

Smart Public Transport for Smart Cities

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Abstract—Smart cities mission of India gaining popularity day by day. With the introduction of Internet of Things into smart cities the goal of smart cities mission is easy to achieve. One of the key feature of smart cities is Public transport. A smart city should possess an Intelligent public transport system. Today with the lack of appropriate information system in the public transport system, passengers are facing huge problems in the crowded cities. Passengers are forced to wait for long time since they don't know the information of an upcoming Bus or Train reaching to a terminus. With the introduction of technology into the public transport system a passenger can travel with an ease in the city. Here we propose a system where the current position of the buses and the arrival and departure times of the buses can be informed to the passengers via the display boards in the bus terminus or via the app installed in smart phone by incorporating latest technology into existing bus systems. The proposed technology has GPS system that tracks the location of the bus, a sensor incorporated in the bus to know passenger count. The GPS and sensor data is processed by a Raspberry Pi3 computer and then sent to a server. At the Bus terminus this information can be accessed through WiFi/Internet by the passengers.

Index Terms—Internet of Things; Smart City; Intelligent Public transport; Raspberry Pi3; sensor ; GPS.

I. INTRODUCTION

A 'smart city' is an urban region that is highly advanced in terms of overall infrastructure, enriched with high end technology, using reliable communications and smart security keeping in perspective the market viability. A smart city should be built considering aspects such as Environmental Sustainability, Economic Viability, and Social equitability. The goal of building a smart city is to improve quality of life by using urban informatics and technology to improve the efficiency of services and meet residents' needs. The concept of creating a Smart City is now made easy with the extensive development of the Internet of Things. With the rapid growth of population in urban areas there is an urgency to shift towards technological solutions to cater the needs of smart cities. At present all over the world this shift towards smart city development has become famous and individual countries are striving for the betterment of urban locations, through advancement in technologies. Government of India introduced smart cities mission to develop 109 cities all over the country making them citizen friendly. The government of India allocated about Rs 7,296 crore for two central schemes - Atal Mission for Rejuvenation and Urban Transformation



Fig. 1. Overview of Smart city components

(AMRUT) and 'Smart Cities' Mission. As we know smart city concept includes many aspects such as e-Governance, sustainable environment, smart waste management, adequate water supply, and efficient urban mobility and public transport, here we focus mainly on significance of smart cities in public transport point of view. This paper covers the aspects regarding to Intelligent public transport for smart cities such as Bus Rapid Transport, smart ticketing, smart GPS based buses and bus stops, automatic fare collection. The section II of this paper contains the present condition of Public transport in India and the distribution of Urban transport. Section III provides the necessity of Smart public transport for smart cities and the basic solutions a public transport requires. Section IV presents the architecture of the Smart public transport system. Section V describes the Implementation and working of the proposed system. Section VI shows the key features of Hardware components used. Section VII concludes the paper.

II. PUBLIC TRANSPORT IN INDIA

Population growth and rapid urbanization both combined creating huge challenges for Indian cities. Indias urban population growth is 3% per year. The most populated cities in India are Delhi, Mumbai and Calcutta with a population of 24.95 million, 20.7 million, and 14.76 million respectively. According to McKinsey, the countrys cities are expected to rise

from 340 million people in 2008 to a whopping amount of 590 million in 2030. The few causes that are leading to increase in urban population is Economic opportunities, Growth of employment in cities is attracting people from rural areas as well as smaller towns to large cities. The most preferred mode of transport in both rural and urban India is Buses followed by auto rickshaws, according to a report by National Sample Survey Organisation (NSSO) - (2014-15).

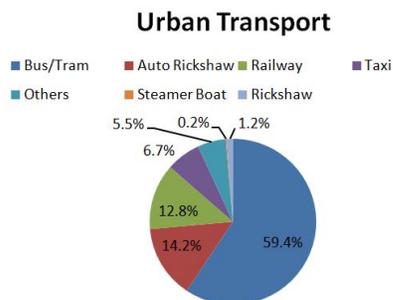


Fig. 2. Modes of public transport and their distribution

According to the study, Bus/Trams are used by about 59.4% urban citizens, constituting the major part of the transport in urban areas. The second major mode of transport in India is Auto rickshaw constituting about 14.2%, and then the major contribution to transport comes from Railway constituting 12.8%. Also statistics show that the expenditure on bus/tram, auto rickshaw, taxi and train constitute more than 90 per cent of the total expenditure on transport both in rural and urban areas of India. The statistics are shown in Figure 2. These studies show that the Buses/trams play a major role in Indian transportation especially in cities. So, there should be a need to develop unique plans in urban transport that satisfy the needs of urban citizens. One of the important features of smart city is the promotion of variety of transport options like Transit Oriented Development, Intelligent public transport and last mile Para-transport connectivity.

III. SMART PUBLIC TRANSPORT SYSTEM FOR SMART CITIES

Making a transport system intelligent for smart city needs, involve smart solutions to be implemented into the existing transport system. Figure 3 shows the comparison between Bus and rail transport in major cities of world. Even in cities with large rail networks buses remain the dominant form of public transport. So there is a necessity for a paradigm shift in Modern bus transport system.

The Smart solutions for transportation in cities may include:

- Smart Ticketing and Automated Fare collection
- Bus Rapid Transit systems
- Smart GPS based buses and bus-stops

A. Smart Ticketing and Automated Fare collection:

Government wants people to make greater use of public transport to help reduce the pressure on an already constrained

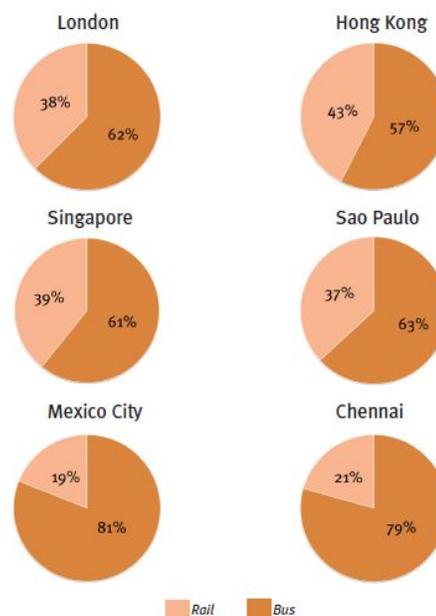


Fig. 3. Even in cities with large rail networks, buses remain the dominant form of public transport

road capacity and to increase mobility, which in turn contributes to national productivity. Smart ticketing is one such technology that reduces the operational cost and makes it easy for the passengers of the public transport. Smart ticketing is the innovative way for many public transportation sectors. Smart ticketing is a system that electronically stores a travel ticket on a microchip, which is then usually embedded on a smartcard. Smart ticketing is a useful tool for public transportation sectors and governments because they can easily track the routes and times taken by passengers. This will help in future development of the public transportation systems and routes for future planning. Furthermore, smart tickets are more secure from fraudulent activities because the card can be deactivated once reported stolen, and the remaining credit can be refunded or transferred to a new card just as similar to an ATM card. It reduces operational costs with the removal of printed ticket machines. Smart ticketing also builds the business case for Mobile ticketing. Figure 4 shows an electronic smart card model for smart ticketing.



Fig. 4. Smart card for smart ticketing

B. Bus Rapid Transit Systems:

Due to heavy traffic in India there is serious problem for the mobility of the public transport like buses.

The Barriers for Bus Mobility are:

- **Fleet size and Quality:**
Suggested a minimum of 40 buses for one-lakh population

TABLE I
 POPULATION AND BUS FLEET STRENGTH IN MAJOR CITIES

| City | Population in 2011 | Bus Fleet strength |
|-----------|--------------------|--------------------|
| Mumbai | 18.4 million | 3430 |
| Kolkata | 14.1 million | 4256 |
| New Delhi | 16.3 million | 6906 |
| Bangalore | 8.4 million | 4185 |

- **Lack of Preventive Maintenance:**
High Breakdown frequency and low operating ratios
- **Congestion**
- **Role of technology:**
 - Real time passenger information systems
 - Bus signal prioritization

The Solution for the above barriers for mobility of Public transport is BRT. Bus Rapid Transit (BRT) is high quality, customer-oriented public transport that delivers fast, comfortable, and low-cost urban mobility to all passengers by combining techniques like Dedicated Right of Way for buses, Busway Alignment, Platform level boarding and other quality of service elements (such as information technology). BRT combines the flexibility of buses with the high-performance and design standards of metros, giving it the nickname, Metro-Bus. The idea is to think metro-rail and do it with buses.

- **Dedicated Central bus lanes:** To ensure fast, reliable service, BRT systems provide exclusive lanes for buses. In an Indian context, it is essential to have dedicated lanes in the centre of the street for them to be effective and free of obstacles. In the Indian context, these central lanes have to be segregated from other motor vehicle lanes with a continuous physical divider.



Fig. 5. Dedicated BRT lane

- **Centrally located stations:** High performance BRT systems typically have a single common station for both directions like a central railway platform rather than having two bus stops, one for each direction. Such stations are

located in the central verge between the two directions of movement and offer access to buses moving in both directions. Special BRT buses, which have doors on the right side with no steps, access such stations. There are many advantages of single central stations.

Central stations are smaller and are up to 40 percent cheaper to build and operate than two bus stations on either side of the central bus lanes. The central station requires a single entry area and single set of turnstiles; whereas the two bilateral stations each require their own entry. They Central stations also optimize the use of street space.

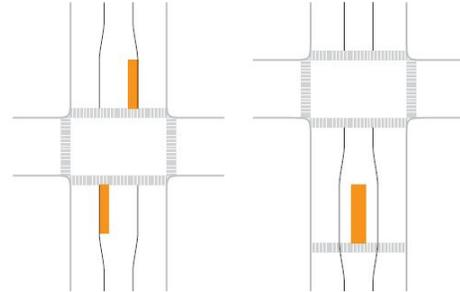


Fig. 6. Compared to bilateral stations(left), centrally located stations (right) are cheaper to build and allow passengers to transfer without leaving the station.

C. Smart GPS based buses and bus stops:

The present problem in Bus transport system is that the passengers don't have the real time information about the Bus location and timings of arrival and departure, at least not precisely. Because of the lack of real time information passengers are late to their work and often forced to take private transport which is not so friendly in the case of expenditure. On the first priority Passenger Information system plays a major role in ease of access of information about the buses and their timing, estimated arrival times, etc. The immediate priority goes to the information about the location of the bus. The location of the bus can be known by enabling the buses with high end GPS technology.

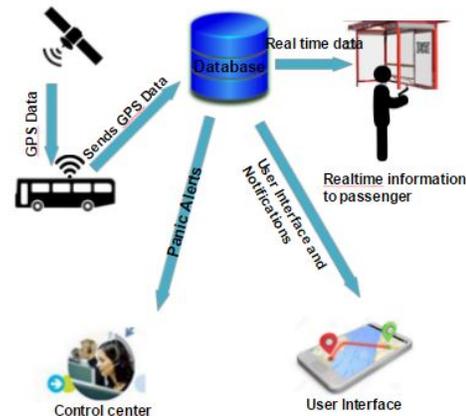


Fig. 7. Smart GPS based bus system

Studies in India show that the people had been late to their destination because they decided to wait for a bus instead of walking. Studies also shown that knowing the position of the buses in cities would be beneficial in deciding whether to take a metro/cab or wait for the bus. The Real Time Bus Monitoring and Passenger Information system is a standalone system that displays the real-time location of the buses in the smart cities.

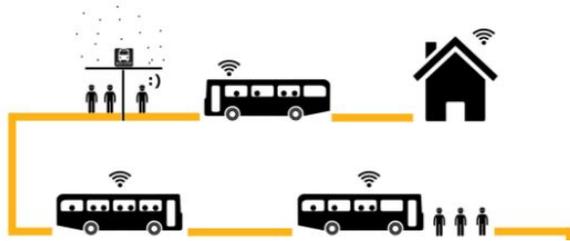


Fig. 8. Ease of transport through Intelligent passenger information system

Intelligent passenger information system: Intelligent passenger information system is a cloud based GPS tracking system incorporating a prediction algorithm to provide minute to minute bus service information. The system knows at any given point of time where a bus is and can predict the bus arrival time at any bus stop. This technology enables the travelers with real time passenger information like the availability of seats of particular bus service, the location of the bus, via websites, smartphone apps, and bus stop displays.

IV. SMART PUBLIC TRANSPORT SYSTEM ARCHITECTURE

The system architecture consists of various modules through which the passengers can gain the most out of the public transport by incorporating latest technologies and telematics. The architecture can be divided into three modules Bus Transmitter Module, Bus Terminus Control Module, Passenger Service Module.

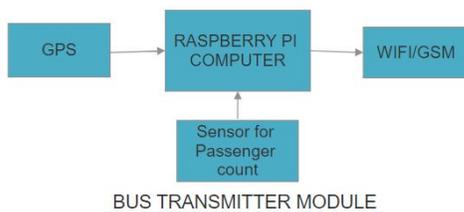


Fig. 9. Bus Transmitter Module

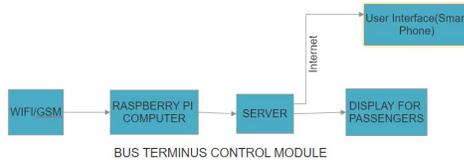


Fig. 10. Block diagram of Smart Public Transport system

A. BUS TRANSMITTER MODULE

It consists of a GPS module, a high performance single board computer called Raspberry Pi, and a GSM Module.

The GPS Module gives the position of the bus(through Maps or through latitude and longitude), which is processed by Raspberry computer. The Sensor data of the availability of seats or the number of passenger On board is collected which is processed by the Raspberry Pi and gives updates through WiFi. The sensor for computing number of passengers on board can be a Motion sensor or a camera. The WIFI/GSM Module works as a mediator for information transmission to the Bus Terminus control module. The GSM module here is optional as Raspberry Pi is inbuilt with WiFi module, only in certain cases where sms information to be sent to the passenger this GSM module is useful. The Data collected by Raspberry pi is sent to the Bus Terminus control module through WiFi.

B. BUS TERMINUS CONTROL MODULE

This module consists of a WIFI based Raspberry Pi which receives the coordinates of the bus, the arrival times and the onboard passenger information. The Raspberry then processes the information and sends this real time information to the central server and this data can be accessed through User Interface like Apps in Smart phones, and also displays the real time information in the bus terminus. If the passenger can know the timings of arrival of the buses he can decide whether to wait or to look for any alternate transport in a busy schedule. The commuters at home can check the live updates of the position and the time of arrival of a particular bus service at the terminus via their smart phone app using their wireless internet access facility.

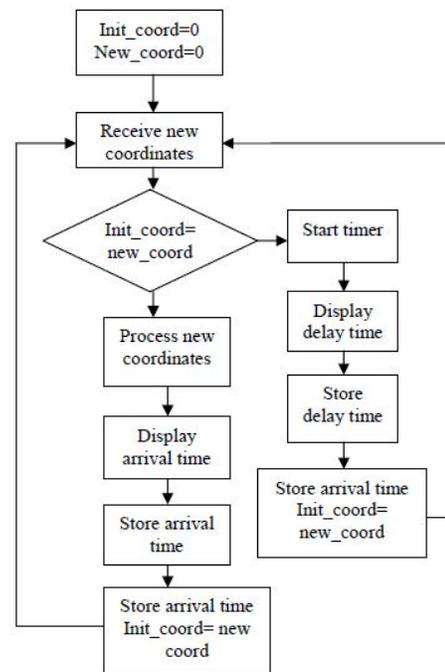


Fig. 11. ATDT Algorithm Flowchart

ATDT Algorithm: ATDT Algorithm is used here to know the co ordinates and the exact arrival times of the bus. In this algorithm two variables are used. The two variables for initial coordinates (init_cord) and new coordinates (new_cord)

are initialized. When the current coordinates are received from the BUS TRANSMITTER MODULE, the new coordinates are assigned with current coordinates. The bus is in either moving or stationary condition. To know the status of the bus a condition is checked. The condition is that the previous coordinates are checked with the present coordinates. Depending on this condition check a decision can be taken whether a bus is moving or stationary. If the checked condition shows that new coordinates and initial coordinates are different, then the bus is moving. Once the bus is in moving condition then the latitude and longitude values are used to calculate the distance of the bus from the bus terminus and the estimated time of arrival. This information is stored on the server through which the information can be accessed by passenger from any place on their smart phone app. Also this information can be displayed on a screen at the bus stop for the passengers waiting for the bus. If the previous coordinates are equal to the present coordinates then the ATDT algorithm decides that the bus is stationary. Apart from this ATDT can also decide the speed of the bus by checking the speed with which the new coordinates changes. So the arrival times can be correctly calculated by the ATDT algorithm through this way.

C. PASSENGER SERVICE MODULE

The Passenger Service module consists of a smart phone with the app to find the location (through google maps) of the bus and the time it will take to reach the destination. This is very useful for passengers to delay their departure from home to the bus terminus if they can know in advance, the time of arrival of the bus at the terminus. The passenger service module can also contain the display at the bus stops to know the coordinates and arrival times of the buses for the passengers at the bus stops. The Passenger Service Module also contain the information about the number of passengers boarded on the Bus. The passenger can access the time information via wireless internet connection available in the smart phones. By using real time Passenger Information system we can also respond quickly to accidents that are happening.

V. IMPLEMENTATION AND WORKING

The Bus transmitter module is will be containing the Raspberry Pi 3 computer. This Pi 3 computer will be connected to the Neo 6M GPS module, and the Raspberry Pi camera module. The Neo 6M module is connected to Raspberry pi computer. The VCC pin of Neo 6M is connected to pin 1 of Pi board, this ensures the required voltage of 3.3V to be given to Neo6M through Pi board, the transmitter pin of Neo6M connected to pin10(GPIO15) of pi board, the receiver pin of Neo6M is connected to pin8(GPIO14), and GND is connected to pin6 of Pi board. The Raspberry Pi camera module is connected to the CSI interface of Raspberry Pi computer through a serial bus. The GPS module connected to Pi board tracks the coordinates of a particular location and sends it to Raspberry Pi computer. Also the Pi camera counts the number of passengers on board and sends it to Pi computer. This information received by Raspberry pi computer is analyzed and stored in a central server through WiFi. Figure 12 shows

the circuit connection of the system. Mobile application and online portal are developed to access the location and arrival times of the bus through smart phones and displays at the bus terminus.

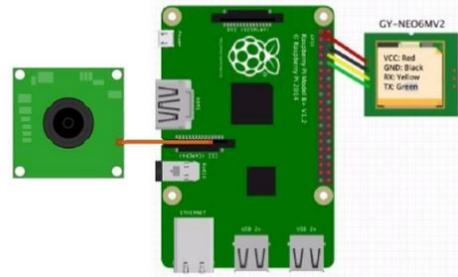


Fig. 12. Circuit connection of the system

VI. HARDWARE ASPECTS

A. Raspberry Pi3

Raspberry Pi is an ARM based debit card sized Single Board Computer. Raspberry pi 3 is the latest version of the Raspberry pi series. It runs on operating system called Raspbian. Figure 13 shows the available interfaces of Raspberry Pi board. The specifications of Raspberry pi 3 model B are given in table 2.

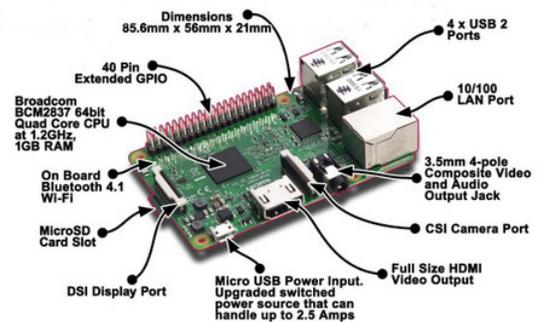


Fig. 13. Raspberry Pi3 single board computer

TABLE II
 RASPBERRY PI3 SPECIFICATIONS

| Specifications | Values |
|------------------|------------------------------|
| CPU | 1.2GHz 64bit quadcore ARM v8 |
| RAM | 1GB |
| USB ports | 4 |
| GPIO pins | 40 |
| CSI camera port | 1 |
| DSI display port | 1 |

B. Neo 6M GPS Module

The Neo-6M is a high performance GPS module which is used for navigation, positioning etc. The Neo 6M module here is connected with Raspberry Pi3 and installed in Bus Transmitter Module. The specifications of Neo 6M GPS module is shown in Table 3

TABLE III
 GPS MODULE SPECIFICATIONS

| | |
|--------------------------------------|---------------------|
| Receiver type: | 50 channels, GPS L1 |
| Navigation update rate: | 5Hz maximum |
| Tracking and Navigation sensitivity: | -161dBm |
| Serail Baud rate: | 4800,9600(default) |
| Operating voltage | 2.7v 5v |
| Operating current | 45mA |



Fig. 14. Neo 6M GPS Module

C. Raspberry Pi camera module

Raspberry pi camera module has two variants of 5 MegaPixel and 8 Megapixel. It has many features as described: Video modes of 1080p30, 720p60, Sensor of Omnivision OV5647, Focal ratio of 2.9, Picture formats of JPEG, GIF, BMP, PNG, YUV40, RGB888.



Fig. 15. Raspberry pi camera module

VII. CONCLUSION

The smart cities mission of India inspired every citizen to develop smart solutions and use the technology efficiently for sustainable growth of smart cities. The aim to develop 109 smart cities is a challenging aspect but can be achieved by the

active participation of citizens. In this paper one of the features of smart city that is smart public transport is proposed. The various solutions regarding to public transport are discussed such as Bus Rapid Transit(BRT), smart ticketing, Smart GPS based buses and bus stops are presented. In the proposed model the passengers no longer need to wait for the buses. The passengers can access the information about the location of the bus and arrival and departure times of the bus accurately by incorporating IoT solution into the present bus transport system. The passengers can know the information about public transport through an application in their smart phone.

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