels at various bus stops within the IIT Delhi campus, we conducted a thorough assessment of each stop's geographical coordinates, WiFi signal strength, and potential installation challenges. Our findings indicate a range of scenarios across the surveyed bus stops.

Starting with Shivalik, situated at latitude 28.54797 and longitude 77.18564, the WiFi signal strength was measured at 65 dBm. However, due to limitations in solar panel installation, alternative locations for WiFi deployment were explored, with the nearest viable option identified as the SAC circle.

Moving on to Kailash, located at latitude 28.5441928 and longitude 77.1957229, the WiFi signal strength was significantly lower at -78 dBm. Similar to Shivalik, solar panel installation was deemed impractical. The Himadri circle emerged as a potential alternative location for WiFi deployment.

In contrast, IIT Market and Kumaon exhibited stronger WiFi signal strengths at -65 dBm and -74 dBm, respectively, rendering them suitable for solar panel installation. For Kailash Market, the identified installation spot was supported by adjacent solar exposure, while Kumaon's alternative location lay on the opposite side of the stop.

Additionally, stops such as Aravali, Karakoram, and the main building boasted favorable WiFi signal strengths, allowing for solar panel installation. These stops presented opportunities for enhancing connectivity within the campus environment.

However, challenges were encountered at Central Workshop, where WiFi signal strength was suboptimal, and solar panel installation was unfeasible. Similarly, Nilgiri and Rajdhani/Yulu Bike Zone displayed poor WiFi connectivity, limiting installation options. The nearest place for wifi installation for Rajdhani stop is SAC circle or Apollo pharmacy. DMS stop exhibit poor connection but solar battery can be installed.

Furthermore, assessment of stops near girls hostel :
Kalyan Mandap: Despite no steel pole availability, sunlight exposure within the premises offers potential for alternative power sources. Local WiFi networks are operational, providing connectivity options.
B15 Gate 3: With a steel pole available and sunlight exposure, this stop offers favorable conditions for solar panel installation. Local WiFi networks contribute to connectivity options.
Block B-18: Although lacking a steel pole, the presence of a nearby pole offers a mounting solution. Sunlight exposure and operational local WiFi networks enhance feasibility.
B-12 Bus Stop: Featuring a steel pole and sunlight exposure, this stop presents ideal conditions for solar panel installation. Operational local WiFi networks contribute to connectivity options.
For above four stops. IITD WiFi seemed not to be working, but local blocks wifi were available and connection to these local WiFi could not be made to measure their strength.
Photographic evidence was provided for each bus stop, facilitating visual inspection of site conditions and potential installation challenges. Based on the survey findings, recommendations were made regarding suitable locations for WiFi hotspot installation, considering factors like WiFi signal strength, sunlight exposure, and availability of steel poles for mounting solar panels.

6 Specifications

6.1 Energy Specifications

6.1.1 Display

- We will use the 8x8 dot LED matrix, which is highly efficient for the display in the project.
- Forward Voltage: 2.1V $\approx$ 2.5V
- Forward Current: 20mA
- The power consumption per LED can be calculated as P = IV, where P is power in watts, I is current in amperes, and V is voltage in volts. For a 3.3V supply and a forward current of 20mA, the power consumption per LED would be P = 0.02A $\times$ 3.3V = 0.066W or 66mW. For the entire display, this would be 64 $\times$ 0.066W = 4.264W.
- The display has to work from 07:00 to 19:30.
- There are 17 stops, each with a display.
- Therefore, the maximum energy requirement per day = 4.264$\times$12.5$\times$17 = 0.906 kWh

6.1.2 Micro-controllers

- We will be using ESP32 Dev Boards
- 4 ESP32-Dev boards will be powered by USB cables and a power bank.
- The ESP32 board can draw up to 600mA during peak operations, and the typical operating voltage is 3.3 V with support for external power with an input voltage range of 5V-9V, which is regulated onboard.
- These boards will operate continuously for 24 hours.
- Therefore, the estimated daily energy requirement = 3.3$\times$0.6$\times$24$\times$4 = 0.19 kWh

6.1.3 Person Detector Sensors

- Passive Infrared sensors will be installed on all 17 bus stops
- Passive Infrared Sensor (PIR) sensors typically operate on a voltage range of 5V to 20V
- The power consumption of PIR sensors is relatively low, with a power consumption of 65 mA at 5V
- PIR sensors will work from 07:00 to 19:30
- Therefore, average daily energy requirement = 0.065$\times$5$\times$12.5$\times$17 = 0.069 kWh

6.1.4 Accelerometer

- 2 accelerometers will be used, one in each BUk unit. The part number of one of these units is MPU 6050
- They will draw power indirectly via the ESP32 Board. They will operate via the provided power bank when on secondary power and directly from the bus battery when on primary power. They will power down when the bus is not in business hours
- The Voltage requirement of the device is 5 V, and the max current intake of the device is 3.9 mA
- The device will be on during business hours from 07:00 to 19:30, which is 12.5 hours
- Therefore, the estimated daily energy requirement = $5 \times 3.9 \times 0.001 \times 12.5 \times 2 = 0.4875$ Wh ≈ 0.0005 kWh

6.2 Space Specifications

- **Enclosures**
  1. Display Units (DU)
     - Dimension - 27.5cm $\times$ 27.5cm $\times$ 10.5cm
  2. Bus Units (BU)
     - Dimension - 15cm $\times$ 12cm $\times$ 8cm
- **Solar Panel**
  - Active Panel Area - 30cm $\times$ 21.5cm
  - Total Area - 25.5cm $\times$ 35cm
- **Wires**
  - The wires are noted to have a minimal spatial impact, as they are either positioned underground or closely attached to the steel pole.

6.3 Cost Specifications

6.3.1 Installation Costs (On all Bus Stops)

- Display Unit
  1. Cost of Single Unit = 144 INR
  2. Number of Units Required = 17 + 3 (Spare)
  3. Total Cost = 2880 INR
- ESP32 Dev Board + Connecting Cable
  1. Cost of Single Unit = 500 INR
  2. Number of Units Required = 4

3. Total Cost = 2000 INR

- Accelerometer
  1. Cost of Single Unit = 101 INR
  2. Number of Units Required = 2
  3. Total Cost = 202 INR
- PIR Sensors
  1. Cost of Single Unit = 150 INR
  2. Number of Units Required = 17 + 3(Spare)
  3. Total Cost = 3000 INR
- Solar Panels
  1. Cost of Single Unit = 900 INR
  2. Number of Units Required = 17 + 1(Spare)
  3. Total Cost = 16200 INR
- Solar Charge Convertor[11]
  1. Cost of Single Unit = 200 INR
  2. Number of Units Required = 17 + 1(Spare)
  3. Total Cost = 3600 INR
- DC-DC 12-5 Volts Converter[2]
  1. Cost of Single Unit = 100 INR
  2. Number of Units Required = 2
  3. Total Cost = 200 INR
- Wire
  1. Cost per m = 15 INR
  2. Length Required = 20
  3. Total Cost = 300 INR
- Enclosures
  1. Cost per unit = 200 INR
  2. Number of Units required = 17 + 2 + 3(Spare)
  3. Total Cost = 4400 INR

6.3.2 Operation Costs

- The devices are self sufficient. They are powered via solar panels
- The only operation cost is the maintenance of the devices and the maintenance of the database, which is minimal compared to the installation cost.

6.4 Performance Specifications

6.4.1 LED Matrix

The red colour emitted by the LEDs[7] is chosen for its visibility in low-light conditions. The contrast between the black background of the display and the red LEDs helps in making the display content stand out, making it easier to read . The forward current of 20mA is sufficient to ensure the LEDs are bright enough to be readable from a distance of 8 feet. The operating temperature range of the device is 40 to 85°C which ensures that the display can be used in a wide range of environments, including those with varying temperatures.

6.4.2 MPU 6050

The MPU 6050[8] supports I2C communications[1] at up to 400kHz. Given you use 400kHz I2C speed, the highest data rate to read all values is theoretically 2.61kHz, 2.96kHz if you omit the temperature reading (15 bytes must be transmitted, needing 9 clocks each). The MPU 6050 can have a sample rate of 1 KHz if you are able to read values out at that speed. It will be difficult if you are reading every gyro and accel every time and you are using I2C. Your MPU allows a sample rate of 8kHz only for the Gyrometer, the accelerometer allows only 1kHz.

6.4.3 Passive Infrared Sensor

Human bodies typically radiate infrared energy concentrated in the wavelength range of 8 um-12 um.The sensor detects infrared radiation from the human body, triggering an alarm.

- Field of View: Narrow field of view, typically around 90 to 180 degrees.
- Input/Output Type: Digital output indicating motion detection .
- Range: Typically up to 10 meters.
- Changes in Weather: PIR[5] sensors may be affected by temperature changes, especially extreme variations between summer and winter.
- Day Switches: Can be affected by changes in ambient light levels, such as transitioning from noon to evening.
- Price: Generally affordable.
- Ease of Use: Easy to install and set up.
- Needs An optical system, including a plastic Fresnel lens, focuses infrared radiation onto the pyroelectric sensor to enhance detection distance.

6.4.4 ESP32

The ESP32[4] is a series of low-cost, low-power system-on-chip microcontrollers. It is designed and manufactured by Espressif Systems. It is a successor to ESP8266 SoC and comes in single-core and dual-core variations of the Tensilica's 32-bit Xtensa LX6

Microprocessor with integrated Wi-Fi and Bluetooth. Its integrated RF components include Power Amplifier, Low-Noise Receive Amplifier, Antenna Switch, Filters and RF Balun. This makes designing hardware around ESP32 very easy as you require very few external components. Some of its Specifications are-

- Single or Dual-Core 32-bit LX6 Microprocessor with clock frequency up to 240 MHz
- 520 KB of SRAM, 448 KB of ROM and 16 KB of RTC SRAM.
- Supports 802.11 b/g/n Wi-Fi connectivity with speeds up to 150 Mbps.
- Support for both Classic Bluetooth v4.2 and BLE specifications.
- 34 Programmable GPIOs.
- Up to 18 channels of 12-bit SAR ADC and 2 channels of 8-bit DAC
- Serial Connectivity include 4 x SPI, 2 x I2C, 2 x I2S, 3 x UART.
- Ethernet MAC for physical LAN Communication (requires external PHY).
- 1 Host controller for SD/SDIO/MMC and 1 Slave controller for SDIO/SPI.
- Motor PWM and up to 16-channels of LED PWM.
- Secure Boot and Flash Encryption.
- Cryptographic Hardware Acceleration for AES, Hash (SHA-2), RSA, ECC and RNG.

6.5 Manhour Specifications

- Estimate of Man-Hours in Development of Product
  45 (Persons on Team) $\times$ 10 (Hours per member) = 450
- Estimate of Man-Hours in Installations
  17 Stops $\times$ 2 hours per stop = 54 hours
- Estimate of Man-Hours in Maintenance
  Once every month for 17 stops $\times$ 15 mins per stop = 5 hours/month

6.6 Milestone Specifications

Milestone	Description	Division	Marks	TRL
1	Survey	Decision of what to be collected and Methodology	6	TRL-1
		Collecting of data near girls hostel	6	
		Collecting of data near boys hostel	6	
		Collecting of data near Amul and insti area	6	
2	Design of Algorithm	Design of suitable logging mechanism	6	TRL-2
		Design of suitable Communication Protocol	6	
		Design of suitable protocol for Display of bus timings	6	
		Contingencies in case of a Wi-fi failure	6	
3	Model Design	Implementation of basic communication between modules(Wifi and Bluetooth deployment)	6	TRL-3
		Circuit Design of BUk	6	
		Circuit Design of DUk	6	
		CAD Model of device	6	
4	Final Demonstration	Logging of Data	7	TRL-4
		Communication between BUk and DUk	7	
		Communication between BUk and Wi-Fi	7	
		Display of Timings on device	7	

Table 7: Milestone TRL

References

[1] Basics of the I2C Communication Protocol.

[2] DC to DC Buck Converter Tutorial & Diagram | Analog Devices.

[3] Fixed frequency integral sliding-mode current-controlled MPPT boost converter for two-stage PV generation system - Chinnappan - 2019 - IET Circuits, Devices & Systems - Wiley Online Library.

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[7] In-Depth: Interfacing MAX7219 LED Dot Matrix Display with Arduino, October 2020.

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Acronyms

AC Activity Coordinator. 1, 2

BLE Bluetooth Low Energy. 13

BUk k'th Bus Unit. 12

GSM Global System for Mobile Communication. 13

IF Involvement Factor. 1–4, 6

LCD Liquid Crystal Display. 12

LED Light Emitting Diode. 4, 12, 13, 17, 20

PIR Passive Infrared Sensor. 4, 17, 20

TC Tribe Coordinator. 1

TRL Technology Readiness Level. 6, 22

WBS Work Breakdown Structure. 4, 6, 9

Glossary

Accelerometer An accelerometer is a device that measures the vibration, or acceleration of motion, of a structure. 4, 18, 19

ESP32 ESP32 is a series of low-cost, low-power system on a chip microcontrollers with integrated Wi-Fi and dual-mode Bluetooth.. 4, 18, 20

Gyrometer Gyrometers compliment accelerometers as game controllers. The accelerometer can measure linear motion while the gyrometer measures angular velocity or rotational motion. Note. For a more complete implementation, see the gyrometer sample.. 20

IP67 An IP67 rated enclosure offers dust tight protection against solid ingress from sources like windblown dirt. Combine that with strong water resistance to everything from hose sprays to temporary submersion, and it's easy to see why designers often specify IP67 enclosures for their devices.. 12

MPU 6050 The MPU-6050 devices combine a 3-axis gyroscope and a 3-axis accelerometer on the same silicon die, together with an onboard Digital Motion Processor™ (DMP™), which processes complex 6-axis MotionFusion algorithms.. 4, 18, 20

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A Appendix: Document ID

1. Document Type: Private Release
2. Document Authorised by: Subrat Kar, Instructor (subrat@ee.iitd.ac.in)
3. Publication Date: 2 April 2024
4. Version Number: 1.0
5. Github Repository Details: https://github.com/priyallj05/Project-2-NEXTBUS-ELP305

B Appendix: Document Statistics

- Word Count: 4956
- Number of Sentences: 603
- Number of Characters: 32,097

C Appendix: Readability Indices

- **Automated Readability Index[1]:** 21.07
  This means that this text is extremely difficult and can be read by college students, US education standards.
- **Gunning-Fog Index[2]:** 20.3
  This means that the text is extremely difficult and can be understood by a college graduate, US education standards.
- **Flesch Reading Ease[3]:** 30
  This means that this text is difficult to read and can be understood by college students, US education standards.
- **Coleman Liau Index[4]:** 16.67
  This means that the text is extremely difficult to read and can be understood at college level, US education standards.

[1]The automated readability index indicates the approximate reading grade level of a text based on the US education system. The formula takes into account characters in a given word and the words in a given sentence. It varies from 0 - 16+.

[2]On a scale from 0 -20, the Gunning-Fog Index is a weighted average of the number of words per sentence and the number of long words per word. This can be understood as the text can be understood by someone who left full-time education at a later age than the index. Hence a lower Gunning-Fog index is easier to read.

[3]The Flesch Reading Ease indicates the approximate reading grade level of a text. The formula takes into account sentence length and word length. It is based on a 0-100 scale. A high score means that the text is easier to read.

[4]On a scale of 0 - 17+, the Coleman Liau Index relies on characters and calculates the index based on the number of characters in a word and the number of words in a sentence. The score of the text indicates the US school level a person needs to understand the text.