AURUM

Mantra Solanki
Department of Electronics and Communication

Vedanti Patel
Department of Electronics and Communication

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1. Introduction

From World War 1, data of French Doctors mentioned a concept of “Golden Hour” between life and death. They suggested that an injured person should be under medical treatment within the Golden Hour if he wants higher chances of survival.

Numbers of vehicles increase everyday but we cannot accommodate them all on the same size of roads. To make it easier for EVs (Emergency Vehicles like ambulances, fire brigades, etc.) to beat traffic we have to manage the traffic.

We can widen the roads to accommodate more vehicles, but it is too costly to and tough to match the rate of road development with the rate of increasing vehicles

So the only option is to manage traffic in such a way that the EVs never need to deal with traffic.

“AURUM” provides an effective way of dealing with traffic and strives to get the EV at location in the shortest time possible: the “AURUM Time”.

2. Working

2.1 Working In Detail

2.1.1 AURUM App

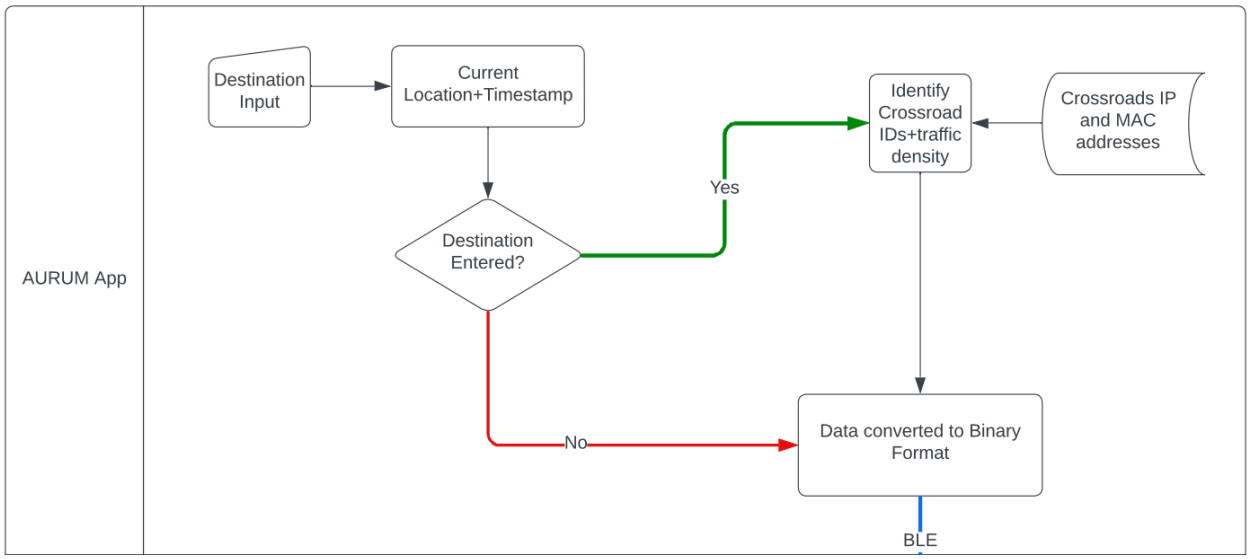
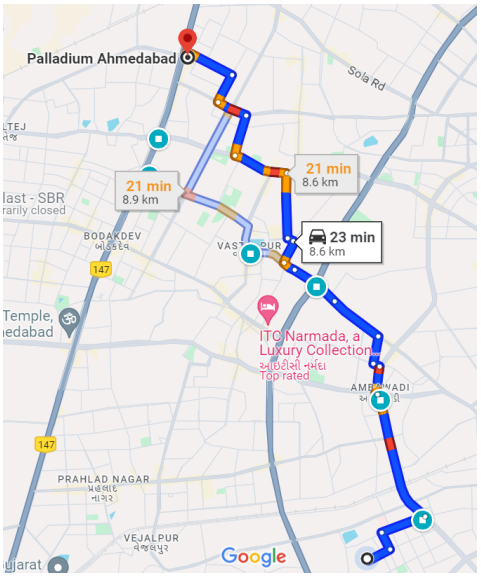


Figure 2.1 Flow chart of the Application, AURUM

The application takes the destination address as input and performs the following tasks:

1) Calculates the shortest path to the destination.
2) Identifies the traffic signals along the route.
3) Displays traffic density and flow at each crossroads.



The app has a preloaded list of traffic signals, including their

1) IP address,
2) MAC address, and
3) Location of Traffic signal

Upon selecting the destination, the app automatically retrieves this list and identifies the traffic signals that match those on the route.

The data will be sent in **binary format** over **Bluetooth Low Energy (BLE)**.The application sends the following data:

1) Emergency Vehicle information:
    a) Longitude: 4 bytes (32-bit float)
    b) Latitude: 4 bytes (32-bit float)
    c) Timestamp: 4 bytes (32-bit unsigned integer)
2) Traffic Signal information:
    a) IP Address: 16 bytes (IPv6 address)
    b) MAC Address: 8 bytes (assuming 64-bit MAC addresses)
    c) Traffic Density: 1 byte

Q) Why use the Binary format?

Binary format:

- Is highly compact, which reduces transmission time and power consumption
- Can add Error checking, either through a simple checksum or a CRC-8(8-bit Cyclic Redundancy Check)
- Is quick and easy to parse.

Q) How would the data be handled over BLE?

Assuming the there are 10 traffic signals in the route. The data requirements will be

1) Emergency Vehicle Information: 12 bytes
2) Traffic Signal Information: 25 bytes$\times$10 = 250 bytes

BLE can handle a maximum of 31 bytes per packet.

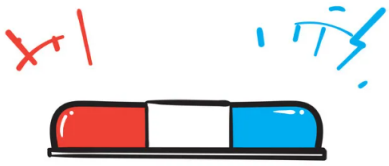
1) The continuous transmission of emergency vehicle data, which is 12 bytes per update, fits within a single BLE packet. It will consume less bandwidth and power as each update is small and fits within a single packet.
2) The one-time setup information for the 10 traffic signals will be sent in:
   250$\div$31 = 9 packets
   Although requiring multiple packets, it is manageable overhead, given its infrequent nature.

Q) How to prevent floating-point errors due to coordinate data?

Geographical data typically require precision up to 6 decimal places. This requirement can be fulfilled by Single Precision (32-bit float), which gives precision 7 decimal digits.
Double Precision (64-bit float), which gives precision 15-16 decimal digits can be used if higher precision is required.

2.1.2 Ken-Tx (Leaf Node)

The Ken-Tx module is a WiSUN module installed with the siren lights on EV(Emergency Vehicle). It is powered on when the siren lights are activated because it shares the same power source.



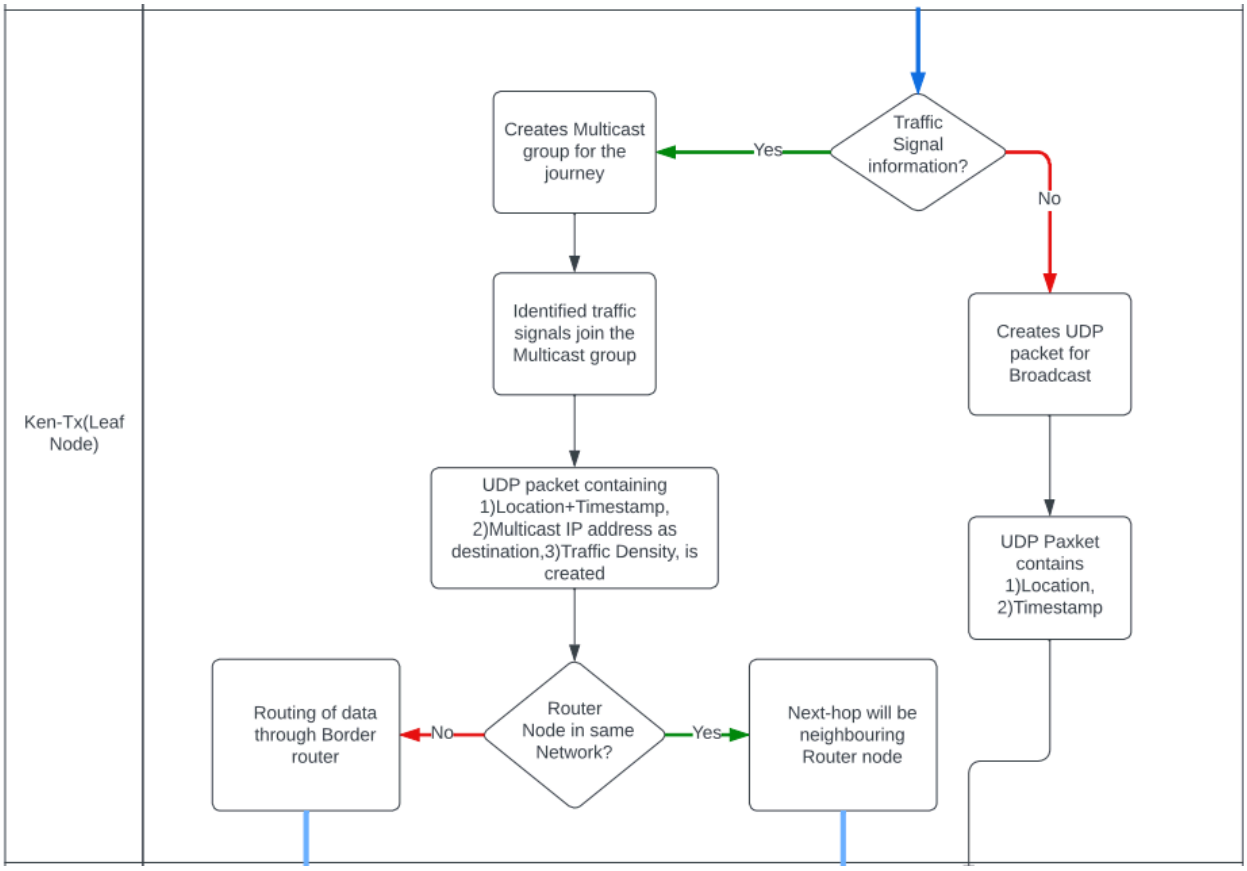


Figure 2.2 Flow chart of the Leaf Node

The Ken-Tx module receives data over Bluetooth (BLE) from a phone and transmits information about upcoming traffic signals and the live location of the vehicle.

Once the data is received by the Explorer kit, it follows the following steps for **data transmission**:

1. A UDP Multicast group address is allocated to each new journey.
2. The identified traffic signals are instructed to join the newly created multicast group address using **Multicast Listener Discovery (MLD)** protocol.
3. The leaf Node creates a UDP packet with Multicast group IP Address.
4. Routing Table of the Leaf Node indicates the next hop (IP of next Router Node)
5. The leaf node resolves the MAC address of the next-hop node using protocols like Neighbor Discovery Protocol (NDP) in IPv6
6. The leaf node encapsulates the UDP packet in a frame with the next-hop node's MAC address as the destination MAC address.
7. The next Router Node receives the frame, checks its routing table, and forwards the packet towards the destination Router Node

Note: Routing protocols within the Wi-SUN network (such as RPL - IPv6 Routing Protocol for Low-Power and Lossy Networks)

Note: In case the destination is on a different network, the Border Router connects the local network to the different network.

2.1.3 Ken-Rx (Router Node)

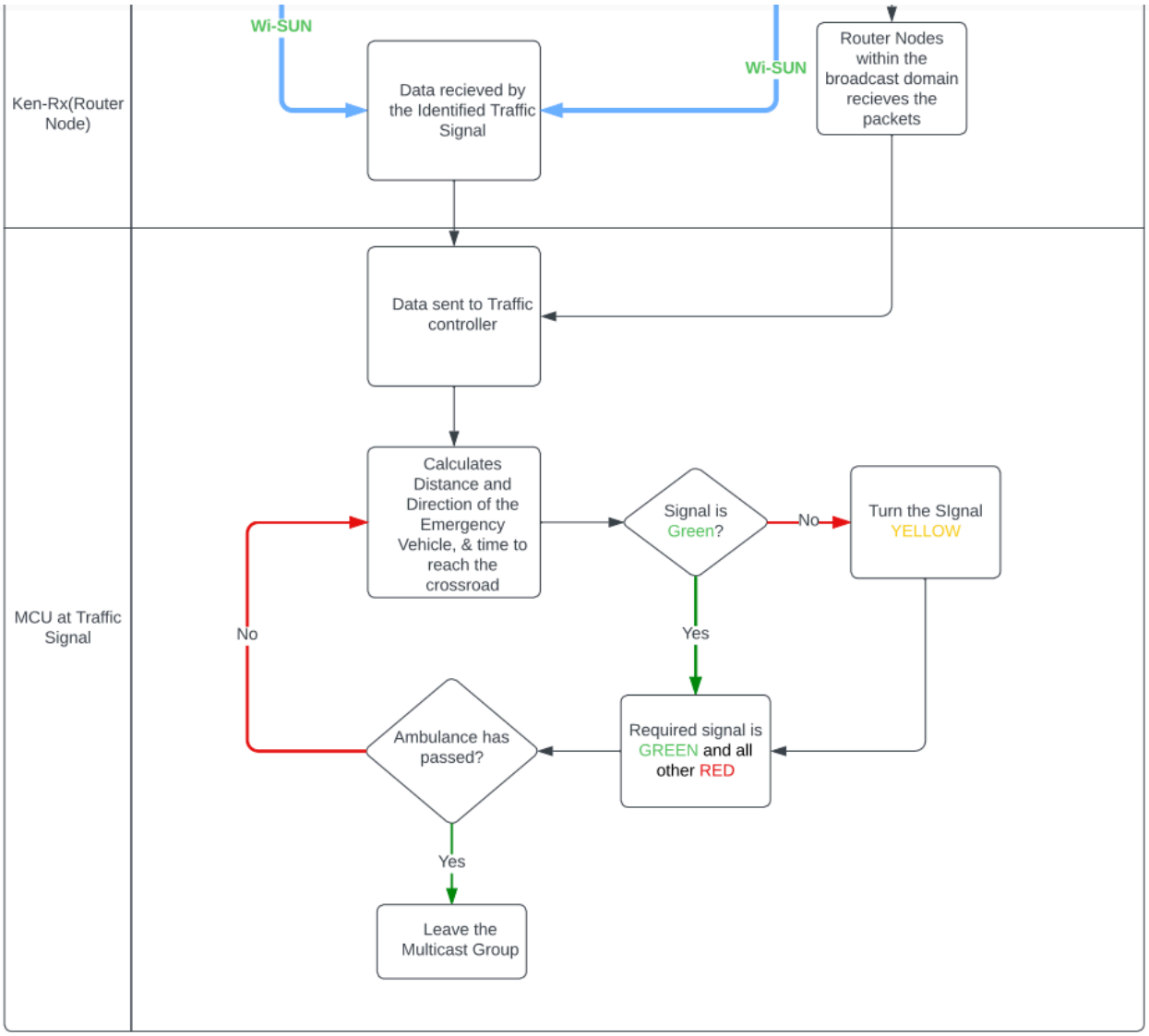


Figure 2.1 Flow chart of the Router Node at the Traffic Signal

Ken-Rx nodes are installed at traffic signals, and are connected with the Traffic Signal Controller sharing a common power source between them.
Router Node receives the emergency vehicle information every 2-5 seconds. The data received by the router node is sent to the MCU over a wired **connection**.

1) The MCU calculates the **distance** (from the crossroads) **and direction** of the emergency vehicle. The distance is calculated using the coordinates received from the leaf node and the coordinates of the crossroads that is set on installation.
2) The MCU also receives the information about **traffic density and flow** at that crossroads. This information is used to calculate the approximate time for the emergency vehicle to reach the crossroads. This helps coordinate the switching time between red, yellow and green.
3) To determine if the emergency vehicle has passed a traffic signal, the system monitors the vehicle's distance from the intersection. The distance decreases as the vehicle approaches the crossroads and increases as it moves away. This pattern helps identify the vehicle's movement relative to the signal.
   Once the ambulance passes the traffic signal, the MCU triggers the Router Node to leave the multicast group.

2.1.4 Border Router

Border Router handles the following functions:

1) *Gateway Functionality:* connecting Wi-SUN network to other networks.
2) *Routing:* manages routing of data packets within the Wi-SUN network and to/from external networks.
3) *Data Relay:* forwards data to the central monitoring system or cloud service.

2.2 Summary

The **AURUM application** takes a destination address as input and performs several key tasks: calculating the shortest path, identifying traffic signals along the route, and displaying traffic density and flow at each crossroads. The app contains a preloaded list of traffic signals, including their IP address, MAC address, and location. Upon selecting the destination, the app retrieves this list and identifies the traffic signals on the route.

Data is sent in binary format over **Bluetooth Low Energy (BLE)** to ensure compactness, reduce transmission time and power consumption, and allow for error checking. The data sent includes:

1. **Emergency Vehicle Information**:
   a. Longitude: 4 bytes
   b. Latitude: 4 bytes
   c. Timestamp: 4 bytes
2. **Traffic Signal Information**:
   a. IP Address: 16 bytes
   b. MAC Address: 8 bytes
   c. Traffic Density: 1 byte

For BLE, the continuous transmission of emergency vehicle data (12 bytes per update) fits within a single packet, while traffic signal information for a route with 10 signals (250 bytes) will be sent in 9 packets.

To prevent floating-point errors in coordinate data, single precision (32-bit float) is used, which provides sufficient precision for geographical data.

Ken-Tx module(Leaf Node), installed with the siren lights on the emergency vehicle, is powered on with the siren. It receives data over BLE from a phone and transmits information about upcoming traffic signals and the vehicle's live location. Upon data reception, the module allocates a UDP Multicast group address for the journey, instructs identified traffic signals to join this group using the Multicast Listener Discovery (MLD) protocol, and creates a UDP packet with the multicast group IP address. The packet is routed using the Wi-SUN network's routing protocols.

Ken-Rx nodes(Router Node) are installed at traffic signals and share a power source with the Traffic Signal Controller. These nodes receive emergency vehicle information every 2-5 seconds, which is sent to the MCU over a wired connection. The MCU calculates the distance and direction of the emergency vehicle, and uses traffic density information to estimate the vehicle's arrival time at the crossroads. This helps coordinate signal switching times. The system monitors the vehicle's distance from the intersection to determine if it has passed the signal, and the MCU triggers the router node to leave the multicast group once the vehicle has passed.

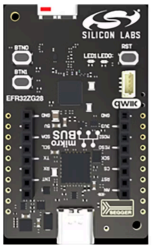
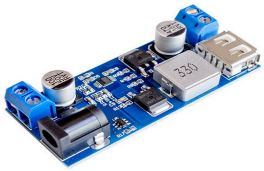
Border router connects the Wi-SUN network to other networks, manages routing of data packets within the Wi-SUN network and to/from external networks, and forwards data to the central monitoring system or cloud service.

3. Plan of Implementation

Here we assume that,

- The router nodes are already installed at every traffic signal,
- The network of the router nodes and border router is already established, and
- The city is Wi-SUN enabled.

3.1 Hardware components

Sr. No.	Component	Description	Qty.	Price
Ken-Tx (Leaf Node) (on Emergency Vehicle)				
1	Wi-SUN Explorer Kit (EFR32ZG28)	Acts as Leaf Node 	1	$34/₹2,838.6
2	XY3606	Buck Converter 12V/24V to 5V DC 	1	₹99
3	Enclosure (Inner Layer - Polycarbonate Outer Layer - Polyurethane)	IP65 rated 80x50x50 mm	1	Can vary according to vendor
		Polyurethane outer layer for temperature insulation from outside		
		Polycarbonate Radome enclosure layer for protecting the hardware from outside environment and impacts		

		Both materials are RF transparent and insulating		
4	USB A-to-C cable (optional)	To connect XY3606 with EFR32ZG28 to give power supply	1	₹300
Total - USB A-C cable is optional, can also power via simple wires - Enclosure prices can vary				₹2,937.6 (without USB A-C Cable and Enclosure)

Table 3.1.1 List of Hardware Components at Leaf Node

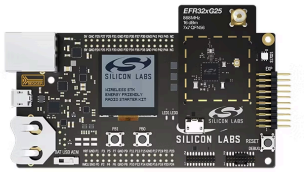
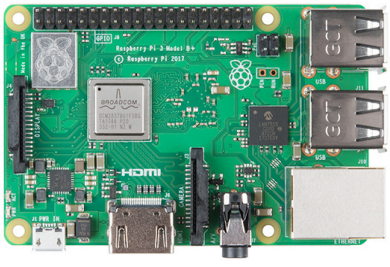
Ken-Rx (Router Node) (1 at each Traffic Signal)				
3	Wi-SUN Pro Kit (EFR32FG25)	Acts as Router nodes and overrides TSC (Traffic Signal Controller) 	1	$635/ ₹53,015.01
Total				₹53,015.01

Table 3.1.2 List of Hardware Components at Router Node

Border Router				
4	Raspberry Pi 3 Model B+	Connects to the backhaul/ cloud connectivity 	1	₹ 3679
5	Wi-SUN Pro Kit (EFR32FG25)	- Works as Wi-SUN module for the Border Router	1	$635/ ₹53,015.01

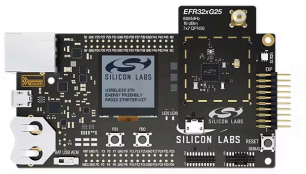
				
Total				₹56,694.01

Table 3.1.2 List of Hardware Components at Border Router

- **We are only accounting the prices of Leaf Nodes.** Costs of Router Node and Border Router are just added for information.The main application (Leaf Node) only needs a buck converter and an enclosure other than the Explorer Kit.

Note: These are retail prices, prices can vary depending on the quantity of hardware and vendor.

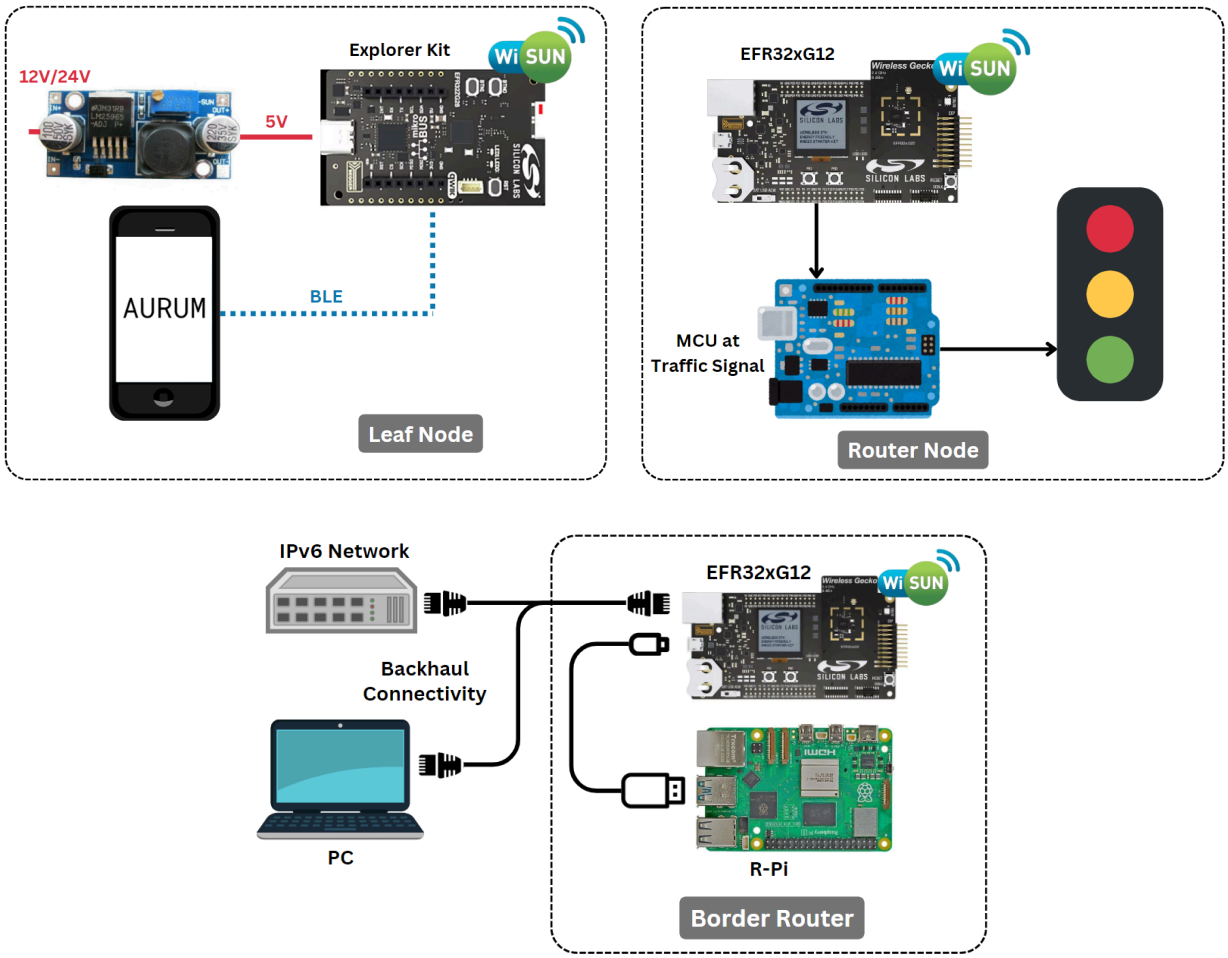


Figure 3.1 Hardware Components Connection

3.2 Software Components

Sr. No.	Software	Description	Price
1	Simplicity Studio v5	For programming EFR32ZG28 and EFR32FG25	Free
2	Android Studio	For building Aurum App	Free
3*	Google Cloud Console	For APIs of Google Maps	**Dynamic - can vary upon use**
4*	MapMyIndia	For APIs of maps and routes	**Dynamic - can vary upon use**
5	Raspberry Pi OS	For programming R Pi 3B+	Free
6	Raspberry Pi Connect (Beta Version)	Access the Raspberry Pi from anywhere	Free
7	Wireshark	To view the UDP multicast traffic	Free

Table 3.2 List of Software

Note: 3 and **4** are alternatives to each other, we can use any one of them.

3.2.1 Comparison Between Google Maps and MapmyIndia

We will be using **Google Maps Platform**'s **Routes API**, in which we will use **Compute Routes - Advanced SKU**. We get $200 credit every month from Google.
Its prices are,

MONTHLY VOLUME RANGE Price per QUERY		
0–1,00,000	1,00,001–5,00,000	5,00,000+
0.01 USD per each (10.00 USD per 1000)	0.008 USD per each (8.00 USD per 1000)	Contact Sales for volume pricing

Queries generated per day	Total Monthly Queries (31 days)	Cost of using Google Maps API per month	Cost after deducting $200 credit every month
500	15,500	$155	Free
650	20,150	$201.5	$1.5
1000 (Worst Case Scenario)	31,000	$310	$110
2000	62,000	$620	$420

- ➔ For reference, the whole Gujarat state combined makes 4,000 calls/day. A city will never have these many queries in a day.
- ➔ Also, Google gives extra credits under "Public Programs" which includes Crisis Responders, Startups and Nonprofits. Offers applied upon registration only.

MapmyIndia by MAPPLS is a Strong alternative for Google Maps Platform.The prices of APIs are shared only upon inquiry.

As of now, for a city-based application, we will use Google Maps Platform for development of AURUM App.
There will be different AURUM Apps for different cities.

3.3 Deployment

This section gives detailed information about how the devices and software are to be installed on the site.

3.3.1 AURUM App

For the clients who do not have their own app, we will provide the app.

- The app gives a map, list of hospitals, routes with live traffic, and live location.
- In the backend, we will have a list of traffic signal information and interfacing with the Ken-Tx.
- It will connect to Ken-Tx via Bluetooth.

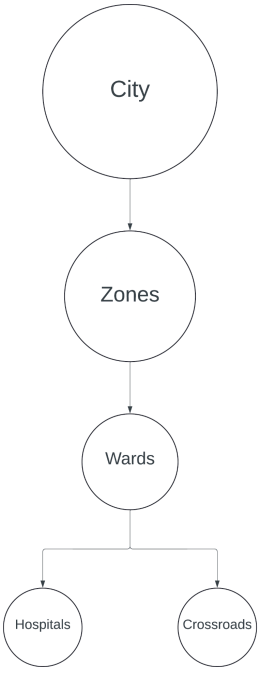
Many services like GVK EMRI have their own app which already gives most of the functionality mentioned above, in that case we just need to integrate our functionalities with them.

3.3.2 Ken-Tx

Ken-Tx needs to be directly installed on the roof of the emergency vehicle, and powered from the same source as siren light.The device turns on with siren light.

3.3.3 Ken-Rx

Every city is divided into Zones and Wards by the municipal corporation. We will deploy the system ward by ward.



In every ward, we will identify how many hospitals and traffic signals there are and where they are located.The traffic signals near the hospitals will get priority.

- ➔ Ken-Rx (Router Node) will be **installed at every crossroads,** and the **coordinates will be set** on installation.
- ➔ Ken-Rx will be installed as an **add-on to the TSC(Traffic Signal Controller)**. Based on our research, most of the TSC manufacturers use **MCU (microcontroller)** , and have inbuilt **GPS**.
- ➔ Ken-Rx will be interfaced with their MCU using **I2C or UART or any other protocol** they support, and it will use the **same power supply as the TSC**.
- ➔ MCU and Router Node will be integrated.
- ➔ The final deployment will be done from the Border Router to all the Router Nodes using **Over-The-Air Device Firmware upgrade**.

The entire city will be covered with Wi-SUN by deploying it ward by ward and then zone by zone, given the large number of traffic signals in cities.

4. Corner Cases

These are extreme situations or very rare to happen. When they occur, the following steps could be taken to mitigate the effect.

Cases	**Mitigation**
More than 1 ambulances at same time, at same traffic signal	- The ambulance which is nearer at certain point will be given priority
	- The override mode of router node will continue even if 1 ambulance is gone - Override mode will only be terminated when no ambulances are there
The destination is not selected	- If it is emergency, the siren lights will turn on which will also turn on the Ken-Tx
	- Without destination, it will work in static mode, it will only share its Live Location fetched from the mobile phone
Driver not connected with phone	- After turning on, if the Ken-Tx doesn't get any data from the phone over BLE for a certain time period, it can not work
	- In future we can integrate L89 GPS for such cases, then it will send location data on its own - Right now not included because using phone's Location data is more efficient
Ambulance is already close to traffic signal when the Ken-Tx turns on	- Ken-Rx will start the Green signal based on direction,also turning the other signals red immediately. if it is within 100 meters already

5. Failure Scenarios

Failure Scenarios	**How to know?**	**Consequences**	**Suggested Solution**
No Power supply	Phone will not connect to the kit over BLE	Ken-Tx will not work, but no damage is experienced	Check power supply
Buck Converter doesn't work	Phone will not connect to the kit over BLE	Ken-Tx will not work, but no damage is experienced	Change buck converter
Live Location lost	Signal do not change	Signal will not change	It cannot happen, because location is determined not only by GPS but also factors like WiFi towers and nearby devices
EFR32ZG28 doesn't work	Phone will not connect to the kit over BLE	Ken-Tx will not work	Depends on the fault
Router Node doesn't work	Signal do not change	Signal will not change	Turn on **Test Mode** - Multicast Group Test - Data Integrity Test
Data not sent form Mobile to Leaf Node	Signal do not change	Signal will not change	Turn on **Test Mode** - Connectivity Test - Data Transmission Test

5.1 Maintenance

Maintenance Activity	**Frequency**	**Description**
AURUM App updates	When Required	Removing any bugs and adding new information about the city if required
Ken-Tx Inspection	Weekly (Done by the driver)	Driver will test run it without emergency every week and report to us if issues are observed Operate in **Test Mode** for Mobile to Leaf Node Test
Ken-Rx Inspection	Weekly	Inspection through border router and Operate in **Test Mode** for Leaf Node to Traffic Signal Test

6. Business Analysis

6.1 Value Proposition To The Client

- Our clients are municipalities and emergency services, but our beneficiaries are the citizens of India.
- Where every moment matters in emergencies, we will be saving much more time to make the emergency response even faster.
- How can we measure it?
    - Google Maps will show you the time to your destination with considering traffic. Once applied successfully over the city, we guarantee that the EVs will always beat that time.

6.2 Potential Market Size

- There are 242 Municipal Corporations and 2,200 Municipalities in India as of now.
- These all are big cities with a large number of traffic signals and EVs.
- They are our potential clients in India, we also plan to provide the solution to foreign countries.
- Our first target will be Municipalities, because they are smaller than Municipal Corporations and we can implement and monitor the solution easily in smaller cities first.
- Then we will approach the Municipal Corporations.

6.3 Target Clients

- Municipal Corporations and Municipalities
    - All the cities have TSC providers on contract basis. They can connect us to them for implementation.
    - They either have their own EVs or providers like GVK EMRI are supporting with their EVs and services. If they have their own EVs, we can directly implement our Ken-Tx on them.
- GVK EMRI
    - They are the biggest provider of emergency services, handling “108” service in most of the country.
    - We can collaborate with them to make all their EVs AURUM Enabled.
- Other EV providers
- Traffic Signal Controller providers
    - Some of the providers are,

TSC Manufacturer	What do they use as a controller?	Clients
Envoys	32 bit MCU	Municipal Corporation of Delhi, Jammu, Patna, Ahmedabad, and companies like Adani, DLF, NHAI
Nucleonics	ASIC Board	Exporting to other countries
CMS	32-bit ARM9 based CPU and ASIC Energy chip	Very large client base
Microtrans	32-bit MCU	Cities of Rajasthan, Uttar Pradesh and Haryana
Osho Automation	8-bit MCU	Companies
Keltron	32-bit MCU	Ahmedabad Municipal Corporation

    - Most of these manufacturers are using MCU, and also they have inbuilt GPS. So it is easy to integrate the Ken-Rx with their TSC.
    - On the existing controllers, we can integrate Ken-Rx as an add-on. In that, we only need to make some changes in the code and interfacing from both sides.
    - We can have partnerships with various TSC manufacturers to provide the TSC which are already AURUM Enabled.

- This solution is for Emergency Services only. It is not for commercial use or any other services.

All the Ken-Rx and Ken-Tx are compatible with each other.
Clients can buy them,

- Separately - TSC providers only buy Ken-Rx and EV providers only buy Ken-Tx
  Or
- Together - Municipal Corporations can buy both and distribute among providers

6.4 Current Solutions

We talked with Jashvant Prajapati, COO of GVK EMRI about how their whole system works and also shared about our solution.
He suggested to refer some current solutions, which are:

- Automatic Green signal on detection of ambulance in Ahmedabad
    - This solution is applied on River Front, which is a straight road alongside Sabarmati river.

    - That road doesn't have very high traffic and 4-way cross roads. It only has 3-way crossroads and also it is not implemented in the city.
    - Our solution is much more dynamic, which also takes into account the live traffic and it can handle 5-way crossroads, too. The current solution implemented on River Front is the same as our "Static Mode" which we consider as a corner case in our solution.
- Realtime Info of Ambulances in Vadodara by IUDX
    - They make temporary green corridors for ambulances
    - They are software based company, hardware is not included
    - They have kept information about the solution private
- Cameras and Machine Learning algorithms
    - Many cities use cameras and AI to detect ambulances
    - It is cost intensive and also computation intensive
    - Also maintenance required is very high compared to our solution
    - There can be errors in their detection, but our solution can not fail in typical cases

6.5 Cost Analysis

Assuming that the whole Routing Network is already implemented in the city (Router Nodes at every traffic signals).

Device / Service	**Description**	**Cost**	**Subscription / One-Time**
Ken-Rx	The code for interfacing with Ken-Tx, TSC and logic of controlling signals	₹70,000	One-Time
	Includes future changes and custom requirements		
Ken-Tx	Whole device installation on EV	₹6,000/unit	One-Time
AURUM App	For clients who doesn't have any app	₹8,000	First time activation and also counted as 1st month subscription fees

		Upon usage	Monthly postpaid subscription
AURUM Functions	For clients who have their own app and we need to add our functions or APIs	Based upon requirements	One-Time or Subscription if using our APIs

- These are introductory prices, and can vary in future.
- These prices includes after sales support
- AURUM App is using Google Maps API, so the monthly postpaid bill will be based upon how many queries are generated in that month
- AURUM Functions is for clients like GVK EMRI who already have their own app and we only need to add-on our functions or APIs. Prices can vary depending on their requirements.

6.6 Comparison With Other Solutions

Compared to other solutions, our solution is/has

- Cheaper with minimal hardware
- Easier to implement
- Lesser the hardware, lower the chances of faults
- Lower power consumption
- More dynamic
- Easier maintenance
- Can have predictive maintenance
- Large scope for upgradability
- Easier and faster to use

7. Future Scope

Router nodes have versatile applications that can be expanded beyond their primary functions:

- **Dynamic Traffic Control:** Managing traffic in normal conditions by adjusting signals based on real-time data.
- **Sensor Integration:** Adding various sensors to monitor temperature, air pollution, noise pollution, and other environmental factors at different times.
- **Data Correlation Analysis:** Identifying correlations between different variables that may not be immediately apparent. By collecting data on multiple variables, these hidden relationships can be discovered.
- **Cloud Connectivity:** Enhancing functionality through cloud connectivity, enabling more dynamic and versatile applications.