

# A Low Cost M2M Architecture for Intelligent Public Transit

An Approach to Modernise City Public Transport for Developing Countries

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**Abstract**— The paper proposes a system which focuses on enhancing the usability and productivity of existing bus transportation system in Indian cities. The technology has a role to play for completion of the goal by means of providing an effective solution by establishing a wireless communication network in the city.

The paper introduces a framework as an improvement to the existing city bus public transport system in India - Arrival Time Prediction of bus in real time and approximate Seat Availability in the bus. ZigBee and GSM/GPRS Technologies can be utilized to establish a wireless network among Buses, Bus Stops and Central Bus Stand in order to create this interconnection. The paper also suggests modifications in the design of currently used Digital Ticketing Machine to implement the feature of conveying the seat availability.

ZigBee modules are used for short-range communication and Long-range communication is established using GSM messaging. The improvements in the system are expected to encourage more and more people to use public transport in order to overcome the problem of traffic and excessive fuel consumption.

**Keywords**— Central Server, GPRS, GSM, Intelligent Transport Systems (ITS), Public Transport, SIM900, Wireless Communication, ZigBee

## I. INTRODUCTION

Current bus services are congested, unreliable, untimely and uncoordinated in India. The ownership and operation of most public transport services have significantly reduced its productivity. India's cities desperately necessitate improved and trustworthy public transport service. The public transport needs to scale the productivity with increasing population and its needs, the improvement in infrastructure must be assisted with the smart approaches of Machine-to-Machine (M2M) communication.<sup>[1][2][3][4]</sup> This social issue has encouraged us to come up with an idea for the betterment.

This proposal best describes a low cost and frugal, yet practical solution for the concerned problem using ZigBee and GSM/GPRS as a communication medium. The usability of public transport can be enhanced by informing the real waiting time and occupancy/vacancy to the passengers.<sup>[3]</sup> So the main objective of this paper is to give a possible solution to implement the proposed changes in existing public transport system to enhance its usability and profitability.

## A. Technical Background

It is possible to establish a wireless network between various components of public transport system e.g. buses, bus stops and central bus stand; by several means. Some of the Intelligent Transport Systems in several countries use short range communication technologies and 3G internet connectivity solutions.<sup>[5]</sup> The costs involved to setup and run the systems are high as well as reliability associated with TCP/IP connectivity is poor; which tends to increased complexity and reduced reliability of system algorithm.

The referred system can be modified for performance improvement and cost deduction from earlier ones.<sup>[6][7]</sup> The short distance connectivity between bus and bus stops can be established by means of Bluetooth, ZigBee or Wi-Fi technology. By considering parameters like cost, power consumption it is a wise decision to go with ZigBee technology; which facilitates low power consumption and low cost over others. Hence by using ZigBee technology and GSM services which will allow reliable point to point connectivity system can be developed.

Below is the comparison of above-mentioned technologies, which justifies the selection of ZigBee for the intended application.

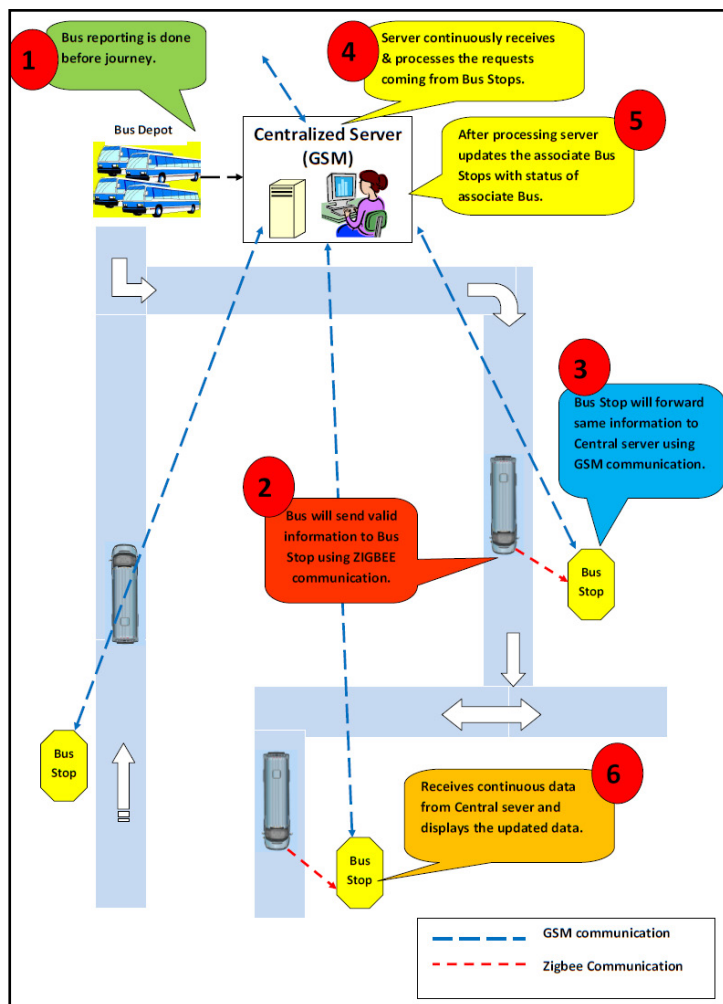
**TABLE I**

Comparison between Short Range Wireless Technologies

Parameter	ZigBee	WiFi	Bluetooth
System Resources	50 to 60 Kbyte	More than 1Mbyte	More than 250Kbyte
Battery Life (days)	More than 1000	1 to 5	1 to 7
Network Size	65535	32	7
Bandwidth (Kb/s)	20 to 250	11000	720
Transmission Range (m)	100	70	10
Success Metrics	Reliability, Power	Speed, flexibility	Cost, Convenience
Application	Monitoring and Control	Web, Heavy data transfer	Cable Replacement

### B. Proposed Algorithm

The algorithm is devised in such a way that the passengers become aware of bus arrival time and the probable occupancy in the bus, displayed on a screen at the stop. Figure 1 shows the algorithm for the proposed system. After reaching the bus stop, bus transfers information to Bus stop and Bus Stop transfers all the information to Control Center which then sends the information to all relevant bus stops next on the route. The steps in the algorithm are given below.

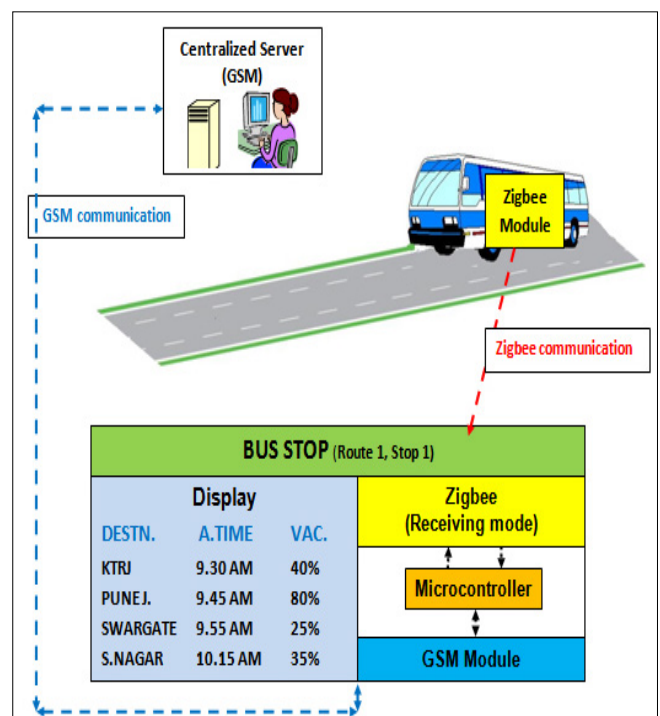


**Figure 1: Proposed System**

### Methodology:

1. Reporting of the bus for a particular route will be done at bus stand (Central Server) and all the stops on that route will be informed about start of the journey. At the same time, server will store the time at which reporting was done for further calculations.
2. When bus reaches the stop on concerned route (e.g. Stop 1 on Route 1), ticketing machine will send the information about the occupancy in the bus to the bus stop by using ZigBee communication.
3. The Bus Stop will forward the same information to the central server along with a time-stamp (time of arrival).
4. The Central Server will analyze the information and calculate the arrival time and vacancies at all next stops and send the information to each stop.
5. All the stops, after receiving the information from the Central server will update the display.

## II. SYSTEM ELEMENTS



**Figure 2: Scenario at Bus Stop**

The system comprises of a combination of hardware and software along with some networking features to complete the objectives. The interdependency of the elements is described below.

### Hardware Components:

Short distance communication between bus and bus stop, is established by using **ZigBee module** mounted on digital ticketing machine. Long range communication between the bus stop and central server is developed by using **SIM900 GSM module**. A central server can be configured by using appropriate operating system.

### Software Components:

Certain modifications in the existing ticketing machine's programming are suggested to get the required task done. To utilize the features of ZigBee<sup>[8]</sup> and SIM900 module, responses of these modules needed to be taken into account. The program shall be developed in such a way that it can respond to notifications of GSM services. AT commands<sup>[9]</sup> enable us to send and receive message transfer.

### Data formats:

For ensuring synchronous operation among all the 3 major components i.e. ZigBee, GSM and the central server it is very important to develop a specific data format that can be handled by all the above elements.

Every message transfer taking place in the system is in the form of packets. Further, each level of communication has different packet format. In order to make the system automated, these formats play an essential role.

Figure 3 : Communication between Bus XBee and Bus Stop XBee

#	HH (Resv.)	MM (Resv.)	SS (Resv.)	Bus_ID	Route_ID	CR
Stop_ID	Occupancy	CR				
Stop_ID	Occupancy	CR	#			

Figure 4 : Communication between Bus Stop and Central Server (Unidirectional)

\$	HH	MM	SS	Bus_ID	Route_ID	CR
Stop_ID	Occupancy	CR				
Stop_ID	Occupancy	CR				
Cur_Stop_ID	\$					

Figure 5: Communication between Central Server and Bus Stop (Unidirectional)

@	Bus_ID	HH	:	MM	<space>	AM /PM	Vacancy (%)	CR
	Bus_ID	HH	:	MM	<space>	AM /PM	Vacancy	CR
@								

## III. IMPLIMENTATION OF PROPOSED SYSTEM

### A. Hardware Implementation

The system is divided into 3 different modules. It consists of a Digital Ticketing Machine, Control and Communication Module at Bus Stop and Central Server.

#### 1. Digital Ticketing Machine

This simple digital ticketing machine provides very primitive features for taking the tickets. It uses P89V51RD2 controller as controlling and decision taking unit. For providing user interface, a keypad and LCD is provided. It has ZigBee mounted for wireless communication.

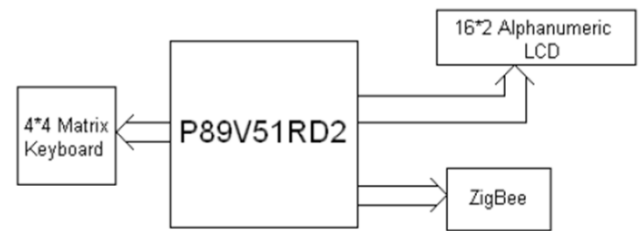


Figure 6: Ticketing Machine

Keypad and LCD are interfaced with parallel communication whereas; ZigBee is interfaced using Serial communication protocol. Figure 6 shows the hardware implementation of digital ticketing machine

#### 2. Module at Bus Stop

The module installed at the bus stop has to perform dual communication tasks, one with ZigBee of the ticketing machine and another with GSM module located at central server. So, we need a microcontroller which has the capability to communicate with two devices at the same time without any conflict. So, we chose LPC 2148 for our development.<sup>[10]</sup>

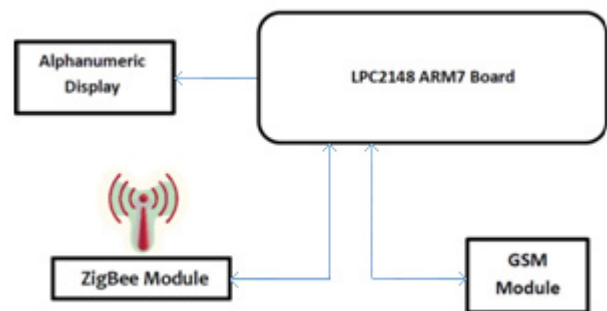


Figure 7: Module at Bus Stop

Figure 7 above shows the hardware components present at the bus stop. LPC 2148 development board has a ZigBee module installed.

### B. Software Implementation

Several IDEs such as Keil, Yagarto, Cross-Works, mikroC are available for programming the ARM and 8051 controllers. Out of these Keil  $\mu$ Vision4 is used for programming both of the controllers. As the code size of the programs is not very large, evaluation version of this IDE is sufficient. LPC2148 is a 32 bit RISC controller with ARM7 TDMI-S architecture while P89V51RD2 is 8 bit CISC controller with Harvard Architecture.

In digital ticketing machine, firstly all the IO pins are initialized as per requirement of the matrix keyboard and 16x2 alphanumeric LCD. UART is initialized for 8 bit data transfer with 1 start and 1 stop bit.

In the software implementation, the controller continuously scans the matrix keyboard for ticketing inputs and the corresponding number is updated on the LCD. It has the primitive features which ask the conductor for the number of tickets, source and destination stop. Accordingly the cost is

calculated and upon pressing the given button (interrupt), a communication process is initiated between bus and bus stop ZigBee. The hardware features of LPC2148 used are on-chip RTC, two UARTs and IOs. First of all required pins are configured as per requirement (as an IO pin or serial communication pin). Both of the serial ports communicate with a baud rate of 9600.

After that, the controller waits for the ZigBee module to receive the data packets from the ticketing machine. Then it attaches the time stamp in the packet and sends to the central server through GSM module connected at the other UART. Then it waits to receive the message from the central server about information of arriving buses and seat availability. When it receives that message, it decodes it and displays the information on the alphanumeric LCD in readable format.

This whole procedure is cyclic in nature.

### C. Server side programming

The central server has been designed on MATLAB Tool using its serial communication handling capability and handy GUI design method. MATLAB also provides the necessary computing power for text processing. The central server is connected with a SIM300 module in order to control and monitor all Bust Stop Modules. Here is the design overview:

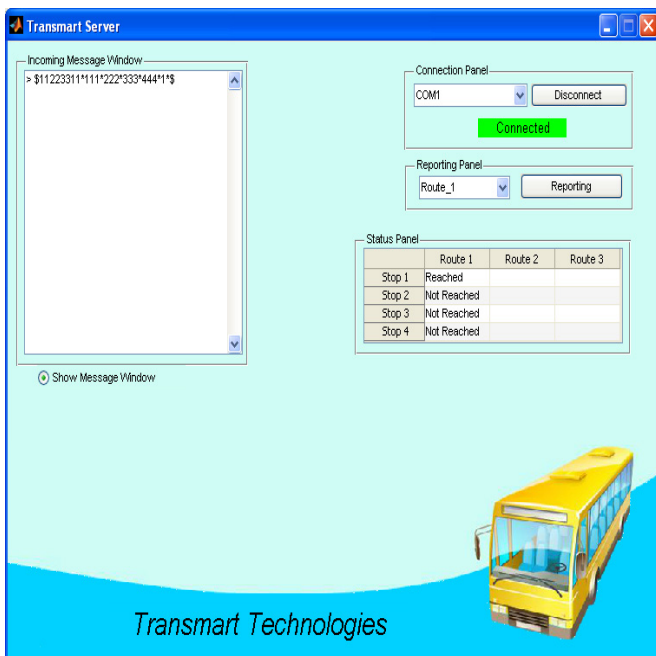


Figure 8: Server-side GUI

#### 1. Connection Panel

This is the detailed view of the connection panel. It contains a dropdown menu for selecting the COM port, a Connect button for connecting to selected COM port and a status text with background for displaying the connection status.

#### 2. Reporting Panel

Reporting panel consists of two UI controls. A dropdown menu for selecting the Route and a Reporting button for taking action on it.

#### 3. Incoming Message Window

Incoming Message Window shows the messages received from GSM module

#### 4. Status Panel

The status panel is used to show the status of the bus at a particular stop. i.e. either reached or yet to reach.

### Estimation of Arrival Time - Algorithm at Server

The central server estimates the arrival timing of a bus and informs it to all next stops carrying out the mathematical calculation. It uses linear prediction using immediate previous record.(Eq 1,2,3)

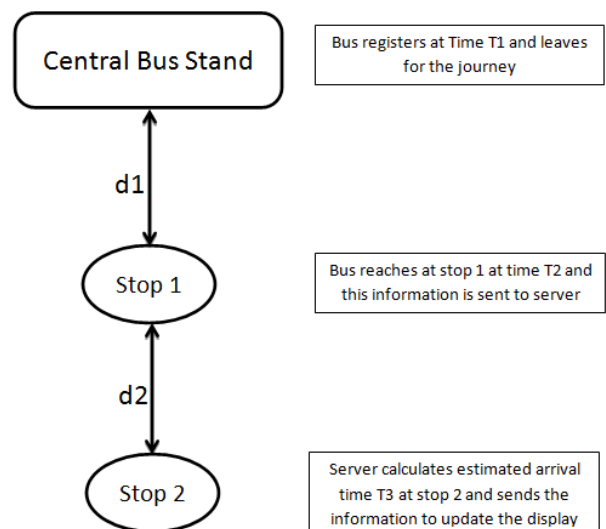


Figure 9 : Example flowgraph

#### Arrival Prediction:

$$T_3 = T_2 + \frac{D_2}{\text{Speed}(\text{Bus Stand}, \text{Stop 1})} \dots \dots (\text{Eq 1})$$

$$\text{Speed}(\text{Bus Stand}, \text{Stop 1}) = \frac{D_1}{T_2 - T_1} \dots \dots (\text{Eq 2})$$

$T_3$  = Distance between central Bus Stop and Stop 1

$T_2$  = Distance between Stop 1 and Stop 2

$D_2$  = Distance between Stop 1 and Stop 2

$D_1$  = Distance between central Bus Stop and Stop 1

$T_1$  = Registration Time of Bus at Central Bus Stand

#### Vacancy Prediction:

$$\text{Vac}(i) = \text{Occ}_{\max} - \sum_{j=i+1}^n \text{Occ}(j) \dots \dots (\text{Eq 3})$$

$\text{Vac}(i)$  = Vacancy at  $i^{\text{th}}$  stop

$\text{Occ}_{\max}$  = Maximum No. of seats (Bus Capacity)

$\text{Occ}(j)$  = No. of passengers boarding off at  $j^{\text{th}}$  stop

$n$  = No. of stops in the route



### Observation:

Upon testing the whole system rigorously, by considering real time situation, experiments were performed and observations were taken (refer Figure 9) :

1. Bus reporting at central bus stand at time:  $T1 = 11.50\text{AM}$
2. No. tickets issued to passengers boarding off at Stop 3 = 5
3. Distance between Central Bus stand and stop1:  $d1 = 4\text{ Km}$
4. Bus Reaches at Stop 1 at time:  $T2 = 12.05\text{PM}$
5. Distance between Stop 1 and Stop 2:  $d2 = 3\text{ Km}$
6. Conveyed Arrival Time of the bus at Stop 2:  $T3 = 12.15\text{PM}$
7. Conveyed Vacancy at Stop 2 = 90%

### Performance Analysis:

The ZigBee module has an ideal range of 100 m, indoor. In testing 70-75m was the range observed due to weakened signal because of interference with the obstacles. Average delay to receive a GSM message: 4 sec  
Average delay to display the information from the time of arrival of the bus on all the next bus stops : 10 sec

### Future Scope:

1. Use of Real-Time Operating System (RTOS) for better flow control of the program
2. Use of XBee Pro with for better collision avoidance.
3. Use of commercial messaging service instead of SIM service for cost effectiveness.
4. Use of Visual BASIC (VB) or similar platform to develop Transmart Server for avoiding compatibility issues.
5. Once the system is implemented, a strong network of ZigBee and GSM can be utilized for many purposes; such as Pollution Monitoring e.g. Air and sound and to collect the data throughout the city.
6. Use Low power displays such as LED displays in order to enhance the display capabilities and reduce the power requirements.

### Conclusion:

More reliable the public transit, more will be its usability. The key areas of project development were:

1. Occupancy Indication: Ticketing machine with primitive features was made to ensure accurate vacancy information.
2. Creation of a Central Server: The critical operations for the autonomous monitoring require GUI and centrally managed system. We were successfully able to meet this requirement by developing the backend using algorithms and MATLAB programming.
3. Setting up a coordinated small-distance and long distance wireless communication network: The team worked on different types of communication networks and established interchange of information. The specially developed data formats were used for it.

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