# TRAFFIC CONGESTION DETECTION SYSTEM USING WIRELESS SENSOR NETWORK

By

AHMAD SYAFEEQ IMTIAZ BIN AHMAD FARHAN

13626

DISSERTATION

Submitted to the Electrical & Electronics Engineering Programme
in Partial Fulfillment of the Requirements
for the Degree
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)
MAY 2014

Universiti Teknologi PETRONAS

Bandar Seri Iskandar

31750 Tronoh

Perak Darul Ridzuan

# CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
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Approved by,

____________________________

Dr. Nasreen Bt Badruddin
Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

May 2014

# CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Ahmad Syafeeq Imtiaz bin Ahmad Farhan

# ABSTRACT

Traffic congestion has been a problem for a long time. It is known that traffic congestion would cause delays, high fuel consumption and high pollution index. In order to avoid high levels of road traffic congestion, a reliable and accurate detection system is needed. By using traffic parameters such as speed and density of vehicles the road, an application of Wireless Sensor Network (WSN) could be utilised. The evaluation of the road traffic congestion detection system includes the presence of congestion and the level of congestion itself. This detection system will be implemented on a scaled-down prototype/modelling in order to test the effectiveness.

# ACKNOWLEDGMENTS

Special thanks to my supervisor Dr Nasreen Bt. Badruddin for her dedication helps to spend her precious time to teach, and guide me despite she has many other obligations. My gratitude towards Dr. Micheal Drieberg, for sharing his expertise on wireless sensor networks and always keeping his door open. Many thanks to my family back home for their sacrifices coupled with their continuous encouragement and support and heading me towards the stars. Special thanks to all the friends that help me completing this project and together brainstorming in order to encounter problem faced. Each and every helps of them means the world for me.

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# CHAPTER 1: INTRODUCTION

This chapter explains briefly the project topic, "Traffic Congestion Detection Using Wireless Sensor Networks". Background of the study, problem statement, objectives and the scope of study is highlighted throughout this chapter.

## Background of Study

Since urban transportation arises, traffic congestion has also increased in big cities throughout the world. Traffic congestion has given several impacts throughout peoples' daily lives. Some of them are delays, heavy fuel consumption, high pollution index and increase in number of road rages [1]. In order to overcome this problem Intelligent Transport System (ITS) has been developed widely. According to [2] ITS is defined as an integrated system which can monitor and manage traffic accurately and efficiently in real-time.

Many research has been done in order to perfect the purpose of ITS with the lowest cost possible. Since there are still weaknesses or imperfection in the development, there is still room for improvement. A wireless sensor network (WSN) can be implemented for the purpose of ITS. With WSN, a system that can detect the occurrence of traffic congestion through sensor networks and transmit back the information analysed as warning to the users can be developed. With this system, it can help drivers to avoid congested roads and also alleviate the congestion which are parallel to the objective of ITS itself.

## Problem Statement

In order to avoid traffic congestion level to be high, a reliable and effective traffic monitoring system is needed. One of the ways to achieve this is through a WSN system that can detect traffic congestion with the use of sensors and can transmit the information wirelessly to all other drivers. Although there are many sensors available in the market, not all of them can deliver the information needed accurately and in real-time. With this problem at hand, an appropriate combination of sensors needed to be determined in order to detect congestion precisely. Furthermore, the data acquired from this sensor combination needs to be analysed in order to identify and quantify the traffic congestion level.  Besides that, a properly designed WSN is also needed for relaying all the information gathered.

**Objectives**

The objectives of this project are:

- To identify the best combination of sensors which can accurately detect traffic congestion
- To design a working scale-down prototype of a WSN system which takes the sensor readings and relays information regarding the congestion

**Scope of Study**

The scope of study of this project is as follows:

- Determine the sensors that can perform and provide the data needed for traffic congestion detection
- Determine the best technique to analyse the data retrieved from the sensors in order to decide on the traffic congestion level
- Produce a working scale-down prototype with proper WSN system in order to prove the effectiveness of the system

# CHAPTER 2: LITERATURE REVIEW AND THEORY

This chapter reviews the critical points and theories covered in this project

## 2.1 Intelligent Transport System

Based on [3] Intelligent Transport System (ITS) is a subjective term where there is no definite definition. Basically ITS is an integrated system that utilise the technologies of communication, control, electronic sensor and information processing with regard to transport system [2]. The main reason of ITS existence is to provide solution regarding traffic matters where this solution could save more lives, time, money, energy and the environment. From [3, 4] ITS has been used widely in world for travel and transportation management, travel demand management, public transportation operations, electronic payment services, commercial vehicle operations, emergency management, environmental management and advanced vehicle control and safety system.

One of the ITS usage is for travel and transportation management where one of the element in it is traffic congestion detection. Many have done research and studies on this element by using various technologies.[5-9] had developed on traffic congestion detection where it utilise the technology of Vehicular Ad-hoc Networks (VANET). VANET is a network of mobile nodes which are the vehicles that roamed a section of a road and communicate with each other [8, 9]. The communication done by the nodes is actually a change of information regarding the node's status at the time such as their velocity, travel time and position. With these information at hands VANET can be used for traffic congestion detection. Different studies used different techniques of utilising VANET technology in order to detect the traffic congestion. [5] used information gathered within the VANET network and processed them on-the-fly. They utilise the information and used the geocast protocol for exchanging road traffic information between the vehicles and suggest the user the least congested route using their own modified Dijkstra algorithm. Whereas [6] used information from the tail vehicle in order to determine the queue length of vehicle during traffic congestion. The information will be relay to a road side unit (RSU) for processing. Figure 1 shows their scheme of detecting the traffic congestion.

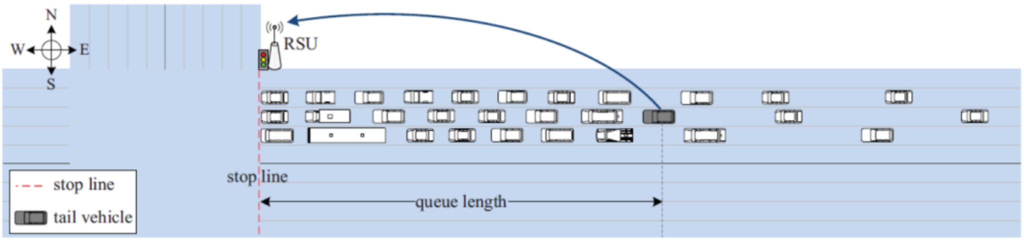



Figure 1 Traffic Congestion Detection Scheme by using Queue-Length utilising the VANET technology [6]

Based on the studies done on VANET technology, it can be observed that the information gathered can be used for detecting traffic congestion by using different techniques.

In other studies, [10] used the probe vehicle technology in developing a traffic congestion prediction model. The probe vehicle technology is basically a method of obtaining the journey time and speed of the probe vehicle by recording the data utilising the Global Positioning System (GPS) technology. [10] used the obtained data and analysed them with back-propagation neural network and fuzzy logic judgement in order to predict the traffic congestion probability, level of congestion and possible forming time. This study is basically to predict the traffic congestion before it is happening. Figure 2 shows the model they have developed in order to predict the congestion before it happens.

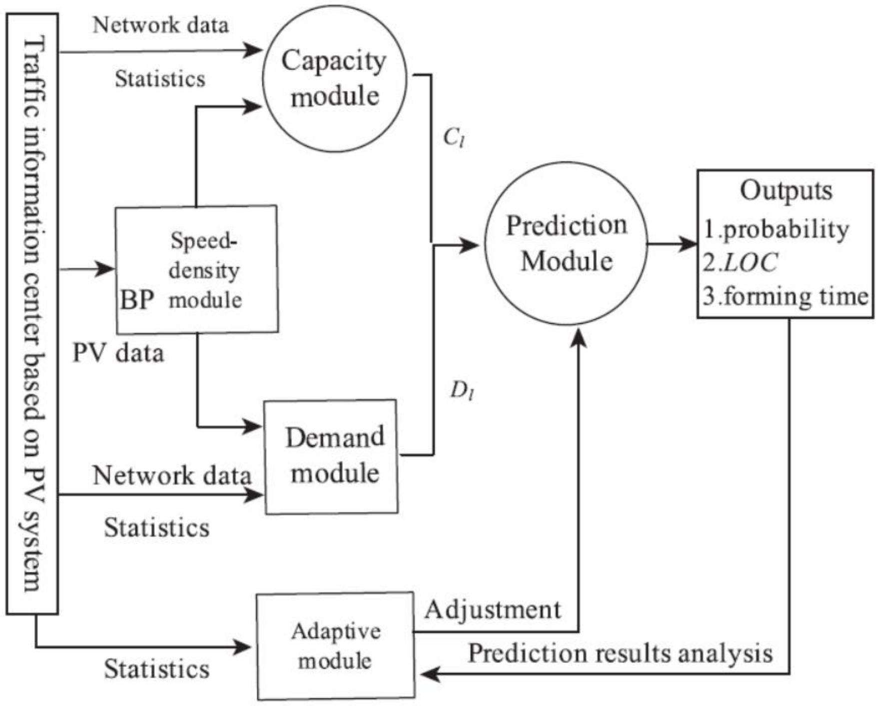



Figure 2 Model outline of detecting traffic congestion by using probe vehicle (PV) technology [10]

There are also studies that rely on RF technology for traffic congestion detection. Research [11, 12] utilised this technology in order to have fast and wireless system of acquiring and analyse data for detecting traffic congestion. Based on studies done by [11], they utilised the differential behaviour of RF wireless links in line-of-sight (LOS) and non-line-of-sight (NLOS) condition. Figure 3 shows how do they interpret the traffic congestion.

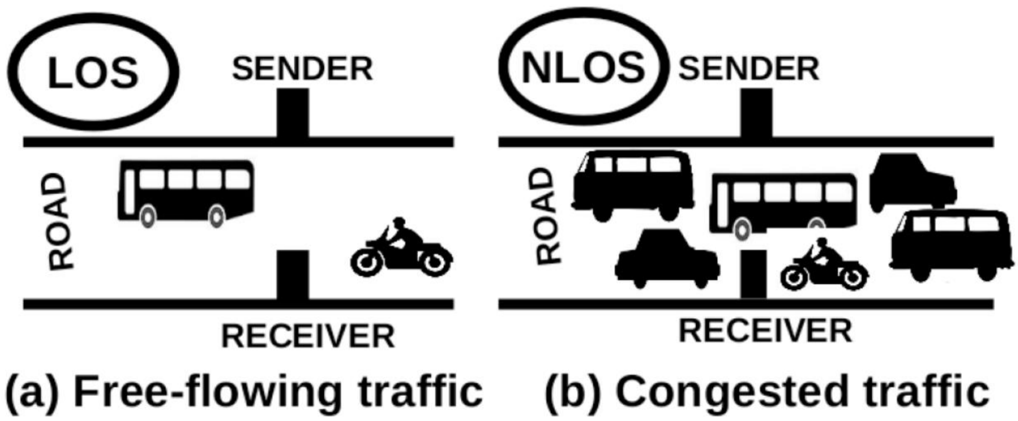



Figure 3 Traffic congestion definition in using RF technology [11]

[12] also utilising the RF technology in detecting traffic congestion but they came with a different approach that is using the active RFID tag together with GSM technologies. They make use of the technology in order to get information of trip time and total waiting time of a vehicle in order to define congestion. Figure 4 shows the summary of how their congestion detection scheme are.

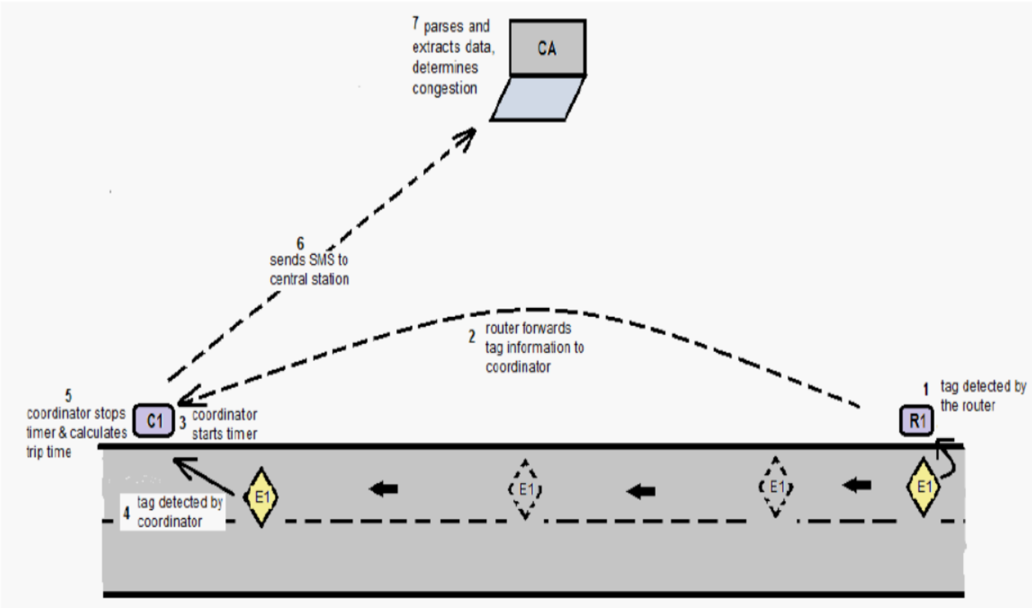



Figure 4 Congestion detection scheme by using RFID and GSM technology [12]

Application of wireless sensor network (WSN) for detecting traffic congestion has also been done by [2]. They used the WSN in order to forecast traffic flow and to control traffic congestion. The reason of the usage of WSN is because of the features that it give which are no space constraint, mobile convenient, quick reaction and flexible distribution. In their studies, the WSN is used for gathering information of the traffic data in real-time and they used gray forecast Adaptive GM (1,1) Model to forecast the traffic flow. The architecture of traffic monitoring network using the WSN by them can be seen in Figure 5. Based on the architecture, it can be observed that they used the multi-hop relay network with hierarchical architecture. It can be observed that the usage of WSN also reflects on high energy efficiency, self-organized, multi-hop routing and dynamic topology.

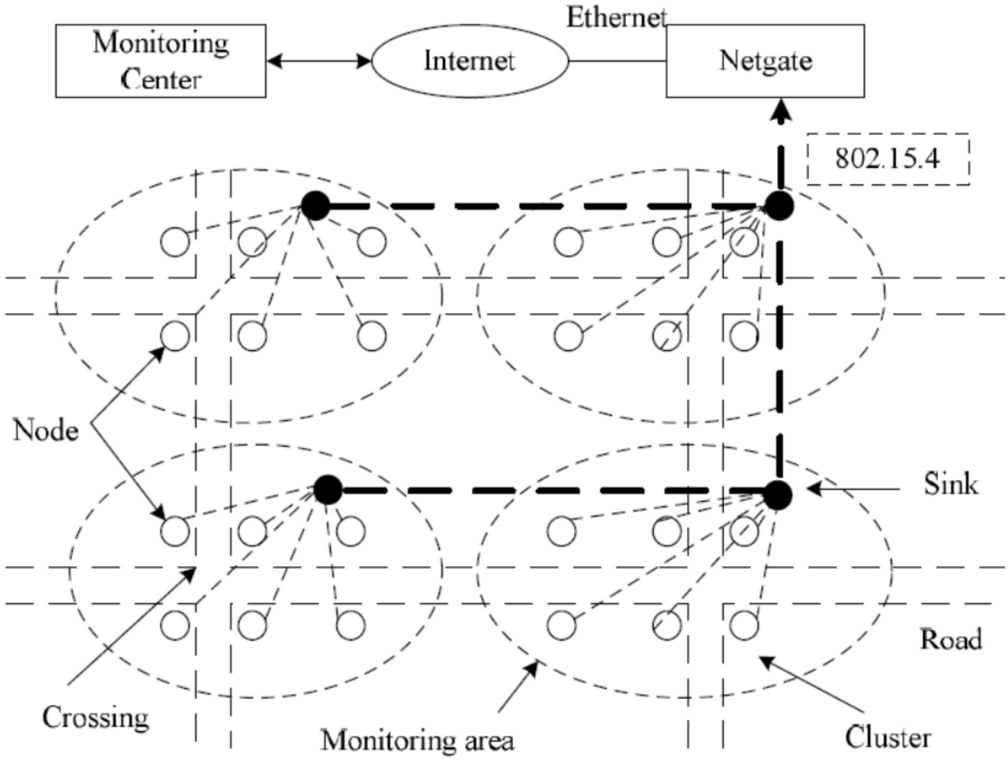



Figure 5 Architecture of WSN in traffic monitoring network

Many studies had been done for traffic congestion detection with various different technologies because there is no perfect model for the detection. Each study has a unique background and cases where their findings could only suit their problem. Even with that, it can be observed that all of the technologies used have a similarity that is they are being used for acquiring traffic parameters such as velocity, travelling time, total waiting time and etc. Therefore in order to detect traffic congestion even on a scale-down model, a suitable technologies should be selected. Since there is no standard method in detecting the traffic congestion, there are always rooms for improvement that can be made in order to have a near perfect model for the traffic congestion system.

## 2.2 Wireless Sensor Networks

A wireless sensor network (WSN) is a wireless network consisting of spatially distributed autonomous devices using sensors to monitor physical or environmental conditions which will transmit the information or data through the network to a main base [13, 14]. Nowadays the transmission of data can be a bi-directional transmission between the sensor and the main base. A WSN usually consists of nodes of sensor where it will transmit data to the main base where all the analysis will be done. Based on [14], a WSN have the following characteristics:

- Able to detect and cope with failure of nodes
- Have node that can be mobile
- Limitation on communications
- Easy to use
- Can survive in a harsh environment

There are many application can be done with usage of WSN. This application includes different type of area such as environment, health, military, traffic, natural disaster and data logging. WSN also has been used in studies for traffic congestion monitoring and forecasting. This is based on the dynamic behaviour of traffic congestion itself where it can happen anywhere and anytime. From the feature known, it is not appropriate to install equipment in a fixed location for monitoring and detecting traffic congestion [2]. WSN has also being used in traffic congestion monitoring not only because of the highly mobility of the system. It also has been used because of the low cost installation, low maintenance demand and low power consumption [15].

Even it is possible to have a good application with WSN, there are several challenges in order to handle it. According to [16] one of the challenges is to interpret the data acquired into a useful knowledge. Another challenge that needs to be face is on handling all the data in real-time. In order to have a quick response of a system, a good real-time data handling is needed.

Since one of the objective of this project is to build a scale-down prototype in order to simulate the traffic congestion system, a WSN system is really a suitable technology to be used. This is based on the fact it has low cost for installation, highly mobility for installation and do not require high demand on maintenance.

### 2.3 Quantifying Road Traffic Congestion

A good traffic congestion detection system should be able to determine different levels of congestion. Many have done research in order to quantify different level of road congestion. Up until now, no definitive method has been laid in order to measure the level of congestion. Even with that, several parameters has been widely used in order to quantify the road traffic congestion. The parameters include speed reduction index, travel delay, travel rate index, and travel time index[17]. The analysis of the acquired parameters also varies depending on the problem. Table 1 shows the definitions of parameters based on [18]:

Table 1 Traffic parameters definitions

| Parameters | Measurement |
|---|---|
| Travel Rate (minutes per mile) | $\frac{Travel\ Time\ (min)}{Segment\ Length\ (miles)}$ |
| Delay Rate (minutes per mile) | $Actual\ Travel\ Time\ (min/miles) - Acceptable\ Travel\ Rate\ (min/miles)$ |
| Total Segment Delay (veh/min) | $[Actual\ Travel\ Time\ (\text{min}) - Acceptable\ Travel\ Time\ (min)] \times Vehicle\ Volume\ (veh)$ |
| Relative Delay Rate | $\frac{Delay\ Rate}{Acceptable\ Travel\ Rate}$ |
| Delay Ratio | $\frac{Delay\ Rate}{Actual\ Travel\ Rate}$ |

One of many studies, [17] used mean velocity of vehicle in order to quantify the level of congestion. According to their study, quantifying traffic congestion does not rely only on quantitative data yet also rely on the qualitative data. They use the approach of having opinion from experienced driver in order to help them to build up their congestion index. Their congestion index is based on a threshold regarding velocity. These thresholds are determined by the mean velocity of a certain segment of the road and based on the definition of congestion from the familiar driver of the same segment of the roads. Their study was only based on one traffic parameters in order to quantify the level of congestion and yet the result was 47.06% correct all the time. From here it can be observed that the percentage of success can be increase if several traffic parameters are also taken into account.

As for analysing the data acquired, [19, 20] uses the fuzzy logic in order to conclude different level of traffic congestion. Even these studies uses the same analysis tool, the parameters taken as inputs are different. For instance [19], uses the mean velocity of vehicles and the road density in their study. They defined the road density as total number of vehicles at a segment of road at a certain period of time. Based on these parameters they trained the fuzzy logic and conclude a certain parameters called level of congestion (LOC). The training also involved in accounting the capacity of the roads.

In[20], 5 evaluation index in their analysis that are the average travel speed, the average delay per unit distance, the average stop number per unit distance, the average stops time per unit distance and the road saturation. The following are their definition of the evaluation indexes:

a) The average travel speed:

$$V_{travel} = L \times n / \sum_{i=1}^{n} t_i \quad (1)$$

Where $V_{travel}$ refers to the average travel speed, L refers to the travel length, n refers to the traffic flow and t refers to evaluation time

b) The average delay per unit distance:

$$D_{delay} = \left(1/V_{travel} - 1/V_{free}\right) \times 3600 \quad (2)$$

Where $D_{delay}$ refers to the average delay per unit distance, $V_{travel}$ and $V_{free}$ refers to the average travel speed and the free flow speed

c) The average stop number per unit distance

$$C_{stop} = \left(\sum_{i=1}^{n} C_i\right) / (L \times N) \quad (3)$$

Where $C_{stop}$ refers to the average stop number per unit distance and $C_i$ is the stop number of vehicle i

d) The average stops time per unit distance

$$T_{stop} = \left(\sum_{i=1}^{N} \sum_{j=1}^{k_j} t_{ij}\right) / (L \times N) \quad (4)$$

Where $T_{stop}$ refers to the average stop time per unit distance, $t_{ij}$ refers to the stop times of vehicle i in the stop process j.

e) The road saturation

$$M = N/C \tag{5}$$

Where M refers to the road saturation, N refers to the flow and C refers to the capacity

Based on the finding, there are wide ways in order to quantify congestion level. These includes the parameters to be obtain and the analysis tool to be used for concluding the data acquired. In order to simulate the traffic congestion in a small-scale prototype, the suitable traffic parameters are needed to be selected. Based on the finding, it can be said that the most popular and reliable parameters to be used are the velocity and density of the road. With the design planned, these parameters can be acquired using the WSN technology within the scale-down prototype.

## 2.4 Sensors in Traffic Monitoring

Traffic monitoring is one of the solution that coincide with the function of ITS. In order to monitor traffic conditions efficiently, appropriates sensors are needed. Many studies have been done in order to utilise the sensor technology in objective of monitoring the road traffic condition. [21] used vision-based sensor as an approach in monitoring the traffic. Based on them, the installed video camera along the road-side can be used in order to monitor traffic parameters such as entry and exit statistics, travelling time and incident or accident detection. With a vision-based sensor they achieved to extract the position of the vehicle, the orientation of the vehicle and the principle dimension of the vehicle. Based on the acquired data they manage to process the information in order to attain the traffic parameters such as vehicle count, mean average, the vehicle density, the queue length and even detect congestion and incident.

Aside from vision-based sensor, [22] utilised the loop detector in order to monitor the traffic status of a certain segment of roads. In their study they proposed a measurement for the road outline and based on their algorithm they managed to report back the traffic state in real-time. Basically they used approach of WSN technology in order to relay the information from the loop detector to the base station for algorithm implementation and status clarification. Figure 6 shows how they set up their sensors and to relay the information to the user of the roads.

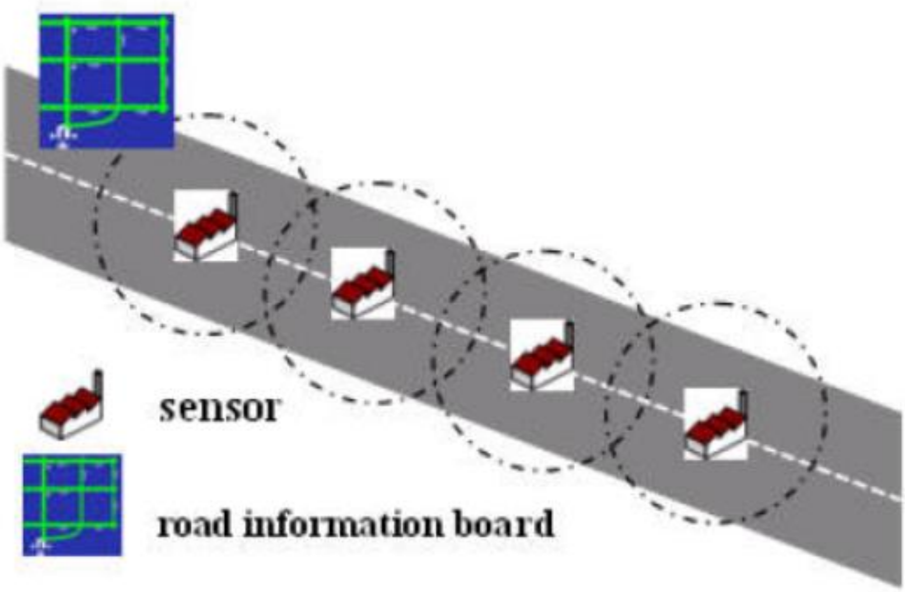



Figure 6 Monitoring scheme by using loop detector [22]

Usage of acoustic sensors in traffic monitoring has also been done in a study by [23]. In their study, they used a number of acoustics sensors as nodes and relay the information to the master nodes for analysing. They made use of the sound waves of the travelling vehicles in order monitor the traffic condition. Their findings are basically on the fact that the sound waves of the travelling vehicle reach to different acoustic sensors at a separate time due to the difference in the air path. Figure 7 shows how they configure the acoustic sensors in order to monitor road traffic.

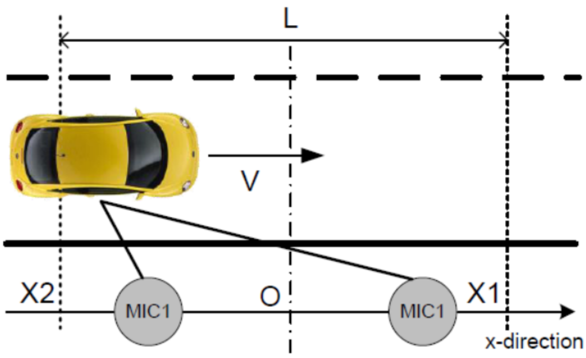



Figure 7 Configuration of acoustic sensor in traffic monitoring

While in [24], they use vehicle sensor with implementation of WSN in order to monitor the road traffic status. The vehicle sensor gives output to the road side sensor as the position of the vehicle, travel direction, velocity and even the exhaust emission data. The road side sensor then transfer the information to the intersection sensor nodes where post-processing is being done in order to monitor the road traffic status. Figure 8 shows the distribution of the sensors node being used by them.

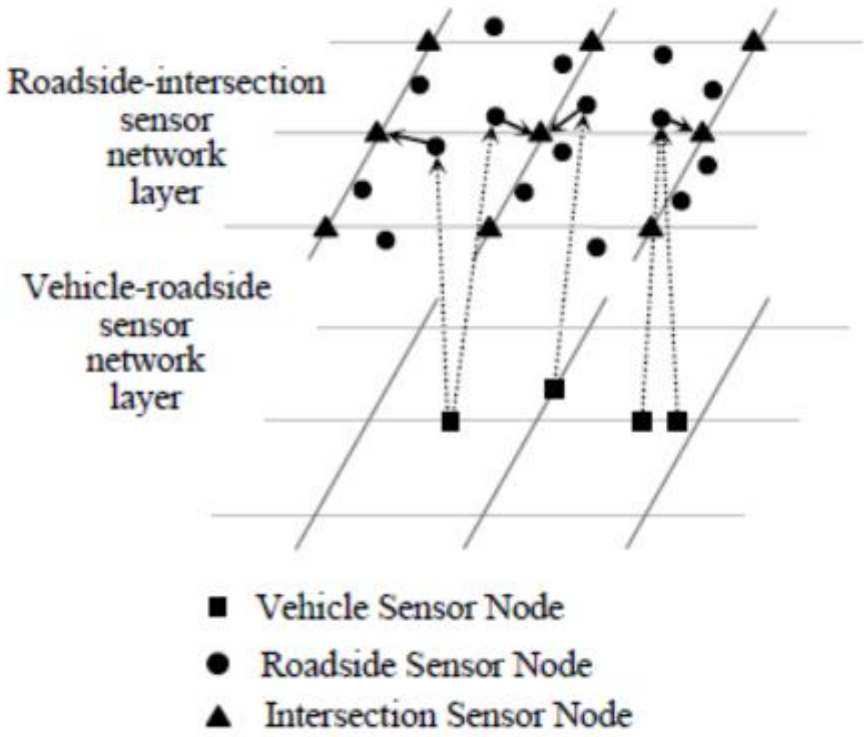



Figure 8 Distribution of vehicular sensor node in traffic monitoring

Based on the sensor that has been used by the studies above, it can be observed selection of sensors are depending on the method the data acquired being analysed. For a scale-down prototype, a low cost and easy installation need to take account in selecting the sensors that need to be used. The sensors are also need to be able to give the data that will help in order to quantify and detect the traffic congestion.

# CHAPTER 3: METHODOLOGY / PROJECT WORK

This chapter discusses the processes of work to be done in order to achieve the objectives of this project.

## 3.1 Project Methodology

Figure 9 shows the flow of the project methodology.

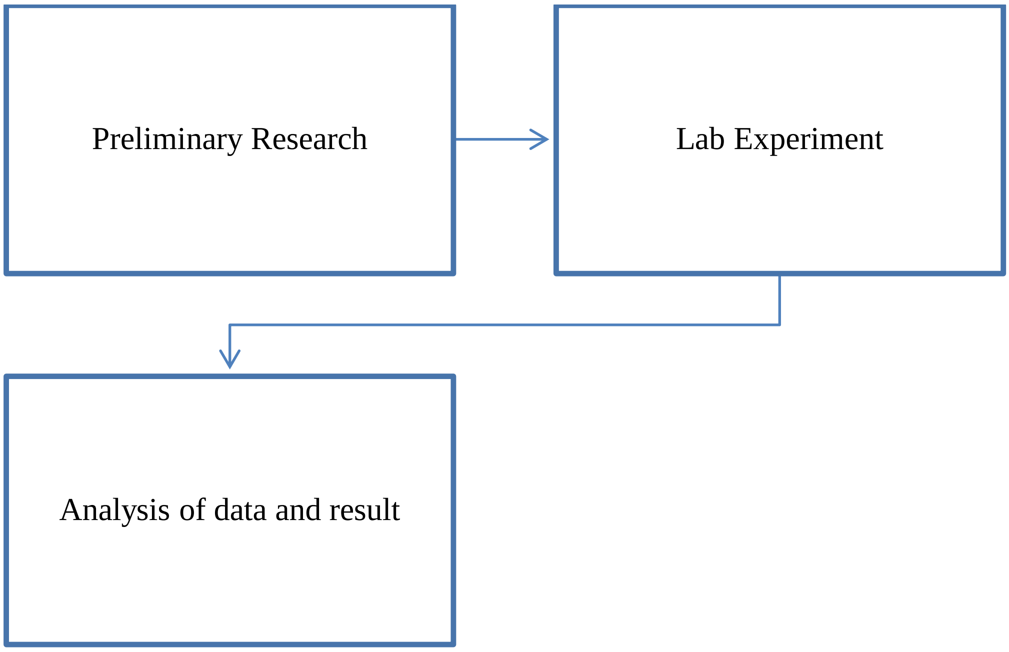



Figure 9 Flow of methodology

## 3.2 Project Activities

### 3.2.1 Preliminary Research

This is the first step to take in order to complete the project. This step focused on collecting all relevant information that is related to the project. The information were obtained from trustworthy sources such as journals, articles, books, and technical papers. All the information obtained later will help in planning the best way to undertake the project and what to expect at the end of the project.

### 3.2.2 Lab Experiment

The next step to complete this project is to execute experiment in order to achieve the objective. Few steps of experiment have been planned and they are divided as below:

a) Familiarisation Process

This process is to familiarise with the wireless mote that will be use. The familiarisation process includes handling the hardware, software and coding of the mote.

b) Sensor Calibration and Application

The purpose of this process is to familiarise and to ensure the sensors are working as intended. This includes ensuring that the sensors will give the most accurate data and the data that will be obtained is valid.

c) Sensor Network Integration

This next step will be executed once all the sensors are functioning properly. This step is to be done in order to integrate all the sensor in one functional system. This system will later provide the data for the next step.

d) Wireless Sensor Network Testing

Since the sensor network has been integrated, the next step is in testing the wireless sensor network to ensure it is working accordingly. The network should relay the same information regardless of any nodes.

e) Wireless Sensor Network Integration

The reason for this integration is to have wireless data transfer from the sensors network to a base station. In this step, all the data obtained before will be ensured to be sent and capture by the base station. At the base station all the analysis will be done in order to achieve the project's objective.

f) Scaled-down prototype building

This process is regarding to prove the wireless sensor network is working. The network will be installed on a scaled-down prototype where data will be analysed in real-time and the efficiency and accuracy of the system will be studied and determined.

### 3.2.3 Analysis of Data and Result

After the data can be obtained from the experiment, analysis of data will be done. All the collected data will be used in order to justify and meet the objective of the project which is to detect traffic congestion. If the analysis could not meet the objective, changes would be done and experiment will be repeated until desired result is achieved.

## 3.3 Tools and Software Required

Tools and software that will be needed throughout this project are as below.

### 3.3.1 XM2111CA

XM2111CA is a wireless motes a product from MEMSIC. It uses the ATMEL RF230 and has ZigBee radio frequency transceiver integrated with an Atmega1281 micro-controller. This wireless mote will be used in transferring and receiving the data from the sensor to the base station as a purpose of transmitting data medium.

### 3.3.2 MDA300CA

MDA300CA is a sensor board that was designed as a general measurement platform for XM2111CA. This sensor board provides 7 single-ended analog channel, 7 differential analog channel, 7 digital channel and a counter channel. This sensor board will be used as an interconnection between sensors and XM2111CA.

### 3.3.3 MIB520CB

MIB520CB is a USB PC interface board. It is functioning as communicator between the XM2111CA wireless motes and the PC via USB.

### 3.3.4 Speed sensor

Speed sensor can sense the velocity of a moving object. This sensor need to be on the same object that it is sensing. This sensor will be used for velocity measurement in the project.

### 3.3.5 Proximity sensor

Proximity sensor is a sensor that can detect distance within its range. The sensor will give output according to the distance of the object in front of it. This sensor will be used in order to measure the density of the road in the project.

### 3.3.6 Remote Control Car

A remote control car will be used in this project in order to model the scale-down prototype. It will represent the actual vehicle on the actual road. The sensors and wireless mote will be attached within this remote control car

### 3.3.7 MATLAB

MATLAB software will be used in analysing the data acquired from the wireless sensor network in order to conclude the traffic congestion detection.

### 3.3.8 MoteWorks

MoteWorks is the end to end enabling platform for the creation of wireless sensor networks. This software will be used in order to program the wireless motes for sending and receiving data purposes.

### 3.3.9 MoteView

MoteView is a viewing software provided by MEMSIC complimentary with their wireless sensor network products. It is an interfacing software that can be used as a monitor of all the data transmits within the wireless sensor networks.

### 3.4 Gantt-Chart and Key Milestone

| Project Work/Task | Week | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| Title Selection | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Preliminary Research | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Detailed Study | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | |
| Purchase Material | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Familiarisation Process | | | | | | | | | | | | | | 2 | | | | | | | | | | | | | | |
| Sensor Calibaration and Application | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Sensor Network Intergration | | | | | | | | | | | | | | | | | | | 3 | | | | | | | | | |
| Wireless Sensor Network Integration | | | | | | | | | | | | | | | | | | | | 4 | | | | | | | | |
| Data Analysis | | | | | | | | | | | | | | | | | | | | | | 5 | | | | | | |
| Debugging and Improvement | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Project Wrapped Up and Conclusion | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Key Milestone

1. Identify the sensor needed
2. Able to handle all hardware and software related to the wireless motes
3. Able to integrate all the sensor as one system
4. Scaled-down prototype working
5. Manage to conclude from data analysed

## 3.5 Experiment Procedures

### 3.5.1 Sensor Identification

Based on the research done, it can be observed that main parameters that can detect the traffic congestion is the velocity of the vehicle and the density of the road. Based on that, two sensor have been selected and they are the speed sensor and proximity sensor. This is based on the method chosen for now to determine for the detection of road congestion and quantify the congestion level. For now in order to detect congestion, the following parameters will be used in order to detect congestion: speed of vehicle and saturation of the road. This parameter can be acquired by both of the sensor that has been selected.

In order to quantify the level of congestion, the same parameters will be used that are the velocity and the density of the road. The congestion level is divided into 3 that are low, medium and high. By using velocity [17], the relationship shown in Table 2 will be used:

Table 2 Relationship of velocity in quantifying level of congestion

| Relationship | Level of congestion |
|---|---|
| $V \leq \alpha$ | High |
| $\alpha \leq V \leq \beta$ | Medium |
| $V \geq \beta$ | Low |

V is the mean velocity whereas β and γ are the threshold value that will be needed to be determined later.

For defining the saturation of the road [20], the following relationship will be used:

$$M = \frac{N}{C}$$

M is the saturation of the road whereas N is the traffic flow and C is the capacity of the road that will be needed to be determined once the scaled-down prototype design has been finalized.

### 3.5.2 Sensor Purchasing

Since the type of sensor has been identified, purchasing the sensors would be next. There are many models of the required sensor in the market. A suitable model will be needed for purchasing in order to complete the project. The main objectives in selecting the models are within the budget limit, easy to handle and compatible with MDA300CA board that will be the connection between the sensors and XM2111CA.

After surveying, the proximity sensor that was chosen for purchasing is the GP2Y0A21YK by Sharp. It is actually a general purpose type distance measuring sensors. It can measure or detect distance within 10 to 80 cm. The sensor also does not require any external control circuit as it can be straight forward being use on the MDA300CA board. The sensor's capability of measuring those distances really meet the requirement for the project as one of the parameter needed is distance between cars. Based on the datasheet, 4.5V to 5.5V is needed as supply voltage in order to use the sensor. This requirement can be achieved since the MDA300CA has a pin that reserves to excite voltage of 5V. Besides that, the output voltage of the sensor is labelled as -0.3V to $V_{cc}$ +0.3V whereas the analog input voltage line range of MDA300CA board is labelled as -0.2V to $V_{cc}$ + 0.5V. From here it can be seen that the output voltage from the sensor is within the range that the MDA300CA board can handle. These two points proves that GP2Y0A21YK sensor is compatible to be used with the MDA300CA board.

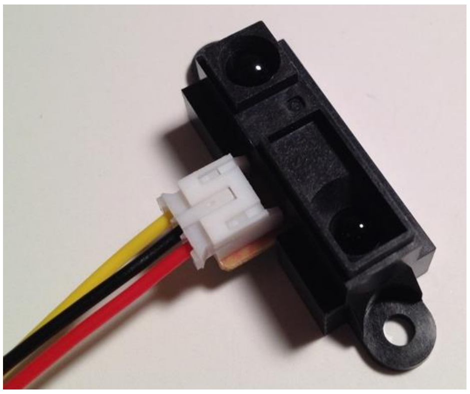


Figure 10 GP2Y0A21YK Sensor

For the speed sensor, RE08A a rotary encoder kit from Cytron Technologies has been selected. This encoder kit is basically a sensor that convert data of rotary motion into a series of digital pulses. The encoder kit is package with an optical sensor. This sensor is being used to sense a total of 16 transitions of a slotted disc that is also come with the package. This transitions can be used for velocity measurement. It is basically based the following relationships:

$$16\ transitions = 1\ whole\ cycle\ of\ the\ tyre = Circumference\ of\ a\ tyre$$

$$Velocity = \frac{Circumference\ of\ a\ tyre}{Time\ taken\ for\ 16\ transitions}$$

This encoder has a simple interface where there are 3 pin. One of the pin is for voltage supply for the sensor which it needed 5V to be working. This 5V can be supply by MDA300CA board which are the same case with the proximity sensor. Another pin from this encoder kit is the signal pin. This signal pin will give digital value based on the condition of optical sensor. If the optical sensor is being blocked the signal pin will give out high value while if it is unblocked, low value will be given by the signal output pin. Those output from the signal output pin of the encoder can be connected to the digital input channel or the counter channel of the MDA300CA board for collection of data. Therefore the encoder kit is suitable and compatible to be used together with the MDA300CA for this project.

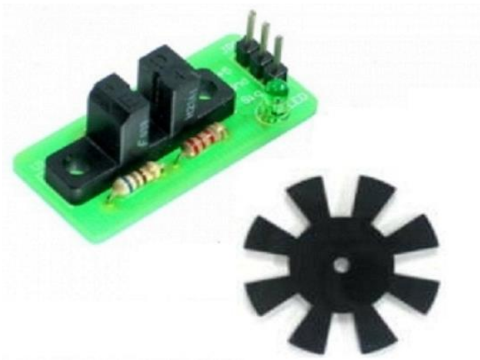


Figure 11 RE08A Rotary Encoder Kit

### 3.5.3 Software Installation

In order to acquire data from XM2111CA, MEMSIC has provided software that will ease up the monitoring and storing the databases of data acquired. The software needed were:

- MoteWorks – required for programming the XM2111CA
- MoteView – to parse the database where all the data acquired are being stored

The installation files for both of the software are provided by MEMSIC together with the purchases of the wireless motes. Aside from these software, a proper driver is also needed to be installed in order for the MIB520CB to work properly. The MIB520CB interface gateway uses the FTDI FT2232C driver in order to make the USB port as a virtual COM port. The installation is rather easy as Windows will detect a new hardware once the MIB520CB is being plug to the PC and automatically find the drivers and installed it. In order to ensure that the driver has been properly installed, change to the following directories for checking: Control Panel>System>Device Manager>Port. Two new serial ports will be added in the Port tab if the driver installations is successful. Figure 12 shows how it should look like once the installation is a success.

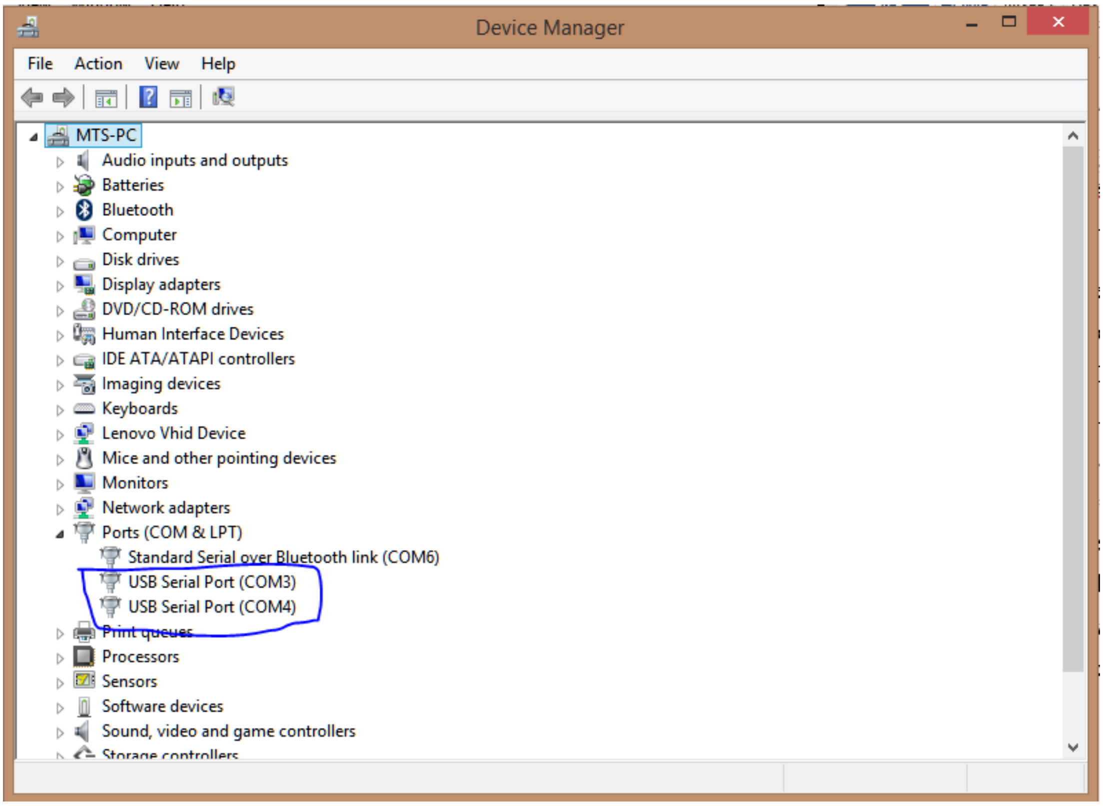



Figure 12 Additional USB Serial Port added

As all software has been installed properly, next step is to familiarise on how to operate the software. Based on the Getting Started Guide provided by MEMSIC, several basic application that is sufficient for the project has been able to be done. One of it is to acquire data from a sensor board that is connected to a wireless node into a base station node. In order to run this 2 XM2111CA and 1 MTS310 sensor board is needed. Figure 13 shows how the MTS310 is being connected on a XM2111CA wireless mote.

There are two ways in order to program the wireless motes to be working. One of it is by using a programmer software that is called Programmer Notes 2 (PN2). This software is included together inside the installation files of MoteWork. Basically there are two sets of coding modules needed for this application. One of it is for the base station node and another is for the sensor node.


Figure 13 Configuration of MTS310 board connected to XM2111CA

MEMSIC has installed together all the required coding for their product to be working as default. In order to work, these coding are just needed to be upload inside XM2111CA. For the base station node, the coding modules can be found at the following directory:

C:\Memsic\cygwin\opt\MoteWorks\apps\xmesh\XMeshBase2.4

While for the sensor nodes, the modules are in the following directory:

C:\Memsic\cygwin\opt\MoteWorks\apps\xmesh\XMTS310

In order to upload the modules onto XM2111CA, a command parameters need to be executed in PN2. The command parameters are as shown in Figure 14. The term ‘make micazc install’ is by default the command needed. The term ‘1’ is basically the node id allocation while ‘mib520’ is the gateway interface that to be used together with the XM2111CA. The term ‘com3’ is the lower USB Serial Port that the MIB520CB took.

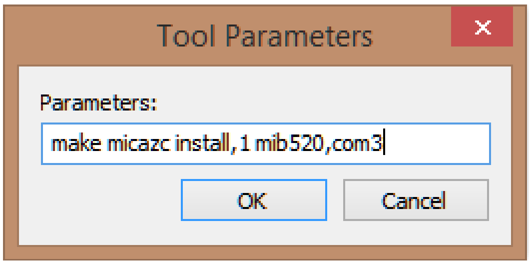



Figure 14 Command parameters for uploading codes into XM2111CA

Another way of running this application is by using the MoteConfig software. This software is also being installed together with the MoteWork. By using MoteConfig, no modification can be done to the coding as it will upload an execution file (.exe) onto the wireless motes. This can be seen from Figure 15. The same procedures apply in this method where each of the sensor and base station nodes have their own execution files. For the base station, the directory for the execution file is as follows:

C:\Program Files (x86)\Memsic\MoteView\xmesh\iris\XMeshBase

While for the sensor node the file are in the following directory:

C:\Program Files (x86)\Memsic\MoteView\xmesh\iris\MTS310

Once all the motes has been installed with the respective coding, all the hardware are being configured as in Figure 16 and the application can be run and monitor by using MoteView.

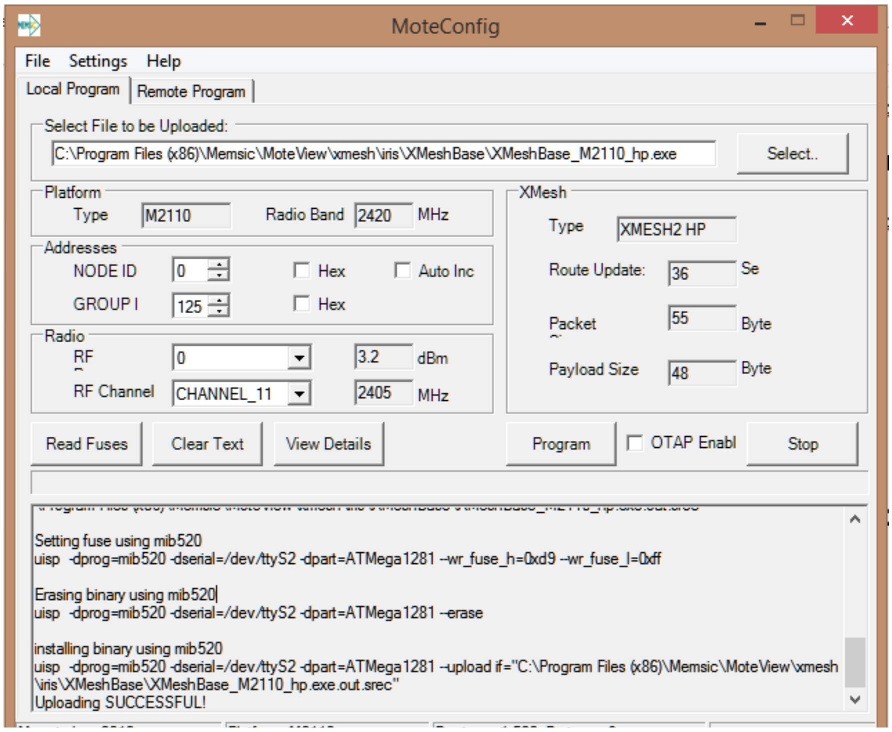



Figure 15 Installation of .exe files onto wireless motes using MoteConfig

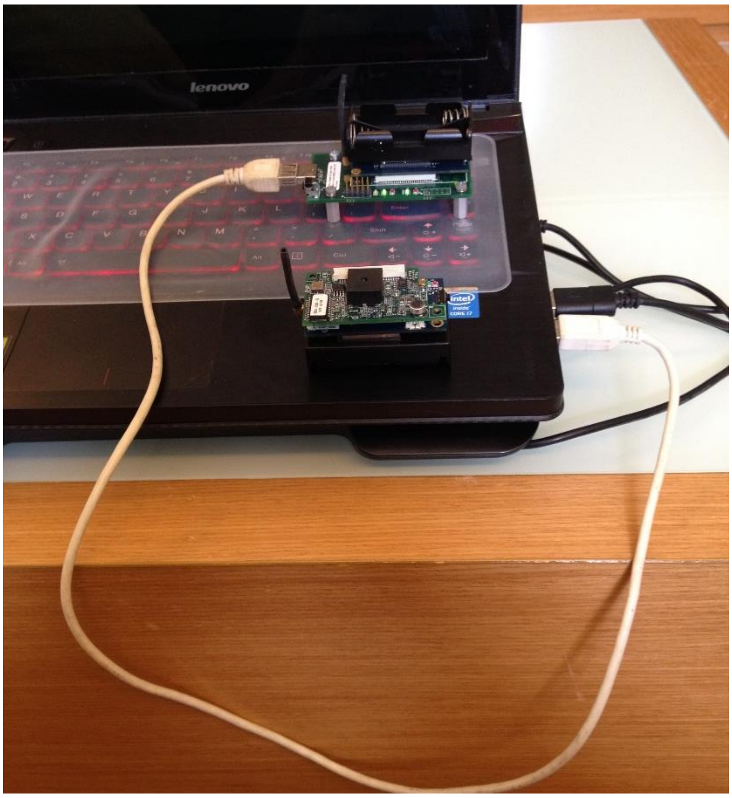



Figure 16 Configuration of sensing application

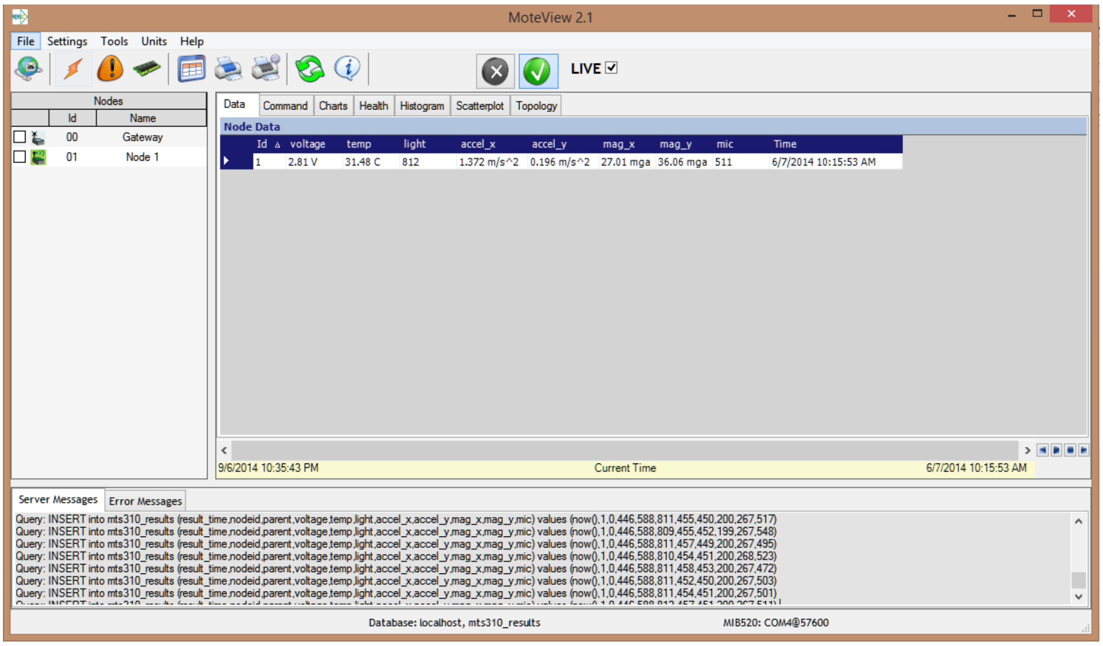



Figure 17 Monitoring data acquired by sensor using MoteView

### 3.5.5 Sensor Verification

In order to ensure that the sensor purchased is working accordingly a verification is needed to be done. For verifying the proximity sensor, a test was to make in order to observe the similarities between actual value and the claimed value from the database. The procedures on verifying the proximity sensor is rather simple. The configuration of the test are as shown in Figure 19 and the wiring connection between the MDA300CA and the sensor is shown in Figure 20.

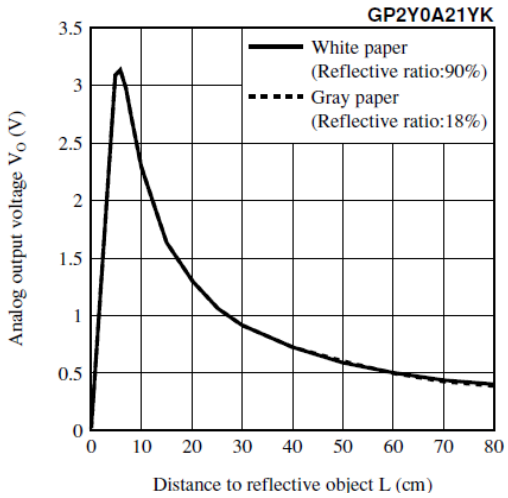



Figure 18 Claimed relationship between analog output voltage and distance to reflective object

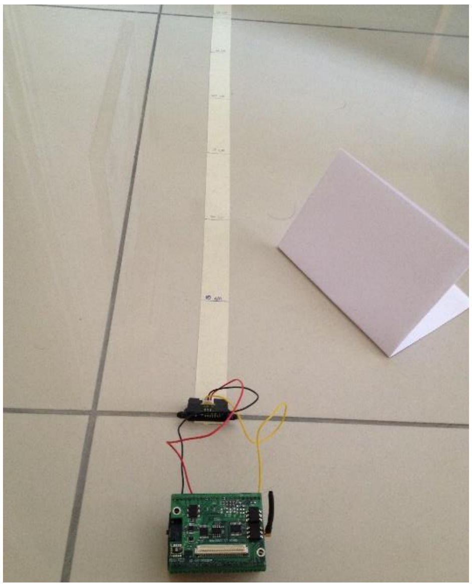


Figure 19 Proximity testing configuration

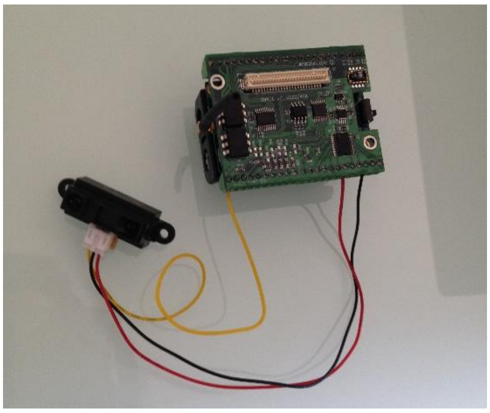


Figure 20 Wiring of proximity sensor to the MDA300CA board

The test is basically to take the reading of each distance and compare it with the relationship curve from Figure 18.

In order to verify the functionality of the rotary sensor purchased, a test was conducted in order to observe whether the sensor gives a counter for each of the transitions of the slotted disk provided. The configuration for the wires of the rotary sensor to the MDA300CA board are based on Figure 21.

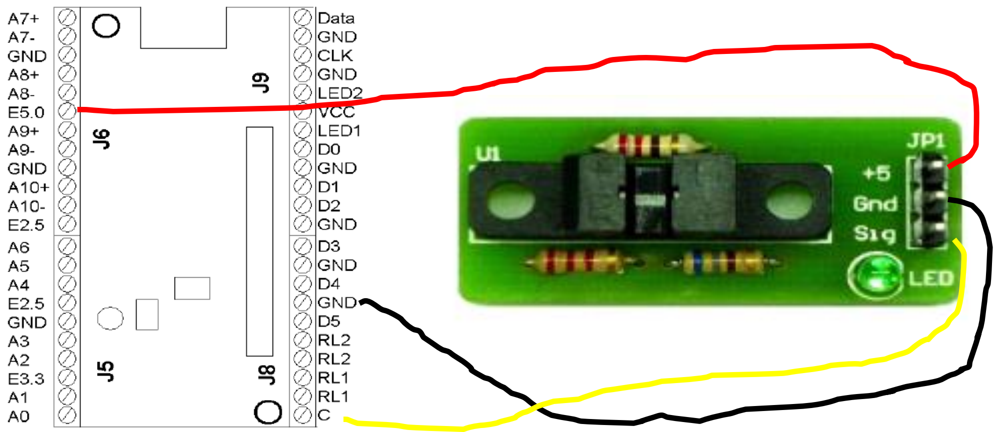



Figure 21 Wiring configuration of RE08A rotary sensor with MDA300CA board

The test was basically utilised a LEGO NXT Mindstorm. The LEGO NXT Mindstorm was used in order to verify the number of counter counted by the rotary sensor. Since the LEGO NXT Mindstorm has the capability to count the number of rotation of its motor, the slotted disk of the rotary sensor was mounted to the motor and the number of rotation made by the motor were measured. The testing was run for 5 times in order to detect consistency of the measurements. Figure 22 shows the way the slotted disk was mounted on the LEGO NXT Mindstorm motor.

Figure 22 Mounted slotted disk on LEGO NXT Mindstorm Motor

### 3.5.6 Sensor Mounting

As all the sensors purchased have been verified to function, a way to mount all the sensors on the remote control car is needed for data collecting. A simple design of sensor mounting has been done in order to achieve that. Figure 23 shows the sensors that has been mounted on a remote control car. Figure 24 otherwise shows the whole configuration of the remote control car with XM2111CA and the sensors mounted together.

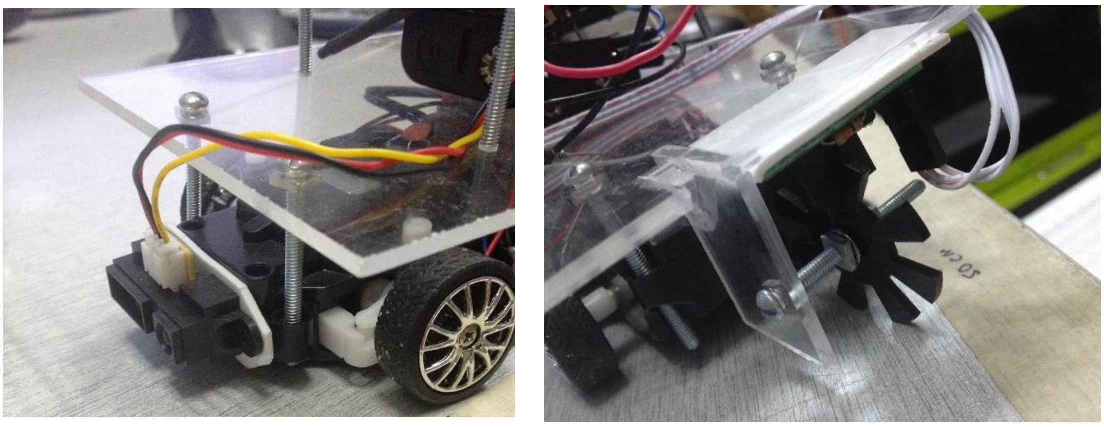


Figure 23 Proximity sensor and rotary sensor mounted on a remote control car

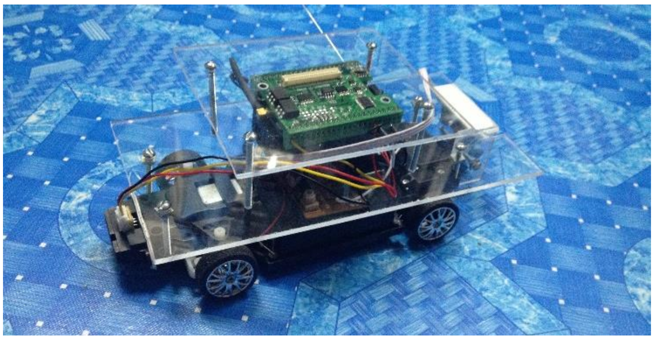


Figure 24 Remote control car with all the sensors and XM2111CA mounted on

### 3.5.7 Scaled Down Prototype

As all the sensors has been mounted on the remote control car, a scaled-down prototype is needed in order to show that wireless sensor network can be utilised for traffic congestion detection system. The prototype consists of 4 remote control car that are all mounted with the XM2111CA wireless motes and the sensors. Three out of four cars are with the same frequency where all of them can be controlled by a remote controller. The remaining one car is used as obstruction in order to create or model a congested situation.

Since all four cars are identical, the manipulation of situation can be done only at the beginning of the experiment. There are 5 experiments have been done in order to show the wireless sensor network can detect a traffic congestion. The initial position of the cars for the first experiment is as per Figure 25. In experiment 1, all the car used were with the same frequency. The nature of this experiment is to control all the cars with slow speed. As the cars moves, data are measured and analyse. For experiment 2, the initial position of the cars are also as per Figure 25. The same method as experiment 1 was used for experiment 2 but instead of moving the cars with slow speed, high speed was used.

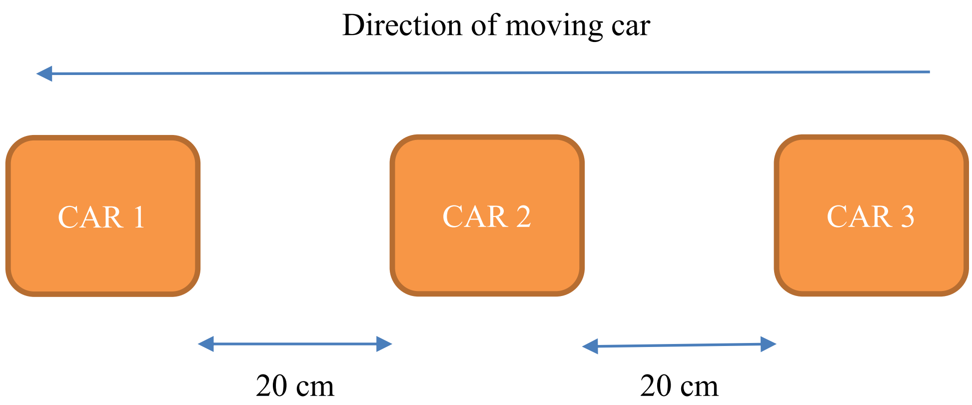



Figure 25 Initial position of cars for experiment 1 and 2

For experiment 3, the initial positions of the cars are as shown in Figure 26. In experiment 3, all the cars used were having the same frequency. The nature of the experiment was the same as in experiment 1 where the cars were moved together at slow speed. The same nature and initial positions of the cars was used for experiment 4 but instead moving the car at slow speed, high speed was used.

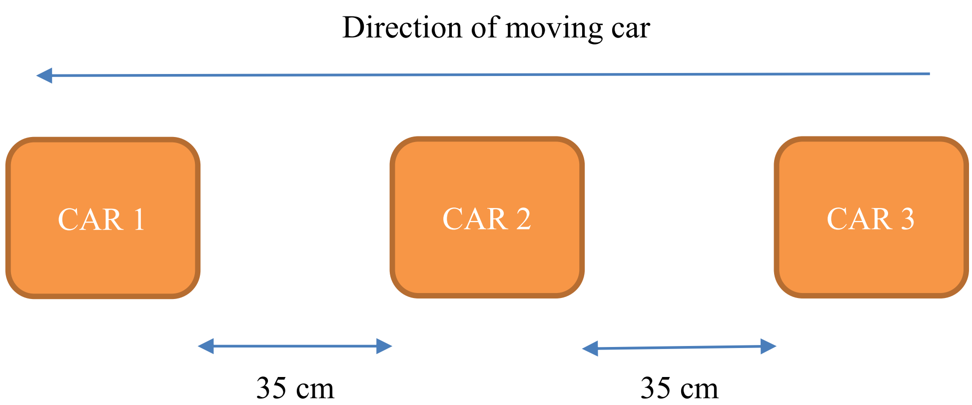



Figure 26 Initial position of cars for experiment 3 and 4

In experiment 5, the initial position for the car are as shown in Figure 27. For this experiment, Car 1 is using the different frequency as Car 2 and Car 3 therefore was controlled by a different controller. The nature of this experiment is that Car 1 was moved in slow speed while Car 2 and Car 3 were in high speed initially. Once Car 2 and Car 3 caught up with Car 1 in front, both of the car will be in slow speed to follow the speed of Car 1. While this experiment was running, all the data were measured and analysed.

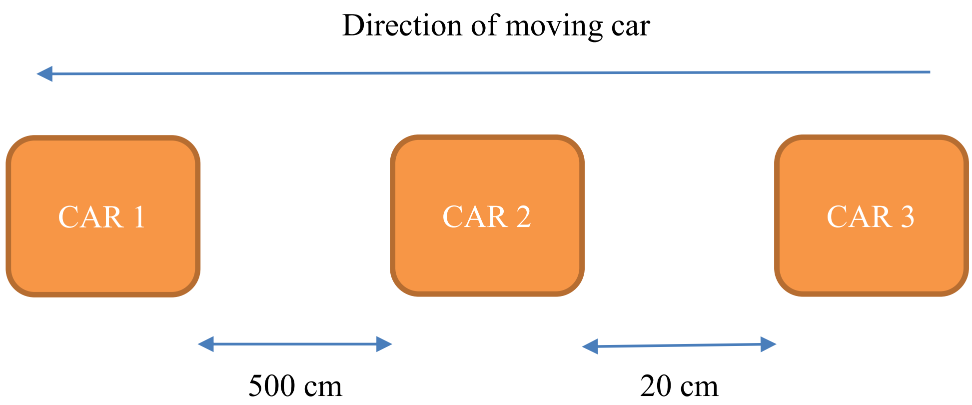



Figure 27 Initial position of cars for experiment 5

### 3.5.8 Data Analysis

Data analysis of the data gathered during the experiment was done in real-time by utilising the MATLAB software. The MATLAB code can be referred in Appendix A. Within this code, the data were sampled every 5 seconds. Each time the data were sampled, average distance between cars and average numbers of rotation of the rotary sensors were calculated. These parameters are used in order to detect whereas the traffic is congested or not.

# CHAPTER 4: RESULTS AND DISCUSSIONS

## 4.1 Software Installation

At first there was compatibility problem regarding the software used for programming the wireless motes. The problem was the installer at hand was not compatible with the Operating System used which are Windows 7. After contacting back the product provider, the problems has been solved. This is because the product provider has provided the latest version of the program installer which is compatible with Windows 7 Operating Systems. This setback has made some delay in order to get familiarise with the wireless motes operations.

Since that, familiarisation process of the wireless motes operation can be done.

## 4.2 Sensor Verification

For verifying the proximity sensor, the test result can be seen from Figure 28. Based on the result, it can be observed that the value given by the sensor are not the same as portrait in Figure 18. This may due to different reflective object and environment used during the testing and with the one that the manufacturer used for their testing. Even with the difference value, the sensor can be verified as the trend shows by the graph in Figure 28 is similar to the graph that has been provided by the manufacturer as per Figure 18.

During the testing of the proximity sensor, weird output voltages can be seen given by the sensor. It was suspected to have problem from the voltage that is supplied for the sensor from the MDA300CA board. Measurement were made into verifying the problem. From the measurement, it was observed that the excitation voltage 5V pin does not gave 5V instead giving spikes of random voltages. This can be seen through Figure 29.

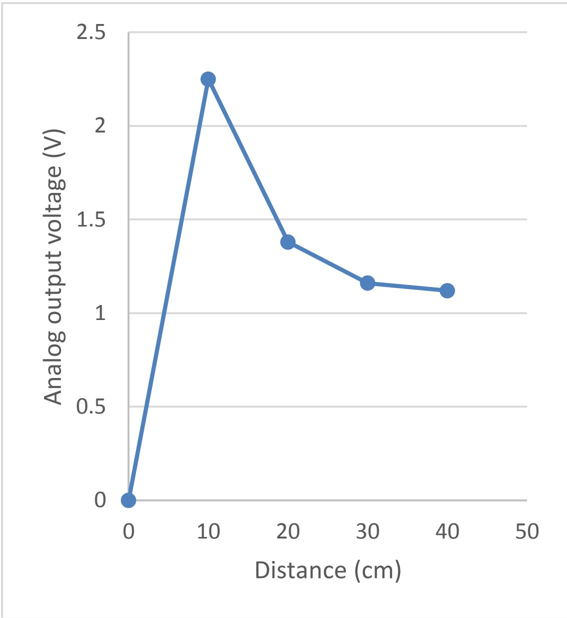



Figure 28 Relationship between analog output voltage and distance to reflective object

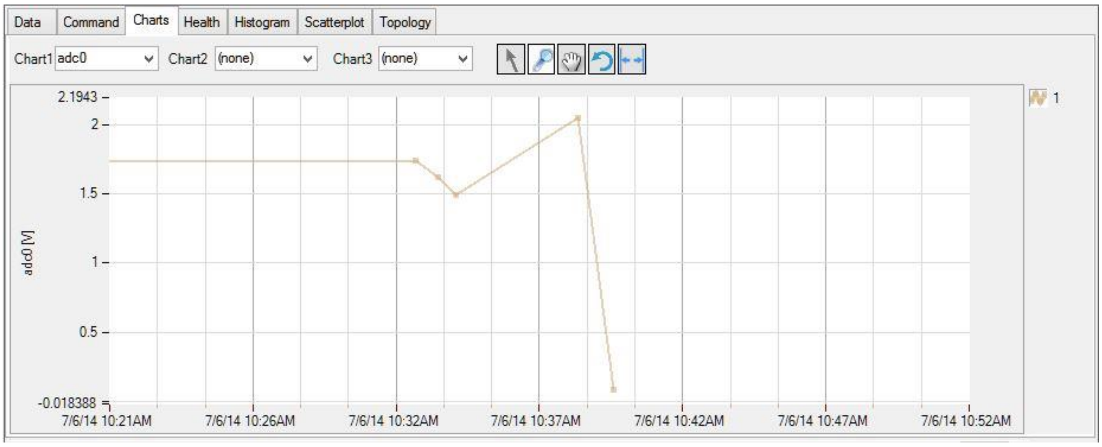



Figure 29 Spike value of voltage given by excitation voltage pin

In order to troubleshoot the problem, a study on the default module code XMDA300M.nc has been done. Resulting from the study, a modification of the module code has been done in order to get a fixed value of excitation. The modifications are as in Figure 31. Since the modification has been done, the excitation voltages given by the pin is constant. This can be seen through Figure 32.

```
//start sampling  channels. Channels 7-10 with averaging since they are more percise.channels 3-6 make active excitation
record[0] = call Sample.getSample(0,ANALOG,ANALOG_SAMPLING_TIME,SAMPLER_DEFAULT | EXCITATION_33 | DELAY_BEFORE_MEASUREMENT);

record[1] = call Sample.getSample(1,ANALOG,ANALOG_SAMPLING_TIME,SAMPLER_DEFAULT | EXCITATION_25 | DELAY_BEFORE_MEASUREMENT);

record[2] = call Sample.getSample(2,ANALOG,ANALOG_SAMPLING_TIME,SAMPLER_DEFAULT | EXCITATION_50 | DELAY_BEFORE_MEASUREMENT);
```

Figure 30 Original partial code from XMDA300M.nc

```
//start sampling  channels. Channels 7-10 with averaging since they are more percise.channels 3-6 make active excitation
record[0] = call Sample.getSample(0,ANALOG,ANALOG_SAMPLING_TIME,SAMPLER_DEFAULT | EXCITATION_33 | EXCITATION_ALWAYS_ON);

record[1] = call Sample.getSample(1,ANALOG,ANALOG_SAMPLING_TIME,SAMPLER_DEFAULT | EXCITATION_25 | EXCITATION_ALWAYS_ON);

record[2] = call Sample.getSample(2,ANALOG,ANALOG_SAMPLING_TIME,SAMPLER_DEFAULT | EXCITATION_50 | EXCITATION_ALWAYS_ON);
```

Figure 31 Modified partial code from XMDA300M.nc

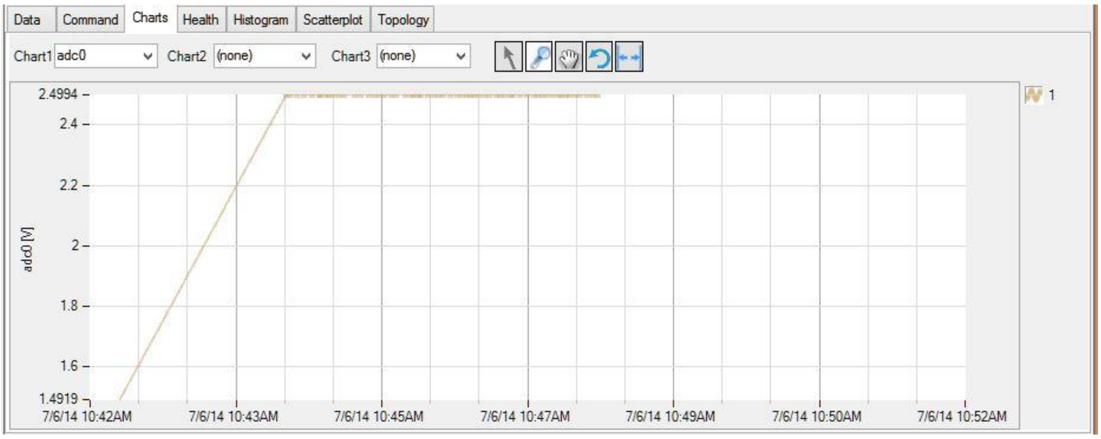



Figure 32 Constant value of voltages from the excitation voltage pin

The verification test for the rotary sensors results can be seen through Table 3. Based on the result, it can be said that the sensor can measure and gives correct counter for the number of rotation for the motors.

Table 3 Result for verifying test of rotary sensors

| Run | LEGO NXT Mindstorm (No of rotation) | RE08A (No. of count) | RE08A (No of rotation) |
|---|---|---|---|
| 1 | 12.02 | 97 | 12.13 |
| 2 | 11.97 | 96 | 12 |
| 3 | 11.95 | 95 | 11.88 |
| 4 | 12.06 | 96 | 12 |
| 5 | 12.04 | 95 | 11.88 |

During verification of the rotary sensor, two major problems have been encountered. The first one was that the potential drop between the 5V pin and the ground pin of the sensors was not nearly 5V. The reason was suspected that the RE08A draws a lot of current from the XM211CA and would resulting on malfunctioned of the proximity sensor as it shared the same 5V power supply from the wireless motes. In order to counter this problem, a three 1.5V battery holder has been used resulting a new mounting on the remote control car. The new configuration of the sensors, wireless mote and battery holder mounting on the remote control car can be seen as Figure 33.

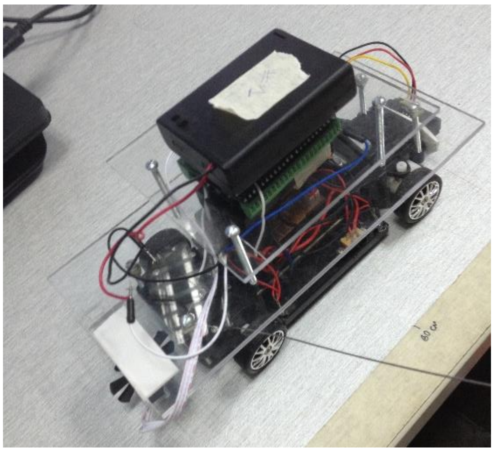
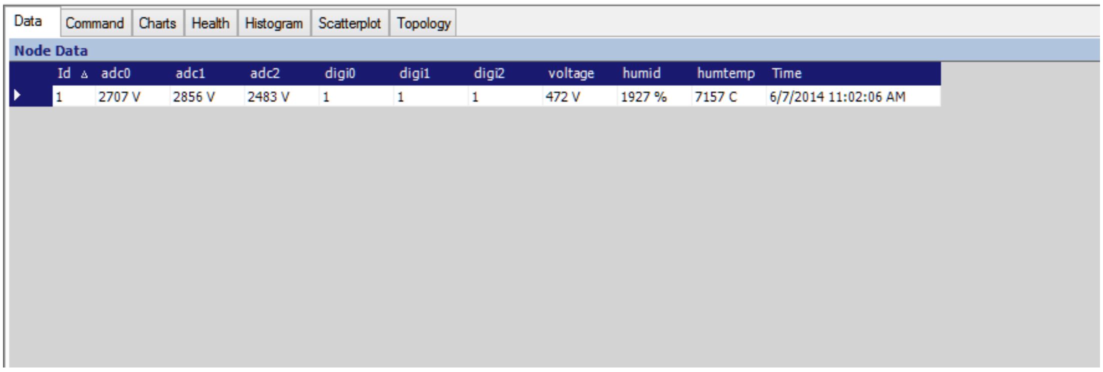


Figure 33 New configuration of mounting on the remote control car

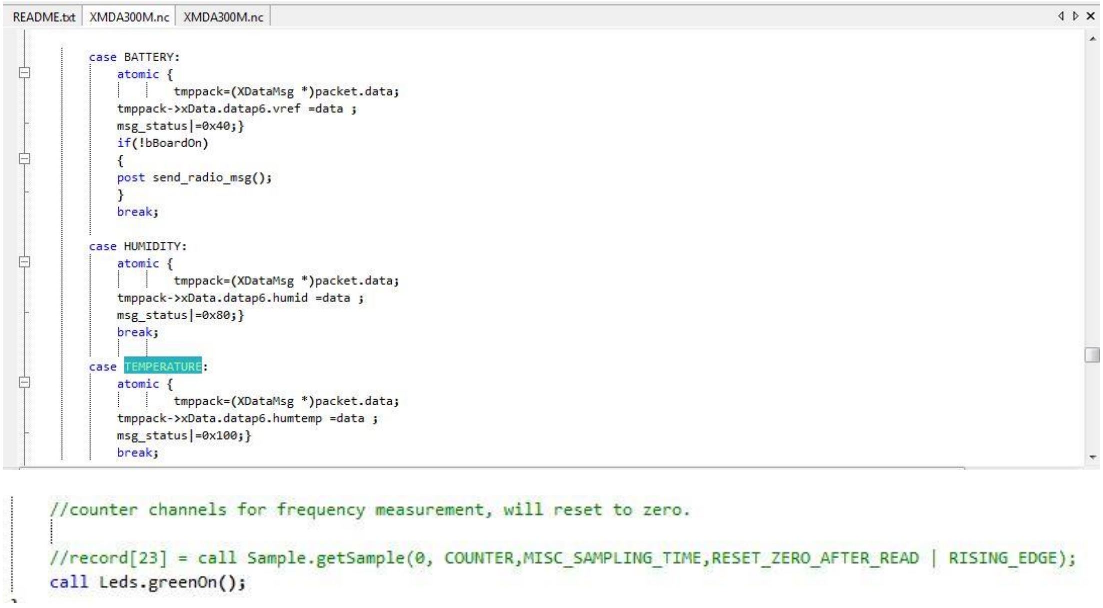
Another problem encounter while verifying the rotary sensor was data monitoring of counter channel. Since the output of the rotary sensors would be a counter, counter channel of MDA300CA board is needed. The problem was with the default program that MEMSIC's developer has developed. By default, the database for MDA300CA's result did not include data for counter channel. This can be seen as in Figure 34.




| Id | adc0 | adc1 | adc2 | digi0 | digi1 | digi2 | voltage | humid | humtemp | Time |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2707 V | 2856 V | 2483 V | 1 | 1 | 1 | 472 V | 1927 % | 7157 C | 6/7/2014 11:02:06 AM |

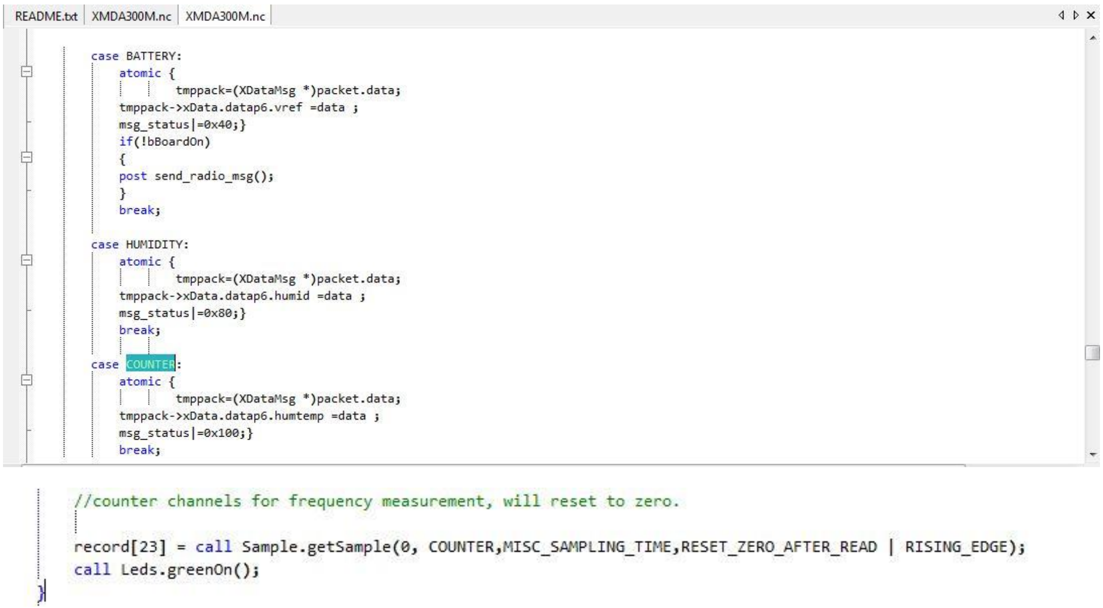
Figure 34 Default channel in the MDA300CA's result database

In order to troubleshoot with this problem, a modification of default programming has been made. The modifications were meant to take the channel reading and write it in the database under different channel. Since the *humtemp* channel is not in used, this channel was selected to be exchanged with the counter channel. The code modification can be seen in Figure 36.



```
README.txt | XMDA300M.nc | XMDA300M.nc

        case BATTERY:
            atomic {
                    tmppack=(XDataMsg *)packet.data;
            tmppack->xData.datap6.vref =data ;
            msg_status|=0x40;}
            if(!bBoardOn)
            {
            post send_radio_msg();
            }
            break;

        case HUMIDITY:
            atomic {
                    tmppack=(XDataMsg *)packet.data;
            tmppack->xData.datap6.humid =data ;
            msg_status|=0x80;}
            break;

        case TEMPERATURE:
            atomic {
                    tmppack=(XDataMsg *)packet.data;
            tmppack->xData.datap6.humtemp =data ;
            msg_status|=0x100;}
            break;

    //counter channels for frequency measurement, will reset to zero.

    //record[23] = call Sample.getSample(0, COUNTER,MISC_SAMPLING_TIME,RESET_ZERO_AFTER_READ | RISING_EDGE);
    call Leds.greenOn();
```

Figure 35 Original partial code from XMDA300M.nc



```
README.txt | XMDA300M.nc | XMDA300M.nc

        case BATTERY:
            atomic {
                    tmppack=(XDataMsg *)packet.data;
            tmppack->xData.datap6.vref =data ;
            msg_status|=0x40;}
            if(!bBoardOn)
            {
            post send_radio_msg();
            }
            break;

        case HUMIDITY:
            atomic {
                    tmppack=(XDataMsg *)packet.data;
            tmppack->xData.datap6.humid =data ;
            msg_status|=0x80;}
            break;

        case COUNTER:
            atomic {
                    tmppack=(XDataMsg *)packet.data;
            tmppack->xData.datap6.humtemp =data ;
            msg_status|=0x100;}
            break;

    //counter channels for frequency measurement, will reset to zero.

    record[23] = call Sample.getSample(0, COUNTER,MISC_SAMPLING_TIME,RESET_ZERO_AFTER_READ | RISING_EDGE);
    call Leds.greenOn();
}
```

Figure 36 Modified partial code from XMDA300M.nc

## 4.3 Scaled Down Prototype

While running the scaled-down prototype/modelling, several problems have been encountered. One of them is the limitation of the remote control car. The remote control car purchased has only one level of speed. Therefore every car will move at same speed. In order to have a good simulation of a traffic situation, variety in speed is needed. Therefore as the limitation goes, the only way to simulate traffic condition is by fixing the initial position of the car before the simulation starts.

Another problem encounter was with the sensor mounted. It seems that the design chosen to mount the sensors is not very efficient especially for the rotary sensors. It is hard to get a smooth data with the mounting design. Several run were needed during the experiment in order to get the correct data.

## 4.4 Data Analysis

Once a reliable data has been captured, the data was analysed. The analysis was rather a simple analysis. From the data provided by the wireless sensor network, the traffic condition can be deduced. The following relationship was used to determine the traffic status:

Table 4 Relationship between average distance between cars and average rotation with traffic conditions

| Average distance between cars (cm) | | Average rotation in 5 seconds | | Traffic conditions |
|---|---|---|---|---|
| ≥ 25 | < 25 | ≥ 55 | < 55 | |
| √ | × | √ | × | Fine |
| √ | × | × | √ | Fine |
| × | √ | √ | × | Fine |
| × | √ | × | √ | Congested |

Data taken from experiment 1 and 2 can be seen as in Figure 37. From the graph, it can be observed that the number of rotation that decides which condition of the road traffic it is. This is due to the same average speed of the cars which makes their distance with other car maintains throughout the experiments.

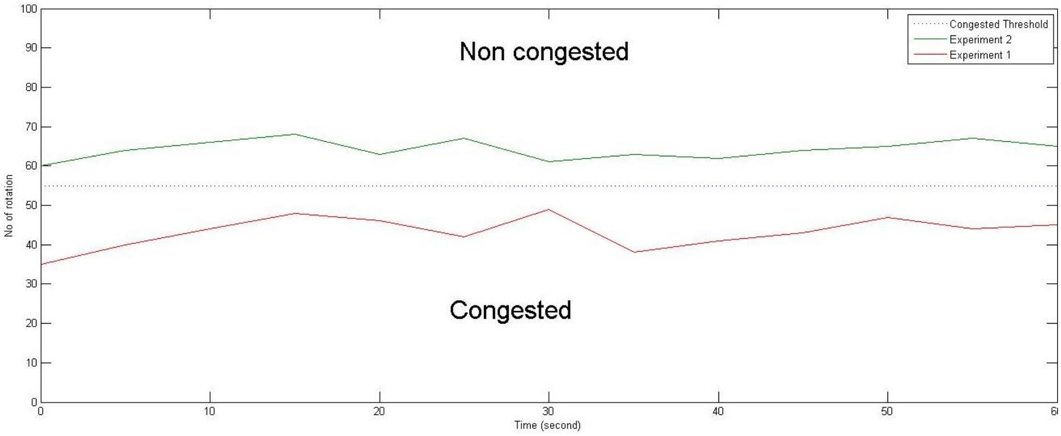



Figure 37 Data taken from experiment 1 and 2

Data for experiment 3 and 4 otherwise can be seen through Figure 38. From the data taken, it is observed that no conditions has been categorised as congested. This is due to the average distance of the cars which is always more than 25 cm from each other. This distance does not affected even though the speed is varies since all cars used has similar average speed.

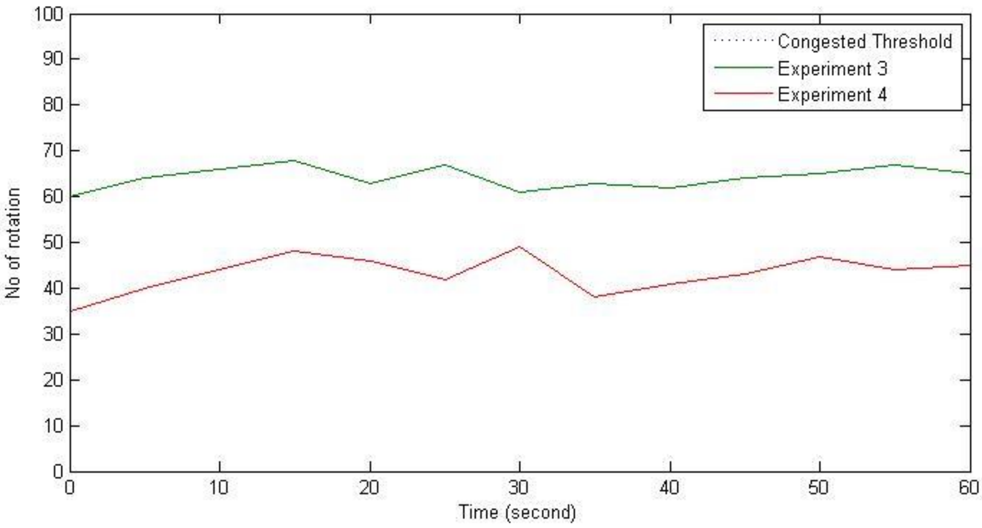



Figure 38 Data taken from experiment 3 and 4

Data for experiment 5 can be seen as in Table 5. From the data, it can be seen that at first when the average distance between cars are far, the traffic are fine even with different speed. Once the average distance between cars become close to each other, the analysis will detect that the traffic is congested.

Table 5 Data taken from experiment 5

| Time (second) | Average Distance (cm) | Average No of Rotation | Traffic Conditions |
|---|---|---|---|
| 0 | 260 | 0 | Fine |
| 5 | 137.6 | 47 | Fine |
| 10 | 23.5 | 48 | Congested |
| 15 | 22.8 | 45 | Congested |
| 20 | 20.9 | 47 | Congested |
| 25 | 21.4 | 46 | Congested |
| 30 | 23.8 | 48 | Congested |
| 35 | 21.5 | 47 | Congested |
| 40 | 22.1 | 49 | Congested |

# CHAPTER 5: CONCLUSION & RECOMMENDATION

## 5.1 Conclusion

The project has been completed within the time frame even though many setback have been encountered throughout finishing it. It is proven that the wireless sensor network technology can be utilised as a traffic congestion detection system. This is provided with suitable traffic parameters measured by using a suitable sensors.

## 5.2 Recommendation

In need of exploring other road or traffic parameters in order to quantify or detect traffic congestion. Besides that, a better sensor selection can be made in order to have more accurate and reliable data measurement. More complex remote control car can be used for simulating the traffic conditions.

Better understanding of the TinyOS programming language could ease up the development of the traffic congestion detection system.

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# APPENDIX A

## MATLAB Coding for Data Analysis

```
clc;
clear all;

s = dos('read.bat &');
keeplooping = true;
count = 0;
voltage = [1.12 1.16 1.38 2.25];
dis = [40 30 20 10];
lengthb4 = 0;


setdbprefs('NullNumberRead','0');

setdbprefs('DataReturnFormat','numeric');

while keeplooping
conn = database('PostgreSQL30','tele','tiny');
node1 = exec(conn,'SELECT EXTRACT(HOUR FROM result_time) AS Hour,
EXTRACT(MINUTE FROM result_time) AS Minute, EXTRACT(SECOND FROM
result_time) AS Second,adc0 AS Distance,humtemp AS SlitChange FROM
mda300_results WHERE nodeid = 1');
node1 = fetch(node1);

node2 = exec(conn,'SELECT EXTRACT(HOUR FROM result_time) AS Hour,
EXTRACT(MINUTE FROM result_time) AS Minute, EXTRACT(SECOND FROM
result_time) AS Second,adc0 AS Distance,humtemp AS SlitChange FROM
mda300_results WHERE nodeid = 2');
node2 = fetch(node2);

node3 = exec(conn,'SELECT EXTRACT(HOUR FROM result_time) AS Hour,
EXTRACT(MINUTE FROM result_time) AS Minute, EXTRACT(SECOND FROM
result_time) AS Second,adc0 AS Distance,humtemp AS SlitChange FROM
mda300_results WHERE nodeid = 3');
node3 = fetch(node3);

node4 = exec(conn,'SELECT EXTRACT(HOUR FROM result_time) AS Hour,
EXTRACT(MINUTE FROM result_time) AS Minute, EXTRACT(SECOND FROM
result_time) AS Second,adc0 AS Distance,humtemp AS SlitChange FROM
mda300_results WHERE nodeid = 4');
node4 = fetch(node4);

if count == 0
hour1 = node1.Data(:,1);
min1 = node1.Data(:,2);
sec1 = node1.Data(:,3);
distance1 = interp1(voltage,dis,2.5*node1.Data(:,4)/4096);
distance1(isnan(distance1))=0;
avgdis1 = mean(distance1);
slit1 = node1.Data(:,5);
rpm1 = sum(slit1)/8;
b4length1 = length(hour1);

hour2 = node2.Data(:,1);
min2 = node2.Data(:,2);
```

```
sec2 = node2.Data(:,3);
distance2 = interp1(voltage,dis,2.5*node2.Data(:,4)/4096);
distance2(isnan(distance2))=0;
avgdis2 = mean(distance2);
slit2 = node2.Data(:,5);
rpm2 = sum(slit2)/8;
b4length2 =length(hour2);

hour3 = node3.Data(:,1);
min3 = node3.Data(:,2);
sec3 = node3.Data(:,3);
distance3 = interp1(voltage,dis,2.5*node3.Data(:,4)/4096);
distance3(isnan(distance3))=0;
avgdis3 = mean(distance3);
slit3 = node3.Data(:,5);
rpm3 = sum(slit3)/8;
b4length3 =length(hour3);

hour4 = node4.Data(:,1);
min4 = node4.Data(:,2);
sec4 = node4.Data(:,3);
distance4 = interp1(voltage,dis,2.5*node4.Data(:,4)/4096);
distance4(isnan(distance4))=0;
avgdis4 = mean(distance4);
slit4 = node4.Data(:,5);
rpm4 = sum(slit4)/8;
count = count + 1;
b4length4 =length(hour4);

count = count + 1;

else
hour1 = node1.Data(:,1);
afterlength1 = length(hour1);
min1 = node1.Data(:,2);
sec1 = node1.Data(:,3);
distance1                                                    =
interp1(voltage,dis,2.5*node1.Data(b4length1+1:afterlength1,4)/4096);
distance1(isnan(distance1))=0;
avgdis1 = mean(distance1);
slit1 = node1.Data(b4length1+1:afterlength1,5);
rpm1 = sum(slit1)/8;
b4length1 = afterlength1;


hour2 = node2.Data(:,1);
afterlength2 = length(hour2);
min2 = node2.Data(:,2);
sec2 = node2.Data(:,3);
distance2                                                    =
interp1(voltage,dis,2.5*node2.Data(b4length2+1:afterlength2,4)/4096);
distance2(isnan(distance2))=0;
avgdis2 = mean(distance2);
slit2 = node2.Data(b4length2+1:afterlength2,5);
rpm2 = sum(slit2)/8;
b4length2 = afterlength2;

hour3 = node3.Data(:,1);
afterlength3 = length(hour3);
min3 = node3.Data(:,2);
```

```
sec3 = node3.Data(:,3);
distance3                                                          =
interp1(voltage,dis,2.5*node3.Data(b4length3+1:afterlength3,4)/4096);
distance3(isnan(distance3))=0;
avgdis3 = mean(distance3);
slit3 = node3.Data(b4length3+1:afterlength3,5);
rpm3 = sum(slit3)/8;
b4length3 = afterlength3;

hour4 = node4.Data(:,1);
afterlength4 = length(hour4);
min4 = node4.Data(:,2);
sec4 = node4.Data(:,3);
distance4                                                          =
interp1(voltage,dis,2.5*node4.Data(b4length4+1:afterlength4,4)/4096);
distance4(isnan(distance4))=0;
avgdis4 = mean(distance4);
slit4 = node4.Data(b4length4+1:afterlength4,5);
rpm4 = sum(slit4)/8;
count = count + 1;
b4length4 =afterlength4;

count = count + 1;
end

totalavgdis = (avgdis1 + avgdis2 + avgdis3 + avgdis4)/4
avgrotation = (rpm1 + rpm2 +rpm3 + rpm4)/4

if totalavgdis < 25 && avgrotation < 40
    disp('Traffic is congested')
else
    disp('Traffic is fine')
end

pause(5);
end

close(node1)
close(node2)
close(node3)
close(node4)
close(conn)
```