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Technical Research

VEHICLE BLACK BOX IMPLEMENTATION FOR INTERNET OF VEHICLES BASED LONG RANGE TECHNOLOGY

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Abstract: Vehicle Black Box system records variations in vehicles in order to minimize and analyze accidents; or records traffic rules violations automatically and report them to traffic authority system. In many countries (like Iraq) traffic violation recording implemented manually causing false traffic fine recordings, even when the vehicle is not at the same location at traffic fine recording, so it is necessary to develop such systems that confirm the availability of the vehicle in that location during violation occurrence. In this paper, a Vehicle Black Box system based 433MHz long-range wireless modulation technology developed for safe driving issue by utilizing gas and flames sensors, and for false traffic violation recordings issues with proofing the availability of the vehicle at traffic violation location by utilizing GPS module. The system based Internet of Vehicles model to transmit the acquired data, where two nodes representing vehicles used with one base station forming Vehicle-to-Infrastructure communication mode. The system tested in real time and the sensed data transmitted and stored in a database for future analyzing purposes where the acquired GPS data used as a proof to vehicle's correct location with date and time stamps. Two vehicles data where captured and stored indicating their correct location with date and time stamps and stored in a database at the base station. The measured Received Signal Strength indicator and Signal to Noise ratio values are stored for analyzing purposes. The performance of the system in such Internet of Vehicle environment discussed according to the readings.

Keywords: *Internet of vehicles; long-range modulation; traffic violation recording; vehicle black box; vehicular sensor network*

1. Introduction

For safe driving without accidents due to many reasons related directly with the status of the vehicle or the driver, Vehicle Black Box (VBB) concept introduced. Traffic rules violations (red light crossing, speed exceeding, wrong side driving, etc.) also recorded with some black box systems to alter the driver or report to a monitor center in order to analyze accidents after occurring or to record traffic fine. Many countries (like Iraq) do not have such ability to record traffic fine automatically. So they tend to record violations manually, and this leads to many problems such as recording vehicle details (number, city, code) from its license plate mistakenly due to (either the vehicle was at high speed or blurred vehicle license plate) [1], then this mistake may record traffic fine to another vehicle rather than the violate vehicle. Unfortunately, sometimes traffic fines recorded at locations that the vehicle has not been there at all. So to guarantee driver rights of wrong violations recordings, it is necessary to develop systems that confirm the availability of the

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vehicle in that location during violation occurrence.

In general, (VBB) consists of two parts (data acquisition unit) and (data monitoring and alerting unit). Also the (VBB) system consists of many sub-systems each with a specific function, performing data gathering operation, alerting and analyzing these data to decide accident causes or tracking the vehicle. Different types of sensors connected to the (VBB) to gather data from vehicle and any changes in surrounding environment to the vehicle. The collection of sensors connected to a central controller, which manage these sensors for data gathering from the entire vehicle parts or the surrounding environments to the vehicle, forms a network known as Vehicular Sensor Network (VSN) [2].

Some (VBB) systems utilize wireless communication technologies to transmit the recorded data to analyze center in order to perform a specific functions or analyze these data to know the reason of an accident, etc., while some earlier systems did not use any wireless communication technologies to do so. Such wireless communication technologies used like Bluetooth, ZigBee, WiFi or GSM. Earlier (VBB) systems designed to deal with (vehicle location, vehicle speed) before and after an accident. In this paper, a vehicle Black Box (VBB) system is designed on two phases; the first phase deals with safety, that is to detect gas leakage and fire setting in the vehicle; the second phase deals with driver rights, that is to indicate (record) the location of the vehicle in case if false traffic fine recorded mistakenly to the vehicle. The system utilizes Long Range (LoRa) radio communication technique defined on Long Range Wide Area Network (LoRaWAN) architecture to send data via it, through Vehicle-to-Sensor (V2S) architecture and Vehicle-to-Infrastructure (V2I) architecture.

2. Related Works

Earlier (VBB) systems designed as accident detection (data recorder) system and/or vehicle warning system. Many earlier systems never used wireless communication technologies for data transmission, but they limited only for data recording for future analyzing. In Chet [3], a black box designed and developed which monitors vehicle speed via speed sensor and Programmable Logic Device that warns the driver when the speed exceeded a specific threshold limit. In Lee et al. [4], an embedded controller designed for car black box System on Chip, which implemented into FPGA utilizing CAN controller and image compressor to reduce size, power consumption and cost. In Kassem et al. [5], a vehicle black box designed which after an accident happens then a microcontroller takes 20 samples from data readings of the sensors (about 10 second after accident) then analyzing starts, such sensors were used with a microcontroller (PIC16F877A) are (speed sensor, water sensor, brake sensor, seat belt sensor and light sensor). In Jiang et al. [6], data processing software proposed to analyze the recorded data in real time for accident reconstruction. In Kim et al. [7], a camera captured image and 24GHz Frequency Modulation Continuous Wave radar utilized for speed and distance estimation of obstacles surrounding the vehicle, the captured images analyzed to widen the view angle to minimize accident probability. In Hui et al. [8], vehicle black box based dual core system and Micro-controller Operating Systems designed for data recording. In Leyva et al. [9], car black box as data recorder and analyzer designed based FPGA and accelerometer to determine car statistical properties according to its orientations on various land inclinations. In Hamdi et al. [10], vehicle black box designed that does not require any installed Road Side Unit (RSU) as infrastructure, but it depends on smart phone as a data recorder. In Kim [11], real time vehicle detection from vehicle black box images using deep learning technique is proposed to minimize accidents limits.

Recent (VBB) systems utilized wireless communication systems for data transmission after sensing via sensors. In Megalingam et al. [12], an accelerometer utilized to detect accidents and prepare a data with vehicle location that is detected via on-road RF receiver which appends its address code to the sensed data forming a code word to be sent to the cloud via RF transmitter/receiver then to be analyzed at the monitoring center to decide collision occurrence. In Patil et al. [13], speed measuring unit utilized for vehicle speed measurement, and vehicle location is detected via Global Positioning System (GPS) unit then gathered data is sent via Global System for Mobile communications GSM. In Prasad et al. [14], seat belt sensor, noise sensor, alcohol sensor, and up to 12 other sensors utilized for accident detection and analyzing, then a short text message (SMS) is prepared with time stamp and vehicle location and is sent via GSM to the concerned people. In Rekha et al. [15], pressure sensor for accident detection and GPS module for location determination are utilized, after accident SMS with accident occurrence and location of vehicle is sent to concerned people via GSM.

Many studies focused on vehicle accident detection and related it with black box design purposes, but few studies focused on traffic violation recordings. In Nejati et al. [16], violation recorder proposed using RFID with traffic signs and M-RFID, this system is able to receive the data from sign's tag and record the information for the offending person. In Aliane et al. [17], traffic-violation detection system proposed that based on a computer vision, which detects traffic signs, the system also designed as event data recorder to manage driver's traffic violations.

From above, no study deals with false traffic violation fines to guarantee driver rights, so it is important to design a vehicle black box that record vehicle correct location as a proof when false traffic fine recorded against the driver at location he never went.

3. Methodology

3.1. Internet of Vehicles (IoV)

In general, IoV environment classified into three layers; sensors layer inside vehicle data collecting, wireless communication modes layer like; Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I), Vehicle-to-Pedestrian (V2P) and Vehicle-to-Sensor (V2S) and data processing layer for analyzing and providing data from storages, then making decision for different cases related with the vehicle [18].

Some IoV architectures based on three, four or more layers, this is due to the case in which they operate in [19]. (V2V) allows for short and medium range communications among vehicle users, with cost and short message delivery with low latency. (V2I) enables vehicles to connect to internet for transmitting and receiving information via Roadside Base Stations. Mix of (V2V and V2I) or more constructs the heterogeneous (IoV) Network [18]. Fig.1 depicts types of vehicular communications of Internet of Vehicles. Vehicle-to-Infrastructure (V2I) and Vehicle-to-Road (V2R) used interchangeably sometimes.

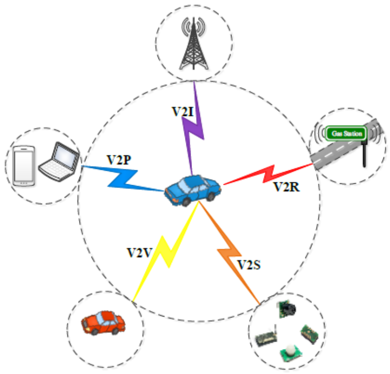


Figure 1. Types of vehicular communications of IoV [19]

3.2. Vehicular Sensor Network (VSN)

Vehicular Sensor Networks (VSN) is a concept of utilizing sensors as networks inside vehicles or on roads to sense road and vehicle environments then send gathered data from sensor to monitoring centers [2]. (VSN) is sub-set of Vehicular Ad-hoc NETworks (VANETs).

In general, (VSN) are considered as Wireless Sensor Networks (WSN) [20], with some differences like power consumption which is not big deal due to the battery of vehicle that provides energy with low cost. (WSN) has an architecture that is similar to (VSN); both have Sensor Nodes (SN) as shown in Fig.2 (a) and Base Station (BS) infrastructure as shown in Fig.2 (b) [21]. The (SN) has sensors for surrounding environment data sensing, a microcontroller as processing unit, power source and transceiver unit as a data-transmitting unit. The (BS) usually has same parts of (SN) except sensors, (BS) may include data visualization unit and/or control unit instead [21]. One of the applications of the (WSN) is the Internet of Bicycle based LoRa for smart campus applications in order to monitor e-bicycle location in real-time [22].

In this paper, the (SN) is a vehicle in mobility with a Black Box interconnected with sensors and a transceiver unit (LoRa in our case), and the (BS) that includes (LoRa transceiver) and storage unit to receive and store data from (SNs).

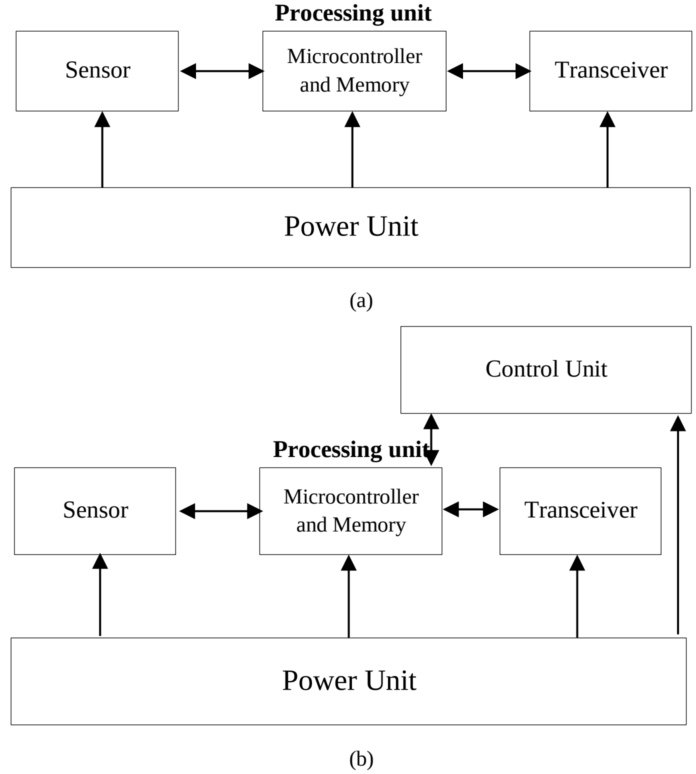


Figure 2. (a) Typical WSN Sensor Node infrastructure, (b) Typical WSN Base Station infrastructure [21]

3.3. Long Range (LoRa) Technology

Long Range (LoRa) wireless communication technology, utilized for transmitting data over ranges of kilometers (5Km – 15Km), adopts Chirp Spread Spectrum modulation with Spreading Factors (SF) ranging from (7 to 12) and data rate between (30bps to 50Kbps) [23]. Additionally to long range coverage, this technology stands on some properties which are: high robustness, multipath resistance, very high immunity to Doppler Effect and low power consumption [24].

LoRa transceivers may operate in Industrial, scientific and medical (ISM) frequency bands (868MHz and 433MHz for EU, 915MHz and 433MHz for USA) [24].

Different protocol architectures (star, mesh) can utilize LoRa modulation. Long Range Wide Area Network (LoRaWAN) Media Access Control (MAC) defines the communication protocol and system architecture with three classes (A, B and C). LoRaWAN network nodes transmit data to multiple base stations [25]. Fig.3, depicts the LoRaWAN communication protocols and system architecture, depending on the application required then classes are chosen [25].

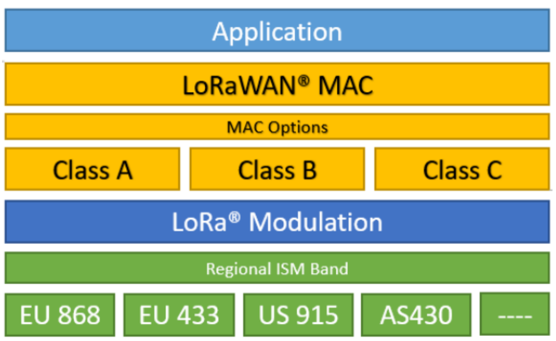


Figure 3. LoRaWAN communication protocols and system architecture [25]

In this paper, 433MHz RF LoRa module based SX1278 PM1280 chip used as a transceiver, shown in Fig.4.

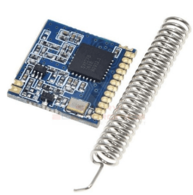


Figure 4. 433MHz RF LoRa-module

4. The Proposed System

The proposed Vehicle Black Box system (VBB) consists of two parts: transmitter (TX) and receiver (RX). But since IoVs is considered in this paper, then two transmitters are designed with same specifications denoting Black Boxes on the vehicles (nodes), these both nodes gather information (via onboard sensors) from their corresponding vehicles forming Vehicle-to-Sensor (V2S) architecture, and then transmit these information to a receiver denoted as Base Station (BS), this forms Vehicle-to-Infrastructure (V2I) architecture, Fig.5.

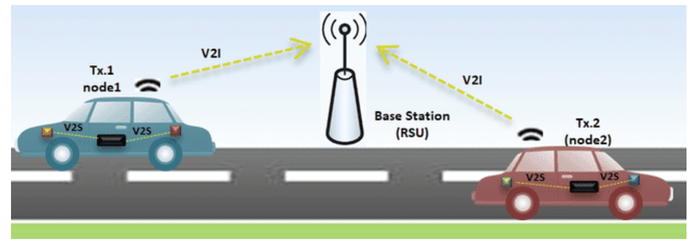


Figure 5. Proposed system architecture

The system design architecture consists of four layers: Acquisition layer, Monitoring layer, Communication layer and Storage layer, as depicted in Fig.6.

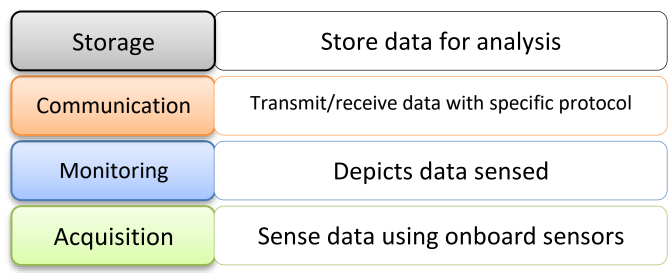


Figure 6. Proposed system layers

At the **Acquisition** layer, the system (at node side) utilizes (MQ-5 gas sensor, flame sensor and Global Positioning System (GPS) module). All of them connected to Arduino Mega 2560 board forming (VSN) in which the MQ-5 detects gas leakage and the flame sensor senses flame (fire) and the GPS module retrieving vehicle position and some information like (longitude, latitude, date, time and speed) performing data acquisition process. At the **Monitoring** layer, the system displays the sensed data (at node side) using LCD 16×4 display module. At the **Communication** layer, the gathered information prepared as a packet to be transmit via LoRa technology to the (BS). At the **Storage** layer (BS side) and after data reception, data displayed again for monitoring purposes, and stored in a memory card using Micro SD TF Card Storage Memory Module.

4.1. System Implementation

Fig. 7 shows a fritzing schematic diagram of the Black Box system at the node (vehicle) side. Fig.8 shows a fritzing schematic diagram of the Black Box system at the (BS) side.

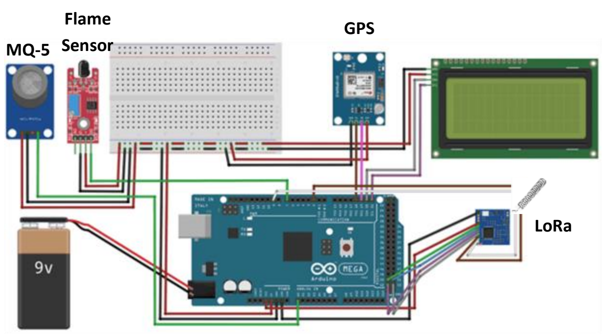


Figure 7. Proposed Vehicle Black Box system (TX)

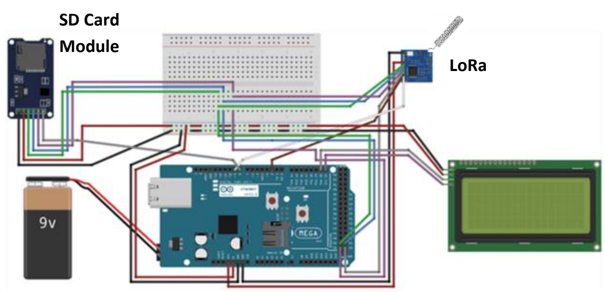


Figure 8. Proposed Base Station system (RX)

Two nodes considered in this architecture representing two moving vehicles with their own Black Box onboard. These Boxes gather and send (gas leakage and fire flame) status; vehicle position (longitude and latitude); date; time and speed. The information sent via LoRa technology using Long Range (LoRa) 433MHz based on SX1278 chip with spring antenna.

4.2. Data Packet and Frame formation

Transmitted data (payload) packet consisting of all sensors readings which are gas (g), flame (f), latitude (lat), longitude (lng), day (dd), month (mm), year (yy), hour (h), minute (min), second (s) and speed(v). The payload is attached with destination address (DestAdr), sender address (SendAdr), message identification (MsgID), payload length (PayLen) and payload (Pay) forming the frame to be transmitted as shown in Fig.9.

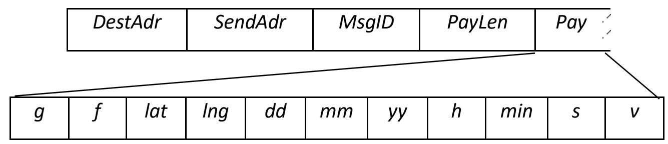


Figure 9. Frame and packet formats of transmitted data

(DestAdr) is the receiver BS address to which the frame sent. (SendAdr) is the transmitter node address in which data send from (since two nodes considered in this network, then each node has its own address). (MsgID) is the incoming frame identification. (PayLen) is the transmitted packet length, and (Pay) is the transmitted packet that is carrying sensors data.

5. Results and Discussion

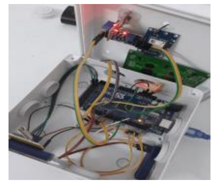
Table 1 shows a comparison of this work with related works mentioned before according to the applications and function that (VBB) used for, wireless communication technologies utilized and (IoV) environment utilization.

Fig.10 shows the designed hardware of Vehicle Black Box (VBB), (VBB) Node1 prototype and Base Station (BS) prototype. The designed IoV architecture which is consist of one (BS) and two nodes (Node1, Node2), where each node represents a vehicle, is shown in Fig.11 with two readings as a test.

Table 1. Comparison between this work with Related Works

Ref.	Applications	Wireless Technology	IoV Utilization
[3]	Speed monitoring	No	No
[5], [6]	Accident analyzing	No	No
[7]	Speed and distance estimation	No	No
[12]	Accident and location reporting	RF transceiver	No
[13], [14] and [15]	Speed and location reporting	GSM	No
[16]	Traffic fine recording	RFID	No
This work	Safe driving and traffic fine recording	LoRa	Yes

After fixing the Black Boxes on the nodes (vehicles), readings (data) received from the sensors and the GPS module, and then transmitted using a LoRa module sender to the (BS), these data shown in the Serial monitor window of the (BS) as depicted in Fig.12. This Serial monitor shows gas sensor value, flame sensor value and GPS data (latitude, longitude, date, time and speed), Received Signal Strength Indicator (RSSI) and Signal to Noise Ratio (SNR). These data received from two nodes coded as (0xbb and 0xcc) and each node with its own data.


Top Left


Top Right


Bottom

Figure 10. The proposed hardware prototypes (Top Left: inside box, Top Right: Node1 prototype, Bottom: Base Station)


Top

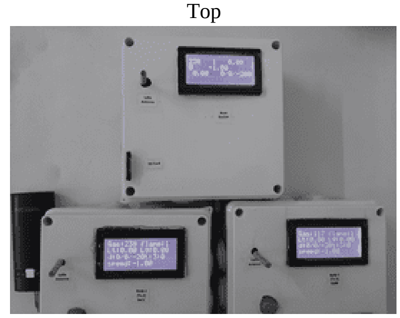

Bottom

Figure 11. The Proposed IoV architecture (Top: BS matches Node1 readings, Bottom: BS matches Node2 readings)

The received data is stored as a text file in a (TF SD memory card) at the (BS) side and arranged as shown in Fig.13.

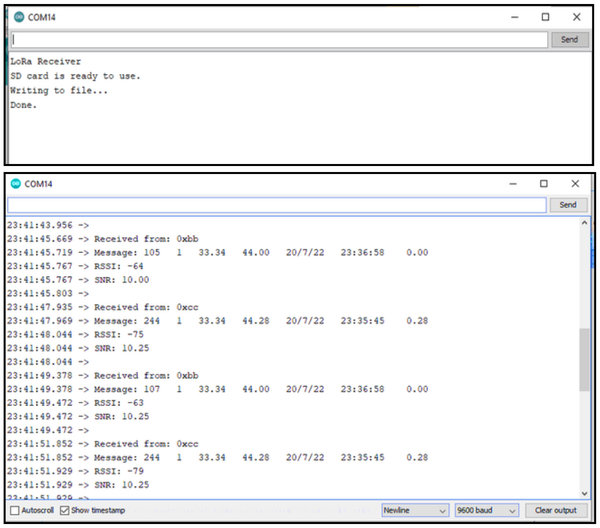
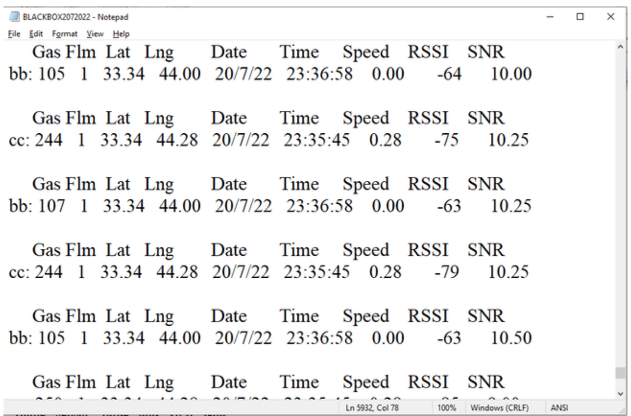


Figure 12. BS serial monitor



	Gas	Flm	Lat	Lng	Date	Time	Speed	RSSI	SNR
bb:	105	1	33.34	44.00	20/7/22	23:36:58	0.00	-64	10.00
cc:	244	1	33.34	44.28	20/7/22	23:35:45	0.28	-75	10.25
bb:	107	1	33.34	44.00	20/7/22	23:36:58	0.00	-63	10.25
cc:	244	1	33.34	44.28	20/7/22	23:35:45	0.28	-79	10.25
bb:	105	1	33.34	44.00	20/7/22	23:36:58	0.00	-63	10.50

Figure 13. SD card memory stored data

From the side of security issue, the gas senor value changes as the level of the gas inside vehicle increase or decrease, the flame sensor value changes from (no flame = 1) to (flame = 0) if there is a fire inside the vehicle. The vehicle (0xcc) has high level of gas unlike vehicle (0xbb), both vehicles has no fire. On the other side of false traffic fine recording (driver rights), this paper focuses on proofing the position of the vehicle in case of false traffic fine recording. The latitude and longitude recorded values can be copied to Google map site to check the correct location of the vehicle and compare it with the location of false fine which is recorded to the driver. For example for vehicle (0xcc) with false recorded traffic fine, then its true location at (latitude: 33.34, longitude: 44.28) during false fine recording is shown in Fig.14 with the red map marker.

The RSSI values shows the distance between the Nodes and the (BS), its value is in negative and as it gets closer to zero then this means that the Node is closer to the (BS). As shown in Fig.12 at (RSSI = -64) for vehicle (0xbb) and (RSSI = -79) for vehicle (0xcc), this mean that vehicle (0xbb) is closer to the (BS) than vehicle (0xcc).

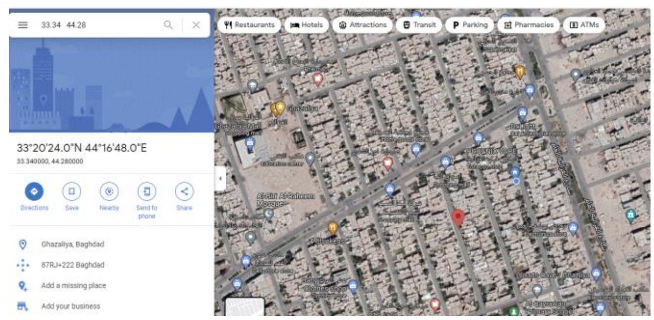


Figure 14. Google map explaining correct location

6. Conclusions and Future Scope

A Vehicle Black Box System designed for safety and false traffic fine recording approaches, utilizing Vehicular Sensor Network under Internet of Vehicles model utilizing 433MHz Long Range wireless modulation technology. For security approach, gas and flame sensors are used. In addition, for driver rights of false traffic fine recording approach, GPS module used to get the correct location of the vehicle represented with latitude and longitude readings with date and time stamps to ensure the availability of the vehicle at the correct location during traffic fine recording. In case of wrong traffic fine is recorded to the driver at a place that he never been there before, then it is easily can be returned to the recorded data of the vehicle location with their recorded date and time for checking. The IoV architecture used is (V2S and V2I) with two vehicles and one Base Station. The values of (RSSI) of the signal returned from the LoRa module, it is concluded that as the (RSSI) value get closer to zero then the signal strength is better than when (RSSI) values are far of zero, where close vehicle to the (BS) returns about (RSSI = -44) whereas far vehicle may return (RSSI = -80). As comparison of this work with the related mentioned works, LoRa technology utilized instead of GSM or Bluetooth technology (as some related works done) minimizing cost problem when designing such systems and providing large coverage area to the system. For future scope, this system developed to be monitored using Internet of Things analytic platform (such as ThingSpeak) by utilizing Arduino compatible Ethernet shield at the (BS) side.

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Conflict of interest

The authors confirm that there is no conflict of interest associated with the publication of this article.

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