DESIGN OF REAL TIME INTELLIGENT BUSES NOTIFICATION SYSTEM FOR PASSENGERS

MUHAMMAD RAUF

MASTERS OF ENGINEERING (ELECTRONICS)

UNIVERSITY MALAYSIA PAHANG

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MUHAMMAD RAUF

A thesis submitted in fulfilment of the requirements of the award of the degree of Masters of Engineering in Electronics

Faculty of Electrical & Electronics Engineering
UNIVERSITY MALAYSIA PAHANG

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SUPERVISOR'S DECLARATION

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Engineering (Electronics).

Signature: ....
Name of Supervisor: Assoc. Prof Dr. Ahmad N Abdalla.
Position: Associate professor
Date: ....

Signature: ....
Name of Co-Supervisor: Mr. Nik Mohd Kamil bin Nik Yusoff
Position: Senior Lecturer
Date: ....

STUDENT'S DECLARATION

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Signature : ____________________

Name : Muhammad Rauf

ID : MEE09003

Date :

DEDICATION

To my parents, sister and brother

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In the name of Allah, the Most Benevolent, the most Merciful. First of all I wish to record immeasurable gratitude and thankful fullness to the One and The Almightly Creator, the Lord and Sustainer of the universe, and the Mankind in particular. It is only through His mercy and help that this work could be completed and it is ardently desired that this little effort be accepted by Him to be of some service to the cause of humanity.

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ABSTRACT

Waiting passengers at bus stops for their desired buses seems a commonly observed phenomenon. The obvious reason behind is increased personal vehicle, causing traffic jams. The requirement of a reliable public transport monitoring system is actually the outcome from this unnecessary congestion of traffic observed. Since most of the modern technologies for the Intelligent Transportation System (ITS) have developed since more than 15 years. The need of a Global Positioning/ inertial (GPS/INS) augmentation with a reliable communication system stems from the shortcomings of each individual technology. Besides further advancement, the researchers are now developing implementable technologies for the ease of mankind so that problems related to daily life could be solved. In this dissertation, a new real time intelligent public transport movement monitoring system and station reporting based on GPS and succession of RF Radio Chips is presented. From the societal perspective, the major apprehension of this research, under the framework of a public transit network with bus service providers and users, presents detailed technical solutions for different buses' routes with poles apart IDs using multi technologies applied. GPS is selected to achieve the position data. In order to build the most convenient and reliable system, map matching for location data comparison using optimization technique, Design of Experiment (DOE) is applied. Using the techniques, one single route's coordinates are optimized to single equation, whose output is the bus stop number in accordance to the bus stop coordinates received. The equation is obtained after a number of run through simulation and then successfully trained to the MCU. Road networks are one of the important surveillance tools in the proposed transport navigation system. In the proposed system, a careful and implementable deployment (hundreds of meters apart) of the ranging sensors is suggested for the cost-effective multi ID buses information at their particular bus stops. These are made configured to create a dedicated network for individual bus ID. Thereby, the extraordinary quality can be shown which is realized by the described algorithms. The experimental results show the promising outcomes. The statistical analysis of equation provides up to 98% efficiency while the designed prototype showed a remarkable agreement between the simulated and actual results. The proposed system surely have the ability to improve the comfortable visibility of moving vehicle at another node as well its smooth and linear transmission to the bus stations by sophisticated transceiver modules, which led people to take a decision either to wait for bus or not. This system can also be supportive to change the trend of people from using their own vehicles to public transport, which lead to solve major problem related to energy consumption, environment and traffic congestion.

ABSTRAK

Menunggu penumpang di perhentian bas untuk bas yang mereka kehendaki seolah-olah satu fenomena yang lazim dilakukan. Sebab yang jelas di sebalik bertambah kenderaan peribadi, menyebabkan kesesakan lalu lintas. Keperluan sistem pemantauan pengangkutan awam yang dipercayai adalah sebenarnya hasil daripada kesesakan ini tidak perlu trafik yang diperhatikan. Oleh kerana kebanyakan teknologi moden untuk Sistem Pengangkutan Pintar (ITS) telah dibangunkan sejak lebih 15 tahun. Memerlukan pembesaran Global Positioning / inersia (GPS / INS) dengan sistem komunikasi yang boleh dipercayai berpunca daripada kekurangan teknologi setiap. Selain kemajuan lanjut, penyelidik kini membangunkan teknologi dilaksanakan untuk memudahkan manusia supaya masalah-masalah yang berkaitan dengan kehidupan harian dapat diselesaikan.Dalam disertasi ini, masa yang pintar sebenar baru pengangkutan awam pergerakan sistem pemantauan dan laporan stesen berdasarkan GPS dan berturut-turut Cip Radio RF dibentangkan. Dari perspektif masyarakat, kebimbangan utama kajian ini, di bawah rangka kerja rangkaian transit awam dengan pembekal perkhidmatan bas dan pengguna, membentangkan penyelesaian teknikal terperinci untuk laluan bas yang berbeza dengan kutub selain ID yang menggunakan teknologi multi memohon. GPS dipilih untuk mencapai data kedudukan. Dalam usaha untuk membina sistem yang paling mudah dan boleh dipercayai, peta yang hampir sama bagi perbandingan data lokasi anda dengan menggunakan teknik pengoptimuman, Rekabentuk Eksperimen (JAS) digunakan.Dengan menggunakan teknik-teknik, koordinat salah satu laluan tunggal yang optimum kepada persamaan tunggal, yang keluaran bilangan perhentian bas mengikut perhentian bas koordinat menerima. Persamaan diperolehi selepas beberapa jangka melalui simulasi dan kemudian berjaya dilatih untuk itu MCU. Rangkaian jalan raya adalah salah satu daripada alat-alat pengawasan yang penting dalam sistem pengangkutan yang dicadangkan navigasi. Dalam sistem yang dicadangkan, kerahan berhati-hati dan boleh dilaksanakan (beratus-ratus meter selain) sensor antara yang disyorkan untuk kos efektif ID bas maklumat pelbagai di perhentian bas tertentu. Ini adalah dibuat dikonfigurasikan untuk mewujudkan satu rangkaian khusus bagi ID bas individu. Dengan demikian, kualiti yang luar biasa boleh ditunjukkan yang dicapai turut ditunjangi oleh algoritma yang dinyatakan. Keputusan eksperimen menunjukkan hasil yang menjanjikan. Analisis statistik persamaan menyediakan sehingga kecekapan 98% manakala prototaip yang direka menunjukkan perjanjian luar biasa antara hasil simulasi dan sebenar. Sistem yang dicadangkan pasti mempunyai keupayaan untuk memperbaiki penglihatan selesa bergerak kenderaan di nod yang lain serta penghantaran lancar dan linear kepada stesen-stesen bas oleh modul transceiver canggih, yang membawa orang ramai untuk mengambil keputusan sama ada untuk menunggu bas atau tidak. Sistem ini juga boleh menyokong untuk menukar trend orang daripada menggunakan kenderaan sendiri kepada pengangkutan awam, yang membawa kepada menyelesaikan masalah utama yang berkaitan dengan penggunaan tenaga, alam sekitar dan kesesakan lalu lintas.

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AI	Artificial Intelligence
ATTS	Advanced Transport Telematics systems
ANN	Artificial Neural Network
aMM	advanced Map Matching
CDMA	Code Division Multiple Access
DOE	Design of Expert
DGPS	Differential Global Positioning System
DSS	Decision Support System
FL	Fuzzy Logic
GDP	Gross Domestic Product
GIS	Geographic Information System
GNSS	Global Navigation Satellite Systems
GPRMC	Recommended minimum
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSM	Global System for Mobile communication
GUI	Graphical User Interface
gMM	geometric Match Matching
ICT	Information and Communication Technologies
IDE	Integrated Development Environment
INS	Inertial Navigation System
IPTMS	Intelligent Public Transport Monitoring System
ITS	Intelligent Transportation System
KF	Kalman Filter
LA	Logic Analyzer
LAN	Local Area Network
LCD	Liquid Crystal Display
MCC	Monitor and Control Center
MCU	Microcontroller Unit
MM	Match Matching
PAN	Personal Area Network

PRN	Pseudo-Random
pMM	probabilistic Match Matching
RF	Radio Frequency
RFID	Radio Frequency Identification
RSM	Response Surface Method
RSSI	Received Signal Strength Indicator
SMS	Short Message Service
TI	Technical Inspection
tMM	topological Match Matching
UART	Universal Asynchronous Receiver/ Transmitter
UTC	Coordinated Universal Time
VDS	Video display stations
VII	Vehicle-to-Infrastructure Integration
V2V	Vehicle-To-Vehicle integration
WAAS	Wide Area Augmentation System
WSN	Wireless Sensor Networking

CHAPTER 1

INTRODUCTION

1.1 MOTIVATION

The incessant increment of the population and lack of the facilitated public transport system in big cities is causing the boost of the private owned cars, has created major traffic problems. Existing public transport infrastructures are unable to handle the major problems of those vehicles with the result of heavy congestions for significant periods of time each day. Now a day around 180,000 daily customers are observed travelling by the economic planning unit, PM department, Malaysia using public transport. The Kuala Lumpur Structure Plan 2020 for the transportation is the blueprint that guides the development of Kuala Lumpur's public transport system for the next 20 years. The plan, with its pronged approaches, outline the goals, strategies and policies in the direction of achieving the vision as well as identifies ways to lessen or solve issues and trouble faced by the passengers. It is stated in the case study of plan that "*Although traffic management measures have done much to ease traffic flows particularly in the city centre, they cannot continue to do so indefinitely if traffic demand on the roads continues to grow. Traffic management measures alone cannot effectively increase existing road capacity levels"* (KL Structure Plan, 2010).

1.2 EXTRACTED PROBLEM BACKGROUND

The requirement of a reliable public transport monitoring system is actually the outcome from the unnecessary congestions of traffic observed. These congestions can be classified in two categories. The recurrent congestion occurring periodically during rush hours, mainly when people go to their works or return from them and the incidental congestion occurring due to special circumstances such as accidents or extreme weather conditions. This problem affects many aspects of people's everyday life. Mainly, it degrades the overall quality of life of individuals. Furthermore, it has major economic and environmental impacts. Now the extracted problem statement not only belongs to the KL but the same or worst public transport network management situation can easily be observed in most of the metropolitan cities of the world. It means the passenger at the bus station had been the victims for long time, especially where the public transport facilities are not compatible with the city's problem. Public traffic facilities with the high-tech and intelligence system have been a standard to guesstimate the development of the country and its international image. With the advent of technology, now passengers want to get the clear and optimum information of their desired vehicle at station like the position and estimated time of arrival of buses, etc.

By observing the above described problem, it can be estimated that a wide solution can be provided to the suffered passenger. It will surly give long term comfort to the City Government by encouraging people to use public transport instead of own car, which will lead to less congestion, less fuel and energy utilization as well benefits to the public transport providers. A model of such a requirement which highlighted the problem statement can be observed by an over view to the Government Funding for Intelligent Transportation Systems Development. The leading countries in intelligent transportation systems have not only developed an explicit national strategy for ITS, they have also invested heavily in it. A shadow of such investment in the field of ITS is shown here, "*South Korea's national ITS master plan 21 commits to investing a total of $3.2 billion from 2007 to 2020 in intelligent transportation systems, an average of $230 million annually over the fourteen-year period. Japan invested ¥64 billion in ITS from April, 2007 to March, 2008 and ¥63.1 billion in ITS from April, 2008 to March, 2009, on average about $690 million annually. Aggregate investment in ITS at all government levels in the United States in 2006 was approximately $1 billion (including $110 million in federal funding and over $850 million in funding from the U.S. states). As a percentage of GDP, South Korea and Japan each invest more than twice as much in intelligent transportation systems than the United States*" (Ezell, 2010).

Another support for the problem statement was studied by Abdul Azeez and Miura, (2005) in Figure 1.1. It shows the trend in hourly fluctuation of traffic volume on each of the selected road. *Traffic volume was counted to be more than 12000 vehicles per hour during morning and evening peak hour along the major arterial road. Generally, traffic volume during peak hour was between 1.7 and 2.7 times than traffic volume during non-peak hour.* The above figure clearly identifies the increasing number of personal own vehicles utilization in peak hours. Now a days, sharp increment in personal vehicle caused heavy traffic jam.

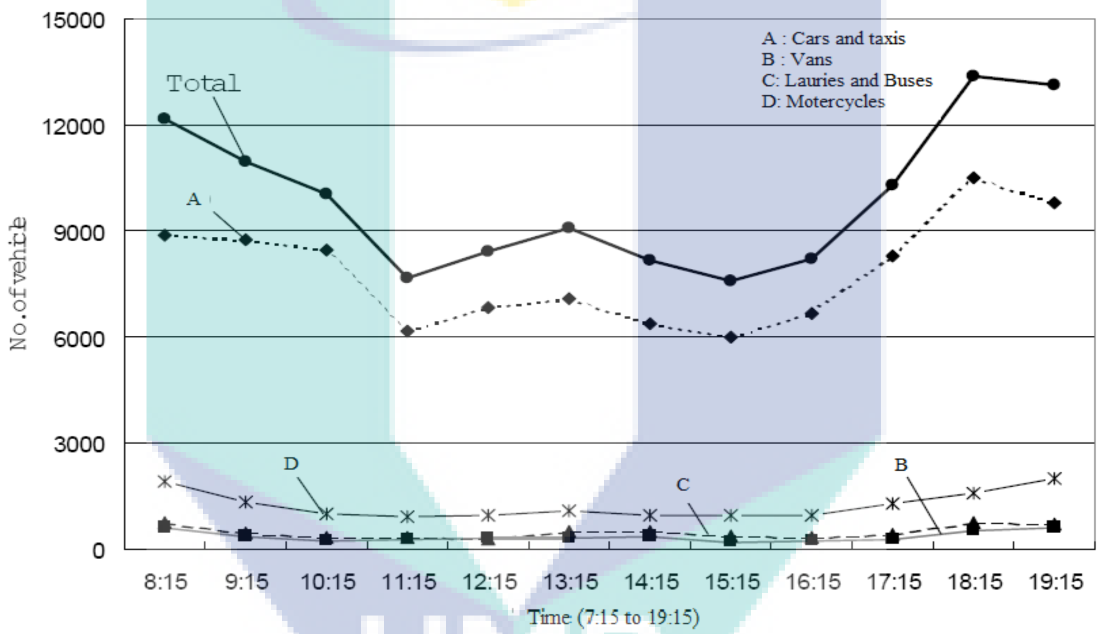


Figure 1.1: Hourly Fluctuation of Traffic Volume (Abdul Azeez and Miura 2005)

1.3 BACKGROUND OF SIMILAR SYSTEM

Many transportation agencies are already using ITS effectively to reduce traffic congestion and its nearly $200 billion estimated impact on economic productivity and the environment. Just a few examples of efficient ITS applications include real-time traffic, transit and parking information, intelligent intersections, smart transit vehicles, open road tolling systems, ramp metering, variable speed limits, and weigh in motion truck inspections. These and other technologies can greatly improve economic productivity by helping people and goods get from their origin to destination on time (Belcher, 2008).

In order to approach and achieve an optimal design of a public transport management and monitoring system, researchers in the last several decades proposed many design and optimization approaches. Most of the designs and methods were given sound weight because those can project the Cities' modernization and enlighten. Some of them are discussed here. Like the study conducted for the implementation of bus priority at traffic signals has grown steadily since the successful large-scale trial conducted in the Selkant-London (Hounsell and McLeod, 1998) came up with more enhancements in 2007. According to him, it has kept pace with the development of new technologies by updating its bus priority system in London to tackle the challenge posed by locational error associated with GPS where a traffic signal is close to a bus stop.

Performance evaluation with technology utilization may capable of holding the increasing burden of passengers as well as to resolve the exertions faced by Public transport system. Guohua el al. (2007) analyzed the present status of the application of the Advance Public Transport System (APTS) in different cities of China. It is also included an investigation of the possible future application and improvement of APTS based on situation in China. Moreover, he mentioned that with the help of the theories and methods of the system engineering, various new technologies are used, such as, the modern communication, information, electronics, controlling, computer, internet work, Global Positioning System (GPS), Geographic Information System (GIS), and so on. It brings in a modern information management system and a modern controlling and scheduling method, by which, information and intelligence techniques can be fused for the modernization of the public traffic system's controlling, scheduling, and managing.

Incorporating visualization technique to facilitate the modern Intelligent Transportation System (ITS), traditional display of several parameters using GPS data had been the part of papers and projects for the real time monitoring. But unfortunately there is no progress observed for the efficient and reliable monitoring systems and to manage the accuracy by utilizing intelligent techniques. Before the era of the mobile internet, characterized in particular by the emergence of location based services heavily relying on GPS, the traffic monitoring infrastructure mainly contained of some specific equipment, such as loop detectors, cameras, and radars. Installation and maintenance costs are found as sufficient burden in exploitation of these technologies for the entire arterial network and even for highways in several places around the world (Herrera, 2010). Moreover, he explained inductive loop detectors are prone to errors and malfunctioning. The means of location data transmission lead to utilize new technologies to aid intelligent transportation system. Qin et al. (2008) proposed a vehicle monitoring system using the existing GPRS network for location information transmission collected by the GPS module to the IP-fixed control centre in the internet. He explained his paper by dividing the whole idea into basic two sections: hardware and software. Hardware part implies in detail the design of the main circuit unit and introduces the application of GPRS module named MC55. Hardware system uses S3C44B0 to control ISD25120 voice chip and LCD module after receiving location information by GPS module. Meanwhile this location information will be sent to the control centre by using GPRS module. Software section determines the flow chart of station reporting and network access system. Besides, it also introduces the software design of the monitoring centre. Niu et al. (2009) developed a navigational system for overall solution on Beijing Bus Monitoring System (BJ-BMS) based on GPS. The BJ-BMS is composed of GPS satellite positioning and ground moving control system. And the ground moving control system was divided as on-board GPS terminals, GPRS mobile communication network, transmission canter server, client background program and GIS interface. Bao et al. (2002) investigate a GPS based vehicle monitoring system in Xiemen city of China. According to the study, system composed of the moving parts in the individual cars and the fixed part on the monitor and control centre in a command centre office, and whole system is linked with a radio channel. The Monitor and Control Center (MCC) includes an intelligent monitoring platform, a control and modem card for digital data transfer, a broadcast station in the base, and an antenna for the main control station. Athenian (Greece) transport network are based on the telecommunication systems and it has about 300 intelligent bus stops equipped with screens and audio announcements to inform users about buses and timetables (Athens in 21st century, 2004). Study by Lu et al. (2007) is based on Positioning and tracking of construction vehicles in highly dense urban areas. In his paper, he reviewed past research related to radio frequency (RF) in construction area and further asses the reasons of utilizing several RF-based technologies including GPS, RFID, and Bluetooth for monitoring and applying GPS for tracking construction vehicles in a dense area by performing widespread field tests. Soo Thong et al. (2007) proposed an idea for intelligent fleet monitoring and management system which combines the utilization of concurrent Global Positioning System (GPS) and Global System for Mobile Communications (GSM) for real-time positioning, frontend intelligent and web-based management software.

"*Taxi fares in Spain are revised every year and the taximeters must be recalibrated and verified by a Technical Inspection (TI) via certified station*". Local government authorities in Spain were using specific mechanism including machines with rolling cylinders for testing and verification of taximeters. Global positioning system (GPS) sensors can be intuitively well suited for this process, because they provide the position as well as speed, which can separate them from those car devices that are under test. However GPS measurements are some sort of imprecise and GPS-based sensors are difficult to confirm as recognised location information. For the purpose, the author proposed a method for computing an upper bound of the length of the route, taking into account the imprecision of the GPS data. Fuzzy techniques are selected to model the GPS data due to its uncertainty described. The upper bound was computed using a multi-objective evolutionary algorithm (Villar et al., 2009).

Numerous research can be observe on the utilization of intelligence techniques to enhance the visibility and observability of GPS. It is observed that most of today's land vehicles use to come up with pre installed navigation equipment, to provide location and velocity information. However, there are several situations where GPS experience either total system outage (due to satellite signal blockage) or deterioration of accuracy (due to multipath effects and clock bias error). Recently, methods based on Artificial Intelligence (AI) have been suggested to provide reliable positioning information for different land vehicle navigation applications integrating the Global Positioning System (GPS) with the Inertial Navigation System (INS). A study conducted by Noureldin el al., (2011), suggests the use of Input-Delayed Neural Networks (IDNN) in order to integrate the INS position and velocity errors based on current and some past samples of INS position and velocity, respectively. The results showed a better positioning solution during long GPS outages. The proposed method is evaluated using road test data of different trajectories while both navigational and tactical grade INS are mounted inside land vehicles and integrated with GPS receivers. Fan and Jiancheng (2007) put forward an error compensation method of velocity and position coordinates by the GPS using neural network. His research aimed an effective solution that can approximate and reduce the navigation errors caused by the initial misalignments as well as the inertial sensors errors by utilizing neural network integration with the kalman filter. Now present INS/GPS integration techniques using kalman filtiring, have some inadequacies related to the stochastic error models of inertial sensors, immunity to noise, and observability. Sharaf and Noureldin (2007) aim to introduce multi sensor system integration approach for fusing data from INS and GPS for the navigation purpose, utilizing artificial neural networks (ANN). A multi layer perceptron ANN has been recently suggested to fuse data from INS and differential GPS (DGPS). According to Liu and Amin (2009), the severe degradation of the performance of GPS receivers is due to the multipath problem in geo-location. The level of the tracking errors in compromising the receiver performance depends on the multipath amplitude, delay, and phase relative to the direct path. For the purpose, author provided analyses of the effect of multipath carrier phase offset on GPS navigation error bounds as well as statistical average error values.

Regarding other optimization techniques, beside traditional neural network, Design of Experiments (DOE) had been a useful tool that used for exploring new processes, gaining increased knowledge of the exiting processes and optimizing these processes to achieving a better performance (Rowlands and Antony, 2003). Surface Response Methodology (RSM) is foremost important tool of DOE, wherein the relationship between responses of a process with its input decision variables is mapped to achieve the objective of maximization or minimization of the response properties (Raymond and Douglas, 2002).

Some studies provided only the frame work for safety issues in the area of ITS, to increase the performance percentage of overall public transport network (Chang and Yeh, 2005). The associations between safety performance and company characteristics, including the type of operation and the size of fleet, were also explored by Corsi (2002) for passenger motor carriers. Some theoretical solution on the provision of bus services along different routes that comprise a public transit network is assessed taking into consideration in (Sheth et al., 2007), along with the service providers, the users and the societal perspectives.

A very recent announcement by the ministry of regional development and competitiveness Greece, invited a tender for the development of a new integrated information system for management and control of buses and trolleys in the capital (GR Reporter, 2011). The plan is part of the modernization programme of the public transport network in Athens. According to the report, "*The state has budgeted 52 million Euros with a cooperation agreement of 12 years. The aim of the programme is to install the "smart" stops, which will have an electronic display showing where the bus is and after how many minutes it will take to arrive. The precise timetable of public transport will also be provided on the internet and mobile phone*." The report shows the keen interest towards upgrading of metropolitan city through vast investment in the public transport management sector.

According to United States GAO report (2009), real-time traffic information systems, along with other types of ITS, can be used to increase a smooth traffic flow and decrease congestion. Existing research has shown that real-time traffic information systems can alleviate traffic congestion by providing travellers with information about traffic and other travel conditions, as well as on alternative routes. According to this report, "*Department of Transportation (DOT) promotes the deployment of real-time traffic information technologies. For example, DOT's ITS joint program office and the Federal Highway Administration (FHWA) promotes such deployment. DOT is currently developing an ITS strategic plan which will recognize the direction, goals, and objectives for the department's ITS program over the next 5 years.*" In developing this strategic plan, DOT is working to further define its role in promoting real-time traffic information systems.

Amongst all studies, some gave good answers for the effective wireless solutions for navigation system of the buses location while some provided optimization based ideas but these measures and dimensions have not been consolidated in an integrated framework where different views are considered along with multiple goals. The reports included in the problem background, still facing implementation problem from several aspects. By keeping an eye on the cited research and reports, this dissertation came up with the objectives which can cover most the lacks and exertion faced by ITS.

1.4 OBJECTIVES

The main objective of this study can be summarized as follows;

i. To design an intelligent public transport monitoring system using GPS and Zigbee which can be utilized for large scale dedicated infrastructure.
ii. To evaluate and enhance the performance of the ITS using optimization technique.

1.5 BRIEF RESEARCH CONTRIBUTION

The related art evidently describes that in the vast domains of navigation system for public transport system, the crucial issues are the consistent monitoring system with reliable error compensation using maximum faultless techniques. Although many researchers have addressed and proposed monitoring systems to track vehicle or critical moving entities but still the accuracy is the considerable question mark. This dissertation focus on proposing a new intelligent multi ID buses position notification system for passenger based on intelligence technique. The proposed system investigates the technology utilization to overcome the extracted problem background from multiple aspects. Regarding technological approaches, the improved accuracy of global positioning systems (GPS) technology has seemingly become as the preferred choice of location detection method for 'high-end' system. It will provide the individual vehicular position information by the means of location coordinates. In order to make the overall system more compatible and reliable with the real world, the intelligent map matching based looping of several configured RF embedded radio chips (which can be installed on bus stops), are decided to include in the proposed solution. For the map matching to be intelligent and reliable, the optimization technique named as DOE is utilized. The use of a radio frequency allows for a much more selective location transmission down to specific vehicles as well bring advancement in our frame work.

The aim of our decision support system for the passengers is to propose an adapted answer to the problems related to real-time bus network monitoring and management system particularly in dense urban areas where GPS reception could not be up to the mark like the multipath error can easily be observed. In order to challenge these exertions, the comprehensively proposed system comprises of two major parts; one is the technical while other is management of overall paradigm. Regarding Technical, the whole proposed system is typically divided into two key modules; one is master module (the buses) while second one is named slave module (the bus stations).The package of designed embedded system consists of the advanced control technique comprising of master part, mounted on the bus, containing MCU integrating GPS receiver, station related information identifier, long range wireless transceiver Xbee Pro RF Module (IEEE 802.15.4). While the slave part, can be mounted on every bus station, also contains same MCU, this time integrating the LED indicators and same wireless protocol. This system would be able to expect position to display at every bus stations found at every particular route, in the convenient way for the persons come to bus. This required core software used for programming the setup and creating a replica of the real network. The base and Bus station hardware is responsible for receiving the GPS data transmissions and making them available for the most convenient real time display. The software part includes the IDE part and optimization part, developed to monitor and maintain the reliability of the system. A compiler for the advanced controller unit is selected so both the hardware and software solutions are integrated in the proposed system to make it most reliable and user friendly. For this reason, PROTON+ IDE and DOE version 8 are chosen as research tools. Besides the technical contributions, the dissertation also provides a relevant discussion on its real world implementation from technical side until its social aspects.

The goal of this thesis work is to investigate over the area of public transport sector and find available technologies that can be combined in order to figure out a complete real-time traffic monitoring and management system for the any urban modernization plan.

1.6 OUTLINE OF THESIS

This thesis organizes; the second chapter contains the detailed knowledge of the technologies utilized like history of surveillance system, the map matching techniques and communication technique. All the technologies are given the weights by providing relevant citations.

Third chapter provides the methodology of overall proposed system with advanced hardware implantation. The proposed intelligent public transport notification system interlink with Decision Support System (DSS) for the passenger with reliable visualization context describe in detail. It also includes expert hardware and software implementation with the optimization techniques applied.

The forth chapter talks about the result. This critical section includes the map matching result and configuration of transceiver. Besides, the discussion is presented in broader view. It covers the discussion from technical part implementation until its social prospects.

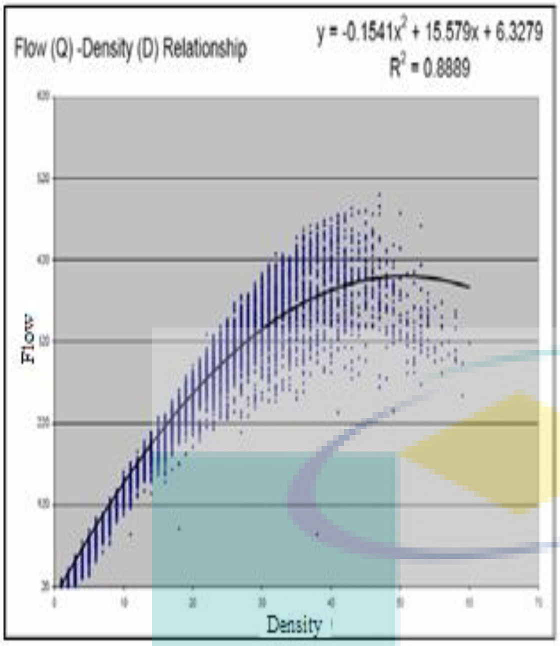
Finally fifth one gives the conclusion for each of the objective with the benefits and its future enhancement.

CHAPTER 2

RESEARCH SURROUNDING WITH TECHNOLOGY UTILIZATION

2.1 INTRODUCTION

No one can deny with the importance of time in this 21st century. However, the problem with time management is its unwanted wastage of time for people's life due to plenty of reasons, including growing infrastructure of traffic and their poor management, which lead towards the daily observed traffic congestion. Passenger at the bus station had been the victims of this unwanted wastage of time since long time, especially in the big cities where the public transport facilities are not compatible with the city's problem. Public traffic facilities with the high-tech and intelligence system with a proper management system have been a standard to estimate the development of the country and its international image. For instance, have a look towards the study conducted by Mahfix (2006). According to his research, based on (Video display stations) VDS, data collected over a period of time, work has started to profile the various roads to gain a better understanding of the parameters impacting on local and network congestion. Figures 2.1(a), (b), (c), (d) below show the trend, scatter and relational analysis based on flow, speed and densities of traffic.



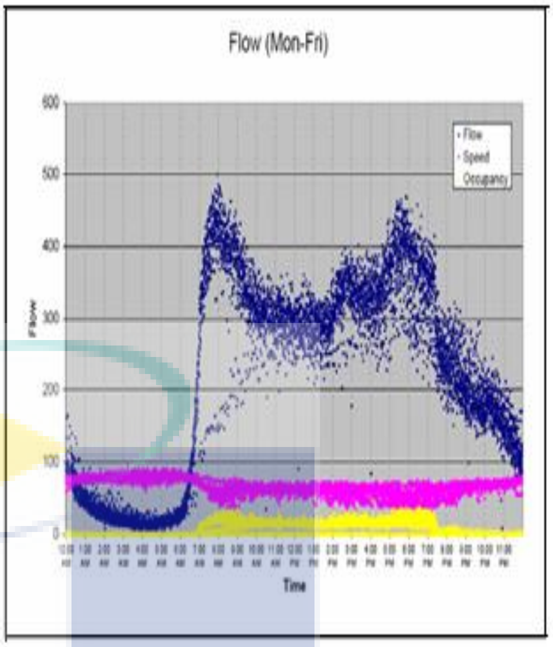
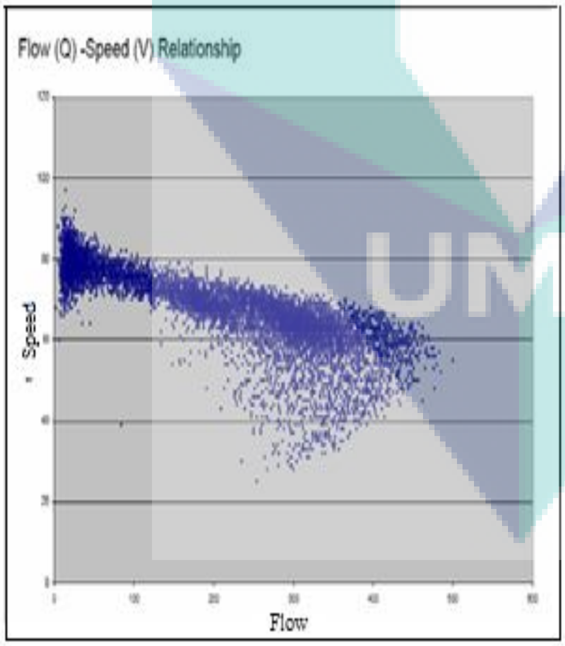


Figure 2.1(a): Traffic Flow Vs Density **Figure 2.1(b):** Traffic Flow Vs Time



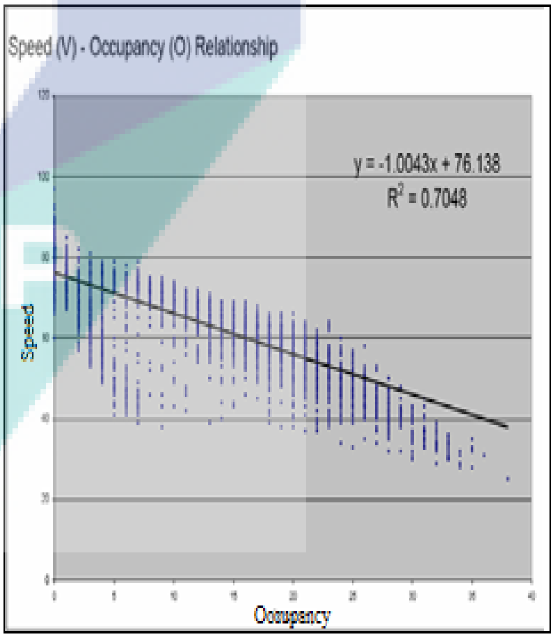


Figure 2.1(c): Speed Vs Flow **Figure 2.1(c):** Speed Vs Occupancy

Figure 2.1 (a) (b) (c) and (d) Mahfix (2006)

From figure 2.1, it can easily observe the trend amongst the major factors affecting any transport infrastructure. The increasing trend in especially flow verses density is considerable. This situation is even going to become worst in the upcoming days. Nowadays, passengers want to get the clear information of the station like the estimated time of arrival of bus etc. So quality services of any transit network which can enhance the economical and social importance of any city or even whole country, typically rely on one or more of three elements to attract customers;

i. Enhanced service through increased frequency, faster journeys and greater reliability.
ii. Better information both before and during journeys through a number of media including printed timetables of specific bus at bus stops, the internet and real-time information signs at bus stops.
iii. Availability on pre determined time with structured departure and arrival schedule.

It is evidently observed that the whole Decision making Support System (DSS) for any ITS mostly relay on the behaviour of navigational and communication equipment, selected to utilize. Building on past research, further investigation was undertaken to study the effect of location error in the case when there is a bus stop closer or in front to each other. Based on the effects, this dissertation concentrates particularly on the practical implementation of existing technologies for bus monitoring. The technologies utilized in the proposed buses network and monitoring management system, to overcome the flaws of previously discovered solutions are discussed shortly here.

2.2 THE SURVEILLANCE SYSTEM

This rapid expansion of public transport has brought many reimbursements but also substantial costs in terms of rapidly increasing congestion levels and associated environmental pollution (air and noise), risk of accidents and time wastage during journeys, particularly in urban areas. Recently there have been advances in the technologies accessible to hold up the collection, storage, processing and dissemination of spatially referenced data in order to resolve the issues rose due to lack of intelligent monitoring technique implementation in the past. Advanced Transport Telematics Systems (ATTS) or intelligent transport systems aim to attempt everyday transport problems through the use of state-of-the-art communications, data capture, computing, navigation and electronic control technologies. Today, one of the fastest growing markets for GPS technology is vehicle tracking and location technology also called fleet management. Using this technology real time as well as passive vehicle tracking for fleet owners and dispatchers is being done. This has resulted in a continuous growth in the assimilation of GPS in order to ensure competency and security in transportation systems. Now these technologies could be combined in many different ways, leading to a potentially enormous range of surveillance systems for different services, including public transport provider.

The GPS system is satellite based navigation system made up of a network of at least 24 satellites. GPS satellite actually transmits two power radio signals, termed as L1 and L2. The GPS used by the civilian is L1, having frequency 1575.4MHz in the UHF-band. It contains a Pseudo Random Noise code along with Ephemeris and Almanac data. The receiver can discriminate the signals coming out from different satellites because GPS uses a Code Division Multiple Access (CDMA) spread-spectrum technique where the low-bit rate message data is encoded with a high-rate pseudo-random (PRN) sequence that is different for each satellite. Ephemeris data contains a very precise orbital and clock correction message as well important information about health of satellite while the almanac data consists of coarse orbit and status information for each satellite in the constellation, an iono-spheric model, and information to relate GPS derived time to Coordinated Universal Time (UTC). (Garmin GPS beginner guide, 2008)

A GPS receiver is made capable to work the best by receiving from at least three GPS satellites in order to find out the 2D location using latitude and longitude. The GPS receiver compares the time signal was transmitted by a GPS satellite with the time it was received. The time difference tells the GPS receiver how far away the satellite is. By this way, the receiver can determine the user position. Today's GPS receivers are extremely accurate due to their parallel multi-channel design. Like a receiver with 12 parallel channels is quite enough to look up to 12 satellites simultaneously when turns on. In the dense urban areas, certain atmosphere factors and another source of errors can affects the accuracy of reception but still today's GPS receiver are accurate to work with in 10meters (Herrera, 2010). Now GPS receivers have been miniaturized to just a few integrated circuits and so are becoming very economical. And that makes the technology accessible to virtually everyone. However, GPS technology is also known to produce inaccurate position estimates in certain conditions. The most significant contributors to these inaccuracies are: satellite visibility, where the location cannot be found because satellite signals cannot reach the receiver due to large surrounding structures or dense foliage; and multipath conditions, where signal reflections off of large buildings create large errors in the location estimate (Ochieng, 2002). The result is that GPS technology has difficulty providing accurate position estimates in urban environments, where the intelligent transport systems employing this technology would arguably provide the most benefit.

A related approach is the Wide Area Augmentation System (WAAS). This is a Satellite-Based Augmentation System (SBAS), using satellites rather than base stations to broadcast correction data to receivers within a wider area than a single DGPS base station. Many receivers are capable of using the WAAS service, which improves horizontal position accuracy to approximately 2 meters (Gustavsson, 2005). The GPS receiver utilizes in the research is selected by taken several aspects into consideration. Since the major requirement of the research is to construct an on board hardware which must capable to hold the promise of proposed solution.

Now a day, easily observed Global Positioning Systems (GPS) equipped land vehicles to provide accurate position and velocity information. This System has been used in various fields including automated car navigation, emergency assistance, fleet management and automotive assistance. GPS technology used in the intelligent transportation system will surly reduce driver's workload, improve safety of steering, and promote the utilization of public traffic system amongst the passenger since it can be use to confirm the position of the bus. A study conducted which concentrates on experimental implementation of the control system. The experimental demonstration is carried out on a truck using a differential global positioning system (GPS) to sense the position of the vehicle (Zhu and Rajamani, 2006). A field experiment was carried out, presents a field experiment nicknamed Mobile Century, which was conceived as a proof of concept of such a system. Mobile Century included 100 vehicles carrying a GPS-enabled Nokia N95 phone driving loops on a 10-mile stretch of I-880 near Union City, California. His idea proposed a traffic monitoring system based on GPS-enabled smart phones, exploits the extensive coverage provided by the cellular network, the high accuracy in position and velocity measurements provided by GPS devices, and the existing infrastructure of the communication network (Herrera et al., 2010). The application of GPS in the land transportation system was also explored by Minitsis (2004). In the framework of the research, a short overview of applications in the area of transportation in Greece and abroad is presented. Emphasis is placed on an ongoing application in railway mapping, through the presentation of its pilot phase in Greece. The use of modern technologies, the problems identified and the statistical results produced are presented and discussed.

Intelligent vehicle monitoring system also demanded as collecting and processing the large amounts of information all the time. First time, the data warehouse technique is applied to intelligent vehicle monitoring system, in order to store and manage the information. Based on the analysis of the subject field in the system and the design of dimension table, the system logical model and physical data model, the data warehouse of system is built. And, the data in the data warehouse are analyzed and summarized by the data analysis and display tools (Wang et al., 2010). Another reviewing approach is presented on the past, present and future of surveillance system. According to the study, satellite based systems compute any point’s position, velocity and time information on earth, are known as Global Navigation Satellite Systems (GNSS). Generally, GNSS system is divided into three main categories, namely global, regional and augmentation systems. Beside of this, it is also discussed spatial geodetic infrastructure works in the world, real-time positioning techniques, and communication systems used for them (Taylan and Nursu, 2010). Figure 2.2 shows several monitoring aspect of the surveillance system.

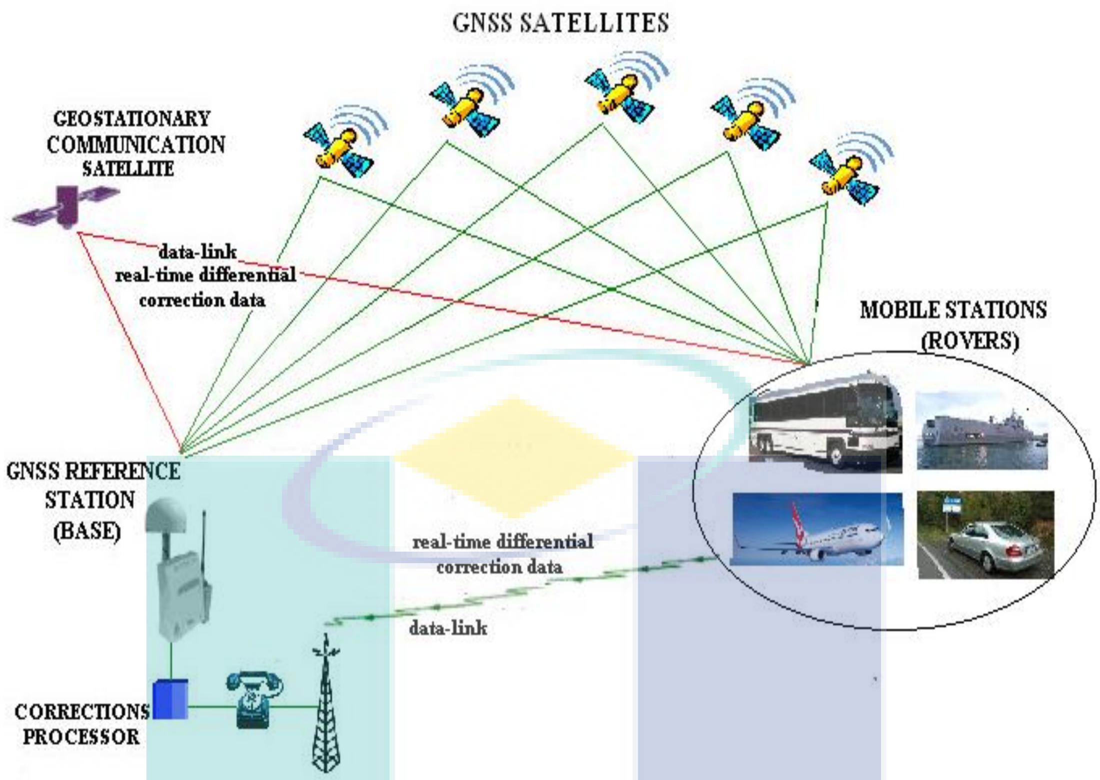


Figure 2.2: The aspects of surveillance system (Öcalan and Tunalıoglu, 2010)

Since long, the construction companies had been utilizing data collection including environmental and geographical data for evaluating overall construction performance. Lee and Han (2003) investigated a data collection method in the earthmoving operation based on GPS, and compare and assess both the traditional and the advanced earthmoving operation using GPS. The GPS receiver receives real time location information. Using this information, the system operator can easily determine the exact amount of certain parameters like excavation, backfill, or grade, minimizing wasteful earthmoving and repeated placement of grade stakes. At the same time, the responsible authorities share this information at their individual locations. It is found that the dozer or grader operators are in total control by advanced earthmoving system using GPS, guided by a screen expediently equipped in them.

2.3 OPTIMIZED MAP MATCHING TECHNIQUE

In order to ensure the valid and steadfast monitoring systems, several techniques had been proposed out of which, the Map-matching (MM) technique had given a significant weight. MM integrates navigation sensor data with spatial road network information with the aim of identifying the road segment on which a user (or a vehicle) is travelling and the location on that segment. The aim of the technique is to provide the real-time, accurate and reliable positioning information required by many ITS services such as the route guidance, fleet management and accident and emergency response. A verity of literature is found related to this techniques like (Li and Chen, 2005; Ochieng et al., 2004; Zhao et al., 2003). Among the family of MM algorithms consisting of geometric, topological, probabilistic and advanced topological MM (tMM) algorithms are relatively simple, easy and quick, enabling them to be implemented in real-time. The earliest geometric MM (gMM) algorithms, used geometric information, on the shape of the curve of the road segment (Quddus et al., 2007; White et al., 2000), but they perform inadequately especially when there is a need of matching at junctions and parallel roads. gMM algorithms may be improved by including historical data (such as the previously matched road segment), vehicle speed and topological information on the spatial road network (such as link connectivity). A MM algorithm that uses such additional information is called a topological MM (tMM) algorithm (Li et al., 2005; Marchal et al., 2005; Quddus et al., 2003, 2007). Probabilistic MM (pMM) algorithms use probability theory to identify the set of candidate segments by taking into account the error sources associated with both navigation sensors and spatial road data. Nagendra et al (2009) describes the advancement of an enhanced weight-based tMM algorithm in which the weights are determined from real-world field data using an optimisation technique. Two new weights for turn-restriction at junctions and link connectivity are introduced to improve the performance of matching, especially at junctions. The MM algorithms classed as advanced MM (aMM) algorithms include applications of extended Kalman filter (EKF), belief theory, fuzzy logic (FL) and artificial neural network (ANN) techniques (Syed and Cannon, 2004; Yang et al., 2003).

Most of the problems encountered and suggested to solve for the map matching, are ensured to reduce in the study by applying the efficient technique using the communication tools. The PAN ID in a network can be capable of reducing the complexity of MM, since in the projected system; every node is identical in its network. Even the same ID of a node draws close together. Still in order to create an optimized MM by the location of the slave node, there is observed a need of optimization technique for MM. It is found that many times the bus does not stop at the exact bus stop (the pre defined position of the slave node). In the case, MM will not be conducted well, resulting in improper location transmission could occur. DOE is a useful tool that used for exploring new processes, gaining increased knowledge of the exiting processes and optimizing these processes to achieving a better performance (Rowlands and Antony, 2003). In order to understand properly Design of Experiment, it is essential to have a good understanding of the whole process. A process is the transformation of inputs to outputs. In the context of manufacturing, input is factor of process variable such as people, material, method, environment, machine, procedure, coordinates, position data, etc. and output can be performance characteristic or quality characteristic of the require output with respect to the input. Sometimes, an output can also be referring to as the response. In the attempt to utilize this optimization tool for our system, we came up with the calculated probabilities of the selected position coordinates. As the result, it is got a precise equation for the bus stops. The generated equation is trained to the MCU for best MM results.

2.4 COMMUNICATION TOOLS

Wireless data communication technology is the core technology in gathering location data and operating information for most of the monitoring and surveillance systems. Now a day, the wireless technologies are growing day by day. Many enhancement and innovations are going to be observed in the field of wireless. Beside satellite communication, long range point to point or point to multi point communication protocols have been developed. The beacon resembles the RFID tag in functionality but operates on the Bluetooth for establishing communication links with the in-vehicle navigation unit (Lu et al., 2007). In addition, the real-time location and status of a particular vehicle in any intelligent transport system (ITS) can be transmitted to another node by the use of Short Message Service (SMS) over mobile phone networks as discussed in the literature cited before.

2.4.1 Wireless Sensor Networking

Wireless sensors networks (WSN) are very promising technology in the field of monitoring and efficient communication. A wireless sensor network is a system comprised of radio frequency (RF) transceivers, sensors, microcontrollers and power sources (Wang et al., 2006). As explained by Ruiz-Garcia et al., (2008), "*Wireless sensor networking can operate in a wide range of applications and provide advantages from several aspects like cost, size, power, flexibility and distributed intelligence compared to wired ones*." In a network, if a node cannot directly contact the base station, the message may be forwarded over multiple hops. By auto configuration set up, the network could continue to operate as nodes are moved, introduced or removed. Because of such advancements, WSN applications have been developed in medicine, agriculture, environment, military, machine/ building, toys, motion tracking and many other fields (Baronti et al., 2007; Jedermann et al., 2006). Figure 2.3 shows the aspects of WSN utilization in cooperating with satellite communication.

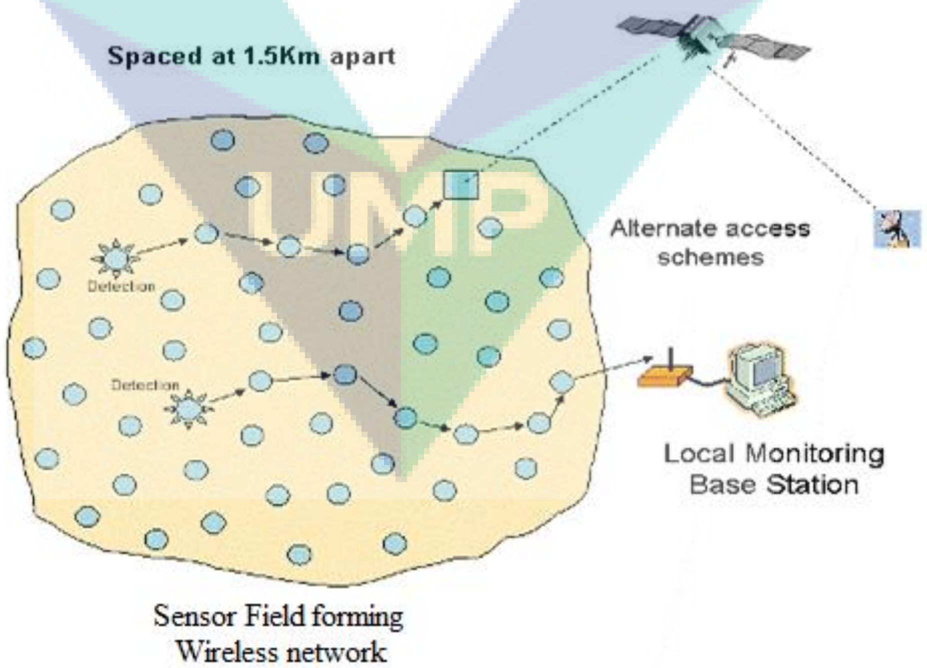


Figure 2.3: Wireless Sensor networking
(http://embedsoftdev.com/embedded/wireless-sensor-network-wsn/)

2.4.2 WSN for ITS

These changes in scale of communication network activity have to be accompanied by technological changes to the management system. That's why many researchers are keen to utilize this rising wireless technologies for the intelligent transport system like Herrera et al. (2010) evaluated the traffic monitoring system by utilizing the GPS enabled mobile phones. Forecast model and policy guidelines for building Buses Information System/Buses Monitoring System BIS/BMS with wireless communication system in Korea were presented and bring lot of achievements (Kim et al., 2007). According to his research, BIS and BMS are an integrated system applicable to existing bus operating systems that encompasses GPS and IT features such as information, computers, electronics, controls and so on. It is a field in ITS (Intelligent Transport System) that enhances the efficiency of bus usage. Gupta et al. (2010) emphasis on goals require an efficient monitoring infrastructure to be deployed, which can offer the maximum amount of information regarding the network status even utilizing the least potential amount of network resources. He first evaluated the impact of monitoring overheads on data traffic, and show that even small amounts of overhead can cause a large degradation in the network performance. He then explored several different techniques for reducing monitoring overheads, while maintaining the objective (resource provisioning, fault management, and others) that needs to be achieved.

Another approach was to reduce the surplus and utilizing of petroleum products in traffic flow. A surveillance system is proposed for tank truck transportation. In the system, a vehicle transport plotter is developed to monitor the operations of inputs and outputs of a tank truck via a kind of Hall Effect switch sensors. Wireless data transceivers are suggested in order to initiate and stop monitoring in the starting stations and destinations automatically. The information recorded by the vehicle transport recorder is collected by a smart card and then it is transferred to the host management software which is developed to manage the transportation data (Chen et al., 2010).

The enhanced, wireless communication technologies such as Wi-Fi (IEEE 802.11b) and ZigBee (IEEE 802.15.4) have enabled wireless LAN (Local Area

Network) and PAN (Personal Area Network) and are also widely used for tracking and monitoring in automation applications. ZigBee and Bluetooth, both are within the Industrial Scientific and Medical (ISM) band of 2.4 GHz, which provides license-free operations, huge spectrum allocation and worldwide compatibility. ZigBee is more suitable for WSN, mainly because of its low power consumption derived from its multi-hop communication. In particular, ZigBee holds the promise of providing a more cost-effective wireless sensor networking and replacing Bluetooth. ZigBee also provides better network flexibility than Bluetooth, along with providing different topologies such as star, cluster tree or mesh networks. Some of the other features of Zigbee include the ability to support multiple network functions like the point to point or multipoint to point. ZigBee allows a larger number of nodes, more than 65,000, according to specification. Casual transmission range is also appropriate (1–1500 m) for ZigBee than for Bluetooth (1–10 m) (Baronti et al., 2007). It has been designed with the facility to be able to provide an easy to use wireless solution which creates a secure and reliable network. Since it functions on a low duty cycle it is also considered to be very good on battery life. And it has the direct sequence spread spectrum as well. It also has the ability to run for years without any kind of maintenance and with an automatic meter reading. In a review paper by Xuesong et al. (2008), it is intend to evaluate the technical feasibility of applying emerging wireless network technologies for resources tracking at building construction sites. Based on critical reviews of available localization methods and state-of-the-art wireless communication technologies, it is identified that the Zig-Bee-based wireless sensor network and the received signal strength indicator (RSSI) method are most promising for solving on-site resources tracking problems.

The expanding utilization of this technology in almost every walk of life encouraged us to use in our research. For the purpose specially designed long range Xbee pro RF modules are favoured. These modules provide OEMs and integrators with reliable, long-range wireless data communications. The module typically yields two- to eight-times the range of competing RF modules due in large part to its superior receive sensitivity (Xbee data sheet). Since the system ought to be cautiously inspected for transceivers capacity to collect and transmit information about the operating dense urban area. So the onboard high tech MCU is selected, which is manufactured fully compatible with the overall system as well the transmission modules through software.

The novelty of the proposed frame work lies in the intelligent configuration of these embedded radio chips which are carefully made companionable for the better system plan.

The appropriate preference of materials and technology employed for a research exist as influential as it real time implementation. So after having a resourceful literature review cited, the optimal operational components and technologies are preferred to utilize.

2.5 SYNOPSIS

This chapter offered a review of existing intelligent transportation systems from past to present and the fundamental components that make up the system resourceful. Real time status has the ability to be a significant part of a complete vehicle monitoring system. Amongst all the surveillance systems, GPS is the basis for the most of vehicle monitoring systems for finest reason; it identifies a simple method to determine an absolute location, and is sufficiently accurate in most situations. The faults which are mostly observed with GPS occur in urban environments, where multipath and satellite signal loss make the computed position biased or unavailable. Map matching can provide somehow accuracy improvement. Communication protocols in the area of wireless sensor networking are developing day by day. IEEE 802.15.4 based technology can provide the better solution for moving object vision transmission down to the respective node. The real time visualization has so far found successful way to facilitate the passengers. These all technical aspects are discussed in this section to come up with a reliable and durable monitoring system.

CHAPTER 3

METHODOLOGY

This chapter presents a wide variety solution to the stated problem back ground in the scenario of research methodology. It contains the general concept of proposed system, then the role of several selected active and passive technologies to build the idea. Then finally integrating the whole GPS based monitoring system with the communication and map matching technique. It is also highlighted the features of the overall framework designing of dedicated ITS at the end.

3.1 INTELLIGENT BUSES POSITION NOTIFICATION SYSTEM

Intelligent system has brought revolutions in many industries, from country's defence to health care to government, and is now entered in the early stages of transforming transportation systems. While the concept of improving a country's transportation system solely means constructing new roads or building aging infrastructures, the future of transportation slanders not only in concrete and steel, but also increasingly in utilization of intelligent system together with IT. IT enables elements within the transportation system vehicles, roads, traffic lights, message signs, etc. to become intelligent by embedding them with microchips, navigational and positioning sensors and empowering them to communicate with each other through reliable wireless technologies. In the leading nations of the world, ITS brought significant improvement in transportation system performance, including reduced congestion and enhanced safety and passenger convenience

Given the lack of an established body of research on the design of public transport network services and the small number of practitioners concerned in this field, a quantitative approach seemed inappropriate in relation to the nature of the enquiry. For the purpose being author focused multi-dimensional approaches emerge regarding design. For the purpose, initially some rules and regulations are described as the initial system assumptions. These assumptions are described to make the proposed frame work as resourceful as possible. Second is the hardware implementable design, the center of focus of this study, for the overall system to work. This phase contains best functional components selection according to the proposed design.

3.1.1 Assumptions

As urban environment density increases, management techniques classically used by bus network regulators (the staff responsible of monitoring the bus network) became obsolete. These proposed assumptions in the study are as important as other sections in order to achieve best targets. Unless the rules are not described and justified before proposing a new idea, it will be surly found under lack of final implementable destination. The frame work presented in the methodology below, is based on the following some assumptions must be imposed by the regulators: (1) Each bus route is isolated entities, are assigned similar activities; (2) The inter-linked network of nodes represents the service along a bus route and hence the efficiency of the network is equivalent to that of the service provided along the route; (3) Buses of same IDs are sent by a proper interval of time. In case, any two or more buses of same IDs join each other due to any reason then second one need to stop for the time until first one reach at the next bus stations; (4) Buses' driver are strictly ensured, not to change the predefined route. In case any emergency, they are restricted to inform to the monitoring room so that the monitoring plan could be change to facilitate the passengers.

3.1.2 Proposed Frame Work: The Concepts

Real-time traffic information for almost every bus stop or major roadway in the city and having that information available on multiple platforms contain the ability to change the trend of traveller from using their personal vehicle to the single public transport. Driving down a roadway with the navigation and communication unit using GPS with real-time traffic information, could audibly alert that the vehicle is approaching towards a predefined spot to stop. Envision enjoying reliable static device that can display real-time traffic information while simultaneously helping to generate that information will preferably a best choice for ITS.

The present market for bus information systems in the KL is very fragmented. There are quite less numbers of systems with varying complexity providing solutions for public transport movement monitoring and route management systems. Although the financial cost of the more advanced system can be beyond the budget of some local authorities, still there is a clear demand for some form of systems, which can bring simplicity with effectiveness for the transit service provider as well passengers. For the purpose being a wide range solution is provided by considering for many problems being surveyed by the author even for any naturally occurred fault like traffic jam or any other problem because of which bus could not reach on the specified time, and passenger faced the problems. Now with the proposed system, the passengers will be facilitated by the location display containing position data of their desired buses with maximum accuracy measures. These provided facilities can be lead them shift from using private own cars to the public transport.

The concept of the proposed methodology is carried out by managing the actual utilization of the entire technologies as described in the research technical background. During an informal survey to the roads of KL, many problems are commonly observed which must consider during framework designing. Like many time buses having same IDs draw closer together. Some time bus stops are found in front of each other across the road. The conceptual solution suggested for the difficulties found, are the scheming of our system, GPS based monitoring and their location transmission down to the specific bus stops only found on their routes, not even at the bus stop found across the road as exposed in Figure 3.1 below.

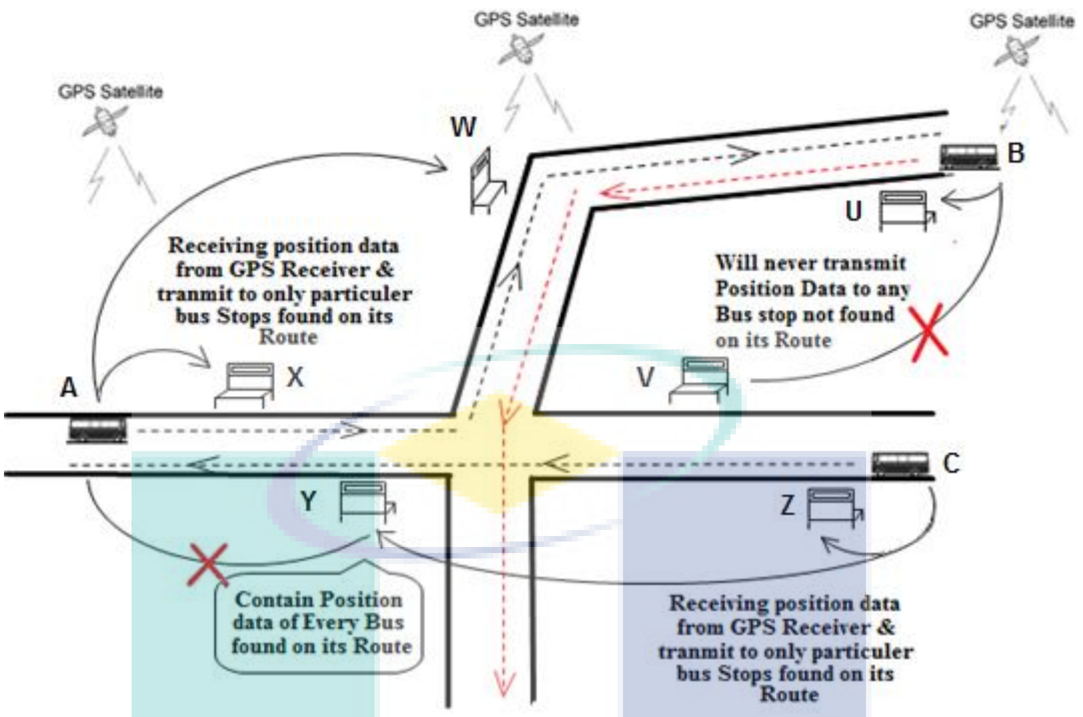


Figure 3.1: Proposed concept of framework

In order to elaborate the conceptual framework, an example is taken containing three buses with different routes named A, B and C and 6 bus stops with different route location named U, V, W, X, Y and Z. Bus ID "A" will pass through bus stop W and X. It can be observed from figure that bus stop X and Y are found in front each other and there is a sound possibility for Y to receive the signal from bus "A". This problem is figure out by giving dedicated PAN ID same as the bus ID. Let suppose, the bus A have its ID 'B103', then transceiver modules of bus "A" and its stops W and X are configured "0103" as PAN ID. Through this scheme, the bus is made responsible to communicate or to send its location information to its relevant bus stops, not even the one found in front or in range. The same scheming is applied on bus "C". The bus stops, Y and Z are the relevant stops for bus "C", while on following the route, the stops V and X would found in front and in the range of transceivers too. But the configuring the bus "C", Y and Z with same PAN ID will restrict "C" to send its location information to irrelevant bus stops. The same procedures will be following by bus "B". The figure 3.2 below can clarify more about the presented conceptual framework.

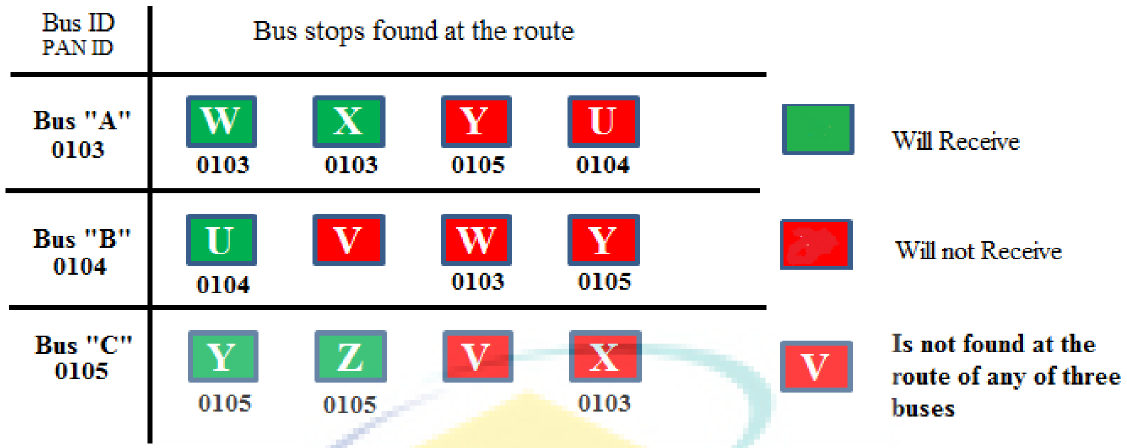


Figure 3.2: WSN using PAN for specific data transmission at bus stops in accordance with Figure 3.1

3.1.3 Frame Work Designing of Integrated Bus Notification System

The intelligent buses notification system assures the real time processing of data related to monitoring the position of the bus and more towards its implementation through straightforward display system for passengers. The system is also capable to support the preparation of the daily operations programme since the whole frame work is carefully designed to meet the challenges of referred problem statement from several aspects. In order to ensure the exact monitoring at the particular bus stations, several measures have been designed like at the starting of every journey, the driver is restricted to input some data using keypad same as unique bus ID. Each vehicle (master module) in the fleet can be equipped with on-board MCU that take data from sensing device GPS as well as driver, and can rigorously monitor the position of the vehicle. After receiving by the first bus stop (slave module), looping through radio links allow information to be sent to only the specified bus stop only found on their particular routes. They are particularly configured to receive only the position data of unique ID being trained. The travelling public are informed on displays at bus-stops and bus-stations of the expected arrival time and position of their desired buses. The design can also put support within the central control; the controller can see the current situation at a glance using location displays of the bus network and routes that show the location of buses and whether they are on schedule. In summary of the concept of frame work and its designing, the bus operations and management system uses information technology to provide a permanent communication between vehicles and the operations centre as well as passengers, which integrates the operations, passenger information and system management functions of the public transport company. The master and slave modules with their integration and process flow is described below

3.2 MASTER MODULE

This designed will provide the right answer for multifaceted problems found in the existing buses monitoring system. Since the whole decision support system is typically divided into two basic parts, out of one is master. This part is embedded on the every bus unit. The system comprises the MCU produced by Microchip. It is responsible for receiving information, means it will receive the positioning information send by GPS module to MCU, deal with the input of keyboard information, like Bus unique ID, either up or down and time of departure. Then finally send by the specially selected and configured transceiver chips.

3.2.1 Role of GPS for proposed system

GPS receivers embedded in vehicles' on-board units. OBus are general term for telematics devices. These OBus are made responsible to receive signals from a number of different satellites to compute the vehicle's position. This requires line of sight to satellites, which can inhibit use of GPS in downtown settings because of today's urbanization effects. But still location can usually be determined to within ten meters. GPS is the core technology behind many in-vehicle navigation and route monitoring systems. "*Several countries, particularly Holland, China and Germany, are using or will use OBus equipped with satellite-based GPS devices to record miles travelled by automobiles and/or trucks in order to implement user fees based on vehicle miles travelled to finance their transportation systems*" (Ezell, 2010).

The importance of GPS can be observed in several intelligent transportation systems (ITS) from past researches. It is for the reason that in the practical monitoring system using GPS, we can set certain time intervals to update latitude, longitude and time data according to need in order to get the device positioning data. The GPS module used follows the NMEA0183 protocols. For the location finder, The RXM-SG GPS Module is selected as shown in Figure 3.3. It provides a high quality, highly sensitive GPS receiver with an external antenna to provide a complete GPS solution for both MCU and PC applications. The high-performance SiRFstar III chipset features 20 parallel satellite tracking channels for fast acquisition of NMEA0183 data for robotics navigation, telemetry or experimentation. A Windows application provides a graphical display of the GPS data and can even show location visualization on Google Maps (internet connection required). Four general purpose I/O pins provide expansion for pin-intensive projects. Communicate on 3.3 V CMOS asynchronous serial @ 9600 baud default for microcontrollers. Any signals going into the GPS module would need to be buffered using a level translator or buffer chip such as the 74LVC244A (Parallex GPS manual #28505). The selected GPS in the study will responsible to receive Position data and continuously send to the MCU. The NMEA sentence $GPRMC is selected to get the longitude and latitude, to acquire the location.

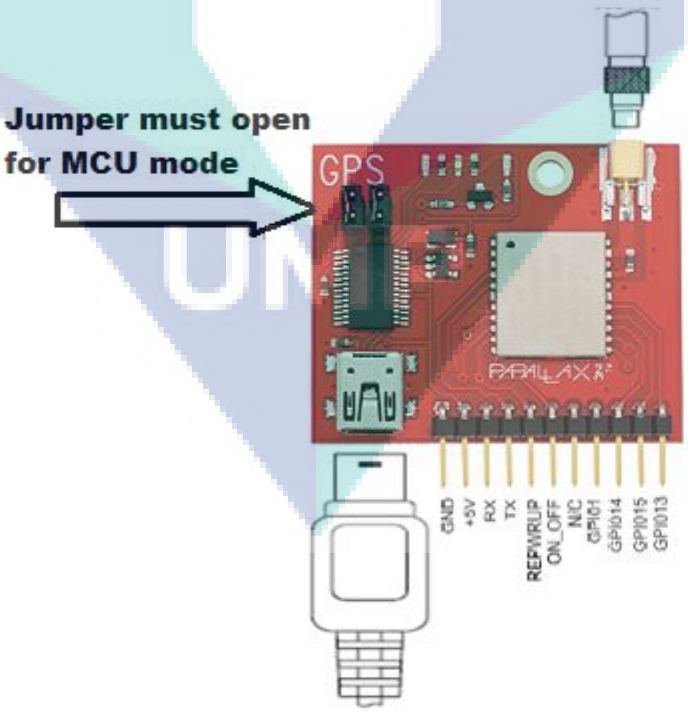


Figure 3.3: Selected navigation module (Parallex GPS manual #28505)

In most of the navigational systems, the positioning data, we are concerned about such as latitude and longitude, speed, time can gain from the several NMEA sentence which GPS receiver and sends to the MCU. So our bus positioning data can easily be selected by using this frame. Output baud rate is 9600. It is programmed to allow MCU to receive and store data, and then bus location will be calculated. The $GPRMC gives the Recommended Minimum specific GPS/Transit data. The very first location sentence received at the working place, is described for elaboration below. Its format received by our GPS receiver is akin to;

$GPRMC: 225446,A,4916.45,N,12311.12,W,000.5,054.7,191194,020.3,E*68.

The description as follow in Table 3.1 below;

Table 3.1: $GPRMC description

225446	Time of fix 22:54:46 UTC
A	Navigation receiver warning A = OK, V = warning
4916.45,N	Latitude 49 deg. 16.45 min North
12311.12,W	Longitude 123 deg. 11.12 min West
000.5	Speed over ground, Knots
054.7	Course Made Good, True
191110	Date of fix 19 November 2010
020.3,E	Magnetic variation 20.3 deg East
*68	mandatory checksum

After receiving the position frame from master node, the MCU is programmed to save only concern navigation receiver warning, longitude and latitude serially. For working code structure of particular digits receiving using GPS module, refer to appendix C1. The code clearly shows the specific digits were received in separate orders so that could be utilized in required way for the input to the equation. The subsequent step is those digits will be sent for the map matching mechanism. Map matching is the critical element of the methodology. To tackle this issue, this work is inspired by the fact that vehicles move along routes with a known map, which means the characteristics of the predictable vehicle mobility and the road network layout can be find out. For the purpose, fixed location coordinates of the selected bus route are collected since the bus stations are the fixed identity.

3.2.2 Map Matching for Proposed System

Need of Map Matching

The lack of exact data forwarding is observed to the respective node after receiving the position frame from GPS. The missing data or time delay played an important role against the resource full communication and real time implementation of system. There are found many reasons beside, for example dense urban traffic, long buildings and atmospheric effect on data rate and reliability. This lead the research to create new idea of reduced amount of the data to be transmitted and forwarded. In this section of the research, an intelligent formulation is design to get optimum result. There are also found some possibilities for exact MM comparison, since the master node (bus) is observed, do not stop on the particular predefined slave node (bus stops).

Data Collected and Analysis

A series of experiments are conducted to get and observe the data. Every time, the respected location data is collected. The map and table below shows the bus stops, from where the position data is collected. A particular bus route map is selected randomly, which is found as one of the busy routes in the city of Kuala Lumpur. Later on, the similar methodology can be applied on any other route. For the purpose of collecting location coordinates to train for MM, the hand held utility of Garmin GPS receiver is utilized. From the experiments, it is found that during one full journey from first until last stop, there are few digits from the longitude and latitude are subject to be changed. The Table 3.2 below shows the actual static address of slave nodes and significant digits for training.

Table 3.2: Location data collected for analysis

NAME OF BUS STATIONS (SLAVE NODE)	Received coordinates						Trained coordinates			
	Longitude			Latitude			Longitude		Latitude	
	Deg.	Min.	Sec.	Deg.	Min.	Sec.	Min.	Sec.	Min.	Sec.
JALAN IPOH										
Hospital Damai (P_{i1})	101	41	42.44	03	10	12.36	41	42.4	10	12.3
Stesen Monorel Chow Kit (P_{i2})	101	41	55.51	03	10	03.11	41	55.5	10	03.1
JALAN RAJA MUDA ABD AZIZ										
Stadium Raja Muda (P_{i3})	101	42	11.21	03	10	04.83	42	11.2	10	04.8
Menara TH Selborn (P_{i4})	101	42	43.02	03	10	04.71	42	43.0	10	04.7
JALAN TUN RAZAK										
City Square (P_{i5})	101	42	58.45	03	09	50.41	42	58.4	09	50.4
JALAN AMPANG										
Hotel Nikko (P_{i6})	101	43	03.50	03	09	36.57	43	03.5	09	36.5
KLCC (P_{i7})	101	42	45.48	03	09	31.79	42	45.4	09	31.7
Hotel Renaissance (P_{i8})	101	42	19.08	03	09	23.84	42	19.0	09	23.8
JALAN SULTAN ISMAIL										
Hotel Concorde (P_{i9})	101	42	20.94	03	09	18.55	42	20.9	09	18.5
JALAN P RAMLEE										
Menara KL(P_{i10})	101	42	26.60	03	09	13.10	42	26.6	09	13.1
Wisma Lim Foo Yong (P_{i11})	101	42	30.21	03	09	01.93	42	30.2	09	01.9

For an autonomous passive localization transmission loop, those few digits are selected to be as the raw data for our MCU to be compared. The reason will be well explained later on. Beside this, a problem is found that sometimes the master node (bus) behaviour is not expectable. It is commonly observed that the bus do not stop exactly on the particular place of station. Firstly the drivers are kept restricted, even though the probability of error in parking at bus stop is high. For the purpose, there are some expected possibilities also being collected. The comparison is made between the selected received and output response from trained data.

Map Matching Optimization

Optimization has been applied to problems in several scopes of life including engineering, sciences, medicine and finance etc for at least the last half century. The objective is usually to maximize profit and reliability or minimize risks and errors. Stochastic optimization delivers new nominal values in the design variables that satisfy the targets. A stochastic process is a probabilistic model of a system that evolves randomly in time and space. Stochastic optimization consists in combining the deterministic optimization methods with uncertainty quantification techniques to measure the sensitivity and variability of the response. The decision making tools based on optimization procedures are successfully applied in a manufacturing of practical problems.

We have observed in the past many researchers used the optimization techniques for ITS. For the proposed system, since it is found certain possibilities of error due to driver defined factor, it is selected to use DOE as the optimization techniques. DOE is not only a collection of statistical techniques that enable an engineer to conduct better experiments and analyze data efficiently; it is also a philosophy. In this section, general guidelines for planning efficient experiments are given. The following seven-step procedure is presented in Figure 3.4 (Montgomery, 2001).

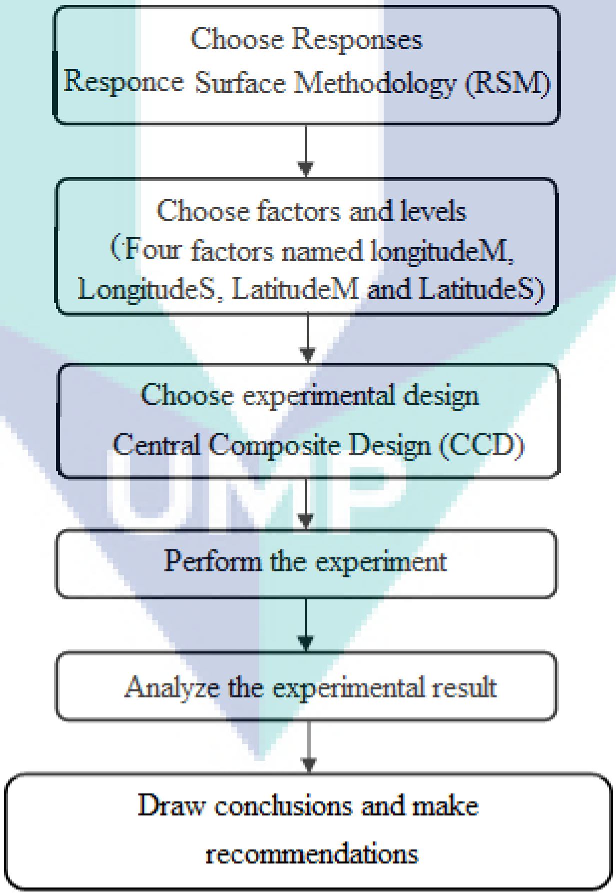


Figure 3.4: General guidelines for conducting DOE 4 (Montgomery, 2001).

The objective of the experiments was clearly stated. According to the objective of the experiments, the analysts will need to select the number of factors, the number of level of factors, and an appropriate design type. Responses are the experimental outcomes. An experiment may have multiple responses based on the stated objectives. The responses that have been chosen should be measurable. In this dissertation, Response Surface Methodology (RSM) is selected. A factor is a variable that is going to be studied through the experiment in order to understand its effect on the responses. There are four (04) major factors chosen named as longitudeM, LongitudeS, LatitudeM and LatitudeS. Once a factor has been selected, the value range of the factor that will be used in the experiment should be determined. For the purpose, the range of coordinates from first bus stop until the 11th bus stops is selected as array. These values are referred to as levels or settings. A cause-and effect diagram or a fishbone diagram can be utilized to help identify factors and determine factor levels. A design matrix should be used as a guide for the experiment. This matrix describes the experiment in terms of the actual values of factors and the test sequence of factor combinations. Statistical methods such as regression analysis and ANOVA (Analysis of Variance) are the tools for data analysis. Once the data have been analyzed, practical conclusions and recommendations should be made. In this research, ANOVA is applied. The clear objective is to achieve a simplified mathematical equation. Practical recommendations are provided in next chapter.

3.2.3 Role of Communication Link for Proposed System

Any ITS comprise of a broad and increasing suite of technologies and applications including real-time traffic information systems, in-car navigation (telematics) systems, vehicle-to-infrastructure integration and vehicle-to-vehicle integration. The review and specification of Chapter 2 significantly also narrowed down the field of communication protocol that could serve as the best communication tool for the applications. The proposed tool will be utilized to find the automatic vehicle location of the buses, to report their current position, making it possible for passengers to build a real-time view of the status of the public transportation system.

ZigBee is a global standard for wireless mesh network technology that addresses remote monitoring and control applications. The technology defines the physical and medium access control (MAC) layers for low cost and low rate WPAN. The Xbee-PRO RF module is a ZigBee/IEEE 802.15.4 compliant solution for long range WSNs. Advanced configurations can be implemented using simple AT commands. According to the manufacturer, it uses 60 mW (18 dBm), 100 mW EIRP (Equivalent isotropically radiated power) power output (up to 1.6 km range) (Appendix B2). These merits provides a moderate structure but in order to make available a perfectly efficient solution for large scale dedicated ITS system, the other upgraded module would be more suited. Still these merits show the upper hand to utilize them for the well functioning prototype designing. Two different types of experiments are done to exploit the modules. Firstly analyzed to send the one way communication for sending bus unique ID from the master node to the nearest determined slave node. This determination is done by assigning the single route with its relevant bus, a unique PAN ID. This is a number responsible to have a joint amongst each Xbee in a network. For the prototype, one master and three nodes are managed and configured. But there could have many, many more in a single network. Xbees on different networks cannot communicate with each other. The property lend the hand to unravel the problem of two bus station (slave node) found in front of each other. The default PAN is 3332, so should avoid that number. The PAN ID is stored in ATID. The second experiment is related to slave node. In both cases, the configurations of the RF modules are carried out using X-CTU software. X-CTU allows setting all of the parameters we describe above, using a Graphical User Interface. The software is a Windows application. The configuration window is shown in Figure 3.5.

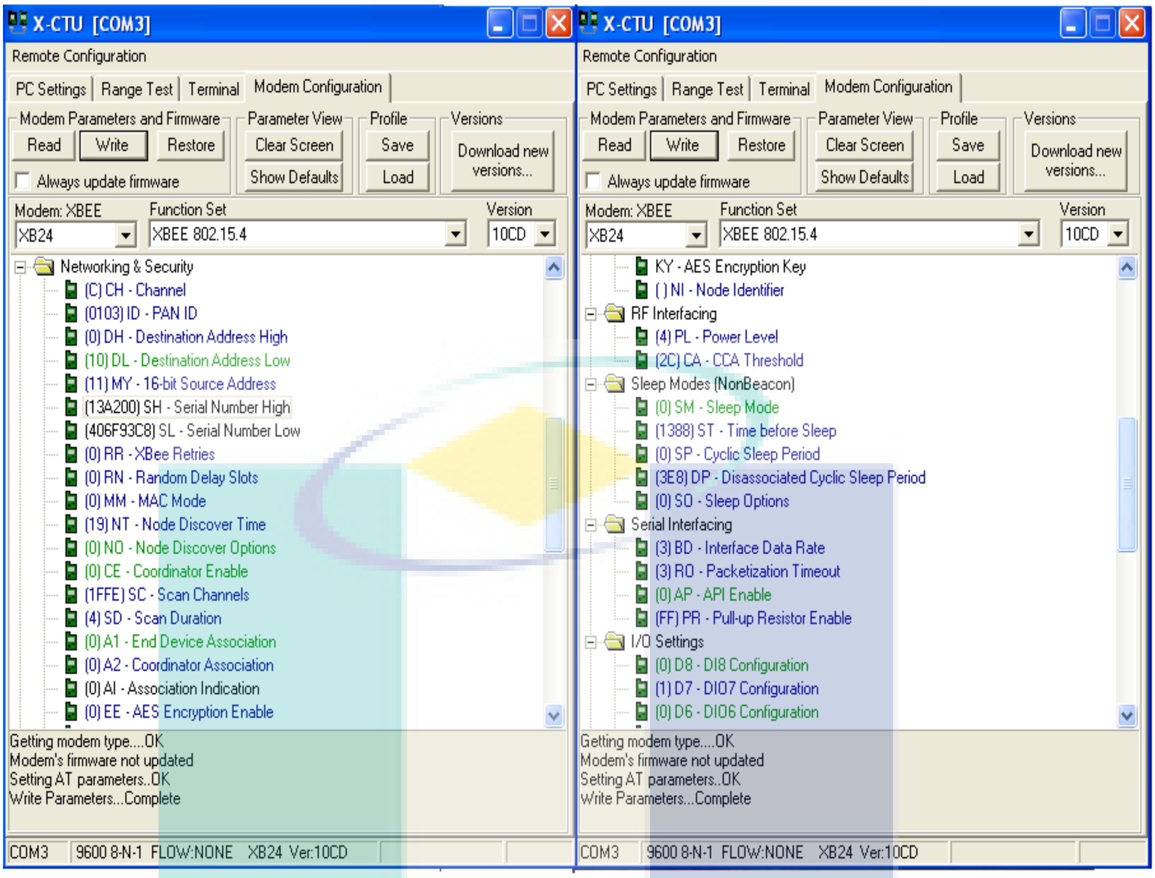


Figure 3.5: Configuration window for master module

From above specification, it is found that the communication link between moving vehicles, ZigBee provides a relatively ideal technology over other candidates. The configuration window shown in Figure 3.5 above highlights the parameters needed to be configured. There are four parameters named as PAN ID, ATMY (source address), ATDL (destination address) and Baud rate must be configure in order to create a reliable WSN for suggested system. For practical transmission loop between nodes, the destination address must be the source address of next node. The actual working values of configurations will be explained and described in next chapter.

When proposed to deploy at buses station to develop the road network, Initially Zig-Bee nodes were suggested to divide into two categories: static nodes and mobile nodes. Static nodes with well-defined coordinates are scattered in a road site and constitute a customized ad-hoc network for resource tracking and wireless data communication. It is named as slave node as also described in chapter 1 and in the concept of this chapter. Mobile nodes are deployed on every bus, getting data from inertial sensor. After receiving position data and map matching, the data is transmitted through the radio chip serially to the nearest first bus stop identity, then a loop till then end of the bus route.

3.2.4 Master Module Integration

Given the design needs and requirement for the problem, it is proposed to come up with the simplest and efficient design of the system that would be able to forecast the real time visualization down to the respective node. In order to construct an appropriate design of master module, several best functioning components are selected as described in chapter 2. In this section of methodology, there are three key modules used in master node: MCU: PIC16f877A, GPS module: Parallax RXM-SG GPS Module and the advanced wireless: Xbee pro RF Modules (IEEE802.15.4). The MCU of the embedded gateway is 8 bits MCU produced by Microchip, designed to provide a cost-effective and high performance microcontroller solution for general applications. The criteria of selection were made on the basis of GPS and radio chips specifications. To reduce total system cost with maximum efficiency, it also provides the following: operating speed 20MHz, 200 ns instruction cycle, 1-channel UART with a handshake, System manager (chip select logic, FP/ EDO/SDRAM controller), I/O ports, interfaces and so on (for further, refer Appendix B3). For GPS module, Parallex GPS receiver is adopted, and its characteristic is: 20 parallel channels, Sensitivity -158dbm, 5Hz Update Rate, support DGPS technology, NMEA 0183 protocol, and 9600bps (for further, refer Appendix B1). Regarding coordinates transmission, Xbee Pro® OEM RF Module is selected. The module provides OEMs and integrators with reliable, long-range wireless data communications. It is available as 2.4 GHz (worldwide) RF solution (for further, refer Appendix B2).

The power supply section is one of the significant sections. It is made selected on the basis of power consumption and requirement by the equipments utilized. All the equipment listed to build master and slave nodes are energy efficient in terms of low power consumption. The RF modules need 3.3VDC. For the purpose, LM1117t is suggested to utilize. The LM1117t is a low power positive-voltage regulator designed to meet 1A output current and comply with SCSI-II specifications with a fixed output voltage of 3.3V. This device is an excellent choice for use in battery-powered applications, as active terminators for the SCSI bus, and portable computers. All these features encouraged the research to use as the main voltage supply for the Xbee pro RF modules to work.

The GPS and XBee-PRO® RF Modules interface to a host device through a logic-level asynchronous serial port. Through its serial port, the module can communicate with any logic and voltage compatible UART; or through a level translator to any serial device. According to the designed specifications, MCU module has one channel for Rx/Tx (serial port). From that, Rx is specified for the GPS while Tx is reserved for the Transceiver (Xbee Pro RF Modules). It is only need the MCU RxD to connect with TXD of GPS. Position information can be getting from the GPS module. The next is to connect the remaining TxD of MCU with the RxD of the wireless module as shown in Figure 3.6. Both of the modules are made serially communicated by MCU at the baud rate of 9600. For GPS module, the baud rate was selected using the PROTON IDE while the baud rate for Xbee was selected using X-CTU as well as programming software. Regarding RF module, data enters the module UART through the DI pin (pin 3) as an asynchronous serial signal. For further details, refer to Appendix B2. The communication environment of the modules is given below. The difference in logic levels required to use the voltage divider circuit while communicating the RF module with MCU. For the working circuit diagram, refer to Appendix A1.

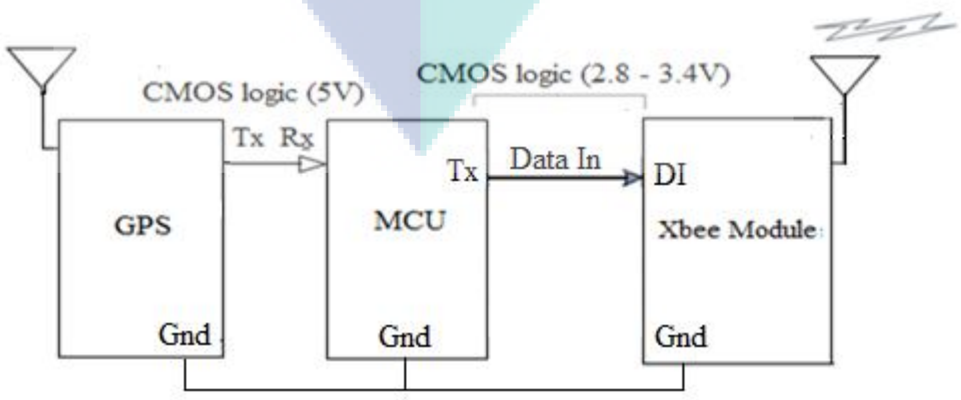


Figure 3.6: Master node generalized connection

Through specific programming, GPS is made responsible to receive the data and send to MCU for comparison. The master node (bus) positioning data can easily be selected by using the received frame. $GPRMC is selected for the purpose. MCU is required to save only selected digit in order to compare. The equation got from DOE will be utilized to train to the MCU in order to trigger the RF module at the optimum point. The simply designed keypad is also connected to the MCU in order to enter the unique bus ID. In the prototype, the keypad is used to trigger the salve nodes using the assumed output of the equation, which is actually a single digit number representing bus stop, related to coordinates received. The generalised integration is shown in Figure 3.7. For the working pictorial prototype design, refer to Appendix D. The decision making part of the flow diagram shows that in case the received and processed data through equation is matched by a digit representing bus stop, then that digit will be send to nearest bus stop, in case matching does not success, then the GPS is programmed is get the location data again and again in a loop (Appendix C2). The flow diagram for the master node is described below in Figure 3.8.

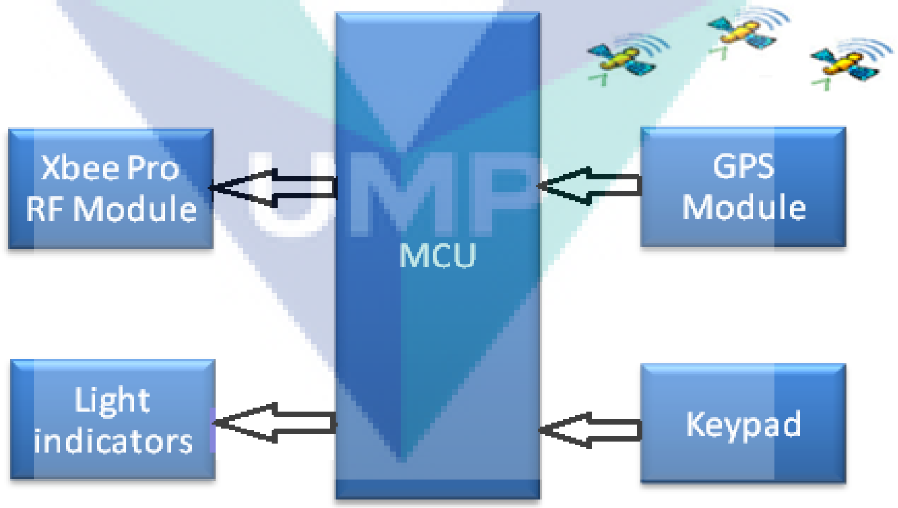


Figure 3.7: Master node integration

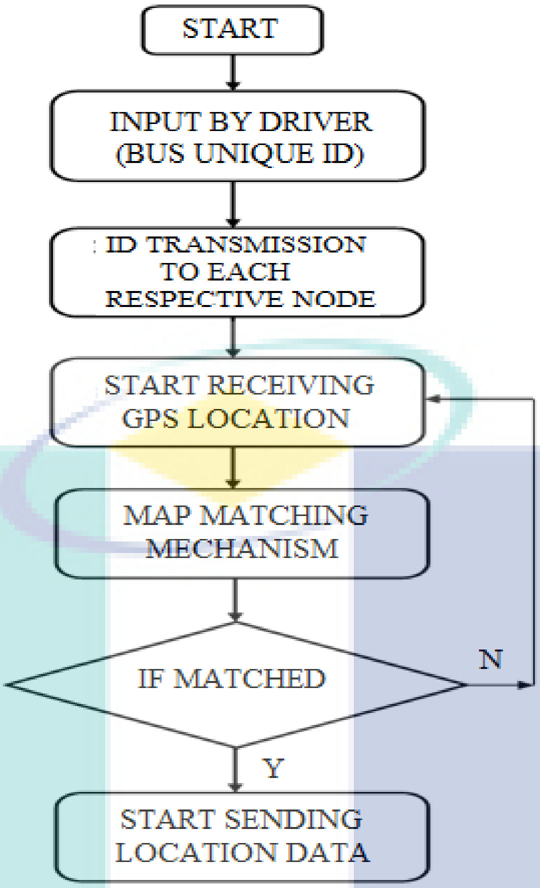


Figure 3.8: Master node functioning flow

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3.3 SLAVE MODULE

The novelty of the study lies in the slave modules, which are the critical section of presented study. As discussed in introduction section of previous chapter and concept of this chapter, several measures had been taken to send the buses location down to specific bus station. But due many reason growing day by day, most of them seems unable to provide reliable solutions to the suffered passengers. For the purpose, special algorithms are designed to operate the number of slave modules corresponding to the number of bus stations. These algorithms made this decision support system capable of holding the promise to overcome the lacks of past research. So the number of steps is described to facilitate the passengers waiting for the bus.

3.3.1 Need of Looping Concept

From initial second phase of experiments, it is found that in order to compute vehicle position, the proximity sensors would not be adequate themselves, since the distance from the sensor to the vehicle as well as sensor to another sensor node, can create certain errors. Accordingly, after having literature review and experiments, it is decided to create looping of RF nodes. According to the concept, along the roadway of particular route, a series of nodes named as slave nodes can be deployed. Each sensor node will also capable of receiving as well as transmitting the position output trigger data to other node found on the same network. The number is slave nodes must be equal to the maximum number of bus stops found on the way of particular bus ID. Figure 3.9 shows the location transformation map through looping.

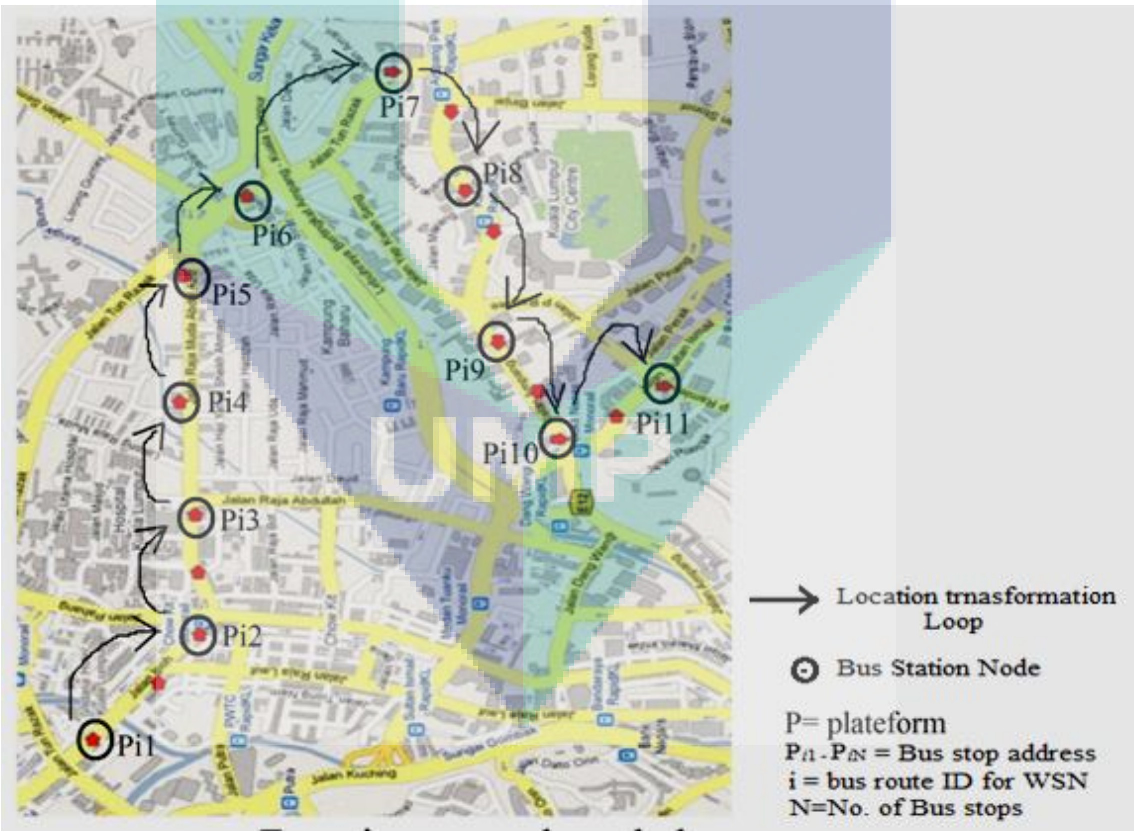

Figure 3.9: Looping of RF chip for location transmission for 11 bus stops route in Kuala Lumpur

3.3.2 Slave Node Deployment recommendations

The slave node deployment in the network is not a bottle neck; they can be placed in predefined manners. In particular, the nodes are able to be placed along the side of the roadway, mostly on the bus stops, being monitored such that the following assumptions are met:

i. The entire width of the roadway must fall inside the range region of the module being used.
ii. Separation between nodes in the network must be uniform.

This suggested deployment architecture, and the assumptions it makes, is quite well suited for the target application designed for the proposed system. There are two types of deployment suggested. One on the bus stops while second deployment can be done on needed in between two bus stops if they are found distant from each other and not be able to acquire the ranging of selected RF modules. For one, the sensing hardware can be integrated easily on the bus stops. Further, road side deployment can be managed on the particular electric or indication poles found on the way. The overall integration of the module will be discussed in upcoming section.

3.3.3 Process Flow

After having a testing of prototype nodes, here is described the process flows for the slave modules to work. Initially when the bus (master module) is ready to move, after some data is input as described above, the master system will be configured as just transmitter first and the nearest bus station (slave module 1) will be configured as receiver first. So after login the system, the master module will receive the GPS signals for the bus location then after matching with the predefined coordinates being saved in the registers of MCU, will literally start to transmit to the first nearest bus station. Now when the bus is on the move, the slave module 1 will be configured as transceiver and will send the bus position data to slave Module 2 (2nd next bus station) and up to so on. This chain for receiving, displaying and transmitting bus positioning information will be last till the final bus station for every bus found in the particular route. For the prototype testing, some light indicators (LEDs) are integrated to make the system user friendly and implementable. The main concept is designed via core programming to provide maximum benefits to the passengers. The facilities contain the current position of total buses coming to the particular stop. The separate network ID for every unique ID of bus provided a resourceful solution for the visualization.

3.3.4 Slave Module Integration

Slave nodes are designed to provide an efficient and user friendly monitoring system in visualization context. The power supply and configuration is same as explained in the master module integration section. The module comprises of same MCU and Xbee pro RF modules. But this time, it is integrating visually monitored features. The Xbee pro modules in the node are configured to receive the position data from moving master nodes serially. By default, Modules operate in transparent mode. When operating in this mode, the modules act as a serial line replacement, all UART data received through the DI pin is queued up for RF transmission. When RF data is received, the data is sent out the DO pin. This reception, displaying and transmitting continue until the last predefined bus stop (slave module). They are programmed to display the current location of master node and then send immediately to the nearest next slave node. For working programming code, refer to Appendix C3. For real time monitoring, LED light indicators are used. Figure 3.10 shows the generalised connection block diagram for slave module integration. For genuine circuit diagram of slave module, refer to Appendix A2.

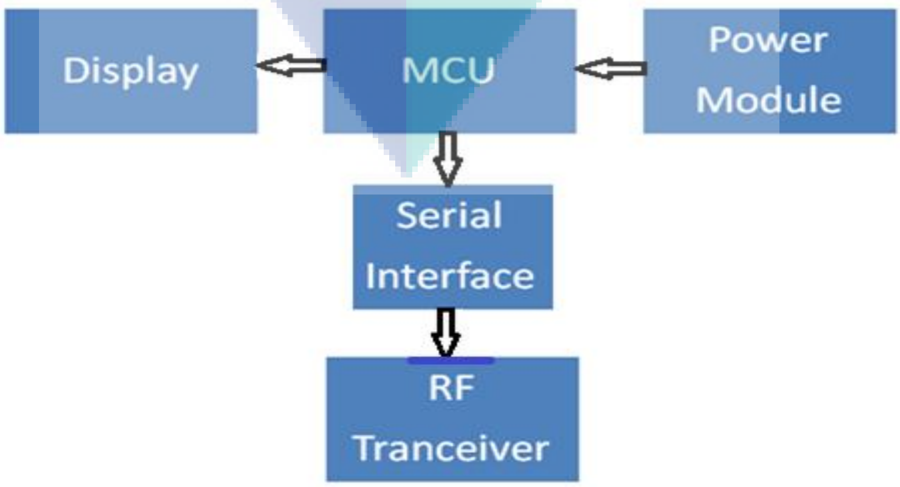

Figure 3.10: Generalized slave module integration

The integration techniques of Xbee pro RF module is quite same as defined in the master module integration. This time, the module is not only held responsible to transmit the position data but also utilize as the transceiver. The interface with a host device is established through a logic-level asynchronous serial port. When serial data (location representative) enters the RF module through the DI pin (pin 3), the data is stored in the DI buffer until it can be processed. If the module is receiving a continuous stream of RF data, any serial data that arrives on the DI pin is placed in the DI Buffer. In the designed prototype, the master and slave nodes are programmed to receive the data as individual digits rather as continues stream (Appendix C2). The data in the DI buffer will be transmitted over-the-air when the module is no longer receiving RF data in the network. When RF data is received, the data enters the DO buffer and is sent out the serial port to a host device. The Figure 3.11 below the Xbee interfacing environment along with MCU. The difference in logic levels in RF modules with MCU integrated in the slave modules also required the voltage divider circuit specifically while sending data. The original schematic diagram for slave module is provided in Appendix A2.

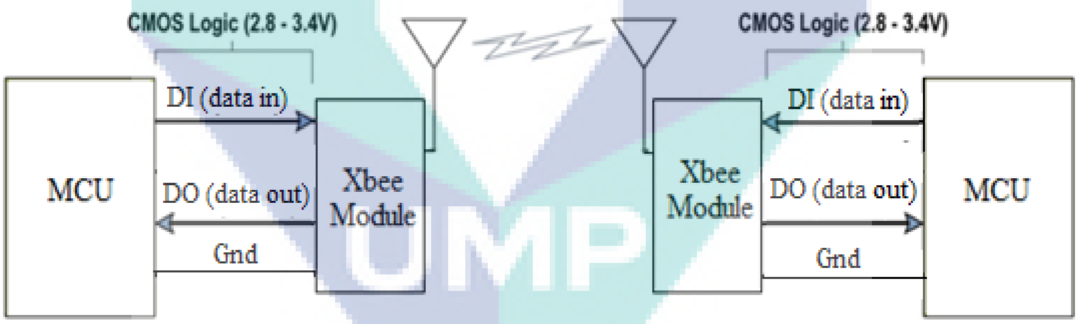

Figure 3.11: Xbee interfacing environment

3.4 THE OVERALL SYSTEM INTEGRATION

After defining the individual master and slave nodes integration, their deployment procedure and functioning flow, finally here is describing the overall system architecture and integration. The block diagram described in Figure 3.12 below shows the real time hardware implementation of the system. This overall system integration implies the novel idea for buses location monitoring to the bus stations using looping of efficiently configured Xbees which can be applicable for any bus route. The hardware connection diagram is mentioned in the appendix A. It includes the schematic diagram for both of the modules which are generally described in Figure 3.12 below. The pictorial form of connected and working modules is shown in Appendix D.

The Figure 3.13 is the overall process flow of designed frame work. It mostly focused on the real time implementation to support our proposed buses network monitoring and management system. It contains several intelligent decision support steps. The process flow starts by taking into consideration all the aspects from initial login system till the ending aim of user friendly display at all slave modules. The individual coding for several decision making steps and components to work is listed in Appendix C.

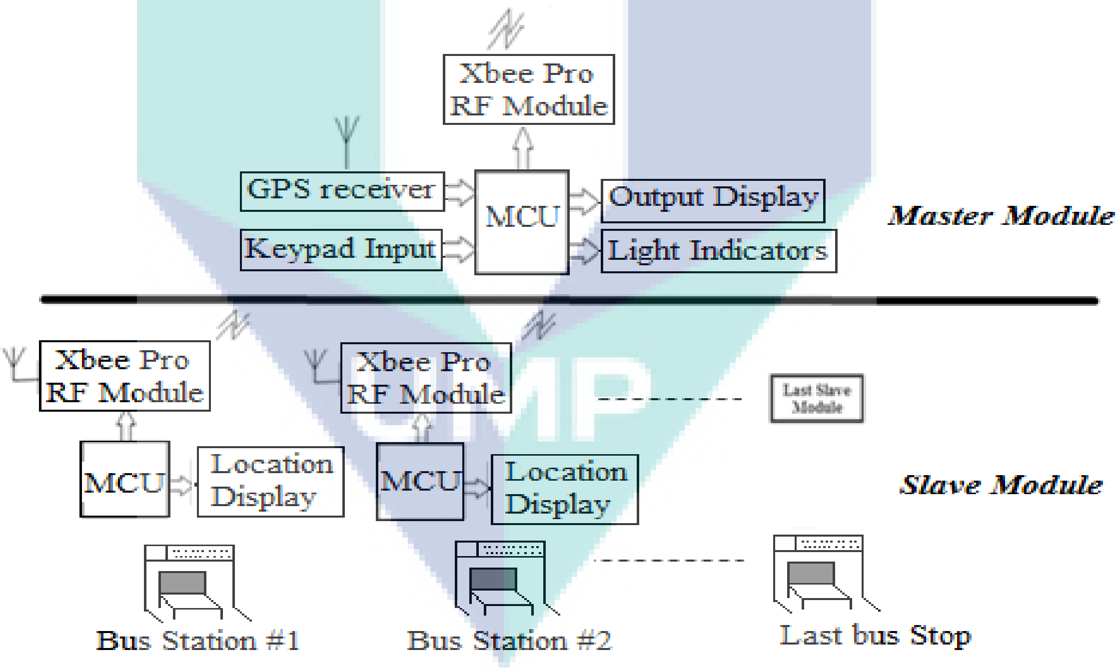

Figure 3.12: Overall system architecture

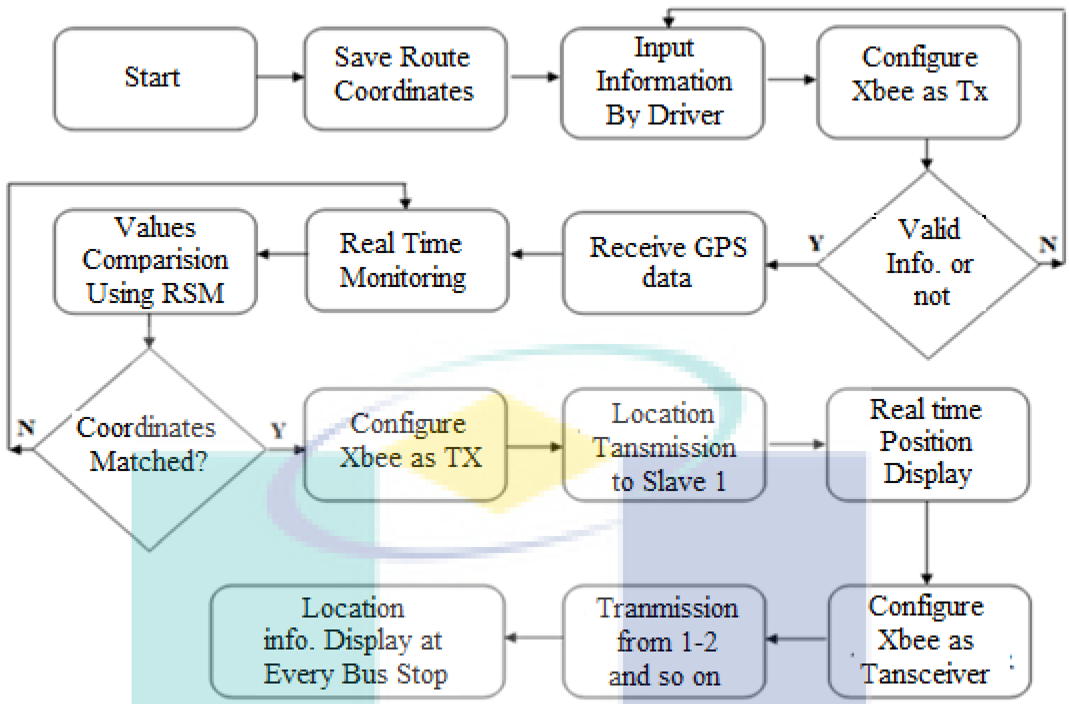

Figure 3.13: Overall functioning flow

3.5 SYNOPSIS:

This chapter provides the research methodology justified by the choice of hardware, and its functioning flow, to serve as the best framework design for the proposed system. It started with the concept of the system, then overall frame work designing then functioning components utilized in the system. The individual role of techniques, equipments and their integration is explained in the detailed circumstances. GPS and Xbee modules are interfaced serially with the MCU. In particular, it demonstrate the means by which location information is derived from GPS (at master module), and then an intelligent map matching is utilized to make sure position display until the last node, through looping of embedded RF modules. While for map matching, selected digits are obtained from coordinate's position data. The optimization technique DOE is applied to acquire a generalized and simple equation which is trained to MCU. The output of the equation is utilized to trigger the particular slave node. Finally the location visualization is provided in the most convenient way for the passengers. The next chapter will present the results obtained from the pre designing of map matching technique and the formation of specific equation to train MCU. Finally it will provide a detailed discussion on the ITS and buses notification system from most of the variables affecting the system.

CHAPTER 4

RESULTS AND DISCUSSION

This chapter will evaluate methodology of the real time implementation, obtained in previous chapter in terms of its outcomes. It presents the results and equation obtained from the optimization technique for map matching. Furthermore, it includes the equation validation and efficiency measures for the system. Finally this chapter includes a wide variety discussion supporting overall implementation of system flow and results. It also include some comments of author's view related to the procedure employed will be given.

4.1 EXPERIMENTAL ANALYSIS

In order to implement the prescribed decision support system for the overall public transport information system, this dissertation explores and suggests a unique design phase containing a system to mount GPS based embedded system with sophisticated RF transceiver on every bus and at the bus station. These specially designed moderate range Xbee pro RF modules are efficiently configured to make sure a practical communication loop only found in the particular bus route. From the hard ware point of view, the combination of RF module proved to be a resourceful pairing in terms of compatibility, reliability and result orientation. For the users, passenger and public transport service provider's prospects, this system is designed to provide the real time, most convenient visualization of the required vehicle at the slave module.

The software part, designed to support the hardware, was required a diligent and dedicated algorithm designing. Initially the general programming algorithm was finalized on the basis of overall process flow discussed in previous chapter. PROTON+

compiler plus IDE is selected as MCU programming software to obtain the best working combination of the embedded system. The PAN and Destination Addresses (DA) of the selected transceiver modules are configured by X-CTU software, so that a proficient looping of location until the last bus station could made possible. The configuring method was already described with Figure 3.5. For prototype testing purpose, three Xbee based slave nodes are arranged to make sure the looping of received data by the master node. The methodology used for selecting the destination and source is kept such a way that the destination address of first slave module is configured same as the source address of successive second salve module. The same destination and source address configuration technique is adopted between second and third. The configuration made using the X-CTU is shown in the Table 4.1.

Table 4.1: Configuring parameters for looping of three (03) RF modules

For Bus route B103	Xbee # 1	Xbee # 2	Xbee # 3
BAUD RATE	(3) 9600	(3) 9600	(3) 9600
PAN ID	0103	0103	0103
ATMY	10	11	12
ATDL	11	12	13

4.1.1 Data Acquisition

The above hardware was incorporating the required software, embedded on a designed board. A data acquisition utility was written in the programming language to interface to the GPS receivers with the MCU (hardware interfacing diagram on Appendix A). The GPS receivers output ASCII sentences every second using the NMEA 0183 serial communications standard. A number of standard NMEA sentences exist for GPS receivers. The specific sentence recorded each second from receivers is the $GPRMC sentence, and contains the time, date, receiver position in latitude and longitude, speed over ground in knots, and bearing relative to North in degrees. The selected digits from $GPRMC sentences are programmed to store in the registers of MCU. The successful reception of a GPRMC sentence from the experimental receiver is used for MM and to trigger the RF transceivers. The way of location data reception for efficient equation validation and MM will be described in section 4.2.

4.1.2 Data Pre-Processing

For the single route optimization, location data was collected by using the acquisition utility of handheld GPS while driving the vehicle around the city of Kuala Lumpur, Malaysia. The city is mostly urban, thus there was wide chance to observe extreme multipath events which was normally occurred. Data was collected during a weekend morning when traffic was not heavy. This was a necessary precaution to create favourable conditions for collecting exact location coordinates. In all, approximately 40 minutes of driving data were collected over 11 set of coordinates from bus stops. Prior to using this data for experimental testing, pre-processing was needed to generate data sets containing the necessary information for the system. Then it is observed from these data sets that not the all were resourceful. The data sets are already mentioned in table 3.2 in previous chapter. The criteria used to create data sets for testing were the following.

i. MM requirement; from the longitude and latitude data, it is observed during one whole route journey, degree and last digits of second are not significant for the MM. Since the 'Degree' remained constant while the 'Second' parameter was found as quite distinguishing. So eliminating degree and last digit of second, helped to reduce processing time and size of dada each time.

ii. Accurate depiction of the master module; any road network database can be design and train for the triggering slave modules using the mentioned methodology.

iii. Unfavourable conditions for the MM; ideally; the bus should stop at the particular platform to have efficient MM. But unfortunately, to stop at the unidentified place may produce irrelevant data as compare to the trained data for proper MM. In order to address this problem, each set of coordinate's data was further distributed in to at least three possibilities as shown in Table 4.1 (the more possibilities, the more accuracy can obtain).

Each of the inputs and outputs resulting MM, are associated with a location within a predefined region of max 1.5Km diameter, since the area is likely be covered by the selected transceivers modules for testing. Since the ranges are taken as IEEE standard so instead of concerning any range test, the research is focused more towards developing the looping concept for different ID. After having a novel idea of looping of wireless chips, a mature prototype design is constructed and tested using static coordinates and after utilizing pre configured transceiver modules, the transmission is checked.

Table 4.2: Received coordinates with their probabilities

Cases		Received coordinates			
		Longitude		Latitude	
		Min.	Sec.	Min.	Sec.
$(P_{i\,1,1})$	1	41	42.2	10	12.4
$(P_{i\,1,2})$	1	41	42.4	10	12.3
$(P_{i\,1,3})$	1	41	42.5	10	12.2
$(P_{i\,2,1})$	2	41	55.2	10	03.4
$(P_{i\,2,2})$	2	41	55.5	10	03.1
$(P_{i\,2,3})$	2	41	55.7	10	03.0
$(P_{i\,3,1})$	3	42	11.0	10	04.9
$(P_{i\,3,2})$	3	42	11.2	10	04.8
$(P_{i\,3,3})$	3	42	11.5	10	04.8
$(P_{i\,4,1})$	4	42	42.6	10	04.7
$(P_{i\,4,2})$	4	42	43.0	10	04.7
$(P_{i\,4,3})$	4	42	43.3	10	04.7
$(P_{i\,5,1})$	5	42	58.2	09	50.7
$(P_{i\,5,2})$	5	42	58.4	09	50.4
$(P_{i\,5,3})$	5	42	58.7	09	50.1
$(P_{i\,6,1})$	6	43	03.3	09	36.8
$(P_{i\,6,2})$	6	43	03.5	09	36.5
$(P_{i\,6,3})$	6	43	03.8	09	36.3
$(P_{i\,7,1})$	7	42	45.1	09	31.5
$(P_{i\,7,2})$	7	42	45.4	09	31.7
$(P_{i\,7,3})$	7	42	45.8	09	31.9
$(P_{i\,8,1})$	8	42	18.6	09	24.1
$(P_{i\,8,2})$	8	42	19.0	09	23.8
$(P_{i\,8,3})$	8	42	19.2	09	23.5
$(P_{i\,9,1})$	9	42	20.6	09	18.9
$(P_{i\,9,2})$	9	42	20.9	09	18.5
$(P_{i\,9,3})$	9	42	21.1	09	18.3
$(P_{i10,1})$	10	42	26.3	09	12.8
$(P_{i10,2})$	10	42	26.6	09	13.1
$(P_{i10,3})$	10	42	26.8	09	13.5
$(P_{i\,11,1})$	11	42	30.0	09	02.3
$(P_{i\,11,2})$	11	42	30.2	09	01.9
$(P_{i\,11,3})$	11	42	30.7	09	01.6

Where,

$(P_{i\ l,m})$ = P = Platform or bus station;

i = Identical network ID for each bus route (PAN address)

l = Number of bus stops (Slave modules)

m = Number of possibilities of particular bus stoppage (master module)

4.1.3 Response Surface Methodology

Parking violation on the pre identified bus stops produce unwanted outputs or error factor. The parking at bus stops is crucial part of the study, in order to have proper MM and triggering of RF modules. The presented technique is aimed to develop the input-output relationships for prediction of bus stop ID. In order to arrive at the most influential variables and its effects a phase strategies were proposed. Response Surface Methodology (RSM) based on Central Composite Design (CCD) was utilized to develop a linear model for prediction. RSM are used to estimate the transfer functions at the optimal region. Hence CCD approach was selected for the present study. The use of statistical Design of Experiment (DOE) techniques provides the engineering community with valuable tools for forecasting the behaviour of a system or process.

The selected coordinate's data is already received from GPS. 11 nodes are used for constructing a full route of one single ID bus. In light of the observation, a decision was taken to study the effects of the four significant factors, namely; longitude M, longitude S, latitude M and latitude S. three more possibilities are suggested. The variables and their levels are listed in Table 4.2.

The Analysis of Variance (ANOVA) results are presented in Table 4.3. It can be seen that the model *F*-value of 906.18 implies the model is significant. It shows that there is minor difference found in between the trained and actual response. There is only a 0.01% chance that a "Model *F*-Value" could occur due to noise. Values of probability less than 0.0500 also indicates model terms are significant. The significance model factors (*A, B, C, D, AC, AD, BC and CD*) are indicated in the Table 4.3. Values greater than 0.1000 indicate the model terms are not significant. A mathematical prediction model has been developed based on the most influencing factors and the validation simulation analysis proved its adequacy. The result aimed towards prediction of bus stop number and its effect on received coordinate's data.

The response equation for von Mises and Displacement in coded form is developed based on the response surface method (RSM). The von Mises and displacement equation can be expressed in Eq. (4.1).

Table 4.3: Analysis of variance (ANOVA) results

Source	Sum of Square	Df	Mean Square	F Value	p-Value Prob>F	
Model	246.98	10	24.70	906.18	< 0.0001	Significant
A-Longitude M	5.284E-003	1	5.284E-003	0.19	0.6647	
B-Longitude S	1.11	1	1.11	40.71	< 0.0001	
C-Latitude M	1.113E-005	1	1.113E-005	4.085E-004	0.9841	
D-Latitude S	4.146E-005	1	4.146E-005	1.521E-003	0.9693	
AB	3.387E-005	1	3.387E-005	1.243E-003	0.9722	
AC	4.120E-003	1	4.120E-003	0.15	0.7017	
AD	1.996E-003	1	1.996E-003	0.073	0.7896	
BC	0.77	1	0.77	28.36	< 0.0001	
BD	0.36	1	0.36	13.30	0.0017	
CD	4.114E-003	1	4.114E-003	0.15	0.7020	
Residual	0.52	19	0.027	Residual		
Cor Total	247.50	29				

$$P = 25.20266832 + 1.321582163*A + 0.02467396989*B - 7.753245435*C - 0.1525904315*D \qquad (4.1)$$

Where,

P = Predicted bus stop number

A = Longitude Minutes

B = Longitute Second

C = Latitude Minute

D = Latitude Second

The equation 4.1 obtained gave a simple dimension of particular bus stop number. The simplicity of the equation encourage the reseacher to use the DOE. This present form of the equation is uncomplicated to train the MCU using the parameters of data. The all four parameter are programmed in the MCU to receive as the long integers continuesly. Instead of comparing digit by digit of all location coordiantes, the above equation provides a single value output representing whole location coordinates. It also correspond to the optimized output for the bus stop location in order to trigger the RF modules for location tranmission through looping. Even though, some time it was observed that a fractional output value is obtained. The conditioning as shown in appendix C1, is capable of making sure to provide a natural number.

The R^2 analysis results are tabulated in Table 4.4. The "Pred *R*-Squared" 0.97994 is in reasonable agreement with the "Adj *R*-Squared" of 0.977857. In fact, when the value of correlation coefficient *R* is close to 1, it means the response correlation of actual received coordinates and predicted values are better. The average accuracy from the R2 analysis is found out as 97.9%. The statistical analysis shows that, the developed mathematical model to predict the exact bus stop, based on central composite design is statistically adequate and can be used to trigger the slave module to start looping of transceiver for a single bus route.

Table 4.4: R^2 analysis results

Parameter	Value
Std. Dev.	3.211308
Mean	6.000
R-Squared	0.980625
Adj R-Squared	0.977857
Pred R-Squared	0.97994

Figure 4.1 below shows the predicted versus actual plot how the model predicts over the range of data. The best fit line plot of the 33 points (Table 4.5) is found to be close to the ideal line ($Y = X$). The difference in the form of residual is found in the range of minimum -0.80622 up to maximum of 0.48940. Both extreme values lie near to the slandered Y=X. Due to this, the predicted responses show the good agreement with actual results. Only observation 4,5,6 and 16,17,18 deviated out from there standard. It caused problem in rounding off the data. The solution is taken by conditioning of the output by their minimum and maximum range. (Appendix C2)

Table 4.5: Comparison between predicted (Fitted) versus actual results

Observations	Actual	Fitted	Residual
1	1.00000	1.00420	-0.00420
2	1.00000	1.02440	-0.02440
3	1.00000	1.04212	-0.04212
4	2.00000	2.69828	-0.69828
5	2.00000	2.75146	-0.75146
6	2.00000	2.77165	-0.77165
7	3.00000	2.70039	0.29961
8	3.00000	2.72058	0.27942
9	3.00000	2.72798	0.27202
10	4.00000	3.51060	0.48940
11	4.00000	3.52047	0.47953
12	4.00000	3.52787	0.47213
13	5.00000	4.62960	0.37040
14	5.00000	4.68031	0.31969
15	5.00000	4.73349	0.26651
16	6.00000	6.71759	-0.71759
17	6.00000	6.76830	-0.76830
18	6.00000	6.80622	-0.80622
19	7.00000	7.23611	-0.23611
20	7.00000	7.21299	-0.21299
21	7.00000	7.19234	-0.19234
22	8.00000	7.71142	0.28858
23	8.00000	7.76706	0.23294
24	8.00000	7.81778	0.18222
25	9.00000	8.55423	0.44577
26	9.00000	8.62267	0.37733
27	9.00000	8.65813	0.34187
28	10.0000	9.62568	0.37432
29	10.0000	9.58730	0.41270
30	10.0000	9.53120	0.46880
31	11.0000	11.3192	-0.31917
32	11.0000	11.3851	-0.38514
33	11.0000	11.4433	-0.44326

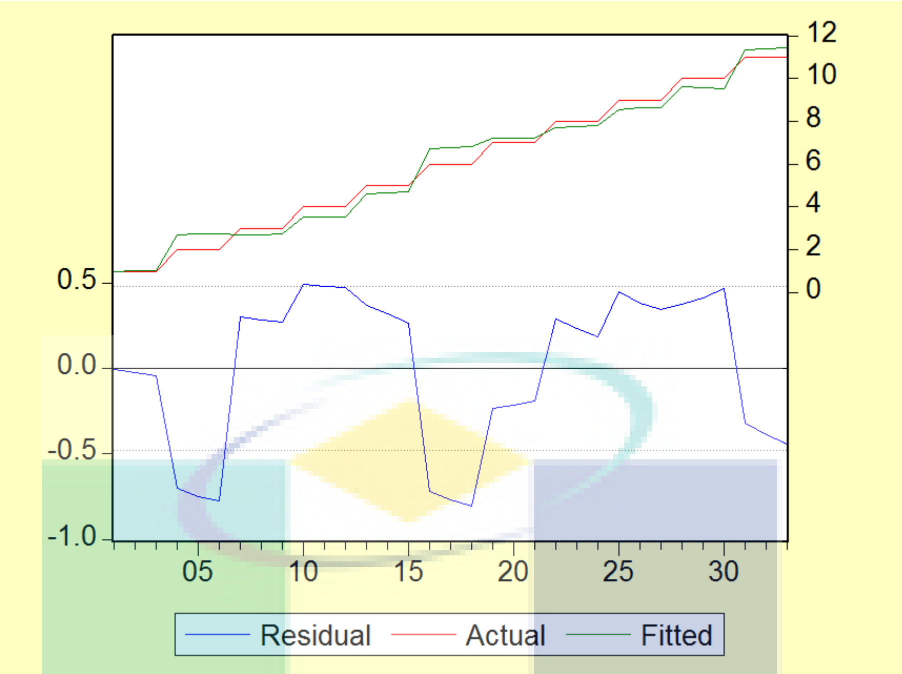

Figure 4.1: The best fit line plot

4.2 EQUATION VALIDATION

Simulation results provided a good agreement between the received and trained coordinates in terms of single digit representing whole location data. The novel equation obtained, gave a simple functional dimension to train to the MCU. The subsequent step was to embed the equation got from RSM to the MCU. In order to validate the equation, it was programmed to the MCU in such a way that all the constant and variable are taken as floating point. The necessary location coordinates are received in a pre defined manner such that the selected digits can be utilized for the variables A, B, C and D mentioned in the equation 4.1. (Appendix C1).

For the testing and equation validation purpose, the master module prototype was brought to the exact route of KL as mentioned in figure 3.8, from where the coordinates for training were collected. The equation and modules gave expected results in the form of one digit representing the exact bus stop. During testing the master modules, the equation is programmed in MCU in such a way, to get the output up to only one (01) digit after decimal number for conditioning and comparison. Later on the five digits (05) after decimals are taken as to verify the accuracy of the system. This selection is inspired by the same quantity of digits obtained by DOE using RSM (table 4.5). During testing, a little missing in obtaining the exact bus stop number was observed too. This might because of several circumstances including the slower 8 bit PIC, rounding off conditions, GPS multi path error or the number of 3 possibilities for each bus stop. The more possibilities, the more accuracy could obtain in the simulation results. Another reason is the unreliable floating point calculation. As mentioned in the PROTON BETA 7 manual, according to which, "*Floating point arithmetic is not the utmost in accuracy, it is merely a means of compressing a complex or large value into a small space (4 bytes in the compiler's case). 32 bit floating point math is extremely microcontroller intensive since the PIC is only an 8 bit processor.*"

For the accuracy measure, the error factor caused due to the more than 8 digits based calculation was taking in to account. The outcomes show nearly the same results upto the 5 significant digits after decimal, obtained by the simulations. For an example from bus stop named as 'Stesen Monorail Chow Kit' is selected to show the scientific evidence. The static coordinates (41, 55.5, 10, 3.1) from the pre defined route (from Table 3.2) were utilized to check the measure of accuracy for MCU to calculate the bus stop number as shown below,

Table 4.6: Comparison of step by step calculation results by DOE and MCU for bus stop#02

Equation constants	**Specific Coordinates**	**Initial digit by digit Calculation by DOE**	**Initial digit by digit Calculation by MCU**	**Accuracy measure**
p2=1.321582163	A= 41	54.184868683 0x4258BD4E	54.18486 0x4258BD4C	1.60E-05
p3=0.02467396989	B= 55.5	1.369405328895 0x3FAF48AC	1.36940 0x3FAF4880	3.89E-04
p4=7.753245435	C= 10	77.53245435 0x429B109E	77.53245 0x429B109D	5.61E-06
p5=0.1525904315	D= 03.1	0.473030338 0x3EF23108	0.47303 0x3EF230FD	7.15E-05
The bus stop number calculation result by DOE: 2.75144				
The bus stop number calculation result by MCU: 2.75146				

The table 4.6 above implies a promising relation between the outcomes of bus stop number by the simulation with the actual digit by digit calculation within the registers of MCU. The worst case of difference in simulation and MCU results obtained when the constant P4 is multiply by the variable C. The evidence is collected by programming the MCU to obtain the results of equation calculation step by step on the serial communicator provided by PIC kit 2 and also display at the LCD. The purpose is to reach at the error factor or in other words, the accuracy for the equation validation. Although there is a very slight difference found in the digits, (the reasons had been stated above) however these distinctions will not cast any effect on calculating the one digit value representing the bus stop number. This neglect-able error factor is also avoided by the help of conditioning of the output of the equation. The condition is applied by observing the maximum limit of the 1 digit after decimal as shown in the Appendix C1. Therefore, it can be interpreted that the accuracy measure check after testing the hardware for more than 8 digits based calculation have no error effect on overall functionality of the system. The table below shows the overall calculation end results comparison through DOE (taken from table 4.3), and MCU for all 11 bus stops.

Table 4.7: Comparison with accuracy measure for all 11 bus stops calculation results by DOE and MCU

Observations	**Actual**	**Fitted (DOE)**	**Fitted (MCU)**	**Accuracy (%)**
1	1	1.0244 0x3F831F8A	1.02439 0x3F831F36	9.76E-04%
2	2	2.75146 0x403017EC	2.75144 0x40301798	7.27E-04%
3	3	2.72058 0x402E1DFC	2.72058 0x402E1DFC	0.00E+00%
4	4	3.52047 0x40614F61	3.52046 0x40614F37	2.84E-04%
5	5	4.68031 0x4095C519	4.68031 0x4095C519	0.00E+00%
6	6	6.7683 0x40D895EA	6.76829 0x40D895D5	1.48E-04%
7	7	7.21299	7.21298	1.39E-04%

		0x40E6D0D0	0x40E6D0BB	
8	8	7.76706 0x40F88BC1	7.76705 0x40F88BAC	1.29E-04%
9	9	8.62267 0x4109F675	8.62266 0x4109F66A	1.16E-04%
10	10	9.5873 0x41196595	9.58729 0x4119658A	1.04E-04%
11	11	11.3851 0x4136295F	11.38513 0x4136297E	-2.64E-04%

The table above shows a comparative analysis of end bus stop results after all calculation for all 11 observations. The remarkable results can be seen above. In the worst condition, it is observed a deviation of 9.76E-04 by calculation for bus stop number 01. Therefore, the overall results from DOE as well as MCU implies that the goal to achieve the target of obtaining single digit bus stop number representative of 17casual digits of location data was found to be capable efficient enough as compared to the DOE based simulation, since the required significant bits for conditioning is just one digit after decimal.

4.3 DATA AND TIME REDUCTION CLAIM

4.3.1 Theoretical Data Size and Time Reduction

In Today's world of nanotechnology, the time consumption is given sound importance. Beside the data bits reduction for efficient comparison, the outcomes of the research also focus to limit the time consumption. This contribution is accomplished using one digit output by the novel route equation. This one digit will represent 17 digits necessary location data consist of longitude and latitude. This one digit has promised the 17 times data size as well as time reduction during standard serial communication. The figure 4.2 below shows the time taken for standard serial data transmission from 01 digit representative to all the 17 digits location data.

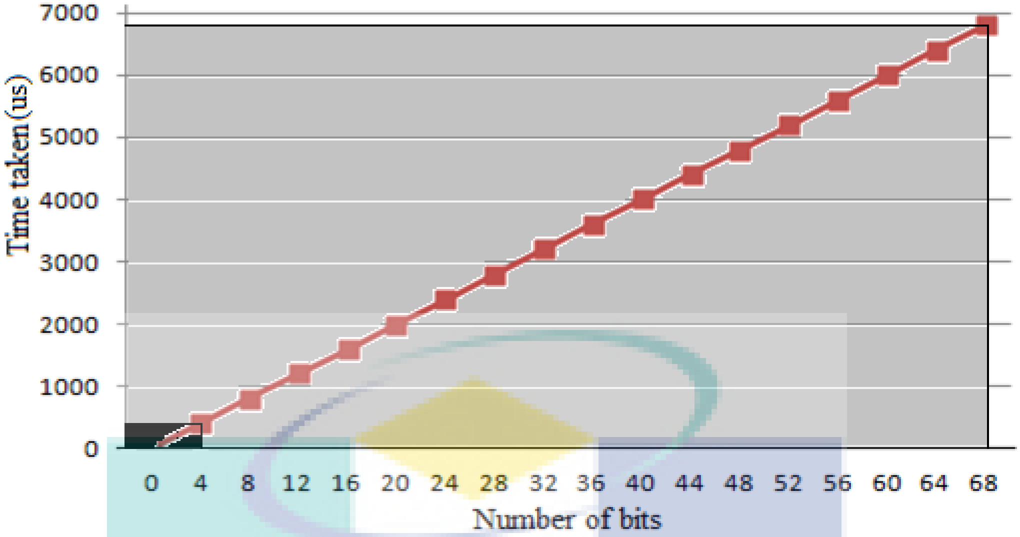

Figure 4.2: Theoretical Data Size Vs Time Taken Graph

Since the baud rate for both of the module is kept @9600 in order to have an effective communication link. Through this most commonly used baud rate, it is easy to find out the time consumed per bit. The rate of line change for 1 bit will be (1/9600) or approx 100us. Therefore for four bits (1 digit) will take about 400us while for 68bits (17 digits) will need around 6800us or 6.8ms. In the real time monitoring system, a commonly used GPS needs to get update by every one second. As the major responsibility of master module, the receiving, comparing and transmitting of 17 digits may cause several malfunctioning. In the figure above, the light shaded area actual time allocated during the standard serial communication between two modules as compare to the dark shaded area shows the redeemed time, by the proposed System. This time and data size reduction does not only facilitate the master to slave serial communication but also contributes for the slave to slave looping where the receiving, matching and transmitting is required. During all the steps, the novel equation optimizes the time and data up to 17 times less.

4.3.2 Actual Processing Time Calculation

In the real world of embedded system applications, although the MCU come up with the standard instruction cycle with respect to the crystal oscillator selected. Still the compiler routine contains several commands, pre defined functions and their sub routine to reduce the programming code. By using those pre defined functions, the processing time of the code to produce relevant output is found to be vary as compare to the standard. Theoretically one digit replacing 17 digits position data surly have a clear potential to reduce the data and time. But practically it does not happen so. For the purpose being, several testing based experiments were conducted to evaluate the actual processing time taken by the modules. Master module is selected since it is a sub set for all the operations done in overall system.

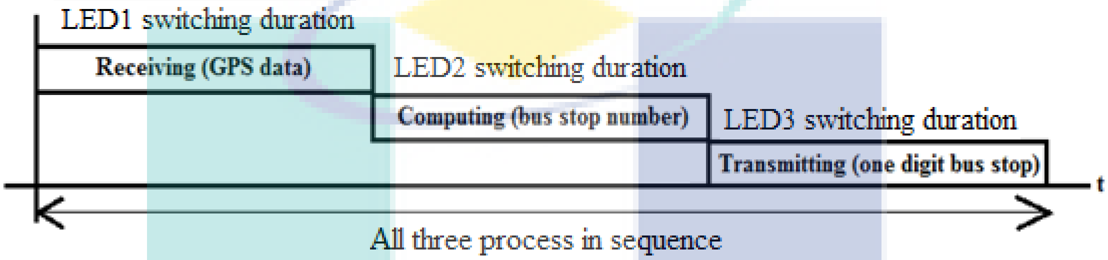

Figure 4.3: Overall processing tasks in sequence

The master node is made responsible of receiving the GPS data, to calculate the bus stop number through a novel equation got from DOE. The equation contains several floating point based calculations. Then send the one digit output to the nearest slave module. The objective of this finding is to estimate the time at which PIC16F877A with 4MHz crystal perform certain calculations. The processing time include receiving, calculating and transmitting as shown in Figure 4.3 above. The purpose is to compare the required time consumption to verify the time reduction claim. We managed to compute the processing time period during three steps through digital oscilloscope GDS 1062A along with its serial simulator to capture on laptop as well as PICkit2 logic analyzer tool (LA).

Initially it was checked either the system is free of error or not. For the purpose, a simple delay of 100ms and 50ms routine was made and verified through the oscilloscope and logic analyzer tool using the digital output and cursor feature respectively at the output pin of PIC using the blinking LED. The sequence of the testing code was output high with the delay and then output low with same amount of delay. This code displayed a square wave with the period cycle of 200ms with 100ms delay and 100ms with 50ms delay. It was observed no error in our procedure. After words, the code was changed to conduct the actual master node operation to be performed for time measurements one by one while performing each processing step through the change of state by LED.

4.3.3 Limitation of the Testing Equipment

As mentioned above, the processing spectra contain three tasks that is receiving, computing and transmitting. There were some limitations found in our oscilloscope and logic analyzer. The selected digital oscilloscope comes up with two channels. The logic analyzer cannot work with 3 channels at a time. The possible reason could be the absence of pull up resistor at the third channel as stated in the manual. Another obstacle with the selected LA was its limited time measuring capability at single window. The least is found to be 500ms. In order to overcome this limitation, the code was written to do all three tasks one by one in loop. Three LED are selected for the tasks. Before every task, the respective LED was made HIGH and, LOW after finishing particular task. Since the duration between them to toggle will help to estimate the actual time consumption. The output was observed at the oscilloscope as well as logic analyzer. For the first task, location data reception was found unable to measure accurately by LA. For the purpose, the oscilloscope was utilized.

4.3.4 Scientific Evidence and Discussion

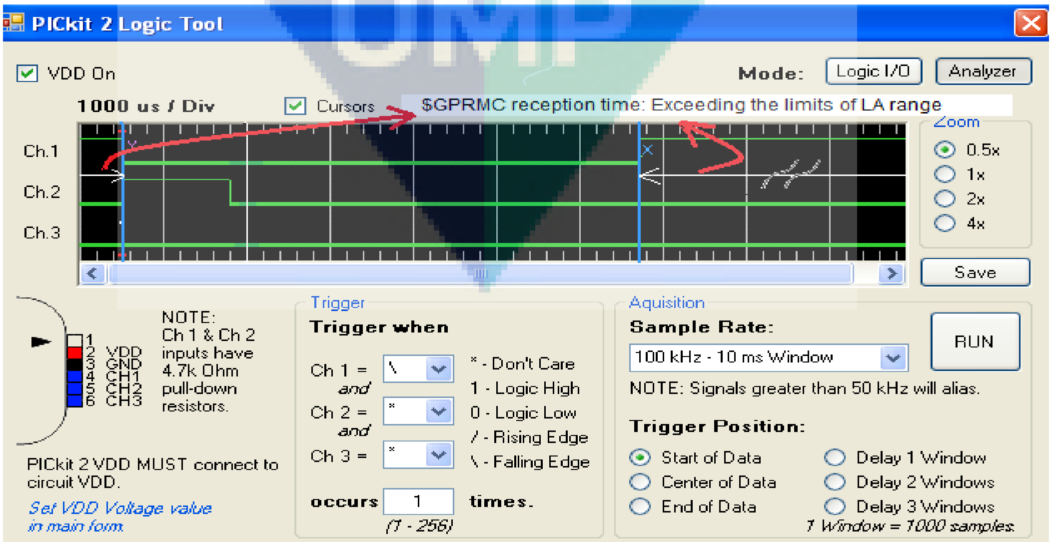

Figure 4.4 (a): Time taken by MCU to receive GPS selected data by LA (Longitude, Latitude, valid and direction character)

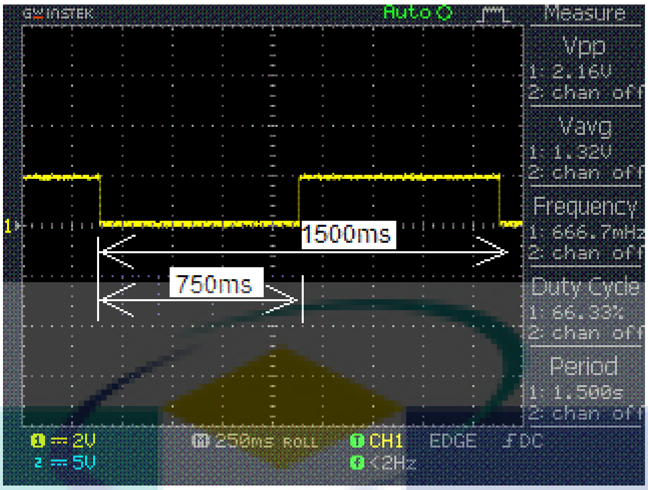

Figure 4.4 (b): Time taken by MCU to receive GPS selected data (Longitude, Latitude, valid and direction character) by Oscilloscope; 750ms

The Figure 4.4(a) and 4.4(b) above shows the time consumption for receiving specific location data by MCU as master module. As mentioned above, in order to capture the duration, LED1 output is programmed to toggle after receiving GPS data, is captured at the channel 1 for both LA and oscilloscope. LA was found having insufficient range to compute the time taken by MCU. Furthermore, the same procedure was followed using oscilloscope as an individual step. Reception is initiated with a high pulse and ended by low one, but the total time period is taken for one complete cycle of period, which is found to be 1500ms as shown in the figure. These results are taken as average by capturing the reading after 5 run by the oscilloscope. It implies the average actual time taken by MCU to receive the selected GPS data took ~1500/2=~750ms.

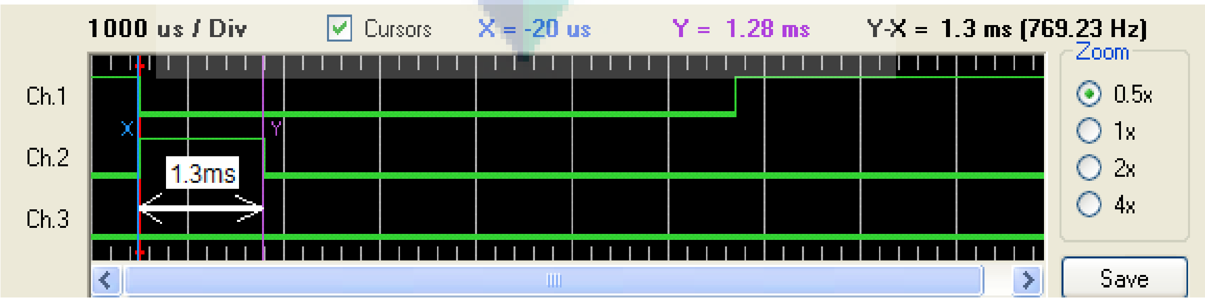

Figure 4.5: Time taken by MCU for all floating point calculation using LA; 1.3ms

The Figure 4.5 shows the time consumption for the floating point based calculation inside master module. In order to capture the duration, an LED2 output is programmed to toggle after completion of all calculation until gives the one digit bus stop number, is captured at the channel 2 using LA. In the programming sequence, this task is kept right second after GPS reception. This can be evidence by the figure, that the X for calculation time starts right after GPS reception pulse fall down. The duration is estimated about ~1.3ms.

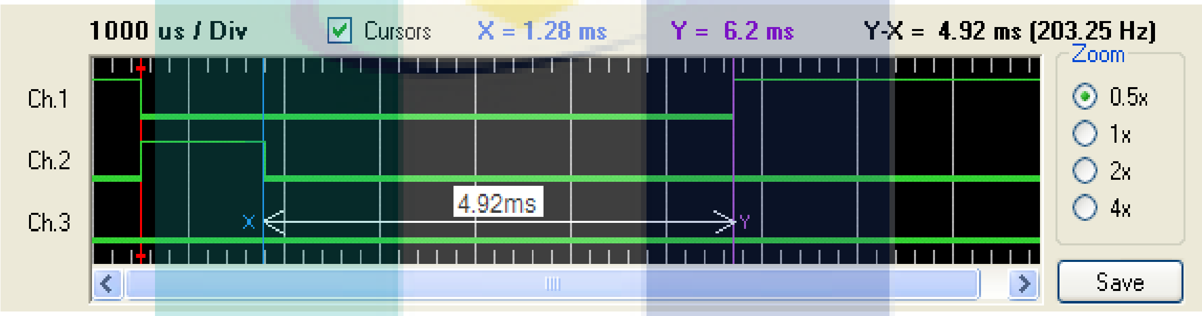

Figure 4.6: Time taken by MCU for transmitting one digit output using LA; 4.92ms

The Figure 4.6 above shows the time consumption for transmitting one digit output from the calculation. The one digit output is the bus stop number sent serially to the slave node. In order to capture the duration, an LED3 output is programmed to toggle after transmitting the digit representing minimum 17digits of location data, is captured at the channel 3 using LA. But as mentioned earlier, the selected LA was found incapable of capturing 3 channels at a time. This problem is solved by the programming sequence. In the sequence, this task is kept right third after calculation complete (2^{nd} task). The time taken was easily captured from falling edge of 2^{nd} task until the rising edge of 1^{st} task, as evidence by the figure. The duration is estimated about ~4.92ms.

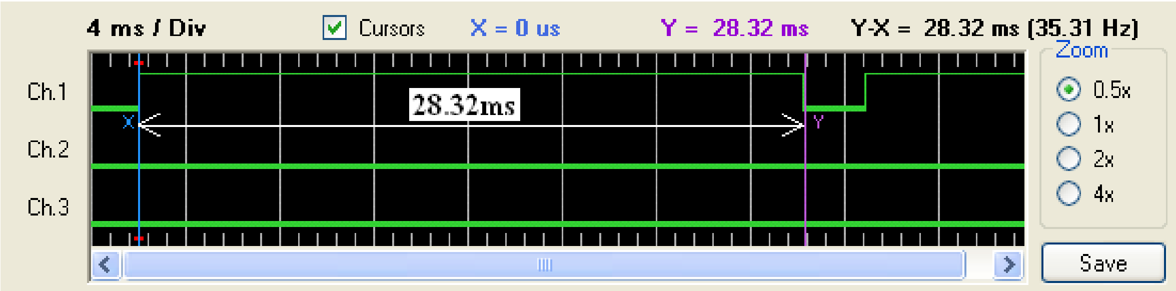

Figure 4.7: Time taken by MCU for transmitting 17 necessary digit output using LA; 28.32ms

The Figure 4.7 above shows the time consumption for transmitting 17 necessary digits output prior to calculation. It was captured through LA separately in order to verify the claim of saving the time and data consumption. The figure clearly shows that the minimum time taken by 17 digits to transmit serially through the MCU is found to be 28.32ms. This time is about 6 times higher than the time taken by 1 digit. The table below summarizes the overall time taken for the selected tasks.

Table 4.8: Processing Time Measurement Summery

Operation	Estimated actual time
Location reception	~750ms
All floating points calculations	1.3ms
One digit transmission	4.92ms
17digit transmission	28.32ms

The conclusion of the task is verified time taken for transmitting/ receiving 17 digits vs. 1 digit. The time reduction is found as 5.75 time more than formal GPS data transmitting. The table clearly shows the time reduction objective was achieved during transmitting the one digit bus stop number from master node and receiving, comparing and transmitting through each slave modules. The major portion of the time taken by overall operation was coordinates reception. Since this operation is not only the function of just 17 digits reception but also several other necessities such as waiting for valid variable "A" and distinction amongst the degree, minutes and seconds by waiting for their proper sign of "." and "," etc.

4.4 OPERATIONAL EFFECTIVENESS OF FRAMEWORK

The provision of services along different bus routes are used to specifically illustrate this framework with the understanding that modifications to the framework can be made to evaluate other modes of transportation. Like each local government may have a different purpose in establishing their own public transport monitoring system. In general, our proposed methodology can made operationally effective by three major reasons:

i. Management improvement by just first time investment and increased profits, service improvement and reorganization of bus service structure;
ii. Setting the promotional policy for public transportation to respond to changes in the bus service industry.
iii. Real time monitoring with user friendly display will bring the increasing interest of passengers to the public transport network.

Based on the conceptual framework developed in this study, the overall performance and implementation for proposed system at individual bus companies is determined by its technical as well as organizational factors too. Technically the implementation of the provided solution in the field of the intelligent transportation system seems a huge task since it required a profound cooperation of the transport service provider and the urban management system. So during the prototype designing, there are several problems faced, one of them is the delay in receiving the position data by GPS and second one is node failure for the wireless sensor systems at buses' station because of poor working conditions and constraint of uncertainty. Therefore, as far the looping mechanism, these conditions should be taken into account that the whole system can work properly, even if some of the nodes do not work temporarily. According to looping routing mechanism designed using RF modules, the basic idea ensuring the reliability of communication is: the unique ID of bus must transmit properly, the main path must be created first from the master module to the slave module one by one. By keeping above scenario, this dissertation adopts an individual as well distributed looping algorithm. That is, the communication is utilized in several ways to have a greater exchange capacity in the network for the intelligent transportation system.

4.4.1 Organizational Factors

A causal factor investigation model relating performance to organizational factors was established in order to identify the significance of this assumed relationship. By taking into consideration the some of the factors described below will surly increase the performance of implementation for the overall designed decision support system for the passengers. The effectiveness measurements of performance using the frame work on organizational factors are presented as follows.

4.4.2 The driver-Defined Factors

There are quite number of driver-specific factor used in this study to make the system in the most implementable form. At the starting, some assumptions were announced for the better prospect of managing the whole monitoring system. Most of those assumptions were greatly related to the specifically driver like just before starting the journey; he is restricted to have some input information about some parameters regarding the bus. Beside this, taking some decision on some crucial stages to bring ease for the passengers as well as keep the average number of total traffic convictions while driving buses, specially prescribed by the regulators of the organization. Parking violations are highly observed at the bus stops. It draws considerable influence on the overall monitoring framework. Even in order to rectify and reduce this factor, the optimization technique have been designed but still if the drivers are kept restricted to stop on the pre-defined bus stop then the overall provision of efficiency can be maximized. So the driver defined factor could be stated as the most effective factor to define the organizational behaviour of any Bus company towards the adaptation of proposed system.

4.4.3 The Vehicle-Defined Factors

Vehicles and relevant equipment are considered the technical factors affecting the monitoring and managing performance of bus companies. The technical factors can make contribution to malfunctioning for overall monitoring system. Since in the proposed system for buses monitoring and route managing, the customized hardware is mounted on every bus and they were configured according to designed framework. For the purpose, two vehicle-specific measurements, GPS and transceiver, are considered in this study. In order to reduce the unwanted or negative effects on monitoring system, the suggested hardware is properly designed to fix on the selected buses to be monitored. Another factor is fleet age affects. First, new vehicles incorporate new technologies that improve safety as well performance. Second, new vehicles tend to have fewer failures in operation. Thus, the index variable (V1) measuring the proportion of vehicles aged and the installed equipment less than five years must be followed to reflect the fleet age. Vehicles aged less than five years are viewed as new vehicles by relevant traffic laws. The higher the proportion of new vehicles a bus company has, the fewer problems it will experience.

4.4.4 Overall Management Factors

The first general management factor considered is the ratio of driver to non driver staff, which represents the depth of support for a bus company. This framework is designed to promote the good effect of the organizational structure on the monitoring and management performance of bus companies. A higher ratio means each non-driver staff member or technical persons must support more drivers. A bus company with higher supporting ratio implies that its organizational structure is flat, and is expected to have a higher level of risk. Furthermore, the firm size, which is measured by the capital of a company, is another general management factor. The bus company with more capital is expected to have a better implementation of proposed methodology. At last the factor, whose requirement varies depending on the community and its social awareness, is the preliminary awareness program to be conducted amongst the user and operators. This social consciousness program to train both the parties can greatly be utilize to make proper usage of the proposed integrated and customized hardware of overall system.

4.5 SYNOPSIS

This chapter presented the experimental results, discussion based on methodology implementation and benefits of proposed system from various aspects. In the experimental result section, the experimental setup is described, the data acquisition procedure explained, and a list of probabilities given that were used to select appropriate data sets for testing. Optimization methods are evaluated to achieve individual vehicle localization incorporating visual context keeping the case of irrelevant data associations at the bus stops.

Eleven data sets are used to train the proposed system. Each set is distributed in three close probabilities. These sets are then utilized to find out the normalized equation. That equation is made responsible to trigger the slave module, trained to the MCU. The goal of is to provide a reliable, efficient vehicle-to- infrastructure data delivery by minimizing the error possibilities related to bus stops.

The discussion section covers the view from technical as well as its management aspects. It draws a considerable concentration towards its technical flaws until several social behaviours to implement the proposed system.

CHAPTER 5

CONCLUSION AND FUTURE ENHANCEMENTS

A number of contributions to the field of intelligent transportation system have been made by this thesis research. This section provides a summary of these contributions on the basis of objective design for the thesis. It also discusses the significance of each to the future of intelligent vehicles, proposed Intelligent Public Transport Monitoring and Management System (IPTMS), and present conclusions reached and questions are raised. It is also proposed future research opportunities that extend the investigations performed in this thesis research or that can helpful in future for the related field.

5.1 CONCLUSION

This dissertation presents a new approach to build a monitoring infrastructure that can hold the promise to provide a reliable monitoring system for public transport. It includes both the vehicular navigation with Route Management of Public transportation services by the technological utilization in the wider aspect. With the increasing popularity of GPS-based navigation systems and communication protocols, we believe that our location data forwarding scheme through looping along with optimization technique opens the new door for exploiting the potential benefits of the public transport system for the vehicle-to- infrastructure data delivery in vehicular networks.

5.1.1 First Objective Concluding Remarks

Firstly this dissertation provides the technical and theoretical solution for the real time implementation of the system. This GPS based scheme envisions the system architecture for multi-ID vehicle localization incorporating simple visual context, in accordance with the first thesis objective given in Section 1.3. The complication of overall system architecture are made dissolve by distributing it into two basic modules; named as master and slave modules. Master module can be mounted on every individual bus while slave modules can be deployed on every bus stop. Chapter 3 illustrates the full description of both of the modules. The design provides a dedicated monitoring infrastructure for the buses navigation system, to build an intelligent public transport monitoring system for passengers. Several techniques including looping of RF modules for better visualization of the individual bus to its all relevant stops and optimization technique for best functioning map matching algorithm are tested using prototype.

5.1.2 Second Objective Concluding Remarks

In order to support second thesis objective, the initials results of the experiment implies that to assess and characterise the performance of GPS in the vehicle navigation environment have shown that the accuracy required for most ITS navigation system cannot be achieved by stand-alone GPS based embedded system. The availability of the required accuracy can be very low doe to several factors. Hence in order to achieve the optimized visualization for the passenger at the bus stops, the intelligent looping of RF modules from the field of communication techniques for WSN and optimization technique for MM is presented. From the literature cited, it was compared several optimization methodologies to come up with the better solution in the location transmission regards. For the MM, it was found several driver defined factors, affecting the efficient monitoring system. The DOE based optimization technique gave a simple solution compatible with the MCU to be trained for better MM and location transmission. The second objective is successfully achieved by optimizing a whole route location coordinates into a single digit representative, which reduce the workload for MM for triggering successive RF module.

5.2 FUTURE ENHANCEMENT

Real time positioning and tracking technologies, which are integral to public transport network and their system management, can also contribute to quenching the thirst for data of the sophisticated, data-driven analytical techniques by providing an automated data collection and its position transmission means. As far as the future works concern, our focus will be on designing of centrally monitoring server based system by which the positioning data base of all the tracked vehicles could be examined. This would be help full to realize the driver efficiency as well as the factors effecting on well-organized monitoring system. For the purpose being, the GSM technology will be suggested to utilize.

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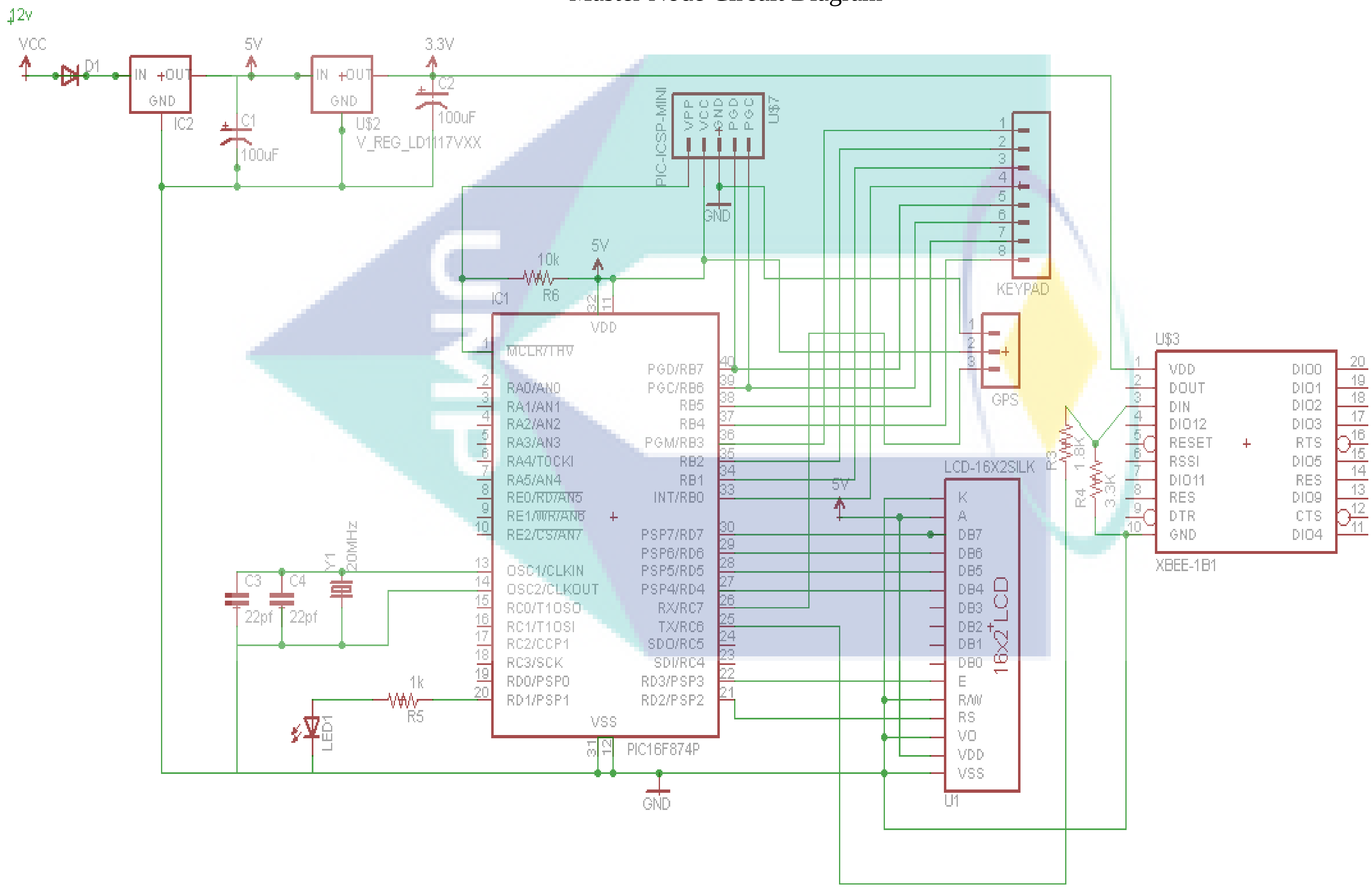
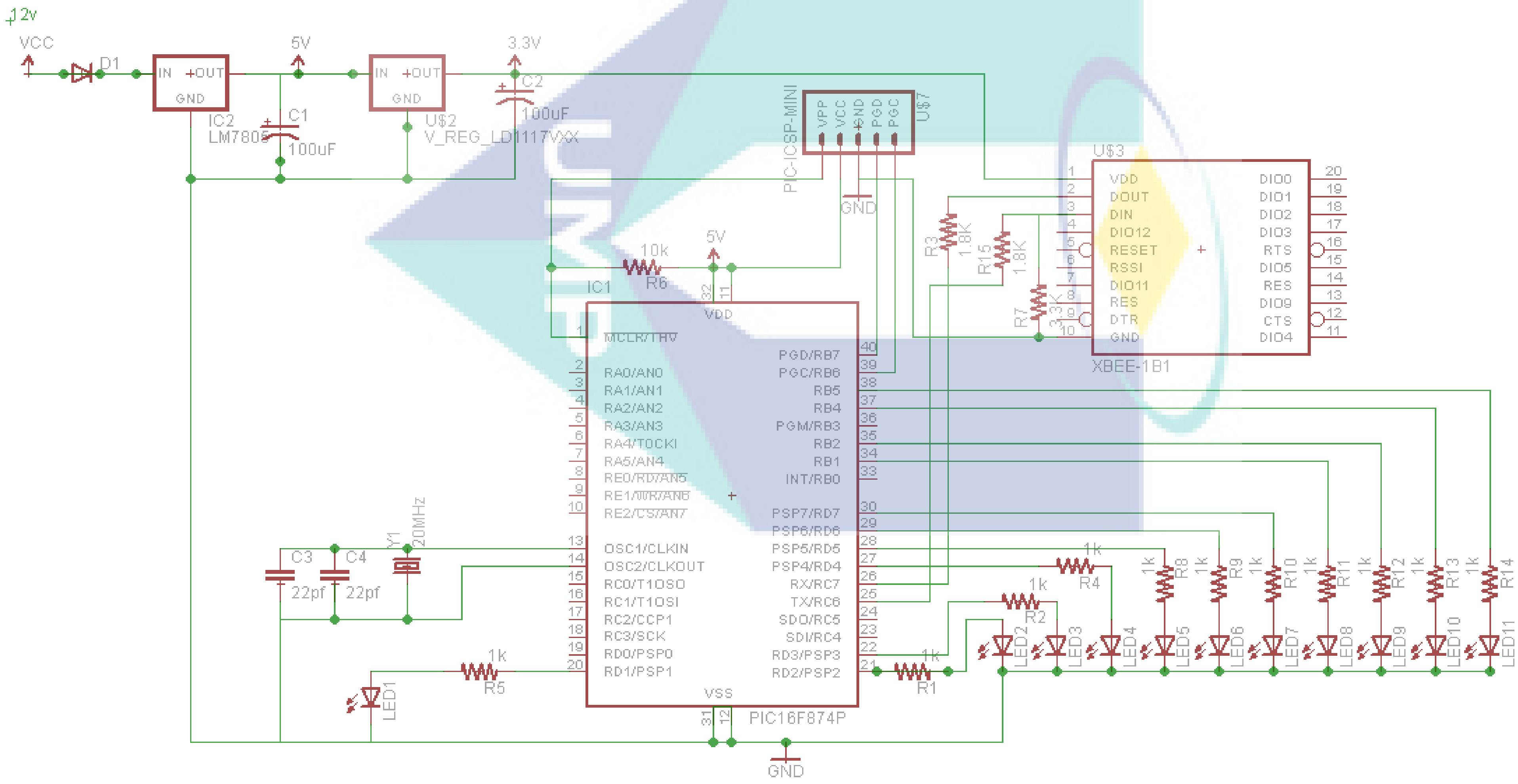
APPENDIX A1

Master Node Circuit Diagram



APPENDIX A2

Slave Node Circuit Diagram



APPENDIX B1
GPS DATASHEET

RXM-SG GPS Module w/Ext Antenna (#28505)

The RXM-SG GPS Module provides a high quality, highly sensitive GPS receiver with an external antenna to provide a complete GPS solution for both microcontroller and PC applications. The high-performance SiRFstar III chipset features 20 parallel satellite tracking channels for fast acquisition of NMEA0183 data for robotics navigation, telemetry or experimentation. This GPS Module can connect to a microcontroller or even a PC (via USB). A Windows application provides a graphical display of the GPS data and can even show your location on Google Maps (internet connection required). Four general purpose I/O pins provide expansion for pin-intensive projects.

Features

1. SiRFstar III chipset
2. Outputs raw NMEA0183 data strings to microcontroller
3. View data graphically on your PC via USB connection
4. 200,000+ correlations
5. Low power consumption
6. High sensitivity (-159 dBm)
7. 20 satellite tracking channels
8. Battery-backed SRAM
9. 11-pin SIP header with breadboard-friendly 0.1” spacing

Key Specifications

1. Power Requirements: 5 V @ ~50 mA (typical)

2. Communication: 3.3 V CMOS asynchronous serial @ 9600
3. baud default for microcontrollers, or USB for PC
4. Dimensions: 1.7 x 1.6 x 0.6 in (4.33 x 4.09 x 1.52 cm)
5. Operating temperature: -22 to +185 °F (-30 to +85 °C)

Packing List

1. RXM-SG GPS Module
2. 2 shorting blocks (pre-installed)
3. 1575.42 MHz external GPS antenna with 9' cable
4. 3 V Lithium battery (CR2032)

Quick-Start Guide

Install the battery on the module: slide the battery under the clip on the back, from the top, ensuring that the + symbol faces away from the PCB. Connect the External GPS antenna to its MMCX connector.

.

For Microcontrollers

Make sure the jumper block is in the Open position, as shown in Figure 2.
Connect the GPS module's GND pin to ground, and +5V pin to regulated 5 VDC.
Minimum I/O connection is to connect the GPS module's TX pin to your microcontroller's available I/O pin set to input. Read the Communication Protocol section on page 3 before interfacing a 5V microcontroller to the GPS module's RX or other input pins.

Theory of Operation

Global Positioning System (GPS) is a space-based global navigation system providing location and time information anywhere on or near the earth. The system was created by the United States Department of Defense and consists of 24 satellites orbiting the earth. With an unobstructed view of the sky the GPS system will attempt to acquire and lock on to three or more satellites to provide a position fix using trilateration. Time information is provided by atomic clocks aboard each satellite. This information is provided to the user in UTC format.

Supplying Power

The RXM-SG GPS module includes one 3 V lithium CR2031 battery. This battery is necessary for the module to operate. The purpose of the battery is to provide a backup power supply for the SRAM and RTC only; it is not sufficient on its own to power the module for operation. There are two power options:

When using a PC connection via USB, the module draws power from the USB port for operation.

When using a microcontroller connection, the module requires 50 mA of 5 V regulated DC voltage on its +5V pin (and a ground connection on GND).

Jumper Block

The purpose of the jumper block is to prevent write contention to the GPS module's TX and ON_OFF lines. The jumper block should always be in the Open position when used with a microcontroller, and in the Shorted position when used with a PC via USB. However, it is possible to receive data from the module by either method with the jumper block in either position.

LEDs

There are three surface-mount LEDs on the GPS module:

1. Red (leftmost): Transmitting data to PC via USB
2. Blue (center): Receiving data from PC via USB
3. Green (rightmost): GPS channel lock status. This LED will blink rapidly while acquiring satellites signals until three channels have locked onto satellites. Once three channels are locked, the blinking will slow to a once-per-second rate.

Communication Protocol

Communication with the RXM-SG GPS Module is via non-inverted, 3.3 V CMOS level serial protocol at a default baud rate of 9600 bps. The baud rate can be set via command to 4800, 9600, 19200, 38400 or 57600 bps via the SetSerialPort command (see datasheet). Note that the GPS is compatible with 5 V microcontrollers from the perspective of the GPS output. Any signals going into the GPS module would need to be buffered using a level translator or buffer chip such as the 74LVC244A (Parallax #603-10004).

Calibration

GPS calibration is not necessary as the GPS Module will download the necessary data from the available satellites automatically, however when the GPS Module is first powered up it must acquire ephemeral data from the satellites, which can take several minutes. Accuracy improves as more satellites are acquired, however civilian GPS resolution is around 20 yards (65 feet).

Please see the RXM-GPS-SG datasheet for additional information.

Pin Definitions

PIN	NAME	TYPE	FUNCTION
1	GND	G	Ground (0 V)
2	+5V	P	Power (5 V)
3	RX	I	GPS Receive
4	TX	O	GPS Transmit
5	RFPWRUP	O	Power State Indication
6	ON_OFF	I	Edge Triggered soft on/off request
7	N/C	—	No Connection
8	GPIO01	I/O	General Purpose I/O
9	GPIO14	I/O	General Purpose I/O
10	GPIO15	I/O	General Purpose I/O
11	GPIO13	I/O	General Purpose I/O

APPENDIX B2
ZIGBEE DATASHEET

XBee®/XBee-PRO® RF Modules

The XBee and XBee-PRO RF Modules were engineered to meet IEEE 802.15.4 standards and support the unique needs of low-cost, low-power wireless sensor networks. The modules require minimal power and provide reliable delivery of data between devices. The modules operate within the ISM 2.4 GHz frequency band and are pin-for-pin compatible with each other.

Key features

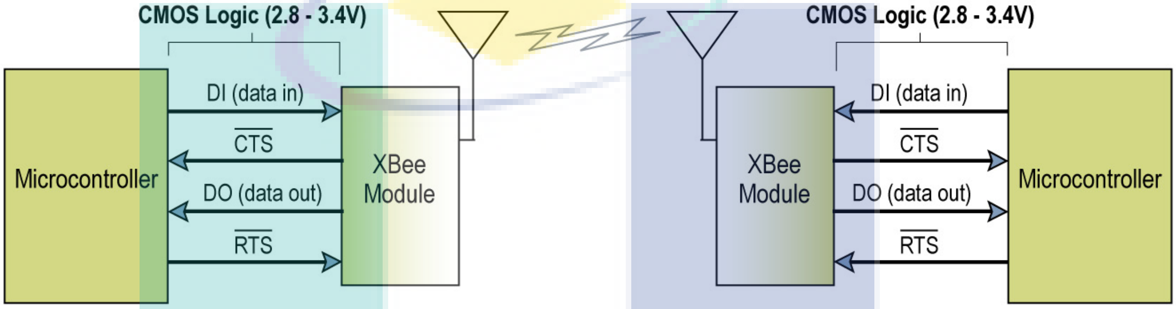
- Indoor/Urban: up to 300’ (90 m), 200' (60 m) for International variant
- Outdoor line-of-sight: up to 1 mile (1600 m), 2500' (750 m) for International variant
- Transmit Power: 63mW (18dBm), 10mW (10dBm) for International variant
- Receiver Sensitivity: -100 dBmRF
- Data Rate: 250,000 bps
- TX Peak Current: 250mA (150mA for international variant)
- TX Peak Current (RPSMA module only): 340mA (180mA for international variant
- RX Current: 55 mA (@3.3 V)
- Power-down Current: < 10 µA

Serial Communications

The XBee®/XBee-PRO® RF Modules interface to a host device through a logic-level asynchronous serial port. Through its serial port, the module can communicate with any logic and voltage com-patible UART; or through a level translator to any serial device (For example: Through a Digi pro-prietary RS-232 or USB interface board).

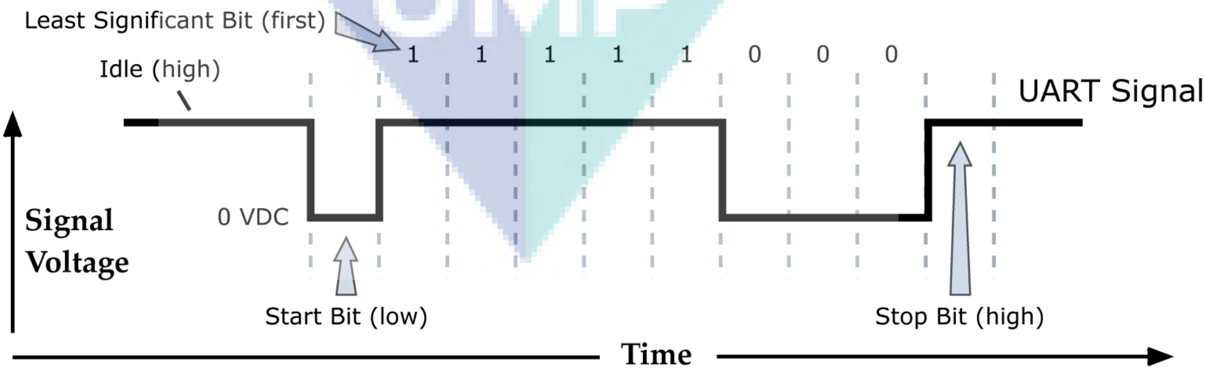
UART Data Flow

Devices that have a UART interface can connect directly to the pins of the RF module as shown in the figure below.



System Data Flow Diagram in a UART-interfaced environment

Data enters the module UART through the DI pin (pin 3) as an asynchronous serial signal. The signal should idle high when no data is being transmitted. Each data byte consists of a start bit (low), 8 data bits (least significant bit first) and a stop bit (high). The following figure illustrates the serial bit pattern of data passing through the module.



UART data packet 0x1F (decimal number "31") as transmitted through the RF module

Example Data Format is 8-N-1 (bits - parity - # of stop bits) Serial communications depend on the two UARTs (the microcontroller's and the RF module's) to be configured with compatible settings (baud rate, parity, start bits, stop bits, data bits). The UART baud rate and parity settings on the XBee module can be configured with the BD and SB commands, respectively.

Transparent Operation

By default, XBee®/XBee-PRO® RF Modules operate in Transparent Mode. When operating in this mode, the modules act as a serial line replacement - all UART data received through the DI pin is queued up for RF transmission. When RF data is received, the data is sent out the DO pin.

Serial-to-RF Packetization.

Data is buffered in the DI buffer until one of the following causes the data to be packetized and transmitted:

1. No serial characters are received for the amount of time determined by the RO (Packetiza-tion Timeout) parameter. If RO = 0, packetization begins when a character is received.
2. The maximum number of characters that will fit in an RF packet (100) is received.
3. The Command Mode Sequence (GT + CC + GT) is received. Any character buffered in the DI buffer before the sequence is transmitted.

If the module cannot immediately transmit (for instance, if it is already receiving RF data), the serial data is stored in the DI Buffer. The data is packetized and sent at any RO timeout or when 100 bytes (maximum packet size) are received. If the DI buffer becomes full, hardware or software flow control must be implemented in order to prevent overflow (loss of data between the host and module).

API Operation

API (Application Programming Interface) Operation is an alternative to the default Transparent Operation. The frame-based API extends the level to which a host application can interact with the networking capabilities of the module. When in API mode, all data entering and leaving the module is contained in frames that define operations or events within the module. Transmit Data Frames (received through the DI pin (pin 3)) include:

• RF Transmit Data Frame

• Command Frame (equivalent to AT commands) Receive Data Frames (sent out the DO pin (pin 2)) include:

• RF-received data frame

• Command response

• Event notifications such as reset, associate, disassociate, etc.

The API provides alternative means of configuring modules and routing data at the host applica-tion layer. A host application can send data frames to the module that contain address and payload information instead of using command mode to modify addresses. The module will send data frames to the application containing status packets; as well as source, RSSI and payload informa-tion from received data packets. The API operation option facilitates many operations such as the examples cited below: To implement API operations, refer to API sections [p57]. 1. No serial characters are received for the amount of time determined by the RO (Packetiza-tion Timeout) parameter.

DI (Data In) Buffer

When serial data enters the RF module through the DI pin (pin 3), the data is stored in the DI Buf-fer until it can be processed.

Hardware Flow Control (CTS).

When the DI buffer is 17 bytes away from being full; by default, the module de-asserts CTS (high) to signal to the host device to stop sending data [refer to D7 (DIO7

Configuration) parameter]. CTS is re-asserted after the DI Buffer has 34 bytes of memory available.

How to eliminate the need for flow control:

1. Send messages that are smaller than the DI buffer size (202 bytes).
2. Interface at a lower baud rate [BD (Interface Data Rate) parameter] than the throughput data rate.

Case in which the DI Buffer may become full and possibly overflow

Refer to the RO (Packetization Timeout), BD (Interface Data Rate) and D7 (DIO7 Configuration) com-mand descriptions for more information.

DO (Data Out) Buffer

When RF data is received, the data enters the DO buffer and is sent out the serial port to a host device. Once the DO Buffer reaches capacity, any additional incoming RF data is lost.

Hardware Flow Control (RTS).

If RTS is enabled for flow control (D6 (DIO6 Configuration) Parameter = 1), data will not be sent out the DO Buffer as long as RTS (pin 16) is de-asserted.

Two cases in which the DO Buffer may become full and possibly overflow:

1. If the RF data rate is set higher than the interface data rate of the module, the module will receive data from the transmitting module faster than it can send the data to the host.

2. If the host does not allow the module to transmit data out from the DO buffer because of being held off by hardware or software flow control.

I/O Data Format

I/O data begins with a header. The first byte of the header defines the number of samples forth-coming. The last 2 bytes of the header (Channel Indicator) define which inputs are active. Each bit represents either a DIO line or ADC channel. Data follows the header and the channel indicator frame is used to determine how to read the sample data. If any of the DIO lines are enabled, the first 2 bytes are the DIO sample. The ADC data follows. ADC channel data is represented as an unsigned 10-bit value right-justified on a 16- bit boundary.

I/O Line Passing

Virtual wires can be set up between XBee®/XBee-PRO® Modules. When an RF data packet is received that contains I/O data, the receiving module can be setup to update any enabled outputs (PWM and DIO) based on the data it receives. Note that I/O lines are mapped in pairs. For example: AD0 can only update PWM0 and DI5 can only update DO5. The default setup is for outputs not to be updated, which results in the I/O data being sent out the UART (refer to the IU (Enable I/O Output) command). To enable the outputs to be updated, the IA (I/O Input Address) parameter must be setup with the address of the module that has the appropriate inputs enabled. This effectively binds the outputs to a particular module's input. This does not affect the ability of the module to receive I/O line data from other modules - only its ability to update enabled outputs. The IA parameter can also be setup to accept I/O data for output changes from any module by setting the IA parameter to 0xFFFF. When outputs are changed from their non-active state, the module can be setup to return the out-put level to it non-active state. The timers are set using the Tn (Dn Output Timer) and PT (PWM Output Timeout) commands. The timers are reset every time a valid I/O packet (passed IA check) is received. The IC (Change Detect) and IR (Sample Rate) parameters can be setup to keep the output set to their active output if the system needs more time than the timers can handle.

Configuration Example

As an example for a simple A/D link, a pair of RF modules could be set as follows:

Remote Configuration

DL = 0x1234

MY = 0x5678

D0 = 2

D1 = 2

IR = 0x14

IT = 5

Base Configuration

DL = 0x5678

MY = 0x1234

P0 = 2

P1 = 2

IU = 1

IA = 0x5678 (or 0xFFFF)

These settings configure the remote module to sample AD0 and AD1 once each every 20 ms. It then buffers 5 samples each before sending them back to the base module. The base should then receive a 32-Byte transmission (20 Bytes data and 12 Bytes framing) every 100 ms.

XBee®/XBee-PRO® Networks; peer to peer

By default, XBee®/XBee-PRO RF Modules are configured to operate within a Peer-to-Peer network topology and therefore are not dependent upon Master/Slave relationships. NonBeacon systems operate within a Peer-to-Peer network topology and therefore are not dependent upon Master/ Slave relationships. This means that modules remain synchronized without use of master/server configurations and each module in the network shares both roles of master and slave. Digi's peer-to-peer architecture features fast synchronization times and fast cold start times. This default con-figuration accommodates a wide range of RF data applications.

The detailed pin signals are given below;

Pin Signals

Pin #	Name	Direction	Description
1	VCC	-	Power supply
2	DOUT	Output	UART Data Out
3	DIN / CONFIG	Input	UART Data In
4	DO8*	Output	Digital Output 8
5	RESET	Input	Module Reset (reset pulse must be at least 200 ns)
6	PWM0 / RSSI	Output	PWM Output 0 / RX Signal Strength Indicator
7	PWM1	Output	PWM Output 1
8	[reserved]	-	Do not connect
9	DTR / SLEEP_RQ / DI8	Input	Pin Sleep Control Line or Digital Input 8
10	GND	-	Ground
11	AD4 / DIO4	Either	Analog Input 4 or Digital I/O 4
12	CTS / DIO7	Either	Clear-to-Send Flow Control or Digital I/O 7
13	ON / SLEEP	Output	Module Status Indicator
14	VREF	Input	Voltage Reference for A/D Inputs
15	Associate / AD5 / DIO5	Either	Associated Indicator, Analog Input 5 or Digital I/O 5
16	RTS / AD6 / DIO6	Either	Request-to-Send Flow Control, Analog Input 6 or Digital I/O 6
17	AD3 / DIO3	Either	Analog Input 3 or Digital I/O 3
18	AD2 / DIO2	Either	Analog Input 2 or Digital I/O 2
19	AD1 / DIO1	Either	Analog Input 1 or Digital I/O 1
20	AD0 / DIO0	Either	Analog Input 0 or Digital I/O 0

APPENDIX B3
PIC DATASHEET

PIC16F87XA, 28/40/44-Pin Enhanced Flash Microcontrollers

High-Performance CPU

• Only 35 single-word instructions to learn
• All single-cycle instructions except for program branches, which are two-cycle
• Operating speed: DC – 20 MHz clock input DC – 200 ns instruction cycle
• Up to 8K x 14 words of Flash Program Memory, Up to 368 x 8 bytes of Data Memory (RAM), Up to 256 x 8 bytes of EEPROM Data Memory
• Pinout compatible to other 28-pin or 40/44-pin PIC16CXXX and PIC16FXXX microcontrollers

Peripheral Features

• Timer0: 8-bit timer/counter with 8-bit prescaler
• Timer1: 16-bit timer/counter with prescaler, can be incremented during Sleep via external crystal/clock
• Timer2: 8-bit timer/counter with 8-bit periodregister, prescaler and postscaler
• Two Capture, Compare, PWM modules
- Capture is 16-bit, maximum resolution is 12.5 ns
- Compare is 16-bit, maximum resolution is 200 ns
- PWM maximum resolution is 10-bit
• Synchronous Serial Port (SSP) with SPI™ (Master mode) and I2C™ (Master/Slave)
• Universal Synchronous Asynchronous ReceiverTransmitter (USART/SCI) with 9-bit address detection

• Parallel Slave Port (PSP) – 8 bits wide with external RD, WR and CS controls (40/44-pin only)

• Brown-out detection circuitry for Brown-out Reset (BOR)

Special Microcontroller Features

• 100,000 erase/write cycle Enhanced Flashprogram memory typical

• 1,000,000 erase/write cycle Data EEPROM memory typical

• Data EEPROM Retention > 40 years

• Self-reprogrammable under software control

• In-Circuit Serial Programming™ (ICSP™) via two pins

• Single-supply 5V In-Circuit Serial Programming

• Watchdog Timer (WDT) with its own on-chip RC oscillator for reliable operation

• Programmable code protection

• Power saving Sleep mode

• Selectable oscillator options

• In-Circuit Debug (ICD) via two pins

CMOS Technology

• Low-power, high-speed Flash/EEPROM technology

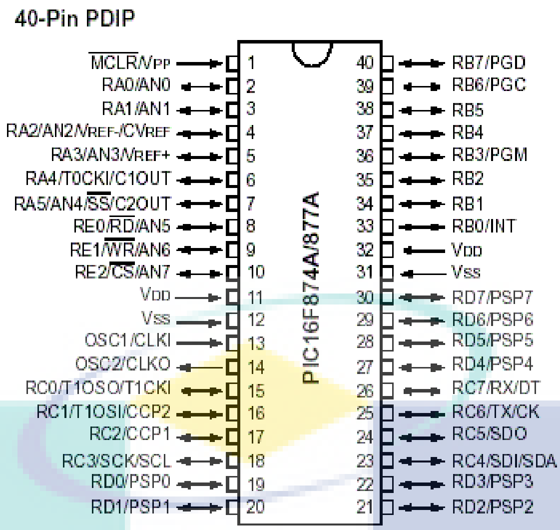
• Fully static design

• Wide operating voltage range (2.0V to 5.5V)

• Commercial and Industrial temperature ranges

• Low-power consumption

Pin diagram



I/O PORTS

Some pins for these I/O ports are multiplexed with an alternate function for the peripheral features on the device. In general, when a peripheral is enabled, that pin may not be used as a general purpose I/O pin. The overall five ports are provided named as

Port A, Port B, Port C, Port D and Port E

PORTC is an 8-bit wide, bidirectional port. The corresponding data direction register is TRISC. Setting a TRISC bit (= 1) will make the corresponding PORTC pin an input (i.e., put the corresponding output driver in a High-Impedance mode). Clearing a TRISC bit (= 0) will make the corresponding PORTC pin an output (i.e., put the contents of the output latch on the selected pin). PORTC is multiplexed with several peripheral functions. The USART is the most commonly used as peripheral. It is found in PORT C, which is described below;

RC6/TX/CK	bit 6	ST	Input/output port pin or USART asynchronous transmit or synchronous clock.
RC7/RX/DT	bit 7	ST	Input/output port pin or USART asynchronous receive or synchronous data.

ST= Schmitt trigger input

APPENDIX C1

GPS LOCATION DATA RECEPTION CODING FOR SELECTED DIGITS

```
'****************************************************************
'*  Name    : UNTITLED.BAS                                      *
'*  Author  : [select VIEW...EDITOR OPTIONS]                    *
'*  Notice  : Copyright (c) 2010 [select VIEW...EDITOR OPTIONS] *
'*          : All Rights Reserved                               *
'*  Date    : 12.08.2010                                        *
'*  Version : 1.0                                               *
'*  Notes   :                                                   *
'*          :                                                   *
'****************************************************************

Device=16F877
XTAL=20
Declare HSERIAL_BAUD 9600
ALL_DIGITAL=true
Dim LAT As Byte           'latitude degree var
Dim LATM As Byte          'latitude minute var
Dim LATS As Word          'latitude seconds var
Dim LATDIR As Byte        'latitude direction var
Dim LON As Word           'longitude degree var
Dim LONGM As Byte         'longitude minute var
Dim LONS As Word          'longitude seconds var
Dim LONDIR As Byte        'longitude direction var
Dim valid As Byte         'GPs valid indication var
Dim X1 As Word
Dim COURSE As Word
Symbol Led=PORTD.1
Input PORTC.7

Main:
'RECEIVE DATA FROM GPS
SerIn PORTC.7,84,[Wait("GPRMC,"),Wait(","),valid,Wait(","),DEC2 LAT,DEC2
LATM,Wait("."),DEC3 LATS,Wait(","),LATDIR,Wait(","),DEC3 LON,DEC2
LONGM,Wait("."),DEC3 LONS,Wait(","), LONDIR,Wait(","),Dec X1,Wait(","),Dec
COURSE]
DelayMS 500

Toggle Led
DelayMS 100
GoTo Main
```

APPENDIX C2

MASTER MODULE CODING FOR TESTING AT KUALA LUMPUR

```
'*************************************************************
'*  Name    : UNTITLED.BAS                                *
'*  Author  : [select VIEW...EDITOR OPTIONS]              *
'*  Notice  : Copyright (c) 2011 [select VIEW...EDITOR OPTIONS] *
'*          : All Rights Reserved                         *
'*  Date    : 12.01.2011                                  *
'*  Version : 1.0                                         *
'*  Notes   :                                             *
'*************************************************************

Device=16F877a
XTAL=4
Declare HSERIAL_BAUD 9600
ALL_DIGITAL=true
Declare LCD_TYPE 0
Declare LCD_DTPIN PORTD.4
Declare LCD_ENPIN PORTD.3
Declare LCD_RSPIN PORTD.2
Declare LCD_INTERFACE 4
Declare LCD_LINES 2

Dim LAT As Byte          'latitude degree var
Dim LATM As Byte          'latitude minute var
Dim LATS As Word          'latitude seconds var
Dim LATDIR As Byte          'latitude direction var
Dim LON As Word          'longitude degree var
Dim LONGM As Byte          'longitude minute var
Dim LONS As Word          'longitude seconds var
Dim LONDIR As Byte          'longitude direction var
Dim valid As Byte        'GPs valid indication var
Dim X1 As Word
Dim COURSE As Word

dim P as float
dim flt1 as float
dim flt2 as float
dim flt3 as float
dim flt4 as float

DIM flt5 as float
dim flt6 as float

SYMBOL p1 = 25.20266832
symbol p2 = 1.321582163
symbol p3 = 0.02467396989
```

```
symbol p4 = 7.753245435
symbol p5 = 0.1525904315

cls

Symbol Led=PORTA.1
Input PORTB.2

Main:
'RECEIVE DATA FROM GPS IN SEPERATED FORMS
SerIn PORTc.7,84,[Wait("GPRMC,"),Wait(","),valid,Wait(","),DEC2 LAT,DEC2
LATM,Wait("."),DEC3 LATS,Wait(","),LATDIR,Wait(","),DEC3 LON,DEC2
LONGM,Wait("."),DEC3 LONS,Wait(","), LONDIR,Wait(","),Dec X1,Wait(","),Dec
COURSE]
DelayMS 500

'A = LONGM
'B = LONS
'C = LATM
'D = LATS

flt1 = p2 * longm
flt2 = p3 * lons
flt3 = p4 * latm
flt4 = p5 * lats

flt5 = p1 + flt1 + flt2
flt6 = flt3 + flt4
p = flt5 - flt6
'P = flt + flt1 + flt2 - flt3 - flt4

'TO PRINT ON LCD
PRINT AT 2,6, "BUS STOP#", dec1 P
Toggle Led
DelayMS 100

if P<=1.5 then PRINT AT 2,6, "BUS STOP#", dec1 P
if P<=2.6 then PRINT AT 2,6, "BUS STOP#", dec1 P
if P<=2.7 then PRINT AT 2,6, "BUS STOP#", dec1 P
if P<=3.5 then PRINT AT 2,6, "BUS STOP#", dec1 P
if P<=4.7 then PRINT AT 2,6, "BUS STOP#", dec1 P
if P<=6.8 then PRINT AT 2,6, "BUS STOP#", dec1 P
if P<=7.2 then PRINT AT 2,6, "BUS STOP#", dec1 P
if P<=7.8 then PRINT AT 2,6, "BUS STOP#", dec1 P
if P<=8.6 then PRINT AT 2,6, "BUS STOP#", dec1 P
if P<=9.6 then PRINT AT 2,6, "BUS STOP#", dec1 P
if P<=11.4 then PRINT AT 2,6, "BUS STOP#", dec1 P

GoTo Main
```

APPENDIX C3

SLAVE MODULE CODING

```
'****************************************************************
'*  Name    : UNTITLED.BAS                                      *
'*  Author  : [select VIEW...EDITOR OPTIONS]                    *
'*  Notice  : Copyright (c) 2010 [select VIEW...EDITOR OPTIONS] *
'*          : All Rights Reserved                               *
'*  Date    : 30.11.2010                                        *
'*  Version : 1.0                                               *
'*  Notes   :                                                   *
'*          :                                                   *
'****************************************************************
Device=16F877a
XTAL=20
ALL_DIGITAL=true
Input PORTC.7
Symbol XbeeDin=PORTC.6
Symbol XbeeDout=PORTC.7
Symbol Led0=PORTC.2

Symbol Led1=PORTb.7
Symbol Led2=PORTb.6
Symbol Led3=PORTb.5
Symbol Led4=PORTb.4
Symbol Led5=PORTb.3
Symbol Led6=PORTb.2
Symbol Led7=PORTb.1
Symbol Led8=PORTb.0
Symbol Led9=PORTD.7
Symbol led10=PORTD.6
Symbol led11=PORTD.5

for t=1 to 20
toggle led0
delayms 400
next t

low Led1
low led2
low led3
low led4
low led5
low led6
low led7
low led8
```

```
low led9
low led10
low led11

main:
SerIn PORTC.7,84,[key]
DelayMS 30
if key= "1" then high led1
if key= "2" then high led2
if key= "3" then high led3
if key= "4" then high led4
if key= "5" then high led5
if key= "6" then high led6
if key= "7" then high led7
if key= "8" then high led8
if key= "9" then high led9
if key= "A" then high led10
if key= "B" then high led11

SerOut PORTC.6,84,[DEC1 key]

GoTo main
```

APPENDIX D

Pictorial Exhibition of Master, Slave and Overall Prototype System

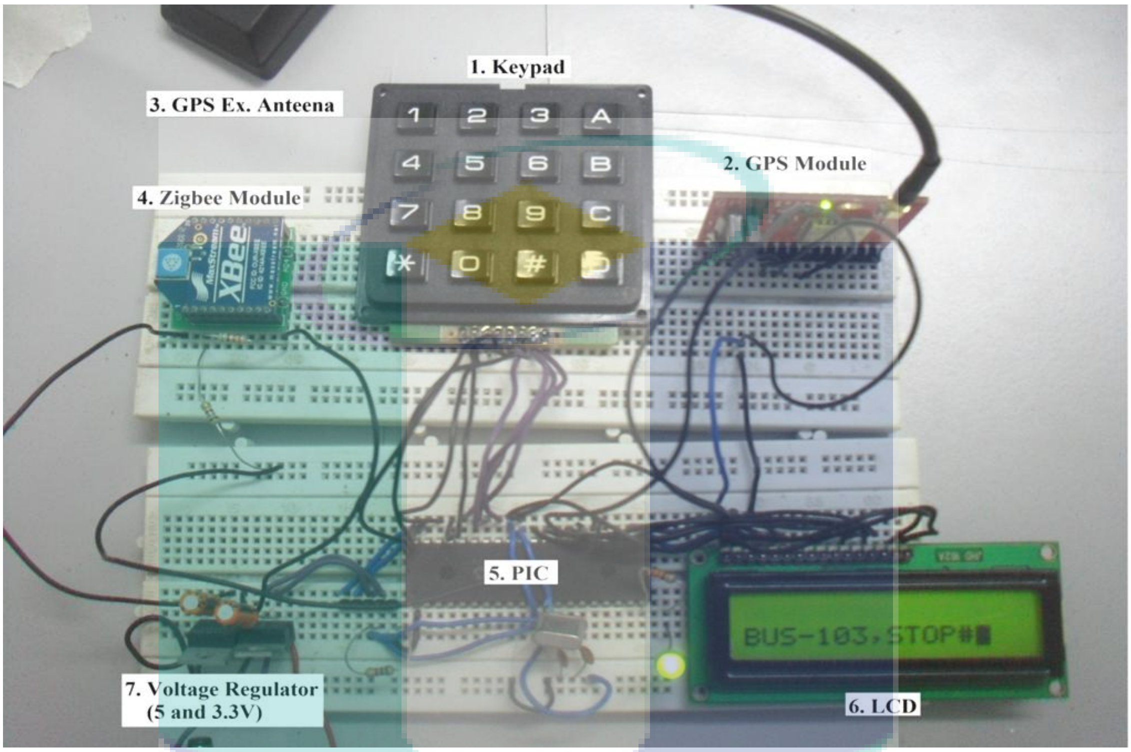


Figure D-1: Master module prototype

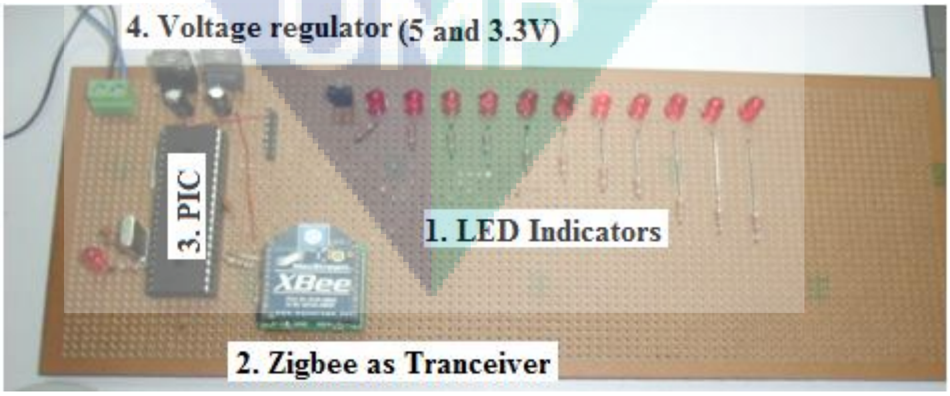


Figure D-2: Slave module prototype

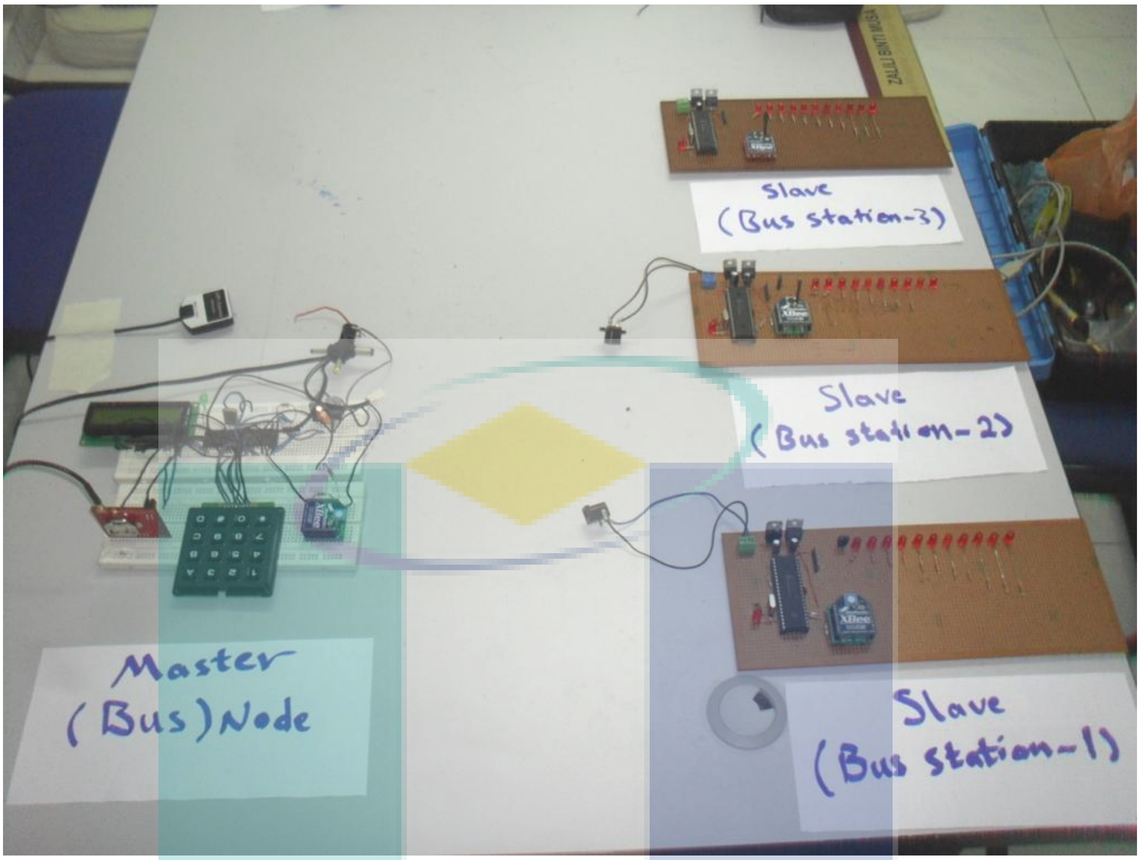


Figure D-3: Overall prototype in pictorial form