TRAFFIC CONGESTION DETECTION
USING
WIRELESS SENSOR NETWORK

By

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FINAL PROJECT REPORT

Submitted to the Department of Electrical & Electronic Engineering
in Partial Fulfillment of the Requirements
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CERTIFICATION OF APPROVAL

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Approved:

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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.

Muhammad Azizulhariz Bin Jalil

ABSTRACT

Nowadays, traffic congestion has becoming one of the biggest problems faced by developing and developed countries. The project aims to produce a solution for traffic congestions using a wireless sensor network by effectively conveying real time information to the public. The wireless sensor network consists of sensors that deployed in each vehicle and have the ability to communicate with each other via wireless motes. An algorithm decides the occurrence of the traffic congestion from data obtained by the speed and distance sensors. At the end of the project, a simple prototype is built using a distance sensor and a motor connected to a speed sensor to represent the sensor connected to the wheels of a vehicle.

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LIST OF ABBREVIATIONS

ACC	–	Adaptive Cruise Control
Co-AMs	–	Cooperative Awareness Messages
IR	–	Infrared
LED	–	Light Emitted Diode
NesC	–	Network Embedded System C
OS	–	Operating System
UTP	–	Universiti Teknologi PETRONAS
V2V	–	Vehicle to Vehicle
VANET	–	Vehicular Ad-hoc Network
WSN	–	Wireless Sensor Network

CHAPTER 1
INTRODUCTION

1.1 Project Background

Automobiles have revolutionized the world we live in but in the sacrifice of time and the environment. Recently, traffic congestion is a crucial problem the world needs to solve as it has becoming one of the stress factors in developing and developed countries. It leads to low productivity and eventually several types of losses. In order to solve this problem, this project is using a wireless sensor network to convey real time traffic information to the public.

Wireless Sensor Network (WSN) is a wireless network between sensors and a controller. The sensor would measure the physical or environment condition such as speed or distance before transmitting the data obtained via wireless network to the controller for further action. This low cost network has low energy consumption that can give real-time information to the public. One of the applications of WSN is Vehicular Ad-hoc Network (VANET). VANET is a wireless network created between vehicles using the vehicle as a wireless node. In the project, the sensors that attached to the vehicle will measure the speed and the distance between other vehicles to detect the traffic congestion. If the speed does not exceed the threshold level or the distance is below the threshold level, congestion message is created and multi hopped to the vehicles at the rear end of the congestion. The message also will be seen by the vehicles approaching the congested road. This allows the drivers to avoid the congestion.

1.2 Problem Statement

In recent years, automobile production and use have skyrocketed. This results in an increment of occurrences of traffic congestions. This problem occurs due to inefficient flow of real time traffic information to the public. This inefficient flow of information results in more automobiles crowding in the already crowded road. An automobile not knowing whether a road is crowded will use that road and be stuck in it due to the traffic congestion.

1.3 Objectives and Scope of Study

The objectives of the project are as follows:

1. To design a wireless sensor network that detects the occurrence of traffic congestion.
2. To build a prototype consists of sensors and wireless motes.
3. To test the prototype in deciding the occurrence of the traffic congestion.

The prototype is built using a distance sensor and a motor connected to a speed sensor to represent the sensor connected to the wheels of a vehicle. In order to transmit the data obtained to the base station, these sensors are connected to the wireless motes. Hence, the base station decides the occurrence of the traffic congestion according to the proposed algorithm for the data obtained by the sensors.

1.4 Relevancy of the Project

In Malaysia, traffic congestions are a very big problem. Commuting between the workplace to our homes has been a dreaded event on a daily basis. This project aims to alleviate the stress faced by the drivers in Malaysia by reducing traffic congestions. This projects effects every individual in Malaysia, the working and non working individuals of Malaysia, as this project will be open for use to the public as well.

1.5 Feasibility of the Project

These days, there are several types of sensors that could measure speed and distance of a particular object such as a rotary encoder and infrared sensor. There are also several wireless sensor network modules that can be programmed to communicate with each other as well as to analyze the data obtained from the sensors such as IRIS and MICA modules. With these existing technology and 8 months given by UTP, it surely an adequate time for this project to be done.

CHAPTER 2
LITERATURE REVIEW

2.1 Traffic Congestion Detection

There are several existing projects and researches being done to solve the traffic congestion issue. One of the existing projects is traffic congestion detection using Vehicle Ad-hoc Network (VANET) [1]. VANET is a mobile ad-hoc network where the nodes are moving vehicles. The system uses wireless motes to communicate and speed sensors to measure the speed of the vehicle. It decides the occurrence of traffic congestion by the speed of the vehicle. If the speed has not reached to the threshold voltage, the system decides that there is traffic congestion. This project uses IRIS motes as their wireless motes. It also uses IR proximity sensor as their speed sensor that will be connected to circuit for interfacing the sensor with the wireless mote. The IR proximity sensor is used to calculate the wheel rotation by detecting the number of rotations made by the shaft of the remote control car.

Other existing project is a technology developed by Honda Motor Co. Ltd. to detect the potential for traffic congestion from the driver's driving pattern. Honda developed this technology which recognizes the acceleration and deceleration behavior of one vehicle that can trigger the traffic congestion [2]. The system monitors the driving pattern that influences the traffic pattern of trailing vehicles. The system is equipped in the vehicle. Instead of receiving real-time information to help the driver avoid existing congestion, the system monitors the driving pattern of the driver as if his driving pattern is likely to create traffic congestion. This technology is able to minimize vehicle congestion and also improving fuel efficiency of that particular vehicle. The system provides the driver with appropriate information to encourage smooth driving. The smooth driving includes the capability of the system to maintain the distance from vehicles in front. If the Adaptive Cruise Control (ACC) is activated, the system could maintain a constant distance between vehicles at some interval.

One of the existing researches is done by Department of Computer Science and Engineering Indian Institute of Technology, Bombay. The research is about detecting the traffic congestion by wireless across road [3]. The system consists of sender and receiver deployed on the road. The sender and receiver are placed between the roads as shown in Figure 1. The receiver measures the signal strength and link quality depending on whether the road in between has free-flowing or congested traffic. The sender will continuously send signal to the receiver. If the receiver receives a weak signal or a signal of poor quality, it will decide that there is congestion of traffic in that particular road. Figure 1 (a) shows free-flowing traffic and Figure 1 (b) shows when the traffic is congested.

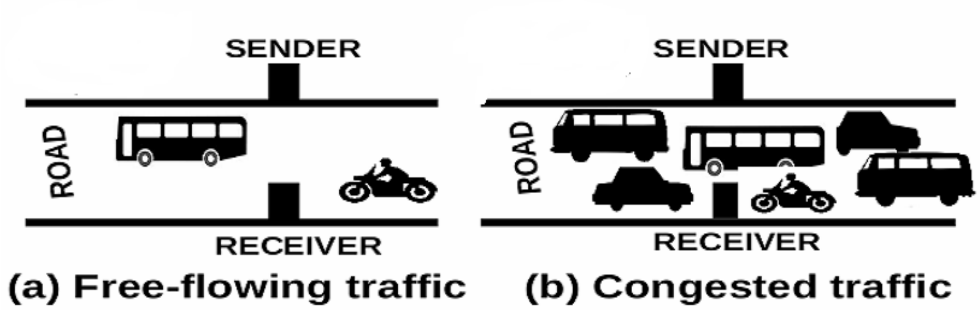

Figure 1 Wireless Across Road [3]

2.2 VANET

Vehicular Ad-hoc Network (VANET) has been envisioned to be useful in many commercial applications [4]. It is a wireless network created between vehicles. It receives data from sensors that attached at each vehicle and communicate with other vehicles to determine the occurrence of traffic congestion. They communicate with neighboring vehicles via a wireless network. The network allows also the vehicles to share the data obtained from the sensors attached. In order to maximizing the network's performance, lots of sensors will be deployed in the particular vehicle. It is to make sure there are still other sensors that can perform the measurement if there are broken sensors.

For communication between the vehicles, V2V (vehicle to vehicle), the vehicles periodically transmit broadcast beacons, also known as Co-AMs (Cooperative Awareness Messages), to announce their presence to neighboring nodes (vehicles nearby) providing information about their speed and distance [5]. Once the vehicle received the information from the neighboring nodes, it will decide the occurrence of the congestion following the proposed algorithm. In the proposed algorithm, there is a threshold level for the speed and the distance of the vehicles. If the speed does not exceed the threshold level or the distance is below the threshold level, congestion message is created and multi hopped to the vehicles at the rear end of the congestion. The message also will be seen to the vehicles that approaching the congestion.

2.3 Sensors and Wireless Motes

There are some low cost wireless sensor networks in the market such as MICA mote and IRIS mote. MICA mote is a third generation device used for enabling low-power, wireless sensor networks available in 2.4GHz and 868/916 MHz while IRIS is the latest generation which has three times the improved radio range and twice the program memory over MICA mote [6]. IRIS is more user-friendly since it is equipped with a new software platform called Mote Runner that eases the testing and debugging process. The chosen mote will be deployed in each car. It will share the speed or the distance of the vehicle to the neighboring nodes before determining the occurrence of the congestion and announce it to the public. Figure 2 and Figure 3 show IRIS and MICA motes respectively.

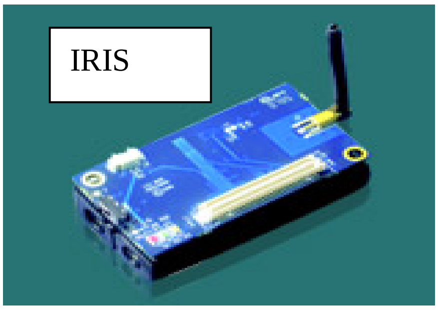

Figure 2 Iris Mote [6]

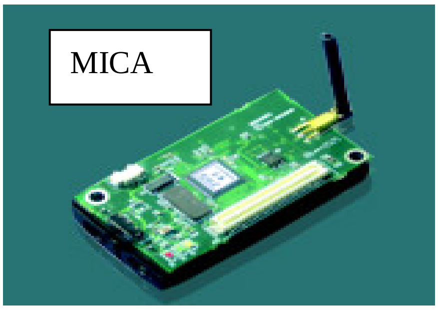

Figure 3 Mica Mote [6]

In this project, sensors for measuring the speed of the vehicle or the distance between the vehicles would be used. In current technology, there are few sensors that could be used in the project. For speed sensors, there are rotary encoder kit and accelerometer. The rotary encoder kit comes with a slotted disc (8 slots) and a simple interface sensor board [7]. It is produced by Cytron to convert the data of rotary motion into a series of electrical pulses which is readable by controller. Figure 4 shows an image of rotary encoder kit.

Figure 4 Rotary Encoder Kit [7]

Accelerometer is a sensor that measures acceleration forces. These forces may be static, like the constant force of gravity, or they could be dynamic - caused by moving or vibrating the accelerometer [8]. It sometimes does not measure the rate of velocity change due to gravity. It will measure 9.81 m/s2 when the object is at rest. It is highly sensitive and complex in measuring the acceleration of a vehicle. Figure 5 shows an example of an accelerometer board.

Figure 5 Accelerometer Board [8]

In order to measure the distance between the vehicles, there are some recommended sensors. They are ultrasonic sensor and medium range infrared sensor. Ultrasonic sensor is a low cost sensor that uses sound waves which making them ideal for stable detection of uneven surfaces and clear objects. It works well for applications that require precise measurements between stationary and moving objects [9]. Figure 6 shows an image of ultrasonic sensor.

Figure 6 Ultrasonic Sensor [9]

Medium range infrared sensor offers simple, user friendly and fast obstacle detection using infrared; it is non contact detection [10]. It can be easily assembled due its small size and its sensing distance can be manually adjusted. This infrared sensor is compatible with all type of microcontrollers. Figure 7 shows an image of the medium range infrared sensor.

Figure 7 Medium Range Infrared Sensor [10]

2.3.1 Sensors and Wireless Motes Comparison

After few researches done on the sensor and wireless motes, Table 1 shows the comparison between them.

Table 1 Sensors and Wireless Motes Comparison

Speed Sensors	
Rotary Encoder Kit	**Accelerometer**
➢ Low-cost ➢ Requires simple programming codes	➢ Expensive ➢ Requires complex programming codes
Distance Sensors	
Ultrasonic Sensor	**Medium Range Infrared Sensor**
➢ Low-cost ➢ Accurate ➢ Requires programming	➢ Low-cost ➢ User friendly ➢ Its sensing distance can be manually adjusted

From the comparison table above, rotary encoder kit is used as the speed sensor and medium range infrared sensor is used as the distance sensor. The speed sensor measures the speed of the motor that represents the wheel of the vehicle while the medium range infrared sensor measures the distance between the vehicles.

CHAPTER 3
METHODOLOGY

3.1 Research Methodology and Project Activities

3.1.1 Research Methodology

There are few methods in conducting the project. It started with the literature review. The literature review listed down all possible wireless sensor networks and sensors that applicable. Research was done to determine the best wireless sensor networks and sensors that can be implemented in the project. There are a few criteria in choosing the right wireless sensor networks and sensors such as the cost and equipment accuracy. From the literature review, IRIS is found to be better than MICA for wireless sensor networks as it has three times the improved radio range and twice the program memory of MICA mote. Moreover, IRIS is more user-friendly since it is equipped with a new software platform called Mote Runner that eases the testing and debugging process.

For speed sensors, rotary encoder kit is the best sensor can be used as it is affordable and requires simple programming codes besides accelerometer’s expensive cost and complexity. For distance sensors, medium range infrared sensor is found to be more user-friendly. It is very convenient as its sensing distance can be manually adjusted without programming involves.

After deciding the wireless modules and sensors that will be used, the wireless modules then need to be programmed. It is programmed so that it can interact with each other. Before producing the programming codes for the sensors, a circuit that connects the sensor with the module needs to be built. In order to construct the circuit, we need to implement it on the breadboard before deploy it on the prototype itself. We need to test the circuits whether the sensors communicate with the wireless modules. Then the wireless modules need to be programmed following the desired algorithm. The sensors will measure the speed and the distance of the vehicle. The modules then will interpret the measurement before decide the occurrence of traffic congestion following the algorithm. If the speed does not exceed the threshold level or the distance is below the threshold level, congestion message is created.

3.1.2 Project Activities

The project activities are shown in Figure 8.

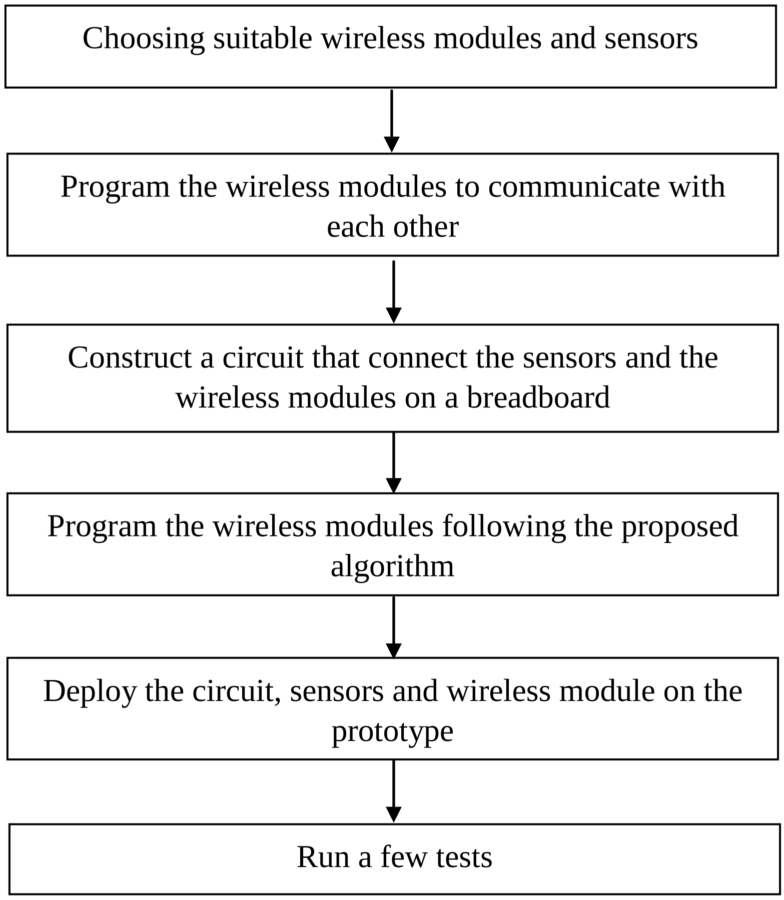

Figure 8 Project Activities

3.2 Key Milestone

These are some key milestones that need to be achieved from this project:

- Week 8 – Completion of wireless modules programming which results in the ability of the modules to communicate with each other.
- Week 22 – Completion of the prototype.

Other milestones are shown later in Section 3.3 Gantt chart.

3.3 Gantt chart

Project activities	**Description**	**Week No.**																											
		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**
Choosing wireless motes & sensors.	The most suitable wireless motes and sensors are chosen.																												
Program the wireless modules	Make the motes communicate with each other																												
Construct a circuit	Connect the sensors with the motes																												
Program the wireless modules	Program the motes based on the algorithm																												
Produce the prototype	Deploy the sensors & wireless motes on the prototype																												
Run a few tests	Testing the prototype																												

3.4 Tools Required

These are main tools that required in conducting the project:

A) NesC

The NesC (network embedded system C) is a dialect of C language and an extension to the C programming language designed to embody the structuring concepts and execution model of Tiny OS [11]. The coding for the motes will be in this language before being executed using Tiny OS. The coding will consist of the algorithm and the communication between the IRIS motes.

B) Tiny OS

Tiny OS is an embedded operating system that using NesC as the programming language and act as a compiler for the NesC codes. It is an open source component-based operating system and platform targeting wireless sensor networks [12].

C) IRIS Mote

Low-power, 2.4GHz wireless sensor network that equipped with a new software platform called Mote Runner that eases the testing and debugging process.

D) Rotary Encoding Kit

The Cytron rotary encoder kit converts the data of rotary motion into a series of electrical pulses which is readable by controller. This sensor is to measure the speed of the motor which represents the wheel of a vehicle.

E) Medium Range Infrared Sensor

Low cost sensor that uses infrared signal to detect the distance between the sensor and an object. This sensor will be attached to the prototype to measure the distance between the vehicles.

CHAPTER 4
RESULT AND DISCUSSION

4.1 Problems Encountered and Solutions

Problem 1 – Incompatible Software

This problem was encountered during the early weeks of the second semester. The codes could not be compiled and uploaded to the motes. There were “avr-gcc” and “no such file or directory” errors popped out from the programmer’s notepad software. Figure 9 shows a snapshot of the error.

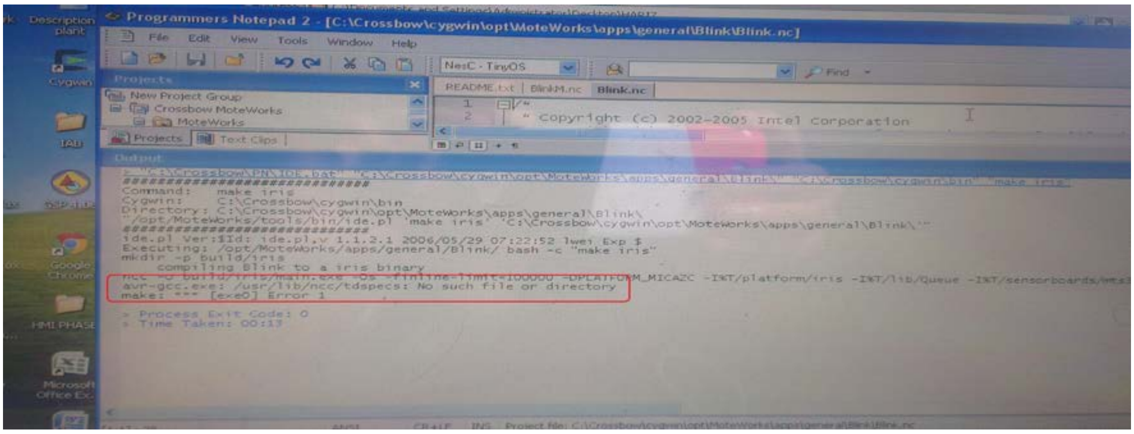

Figure 9 Programmer’s Notepad Error

The problem was because I was using an old laptop that doesn’t meet up to the requirements of the software. The software does not compatible with laptop that using operating system other than Windows XP. After changing the laptops, the codes finally can be compiled and uploaded to the motes. Figure 10 shows a snapshot of the result while Figure 11 shows snapshots of the laptops that being used. Left hand side of the figure 11 shows the old laptop while the right hand side of the figure shows the one I am using right now.

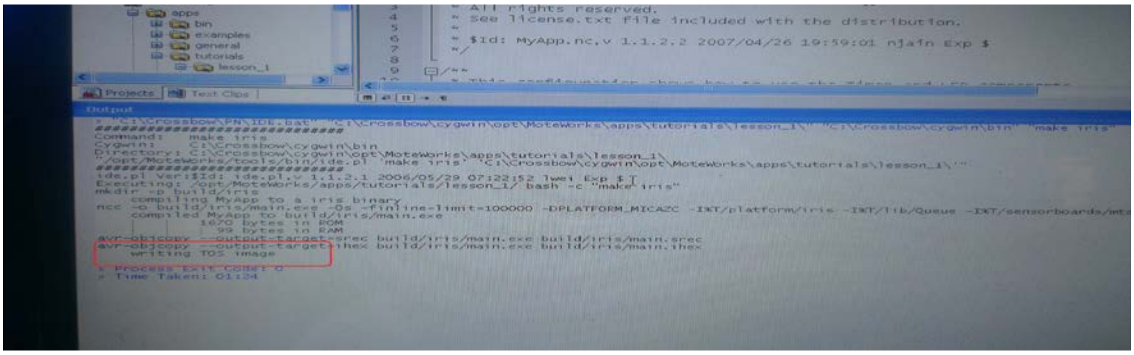

Figure 10 Problem 1 Solved

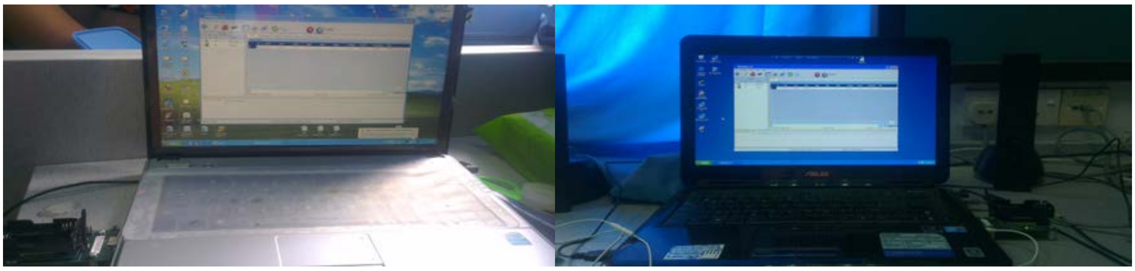

Figure 11 Laptops Comparison (left to right; Old, New)

Problem 2 – Data Extraction Error

After the base station received data from the sensors, it needs to allow the data to be extracted before being programmed according to the proposed algorithm. The project should be using Matlab Software to extract the data from MoteView software but a problem was encountered. The Matlab software could not find the database as results in failure of data extraction. Due to this problem, the data obtained could not be programmed. Hence, in order to decide the occurrence of the traffic congestion, other technique is used. The project decides the occurrence of the traffic congestion by comparing the data obtained by the sensors with a threshold value. The MoteView software produces an alert signal if the data obtained larger than the threshold value. Figure 12 shows a snapshot on how the comparison works.

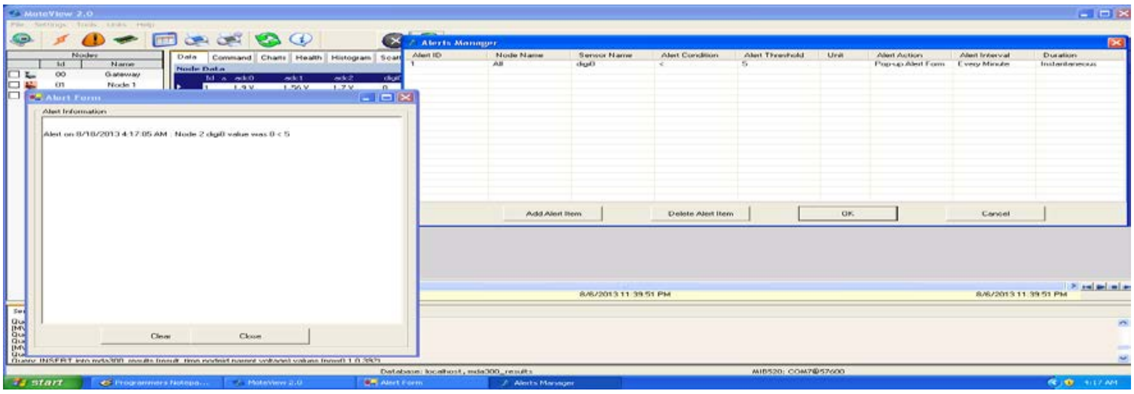

Figure 12 MoteView Alert Manager

Problem 3 – Measuring the Speed of the Vehicle

Using the rotary encoder kit as the speed sensor (explained in section 2.3 Sensors and Wireless Motes), it needs a formula to convert the rotation of the wheels to a speed unit which is in meter per second (m/s). The rotary encoder kit includes an eight slotted disc with a diameter of 35mm. In order to find the speed, time for 16 transitions of the slot is measured and divided by the diameter of the disc. This formula can be done only with a programming which needs an extraction of data from the MoteView to the Matlab software. However, due to Problem 2, it is impossible to carry on with the formula. Hence, by using the threshold value, the numbers of transitions are being compared. For example, the threshold value is equal to 10 m/s which if converted to the numbers of transitions will results in 285 transitions per second. So, if the transitions of the motor are below than 285 transitions, an alert signal will be announced shows that the speed of the car is below than 10 m/s.

4.2 Prototype

The prototype is shown as in Figure 13.

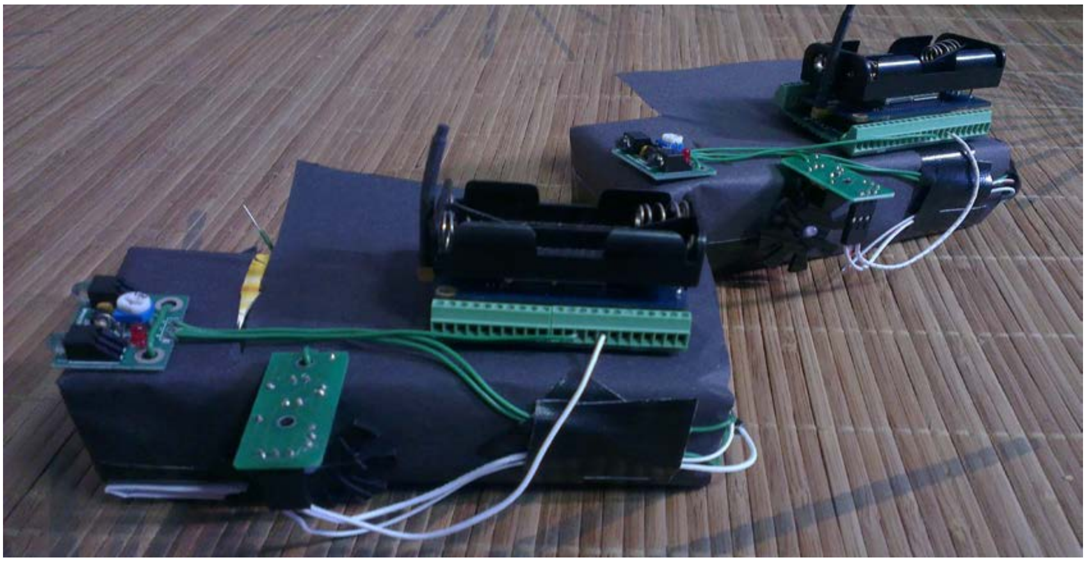

Figure 13 Prototype

The prototype is built using a medium range infrared sensor acting as the distance sensor and a motor connected to a rotary encoder kit acting as the speed sensor to represent the sensor connected to the wheels of a vehicle. From the figure, the wireless motes are put on top of the vehicles while the medium range infrared sensors are put in front of them. The rotary encoder kit is connected to the motor which can be seen at the side of the prototype.

By using a variable resistor, the speed of the motor can be varied. The variable resistor is connected in series with the motor. Figure 14 shows an image of the variable resistor.

Figure 14 Variable Resistor

The prototype is being deployed with wireless mote which is to communicate wirelessly with a base station that connected to the laptop. Eventually, the data obtained from the sensors are displayed at the screen of the laptop using MoteView software. Figure 15 shows an image of the base station.

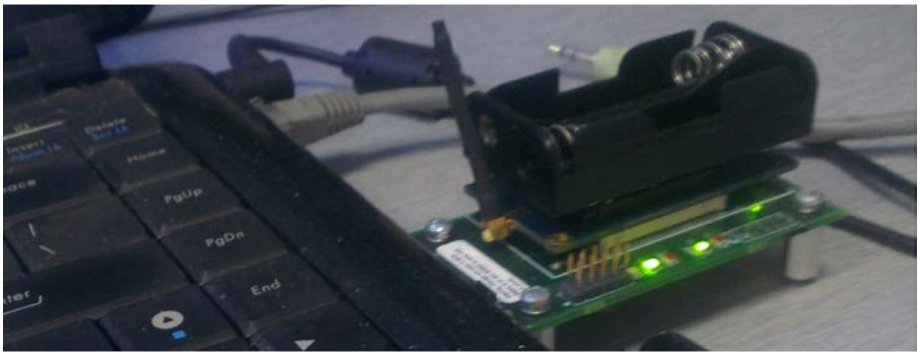

Figure 15   Base Station

4.3 Data Analysis

By varying the speed of the motor and the distance between the vehicles, the results are tabulated. Table 2 shows the data analysis of the project.

Table 2 Data Analysis

Transitions threshold value = 100		
Motor Transitions No.	Remarks	Alert Manager
250	Exceed the threshold value	None
80	Lower than the threshold value	Pop-out
Distance threshold value = 2 cm		
Distance between the vehicle	Remarks	Alert Manager
1 cm	Lower than the threshold value (red LED is on)	Pop-out
6 cm	Exceed the threshold value	None

Hence, whenever the speeds of the vehicles and the distance between them are below than the threshold value, traffic congestion is detected.

CHAPTER 5
CONCLUSIONS AND RECOMMENDATIONS

The project done can detect a traffic congestion by monitoring the speed and the distance between the vehicles which relevant to the project objective. Whenever the speed of the vehicles are slow and the distance between them are really close, traffic congestion is detected. The prototype is consists of sensors and wireless motes that giving real time information transfer between automobiles.

For further action on the project, the prototype could be implemented to a real vehicle. Using low cost and low energy consumption wireless sensor network, the system can detect traffic congestion by the communication between the vehicles via wireless motes. With already installed digital speedometer inside the vehicles, the system could process more accurate results.

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APPENDICES