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An Internet of Things based Intelligent Transportation System

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***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

In the past two decades, the proliferation of new technology has made a huge impact in the lifestyle of the people. Emerging technologies have developed features that are tightly aligned with people's interests like: being compact, easier to use, feature-rich, connected to the internet, being fast and smart. The availability of affordable sensors, together with the proliferation of internet infrastructure enables an interesting technology called the Internet of Things (IoT). IoT had resulted from context aware computing [1], that aims to allow people and things to be connected anytime, anywhere with anything/anyone. In other words, devices and application have the ability to communicate each other without/less human influence.

There is also significant interest and attention towards IoT from the industry [14]. This interest has triggered the development of myriad of sensors for different applications like location sensing, weather forecasting, biomedical applications, and many more. Many companies has come out with their custom board targeting IoT applications [14],[11].

ITS is plays one of the major role in contributing towards smart city development. In most developing countries like India, public transportation system (bus) are the main source of travel for many commuter living in urban as well as rural. Our project theme is to develop a prototype for ITS, which will be useful to track a vehicle through GPS [18], payment of tickets, crowd analysis inside the bus through NFC [19] and finally, the ambience inside the bus can be measured with temperature and humidity sensor[13].

With in our IoT infrastructure, the data collected from our sensors is sent through the internet and processed by the monitoring system to make useful decision and send it to the display system (as per our application requirements). We have grouped the entire architecture into has three systems namely; the sensor system, monitoring system and the display system. The sensor system utilizes GPS, NFC, temperature and humidity sensors, which are always connected with the internet via a GSM network [17] to track the location, commuter and ambience inside the bus. The monitoring system is not only intended to extract the raw data from the sensors database and convert it in to a meaningful context but, it also used to trigger some events with in the bus as well as provide information to the bus driver. The display system is used to show the context data to all the commuters in the bus stop regarding bus and travel information.

II. RELATED WORK

The Internet revolution has opened up new technologies such as ubiquitous computing, Internet of Things (IoT), context-aware computing etc. Researchers in [1], demonstrated a 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 [2][3] demonstrate an SMS based vehicle tracking 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. Also, there are research that has performed Web-based vehicle tracking system [4], where the latitude and longitude are transmitted to the server through HTTP protocols (GET Methods). The Authors in [5] developed vehicle tracking system application for smart

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phone to trace the current location of the vehicle. The researchers then integrated RFID with the GPS [6] for Public Transportation. The Radio Frequency Identification (RFID) are intended to record the flow of people getting on and off the bus through RFID tags. The information from GPS and RFID are transmitted through wireless communication system and can be shared with the public.

Now a days we prefer NFC payments, which are similar to the RFID technology. This NFC technology is more simple and easy for transactions. In countries like India and China people are slowly adapting technologies for commercial applications. NFC enabled phones (sender) can do transaction with the NFC reader (receiver/ ticket provider). Companies like Google[7] and Apple[8] uses mobile phones with NFC feature to make payments very simpler and easier. Authors in [9] developed a NFC based virtual ticketing system with a NFC phone application, wherein it authorizes the purchase of public transportation tickets via a suitable smart poster and initiates a midlet applications for transactions.

Previous works provide some insights about an ITS but none of them proposed/demonstrated a complete system. Through this work, we intend to propose a new IoT system for ITS, which will track the vehicle with GPS system, people with NFC system and the abience in the vehicle through temperature and humidity system. In the following sections, we will discuss about our system architecture and components for a smart bus, following with our idea to integrate multiple smart buses to make an efficient ITS.

III. Architecture

The 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 1. This raw information need to be carefully 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.

A. Sensor system

The sensor form the brain for the system. One of the major function of the sensor is to acquire and send the vital data to the monitoring system. The sensor system has multiple sensors that are used to collect very specific information. We have classified the system in three important aspects like :

- Location Subsystem
- Commuter Subsystem
- Ambience Subsystem

In the following sections, we will be looking on these aspects in detail for a single smart bus.

B. Location subsystem

The location subsystem is essentially a vehicle tracking system that allows the monitoring system to identify the vehicle's current location. Our system uses three modules, GPS receiver, Global System for Mobile communications (GSM) modem and a microcontroller to track the location of the vehicle.

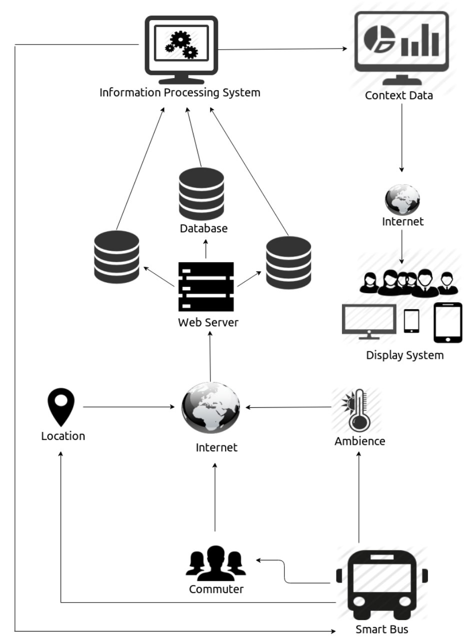

Fig. 1. System Architecture

A GPS is made up of constellation of satellites orbiting around Earth. Each satellite has a atomic clock on its board, so it knows the precise time. Here we use GPS shield [18] provided by Adafruit Industries, which is is a low power module that draws only 20mA current, half of most GPSs. The GPS has -165dBm sensitivity, 10 Hz updates, 66 channels and has both internal patch antenna as well as connector for external active antenna. The GPS captures NMEA sentences from the satellites. In the NMEA sentence, we can find few parameters like latitude, longitude, speed, time stamp, etc. The below shows, one of the NMEA sentence received through the GPS receiver.

```
$GPRMC,194509.000,A,4042.6142,N,
07400.4168,W,2.03,221.11,160412,A*77
 Time/ active/ Latitude/direction/
Longitude/direction/speed/
True course/Date/checksum
```

Similar to this, there are other sentences from which we can capture altitude, satellite coverage and many more.

The system utilizes GSM module from Arduino[17], which has a M10 by Quectel radio modem and uses AT commands[12] to communicate with other device. The M10 is a Quad-band GSM/GPRS modem that works at the frequencies GSM850MHz, GSM900MHz, DCS1800MHz and PCS1900MHz. It supports TCP/UDP and HTTP protocols through a GPRS connection. GPRS data down-link and up-link transfer speed is 85.6 kbps. The GSM module can help to make/receive voice calls, send/receive SMS messages and allows to connect with the Internet through GPRS wireless network. A SIM card is very essential for the GSM module to operate. The GSM shield communication data rate in bits per second (baud) for the serial port is 9600 bps.

Microcontrollers play an vital role in our application. We used Arduino UNO [15] and MEGA [16] with Atmel's microcontrollers ATmega328 and Atmega2560 in it. A software program written in C programming language is compiled, then stored in the flash memory of the microcontrollers.

C. Commuter subsystem

The commuter subsystem predominantly uses NFC technology. The system consist of 3 modules such as NFC reader and Mifare tag [10], GSM and Microcontroller. NFC is a set of short-range (typically up to 10cm) wireless communication technologies designed to offer light-weight and secure communication between two devices. NFC operates at 13.56MHz, and is based around an "initiator" and "target" model where the initiator generates a small magnetic field that powers the target, meaning that the target does not require a power source, this also called as passive communication, and is used to read and write to small, inexpensive 13.56MHz RFID tags based on standards like ISO14443A. For our experiment we use classic Mifare cards with 1K of EEPROM and equipments were from Adafruit Industries.

Before starting a journey in the smart bus, the commuter need to apply for his a Mifare card, which is a unique card for each commuter. During the application process, all the personal information (Name, address, Id proof, photo, email, phone ,etc.) of the commuter are acquired and then a unique id is issued to the commuter. Now, the commuter needs to credit his/her travel card with some money. This can be done online through payment gateways. At the start of the journey, the commuter taps the Mifare card in the NFC reader and enters the details through the serial console of Arduino (shown for the proof of concept, we are plan to extend it to a touchscreen module soon). Once the details are furnished , it is acquired by the NFC reader and sent to the database through the GSM module. Then the details of the commuter along with the sum of amount (credited or debited) is stored in the database. The confirmation of NFC payment and tickets can be generated through a thermal printer or through an SMS to the commuter's phone.

One of the major advantage of this system is that, it provides a cost effective solution (as against the costly CCTV recordings in buses) to identify and track who had traveled in a bus, where was their source and destination location and how many accompanied them. Using these details, there is the possibility to provide a minimal security if there is any accidents or theft.

There are many challenges that needs to be addressed when we do real deployment of such systems for a large commuter base. Most of the items described will be explored in our future work:

- How should the situation be dealt with if commuter don't get down in their specific destinations location?
  We plan to address this challenge through IR(Infrared) sensor deployment. For example, let us consider that , there are "m" commuters whose started at X and their destination is Y. So we expect "m" commuters to get down in the stop Y. We are setting a counter (irmax = m), once we have arrived in Y, every time an IR sensor detects a person getting out of the bus, irmax can be decremented by 1 (ie, irmax-1). At the end, we expect the value of irmax to be 0 else we know that possibly there is a commuter who has overstayed his journey. Then irmax is updated for the next stop.
- What happens if the Mifare card is lost?
  If the Mifare card is lost, we are building an IVR infrastucture to block their card and reissue a new card with the commuter details.

D. Ambient subsystem

In our work we are also interested to analyse the ambience inside the bus. This is because, in countries like India and China which has large population with varying climatic conditions on different parts of its geographical locations. So, when many people get in a bus, the climatic temperature outside the bus and inside the bus varies to an large extent. By placing temperature and humidity sensors, after a certain threshold it can automatically switch the air conditioner on through relay circuit or it can indicate the driver to switch on A/C because of intense temperature in the bus. Here we use seeedstudio's temperature and humidity sensor pro [13] which is mounted on the grove based shield [20] and the detection range of this sensor is 5% RH - 99% RH, and -40C - 80C.

Furthermore, we can analyze vital information through Oxygen and Carbon dioxide sensors as they impact the commuters. We plan to use the above to measeure the air quality in the future.

IV. Monitoring System

Sensors, servers and databases are the key components to drive the IoT infrastructure. We had already discussed the sensors used in this application. In the following, we will be looking at the role of servers, databases and Information Processing Systems(IPS) in this system.

In our IoT infrastructure, server is one of the important component for storing data. There are different servers for different purpose. For our application, we use a web-server. The sensors connects the server through IP address and port number. All the request and response happens through HTTP protocol. As the server gets connected, the database is ready to accept values from the sensors.

For this application, we use three MySQL database for receiving sensor data. One database for location subsystem and other two for commuter and Ambience subsystem. The operation of the database is very simple, each sensors information need to be stored in their respective database. Therefore, we designed web pages with PHP code, that will receive information from the sensor and redirects the values to their respective server database through GSM modem.

IPS is the component that convert the raw data in to the context data i.e., the data from the sensors are called as the raw data and a meaningful information extracted from the raw data is called the context data. IPS has the functionality to trigger some event automatically inside the bus and provide information to the bus driver.

V. Display System

The display system consist of an LCD display with an Internet connection. This should be placed in each bus stops. When the results are obtained from the context data, they are immediately displayed to the public through the LCD display. This would give the commuter very precise and clear information about the bus's current location, number of people inside the bus, temperature and other related information within the bus.

VI. Application Flow

Initially, a circuit is designed by integrating the sensors with the microcontroller. After integration, a program is written and burned in the flash of the microcontroller. Once we compile and execute, we can get the raw value from sensors (location, commuter, ambience) in the terminal. For example, we get different data form GPS such as latitude, longitude, speed etc., from NFC, we get the source, destination, cost related values. Furthermore, from temperature and humidity sensor we get temperature and humidity. All these raw information shown in Figure 2, are transferred to the server through the GSM. The GSM modem begins with searching for 2G/3G network. Once the GSM senses the network, it then connects to the GPRS.

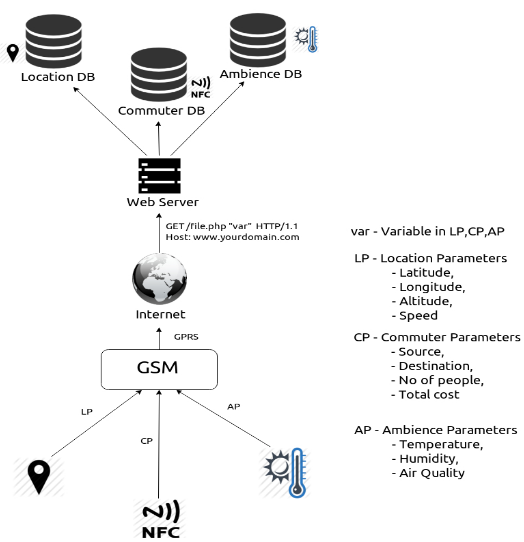

Fig. 2. Storage process of raw sensor data

Once the internet is connected, the data such as LP (Location Parameters), CP (Commuter Parameters) and AP (Ambience Parameters) are transferred to the database through http protocol. The process of storing happens between, HTTP client and HTTP server. Below is the HTTP client request, on which, it first identifies the server with IP address or domain name through DNS. Apart from the server, we need to mention the port number by which it need to connect with the server.

```
GET /file.php var HTTP /1.1
Host:www.yourdomain.com
```

As the server is connected, it looks for the file.php, were the PHP file redirects to a database, where the sensor information are stored. For example, if we want to store the GPS parameters like latitude and longitude, the values are passed to the server and the data are store in the Location DB. Similarly, all the sensor information are respectively stored in the server databases as shown in figure 3,4,5.

Date	Fix	Quality	Latdirection	Latvalue	Londirection	Lonvalue
2014-08-18 01:19:31	1	2	N	+11.40066666666	E	+76.70566666666
2014-08-18 01:24:33	1	2	N	+11.40066666666	E	+76.70566666666
2014-08-18 01:29:32	1	2	N	+11.40233333333	E	+76.706
2014-08-18 01:34:34	1	2	N	+11.4035	E	+76.7035

Fig. 3. Snapshot of the Location DB

Date	Cardno	Source	Destination	People	Cost	Total
2014-10-14 10:54:50	123456789	Ooty	Nundhala	2	50	100
2014-10-14 11:04:00	123456788	Ooty	Lovedale	4	40	160
2014-10-14 11:05:00	123456787	Ooty	Nundhala	5	50	250
2014-10-14 11:08:02	987654321	ATC	Nundhala	7	45	315
2014-10-14 11:09:22	123456787	ATC	Nundhala	4	45	180
2014-10-14 11:13:06	123456789	Charing Cross	Lovedale	3	40	120
2014-10-14 11:13:23	123456788	Charing Cross	Nundhala	2	45	90
2014-10-14 11:14:37	987654321	Coonoor Junction	Nundhala	4	40	160

Fig. 4. Snapshot of the Commuter DB

Date	Temperature	Humidity
2014-08-18 01:19:45	19.10	67.60
2014-08-18 01:22:45	19.50	69.00
2014-08-18 01:25:52	19.40	68.80
2014-08-18 01:28:48	19.40	68.70
2014-08-18 01:32:22	19.30	70.20

Fig. 5. Snapshot of the Ambience DB

Following are the two main functions of the IPS:

- As the raw data gets stored in the database, the IPS will process them to display the context data i.e., it will change the raw data into meaningful information. For example, raw data from GPS, such as latitude and longitude can be depicted into maps for a meaningful information. Similarly, the raw data from NFC of number of people in the bus can be depicted as pie charts. Also, the raw data from temperature and humidity can be measured in a meaningful context.
- The second operation of the IPS, is to give a trigger to the bus or bus driver regarding some issues. For

illustration, let us consider, when the temperature inside the bus increases and when it gradually reaches a critical point, the system will give trigger to the relay inside the bus to switch on the air conditioner. Similarly, if the temperature is low, the air condition is reduced accordingly. This is done automatically without the help of any human intervention. In this way the driver can concentrate completely on driving. However, if there is some problem in triggering the air conditioner automatically, then the IPS system will give a reminder to the driver indicating him to switch on/off the air conditioner.

The context data from the IPS are given below :

- Current location of the bus in maps.
- Number of people in the bus.
- Number of people expected to get down.
- Temperature and humidity inside the bus.
- Air quality in side the bus.

All the above data are meaningful information that need to be transferred to the display system. The display system is a large LCD screen with an internet connection on it. As the display systems are placed on the bus stops, the information from the context data need to be transferred to the display system through the Internet. Then the commuter in the bus stop will be able to analyse the the current location of the bus, number of commuters inside the bus, in which stop maximum crowd expected to get down, the temperature and humidity level inside the bus.

VII. Proposed Architecture for Intelligent Transportation System

In the following section, we have propose an ITS by exploiting the smart buses technology introduced in the previous section using IoT infrastructure. As we have discussed earlier, the smart bus have few sensors (GPS, NFC, temperature and humidity) that generate raw sensor data. So, when there are many smart buses as shown in Figure E, each bus with these sensors is connected to the Internet, can share its current location, number of commuters in the bus with their destination locations and the ambience inside the bus. All this information are stored in different database/tables of the web server with the help of GSM modem.

From the database perspective, each smart bus has its own individual database. For example, lets consider the bus BX001 is always integrated with the BX001 database. So, when ever the sensors data are transmitted, it directly stores in the BX001 database tables. Similarly, other smart buses sensors information are stored in their respective database accordingly. At last, there is a common IPS that converts the raw values in the database to meaningful context. Also, if needed the IPS will trigger specific function in the bus and indicate the bus driver regarding issues in the bus.

VIII. Testbed

Figure 7 shows the picture of our testbed which has our three modules.

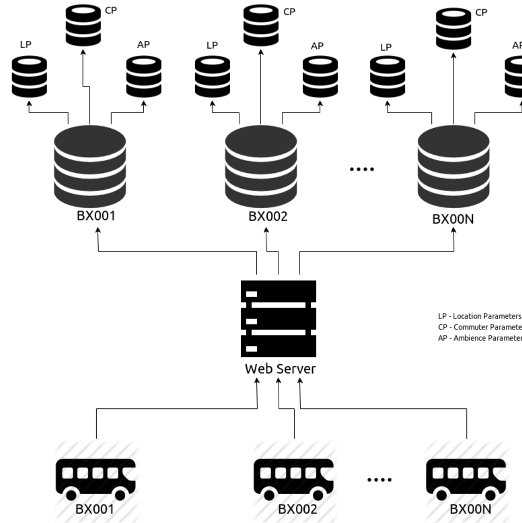

Fig. 6. Proposed architecture for Intelligent Transportation System

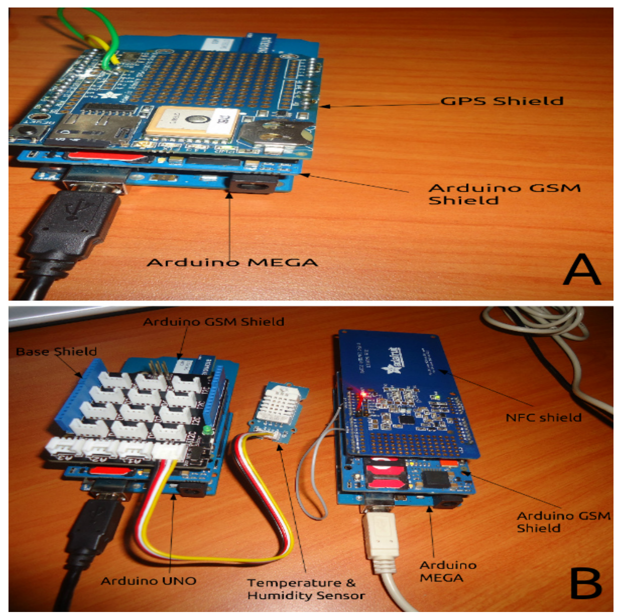

Fig. 7. Testbed

The testbed represent the three modules of the sensor system.

- A refers to the Location Subsystem. It consist of a GPS receiver , a GSM shield and a Atmega2560 microcontroller.
- B (left) refers to the Ambience Subsystem. It consist of a Atmega328 microcontroller with a base shield connected to the Temperature and Humidity sensors.
- B (right) refers to the Commuter Subsystem. It consist of has a NFC reader, a Mifare card, a GSM shield and a Atmega2560 microcontroller.

IX. Result

In the following section we discuss the results obtained during one of our field trials from Ooty town to Nundhala village which covers a distance of around 15km. The location subsystem was perfectly able to transfer the location information (latitude and longitude) to the database for every five minutes (because of memory requirements, but this can be reduced) to the database and the Information Processing System (IPS) converted the raw data to meaningful context in form of maps as shown in figure 8.

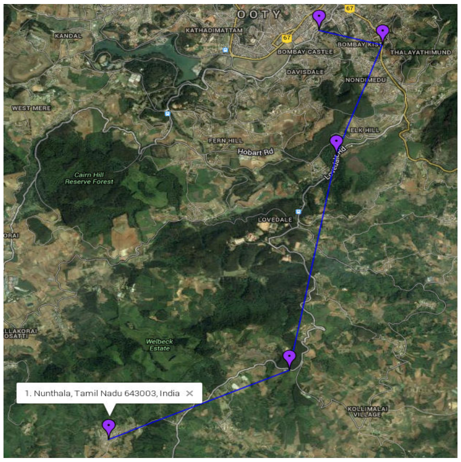

Fig. 8. Map representation for Location subsystem

Secondly, the Commuter subsystem, the NFC reader transferred all the commuter information(Source, Destination and Number of commuter) to the database by deducting a certain amount from the database through NFCpayment and providing e-ticket to the commuter. This raw data is now processed by the IPS for providing a meaningful context mainly on the crowd analysis in the bus, i.e., Source pie chart explain the number of commuters picked up in each bus stops, the destination pie chart illustrates the drop of the commuters. Also, it calculates the current crowd in the bus as depicted in figure 9.

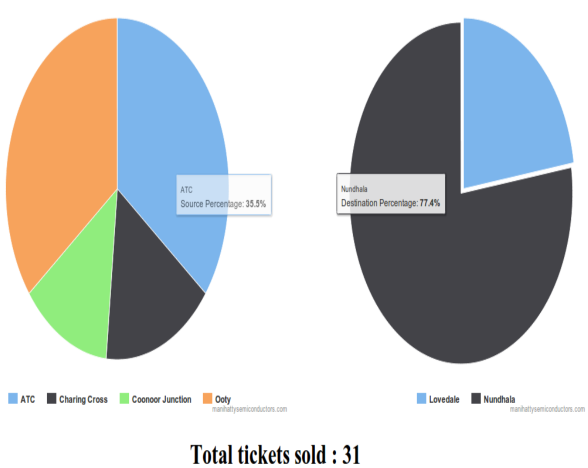

Fig. 9. Pie chart for Commuter subsystem's context data

Finally, the Ambience subsystem, this system provides the temperature and humidity level inside the bus. This raw values are taken from the database and analysed by the IPS for contextual information as shown in figure 10.

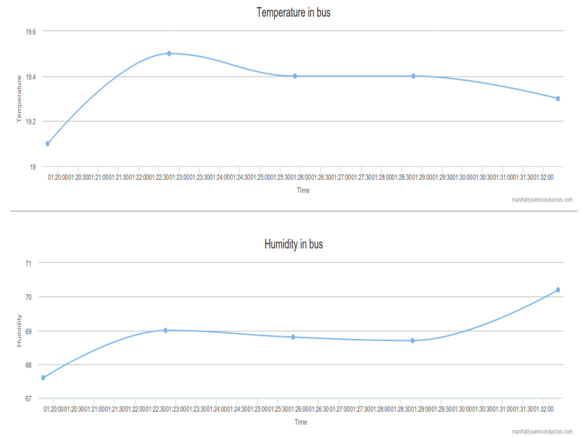

Fig. 10. Line representation of Ambient subsystem's context data

All these above meaningful context are at last transferred to the display system located at each bus stops.

X. Conclusion

In this article, we have presented the overall architecture and the main components of ITS based on IoT infrastructure. We have described our complete solution containing a hardware prototypes, user friendly software application and our initial results though our field trials. We have also proposed how our simple systems can be extended to realize an Intelligent Transportation System. Through this technology we can track three important aspects in the bus: location, commuter information and the ambience.

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[15] http://arduino.cc/en/Main/arduinoBoardUno
[16] http://arduino.cc/en/Main/arduinoBoardMega
[17] http://arduino.cc/en/Main/ArduinoGSMShield
[18] https://www.adafruit.com/products/1272
[19] https://www.adafruit.com/product/789
[20] http://www.seeedstudio.com/depot/Grove-Base-Shield-p-754.html