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A Low cost prototype for Vehicle to Infrastructure communication

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***Abstract*—Exchange of messages in Cooperative Communication and Sharing applications is the significant role in vehicular adhoc network(VANET)s for passengers, driver safety, warning indications, weather updates, traffic updates and road conditions etc can be shared among vehicle nodes in VANET within the STS (Smart Transportation Systems). We conducted an experimental setup to study and create a simple network among five vehicle nodes & it connectivity. Design of each vehicle node composed of communication unit, Processing unit, GPS and power source. Each vehicle node in network exchanges or shares details such as position, speed & direction etc. of the vehicle node to Infrastructure or RSU in which administrator or authorized user can track the mobility path record of that vehicle including current status of a vehicle. This hardware can also useful to trace any missing vehicles, theft vehicles, misbehave vehicles using latitude and longitude of vehicle. Our results showed that the Xbee wifi modules are not enough to track the high mobility vehicle without time gap. We also observed a degradation of network performance in high way scenarios. We created the base station to log and update cloud to record the details. This application can be integrated to Internet to form the Internet of Vehicle (IoV) network which is a subclass of Internet of Everything (IoT).**

I. Introduction

Advances in wireless communication systems specifically in dynamic environment and high computing technologies, motivated us to develop an applications to improve the degree of quality life of people by reducing the waiting time at traffic junctions, know the traffic density (traffic congestion) before starting at source, know the weather conditions of the travel path before itself and an intelligent decision to travel in the shortest route to the destination to minimize waiting & travel time, save fuel etc. Intelligent transportation system (ITS) consists of wireless communication module to enable information exchange among the vehicle nodes equipped with On Board Unit (OBU). These OBUs exchange their beacon data among other vehicle nodes or OBUs. Every OBU module not only provides the position information but also weather conditions such as oxygen levels, CO2 levels, temperature & humidity etc. in environment of travel route. The input sensors used for OBU are GPS Receiver, selected gas sensors (such as temperature & humidity) to gather the status of vehicle node. Every vehicle node or OBUs are designed to act as cooperative manner, derive intelligent decisions with respect to potentially dangerous driving conditions, and to adjust their routes or travel schedule as and when required and same will be indicated to drivers, passenger etc.

A Vehicular Ad-Hoc Network (VANET)[1] is a specific type of Mobile Adhoc Network(MANET) in which each vehicles acts as communication node called OBU. Each OBU is able to share data among nearby vehicles, and nearby fixed units, called as a roadside unit (RSU) to form a Vehicular Network. As the vehicles are high mobility in nature, establish the connectivity in network is major challenge task. The main objective of VANET is to provide safety messages or indications, passenger & driver comfort and interchange of data among road users, drivers & passengers. Wireless Access in Vehicular Environments (WAVE) [3][4] protocol stack is comprised of Five IEEE standards specification for Physical Layer and MAC Layer , including 1609.1 through 4 and 802.11p. The main goal of IEEE 1609.4 Standard for Wireless Access in Vehicular Environments (WAVE) is to improve the performance of vehicular networks among the OBUs or vehicle nodes with multichannel operations that allow for the coexistence of safety and non safety related vehicular applications.

The IEEE 802.11p PHY layer provides the way of possibilities of dedicated short range communications (DSRC), defined by the Federal Communications Commission (FCC), USA. The DSRC technology operates at a 75 MHz bandwidth, positioned in the spectrum range of 5.850 GHz to 5.925 GHz with central frequency of 5.90 GHz. This 75 MHz bandwidth divided into seven 10 MHz channels each. The center channel is called the control channel and the remaining six channels are represented as the service channels.

II. Design of Vehicular Network

The satellite based global position system (GPS) improves the accuracy of position of vehicle in high dynamic conditions (PMB-648 GPS receiver accuracy is 2 meters). Two meters accuracy is negligible in Vehicular System because position of vehicle with two meters variation will not effect in application. The test bed designed for our experiment is shown in Fig 1. Setup has deployed Andhra University campus. One xbee pro communication module was used as RSU because of its communication range in LOS to collect the information such speed, position etc. The standard communication range of Xbee Pro S2B as provided in data sheet was 1.6 km. we decoded only selected information from the GPS Receiver. The RSU was interfaced with one laptop with 8GB RAM & i5 6th generation processor to monitor vehicle. The Xbee Proc[2] was configured in API mode using X-CTU software and an ardiuno code was written to trace vehicle nodes data in network. Network was established among five vehicle nodes or OBUs and one RSU as base station.

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III. Design of Vehicular Node

Association of RSUs & OBUs creates a VANET. When a vehicle enters into network, communication module associate a link to nearby OBU or RSU wirelessly. Generally, RSU are placed at junctions points or flour road points etc. so that every vehicle in crossing the junction, shares its information to RSU. OBU was programmed such that it can respond to the RSU as and when needed by RSU. Technically, OBU search in network & smart response for every 5 seconds. VANET is collection of vehicle nodes. Every vehicle node equipped with OBU. Every OBU node contains the following components. Components are aligned, designed and mounted on board such that minimum number of connections are required to setup a vehicular node. Each OBU or vehicle node has the following hardware modules.

1) GPS Receiver Unit (PMB -648 GPS)

2) Arduino Uno Microcontroller

3) Xbee S2S Communication Unit

4) 9v Battery as power source (vehicle battery can be used in real time)

A. Hardware Description

The PMB -648 GPS Receiver [5] module receive GPS data up to 20 satellites(as per data sheet), it synchronizes every 5 millisecond. The GPS is a self-contained global positioning satellite receiver, capable of receiving exact latitude, longitude, speed, header and other useful information for navigation with 2 meter accuracy(as per data sheet) but experiment result shows around 5m accuracy in 15km/h speed. The data transmitted by the GPS receiver is based on the industry standard NMEA0183 v2.2 data protocol, making it easy to interpret and use. The PMB-648 GPS accuracy measured by acquisition Time such as Cold start is 42 sec, Warm start is 38 sec and hot start is 1sec as specified in data sheet. GPS data consists of text like sentences that contain latitude, longitude, speed and other information as shown in Fig 2. Encode() function in serial software module provides the access to GPS sentence. Usage of encode () is shown below. To minimize the development cost of vehicle nod, Arduino Uno board is used. It provides 1 transmission & 1 receiving pins. It cost around $10. Software or virtual serial communication ports can be created by program.

ss.encode();

Where ss is the object of Software Serial.

Atmega 328p microcontroller [6] available in low cost Arduino Uno board was used to program the node[6]. TinyGPS library provides built-in functions to receive gps data, read & encode and a virtual digital programmed to attach the receiver where as standard hardware serial port was interface with Xbee Pro communication module.

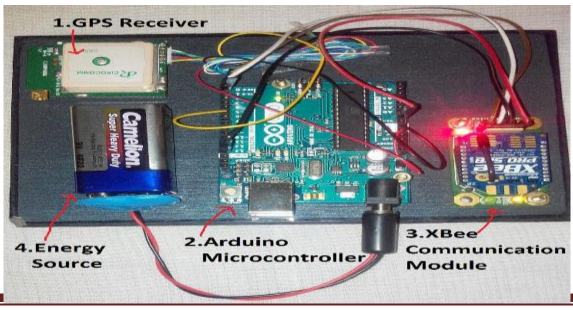

Fig 1: Vehicular Node (OBU)[1]

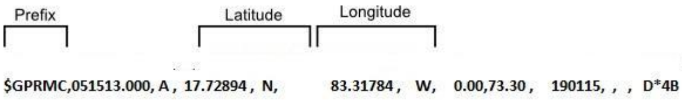

Fig 2: GPS Text Sentence

To minimize the design cost of vehicle node, we selected the Arduino Uno board which has only one hardware serial port. Software or virtual serial ports were created by program logic, written to setup the available digital pins as Software Serial(SS). An additional sensors such gas sensors, GPS receiver etc. can be interfaced to collect the information such as environmental parameters, GPS data etc. Communication module(XBEE) on OBU was interfaced to hardware serial ports of uno board. All vehicle nodes are setup as Zigbee End Device(ZED) nodes in AT mode in which received data from software serial port was transmitted immediately at 2.4 GHz band on channel allocated by RSU (Xbee PAN Coordinator). All the five communication units in network are configured as broadcast mode, baud rate 9600 (default), data bits 8 , start bits 2 , stop bit 1 and rest are flow control bit and parity are set to none. All these specifications are defined for both OBUs and RSU.

B. Software Description

We prefer all open source software's(OSS) in experiment. The list of sofwares used are given below.

1) TinyGPS Library
2) X-CTU Communication Software
3) Ardiuno Integrated Development Environment
4) Serial Library

X-CTU was provided by Digi, used to configure the Xbee Pro communication modules. The one RSU configured as coordinator API (function) to receive the GPS information from every vehicle nodes when it is in the range of RSU. In API mode, coordinator can distinguish the each vehicle by receiving the Vehicle Number in addition to position information. Every OBU was programmed with its registration number. This registration number uniquely identifies every vehicle that joins in Network. Destination High (DH) and Destination Low (DL) are fixed as 0x0000 and 0FFFF respectively. These values indicate broadcast transmission. This indicates that the coordinator is in broadcasting mode. So every vehicle node can communicate with RSU. In the same manner, each OBU configured as AT function in which all parameter configurations are performed using commands. Each vehicle node is configured as Zigbee AT Mode and Destination High(DH) and Destination Low (DL) of vehicle node also configured as 0x0000 and 0FFFF respectively to broad cast GPS Data. Baud rate is set as 9600, Flow Control is none, data bits 8 , Parity none and stop bits 1 for Coordinator and node. Arduino IDE (Integrated Development Environment) is used to program the Atmega 328p microcontroller. Due to limitations of hardware serial ports of Ardiuno uno board, a Software serial port was defined for digital pin 6 as receiver and digital pin 4 as transmitter using

Software Serial library. Syntax of software serial port is given below.

SoftwareSerial ss(RxPin,TxPin);
Where ss is the object of Software Serial class. RxPin and TxPin are receiver and transmitter pins respectively.

TinyGPS library provides functions to encode the sentences received from GPS receiver. The sample format of GPS sentence received by GPS receiver shown in Fig 2. The encode() function returns the all the decoded data received from GPS receiver such as latitude, longitude, speed on earth, date (in UTS), time (in UTS). Experiment results are shown in Result section. Since all five OBUs are configured as AT mode, they can transmit data immediately as and when GPS received. Xbee of OBU broadcast to Nearest RSU which can able to receive and interpret the position and speed details of vehicle. Data collected in experiment are shown in Table1.

C. *Hardware-Software Integration*

The linkage between hardware modules and corresponding Software modules are done the following way.

1. TinyGPS Library activates the GPS Receiver and encode function in Library retries the GPS data from 18 satellites simultaneously to provide more accurate position information.

PMB -648 GPS Receiver→ TinyGPS Library

2. Atmega328p microcontroller was programmed using arduino IDE Tool. This tool allows developers to write logic and configure the pins for a particular purpose.

ATmega microcontroller→ Arduino IDE

3. Xbee modules are controlled using X-CTU software. Function Set allows xbee to operate in a specific function.
Xbee Pro→ X-CTU Software

IV. IMPLEMENTATION OF BASE STATION

RSUs or base stations are setup as API mode rather than AT mode to differentiate the every vehicle individually otherwise it is difficult to identify the position data belong to which vehicle. The following useful data was interpreted form OBU at coordinator.
1) Vehicle unique number
2) Latitude and longitude
3) Speed of vehicle

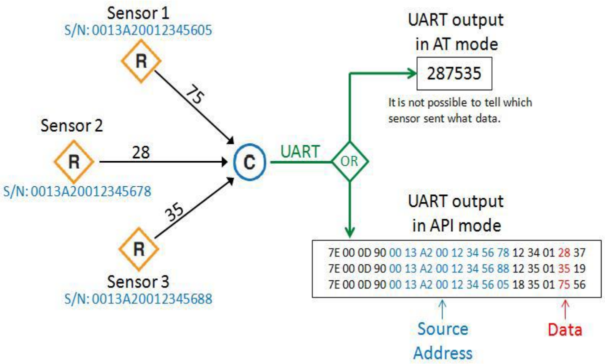

Fig 3 Coordinator Station in API and AT Mode[1]

In figure 3, output data 287535 received at base station which is setup in AT mode. Base station can able to identify which sensor sends 28 data, which sensor send 75 etc. Every sensor sends its unique serial number along with data in API mode. Because we are restricted our design to tracking application, above data are sufficient to identify the route of vehicle simultaneously. Data collected at RSU can be interface to IoV to track the vehicle in addition to log and store in database for analysis and predictions purpose. The last field of frame format represents the sensor data, position information or speed of vehicle (shown in red color figure 3) and Blue color data represents the Unique address (Serial number) of sensor or OBU module specified by vendor. Monitoring station or base station was deployed in the Department of CSSE Andhra University, to receive the positions of vehicle nodes. Received data was shown in red color in the path.

V. EXPERIMENT RESULTS

Each OBU was programmed to transmit the vehicle unique number along with position information and speed to nearby vehicles or OBUs, and also to RSU. Table 1 show the collected data at RSU, when OBU1 is in the communication range of RSU. The designed OBU1 was coded with vehicle registration number such as AP31AU1234. When vehicle moves from one location to another, OBU1 transmits vehicle number along with position, speed detail as shown in the following Table 1. When vehicle node or OBU1 moves in a direction, the travel path was traced online simultaneously by entering received position details. Our target is deployed the low cost vehicular adhoc network. We constrained to network size of five OBUs which are placed within 400 meters range. Five OBUs and one RSU is setup as figure 4 shows. This experiment was conducted in Andhra University, Visakhapatnam and real values are loged, stored in DB and shown in map.

Figure 4 shows the travel path of AP31AU1234 vehicle node (OBU1) in map and similarly travel information of OBU2 & OBU3 are also shown in Fig 5 & Fig 6 respectively. Even though data sheet of Xbee pro S2B provides the range up to 1.6 Km in outdoor (LOS) environment, in experiment conditions, we are able observe the strong signal up to 500 meters range. and similarly OBU2 and OBU3 are also computed and latitude and longitudes are represented in Google map to trace the travel path of second and Third vehicles.

Table 1 : OBU1 log data RSU

Vehicle Node	Latitude	longitude	Speed
AP31AU1234	17.72894	83.31784	5
AP31AU1234	17.72902	83.31819	10
AP31AU1234	17.72916	83.31843	15
AP31AU1234	17.72925	83.31876	20

In the representation of Google map, red color indicates the position of RSU where data is collected and logged. Similarly blue color indicates the positions of travel route of OBUs.

Fig 4: OBU1 in Andhra University Campus

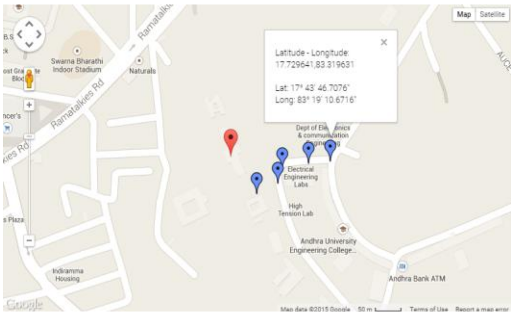

Fig 5: OBU2 Tracking Path

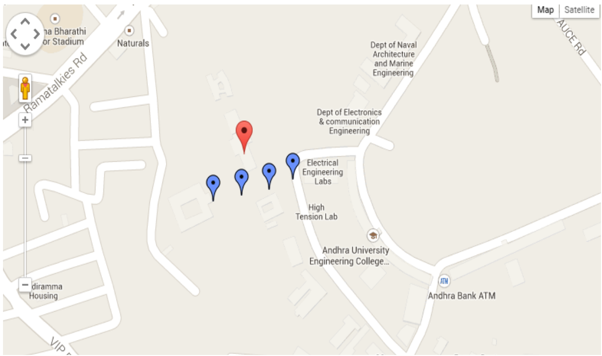

Fig 6: OBU3 in Andhra University

Table1 shows the vehicle registration number, position & speed in km/h.

VI. Conclustion and Future Scope

We established the Vehicular Network using Xbee pro S2b among five nodes. Communication from vehicular node to Road Side Unit (Coordinator) was experimented. All OBUs are transmitted its position data successfully to RSU. All OBUs travel path is traced with help of Google map, logged & stored in database. This is data can be used in security applications. The result proved that the zigbee communications in dynamic and high speed environment works fine. We are able to establish the network with low cost module but result indicates the need of reliable low IEEE 802.11p communication modules.

This work can be extended to update or record the real time data in Cloud using Internet of Things (IoT) for real time monitoring of vehicles and multiple of users can be benefited. We can be extended to facilitate browsing, transfer the multimedia data such as images, video, audio format data to passengers and road users. We can establish communication from one vehicle to another vehicle (V2V) using multi-hop as future work and Share data among vehicles. Designed system can test for safety message communication with respect to accuracy and delay.

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