Tribe: CoolBUS

NEXTBUS

ELP305 : Design and System Laboratory

Indian Institute of Technology, Delhi

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Contents

Introduction

1.1 Overall Coordinators

Name	Entry Number	Email ID	IF
Ayush Gupta	2021MT10697	mt1210697@maths.iitd.ac.in	1.0
Aryan Mishra	2021EE10137	ee1210137@ee.iitd.ac.in	1.0

Table 1.1: Overall Coordinators

1.2 Subtribes[a]

1.2.1 Documentation

Name	Entry Number	Email ID	IF
Archisman Biswas	2021MT10254	mt1210254@maths.iitd.ac.in	1.0
Asmit Singh	2021MT10887	mt1210887@maths.iitd.ac.in	1.0
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Navneet Raj	2021MT10240	mt1210240@maths.iitd.ac.in	1.0
Neelam Kumari Meena	2021MT10938	mt1210938@maths.iitd.ac.in	1.0
Nikhil Choudhary	2020MT10826	mt1200826@maths.iitd.ac.in	0.8
Purushottam Malviya	2020EE10531	ee1200531@ee.iitd.ac.in	1.0
Rahul Bhardwaj	2020MT60877	mt6200877@maths.iitd.ac.in	1.0
Saket Kandoi	2021MT60265	mt6210265@maths.iitd.ac.in	0.95
Sanjay Pooniya	2021EE10148	ee1210148@ee.iitd.ac.in	1.0
Sanskriti Gautam	2021MT10935	mt1210935@maths.iitd.ac.in	0.6
Vaibhav Seth	2021MT10236	mt1210236@maths.iitd.ac.in	1.0

Table 1.2: Documentation

[a] ***Activity Coordinator*** written in bold

1.2.2 APD[b]

Name	Entry Number	Email ID	IF
Shubham Aggarwal	2021EE10809	ee1210809@ee.iitd.ac.in	0.9
Yash Goel	2021EE10984	ee1210984@ee.iitd.ac.in	0.9
Aditya Jain	2021EE10633	ee1210633@ee.iitd.ac.in	0.65
Ameya Mishra	2021MT10637	mt1210637@maths.iitd.ac.in	0.65
Anchal	2021MT10910	mt1210910@maths.iitd.ac.in	0.65
Aniket Abhiraj	2021EE10676	ee1210676@ee.iitd.ac.in	0.65
Aniket Singh	2021MT10256	mt1210256@maths.iitd.ac.in	0.65
Anshul	2021EE10729	ee1210729@ee.iitd.ac.in	0.8
Ark Verma	2021EE10783	ee1210783@ee.iitd.ac.in	0.8
Arnav Goel	2021EE10699	ee1210699@ee.iitd.ac.in	0.65
Aryan Gupta	2021EE10974	ee1210974@ee.iitd.ac.in	0.8
Dhruv Kushwaha	2021MT10235	mt1210235@maths.iitd.ac.in	0.65
Harsh Agarwal	2021EE30977	ee3210977@ee.iitd.ac.in	0.8
Harsh Swaika	2021EE11052	ee1211052@ee.iitd.ac.in	0.65
Harshit Sachdeva	2021EE30705	ee3210705@ee.iitd.ac.in	0.65
Harshit Singh	2021MT10257	mt1210257@maths.iitd.ac.in	0.65
Kaustubh Dev	2021EE10689	ee1210689@ee.iitd.ac.in	0.65
Khushika Shringi	2021EE10665	ee1210665@ee.iitd.ac.in	0.8
Khushvind Maurya	2021MT10238	mt1210238@maths.iitd.ac.in	0.65
Kinjal Anchhara	2021MT60959	mt6210959@maths.iitd.ac.in	0.8
Maithili Joshi	2021EE10653	ee1210653@ee.iitd.ac.in	0.65
Mohit Raj Modi	2021MT10919	mt1210919@maths.iitd.ac.in	0.8
Mridul Ahi	2021MT10901	mt1210901@maths.iitd.ac.in	0.65
Namay Bedi Verma	2021MT61051	mt6211051@maths.iitd.ac.in	0.65
Oshin Kavdia	2021EE10654	ee1210654@ee.iitd.ac.in	0.65
Rohan Das	2021EE10621	ee1210621@ee.iitd.ac.in	0.65
Sai Raj Kolisetti	2021EE10145	ee1210145@ee.iitd.ac.in	0.8
Sarthak Kumar Singh	2021EE10673	ee1210673@ee.iitd.ac.in	0.8
Shubh Chhabra	2021EE10645	ee1210645@ee.iitd.ac.in	0.8
Abhinav Verma	2021EE10978	ee1210978@ee.iitd.ac.in	1.0
Ujjwal Yadav	2021EE10669	ee1210669@ee.iitd.ac.in	0.65
Vishal Sai Bingi	2021EE10668	ee1210668@ee.iitd.ac.in	0.65
Vasu Sharma	2021EE10620	ee1210620@ee.iitd.ac.in	0.65

Table 1.3: APD

[b] Algorithms and Protocols Design

1.2.3 HND[c]

Name	Entry Number	Email ID	IF
Joel Arun Kumar	2021EE10159	ee1210159@ee.iitd.ac.in	1.0
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Abhilasa Das	2021EE10168	ee1210168@ee.iitd.ac.in	0.75
Aditi Shekhar	2021EE10685	ee1210685@ee.iitd.ac.in	0.75
Advait Rajesh Ninawe	2021EE30714	ee3210714@ee.iitd.ac.in	0.6
Ayush Kumar	2021EE10150	ee1210150@ee.iitd.ac.in	1.0
Chetan Chaurasia	2021EE10147	ee1210147@ee.iitd.ac.in	0.68
Chirag Gautam	2021EE10166	ee1210166@ee.iitd.ac.in	0.68
Deepanshu Kumar	2021EE10696	ee1210696@ee.iitd.ac.in	0.68
Disha Katia	2021EE10647	ee1210647@ee.iitd.ac.in	0.75
Durgesh Nandini	2021EE10651	ee1210651@ee.iitd.ac.in	0.75
Eepsita	2021EE10692	ee1210692@ee.iitd.ac.in	0.75
Garvit Dhoot	2021EE30823	ee3210823@ee.iitd.ac.in	0.6
Himanshu	2021EE30177	ee3210177@ee.iitd.ac.in	0.75
Rishabh Barola	2021EE10636	ee1210636@ee.iitd.ac.in	1.0
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Kartavya Khurana	2021EE30710	ee3210710@ee.iitd.ac.in	0.6
Pooja Mahajan	2021EE10652	ee1210652@ee.iitd.ac.in	0.75
Pramukh Jain	2021EE10720	ee1210720@ee.iitd.ac.in	0.75
Ravi Parihar	2021EE10156	ee1210156@ee.iitd.ac.in	0.805
Sheetal Manatawal	2021EE10174	ee1210174@ee.iitd.ac.in	0.565
Shivam Kumar	2021EE10165	ee1210165@ee.iitd.ac.in	0.75
Sudhanshu Raj	2021EE10132	ee1210132@ee.iitd.ac.in	0.445
Tanmai Merugu	2021EE10149	ee1210149@ee.iitd.ac.in	0.6
Vikas Meena	2021EE10169	ee1210169@ee.iitd.ac.in	0.75
Vinay Sah	2021EE10171	ee1210171@ee.iitd.ac.in	0.68

Table 1.4: HND

1.3 Tribe Members with IF less than 1

1.3.1 Documentation

Name	Entry Number	Email ID	IF
Nikhil Choudhary	2020MT10826	mt1200826@maths.iitd.ac.in	0.8
Saket Kandoi	2021MT60265	mt6210265@maths.iitd.ac.in	0.95
Sanskriti Gautam	2021MT10935	mt1210935@maths.iitd.ac.in	0.6

Table 1.5: IF less than 1 (Documentation)

[c] Hardware and Network Design

1.3.2 APD

Name	Entry Number	Email ID	IF
Aditya Jain	2021EE10633	ee1210633@ee.iitd.ac.in	0.65
Ameya Mishra	2021MT10637	mt1210637@maths.iitd.ac.in	0.65
Anchal	2021MT10910	mt1210910@maths.iitd.ac.in	0.65
Aniket Abhiraj	2021EE10676	ee1210676@ee.iitd.ac.in	0.65
Aniket Singh	2021MT10256	mt1210256@maths.iitd.ac.in	0.65
Anshul	2021EE10729	ee1210729@ee.iitd.ac.in	0.8
Ark Verma	2021EE10783	ee1210783@ee.iitd.ac.in	0.8
Arnav Goel	2021EE10699	ee1210699@ee.iitd.ac.in	0.65
Aryan Gupta	2021EE10974	ee1210974@ee.iitd.ac.in	0.8
Dhruv Kushwaha	2021MT10235	mt1210235@maths.iitd.ac.in	0.65
Harsh Agarwal	2021EE30977	ee3210977@ee.iitd.ac.in	0.8
Harsh Swaika	2021EE11052	ee1211052@ee.iitd.ac.in	0.65
Harshit Sachdeva	2021EE30705	ee3210705@ee.iitd.ac.in	0.65
Harshit Singh	2021MT10257	mt1210257@maths.iitd.ac.in	0.65
Kaustubh Dev	2021EE10689	ee1210689@ee.iitd.ac.in	0.65
Khushika Shringi	2021EE10665	ee1210665@ee.iitd.ac.in	0.8
Khushvind Maurya	2021MT10238	mt1210238@maths.iitd.ac.in	0.65
Kinjal Anchhara	2021MT60959	mt6210959@maths.iitd.ac.in	0.8
Maithili Joshi	2021EE10653	ee1210653@ee.iitd.ac.in	0.65
Mohit Raj Modi	2021MT10919	mt1210919@maths.iitd.ac.in	0.8
Mridul Ahi	2021MT10901	mt1210901@maths.iitd.ac.in	0.65
Namay Bedi Verma	2021MT61051	mt6211051@maths.iitd.ac.in	0.65
Oshin Kavdia	2021EE10654	ee1210654@ee.iitd.ac.in	0.65
Rohan Das	2021EE10621	ee1210621@ee.iitd.ac.in	0.65
Sai Raj Kolisetti	2021EE10145	ee1210145@ee.iitd.ac.in	0.65
Sarthak Kumar Singh	2021EE10673	ee1210673@ee.iitd.ac.in	0.8
Shubh Chhabra	2021EE10645	ee1210645@ee.iitd.ac.in	0.8
Shubham Aggarwal	2021EE10809	ee1210809@ee.iitd.ac.in	0.9
Ujjwal Yadav	2021EE10669	ee1210669@ee.iitd.ac.in	0.65
Vishal Sai Bingi	2021EE10668	ee1210668@ee.iitd.ac.in	0.65
Yash Goel	2021EE10984	ee1210984@ee.iitd.ac.in	0.9
Vasu Sharma	2021EE10620	ee1210620@ee.iitd.ac.in	0.65

Table 1.6: IF less than 1 (APD)

1.3.3 HND

Name	Entry Number	Email ID	IF
Abhilasa Das	2021EE10168	ee1210168@ee.iitd.ac.in	0.75
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Advait Rajesh Ninawe	2021EE30714	ee3210714@ee.iitd.ac.in	0.6

Chetan Chaurasia	2021EE10147	ee1210147@ee.iitd.ac.in	0.68
Chirag Gautam	2021EE10166	ee1210166@ee.iitd.ac.in	0.68
Deepanshu Kumar	2021EE10696	ee1210696@ee.iitd.ac.in	0.68
Disha Katia	2021EE10647	ee1210647@ee.iitd.ac.in	0.75
Durgesh Nandini	2021EE10651	ee1210651@ee.iitd.ac.in	0.75
Eepsita	2021EE10692	ee1210692@ee.iitd.ac.in	0.75
Garvit Dhoot	2021EE30823	ee3210823@ee.iitd.ac.in	0.6
Himanshu	2021EE30177	ee3210177@ee.iitd.ac.in	0.75
Kalu Ram Tard	2021EE10680	ee1210680@ee.iitd.ac.in	0.875
Kartavya Khurana	2021EE30710	ee3210710@ee.iitd.ac.in	0.6
Pooja Mahajan	2021EE10652	ee1210652@ee.iitd.ac.in	0.75
Pramukh Jain	2021EE10720	ee1210720@ee.iitd.ac.in	0.75
Ravi Parihar	2021EE10156	ee1210156@ee.iitd.ac.in	0.805
Sheetal Manatawal	2021EE10174	ee1210174@ee.iitd.ac.in	0.565
Shivam Kumar	2021EE10165	ee1210165@ee.iitd.ac.in	0.75
Sudhanshu Raj	2021EE10132	ee1210132@ee.iitd.ac.in	0.445
Tanmai Merugu	2021EE10149	ee1210149@ee.iitd.ac.in	0.6
Vikas Meena	2021EE10169	ee1210169@ee.iitd.ac.in	0.75
Vinay Sah	2021EE10171	ee1210171@ee.iitd.ac.in	0.68
Yash Agarwal	2021EE10638	ee1210638@ee.iitd.ac.in	0.75

Table 1.7: IF less than 1 (HND)

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1.4 Acronyms

WBS Work Breakdown Structure

IF Involvement Factor

USB Universal Serial Bus

GPS Global Positioning System

Wi-Fi Wireless Fidelity

DC Direct Current

MPPT Maximum Power Point Tracking

PWM Pulse Width Modulation

BUk Bus Unit for kth bus

LED light-emitting diode

LHC Lecture Hall Complex

ECDH Elliptic Curve Diffie-Hellman

AES Advanced Encryption Standard

OSI Open Systems Interconnection Model

RSSI Received Signal Strength Indicator

SPI Serial Peripheral Interface

QSPI Quad Serial Peripheral Interface

IEEE Institute of Electrical and Electronics Engineers

1.5 Mind Maps

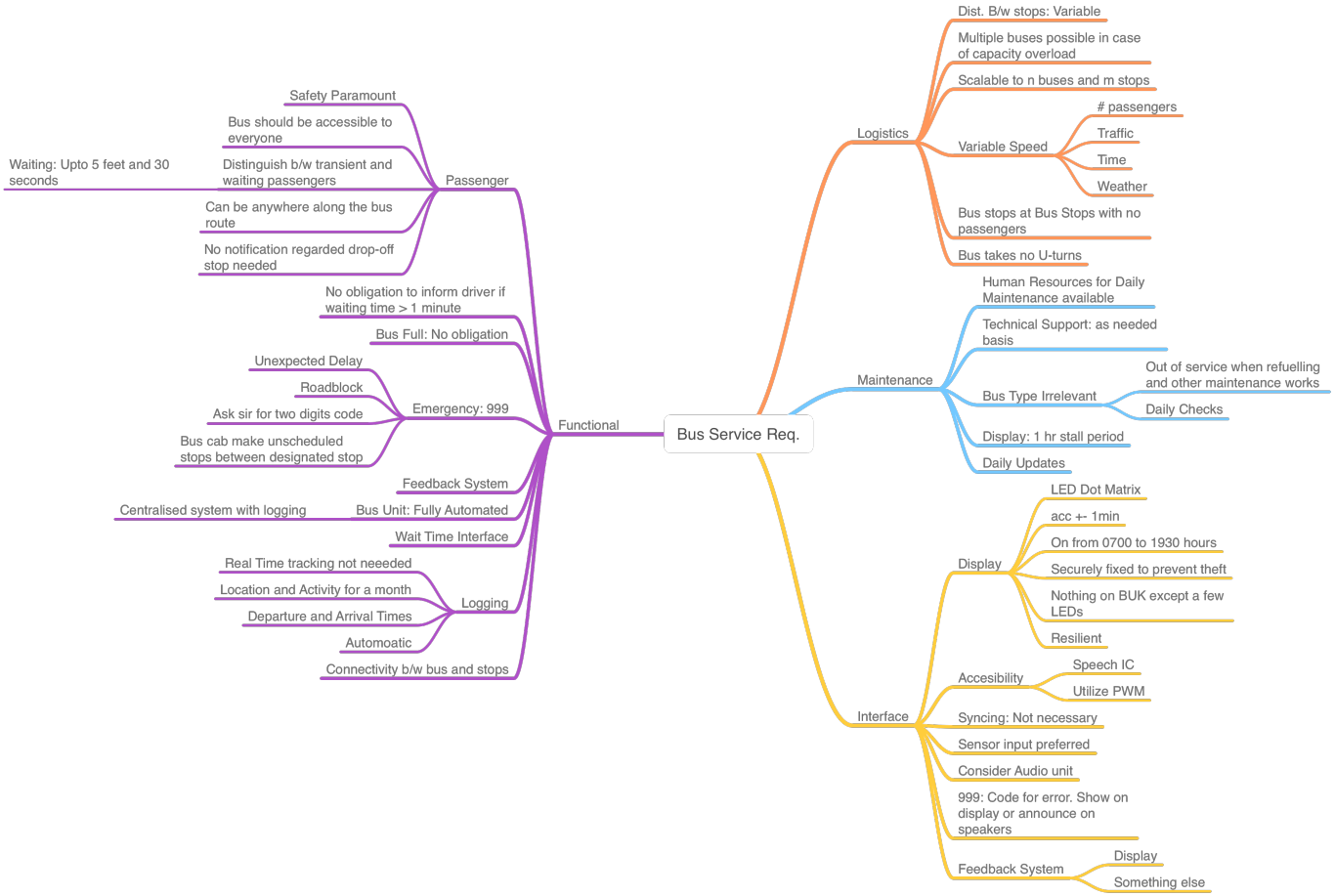

Figure 1.1: **Mind Map emphasizing the requirements** (Made using *MindNote*)

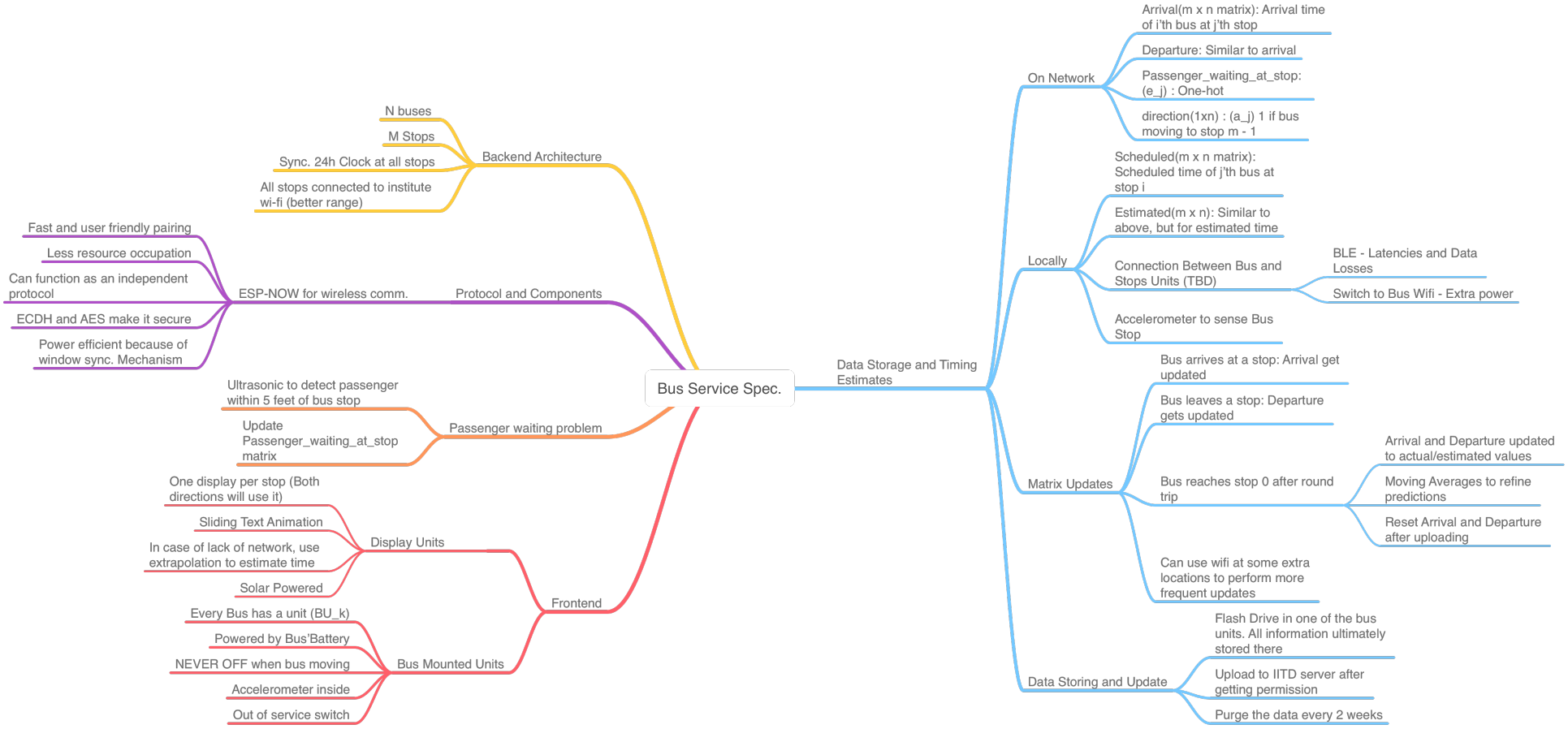

Figure 1.2: **Mind Map emphasizing the Specification** (Made using *MindNote*)

1.6 Project Management Details

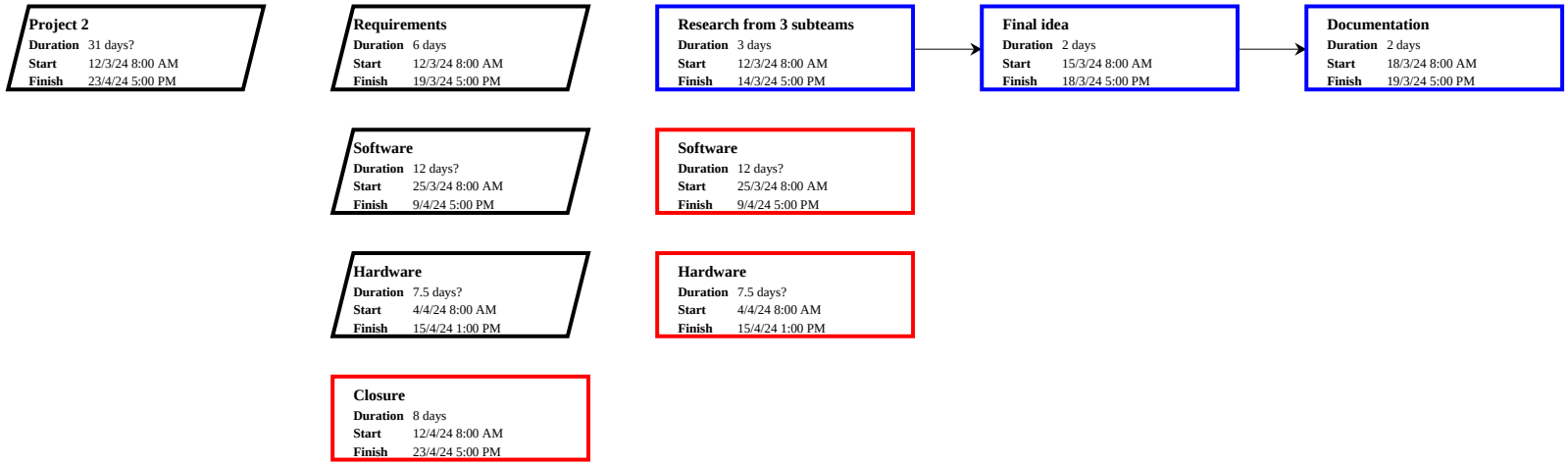

Figure 1.3: **Network Chart** (Created using *Project Libre*)

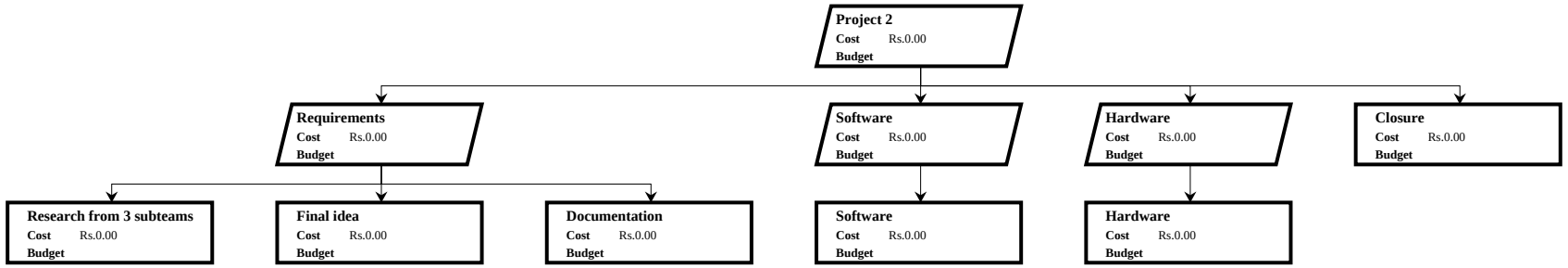

Figure 1.4: **WBS Chart** (Created using *Project Libre*)

		Name	Duration	Start	Finish	Predecessors
1	✔	**Project 2**	**31 days?**	**12/3/24 8:00 ...**	**23/4/24 5:0...**	
2	✔	**Requirements**	**6 days**	**12/3/24 8:00 ...**	**19/3/24 5:0...**	
3	✔	Research from 3 subteams	3 days	12/3/24 8:00 AM	14/3/24 5:00 PM	
4	✔	Final idea	2 days	15/3/24 8:00 AM	18/3/24 5:00 PM	3
5	✔	Documentation	2 days	18/3/24 8:00 AM	19/3/24 5:00 PM	4
6	✔	**Software**	**12 days?**	**25/3/24 8:00 ...**	**9/4/24 5:00 ...**	
7	✔	Software	12 days?	25/3/24 8:00 AM	9/4/24 5:00 PM	
8	✔	**Hardware**	**7.5 day...**	**4/4/24 8:00 AM**	**15/4/24 1:0...**	
9	✔	Hardware	7.5 days?	4/4/24 8:00 AM	15/4/24 1:00 PM	

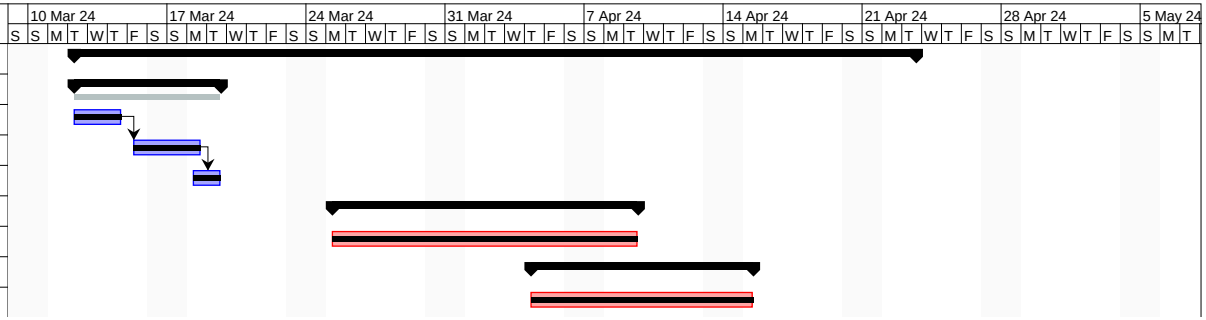

Figure 1.5: **Gantt Chart** (Created using *Project Libre*)

		Name	Type	Text1	Text2	Base Calendar
1		Abhilasa Das	Work	Research	Arduino	Standard
2		Abhinav Verma	Work	Research	Arduino IDE with ESP32 Add...	Standard
3		Aditi Shekhar	Work	Research	LED Dot matrix display, Sola...	Standard
4		Aditya Jain	Work	Research		Standard
5		Advait Rajesh Ninawe	Work	Research	Arduino IDE, Connection of ...	Standard
6		Ameya Mishra	Work	Research	Arduino, CPP	Standard
7		Anchal	Work	Research based work on ho...	C++, Arduino	Standard
8		Aniket Abhiraj	Work	Research	C++, C , Arduino	Standard
9		Aniket Singh	Work	Overleaf, LaTeX, GitHub Act...	Arduino, C/C++.	Standard
10		Anshul	Work	Research		Standard
11		Archisman Biswas	Work	Research		Standard
12		Ark Verma	Work	Research	Arduino, C	Standard
13		Arnav Goel	Work	Research	Arduino code in C	Standard
14		Aryan Gupta	Work	Research	Arduino	Standard
15		Aryan Mishra	Work	RF communication, GPS mod...	ESPNOW Protocol, Protocol ...	Standard
16		Asmit Singh	Work	Research	LaTeX, Overleaf, GitHub, P...	Standard
17		Ayush Gupta	Work	Research		Standard
18		Ayush Kumar	Work	Research	solar pannel, mpu6050,esp32	Standard
19		Chetan Chaurasia	Work	Research		Standard
20		Chirag Gautam	Work	Research, Problem Solving		Standard
21		Deepanshu Kumar	Work	Research	Hardware work	Standard
22		Dhruv Kushwaha	Work	7 segment display		Standard
23		Disha Katia	Work	LCD design, Arduino, triger i...		Standard
24		Durgesh Nandini	Work	Research on occupancy esti...		Standard
25		Eepsita	Work	Research	Arduino	Standard
26		Garvit Dhoot	Work	Research, Browsing, Brainst...		Standard
27		Harsh Agarwal	Work	Research	Doxygen, Arduino, C++	Standard
28		Harsh Swaika	Work	Research	C	Standard
29		Harshit Sachdeva	Work	Research	Arduino code in C	Standard
30		Harshit Singh	Work	Research	VsCode, ArduinoIDE, Wokwi	Standard
31		Himanshu	Work	Research		Standard
32		Joel Arun Kumar Yenubotula	Work	Latex		Standard
33		Kalu Ram Tard	Work	Research, Survey	ESP32, MPU6050 (accelero...	Standard
34		Kartavya Khurana	Work	Research	Connecting two ESP32's con...	Standard
35		Kaustubh Dev	Work	Research		Standard
36		Khushika Shringi	Work	RF communication, System ...	Arduino IDE with ESP32 add...	Standard
37		Khushvind Maurya	Work	Hardware selection	Arduino, C	Standard
38		Kinjal Anchhara	Work	Research	Arduino, C	Standard
39		Maithili Joshi	Work	Research		Standard
40		Mohit Raj Modi	Work	ESP32, networks	Arduino, C	Standard
41		Mridul Ahi	Work	Research	Adruino IDE, C++	Standard
42		Musaib Gani Pirzada	Work	Research	Project-Libre	Standard
43		Namay Bedi Verma	Work	Research		Standard
44		Navneet Raj	Work	Research		Standard
45		Neelam Kumari Meena	Work	Documentation	Latex , Github	Standard
46		Nikhil Choudhary	Work	LaTeX, GitHub, Obsidian/Me...		Standard
47		Oshin Kavdia	Work	Research	Adruino IDE, C++	Standard
48		Pooja Mahajan	Work	Research	Aurdino IDE, ESP32, Dot Ma...	Standard
49		Pramukh Jain	Work	Research on LoRa wireless c...	ESP Now Range Check, Sold...	Standard
50		Purushottam Malviya	Work	Research, transmission tech...		Standard
51		Rahul Bhardwaj	Work	Research		Standard
52		Ravi Parihar	Work	Research		Standard
53		Rishabh Barola	Work	Analysis and Design of Algor...	Dot matrix debugging, PIR c...	Standard

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(a)

Figure 1.6: **Resource Breakdown** (Created using *Project Libre*)

		Name	Type	Text1	Text2	Base Calendar
54		Rohan Das	Work	Research	Arduino, C, Code Conversion	Standard
55		Sai Raj Kolisetti	Work	Research		Standard
56		Saket Kandoi	Work	primarily researched on diff...		Standard
57		Sanjay Pooniya	Work	Projectlibre		Standard
58		Sanskriti Gautam	Work	...		Standard
59		Sarthak Kumar Singh	Work	...	Arduino Programming	Standard
60		Sheetal Manatawal	Work	...		Standard
61		Shivam Kumar	Work	Research		Standard
62		Shubh Chhabra	Work	Research	Arduino Programming	Standard
63		Shubham Aggarwal	Work	Latex		Standard
64		Sudhanshu Raj	Work	Research		Standard
65		Tanmai Merugu	Work	Latex		Standard
66		Ujjwal Yadav	Work	...	Arduino Programming	Standard
67		Vaibhav Seth	Work	...		Standard
68		Vasu Sharma	Work	...	Arduino IDE, C++ for Ardui...	Standard
69		Vikas Meena	Work	...		Standard
70		Vinay Sah	Work	...		Standard
71		Vishal Sai Bingi	Work	2021EE10668	Arduino, C	Standard
72		Yash Agarwal	Work	2021EE10638		Standard
73		Yash Goel	Work	2021EE10984	ESP32 Add-on in Arduino IDE	Standard

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(b)

Figure 1.6: **Resource Breakdown** (Created using *Project Libre*)

Abstract

This project introduces a system to assist users availing the bus facility inside the campus. Our solution consists of a Bus Mounted Unit that shows information about the bus's status on each bus as well as a sturdy, easily readable Display Unit at each stop that informs passengers of the bus's anticipated arrival time (as well as other important details). In addition to making an effort to be economical and energy-efficient, the system helps passengers by giving them important and beneficial details about the buses. This paper details the design process and technological integrations of this comprehensive bus assistance solution.

1.7 Motivation

The existing bus transit system on campus lacks effectiveness, accessibility, and convenience. Uncertain wait times make it challenging for passengers to decide whether to wait for the next bus or seek alternative transportation. Recognizing this limitation, we are developing a solution to address this issue and enhance the convenience of the bus transportation system for passengers. We maximise renewable energy (in the form of solar energy) usage for this solution to minimise any overhead power costs and make a greener solution.

Requirements

2.1 Functional Requirements

1. Passenger Wait Times : Speeding to compensate for delays, even after a passenger waits over a minute and notifies the driver, is prohibited. Safety is paramount and arrival times may fluctuate accordingly

2. Driver Notification : There's no obligation to inform the driver if a passenger waits for more than a minute. Waiting time is restricted to passenger boarding and deboarding

3. Bus Full Indicator : The driver is not obligated to provide information to waiting passengers regarding the availability of space

4. Road Incidents Update : When there's an unexpected delay or a roadblock, the display will flash '999' to signal an emergency

5. Feedback Mechanism : A digital interface could be implemented for users to provide feedback or report issues related to bus services

6. Automation of Bus Unit Operation : It needs to be fully automated, manual input from the driver or staff for every bus direction change or stop is not expected

7. Wait Time Interface : An interface can be devised to allow individuals heading to the bus stop to access information regarding the wait time

8. Passenger Notification : Notifying the bus driver about a waiting passenger does not affect the bus route, even if the bus is empty

9. Empty Bus Stops : The bus stops at empty bus stop as well, for passenger deboarding

10. System Timeline : The desired timeline for the development, testing, and deployment of the system is April 25th, 2025

11. Real-Time Tracking : Real-time tracking of every bus is not required, but it is suggested to keep track of location and travel activity logs for around a month. Only have to keep a log of arrival and departure times at every bus stop, and this activity log is to be stored for the long term. (Can be done at appropriate frequency, no need for real time)

12. Bus U-turn : There may not be sufficient space at every stop for the bus to make a *U-turn* and onboard passengers on the reverse path. Bus follows its route strictly, does not make U-Turns

13. Accessibility Priority : Prioritizing full accessibility for all campus residents on the bus service is not necessary

14. Location Exchange : There's no need for each bus to be informed about the location of other buses

15. Early Departure : Buses should not depart early, even if passengers have been waiting for over a minute, as it can confuse passengers and cause inconvenience

16. Stop Wait Time : Buses typically aim to depart from each stop promptly after passengers have finished boarding and alighting

17. Arrival and Departure Logging : The logging of bus arrival and departure must be automatic and cannot rely on manual input, ensuring accuracy and efficiency in tracking bus movements

18. Centralized Management : The bus service is centrally managed, with everything logged. While there's no real-time monitoring, logs are available for review

19. Passenger Drop-off Notification : There is no notification received when a passenger enters the bus regarding their drop-off

20. Bus Bypass Protocol : If the bus is already full, the driver does not need to stop the bus at every subsequent stop

21. Connectivity Focus :Connectivity is exclusively between buses and stops, with no direct communication link to passengers

22. Capacity Information : It is unnecessary to display a bus's full status at upcoming stops, as passengers may alight at any point, which remains unpredictable to the driver

23. Emergency Stops : In emergency situations, like a passenger feeling nauseous, the bus will make unscheduled stops between designated stops to address the issue and prioritizing passenger safety and well-being

24. Waiting Passengers : The system should distinguish between transient presence and waiting passengers standing up to 5 feet from the bus stop pole for more than 30 seconds. Any passerby standing for 0.5 minutes would qualify them as a potential passenger, this wrong identification is allowed

25. Following Route : Route to be followed and stops to be made should be a fully automated decision

26. Location of Waiting Passengers : The passenger can be waiting anywhere along the route, not necessarily at the next bus stop

27. Account for Delays: Assuming the bus may not always reach X at 8 AM sharp to start the shift

2.2 Logistical Requirements

1. Stop Limits : The number of stops allowed between origin and destination is predetermined by the institute's system
2. Stop Distribution : The spacing between stops is not consistent and needs to be surveyed for accurate measurement
3. Bus Operation : If the number of passengers at the starting station exceeds the capacity of one bus, two buses can be operated simultaneously
4. Bus Deployment : At the moment, there are only 2 buses available. The design needs to consider scalability aspects to accommodate demand fluctuations
5. Bus Speed : Bus speed can vary depending on the amount of traffic, the number of passenger stops, the time of day, the weather, and the quality of the road
6. Alternative Transportation : No alternative transportation options are readily accessible to users
7. Design Scalability : When designing the architecture, the primary scalability considerations to focus on are the number of buses and the number of stations

2.3 Interface Requirements

1. Display Method : Use of an *LED dot matrix display*
2. Accuracy :The reading on the display must be accurate to ± 1 minute
3. Duration Of Activity : Must remain active only between 0700 to 1930 hours, powering on/off should be automated
4. Display Mounting : Secure mounting to prevent theft. Mechanical fixation at unreachable height
5. Accessibility for Visually Impaired : Utilize Pulse Width Modulation (PWM) output or speech IC for accessibility
6. Syncing Capacity : Not necessary for synchronization
7. Budget Constraints : To be Made as cost-efficient as possible
8. Passenger Input : Prefer sensor-based input
9. Audio Announcement : Consider installing an *audio unit*
10. Bus Unit for kth bus (BUk) Functionality : No display on BUk, includes some visual confirmation LEDs
11. Passenger Waiting Notification : Separate indicator integrated into BUk
12. Error Indicator : The Display would read '999' to indicate emergency or unforeseen delays

13. Feedback System : Are there any means for taking feedback from the users or for reporting issues related to bus services?

14. Resilient : Display is exposed to all Delhi weather conditions

2.4 Readability Requirements

1. Base Visibility : Must be readable from any point by a person with *6/6 vision* standing at upto 8 feet in front of the bus stop

2. Visibility in Varied Weather : Clarification on visibility criteria under different weather conditions. Consideration of weather factors in New Delhi, including *smog* and rain

3. Performance Metrics : Identification of specific performance metrics. Proposal to use start times, stop arrival/departure times, and out-of-service durations for evaluation

2.5 Power Requirements

1. Power Supply : Display Unit must be battery-powered. Solar power to be used. It cannot be delivered directly to the *Embedded system*

2. Alternative Power : Solar energy reliability in peak Delhi winter. Suggestions for backup power sources such as larger batteries or panels. Consensus needed on procurement across stakeholders

3. Connection Details :
   Solar Panel→ AC/Direct Current (DC) converter → capacitor → Embedded system
   OR
   Solar Panel → PWM converter (or MPPT converter) → USB → Embedded system

4. Location of Source of Solar Power :Must be installed at a nearby sunny point and directed to nearby bus stop

2.6 Maintenance Requirements

1. Maintenance Feasibility : Human resources are available for daily maintenance of the stops, making monthly maintenance feasible

2. Technical Support : While the system is designed for minimal human intervention, technical support is available on an as-needed basis to address any technical issues that may arise

3. Bus Maintenance : Bus type (electric or not) is not relevant .bus will be labeled as "Out of Service" during refueling, washing, and other maintenance issues. Maintenance checks to be carried out on a daily basis

4. Display Malfunction : In the event of an unforeseen malfunction in the display unit, a *stall period* of 1 hour will be allowed to fix the issue

5. Daily Updates : Service is under the Transport Section which needs certain data to be provided on a daily basis

Specifications

3.1 Backend Architecture Specifications

- There are n buses: $0, 1, 2, \ldots n-1$
- There are m stops: $0, 1, 2, \ldots m-1$ (0: first stop, $m-1$: last stop)
- We have to synchronize the *24-hour clock* at each stop
- In this system, all bus shifts end at the starting stop, i.e. the bus shift ends when the bus is back at the 0^{th} stop. The sequence followed in a shift is
  $0 \to 1 \to 2 \to 3 \to \ldots \to m-2 \to m-1 \to m-2 \to \ldots \to 3 \to 2 \to 1 \to 0$

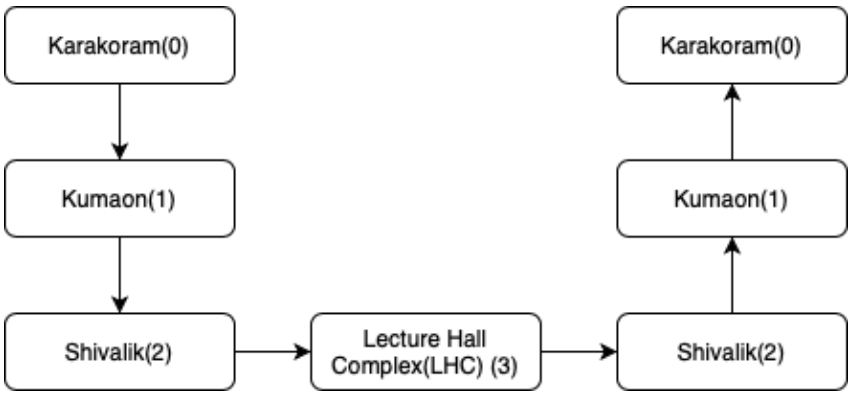


Figure 3.1: **Example route for m = 4**

- All these stops will be connected to the institute's WiFi service, which will be used to transmit relevant information to all the stops
- We use WiFi even when the ESP32 has the option of BLE because:
  - BLEs indoor range is around 100 m, but outdoors the signals are attenuated and therefore the range reduces
  - We need to cover a route of approximately 2 km using 4 bus units. Therefore using BLE is not feasible unless we can have bus stops every 50-100 metres, which seems impractical.

3.1.1 Data Storage and Timing Estimates

Over the Network

1. Maintain the $\textbf{Arrival}_{\text{mxn}}$ matrix : Element (i, j) stores the arrival time of j^{th} bus at the i^{th} stop

2. Maintain the $\textbf{Departure}_{\text{mxn}}$ matrix : Element (i, j) stores the departure time of j^{th} bus at the i^{th} stop

3. Maintain the $\textbf{PassengerWaitingAtStop}_{\text{1xm}}$ matrix : Element $(0, j)$ is x where

$$x = \begin{cases} 1 & \text{if any passenger is waiting at the j}^{\text{th}} \text{ stop} \\ 0 & \text{otherwise} \end{cases}$$

4. Maintain the $\textbf{Direction}_{\text{1xn}}$ matrix : Element (0, j) is x where

$$x = \begin{cases} 0 & \text{if } j^{\text{th}} \text{ bus is moving towards } 0^{\text{th}} \text{ stop} \\ 1 & \text{if } j^{\text{th}} \text{ bus is moving towards } m-1^{\text{th}} \text{ stop} \end{cases}$$

Locally

1. Maintain the $\textbf{Scheduled}_{\text{mxn}}$ matrix: Element (i, j) stores the scheduled time of the j^{th} bus at the i^{th} stop

2. Maintain the $\textbf{Estimated}_{\text{mxn}}$ matrix: Element (i, j) stores the estimated time of the j^{th} bus at the i^{th} stop

3. These matrices can be stored for estimation of arrival times, the passenger waiting functionality

4. **Connection of Bus Units with Stop Units:**

   - Make the Stop Unit switch to the Bus Unit Wifi when available- this method will use more power
   - BLE based connection between Bus and Stop Units- this method will be more power efficient but will involve 2 signals on the same antenna, which might lead to unexpected latencies and data losses

   This mechanism will be finalised only after availability of the hardware, after testing it in our conditions.

5. For sensing whether the bus has stopped or not, we are using *accelerometer* reading.

6. When j^{th} bus arrives at the i^{th} stop: $(i, j)^{\text{th}}$ element of the **Arrival** matrix is updated. Bus stop 'i' acts as the server, and all other bus stops act as clients

7. When j^{th} bus departs the i^{th} stop: $(i, j)^{\text{th}}$ element of the **Departure** matrix is updated. All arrival times of j^{th} column are updated to new estimate times based on average time between stops and departure time from i^{th} stop

8. **Bus stop nodes that can access this matrix** (i.e. nodes that are connected to the network):

   - Arrival time of next bus at i^{th} stop= min$\{i^{\text{th}}$ row$\}$
   - Suppose that j the next bus arriving at i^{th} stop $= j$
   - Direction of next bus = j^{th} element of **Direction** matrix
   - Both Arrival time and Direction of buses needs to be communicated to the commuters

9. **Bus stop nodes that cannot access this matrix** (i.e. nodes that unexpectedly get disconnected):

   - Arrival times of each bus estimated using scheduled time and last known whereabouts of buses:
     Estimated time = Scheduled time + (last known deviation from scheduled time)
   - If estimated time shows a large deviation from scheduled time, we will use scheduled time instead of estimated time
   - Direction matrix can be updated based on these estimates: Direction of j^{th} bus switches when arrival time of stop $m-1$ is crossed
   - Similar to the previous case, both Arrival time and Direction of buses needs to be communicated to the commuters

10. **When the bus reaches stop** 0 **after a *round trip***:

    - The **Arrival** and **Departure** matrices are updated to actual/estimated arrival and departure values, and this can be used to keep log of actual arrival and departure times in the system
    - Moving average of previous runs can be used to refine predictions
    - After uploading these times, we reset **Arrival** and **Departure** matrices to scheduled times

11. **Storing arrival and departure data of buses:**

    - We have a flash drive in one of the bus units, and all information is ultimately stored in that unit. It can be retrieved when required from the bus unit (manually) by the transport department
    - We get the permission to upload all this data on transport department's disk on IITD server.

    Since the data is not much and also not very important to store over a long period of time, we purge the data every 2 weeks. These mechanisms will be finalised later, only after analysing the hardware available to us.

12. **For more frequent time updates:**

    - We can specify some locations (using *GPS*) where *Wi-Fi* is available on the route and send quick location updates to the network

- These locations can be used as pseudo-stops, where the Bus Unit directly informs all Bus Stop nodes its location which can be further used to refine time predictions

3.1.2 Passenger waiting problem

1. We can use an *ultrasonic sensor* at each stop to detect any passenger standing within 5 feet of the bus stop. If the sensor detects an obstacle within 5 feet for more than 30 seconds, then the $(0, j)^{th}$ entry of $\mathbf{PassengerWaitingAtStop}_{1xm}$ matrix is updated
2. The bus unit stores a variable **PassengerWaiting** where **PassengerWaiting** = OR(all elements of **PassengerWaitingAtStop**)
3. This variable can be updated at every stop/pseudo stop

3.2 Frontend Specifications

3.2.1 Display Unit

1. These units will be mounted at every bus stop
2. This unit will tell the time left for the buses from both direction to arrive at the station using the *sliding text animation*
3. There will be one display unit per bus stop. Directional information will be displayed on the unit for buses from both directions
4. When the units cannot connect to network, the time of arrival will be an extrapolation of the past arrival time data. The time of arrival will blink telling the maintenance staff that the unit is not connected to the network, but for the normal people it will be just the time of arrival
5. The display unit will be solar power. This is the connection to be followed:
   Solar Panel→ AC/DC converter → capacitor → Embedded system
   OR
   Solar Panel → PWM converter (or MPPT converter) → Universal Serial Bus (USB) → Embedded Systems

3.2.2 Bus Mounted Units

1. Every bus will have a unit (BUk for the k^{th} bus)
2. The units will be powered from the battery of the bus
3. While the bus is moving, these units will never be turned OFF
4. These units will contain *accelerometer* (to determine the state of the bus whether it is moving or not)
5. These units will also contain a RED switch, when pressed it will signal the system that the bus is OUT OF SERVICE

3.3 Cost Specifications

3.3.1 Bus Stop Unit

The individual components are as follows:

Component	Cost	Source
Solar Charge Controller	**Rs. 150**	[1]
10W/12V Solar Panel	**Rs. 890**	[2]
ESP32 Development Board with Wifi and Bluetooth	**Rs. 345**	[3]
Ultrasonic Distance Sensor Module - HC-SR04	**Rs. 49**	[4]
2 Way Rectangular Sintex Pole Junction Box	**Rs. 270**	[5]
MAX7219 8×8 LED Dot Matrix Display Module × 3	**Rs. 119**	[6]
5mm LED - White Color	**Rs. 2**	[7]

Table 3.1: Bus Stop Unit Components

Total Cost for each Bus Stop Unit: Sum of individual components = **Rs. 2061**

3.3.2 Bus Unit

The individual components are as follows

Component	Cost	Source
ESP32 Development Board with Wifi and Bluetooth	**Rs. 345**	[3]
5mm Bi-color LED Red Green 3 Pin - Common Anode	**Rs. 3**	[6]
5mm LED - White Color	**Rs. 2**	[7]
MPU6050 Gyroscope/Accelerometer Sensor	**Rs. 99**	[8]

Table 3.2: Bus Stop Unit Components

Total Cost for each Bus Unit: Sum of individual components = **Rs. 449**

3.4 Manpower Specifications

3.4.1 Man Hours

Name	Entry Number	Subtribe	Man Hours (in hrs)
Navneet Raj	2021MT10240	Documentation	10.0
Sanjay Pooniya	2021EE10148	Documentation	3.0
Ayush Gupta	2021MT10697	Documentation	4.0
Asmit Singh	2021MT10887	Documentation	5.0
Harsh Agarwal	2021EE30977	Research	4.0
Abhinav Verma	2021EE10978	Research	10.0
Khushika Shringi	2021EE10665	Research	10.0
Yash Goel	2021EE10984	Research	9.0
Aryan Gupta	2021EE10974	Research	9.0
Aniket Singh	2021MT10256	Research	3.0
2021ee10653	2021EE10653	Research	5.0
Mridul Ahi	2021MT10901	Research	1.0
Eepsita	2021EE10692	Research	7.0
Pooja Mahajan	2021EE10652	Research	9.0
Chetan Chaurasia	2021EE10147	Research	6.0
Vikas Meena	2021EE10169	Research	4.0
Anshul	2021EE10729	Research	5.0
Ark Verma	2021EE10783	Research	10.0
Yash Agarwal	2021EE10638	Research	8.0
Sheetal Manatawal	2021EE10174	Research	5.0
Disha Katia	2021EE10647	Research	6.5
Chirag Gautam	2021EE10166	Research	4.0
Shubham Aggarwal	2021EE10809	Research	8.0
Mohit Raj	2021MT10919	Research	5.0
Ujjwal Yadav	2021EE10669	Research	8.0
Aniket Abhiraj	2021EE10676	Research	9.0
Sarthak Kumar Singh	2021EE10673	Research	8.0
Aditi Shekhar	2021EE10685	Research	6.0
Anchal	2021MT10910	Research	8.0
Rohan Das	2021EE10621	Research	7.0
Rohan Das	2021EE10621	Research	7.0
Harsh Swaika	2021EE11052	Research	4.0
Aditya Jain	2021EE10633	Research	7.0
Harshit Sachdeva	2021EE30705	Research	7.0
Kinjal Anchhara	2021MT60959	Research	8.0
Dhruv Kushwaha	2021MT10235	Research	6.0
Shubh Chhabra	2021EE10645	Research	8.0
Rishabh Barola	2021EE10636	Research	5.0
Pramukh Jain	2021EE10720	Research	6.0
Oshin Kavdia	2021EE10654	Research	4.0

Kalu Ram Tard	2021EE10680	Research	8.0
Joel Arun Kumar Yenubotula	2021EE10159	Research	5.0
Ameya Mishra	2021MT10637	Research	9.0
Tanmai Merugu	2021EE10149	Research	8.0
Khushvind Maurya	2021MT10238	Research	3.5
Vinay Sah	2021EE10171	Research	3.0
Vasu Sharma	2021EE10620	Research	9.0
Shivam Kumar	2021EE10165	Research	4.0
Deepanshu Kumar	2021EE10696	Research	4.0
Durgesh Nandini	2021EE10651	Research	8.0
Kaustubh Dev	2021EE10689	Research	8.0
Arnav Goel	2021EE10699	Research	7.0
Ayush Kumar	2021EE10150	Research	5.0
Bingi Sai Vishal	2021EE10668	Research	6.0
Abhilasa Das	2021EE10168	Research	8.0
Ravi Parihar	2021EE10156	Research	4.0
Himanshu Prajapati	2021EE30177	Research	4.0
Aryan Mishra	2021EE10137	Research	10.0

Table 3.3: Manpower Specifications

3.4.2 Skillsets Acquired

Name	Subtribe	Skillsets Acquired
Navneet Raj	Documentation	Overleaf, LaTeX, GitHub Actions, Pandoc
Sanjay Pooniya	Documentation	Latex
Ayush Gupta	Documentation	Research
Asmit Singh	Documentation	Documentation
Harsh Agarwal	Research	Research
Abhinav Verma	Research	Research
Khushika Shringi	Research	Research
Yash Goel	Research	Research
Aryan Gupta	Research	Research
Aniket Singh	Research	Data transfer with minimum internet usage
2021ee10653	Research	Research
Mridul Ahi	Research	Research
Eepsita	Research	Research
Pooja Mahajan	Research	Research
Chetan Chaurasia	Research	Research
Vikas Meena	Research	Research
Anshul	Research	Research
Ark Verma	Research	RF communication, GPS modules, Telemetry, Research
Yash Agarwal	Research	Research
Sheetal Manatawal	Research	Research
Disha Katia	Research	Research
Chirag Gautam	Research	Research
Shubham Aggarwal	Research	Research, Problem Solving
Mohit Raj	Research	Research
Ujjwal Yadav	Research	7 Segment Display
Aniket Abhiraj	Research	LCD design, Arduino, Trigger identifier for bus, Hardware design.
Sarthak Kumar Singh	Research	Research on occupancy estimation
Aditi Shekhar	Research	Research
Anchal	Research	Research, Browsing, Brainstorming
Rohan Das	Research	Research
Rohan Das	Research	Research
Harsh Swaika	Research	Research
Aditya Jain	Research	Research
Harshit Sachdeva	Research	Research
Kinjal Anchhara	Research	Research
Dhruv Kushwaha	Research	Research, Survey
Shubh Chhabra	Research	Research

Rishabh Barola	Research	RF communication, System design
Pramukh Jain	Research	Hardware selection
Oshin Kavdia	Research	Research
Kalu Ram Tard	Research	Research
Joel Arun Kumar Yenubotula	Research	ESP32, Networks
Ameya Mishra	Research	Research
Tanmai Merugu	Research	Research
Khushvind Maurya	Research	Research
Vinay Sah	Research	Research
Vasu Sharma	Research	LaTeX, GitHub, Obsidian/Mermaid, MSWord
Shivam Kumar	Research	Research
Deepanshu Kumar	Research	Research
Durgesh Nandini	Research	Research on LoRa wireless comminication
Kaustubh Dev	Research	Research, Transmission techniques, Receiver hardware
Arnav Goel	Research	Research
Ayush Kumar	Research	Research
Bingi Sai Vishal	Research	Analysis and Design of Algorithms, python
Abhilasa Das	Research	Research
Ravi Parihar	Research	Research
Himanshu Prajapati	Research	GitHub, Research on YT
Aryan Mishra	Research	Research

Table 3.4: Skillsets Acquired

3.4.3 Competency Matrix

Color	Competency Level
	Proficient
	Skilled
	Familiar
	Not Familiar but Interested to Learn
	Not Interested

Table 3.5: Index for Competency Matrix

Name	Python	LaTeX	Excel	GitHub	Pandoc	Project Libre	Obsidian	Zotero
Saket Kandoi								
Dintyala Rahul Bhardwaj								
Archisman Biswas								
Sanjay Pooniya								
Nikhil Choudhary								
Navneet Raj								
Aryan Mishra								
Purushottam Malviya								
Musaib Gani Pirzada								
Vaibhav Seth								
Sanskriti Gautam								
Asmit Singh								

Table 3.6: Competency Matrix for Documentation Team

Name	Arduino	C	Doxygen	Wokwi
Shubham Aggarwal				
Mridul Ahi				
Abhinav Verma				
Aryan Gupta				
Khushika Shringi				
Vasu Sharma				
Ark Verma				
Oshin Kavdia				
Sarthak Kumar Singh				
Harsh Agarwal				
Aditya Jain				
Anchal				
Ameya Mishra				

Aniket Abhiraj				
Aniket Singh				
Anshul				
Arnav Goel				
Dhruv Kushwaha				
Harsh Swaika				
Harshit Sachdeva				
Harshit Singh				
Kaustubh Dev				
Khushvind Maurya				
Kinjal Anchhara				
Maithili Joshi				
Mohit Raj Modi				
Mridul Ahi				
Namay Bedi Verma				
Rohan Das				
Sai Raj Kolisetti				
Shubh Chhabra				
Ujjwal Yadav				
Vishal Sai Bingi				
Yash Goel				

Table 3.7: Competency Matrix for APD Team

3.4.4 How Assignment was done

The first step in conducting this assignment efficiently was formation of **sub-tribes**. Each sub-tribe had **20-25 members**. Each of the sub-tribes **worked independently** of each other to come up with ideas to solve the problem. After a **thorough review** of all the ideas, one final idea was selected. Approaching the idea formulation by formation of sub-tribes allowed us to come up with **multiple ideas**. Each sub-tribe had **creative freedom** to brainstorm over their ideas. Sub-tribes met regularly over the weekend and within each sub-tribe there was further division of work. This approach resulted in the Tribe being very efficient and creative in its ideas.

Once the idea was finalised, we floated a form to understand the skillsets of the whole team. Based on the responses, the tribe was split into sub-teams to perform specific tasks to ensure the efficient utilization of each team member's skills and expertise. **Matching** the skills of team members with the demands of each task was a strategic approach that aimed to leverage their **unique** strengths. This thoughtful allocation of responsibilities not only optimized the utilization of individual skills but also fostered a **collaborative** environment where team members could complement each other's abilities.

The overall result was a well-coordinated and efficient team, and all participating members were **proportionally rewarded with IF**. The thorough assignment of tasks according to skill-sets not only enhanced the quality of the work but also facilitated a smoother workflow, ultimately leading to the successful completion of each task within the **stipulated timelines**.

We used **OverLeaf** and **GitHub** to organise the project. The **.pdf** files were efficiently generated on **OverLeaf** after any changes were made to the files. We used **GitHub** to maintain the versions of the project.

3.4.5 Surplus Manpower

We **did not** need any surplus man power.

Design

4.1 Process Summary

This is the overall view of the finalized design:

- **Initialization:** At the outset, when the bus departs from the depot, the ETA for each bus stop (A and B) will be indicated as 0. Only when the bus arrives at stop A and departs for the first time do bus stop devices generate and exhibit ETAs.
- **Stop A is in contact with Stop B:** Whenever the bus departs from stop A, ETA is updated at bus stop B; conversely, when the bus returns from stop B to stop A, ETA is also updated at stop A. When a bus stops within a scalable range of any of the bus stops (bus stop units within the scalable range can observe the bus unit), but not in the designated bus stop area, the nearest bus stop unit determines the bus stop's halt time (since the bus unit transmits a signal to the nearest bus stop units). The bus stop unit responsible for detecting the bus's halt promptly notifies the adjacent bus stops, resulting in the freezing of their timers as well, upon detection of the bus's halt. At this particular stopover, the bus may be withdrawn from service.In the event that BUS unit B is not operational, the signal is transmitted to the closest bus stop (where the initial detection of the halt occurred; this signal is subsequently transmitted to the adjacent bus stop, and so forth).
- **Halt outside range:** In the event that a bus comes to a complete stop in an area beyond the scanning range of any bus stop unit, the timers within the bus stop commence a countdown process until a predetermined threshold is met (or when the bus's expected top arrives within the scannable range of the bus stop).The timers will remain in the frozen state until bus unit B is detected and passes within the scannable range of the bus stop, which is the location where the bus is en route to next.When a passenger is detected by a PIR sensor at a bus stop and the bus is within a visible range of the stop, a notification signal is transmitted to the bus unit that the passengers are awaiting.

4.2 Network

4.2.1 ESP NOW Protocol

ESP-NOW is a wireless communication protocol based on the data-link layer, which reduces the five layers of the OSI model to only one. This way, the data need not be transmitted through the network layer, the transport layer, the session layer, the presentation layer, and the application layer. Also, there is no need for packet headers or unpackers on each layer, which leads to a quick response reducing the delay caused by packet loss in congested networks.

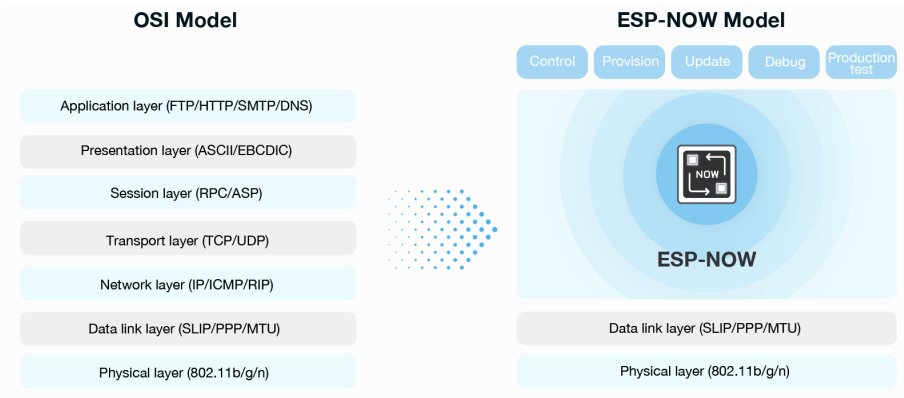


Figure 4.1: Comparison of the OSI standard layers and the ESP NOW protocol layers

Here are the key features of the ESP NOW Protocol:

- It has a fast and user-friendly pairing method that is suitable for connecting "one-to-many" and "many-to-many" devices, while also controlling them
- Occupies fewer CPU and flash resources
- Can be used as an independent protocol that helps with device provisioning, debugging, and firmware upgrades
- ECDH and AES algorithms make data transmission more secure
- The window synchronization mechanism greatly reduces power consumption

The devices communicates directly via the use of the data link and pairing do not require the Wi-Fi connection. Pairing can be done by initiating and multiple pairing can be done like one initiator can pair with multiple responder. Using the RSSI, during the paring the device distance can be found and that distance can be authorised and the device at that distance can be paired. The protocol supports long distance communication which will be helpful in using it outdoors. The portocol is compatible with many sensors implying its wide usability to interact among the units or the user and the unit. ESP NOW can also take data logs from multiple responders for analysis. This will facilitate the user to gather the data from the units without needing to go to the unit, again, the units can communicate the same among themselves to correctly estimate the time or find any abnormality in real time.

4.2.2 ESP-WIFI-MESH

ESP-WIFI-MESH is a networking protocol that operates on top of the Wi-Fi protocol. It facilitates the interconnection of numerous devices, referred to as nodes, across a wide physical area, including both indoor and outdoor spaces, within a single WLAN (Wireless Local-Area Network).It is self-organizing and self-healing meaning the network can be built and maintained autonomously.

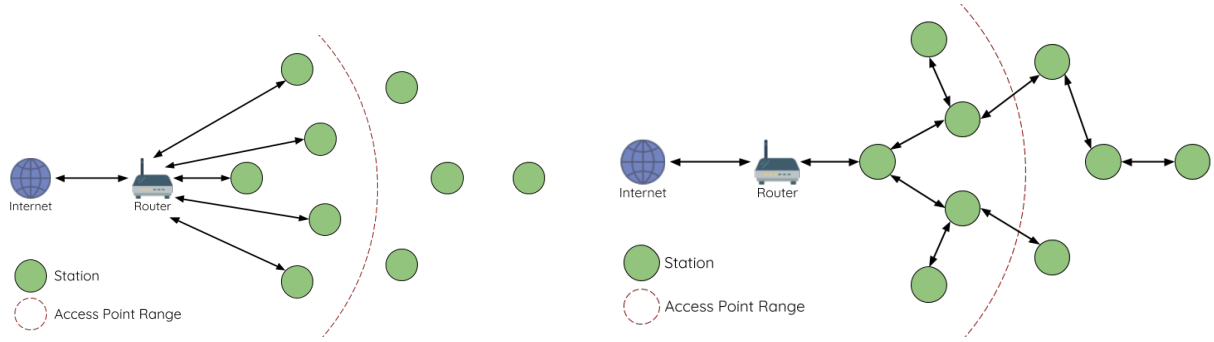


Figure 4.2: Traditional Wi-Fi Network vs ESP-WIFI-MESH Network

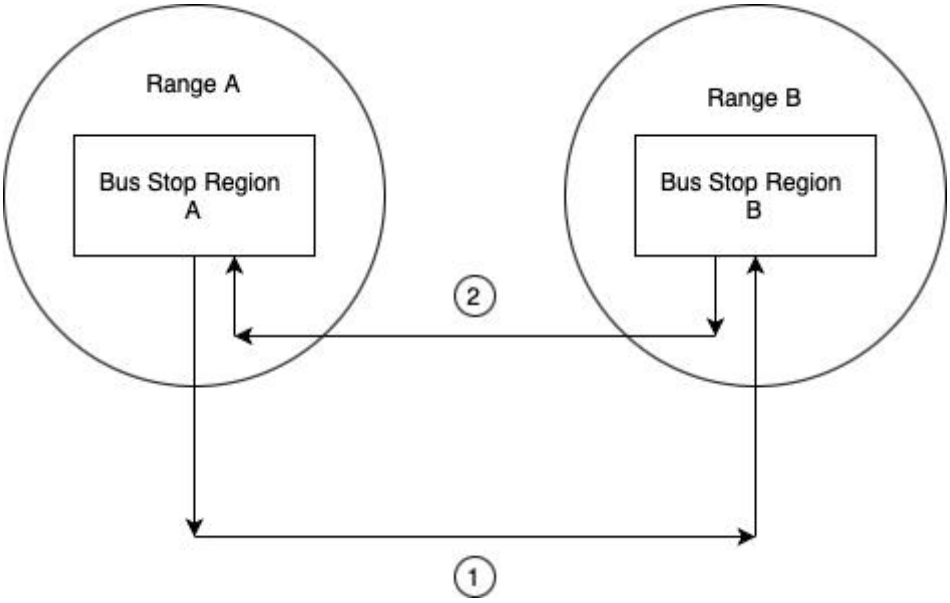
Here are the key features of the ESP-WIFI-MESH:

- ESP-WIFI-MESH networks do not rely on a central node like traditional infrastructure Wi-Fi networks. Instead, nodes connect with neighboring nodes, allowing for greater coverage area.
- Nodes within this network relay each other's transmissions, enabling interconnectivity without the need to be within range of a central node.
- Unlike traditional Wi-Fi networks, ESP-WIFI-MESH is not as susceptible to overloading since the number of nodes permitted on the network is not limited by a single central node's capacity.

4.2.3 RSSI

RSSI stands for Received Signal Strength Indicator. It measures how well your device can hear a signal from an access point or router. It's useful for determining if you have enough signal to get a good wireless connection. Due to the authentication provided by the channel and the incidence of waves from paths of different length, the received signal power is not the same as the transmitted power and RSSI is a measured from the client (receiver).
RSSI is a term used to measure the relative quality of a received signal to a client device, but has no absolute value. The IEEE 802.11 standard (a big book of documentation for manufacturing Wi-Fi equipment) specifies that RSSI can be on a scale of 0 to up to 255 and that each chipset manufacturer can define their own "RSSI_Max" value.

4.3 Backend

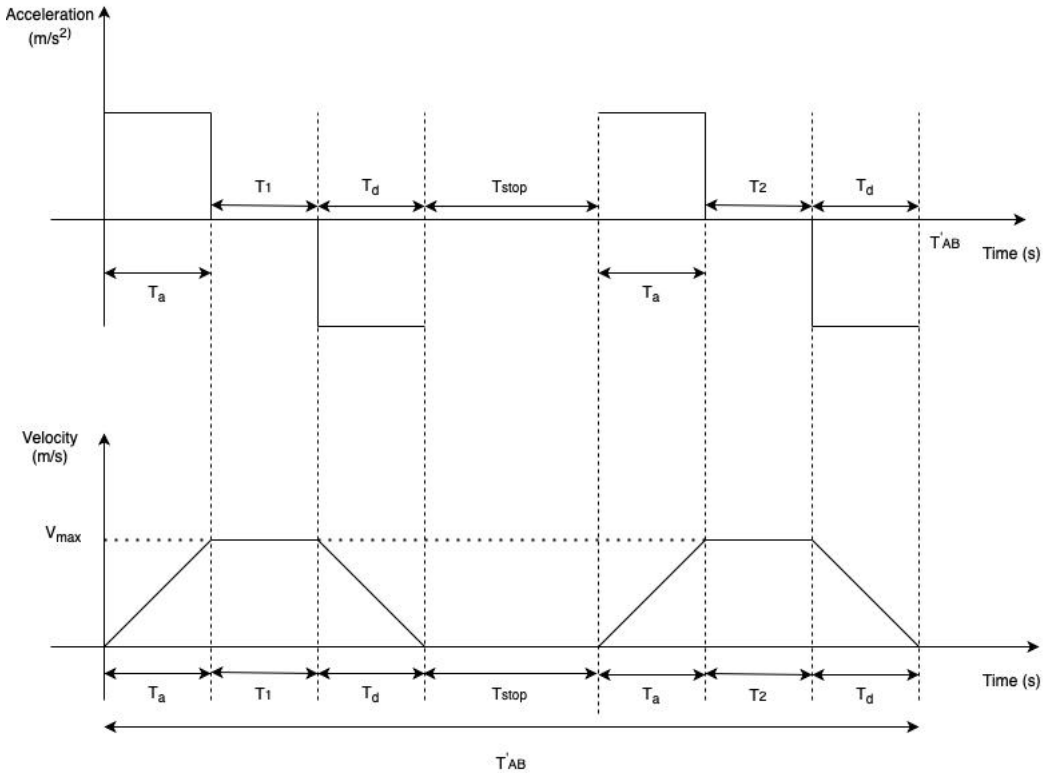


We define the following notations :

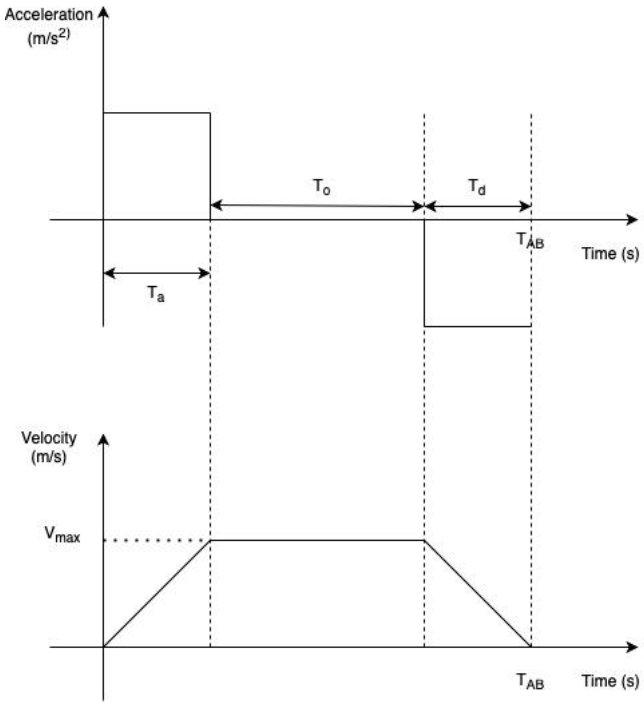
$$T_{AB} := A \rightarrow B \text{ along path 1}$$
$$T_{BA} := B \rightarrow A \text{ along path 2}$$

If the bus stops within the BusStopRegion-A, we update the timer of A to 0 and update the timer of B to T_{AB} when the bus moves again. If the bus stops within the range of A but outside the bus stop region, we paus the timer for both A and B and resume it when the bus moves again.

Proof



We assume that the bus has a fixed acceleration/deceleration profile whenever bus moves and bus moves at $v_{\max}$ from t_0 (when bus doesn't stop in between).



Note that :

$$\begin{aligned} T_{AB} &= t_a + t_0 + t_d \\ T'_{AB} &= 2t_a + 2t_d + t_1 + t_2 + T_{\text{stop}} \end{aligned} \tag{1}$$

Since the distance covered is the same, the area under the curves should also be the same. Writing out the expressions for the areas, we get :

$$\frac{1}{2} v_{\max} \cdot T_{AB} = \frac{1}{2} v_{\max}(t_a + t_1 + t_d) + \frac{1}{2} v_{\max}(t_a + t_2 + t_d).$$

Hence, it follows that :

$$T_{AB} = 2t_a + 2t_d + t_1 + t_2 \tag{2}$$

Combining (1) and (2), we get :

$$T'_{AB} = T_{AB} + tT_{\text{stop}}$$

Hence, pausing the timer as soon as the bus is halted, does the job.

4.4 Components Used

4.4.1 Accelerometer

The MPU-6050 is a popular integrated circuit that combines a 3-axis gyroscope and a 3-axis accelerometer into a single chip. It's commonly used in various applications, particularly in motion sensing, orientation tracking, and gesture recognition systems. For precision tracking of both fast and slow motions, the MPU-60X0 features a user-programmable gyroscope full-scale range of ±250, ±500, ±1000, and ±2000°/sec (dps). The parts also have a user-programmable accelerometer full-scale range of ±2g, ±4g, ±8g, and ±16g. The typical operating voltage range is 2.375V to 3.46V with operating current 100µA.

Product	Package Size *(mm)*	Gyro Full Scale Range *(dps)*	Gyro Sensitivity *(LSB/°/sec)*	Gyro Rate Noise *(mdps/rtHz)*	Accel Full Scale Range *(g)*	Accel Sensitivity *(LSB/g)*	Digital Output
 MPU-6050	4 × 4 × 0.91 24-pin QFN	±250 ±500 ±1000 ±2000	131 65.5 32.8 16.4	0.005	±2 ±4 ±8 ±16	16384 8192 4096 2048	I²C

Figure 4.3: MPU 6050 Details

4.4.2 MAX7219/MAX7221

Description

The MAX7219/MAX7221 are small display drivers with serial input/output capability. They connect microprocessors (μPs) to 7-segment numeric LED displays with a maximum of 8 digits, bar-graph displays, or 64 separate displays.

Light-emitting diodes. The integrated circuit contains a BCD code-B decoder, multiplex scan circuitry, segment and digit drivers, and an 8x8 static RAM that saves each digit. A single external resistor is sufficient to establish the segment current for all LEDs. The MAX7221 is compatible with SPI™, QSPI™, and MICROWIRE™ communication protocols. It is equipped with segment drivers that have low slew rates to minimize electromagnetic interference (EMI). The device features a practical 4-wire serial interface that can be easily connected to any standard microprocessors. Each individual digit can be targeted and modified without having to rewrite the entire display. The MAX7219/MAX7221 additionally provide the user with the option to choose between code-B decoding or no-decode for each digit. The devices are equipped with a low-power shutdown mode that consumes only 150 μA, as well as analog and digital brightness control. They also have a scan-limit register, which enables the user to display anywhere from 1 to 8 digits. Additionally, there is a test mode available that activates all LEDs simultaneously.

Features

- 10 MHz Serial Interface
- Individual LED Segment Control
- Decode/No-Decode Digit Selection

- 150 μA Low-Power Shutdown (Data Retained)
- Digital and Analog Brightness Control
- Display Blanked on Power-Up
- Drive Common-Cathode LED Display
- Slew-Rate Limited Segment Drivers for Lower EMI (MAX7221)
- SPI, QSPI, MICROWIRE Serial Interface (MAX7221)
- 24-Pin DIP and SO Packages

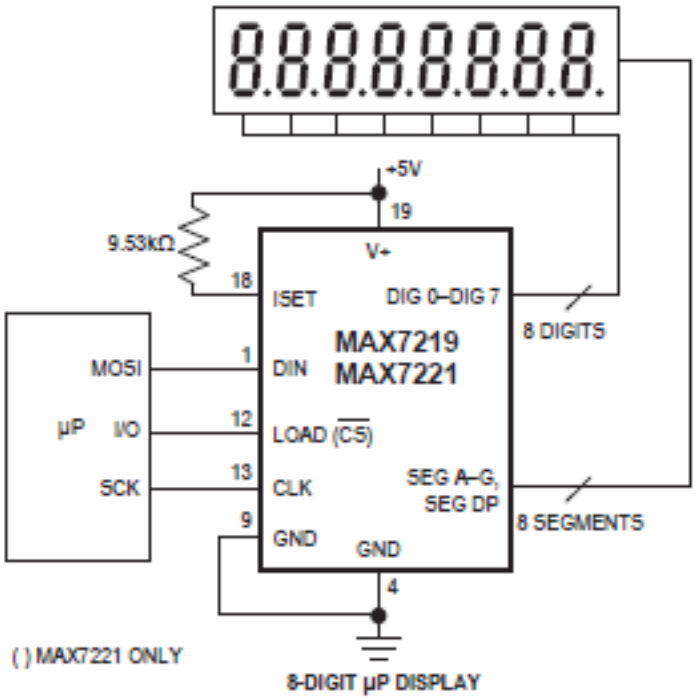


Figure 4.4: Typical Application of **MAX7219/MAX7221**

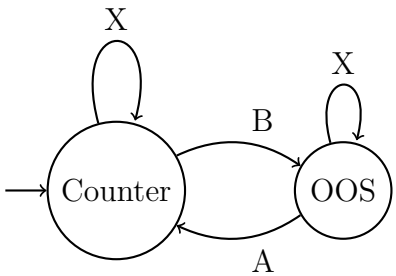


Figure 4.5: FSM diagram for the display

Glossary

24-Hour clock It is a timekeeping system where the hours beyond 12:00 are expressed without the use of AM or PM indicators.. 7

6/6 Vision Denotes normal eyesight, where an individual can see details from a distance of 6 meters equivalent to what a person with typical vision sees at the same distance. 5

Accelerometer An instrument for measuring the acceleration of a body, which in practical terms means changes in speed or direction of a motion.. 8, 10

AES Stands for Advanced Encryption Standard. It is a encryption algorithm utilizing symmetric key cryptography, ensuring data confidentiality and integrity by employing the same key for both encryption and decryption.. 20

Audio unit Provides audio announcements using speakers regarding the estimated arrival time of the bus at specific bus stops.. 4

ECDH Stands for Elliptic Curve Diffie-Hellman. It is a cryptographic key agreement protocol used to establish shared secrets over insecure channels, enhancing communication security.. 20

Embedded system An embedded system is a specialized computer system designed to perform specific tasks within a larger system or device.. 5

GPS GPS stands for Global Positioning System. It is a satellite-based navigation system that enables users to determine their precise location anywhere on Earth.. 9

LED dot matrix display A grid of light-emitting diodes (LEDs) arranged in rows and columns, allowing each LED to be individually controlled to display characters by selectively turning on or off specific LEDs in the matrix.. 4

MICROWIRE A straightforward synchronous serial communication protocol employing three signal lines, offering a simpler alternative to SPI for interfacing microcontrollers with peripheral devices in various embedded systems.. 24

MPPT converter Stands for Maximum Power Point Tracking , it is a type of DC/DC converter commonly used in photovoltaic systems to optimize the power output of solar panels by continuously adjusting the operating point to maximize energy harvest from the panels.. 5, 10

OSI model Stands for Open Systems Interconnection Model. It is a standard framework for network communication protocols, comprising seven layers with specific roles to enable interoperability and communication between systems and devices. . 20

PWM converter A type of power electronics device used to regulate the output voltage or current by controlling the duty cycle of a pulse-width modulated signal.. 5, 10

QSPI Stands for Quad Serial Peripheral Interface. It is an evolution of SPI utilizing quad data lines to boost data transfer speeds, especially advantageous for high-performance applications necessitating swift communication.. 24

Round trip Refers to a journey where a bus travels from a starting point to a destination and then returns back to the original starting point.. 9

Sliding text animation It is a visual effect over a display where text moves smoothly across the screen horizontally, vertically, or diagonally.. 10

Smog A type of air pollution that consists of a mixture of smoke and fog, often caused by industrial emissions, vehicle exhaust, and atmospheric conditions.. 5

SPI Stands for Serial Peripheral Interface. It is a synchronous serial communication protocol enabling data exchange between microcontrollers and peripheral devices using four signal lines.. 24

Stall period Refers to a duration of time during which the system pauses temporarily until the situation is resolved, allowing the system to resume its intended function.. 6

Ultrasonic sensor A device that utilizes ultrasonic waves, typically operating in the frequency range of 20 kHz to 200 kHz, to detect the presence and distance objects by emitting ultrasonic pulses and measuring the time it takes for the pulses to reflect back from objects.. 10

USB Stands for Universal Serial Bus. It is a standardized interface commonly used for connecting peripherals to computers and other electronic devices.. 5

U-turn When a vehicle turns 180 degrees to reverse its direction and proceed in the opposite direction.. 3

Wi-Fi Wireless Fidelity, is a technology that allows electronic devices to connect to the internet or communicate with one another wirelessly using radio frequencies.. 9

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Appendices

A. Document Statistics

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5. **Inline math:** 75

B. Readability Index

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2. **Flesh-Kincaid Grade Level:** 6.3[b]
3. **Coleman Liau Index:** 6.6[c]
4. **Flesh-Kincaid Ease Score:** 63.4[d]
5. **Gunning Fog Score:** 7.4[e]

[a] Should be easily understood by **12** to **13** year olds.
[b] Writing style of the document is comprehensible to individuals who have completed **seventh** grade.
[c] The Coleman Liau Index is designed to evaluate the U.S. grade level necessary to understand text.
[d] A value between 60 and 80 should be easy for a 12 to 15 year old to understand.
[e] The document is written in clear, in fairly understandable language and at a reading level suitable for **eighth** graders.

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Alphabetical Index