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Traffic Clearance for Ambulance during Pandemic Situation and Road Accidents using LoRaWAN Network

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Intelligent Transportation System (ITS) plays an important role in handling pandemic situation and disaster management. Due to rapid urbanization, there is a requirement for implementing an effective traffic control system not only to avoid heavy congestion but also to make a better solution for ambulance clearance which would help to save the human life. The proposed work intends to implement an effective traffic control system using Long-Range Wide Area Network (LoRaWAN) that provides seamless traffic clearance for ambulances, so that they reach the hospitals without any delay. Cupcarbon, a Wireless Sensor Network (WSN) simulator, is used to evaluate the performance of the proposed work. The simulation involves a case study considering an accident zone in Coimbatore city and the performance of the proposed system is compared with that of existing systems. The simulation results prove that LoRaWAN can be used to effectively control the traffic lights with a wider coverage range, as compared to existing systems.

Keywords: Cupcarbon, ITS, LoRaWAN, Traffic management, WSN

Introduction

During pandemic situation, the need for Ambulance services increases drastically due to wide spread of disease like Covid-19. Recently, during the second wave of Covid-19 in 2021, people who were in critical health condition could not avail ambulance services due to unprecedented increase in number of Covid cases. While the patients are being carried to hospitals, the ambulances get stuck in the traffic and could not reach the hospitals swiftly. This leads to more demand for ambulances. On the other hand, according to WHO report, approximately 1.35 million people die every year because of road accidents. Many accident victims have lost their lives because of heavy traffic congestion. So there is a need for better traffic management in such situations.

There are various wireless technologies which are used in traffic monitoring and control systems. One such technology is LoRa, which can be expanded as a Long Range technology. LoRa is an Internet of Things (IoT) standard that supports smart city applications.[1] It works in the license free radio band of 865 MHz to 867 MHz in India. Hence, the system is prone to interference from other devices in the same communication link.

There are methods like frequency hopping, used to overcome the effect of interference. Hence, LoRa technology exhibits a reliable performance even in the presence of noise and interference. Long Range Wide Area Network (LoRaWAN) supports transmission of sensor data at low data rates over a long distance. LoRaWAN supports large number of devices connected per gateway. LoRaWAN devices have a very long battery life and hence are suitable for long-term deployments like street lighting, air quality monitoring and waste management. LoRaWAN offers the best performance even when operated in the extreme environmental conditions.[2] LoRaWAN supports a smart city ecosystem, which meets the convenience of deployment along with the Quality of Service (QoS) requirements.

In major cities, traffic density on roads has increased exponentially in the last decade. Traffic jams have become common nowadays, because of the traffic density during peak hours. Emergency vehicles like ambulance and fire engines get stuck in the traffic jam most of the times and the resulting human causality is a very serious issue. Almost all the traffic signals operate using a microcontroller that switches the lights at fixed time intervals. The static nature of operation of the traffic signals results in the situation where the emergency vehicles also have to wait for the time when the traffic light turns green.

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If there is a police man present at the signal, he can make way for the ambulance. But police men are not always present in all traffic signals because of the automation done. Even when the police man is present, at times the vehicles are queued for a long distance that the siren from the ambulance is not reachable to the police, and hence the vehicle has to wait until the traffic gets cleared. To solve this problem, there is a need for a new automation technology.[3]

LoRaWAN supports a low data rate in the range of 0.3 Kbps up to 50 Kbps. LoRaWAN devices typically have 5 to 10 years of battery lifetime.[4] LoRa technology is used in traffic controlling, so that only less number of nodes are required to establish the network. Main scope of this work is to implement the traffic clearance mechanism for ambulance using LoRa nodes. Coimbatore city in India is taken as a case study and the simulation is performed considering the location of the accident zone in the city.

Literature Survey

Luz *et al*. analyzed the effect of interference on the performance of LoRa network in long range.[5] An empirical model of the immunity region has been determined and it denotes the interference level that does not deteriorate the performance of the LoRa network much. It has been shown that total packet losses occur at an interference level of 14 dBm. Gopika *et al*. illustrated the optimization methods used to configure the transmission parameters like spreading factor and transmission power of LoRa nodes for the reliable transmission of data with minimum energy consumption.[6]

Faisal *et al*. introduced a Smart Accident Management (SAM) algorithm which relies on new sensor technology and tested the system using CupCarbon.[7] Two scenarios are tested to reinforce rescue operations and reducing response time. Hospital's response time to handle injured patients can be reduced by alerting the hospitals with the incoming cases during the rescue operation. Rescue time is dynamic and depends on the status of roads which is considered. Various smart city applications have been illustrated using LoRa technology.[8] Models for observing the air contamination levels and solid waste management in a city are discussed. It also explains a prototype to automate the working of street light according to the level of sunlight. Key strengths of LoRaWAN include scalable device connectivity, low bandwidth requirement, low latency communication, very long battery life and robust performance even in extreme situations.[9] Hence LoRaWAN is suitable for various smart city applications.

CupCarbon is a simulator used for the design and analysis of wireless sensor networks. It uses Open Street Map (OSM) framework for designing a network.[10] Various sensors can be included in the network in order to detect light, gas, fire, etc. The CupCarbon simulation relies on the application layer of the nodes.[11] It can be used to simulate a smart city environment and deploy the required communication technologies in order analyze their performance.

Big data analytics play a key role in Intelligent Transportation System (ITS). The data collected from vehicles and other sensor nodes can be used to analyze the road accidents, traffic flow, optimal routing of vehicles and traffic management.[12] The Vehicle Routing Problem (VRP) has been identified as an emerging research problem in order to combat pandemic situations like Covid-19. Multi-objective VRP model based on ant colony optimization is proposed to solve the problem of vehicle routing by addressing the cost involved in traveling during the pandemic situations.[13]

ZigBee protocol is used in vehicle-to-vehicle communication in order to regulate traffic during emergency situations. The information about the location of ambulance is communicated to the traffic control unit and the traffic signals are cleared for the free movement of ambulance.[14] Other than ZigBee, Wi-Fi is also used for traffic management in a smart city environment. Road traffic monitoring system is implemented based on the information about the smart phones inside the vehicles which are connected to Wi-Fi.[15] The disadvantage of the existing systems based on ZigBee and Wi-Fi is that, they can operate over distances only up to 100 meters under optimal conditions. There is a need for a communication protocol which can be operated in the range of 2 to 5 kilometers.

The literature survey shows that there is no existing research work illustrating a traffic management system based on LoRaWAN technology. Since LoRaWAN has many advantages including large coverage, license-free band, low power consumption and scalability, the proposed work fills the research gap by exploiting LoRaWAN for smart traffic management and signaling based on the location of the accident and the nearby hospitals.

Proposed Methodology

The road traffic is increasing at an alarming rate for the past few years and hence the time taken for the ambulance to reach hospital is increasing. Our proposed methodology will help the ambulance to reach the hospital earlier by controlling the traffic signals. LoRa network has been investigated to enable long range and low power transmission for traffic signal control.

The block diagram of the process involved in the proposed work during the occurrence of an accident is shown in Fig. 1. Firstly, the location of the accident spot is sent to the ambulance or control station. Ambulance then reaches the accident spot. Base station near the accident spot will gather the locations of nearby hospitals and by using the GPS location, the distances from accident spot to the hospitals are calculated. Ambulance then chooses a shortest distance path to reach the hospital among various paths available. As the Ambulance moves towards the hospital, the arrival of ambulance is continuously monitored by sensor nodes in each of the signal junctions. Once the incoming ambulance is detected, the traffic lanes are controlled by the sensor node in that signal junction. After crossing the sensor node at one signal, the ambulance status is sent to the next sensor node which is at the next signal junction and this procedure is repeated at every signal junction until it reaches the hospital. Thus the ambulance reaches the hospital as early as possible.

The simulation flow diagram of the proposed work is shown in Fig. 2. The ambulance starts moving from the accident spot and if it reaches near the traffic signal the message "STOP" is transmitted to the lanes present in that signal. Other signals will have normal functioning. If the "STOP" message is received by sensor node at traffic signal, the traffic light in the ambulance lane will be changed to "GREEN" color and the traffic lights in other lanes are changed to "RED" color. If the ambulance crosses that signal, it checks whether it reaches the hospital, if not the message that the ambulance has crossed will be sent to the next signal. The same procedure will be repeated till it reaches the hospital.

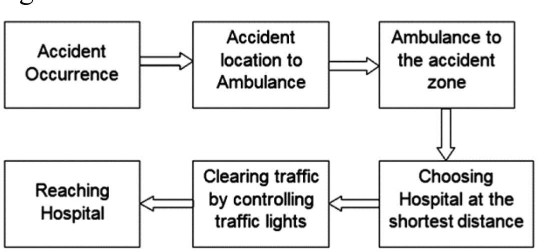

Fig. 1 — Block diagram of proposed work

Analysis of Zigbee, Wi-Fi, LoRa using CupCarbon

CupCarbon U-One 4.2 is a smart City and IoT based Wireless Sensor Network Simulator that can be used to design, visualize, debug and validate algorithms for various applications related to monitoring, environmental data collection, etc. In the proposed work, CupCarbon is used to analyze and compare the performance of ZigBee, Wi-Fi and LoRa technologies.

ZigBee

Zigbee is a wireless standard developed to support low-cost, low-power and low-data rate IoTapplications.[14] In this simulation, two ZigBee nodes named S1 and S2 are connected to find the sensing range of ZigBee standard as shown in Fig. 3. The latitude and longitude values of each node are noted from the radio parameters. These values are substituted for the distance calculation in distance calculator. Now the distance between S1 and S2 is calculated and the range of ZigBee standard is found to be 0.11 kilometer (or) 110 meter.

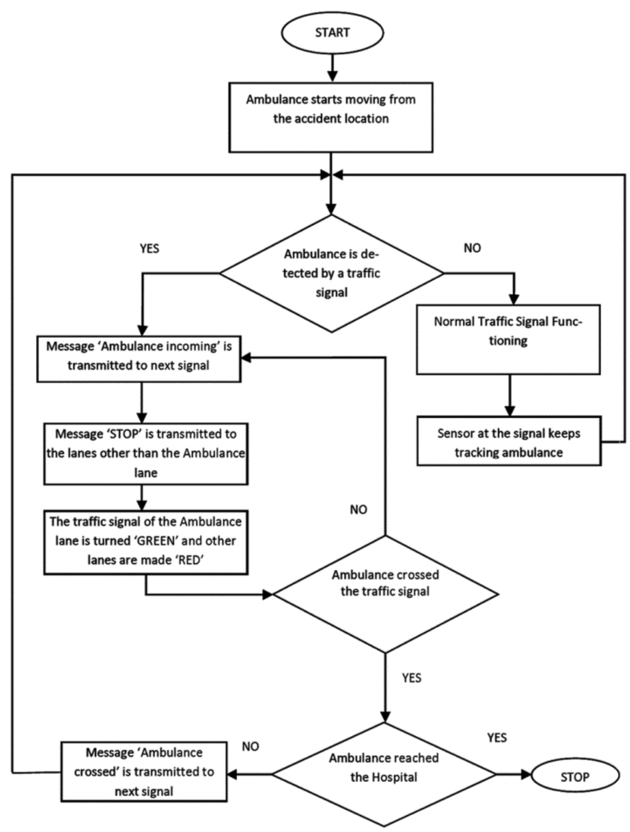

Fig. 2 — Simulation flow diagram of proposed work

Fig. 3 — ZIGBEE nodes

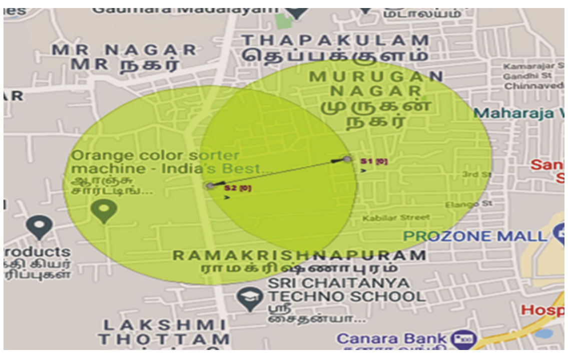

Fig. 4 — WI-FI nodes

Wi-Fi

Wi-Fi is a wireless technology that is used to connect computers, gadgets, smart phones and other devices to the internet.[15] In this simulation, two Wi-Fi nodes named S1 and S2 are connected to find the sensing range of Wi-Fi standard as shown in Fig. 4. The latitude and longitude values of each node are noted from the radio parameters. The distance between S1 and S2 is calculated using these values and the range of Wi-Fi standard is found to be 0.47 kilometer or 470 meters.

LoRa

LoRa is based on spread spectrum modulation technique called Chirp Spread Spectrum (CSS).[4] Two LoRa nodes named S3 and S4 are connected to find the sensing range of LoRa standard as shown in Fig. 5. The latitude and longitude values of each node are noted from the radio parameters. The distance between S3 and S4 is calculated using these values and the typical range of LoRa standard is found to be 5.54 kilometer.

The sensing range of LoRa standard is higher than other standards as shown in Table. 1. So it is clear that LoRaWAN can be used for the Smart city applications which require long distance communication especially in traffic signal controlling.

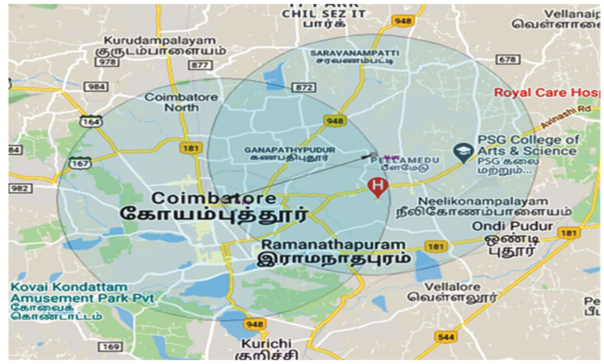

Fig. 5 — LORA nodes

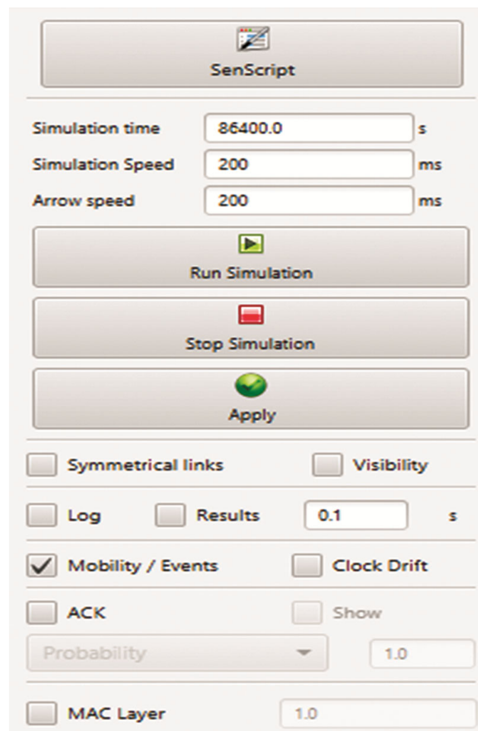

Fig. 6 — Simulation settings

Table 1 —Tabulation of sensing range for different standards

S.NO	STANDARD	RANGE (km)
1	ZIGBEE	0.11
2	WI-FI	0.47
3	LORA	5.54

Simulation

The simulation settings for the proposed work are shown in Fig. 6. The settings include Simulation time, Simulation Speed, Arrow speed, Symmetrical links, Visibility, log file of the simulation, Results, Mobility/Events, Clock Drift, ACK (type), Show if activated, MAC layer.

In the simulation work, an accident zone and three nearby hospitals in the Coimbatore city are considered.

In Fig. 7, source is the accident zone. Assuming that 3 hospitals are connected to the base station, all the existing traffic signals between source and 3 hospitals are shown in the figure. All nodes are considered as LoRa nodes since they can cover a wider range. The sensing range of each signal node is fixed as 200 meter. When the ambulance comes within the range, then the lane on the road in which ambulance is arriving will be turned to GREEN colour whereas all other signal lanes will be turned to RED colour. It means all the vehicles in those roads will stop moving. So that ambulance can move in the road without waiting for the signal. When the ambulance crosses the signal, the information will be sent to the next signal such that the next signal will get alert information. This procedure will be repeated till the ambulance reaches the hospital. There are many hospitals available nearby the accident zone. The ambulance has to reach the nearest hospital as early as possible. When the accident is detected by the base station which is near by accident zone, it will calculate the distance between itself and 3 different hospitals as shown in Fig. 8. Now the shortest distance will be chosen by base station and corresponding route information will be sent to the ambulance. The ambulance can reach the hospital that is in the shortest distance.The functioning of traffic signals while the ambulance is moving in the route with shortest distance is shown in Fig. 9.

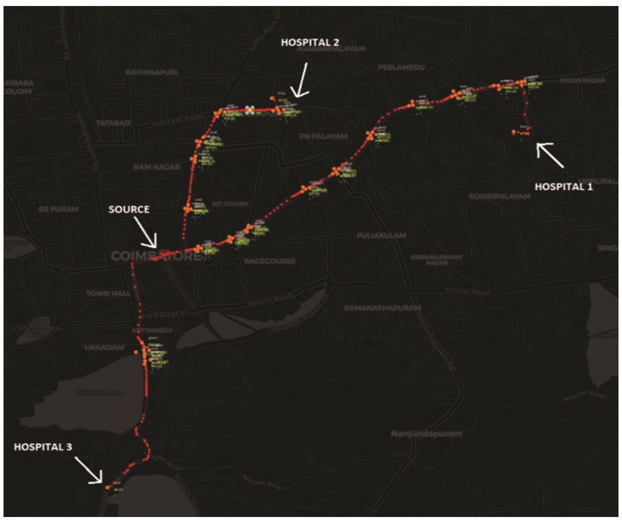

Fig. 7 — A source with three possible destinations

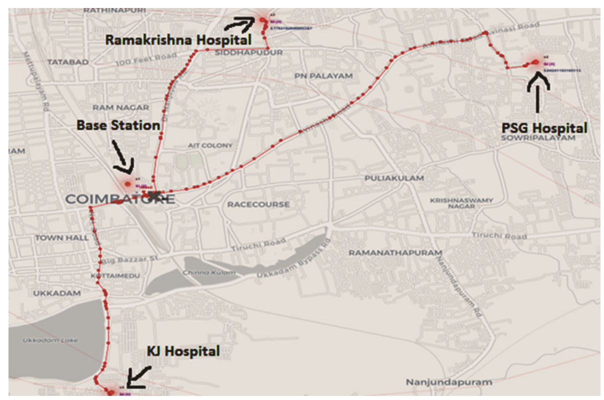

Fig. 8 — Base station to display the calculated distance

Fig. 9 — Functioning of traffic signals when ambulance moving in route with shortest distance

Result and Analysis

The base station computes the distance between the accident location and the nearby hospitals, from which the nearest hospital will be determined, as shown in Fig. 10. The hospital's location will be shared with the ambulance so that the ambulance take appropriate route towards the nearest hospital. As an example, three hospitals are considered which are nearby the accident location. Three routes corresponding to these hospitals are identified and distances are calcualted by the base station. From the Table 2, it is clear that ROUTE 2 is the shortest distance. The information of the route 2 will be sent to the ambulance and ambulance can move to the nearest (Ramakrishna) hospital.

The traffic signals are controlled through sensor nodes present in the route taken by the ambulance towards nearest, Ramakrishna hospital. When the ambulance enters the sensing range of a sensor node in a traffic signal, it will get detected and all the signal lanes will get changed such that the lane in which ambulance comes become GREEN colour and all other signal lanes become RED colour, as shown in Fig. 11. When the ambulance crosses the central node AMBULANCE CROSSED information will be sent to the next central node. The functioning of traffic signals along different routes from source (accident location) to destination (Ramakrishna hospital) are shown in Fig. 12.

The performance of the proposed system can be compared with that of the existing systems. For example if the ZigBee based traffic control system is considered, the emergency vehicle communicates with the nearby vehicle through Zigbee.[14] The vehicles then communicate with each other and finally the information about the emergency vehicle reaches the traffic signal. The system requires a vehicular communication network and if there is a communication failure in any of the vehicle, then the entire system fails. Whereas, in the proposed system based on LoRaWAN, the emergency vehicle directly communicates with the traffic signal. Hence the chance of failure of the system is very low. Moreover the latency in communication can be reduced in the proposed system as compared to the ZigBee based system. Also the ZigBee based system starts to work only after the patient onboards the emergency vehicle. Whereas, the proposed system starts to work once the accident has happended and thus the time taken by the emergency vehicle in reaching the accident spot can be reduced.

In the Wi-Fi based traffic monitoring system, road-side sniffers are utilized to monitor probe signals from

Table 2 — Comparison of different routes

S. NO	ROUTE	DISTANCE (kilometer)
1.	Route 1 – PSG Hospital	5.0585
2.	Route 2 – Ramakrishna Hospital	2.8423
3.	Route 3 – KJ Hospital	3.8778

Fig. 10 — Base station near the accident zone displaying the distances

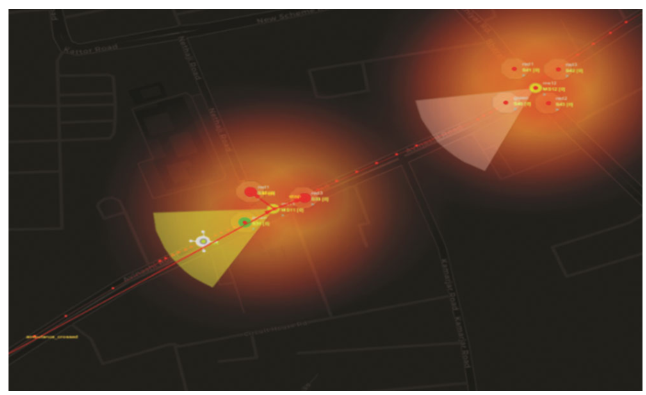

Fig. 11 — Functioning of traffic signals when ambulance enters the sensing range

Fig. 12 — Functioning of traffic signals in different routes

smarphones for estimating the traffic conditions.[15] The limitations of the work include, the cost involved in setting up of road-side sniffers and the finite estimation error. When it is compared to the Wi-Fi based system, the proposed system is cost effective and involves very less estimation error.

Conclusions

The proposed intelligent transportation system using LoRaWAN network enhances the rescue operations during pandemic situation and the performance is analyzed through cupcarbon simulator. The advantage of the proposed work is that the traffic clearance is implemented in such a way that the ambulance can move from its location to accident spot and again from accident spot to the hospital without waiting at any traffic signal. The proposed methodology reduces the time taken for an ambulance to cross a particular traffic signal by enabling communication between ambulance and signal and between two signals. LoRaWAN network enables coverage upto 5.54 km so that nodes at traffic signals and ambulances can communicate effectively. Eventhough Cupcarbon is advantageous in various aspects, the time taken to respond is delayed as the number of sensing node increases, due to the software complexity. The limitation of the work is that the traffic congestion is not considered while determining the optimum route during rescue operations. The future work suggested is that a mobile application can be developed in order to assist the ambulance drivers and automate the complete operation based on LoRaWAN.

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