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BUILDING INTELLIGENT TRANSPORT SYSTEMS BASED ON INTERNET OF THINGS (IOT)

M. Lingaraj [1], B. Anand [2]

[1] M.Lingaraj, Head , Department Of Computer Science,

Sankara College of Science and Commerce, Coimbatore.(India)

[2] Dr.B.Anand, Head of the Department, Govt Arts College , Ooty (India)

ABSTRACT

With the emergence of the Internet, a large quantity of data is generated by the communication network, largely triggered by the human activity. Adding to this, emerging technology like Internet-of-Things (IoT) wherein a large number of devices are getting connected to the Internet, thereby accelerating the rate of data generation. There are also future predictions that the number of devices connected to the internet is going to exceed the number of people connected to the internet. So there occurs the necessity to harness this large amount of data (mostly sensor data), convert them into useful information, make intelligent predictions and use this knowledge to build robust systems. In this paper we demonstrate the idea to build an Intelligent Transportation System (ITS) using the Internet of Things (IoT) platform. The system has three components; the sensor system, monitoring system and the display system. The sensor system has Global Positioning System (GPS), Near Field Communication (NFC), Temperature and Humidity sensors, which are always connected with the internet via a GSM network to track the location, commuter and ambience inside the bus. The monitoring system is used to extract the raw data from the sensors database, convert it in to a meaningful context, triggers some events with in the bus and provide information to the bus driver. The display system is used to show the context data (bus and travel related information) to all the commuters in the bus stop. We describe our prototype and show how this can be used as a fundamental component to build the ITS.

I INTRODUCTION

Transportation of people, goods and services is a multi- million dollar industry and forms the backbone of today's global economy. The users of the transportation networks no longer see transportation as movement from point A to point B, but they are also expect a certain quality of service. Quality of service interms of any transportation system is measured in terms of the safety assurance, journey time, facilities provided during travel. Vehicular tracking systems have proved to be as a useful technology in providing a certain quality of service to its consumers, by efficiently allowing them to track the location of their object of interest, along its journey. Many vehicular tracking systems provide user applications that run on smart phones that connect to the Internet for location tracking [5][7].

Vehicular tracking system is a very useful technology for tracking public transportation (like bus) in developing countries. One of the major problems faced by the commuters is that, the bus can arrive either earlier or later than the expected time and may even be canceled. There are various reasons for the above ranging from poor climatic condition, unforeseen road conditions, low availability of drivers etc. So it will be very useful if there is a way to provide the tracking ability through normal GSM based phones, as the smartphone proliferation is low in developing countries (compared to feature phones)[15] and their need to be continuously connected to the Internet is a challenge by itself. This forces us to think on how to provide vehicle tracking system that can satisfy the needs of the common people in developing countries.

Though there is much demand for such features and services, the vehicular tracking systems have not evolved enough to meet this expectation. We are not limited by the technology itself or access to technology, instead, the closed box and rigid approach in building technology systems remains the bone of contention in taking the technology to the masses. Vehicular tracking systems are provided by large enterprises that are more into volume manufacturing and is not feasible for them to customize the the HW and the vehicle tracking infrastructure according to the needs of the customer. So much of the COTS vehicle tracking system have more or less the same functionality, low level of user customization and a high cost compared to the services offered. There is a growing requirement for developing vehicle tracking system that could be used by all the people around the globe irrespective of their handset and the availability of Internet. This provides a challenge and an opportunity to have more flexible, predictable, accountable and afford-able transportation systems for the remaining transportation modes (like bus, car, fleet management systems). Below is a definition of what these terms mean and how it can be achieved.

TABLE I

FEATURES EXPECTED AND HOW TO ACHIEVE THEM

Features	Definition	How to achieve
Affordability	HW/SW cost should be low	Volume production
Accuracy	HW/SW precision	quality HW/SW modeling
Customization	add features to HW/SW	unified HW/SW standard
Flexibility	modify HW/SW features	provide the infrastructure

As our design is open sourced, the user is provided access to the entire source code, design documents and we encourage user involvement in design process. Scientific advances in material science, semiconductor processing, careful designing and testing will improve the accuracy of the design. We have sourced the best components available in the market to demonstrate our first prototype. Our next step will be fabricate them and go into volume production to bring the cost down. We have made our design robust and feature rich, which will be discussed in the following sections.

II RELATED WORK

The Internet revolution has opened up new technologies such as ubiquitous computing, Internet of Things (IoT), context-aware computing etc. Researchers demonstrated numerous survey regarding context-aware computing for IoT and the market research on the significant growth of sensor deployments over the past decade. There are many applications developed with IoT infrastructure in field of education, entertainment, healthcare, agriculture, transportation, real estates and so on. In specific, IoT has a big influence on transportation. Many researchers have explored ITS with respect to tracking vehicle systems.

Authors in [1][2] demonstrate an SMS based vehicle track-ing system to transfer the latitude, longitude from GPS and automobile data to end systems and map their exact location in Google Earth using Keyhole Markup Language(KML). Researchers have also worked on SMS tracking system with theft identification and lock feature. In [3], SMS is used to trigger the microcontroller subsystem that generates the control signal for electronic relays, which in turn controls the vehicle's engine and door locking mechanism. So once a theft is detected, the vehicle can be tracked and brought to halt through an SMS. A password based authentication is used to release the lock imposed on the door and the engine. A lot of research has also been done on Web-based vehicle tracking system [4], where the latitude and longitude are transmitted to the server through HTTP protocols (GET Methods). Some researchers have also developed open source platform for GPS tracking [5]. There are also efforts to tweet location information of vehicles in the Social media like twitter [6]. There are applications where there is an in-vehicle device with GPS, GSM and microcontroller, a server and a smartphone application are used for the vehicle tracking system [7]

For public transportation system, researchers designed and developed a tracking system that tracks each bus's current location. So that, passengers expecting their buses in the bus stop will know its location information [8]. As technology advances, researchers are exploring Internet-of-Things (IoT) for vehicle tracking, were the system has a GPS and two RF-ID readers to determine the current location and passenger count in the bus. Similarly, the station is also installed with RFID readers that can detect the arrival info of buses. The information are transmitted through wireless communication system and can be shared with the public [9]. There is research presenting approaches towards data handling and tracking of vehicle through SPSS (a statistical tool) [10].

Our approach is to develop a flexible, cost effective and user-friendly public vehicle tracking system that can cater to the needs of both urban and rural communities with minimum technology backing at the user end. The user is provided with the option to choose between:

- A software application running on a smart phone or
- A SMS based tracking through a GSM enabled mobile handset.

By providing the above choices we are able to scale our application through different user base without any bias. This is especially very useful in developing countries like India where:

- The proliferation of GSM enabled mobile handsets is higher than smart phones [15].
- Most of the people are connected to cellular networks than the wifi.

III BUILDING BLOCKS

This section describes the components used to realize our PRIMO [16] architecture. The PRIMO consist of two subsystems called the Nautical and the Native.

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3.1. Nautical prototype

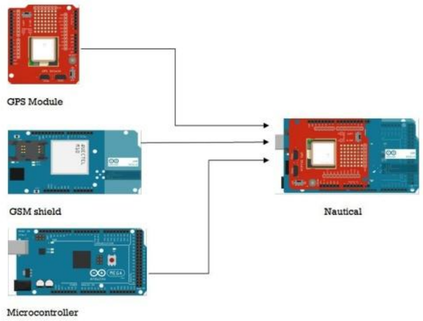

Fig. 1.Nautical prototype

The Nautical device consists of three modules shown in Figure1, the GPS module, GSM module and microcontroller. The main purpose of the Nautical device is to capture the NMEA sentences, filter the sentences (like Latitude and longitude) and transfer these parameters to the web server through the GSM module with the help of microcontroller.

3.2 Native prototype

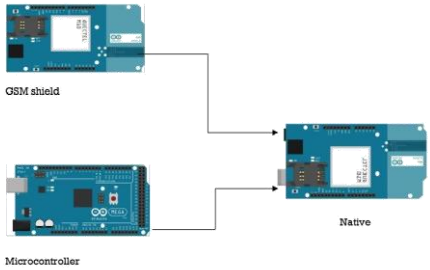

Fig.2.Native prototype

The Native prototype shown in Figure2 is similar to the Nautical but it does not has a GPS module. The Native is purposely designed to provide the current location information from the web server to the GSM module with the help of the microcontroller.

IV HARDWARE

The Nautical apparatus consist of three important modules which are the GPS (Global Positioning System), GSM (Global System for Mobile Communications) and the Micro-controller. Similar to Nautical, Native apparatus also consist only two modules (GSM and microcontroller). The duties of each module are very unique.

V SOFTWARE

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This section provides a brief overview of the software application used by PRIMO.

5.1. Web server

We designed a web page with PHP code that will receive GPS information from the Nautical device and uploads to the server database. In the server, we use MySQL database and to connect to the database, we use mysqli connect command. Once the connection is successfully established, we need to insert the values by using MySQL query.

Once the table is ready in the database, we can program the Nautical device to redirect the GPS values received from the satellite to this PHP file.

VI PRIMO ARCHITECTURE

The architecture represented in Figure 3, describes the structure and blocks present in PRIMO. The Nautical device starts by sending the current location packets captured from GPS receiver through the GSM shield to the web server. The primary function of the web server is to store, process, retrieve and display the information present/given in/to the database. The web server consists of multiple databases, where each vehicle represents one database. Each database has two tables called the Tracer and the Spotter (Spotter is currently implemented as file). For every 5 minutes (can be configurable), the Tracer table helps in storing all the information like date, time, latitude, longitude, altitude and speed sent from GSM module. On the other hand, the Spotter is used to capture the current latitude and current longitude values from the Tracer table and identifies the location name. That is, when there is a new stimulus in the Tracer table, then the Spotter updates the current location name automatically. Now, to identify the exact location and the previously navigated path, we use the Tracker. The tracker is a virtual interface integrated with Google API, that represents the location of the vehicle through maps. All smartphones and other personal devices connected with Internet can view these maps. However, not all the people are equipped with smartphones. Hence, to make this application serve for the other half, we built the Native prototype. Here, the end user, with a basic handset gives a request by calling to the Native. The Native will response to the call by sending the current vehicle location information from the Spotter to the end user through an SMS.

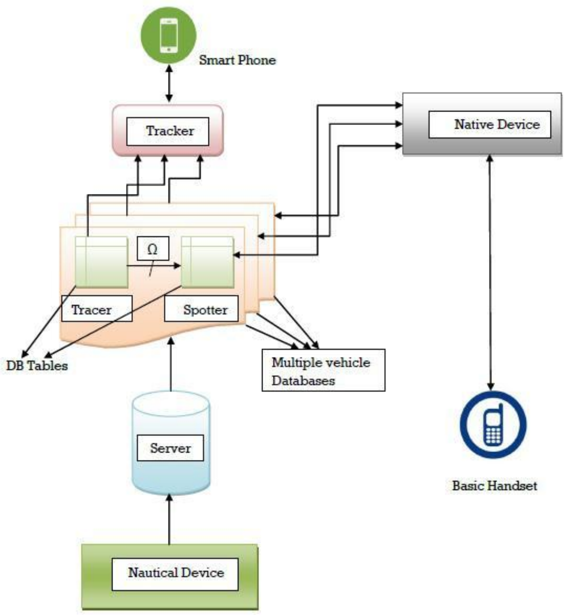


Fig. 3.System Architecture

VII ITS ARCHITECTURE

The ITS system architecture is classified with respect to sensing, monitoring, and displaying systems. All operations are performed by keeping Internet as the backbone. There are different sensors used in this system. All these sensors produce raw data which will be stored in a central database as shown in Figure 4. This raw information need to be care-fully monitored, analysed and then made into a meaningful context. If any issues, actions are taken automatically by the system. At last, the meaningful context are displayed to the public.

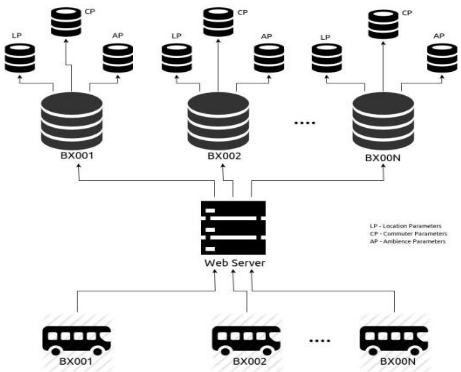


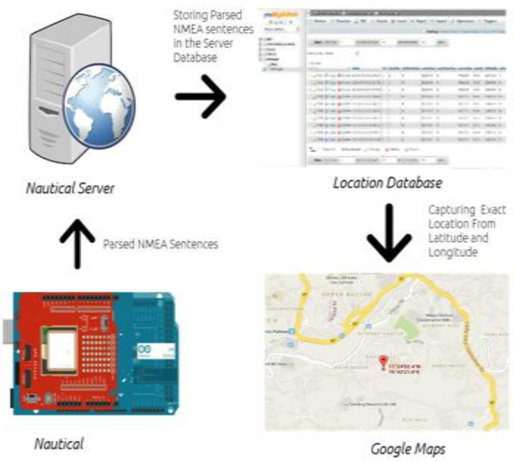
Fig. 4. ITS Architecture

VIII APPLICATION FLOW

The operation begins when the Nautical is placed in the bus and powered with 5V. Then the Nautical device will start to sense the raw GPS NMEA sentences. Once the data is received from GPS as shown in Figure 5, the microcontroller will introduce these information to GSM module. The GSM module will then initiate a GPRS wireless connection. Once the GPRS network is connected, all these data will be transmitted to the database through a web server(Nautical Server) with the help of IP address, path and the port number of the web server.

char server[] = "IP address/domain.com"; char path[] = "/tracegps.php";

int port = 80; // default port for HTTP



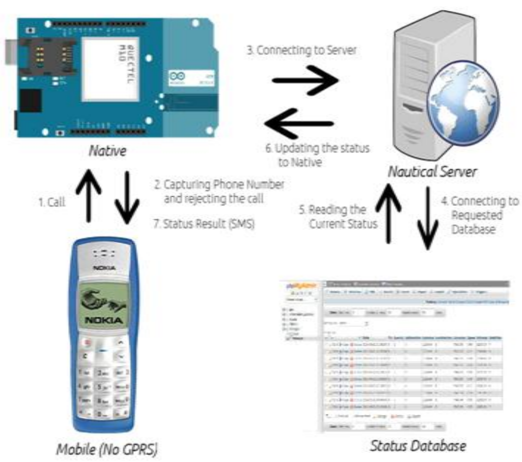


Fig. 5. Nautical flow **Fig. 6. Native flow**

Once the connection is successful, it is very simple to store these GPS information in the database with the help of PHP programming. Once the current location is updated in the Tracer table, the spotter will copy the Tracer table's current location. Finally, with the help of the latitude and longitude details from the tracer table, we can identify virtually, the exact location of the vehicle by integrating with the google maps.

We have satisfied our application for commuters who use a smart phone with Internet facility available on their handset. But our system's intension is to satisfy all the commuters who do not have a smart phone and Internet facility (called a basic set) and this is possible with help of Native prototype.

The Native acts as an intermediate between the web server and the basic handset. The commuters who use the basic handset are mostly interested in knowing about the current location where the bus is traveling. So to make this possible, we created a separate file/table in the Database called the Spotter or Status DB. Here the Spotter just keeps updating whenever there is a new stimulus in the Trace table.

So, the work flow is explained as in the Figure 6. The operation for the Native starts by dialing a number (Native's phone number) from basic handset. When the Native receives the call from end user, it just captures the phone number and rejects the call. As the Native is always connected with the Internet, it connects to web server and looks the Spotter in the database and provides the current location name to the GSM module. Then the GSM module will respond to the end user by sending the current location details via an SMS. Hence from this design, all the commuters will be facilitated to use this application very efficiently.

IX OTHER APPLICATIONS

The PRIMO project can be harnessed with minimal changes to suit different applications as well :

Parents send their kids to school or college through bus which can get delayed or turn up much early. With the aid of our application we can identify the exact location of the bus and travel our journey accordingly.

Our applications can help parents who are worried about their children traveling long distances from work location to their home.

This application would be a boon for the tracking cabs, dynamic courier tracking, goods carrying vehicles and may more.

By exploiting the minimal HW requirements of the mobile phones, our design is not only available for the user who travels in the bus, but also for people who can track the expected arrival time of the user.

X RESULT

In this section, we discuss the results obtained during one of our field trials. The HW prototype was allowed to cover a distance of around 15km from Ooty town to Nundhala village. Through out the course of the journey, the location updates of the HW prototype was send to the Nautical server through the GPS in Nautical.

Date	Fix	Quality	Latdirection	Latvalue	Londirection	Lonvalue
2014-08-18 02:24:33	1	2	N	+11.35166666666	E	+76.68216666666
2014-08-18 02:34:34	1	2	N	+11.36116666666	E	+76.70366666666
2014-08-18 02:44:34	1	2	N	+11.39066666666	E	+76.70916666666
2014-08-18 02:49:32	1	2	N	+11.40583333333	E	+76.71466666666
2014-08-18 02:54:35	1	2	N	+11.40783333333	E	+76.70716666666

Fig. 7. Database imprint showing the parameters provided by the HW

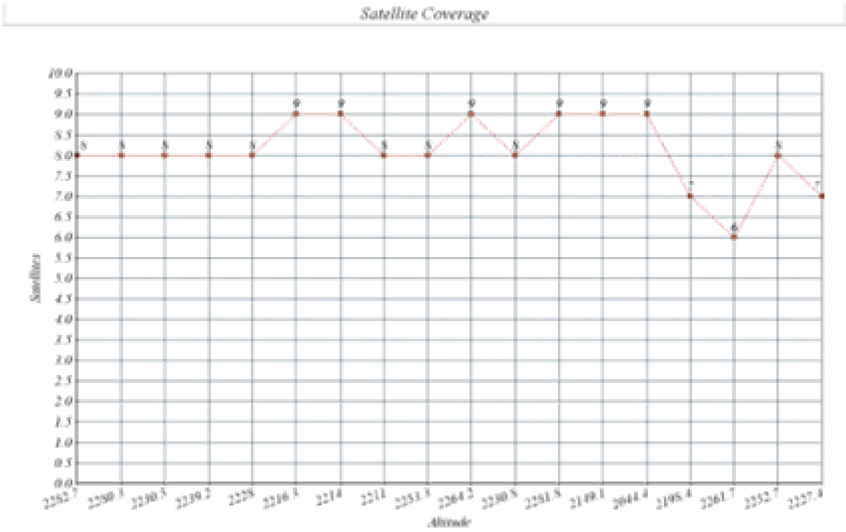


Fig. 8. Satellite coverage Vs Altitude

One of the important features of our prototype is the accu-racy of the HW, which relates to the co-ordinates provided by the GPS. In our trial, we observed the number of satellites covered as we moved through different altitude. Figure 9 shows the number of satellite covered (along X-axis) against the altitude in meters (along Y-axis).Since the geographical location chosen for the field trial is high altitude hilly region covered with forest, there were some slight deviation in the number of satellite observed. One such signal deviation can be observed for the altitude of 2261.7m where the number of satellites observed is dropped to 6 due to the signal interruption when passing through the forest. For the remaing part of the graph, the satellite coverage is good.

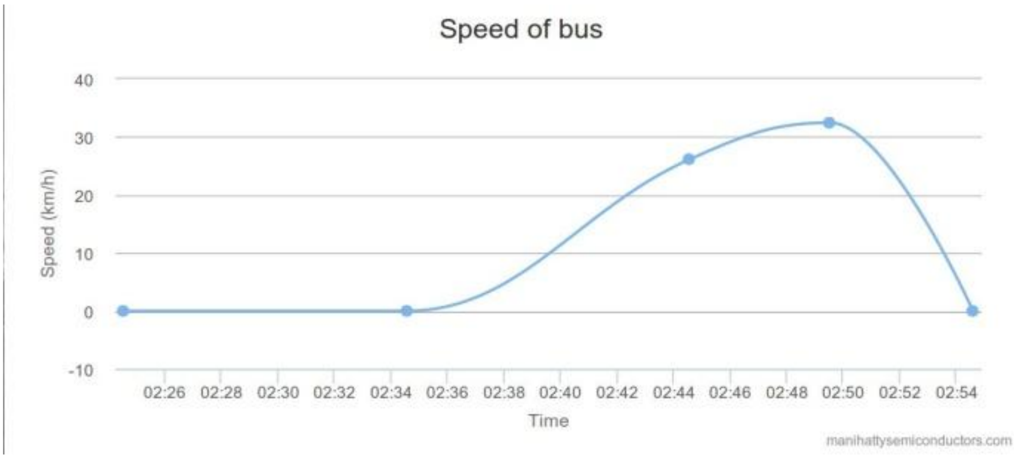


Fig. 9. Dynamic speed Vs Time

Figure 10, shows the plot for the dynamic variation of the bus speed (in km/hr along Y-axis) against the time (along X-axis). The initial value is 0 km/hr when the bus is in the halt state during the first 10 minutes. As the bus starts and move along its destination, we can see a smooth exponential curve extending through most of the time. Since the bus didn't stop in the middle, there are no sudden dips observed. As we reach towards our destination, there is a linear decrease in the speed and grounds to halt (0 km/hr) when the destination is reached. Through this feature, we can track the location of an object of interest as well as estimate the arrival/estimated arrival time. In future, we are also planning to develop algorithms that can interpret the arrival time of the bus based on the traffic and climatic conditions.

XI CONCLUSION

In this work we have developed PRIMO - an open source Vehicular tracking system that is flexible, affordable, customizable and accurate. We have described our complete solution containing a HW prototype and user friendly SW application. Through this technology, we also provide an architecture for intelligent transportation system. There can be various other application that can be built over our existing platform. We have also demonstrated the credibility of the design through field trials and the initial results obtained through our prototype are very promising.

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