NOVEL MODEL FOR VEHICLES TRAFFIC MONITORING USING WIRELESS SENSOR NETWORKS BETWEEN TWO MAJOR CITIES IN SOUTH AFRICA

BY

MBODILA MUNIENGE

(STUDENT NUMBER: 24087467)

DISSERTATION SUBMITTED IN FULLFILMENT OF THE REQUIREMENT FOR THE AWARD OF DEGREE OF MASTER (MSc) OF COMPUTER SCIENCE

NORTH-WEST UNIVERSITY
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT
MAFIKENG CAMPUS

DEPARTMENT OF COMPUTER SCIENCE
SCHOOL OF MATHEMATICAL&PHYSICAL SCIENCES
FACULTY OF AGRICULTURE, SCIENCE AND TECHNOLOGY
NORTH WEST UNIVERSITY – MAFIKRNG CAMPUS

SUPERVISOR: PROF. OBETEN OBI EKABUA

NOVEMBER, 2013

DECLARATION

I declare that this dissertation Project on **Novel Model for Vehicle's Traffic Monitoring using Wireless Sensor Networks between Major Cities in South Africa** is my work, and has never been presented for the award of any degree in any university. All the information used has been dully acknowledged both in text and in the references.

Signature ______________ Date 18-09-2014

Mbodila Munienge

Approval

Signature ______________ Date ______________

Supervisor: **Prof O.O. Ekabua**

Department of Computer Science

Faculty of Agriculture, Science and Technology

North West University,

Mafikeng Campus

South Africa

DEDICATION

This research dissertation is dedicated to my three children:

Preddie Mikwimi Mbodila, Graddi Mabanza Mbodila

And

Merdi Zuka Mbodila

ACKNOWLEDGEMENTS

I would like to express my gratitude and praises to the Almighty God, for making this journey possible for me. I thank God for giving me life, knowledge, wisdom, provision and seeing me through to the successful completion of my Master's degree programme.

I am grateful and thankful to Prof O.O. Ekabua, my supervisor, for his support, advice, and useful criticism while carrying out this research project. I am also thankful for his motivation to me in pursuing this degree.

I am also grateful to the North West University, Mafikeng Campus, for their help and financial support toward this programme.

I also appreciate the help, support and encouragement of all my family, friends, church members and elders – Lazare Mabanza and his wife Silvy Kabobi, Theo Talangwa and his family, Sarah Mabanza, Thete Masonga and her family, Sarah Mbi, Rock Kikunga, to Ndaya Zuka and her family, Andre Van Nierkerk and his family, Sean and Erin, Etienne and Matjeen, Stanley and his family, Pastor Jean Baptiste and Mama Lily Sumbela, Bassy Isong, Nosipho Dladlu.

To my late father Godet Mabanza, my late brothers Zuka and Djona this is also for you, may your souls rest in peace.

I am very grateful to God for my mother, Mrs Mabanza Mikwimi Miyamba, for her love, support.

Finally, I wish to express my love and gratitude to my wife, Blandine Kikunga Muhanji, for her love, support and encouragement. And to my children, Preddie Mbodila, Graddi Mbodila and Merdi Mbodila, for inspiring me, even in the midst of their distractions and demands. Guys, this was not going to have any meaning without you. I love you and you are such a blessing to me.

Table of Contents

List of Figures

List of Tables

List of Acronyms

BNS	Body Sensor Network
CPU	Central Process Unit
DAU	Data Acquisition Unit
DPU	Data Processing Unit
DRSU	Data Sending and Receiving Unit
EPC	Electronic Product Code
ECG	Electrocardiograph
HF	High Frequency
GPS	Geographical Positional System
MANET	Mobile Ad hoc Networks
MAC	Medium Access Control
MEMS	Micro-electromechanical System
N	Nodes
ID	Identification
ITS	Intelligent Transportation System
OTCL	Object Tool Command Language
PC	Personal Computer
UHF	Ultra-high Frequency
RDS	Radio Data Service
RFID	Radio Frequency Identification
RCS	Rohrback Cosasco Systems
TCO	Traffic Control Office
TCM	Traffic Control Monitoring
TCL	Tool Command Language
GSM	Global System Mobile
DSSS	Direct Sequence Spread Spectrum
SENSE	Sensor Network Simulator and Emulator
NCPA	Network Capable Application Processor
OCS	Operation Control System

TEDS	Transducer Electronic Data Sheet
QoS	Quality of Service
PAN	Persona Area Networks
LAN	Local Area Networks
WSN	Wireless Sensor Network
XML	Extensible Markup Language
WAP	wireless Access Point
IP	Internet Protocol
OSI	Open System Interconnection
LR-WPAN	Low-rate Wireless Personal area Networks
ISF	Importer Security Filing
IEEE	Institute of Electrical and Electronics Engineers
OCR	Optical Character Recognition
NFC	Near field communication

Abstract

With the growing number of vehicles and users, monitoring road and traffic within cities is becoming a huge research challenge. With urban scale enlargement coupled with the exponential growth in the number of vehicles, South Africa (SA) is not an exception. Consequently, congestion and pollution (i.e. noise and air) have become the order of the day. Road congestion and traffic-related pollution are well-known for huge negative socio-economic impact on several economies worldwide. For over a decade now, the number of cars on SA roads has increased tremendously and the road transport profile is characterized by its sizeable and total dependence on cars particularly in the highly developed urban areas alongside cycling, and other public transport. This has brought about increasing congestion in public roads which poses a serious problem not only for SA, but many countries of the world and has to be contained. Several solution methods have been proposed requiring dedicated hardware such as GPS devices and accelerometers in vehicles or camera on roadside and near traffic signals. Most other works in literature concentrated on lane systems and orderly traffic, which is common in the developing world and in some cases, the traffic is highly chaotic and unpredictable. The situation in SA cities like Johannesburg and Pretoria is not different. All these methods are costly and require much human effort. Therefore, in this dissertation, we present a novel model that is cost effective, requires less human intervention, but uses wireless sensor networks, GPS and RFID scanner to monitor traffic in major SA cities. The novel model was developed and simulated using VisualSense platform, the results obtained after simulation shows that the congestion level during busy hours was reduced and the traffic was managed.

CHAPTER 1

Introduction and Background

1.1 Introduction

Traffic vehicle monitoring in South Africa is becoming more and more vital due to urban scale enlargement coupled with the exponential growth in the number of vehicles. With this development, congestion and pollution (i.e. noise and air pollution) have been the order of the day. Road congestion and traffic-related pollution are well-known for their huge negative socio-economic impact on several economies worldwide. Over the last 10 years the number of cars on South African roads has increased tremendously by almost 30% and road authorities are struggling to contain the effects of the growing congestion that has resulted [1]. The road transport profile in South Africa is characterized by its sizeable dependence on cars particularly in the highly developed urban areas, alongside cycling and other public transport. Increasing congestion levels in public road networks is a growing problem not only in South Africa but worldwide and has to be contained. The growth of urban areas in South Africa has resulted in an increase in traffic flow on most roads. As road networks usage increases, traffic congestion increases, and this is also characterized by slower speeds, longer trip times, and increased vehicular queuing.

In order to keep the situation under control, there are several monitoring systems that exist, and help in alleviating this problem. However, traffic monitoring of vehicles is a complex issue that requires real-time monitoring. The data processed by the monitoring system is huge, requiring high throughput computation. With the advances in technology of microelectromechanical system (MEMS), developments in wireless communications and wireless sensor networks (WSNs) have also emerged [2]; coming in handy in the monitoring system.

Wireless Sensor Network consists of spatially distributed autonomous sensors to observe changes in physical or environmental conditions. Sensing devices will be able to monitor a wide variety of ambient conditions such as temperature, sound, vibration, pollution, pressure, humidity, soil makeup, vehicular movement, noise levels, lighting conditions, the presence or absence of certain kinds of objects, mechanical stress levels on attached objects and so on. The sensors work cooperatively to pass the data collected through the network to different locations. Lately, with the expansion of computer, network, image processing, transmission technology, video monitoring systems and hardware, wireless sensor networks are widely used in different domains and areas. Today the world is covered with wireless sensor networks which can be accessed via the Internet. This can be considered as the Internet becoming a physical network.

1.2 Background

Given the expected growths in urban areas traffic, geographically the scale and complication of the traffic infrastructure will gradually continue to rise with time throughout South Africa. To guarantee vehicles monitoring efficiency, safety, and security in the presence of such growth and avoiding pollution (such as noise and air) it is critical to develop a system that can adapt to growth while guaranteeing reliability in urban roads in South Africa. With the development of Wireless Sensor Networks many cities around the world have developed a variety of technologies and systems to manage and control their roads network better. Currently the majority of urban road networks in South Africa is controlled by i-Traffic system which is an integrated system of CCTV cameras linked by fiber optic cable to a central control centre [1]. At the control centre, human operators are in charge of continuously monitoring and analyzing a huge amount of data from video cameras system on the roads. The human decision makers must indicate the correct approach by analyzing the CCTV information, and then inform the ground officer and/or remotely configure traffic control equipment using the communication infrastructure. This traffic monitoring system has several problems arising from it.

First, the required communication infrastructures are expensive, particularly as the urban area roads networks system grows in coverage and the number of CCTV connections increases. Certainly, this growth limits the possibility of wide deployment extending to broader suburban and urban areas. From a safety perspective, the communication and control center infrastructure is also vulnerable to any type of risk such as terrorist attacks and natural disasters. Furthermore, the collection and processing of mass data at a centralized location incurs substantial latencies, reinforcing the geographical scope within which acceptable real-time response is possible. Finally, human operators/officers who monitor the CCTV system endure high working stress, which in turn decreases the system reliability.

This research project aims to overcome some limitations in the current traffic monitoring system by proposing a novel system for vehicle traffic monitoring that will use wireless sensor networks technology to monitor traffic vehicles between two major cities roads area.

1.3 Problems Statement

With an increasing number of vehicle and vehicles users, traffic control and monitoring in an effective way has posed an interesting research challenge. Therefore, it has become imperative to have a mechanism by which people can know, in real time, about the traffic conditions on the route on which they wish to travel or are travelling on. Consequently, research on traffic monitoring has gained significant attention in the 21st century [3], [4], and [5]. Obviously, road congestion and traffic-related pollution have a huge negative socio-economic impact on several parts of the world. With the enlarging of urban scale and increasing number of vehicles, traffic monitoring in South Africa is becoming vital. However, most developed countries have developed an intelligent transport system (ITS) as a major way to solve contradiction between the roads and the vehicles. But developing countries like South Africa are still faced with the challenge of vehicle traffic monitoring. Monitoring roads and traffic conditions in a city is a problem that is widely studied in the developed and developing countries, and South Africa is not an exception [3]. Therefore, this research project intends to develop a novel model for vehicle traffic monitoring through the application of sensor networks between two renowned traffic congestion cities in South Africa.

1.4 Research Questions

In order to address the problem as stated above, this research would provide answers to the following questions:

RQ1: With the increasing traffic congestion, how can we minimize congestion in our urban cities?

RQ2: How can we provide traffic congestion information to vehicle users?

RQ3: Is it possible to develop a novel wireless sensor model to enhance traffic monitoring and reduce congestion in our urban cities?

1.5 Research Goal

The main goal of this research project is to design a novel model system for vehicle traffic monitoring using wireless sensor networks between two major cities in South Africa.

1.6 Research Objectives

In order to achieve the main goal of this research, we shall employ the following objectives:

(i) Review different literatures on WSN for vehicle traffic monitoring system

(ii) Evaluate the existing vehicle traffic monitoring system.

(iii) Develop a novel system model for vehicle traffic monitoring using WSN that will overcome the challenges of the current system.

(iv) Implement the model as a proof of concept.

1. 7 Motivation

As the urban road networks is growing day-by-day, the question of how to obtain information about the roads is becoming more and more challenging. The use of a wireless sensor network has offered more opportunities in designing efficient systems for traffic monitoring, smart roads monitoring and intelligent transportation monitoring. Much of the previous work concentrated on lane system and orderly traffic [3], which is rare outside the developed world. For example, in India, the traffic is highly chaotic and unpredictable. With the advancement in sensor technology and sensor networking, decisions regarding efficient allocation of sensor resources are quickly becoming important. Sensor management is the automatic control of a group of sensors including the data fusion processing in a sensor network to achieve a system goal. Its objective is to improve the efficiency of the sensors and communications, simultaneously. Large, complex systems of sensors are emerging due to new networking technology, but advances in sensor management are needed to make the communication system viable [3], [4].

To overcome this challenge on our roads, it is necessary to develop a novel system that will monitor vehicle traffic in urban areas using wireless sensor networks.

1.8 Research Methodology

The methodology to be used during this research shall follow the following headings:

(a) **Literature Survey**: This part will deal with the background of WSN by reviewing related work to build a solid base argument in the actual use of WSN in roads traffic monitoring.

(b) **Evaluation**: A detailed analysis and evaluation of existing models would be carried out.

(c) **Model Development**: With knowledge from existing models, we shall develop a novel model using wireless sensor networks.

(d) **Proof of Concept**: As a proof of concept, we shall implement the novel model.

1.9 Key Terminologies

Wireless: Is a term used to describe telecommunications in which electromagnetic waves (rather than some form of wire) carry the signal over part or the entire communication path. Some monitoring devices, such as intrusion alarms, employ acoustic waves at frequencies above the range of human hearing; these are also sometimes classified as wireless.

Network: In information technology, a network is a series of points or nodes interconnected by communication paths. Networks can interconnect with other networks and contain subnetworks.

Sensors: Are hardware components that can provide a computer with information about its location, surroundings, and more. Programs on a computer can access information from sensors, and then store or use it to help with everyday tasks or to improve the user's computer experience.

Wireless Sensor Network: A sensor network is a group of specialized transducers with a communications infrastructure intended to monitor and record conditions at diverse locations.

Commonly monitored parameters are temperature, humidity, pressure, wind direction and speed, illumination intensity, vibration intensity, sound intensity, power-line voltage, chemical concentrations, pollutant levels and vital body functions. A sensor network consists of multiple detection stations called sensor nodes, each of which is small, lightweight and portable.

Gateway: A gateway is a node that allows one to gain entrance into a network. On the Internet the node which is the stopping point can be a gateway or a host node. A computer that controls the traffic a network or an ISP (Internet Service Provider) receives is a node. In most homes a gateway is the device provided by the Internet Service Provider that connects users to the internet.

Congestion: A state occurring in part of a network when the message traffic is so heavy that it slows down network response time. In road traffic, congestion is a state where the road is busy and cars are not moving in a normal way.

Autonomous Sensors: Autonomous sensors transmit data and power their electronics without using cables. They can be found in wireless sensor networks (WSNs) or remote acquisition systems, for example.

Node: In computing node is an interconnection point on a computer network. In communication networks, a **node** (Latin *nodus*, 'knot') is a connection point, either a redistribution point or a communication endpoint (some terminal equipment).

Hardware: Is a general term for equipment that can be touched / held by hand such as keys, locks, hinges, latches, wires, belts, plumbing, electrical supplies, tools, utensils, cutlery and machine parts.

Physical Hardware Layer: Physical layer in the seven-layer OSI model of computer networking, the physical layer or layer **o**f the basic networking hardware transmission.

Data Link Layer: The data link layer is the protocol layer that transfers data between adjacent network nodes in a wide area network or between nodes on the same local area network segment. The data link layer provides the functional and procedural means to transfer data between network entities and might provide the means to detect and possibly correct errors that may occur in the physical layer.

Network Layer: Is responsible for packet forwarding including routing through intermediate routers, whereas the data link layer is responsible for media access control, flow control and error checking. The network layer provides the functional and procedural means of transferring variable length data sequences from a source to a destination host via one or more networks while maintaining the quality of service functions.

Application Layer: In TCP/IP, the application layer contains all protocols and methods that fall into the realm of process-to-process communications across an Internet Protocol (IP) network. Application layer methods use the underlying transport layer protocols to establish host-to-host connections.

Access Point: Wireless access point is, a device to connect to a wireless computer network. In computer networking, a wireless access point (WAP) is a device that allows wireless devices to connect to a wired network using Wi-Fi, Bluetooth or related standards. The WAP usually connects to a router (via a wired network) if it's a standalone device, or is part of a router itself.

Highway: A highway is any public road. In American English, the term is common and almost always designates major roads. In British English, the term (which is not particularly common) designates any road open to the public. Any interconnected set of highways can be variously referred to as a "highway system", a "highway network", or a "highway transportation system". Each country has its own national highway system.

Lanes: A lane is a part of the roadway (British: carriageway) within a road marked out for use by a single line of vehicles in such a way as to control and guide drivers for the purpose of reducing traffic conflicts. Most public roads (highways) have at least two lanes, one for traffic in each direction, separated by lane markings. Major highways often have two roadways separated by a median, each with multiple lanes. A single-track road carries traffic in both directions within a single lane with passing places to allow vehicles to pass.

1.10 Research Contribution

The main contribution of this research to academia and the research community is the development of a novel model for vehicles traffic monitoring between two cities in South Africa and its simulation.

1.11 Included Publication

Part of this dissertation has been published in a conference as:

Munienge Mbodila and Obeten Ekabua (2013), "Novel Model for Vehicle's Traffic Monitoring using Wireless Sensor Networks between Major Cities in South Africa", *in proc. Of international Conference on Wireless Networks (ICWN)*, WOLRDCOMP'13, Las Vegas, Nevada, July 22-25, 2013

1.12 Dissertation Organisation

The remainder of this dissertation is organised as follows:

Chapter 2 is a review of the related literature and looks at what has been done on traffic monitoring and the use of wireless sensor networks.

Chapter 3 introduces the design of the model and describes the hardware and software used for the model. It also describes the functionality of the model.

Chapter 4 presents the results obtained from simulation of the implemented model.

Chapter 5 is the conclusion of this research report.

CHAPTER 2

Literature Review

2.1 Chapter Overview

In this chapter we review related literature on the use of different components of the novel system. We discuss wireless sensor networks, their application, and types. We also look at the use of RFID scanner and the application of Global Positioning System.

2.2 Wireless Sensor Networks and their Nodes

A wireless sensor network consists of spatially distributed sensor nodes. In a wireless sensor network (WSN), each sensor node is able to independently perform some processing and sensing tasks. Furthermore, sensor nodes communicate with each other in order to forward their sensed information to a central processing unit or conduct some local coordination such as data fusion. One widely used sensor node platform is the Mica2 Mote developed by Crossbow Technology [1]. The usual hardware components of a sensor node include a radio transceiver, an embedded processor, internal and external memories, a power source and one or more sensors.

A wireless sensor network consists of spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, pressure, etc. and to cooperatively pass this data through the network to a main location. The development of wireless sensor networks was motivated by military applications such as battlefield surveillance; but today WSN technology is being used in industrial process monitoring and control [6], [7], machine health monitoring , environment and habitat monitoring, healthcare applications, home automation and traffic monitoring and control [7], [8]. In a typical application a WSN is scattered in a region where it is meant to collect data through its sensor nodes. The WSN is built of several nodes, where by each node is connected to one (or sometimes many) sensors. Each such sensor network node has typically a number of parts: a radio transceiver with an internal antenna or connection to an external antenna, a microcontroller, an electronic circuit for interfacing with the sensors and an energy source, regularly a battery or an embedded form of energy harvesting. A sensor node size might vary from one design to another one. Wireless Sensor Networks technology can help in infrastructure development; in this project we use it to develop our novel system for vehicle traffic monitoring.

A typical wireless sensor network node is composed of power, data acquisition unit (DAU), data processing unit (DPU), data sending and receiving unit (DRSU) [9]. Each hardware unit has a specific task in the system as shown in Figure2.1.

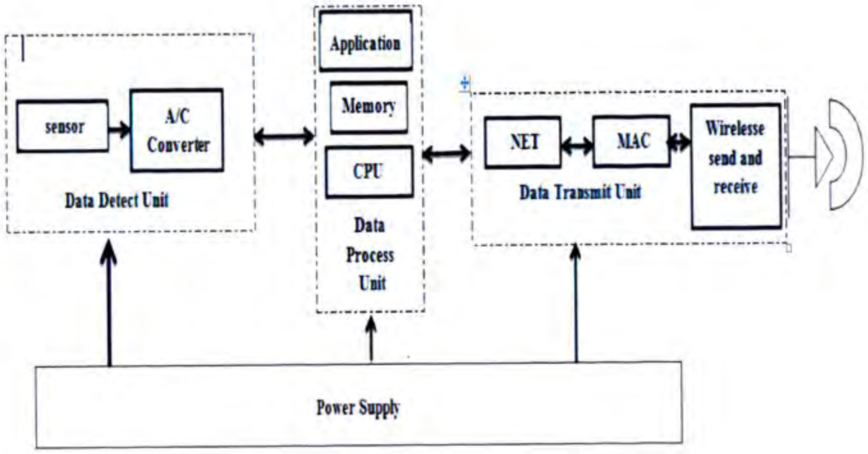

Figure 2.1: General structure of a node

2.3 Logical structure of Wireless Sensor Networks

The applications of wireless sensor networks for traffic monitoring have no space constraints, thus either features show more flexible distribution, mobile convenience and quick reaction [2] than the architecture of diverse applications. Regardless of the architecture of the wireless sensor network, its several parts are logically the same as shown in Figure 2.2.

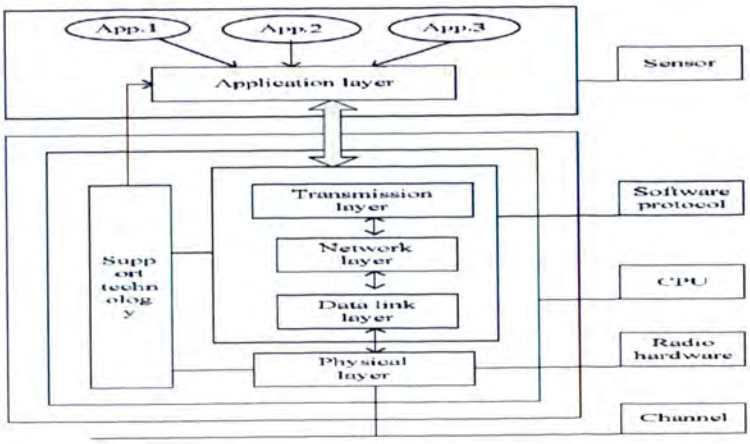

Figure 2.2: Logical structure of wireless sensor network [15]

The Physical hardware layer includes network infrastructure, sensors and other hardware related to wireless sensor networks. It is responsible for modulating, sending and receiving data.

The Data link layer provides communication between the physical layer and network layer and establishes a data link between adjacent nodes, sends the frame organized by a certain format to provide reliable information transmission mechanism for the network layer.

The Network layer deals with routing, data transfer and other issues between sensor nodes and between sensor and observer, including from the physical connection to the exclusive agreements of wireless sensor networks applied to each layer.

The Application layer includes the specific application to meet the user's need, such as traffic flow forecasting.

2.4 Types of sensor

Current WSNs are deployed on land, underground, and underwater. Depending on the environment, a sensor network faces different challenges and constraints. There are five types of WSNs: terrestrial WSN, underground WSN, underwater WSN, multi-media WSN, and mobile WSN [1].

Terrestrial WSNs typically consist of hundreds to thousands of inexpensive wireless sensor nodes deployed in a given area, either in an ad hoc or in a pre-planned manner. In ad hoc deployment, sensor nodes can be dropped from a plane and randomly placed into the target area.

In pre-planned deployment, there are grid placement, optimal placement [10], 2-d and 3-d placement [11] models. Terrestrial sensor nodes must be able to effectively communicate data back to the base station. While battery power is limited and may not be rechargeable, terrestrial sensor nodes however can be equipped with a secondary power source such as solar cells.

Underground WSNs [3], [4] consist of a number of sensor nodes buried underground or in a cave or mine used to monitor underground conditions. Additional sink nodes are located above ground to relay information from the sensor nodes to the base station. An underground WSN is more expensive than a terrestrial WSN in terms of equipment, deployment, and maintenance. Underground sensor nodes are expensive because appropriate equipment parts must be selected to ensure reliable communication through soil, rocks, water, and other mineral contents. The underground environment makes wireless communication a challenge due to signal losses and high levels of attenuation. Unlike terrestrial WSNs, the deployment of an underground WSN requires careful planning and energy and cost considerations. Energy is an important concern in underground WSNs. Like terrestrial WSN, underground sensor nodes are equipped with a limited battery power and once deployed into the ground, it is difficult to recharge or replace a sensor node's battery.

Underwater WSNs [12], [13] consist of a number of sensor nodes and vehicles deployed underwater. As differing to terrestrial WSNs, underwater sensor nodes are more expensive and fewer sensor nodes are deployed. Autonomous underwater vehicles are used for exploration or gathering data from sensor nodes. Compared to a dense deployment of sensor nodes in a terrestrial WSN, a sparse deployment of sensor nodes is placed underwater. Typical underwater wireless communications are established through transmission of acoustic waves. Challenges in underwater acoustic communication are the limited bandwidth, long propagation delay, and signal fading issues. Another challenge is sensor node failure due to environmental conditions. Underwater sensor nodes must be able to self-configure and adapt to harsh ocean environments. Underwater sensor nodes are equipped with a limited battery which cannot be replaced or recharged. The issue of energy conservation for underwater WSNs involves developing efficient underwater communication and networking techniques.

Multi-media WSNs [14] have been proposed to enable monitoring and tracking of events in the form of multimedia such as video, audio, and imaging. Multi-media WSNs consist of a number of low cost sensor nodes equipped with cameras and microphones. These sensor nodes interconnect with each other over a wireless connection for data retrieval, process, correlation, and compression. Multi-media sensor nodes are deployed in a pre-planned manner into the environment to guarantee coverage. Challenges in multi-media WSN include high bandwidth demand, high energy consumption, quality of service (QoS) provisioning, data processing and compressing techniques, and cross layer design. Multi-media content such as a video stream requires high bandwidth in order for the content to be delivered. As a result, high data rate leads to high energy consumption.

Mobile WSNs consist of a collection of sensor nodes that can move on their own and interact with the physical environment. Mobile nodes have the ability to sense, compute, and communicate like static nodes. A key difference is that mobile nodes have the ability to reposition and organize themselves in the network. A mobile WSN can start off with some initial deployment and nodes can then spread out to gather information. Information gathered by a mobile node can be communicated to another mobile node when they are within range of each other. Another key difference is data distribution. Challenges in mobile WSN include deployment, localization, self-organization, navigation and control, coverage, energy, maintenance, and data process. Mobile WSN applications include but are not limited to environmental monitoring, target tracking, search and rescue, and real-time monitoring of hazardous material.

2.5 Standards

While most ongoing work in IEEE 802 wireless working groups is geared to increase data rates, throughput, and QoS, the 802.15.4 LR-WPAN (Low rate-Wireless Personal Area Network) task group is aiming for other goals [9]. The focus of 802.15.4 is on very low power consumption, very low cost, and low data rate to connect devices that previously have not been networked, and to allow applications that cannot use current wireless specifications. Working within a standards organization to develop a wireless solution has the advantage of bringing developers and users of such a technology together in order to define a better solution. The work also fosters high-level connectivity to other types of networks and enables low-volume products that do not justify a proprietary solution to be wirelessly connected. Two physical layer specifications were chosen to cover the 2.4 GHz worldwide band and the combination of the 868 MHz band in Europe, the 902 MHz band in Australia, and the 915 MHz band in the United States. Both physical layers are direct sequence spread spectrum (DSSS) solutions. For further information, the selected proposals can be downloaded from the 802.15 Web site. The efforts of the IEEE 802.15.4 task group will bring us one step closer to the goal of a wirelessly connected world [9]. One of the IEEE 802.15.4 physical layers operates in the 2.4 GHz industrial, scientific and medical band with nearly worldwide availability; this band is also used by other IEEE 802 wireless standards [1]. Coexistence among diverse collocated devices in the 2.4 GHz band is an important issue in order to ensure that each wireless service maintains its desired performance requirements.

On the other hand, the IEEE 1451, a family of Smart Transducer Interface Standards, describes a set of open, common, network-independent communication interfaces for connecting transducers (sensors or actuators) to microprocessors, instrumentation systems, and control/field networks [6]. The key feature of these standards is the definition of a TEDS (Transducer Electronic Data Sheet). The TEDS is a memory device attached to the transducer, which stores transducer identification, calibration, correction data, and manufacture-related information. The goal of 1451 is to allow the access of transducer data through a common set of interfaces whether the transducers are connected to systems or networks via a wired or wireless means. The family of IEEE 1451 standards is sponsored by the IEEE Instrumentation and Measurement Society's Sensor Technology Technical Committee. IEEE P1451.5 defines a transducer-to-NCAP (Network Capable Application Processor) interface and TEDS for wireless transducers. Wireless standards such as 802.11 (Wi-Fi), 802.15.1 (Bluetooth), 802.15.4 (ZigBee) are being considered as some of the physical interfaces [6].

2.6 Protocols

There are several protocols proposed for WSNs (Wireless Sensor Network). The MAC (Medium Access Control) layer reacts to this probabilistic reception information by adjusting the number of acknowledgments and/or retransmissions [15]. It is observed that an optimal route discovery protocol cannot be based on a single retransmission by each node, because such a search may fail to reach the destination or find the optimal path. Next, it is discussed that gaining neighbor knowledge information with "hello" packets is not a trivial protocol. The localized position-based routing protocols that aim to minimize the expected hop count (in case of hop-by-hop acknowledgments and fixed bit rate) or maximize the probability of delivery (when acknowledgments are not sent), are described. An interesting open problem for future research is to consider physical-layer-based routing and broadcasting where nodes may adjust their transmission radii. Expected power consumption may then be considered a primary optimality measure. Further research should address other problems in the design of network layer protocols. For instance, if we consider a more dynamic and realistic channel model, such as multi-path fading, the estimated number of packets may suffer from large variance, and the described protocols may need some adjustments. More realistic interference models can be added, and transport layer protocols also need to be adjusted [15].

A survey of state-of-the-art routing techniques in WSNs is presented by Katiyar [16]. First, the design challenges for routing protocols in WSNs are outlined followed by a comprehensive survey of routing techniques. Overall, the routing techniques were classified into three categories based on the underlying network structure: flit, hierarchical, and location-based routing. Furthermore, these protocols could be classified into multipath-based, query-based, negotiation-based, QoS based, and coherent-based depending on the protocol operation. Design trade-offs between energy and communication overhead savings in every routing paradigm were studied. Advantages and performance issues of each routing technique were highlighted [16].

When compared with now classical MANETs (Mobile Ad hoc Networks) sensor networks have different characteristics, and present different design and engineering challenges [17]. One of the main aspects of sensor networks is that the solutions tend to be very application specific. For this reason, a layered view like the one used in OSI imposes a large penalty, and implementations more geared toward the particular are desirable. Communication, which is the most energy-costly aspect of the network, can be organized in three fundamentally different ways: node-centric, data-centric, and position centric. Node-centric communication is the most popular and well understood paradigm, being currently used in the Internet. The other two, data-centric and position-centric, are more scalable, better adaptable to applications, and conceptually more appropriate in many cases, and therefore may successfully challenge the node-centric way of looking at the sensor networks. Data-centric approaches, on the other hand, tend to provide a top-to-bottom solution, as is the case with directed diffusion. In fact, directed diffusion solves only one problem, but solves it correctly. A new IEEE standard, 802.15.4, is aimed at low-power low-distance communication devices that may allow years of battery life. The standard allows for both hierarchical and flat peer-to-peer topologies, and provisions for one hop reliability and real-time guarantees. At the lower layers, there may be a choice between RF and optical communication, but it is still unclear what the logical and address organization of future sensor networks will be. It can be flat with identical nodes, or hierarchical with cluster heads that are more powerful in terms of storage, computation, and communication. Solutions here are either awkward (triangle routing in mobile Internet) or wasteful (rediscovery of paths in ad hoc node-centric networks). Here position-centric approaches have the advantage because they do not require particular nodes to be involved in forwarding, but use whichever ones provide connectivity. Some of the projects exploring the possibility of installing arbitrary code on sensors are SensorWare and Maté. The use of Tcl (Tool Command Language) scripts and bytecode allows installation of complex distributed algorithms that can access all the communication and sensing capabilities of each node. Finally, if sensor networks are to be deployed in large sizes, scalability with respect to the number of nodes becomes a deciding factor in choosing a communication paradigm. It is likely that position-centric, data-centric, or maybe a combination of them is the best bet for future sensor networks [17].

IS-MAC protocol based flooding protocol (ISF) for a wireless sensor network was introduced [18]. Existing flooding protocols are based on IEEE 802.11 MAC layer that gives ideal listening problems for the sensor networks. Ideal listening is the most prominent cause of energy waste in sensor networks. An ISF routing protocol was proposed that gives energy efficient data delivery mechanism for wireless sensor networks. Special features of IS-MAC protocol make the ISF protocol the most promising candidate for routing protocols for wireless sensor networks. ISF protocol uses hop count/location information to achieve energy efficiency for the data delivery mechanism. Performance evaluation showed the superiority of ISF protocol over the direct and directional flooding protocols.

In the context of coverage, negotiation and resolution strategies are needed to integrate information from this stage to be used in related contexts such as tracking mobile objects in the network and handling obstacles [16]. Although the algorithm was developed for a wireless sensor network, a centralized control server, where nodes are connected using a gateway, was assumed. Other control strategies such as distributed control systems are also feasible. It is possible to compare the centralized coverage algorithm to distributed ones in terms of power consumption, cost, and performance. In practice, other factors such as obstacles, environmental conditions, and noise influence coverage. In addition to nonhomogeneous sensors, other possible sensor models can deal with non-isotropic sensor sensitivities, where sensors have different sensitivities in different directions. The integration of multiple types of sensors such as seismic, acoustic, optical, etc. in one network platform and the study of the overall coverage of the system also presented several interesting challenges [16].

In Arolka [18], two algorithms for the efficient placement of sensors in a sensor field are presented. The proposed approach is aimed at optimizing the number of sensors and determining their placement to support distributed sensor networks. The optimization framework is inherently probabilistic due to the uncertainty associated with sensor detections. An optimization problem was formulated on sensor placement, wherein a minimum number of sensors are deployed to provide sufficient coverage of the sensor field. This approach offers a unique "minimalistic" view of distributed sensor networks in which a minimum number of sensors are deployed and sensors transmit/report a minimum amount of sensed data [9]. Hwang at al [19] state that, the basic topology desired in data-gathering wireless sensor networks is a spanning tree, since the traffic is mainly in the form of many-to-one flows. Nodes in the network can selfconfigure themselves into such a topology by a two-phase process: a flood initiated by the root node, followed by parent selection by all nodes. Four localized topology generation mechanisms are presented – earliest-first, randomized, nearest-first, and weighted randomized parent selection. Network performance of these mechanisms are compared on the basis of the following metrics: node degree, robustness, channel quality, data aggregation and latency. This study shows how localized selfconfiguration mechanisms can impact the global network behavior: earliest-first and nearest-first schemes produce a data-gathering tree with low network reliability, high data aggregation ability, and long response time to an event. Randomized and weighted-randomized schemes, on the other hand, construct a balanced data-gathering tree with high network reliability, low data aggregation ability, and short response time to an event. In addition, the nearest-first scheme outperforms the other three schemes in channel quality [19]. Some sensor nodes may be equipped with special hardware such as a Global Positioning System (GPS) receiver to act as beacons for other nodes to infer their location; some nodes may act as gateways to long-range data communication networks (e.g., GSM (Global System for Mobile) networks, satellite networks, or the Internet) [24].

2.7 Applications of Wireless Sensor Networks

The original motivation behind the research into WSNs was military application. Examples of military sensor networks include large-scale acoustic ocean surveillance systems for the detection of submarines, self-organized and randomly deployed WSNs for battlefield surveillance and attaching microsensors to weapons for stockpile surveillance [20].

Current state-of-the-art sensor technology provides a solution to the design and development of many types of wireless sensor applications. There are various sensors in the market include generic (multi-purpose) nodes and gateway (bridge) nodes. A generic (multi-purpose) sensor node's task is to take measurements from the monitored environment. It may be equipped with a variety of devices which can measure various physical attributes such as light, temperature, humidity, barometric pressure, velocity, acceleration, acoustics, magnetic field, etc. Gateway (bridge) nodes gather data from generic sensors and relay them to the base station. Gateway nodes have higher processing capability, battery power, and transmission (radio) range. A combination of generic and gateway nodes is typically deployed to form a WSN. In order to support different application software on a sensor system, development of new platforms, operating systems, and storage schemes are needed. This can be classified in three range group of class. The first group is called the system, this means that each sensor node is an individual system. The second group is communication protocols, which enable communication between the application and sensors. They also enable communication between the sensor nodes. The last group is services which are developed to enhance the application and to improve system performance and network efficiency. From application requirements and network management perspectives, it is important that sensor nodes are capable of self-organizing themselves. That is, the sensor nodes can organize themselves into a network and subsequently are able to control and manage themselves efficiently. As sensor nodes are limited in power, processing capacity, and storage, new communication protocols and management services are needed to fulfil these requirements. As the costs for sensor nodes and communication networks have been reduced, many other potential applications including those for civilian purposes have emerged. Figure 1 illustrates an overview of WSN applications.

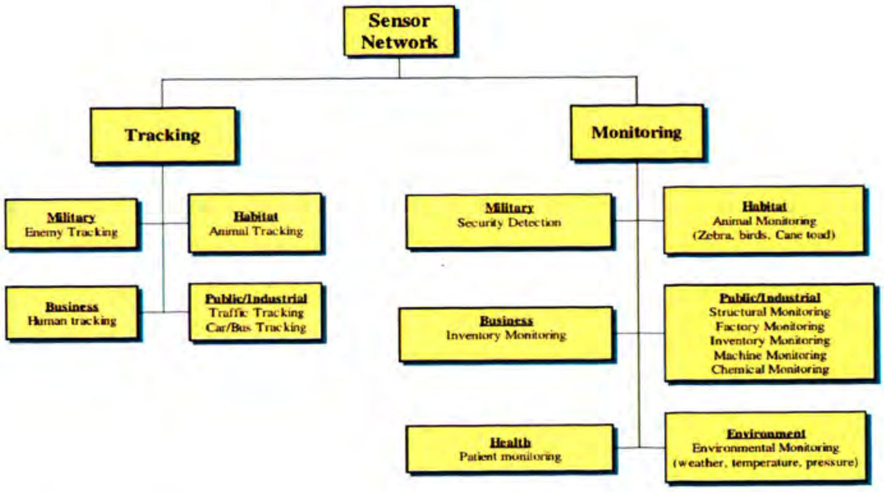

Figure 2.3: Overview of wireless sensor networks applications [21]

Wireless sensor networks applications can be classified into two categories as shown above in Figure 2.3, namely monitoring and tracking. Monitoring applications of wireless sensor networks include indoor/outdoor environmental monitoring, health and wellness monitoring, power monitoring, inventory location monitoring, factory and process automation, and seismic and structural monitoring. Tracking applications of wireless sensor networks include tracking objects, animals, humans, and vehicles. While there are many different applications, below we describe a few example applications that have been deployed and tested in the real environment, from avalanches.

2.7.1 Environmental Monitoring

Environmental monitoring [22] can be used for animal tracking, forest surveillance, flood detection, and weather forecasting. It is a natural candidate for applying WSNs [23], because the variables to be monitored, e.g. temperature, are usually distributed over a large region. One example is that researchers from the University of Southampton have built a glacial environment monitoring system using WSNs in Norway [24]. They collect data from sensor nodes installed within the ice and the sub glacial sediment without the use of wires which could disturb the environment. Another example is that researcher's from EPFL have performed outdoor WSN deployments on a rugged high mountain path located between Switzerland and Italy [23]. Their WSN deployment is used to provide spatially dense measures to the Swiss authorities in charge of risk management, and the resulting model will assist in the prevention of avalanches and accidental deaths.

2.7.2 Traffic Control

Sensor networks have been used for vehicle traffic monitoring and control for some time. At many crossroads, there are either overhead or buried sensors to detect vehicles and to control the traffic lights. Furthermore, video cameras are also frequently used to monitor road segments with heavy traffic. However, the traditional communication networks used to connect these sensors are costly, and thus traffic monitoring is usually only available at a few critical points in a city [22]. Wireless Sensor Networks will completely change the landscape of traffic monitoring and control by installing cheap sensor nodes in the car, in parking lots, along the roadside, etc. Streetline, Inc. [23], is a company which uses sensor network technology to help drivers find unoccupied parking places and avoid traffic jams. The solutions provided by Streetline can significantly improve the city traffic management and reduce the emission of carbon dioxide.

2.7.3 Health Monitoring

WSNs can be embedded into a hospital building to track and monitor patients and all medical resources. Special kinds of sensors which can measure blood pressure, body temperature and electrocardiograph (ECG) can even be knitted into clothes to provide remote nursing for the elderly. When the sensors are worn or implanted for healthcare purposes, they form a special kind of sensor network called a body sensor network (BSN). BSN is a rich interdisciplinary area which revolutionizes the healthcare system by allowing inexpensive, continuous and ambulatory health monitoring with real-time updates of medical records via the Internet. One of the earliest researches on BSNs was conducted in Imperial College London, where a specialized BSN sensor node and BSN Development Kit have been developed [22].

2.7.4 Industrial Sensing

As plant infrastructure ages, equipment failures cause more and more unplanned downtime. The ARC Advisory Group estimates that 5% of production in North America is lost to unplanned downtime. Because sensor nodes can be deeply embedded into machines and there is no infrastructure, WSNs make it economically feasible to monitor the "health" of machines and to ensure safe operation. Aging pipelines and tanks have become a major problem in the oil and gas industry. Monitoring corrosion using manual processes is extremely costly, time consuming, and unreliable. A network of wireless corrosion sensors can be economically deployed to reliably identify issues before they become catastrophic failures. Rohrback Cosasco Systems (RCS) [23] is the world leader in corrosion monitoring technology and is applying WSNs in their corrosion monitoring. Wireless sensor networks have also been suggested for use in the food industry, to prevent incidents of contaminating the food supply chain [22].

2.7.5 Infrastructure Security

Wireless Sensor Networks can be used for infrastructure security and counterterrorism applications. Critical buildings and facilities such as power plants, airports, and military bases have to be protected from potential invasions. Networks of video, acoustic, and other sensors can be deployed around these facilities [22]. An initiative in Shanghai Pudong International Airport has involved the installation of a WSN-aided intrusion prevention system on its periphery to deter any unexpected intrusions. The Expo 2010 Shanghai China [25] has also secured its expo sites with the same intrusion prevention system.

2.7.6 Intelligent Transportation

Wireless Sensor Networks are extensively being used nowadays in the area of transportation, in automatic traffic control systems, efficient multi storage parking location building identification and many other systems.

Authors [18] in their argument have stated that wireless sensor network is very suitable in multi storage parking buildings where sensor nodes are deployed at each parking space. Appropriate sensors send messages to control center which guide the vehicles unoccupied parking spaces.

Finally, Tubaishat et al have discussed a system for reducing traffic by real time monitoring of vehicles using wireless sensor network [26]. The concentration of traffic is measured, all the sensor nodes on different signals co-ordinate with each other and dynamically change the duration of green signals. That helps to reduce traffic in peak hours. Wenjie et al [11] have also discussed real time dynamic traffic control systems using wireless sensor networks. It is obvious that the unique features of WSNs can assist in building diverse applications for efficient vehicle traffic monitoring.

2.8 Road Monitoring Using Wireless Sensor Networks

There have been many research and development efforts in the field of traffic monitoring using wireless sensor networks in the past decade. Vehicles traffic monitoring and tracking has been a central application for sensor networks since 2000. Much of this work has focused on military surveillance applications, where individual vehicles move in unconstrained environments [22], [16], and [20]. However, there has been relatively little work exploring sensor networks applied to the much more common case of urban vehicle traffic, where vehicles are constrained to roadways, but vehicle density is much greater [22] and [6]. Arbabi and Weigle [27] explored vehicle monitoring and data collection for transient, urban situations. Specific users of this system include traffic management around construction zones or during emergencies, and transportation planning and modeling. Urban roadways carry thousands of vehicles each day, and elaborate vehicle traffic monitoring systems have been developed to manage traffic flows.

Currently deployed vehicle traffic monitoring systems consist of either emplaced or relatively accurate sensors such as in-ground induction loops or elevated video cameras, or of deployable but less accurate sensors, such as pneumatic tubes. Both have strengths and limitations:

sophisticated, emplaced traffic control systems can be accurate and are essential to managing traffic flow, but such systems cover only major roadways and cannot be quickly deployed to new areas; substantial amounts of investment and planning are required to extend them. Deployable systems, on the other hand, are more flexible. They can be used for short-term data collection, but current systems provide less accurate estimates of vehicle class and speed, particularly in dense or low-speed traffic. Sensor networks provide a potential solution to this need for observing vehicles in urban environments. Ideally, small, battery-powered sensor nodes, attached to deployable sensors such as tape-down inductive loops, can detect and classify vehicles. More importantly, collections of individual sensor nodes can band together, both to improve overall classification accuracy, and eventually hopefully to do short-term tracking of vehicles in constrained areas, such as port facilities or distribution centers. Although there has been a great deal of research in new sensor technologies to improve classification accuracy, finding a good combination of accuracy, deployability, and cost has remained problematic.

There are many publications under FleetNet project and ACM International Workshop on Vehicular Ad Hoc Networks [28] [6] [17] [18], but these works deal with sensors on vehicles, not on roads, and are therefore not capable of recording the traffic flow of a road. Reference [22] propose the use of magnetic signal sensors deployed on the road to detect vehicles with high accuracy, but they use WSN to detect traffic flow at a cross section of a road, and do not synthesize the whole road. Similarly, [11] utilizes WSN to collect transportation information. Reference [29], propose using WSN to deliver safety-warning messages to relative vehicles. However, their solution focuses on event storage protocol in WSN, not on road monitoring with WSN. The above works collect raw sensor data without any compression and is not energy-efficient. The most similar work to ours is that of Yicle et al [21], which proposes using temporal and spatial correlations to compress traffic flow time-series, however, their method handles 24-hour long time series, which is unacceptable in real time traffic-monitoring scenarios. Furthermore, their method cannot be changed directly to deal with short timeseries because the temporal correlations between short timeseries are not obvious.

There have been a lot of models used to forecast traffic flow including ARIMA, neural networks, non-regression model, and so on. Katiyar [30] presented a nonparametric regression based on pattern recognition and used it for short-term traffic flow forecasts. Tiwan at al [17] introduced an improved short-term traffic flow forecasting algorithm based on the ARIMA model. Neural networks have been used in forecasting traffic flow [2], [31] [32]. Laisheng et al [2] used a mathematical and statistical correlation coefficient and clustering approach to forecasting traffic flow. Because traffic flow is a typical gray system, it is more suitable for gray forecasting system method to forecast. Thus, we have used Adaptive GM (1, 1) Model to forecast, which has a real-time rolling forecast for traffic flow and has better forecast results [2].

On the other hand, traffic congestion is a major issue faced by modern city development. With the continuous development of the economy, traffic congestion has become more and more obvious. Toumpis and Tassiulas [33] studied the problem of traffic congestion by the fuzzy mathematics theory and set up a multi-level fuzzy evaluation for it. Yick [34] used economic theory and methods to analyze traffic congestion mechanism. Pompili [20] presented a solution to the problem of traffic congestion through the implementation of road pricing. However, those methods studied congestion only from the point of view of economy or management, few of them can give a fundamental solution to the problem of traffic congestion from technique. Because there have been few studies about traffic congestion control from technique in the current academia, this dissertation studies the issues of traffic congestion control in details. Having learned from mature congestion control algorithms of computer networks [35] [36], we have designed an algorithm of flow congestion control and scheduling for traffic network, which is called TRED. We have used it for real-time traffic scheduling and have opened up new ways to solve traffic congestion control issues.

2.9 Simulation tools for Wireless Sensor Networks

The simulation tool and the programming environment used for this experiment will now be discussed.

2.9.1 Network Simulator 2 (ns-2)

The Network Simulator version 2 (ns-2) was developed in the University of Berkeley, CA, USA, and it is actually the de-facto standard on network simulation in general. The simulator is object-oriented and based in two languages: C++ as the development language and Object Tool Command Language (oTcl) as the simulation description language. Ns-2 is in constant evolution and worldwide use. The current version is 2.31 released in March 2007 and version 2.32 is still pending release. Some extensions provide Sensor Network simulation, like the one provided by the Naval Research Laboratory. The two languages approach may step up the learning curve. However, Tool Command Language (Tcl) is very appropriate for writing simulation codes, presenting a good learning curve, and C++ provides execution performance.

2.9.2 Java Simulator (J-Sim)

The Java Simulator (J-Sim), was developed by the Ohio State University, USA, and is construction is based on the Autonomous Component Architecture. This simulator also uses two languages, Java and oTcl. J-Sim is component-oriented, so the basic entities are components that communicate with each other via send/receive data through ports. Ports are also components whose behavior is defined by another component named contract. J-Sim also provides a script interface that allows integration with different script languages such as Perl, Tcl or Python. Furthermore, its provides a friendly and appropriate graphical interface for simulation results, although the graphical interface leaves something to be desire. J-Sim provides a model to simulate WSNs; one can clearly define the nodes that will stimulate the WSN (target nodes), the nodes that will constitute the sensor network itself (sensor nodes), and the sink nodes (also known as base stations). As with any simulation, there is a need to know simulation parameters. In J-Sim, Target nodes have only one communication channel, the sensor channel, since they only send stimuli to the sensor network, the sensor nodes communicate in two ways, sensor and wireless channel, and finally the sink nodes only communicate in the wireless channel.

2.9.3 Sensor Network Simulator and Emulator (SENSE)

Sensor Network Simulator and Emulator (SENSE) is the only simulator of the three that was specifically designed for sensor network simulation. This simulator presents a component-based approach, created as a template class that allows the use of the component with different kinds of data. SENSE is still in an early stage of development. When trying to use the simulator we found some issues that were solved by the developers. This simulator provides three user types: high level, network designers and component designers. A component in SENSE communicates through ports: this model frees the simulator from interdependency. This also enables extensibility, reusability and scalability. Component extension in functionality is possible if the interface is compatible and no inheritance between components is used. SENSE only uses C++

language and the interface only uses text, and the results are provided in a text file. This contributes to the efficient use of computational power, but greatly reduces the perceived user-friendliness. SENSE requires that all nodes are identical. A common simulation engine stores the event queues of the system. SENSE compares the received signal strength with a threshold and decides if the packet has reached its destination.

2.9.4 VisualSense

Modelling of wireless networks requires sophisticated representation and analysis of communication channels, sensors, ad-hoc networking protocols, localization strategies, media access control protocols, energy consumption in sensor nodes, etc. VisualSense is designed to support a component-based construction of such models. VisualSense provides an accurate and extensible radio model. The radio model is based on a general energy propagation model that can be reused for physical phenomena. VisualSense provides a sound model based on this propagation model that is accurate enough to use for localization. VisualSense is a modelling and simulation framework for wireless sensor networks that builds on and leverages Ptolemy II. The extension to Ptolemy consists of a few new Java classes and some XML files. The classes are designed to be sub-classed by model builders for customization, although non-trivial models can also be constructed without writing any Java code [43]. It supports actor-oriented definition of network nodes, wireless communication channels, physical media such as acoustic channels, and wired subsystems. The software architecture consists of a set of base classes for defining channels and sensor nodes, a library of subclasses that provide certain specific channel models and node models, and an extensible visualization framework. Customized channels can be defined by subclassing the WirelessChannel base class and by attaching functionality defined in Ptolemy II models [44]. It is intended to enable the research community to share models of disjoint aspects of the sensor nets problem and to build models that include sophisticated elements from several aspects. VisualSense, however, does not provide any protocols above the wireless medium, or any sensor or physical phenomena other than sound. In this research we make use of VisualSense for the simulation of the model.

2.10 RFID Scanner

Radio Frequency Identification (RFID) works for identification of items/objects [37]. Sometimes it only identifies item category or type but it is capable of identifying items/objects uniquely. RFID also enables data storage for remote items/objects through remotely access items information [38]. RFID technology has already proved its use in various areas such as security, library, airline, military, animal forms, sports and other areas.

RFID is being used for various applications in many industries. For example, equipment tracking, access controls including personal and vehicle, logistic, baggage, items security in departmental stores. In general most of RFID system consists following components:

1. RFID tags, this is use as a unique identifier. These tags associate with any items, when the system reads these unique tags the information associated with the tags can be retrieved. For retail applications most of the tags take the form of an Electronic Product Code (EPC).
2. RFID Antennas, these are the first point of contact for reading the tags. The antennas are tuned to receive radio frequency waves emitted by a reader or transceiver for allowing wireless transmission of data to the reader.
3. RFID Scanner / readers, this usually consists of a radio frequency module, a control unit and coupling element to interrogate the tags via radio frequency communication. The scanner / readers are always connected through middleware to a back-end database which is responsible for storing unique item's ID.
4. RFID middleware, this is a kind of software that stands between the scanner / reader network and the application software to assist processing data generated by the reader network. Middleware has the ability of detecting the movement of RFID tags as they pass the read range of one to another. Figure 2.4; shows an illustration of the tag and RFID Scanner

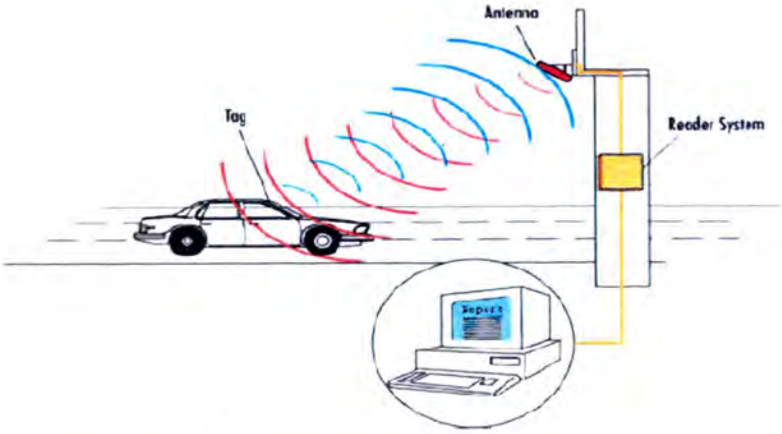

Figure 2.4: Tag detection using RFID scanner [37]

2.10.1 RFID utilisation

In RFID systems, tags are used as unique identifiers, these tags associate with any items, when the system reads these unique tags then information associated with those tags can be retrieved. Antennas are the first point of contact for tags reading. The reader can only work with software residing in the reader's ROM [39]. RFID system is based upon tags and reader's communication and the range of communication/reading depends on operating frequency. When antennas deduct tags then an application which is part of the reader manipulates the tags' information in readable format for the end user. There is a great amount of research being conducted to improve the efficiency of RFID systems, increasing the accuracy of RFID readers and the feasibility of RFID tags. Although RFID accuracy needs to be increased RFID systems are used in many applications [37]. There are a variety of tags, readers and antenna types available. Before implementing RFID system, selection among these types must be done, which needs understanding of these types in relation to their feasibility, capabilities and reliability. It is also necessary to understand combinational use of these types for implementing a single feasible RFID system.

2.10.2 RFID evaluation

RFID technology has continued to evolve in the past years in terms of the variety of shapes of tags for increasing the feasibility of its use, increasing the reading rate of readers and the range of antennas, etc. The use of RFID has also evolved due to enhancement in its components. As the accuracy increases, the use of technology also increases such as baggage handling, goods delivery tracking and courier services. RFID system enhancement also evolves automation applications development e.g. automatic toll payments, automatic equipment tracking and document management etc. [40].

2.10.3 How RFID system works

The basic unit of RFID system is tags and tags have their own unique identification number system by which each tag is recognized uniquely. These unique identification numbers are saved in the tags' internal memory and are not changeable (read-only). However, tags can have other memory which can be either read-only or rewriteable [41]. Tag memory may also contain other read-only information about that tag, such as the date of manufacture. RFID reader generates magnetic fields through antennas for getting acknowledgement from tags [40]. The reader generates a query (trigger) through electromagnetic high-frequency signals (this frequency could be up to 50 times/second) to establish communication for tags [41]. This signal field might get data from a large number of tags, which is a significant problem for handling bulk data together. However, this problem can be overcome through filtering these data. Actually software can perform this filtering and an information system is used to supply this data to a data repository or any other software procedures can be used to control data according to the need and system capability [42]. This piece of software works as a middle layer between user application and reader because the reader normally does not have the capability to handle bulk data at once; it has the job of supplying reading data to the user application for further processing [43]. This buffering capability may supply data from reader to information system interface (user interface) directly or may provide and use some routine to save it into a database for later exploitation; it is dependent on user requirements. Reader and tags communication can be maintained through several protocols. When the reader is switched on then these protocols start the identification process for reading the tags, these important protocols are ISO 15693, ISO 18000-3, ISO 18000-6 and EPC. ISO 15693 and ISO 18000-3 protocols are used for high frequency (HF) and, ISO 18000-6 and EPC protocols are used for ultra-high frequency (UHF). Frequency bands have been defined for these protocols and they work within specified ranges, such as HF has 13.56 MHz and UHF between 860 – 915 MHz [43]. The reader modulates the tags responses within frequency field [43]. The reader handles multiple tag reading at once through signal collision detection technique [42]. This signal collision detection technique uses anti-collision algorithm, the use of this algorithm enables multiple tag handling. However, multiple tag handling depends on the frequency range and protocol use in conjunction with tag type which can enable up to 200 tags to be read at a single time. Reader protocol is not only use for reading the tag but also perform writing on to tags [43]. The use of the reader within RFIFD system can be seen in figure 2.4. This figure also defines the overall cycle of tag reading by the reader through antenna and transforming data into communicable able form to user applications.

2.10.4 RFID system components functionality

RFID system detects tags within the antennas' range and performs various operations each tag. The RFID system can only work effectively if all RFID components logically connect together and these components need to be compatible with each other. That is why understanding of these separate components is necessary. Implementation of complete RFID solution is only possible through integration of these components which needs understanding of the compatibility of each component, realisation of each components compatibility needs property study for these components [40]. These components are gathered and defined as under. Also integration of these components can be understood with figure 2.4.

• Tag has unique ID used for unique identification; tags are attached with objects in RFID solutions.

• Antenna used for reading tags; antenna has its own magnetic field and antenna can only read tags within these magnetic fields.

• Reader works for handling antenna signals and manipulate tags' information.

• Communication infrastructure used for reader to communicate with IT infrastructure and work as middle layer between application software and reader.

• Application software is a computer based software which enables user to see RFID information, this can be database, application routines or user interface.

2.10.5 RFID tags

RFID tag has memory in the form of a microchip which stores a unique code for the tag's identification, this unique identification is called the tag's ID [40]. The microchip is a small silicon chip with embedded circuit. Numbering technique is used for providing unique identification [42]. This microchip could have read-only or writeable characteristics depending on tag type and its application within RFID solution. These characteristics depend on the microchip circuitry which was formed and initialized during tag manufacturing [43]. For some tags (read-only) re-programming is possible, but separate electronic equipment is needed for re-programming the read-only tag's memory. Writable tags also known as re-write tags do not need any separate equipment and the reader can write data on it, depending on the protocol support, if the reader has writing command capability and the tags are in range. Tag selection is very important for use in RFID solution. This selection is dependent on the tag size, shape and material. Tags can be integrated in a variety of materials depending on the needs of the environment. The tag can be embedded in a plastic label in the form of a microchip, stickable material for documents handling, or plastic material with the use of a pin for use in clothes and materials are good examples to be considered [43].

Classification of RFID tags is also possible with respect to their capabilities such as read-only, re-write and further data recording. The examples of further data recording are temperature, motion and pressure etc.

There are three main types of tag, which is Active, semi-active and passive. Tags made up with few characteristics which may vary slightly depending on the type of tag, due to which their use, can be changed in RFID solution [45]. So, selection of tags depends on the functional need of the RFID application. The main difference is between active and passive tags because semi-active tags have a mixture of both tag's characteristics [43]. These types differentiate upon memory, range, security, types of data it can record, frequency and other characteristics. The combinations of these characteristics affects tags' performance and change its support and usefulness for RFID systems [46].

2.10.6 RFID applications

From a RFID application perspective, RFID has two categories: short range and long range. In short range applications the tag needs to be shown to the reader. The application works perfectly over a short range if the objects or tags are read by the reader one by one. For example, in access control, only employees or specified persons can access the secure building. The building has several divisions and each division has a particular set of people who are authorized, for. A person needs to show the tag near the reader before every secure door, which enables the system to decide whether the door should open for that person or not. In long range applications, tags do not need to be near the reader, as compared to short range. For example, tags can be placed on every book in the library, and the user can easily access the exact book shelf for the required book. This enables automated inventory control. Readers can read multiple items simultaneously from a distance. The reading distance can vary depending on the frequency and type of reader. This section further discusses the most common use within short and long range applications.

2.10.6.1 Security and control applications

RFID system can be used for control access and security; it is also useful for audit purposes. These applications are not only used to granted permission to access a particular secure zone but also record who is entering, from which location/areas, at what time and for what duration. These types of RFID systems can maintain building and departmental security. The simplest application of RFID is the identification of objects via an ID number over short distances. This type of RFID solution is also workable for equipment and object controls [43].

2.10.6.2 Patrolling log applications

In this application, security firms use RFID system to control their security guards and use RFID data for various purposes. These purposes include performance checks, and data can be used in reference to unexpected events and audits for a secure area, etc. The main difference between this type of application and other applications is that the reader is variable and the tag is fixed, i.e. the reader goes near to the tag, rather than tag the near to the reader. In security patrolling several numbers of tags can be fixed throughout the building and the security guard needs to swipe the reader with each tag (checkpoint) in a sequential order within an allocated time and repeat this process throughout his/her shift. The reader records each swipe which can be transferable to a computer program later on for audit or other purposes.

2.10.6. Baggage applications

Baggage handling and package delivery is a complex task and needs a large amount of human involvement, which is an expensive resource. Humans do various operations from receiving packages, sorting, assembling and distributing them. Due to human involvement the error rate can be high. The use of RFID tagging system not only reduces human involvement but also automates the process to a certain extent which enables fast package delivery. RFID solutions for baggage and packaging firms including the airline industry, improve their effective operation and reduce the complexity of the overall system.

2.10.6.4 Toll road applications

RFID can provide automated toll collection and maintain the traffic flow without stopping vehicles for payment. In these types of applications, vehicles either pre-pay their toll, yearly, quarterly or monthly, or another kind of scheme can be applied, such as pay-as-you go. In any case, the reader can recognize and record the vehicle entry at each toll, and the fee can be calculated later on by an application program. These applications not only help in toll collection and maintaining traffic flow, but also provide statistical data for the road, which can be utilized for analysis and improvements [47].

2.10.7 Benefits of RFID

RFID provides more data storage capacity even when compared to modern two dimensional barcode systems. The data stored on the tag can be changed according to the needs of the application (e.g. Protocol of test procedures). RFID tags do not need direct line of sight while reading and do not need to be presented to the reader on a flat and clean surface. Some RFID tags provide a much higher reading range (up to 300m with active tags) than optical systems. Only basic security functions (e.g. electronic signatures) can be implemented in optical systems (barcode, OCR). Tags can provide additional functions (e.g. temperature sensor). Because of their higher data storage capacity, RFID tags allow single item identification.

2.10.8 From Identification to Wireless Sensor Networks

At the lower (passive) end of RFID technology the systems simply provide a tag that can remotely identify an object by returning an ID when interrogated over short ranges. As RFID systems are introduced and find acceptance in business and other environments, the functionality provided by these low cost tags will be increasingly seen as insufficient as new applications are developed [48]. There is likely to be a natural progression for RFID that includes the widespread incorporation of sensor functionality [49]. Such devices will be able to make measurements concerning their surroundings and physical location of such variables as pressure, temperature, flow rate, speed, vibrations etc. They will be networked either through RF technologies or through other wireless communications systems and these developments are often referred to as sensor nets, integrated on-chip radios, or wireless networked sensors (WNS). These types of networked, RFID-enabled objects will become similar to what Bohn [50] calls 'spimes'. They will have histories (e.g. every time they are accessed they will record the details of that access), they will be 'precisely located in space and time' and they will become 'protagonists of a documented process' [50]. These RFID-based sensors will need to communicate in order to participate in the network of things. Other protocols currently proposed or developed include ZigBee, Near Field Communication Technologies (NFC), Bluetooth and Wi-Fi – all systems that offer local and personal area networks (LANs and PANs). ZigBee is focused on individual devices (such as smoke alarms, lamps and consumer electronics) that need a robust, low bandwidth, low cost, low power, peer-to-peer communication. NFC is designed for very short-range communication (devices have to almost touch for the signalling systems to work). The applications being developed for NFC to date revolve around situations where it is intuitive for devices to touch in order to communicate e.g. allowing mobile phones to act as electronic tickets or electronic cash wallets when pressed against a suitable reader or kiosk device. Some commentators see these developments as tending towards a form of ubiquitous wireless communications network which encompasses low-bandwidth systems such as RFID, computational and peripheral device networking through ZigBee, NFC and Bluetooth (e.g. digital cameras and printers), and higher bandwidth (telecommunication) devices through 4G cellular and WiMax [51].

Such networking is part of a wider technological development as fixed networks move to wireless networks, *ad hoc* networks, and meshes (Mobile Ad-Hoc Networks, or MANETs). In the latter, mobile communicating devices form *ad hoc* networks (in a peer-to-peer fashion) with nearby devices to form meshes of communication that have varying topologies. The development of these kinds of networks will facilitate the increased use of spatial annotation (e.g. leaving personal messages or information within a given space). Most technological projects exploring spatial annotation use GPS (Global Positioning System) and the use of RFID in conjunction with GPS could allow for another layer of context-specific information.

2.11 Global Positioning System (GPS)

GPS stands for Global Positioning System. It is one of the latest electronic devices used for navigation. These Global Positioning Systems can be used to determine exact latitude, longitude, height above sea level, and even the direction and speed you're moving at. GPS is also used to establish a position at any point on the globe and determine the location of any object (vehicle, building, person, areas, roads etc.), and also to more record the position at regular intervals in order to create a track file or log of activities. The recorded data received can be stored within the tracking unit, or it may be transmitted to a central location, or internet connected computer, using a cellular modem or satellite. GPS is not only useful for vehicle tracking, but it also can be used as a people locator or object locator. GPS uses a network of 24 satellites in staggered orbits around the Earth. At any time, from any location on the planet, four of these satellites are visible and capable of receiving and sending signals [53]. This means tracking devices can be used at any moment in time for vehicle tracking or as a people locator to track staff. The GPS comprises three segments as shown in Figure 2.5.

- The space segment (all functional satellites)
- The control segment (all ground stations involved in the monitoring of the system: master control station, monitor stations, and ground control stations)
- The user segment (all civil and military GPS users)

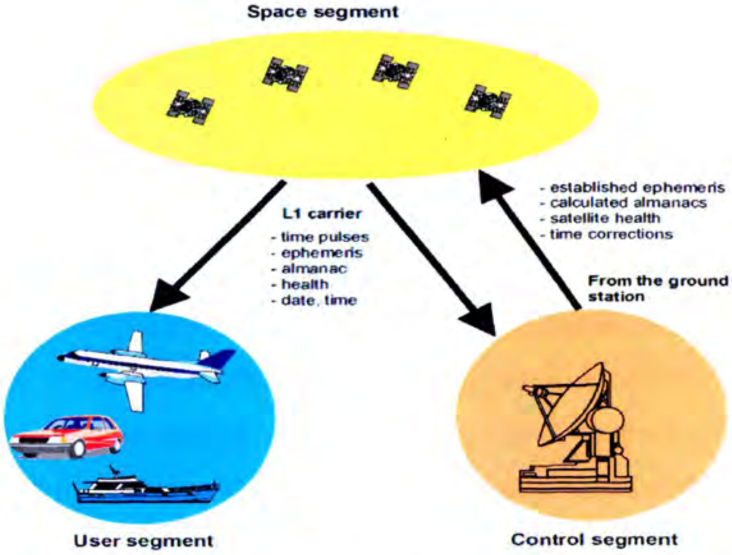

Figure 2.5: The three GPS segments [53]

The space segment currently consists of 28 operational satellites orbiting the Earth on 6 different orbital planes (four to five satellites per plane). They orbit at a height of 20,180 km above the Earth's surface and are inclined at 55° to the equator. Any one satellite completes its orbit in around 12 hours. Due to the rotation of the Earth, a satellite will be at its initial starting position after approximately 24 hours (23 hours 56 minutes to be precise) [53].

The control segment (Operational Control System OCS) consists of a Master Control Station located in the state of Colorado, five monitor stations equipped with atomic clocks that are spread around the globe in the vicinity of the equator, and three ground control stations that transmit information to the satellites [53]. The most important tasks of the control segment are:

• Observing the movement of the satellites and computing orbital data (ephemeris)
• Monitoring the satellite clocks and predicting their behavior
• Synchronizing on board satellite time
• Relaying precise orbital data received from satellites in communication
• Relaying the approximate orbital data of all satellites (almanac)
• Relaying further information including satellite health clock errors etc.

The control segment also oversees the artificial distortion of signals (SA, Selective Availability), in order to degrade the system's positional accuracy for civil use.

The user segment received the signals transmittable by the satellites, which take approximately 67 milliseconds to reach a receiver. As the signals travel at the speed of light, their transit time depends on the distance between the satellites and the user. Four different signals are generated in the receiver, having the same structure as those received from the 4 satellites [53].

In order to determine the position of a user, radio communication with four different satellites is required. The relevant distance to the satellites is determined by the transit time of the signals. The receiver then calculates the user's latitude ϕ, longitude λ, height h and time t from the range and known position of the four satellites. Expressed in mathematical terms, this means that the four unknown variables ϕ, λ, h and t are determined from the distance and known position of these four satellites, although a fairly complex level of iteration is required, which will be dealt with in greater detail at a later stage [55].

2.11.1 How GPS Works

Basically the principle behind GPS is that receivers are able to use the technique of trilateration to calculate their coordinates on Earth by measuring the time taken for signals from various satellites to reach them. The GPS software will account for any irregularities in the signal strength and clock differences between itself and the GPS satellite network by using signals from four separate satellites to improve accuracy [54]. In this process the coordinates are usually then used to locate the GPS device on a map, which is either displayed to the user or used as a basis for calculating routes, navigation, or as input into mapping programs. For example, specific coordinates can be stored as waypoints allowing the user to retrace their steps by calculating the direction and distance to each waypoint that they have stored [53].

When the receivers of the tracking devices are activated, they obtain the following information from the 4 satellites they can communicate with: latitude, longitude, altitude and time. The location data is translated and displayed on a digital street map viewed on a screen built into the unit. The process repeats as the receiver moves and the unit constantly updates the screen. If there is vehicle tracking or a people locator unit in a fleet of taxicabs, for example, the central dispatcher can monitor each vehicle's location, stop time, route taken and speed [54]. An even more critical application would be to have these GPS units installed in a fleet of ambulances or police patrol cars.

This process allows data to be reported in real-time; using either web browser based tools or some specific software.

2. 12 Chapter Summary

This chapter focused on reviewing existing related literature on the use of different components used in the novel model, namely: wireless sensor networks, RFID Scanner and Global Positioning System. We also explained State-of-the-art in Traffic Monitoring by Analysing existing few traffic monitoring research. Finally we discussed the actual impact of traffic congestion and its measurement for effective congestion management.

CHAPTER 3

Model Analysis and Design

3.1 Chapter Overview

This chapter presents the analysis of the novel model. The analysis is useful for the design of the model, associated components and the software used for the model simulation. We also explain in details the design of each hardware component and its functionality. Our hardware modelling is based on hardware components parts and architecture and their functionality in the entire system, what their responsibility is in regard to the system and their internal data and communication models.

3.2 Model Requirements Analysis

Wireless Sensor Networks (WSN) have some unique features that can help to benefit diverse applications for road monitoring, regarding implementation in general, and our novel model in particular. Even if design requirements for WSN architectures hold for any application, we cannot use some of those requirements when dealing with our novel model for traffic monitoring. Below are a few requirement specifications for our novel model.

3.2.1 Network Topology

Vehicle monitoring is the major problem of our novel model. By having precise data about the locations of each zone node, we are able to get accurate information about the situation on the roads. Nodes themselves can also form an ad-hoc network to share information collected by each other. In our model, we deployed sensors on the roadsides, generally at known congestion areas. This is to avoid implementing node localization algorithms. Due to stable environment and the availability of power resources, there is a good opportunity of minimizing the possibility of subdividing the topology of the network by minimizing node failures. Therefore, the change in topology is not a major problem and also the design of routing protocols is simple.

3.2.2 Scalability and Network Costs

Wireless sensor networks are capable of handling a large number of sensor nodes. An advantage of our novel model for traffic monitoring is that it can covers hundreds of roads in urban areas and monitor thousands of vehicles. The sensors are deployed in the most traffic congested places in the urban areas. With traffic estimation, only those specific areas with higher congestion are monitored by a group of nodes called a zone.

3.2.3 Power Consumption

The model uses sensor nodes along the roadsides for monitoring purposes. The sensors installed on the roadsides have a long life because they are charged with solar power. Thus there is no expectation of power constraints for wireless sensor networks in our novel model.

3.2.4 High Communication Reliability

The WSN provides high reliability in terms of communication services. Because the working condition during road monitoring is not static, the error messages rate is kept at an acceptable rate for the road monitoring application. The WSN is able to work in a harsh and dynamic environment taking into account factors like high temperature, dust, vibrations, humidity, poor visibility, and fog or heavy rain.

3.2.5 Fault Tolerance

The WSN prevents performance degradation in case of fault to any part of the model. Our model is deployed in urban areas and is considered to be safe from unstable environmental conditions. This helps to minimize the rate of failure of the sensors. This is an important property for prolonging the lifetime of the sensors and to maintain the topology.

3.3 Model Design

Following the above requirements, in this section we describe each hardware component used in the proposed system and given a detailed explanation of these hardware components in terms of their functionality, installation and capabilities in the system.

3.3.1 System Components

The components of the system are made up of the following:

3.3.1.1 Sensor

Sensors are mostly used to change a physical parameter such as temperature, motion, wind speed or vibration into a signal that can be measured electronically. We made uses of sensors in our model to measure these physical parameters by monitoring the road during traffic peak hours. Since congestion during peak hours can be described by slow speed on the road, the sensor will be able to sensor the state of the road and convert it to an electrical signal. It is easy for a signal to be inputted into a computer in the TMC (Traffic Monitoring Centre) for manipulation and analysis by the traffic officer on duty. They are powered by small batteries or a solar panel which can only supply limited amounts of power and their lifetime is primarily dependent on the extent to which battery power is conserved. The power consumption tends to be dominated by transmitting and receiving messages and in the model we try to minimise the number of messages in order to save power.

In this research project sensors are placed at many points along the roadside network (intersection or places where congestion occurs regularly) to sense congestion. The data received by the sensors sends signals to a computer system which is used as a gateway so that they can be transferred to the Traffic Monitoring Centre for decision making. The sensors are powered with solar power. In case the battery is depleted the solar energy stored is capable of monitoring up to 200 vehicles and sensing 100 m. The sensors along the roadside are placed in groups (Zone1 up to zone X) in a way that if a vehicle cannot be sensed by one zone it may be scanned by another zone.

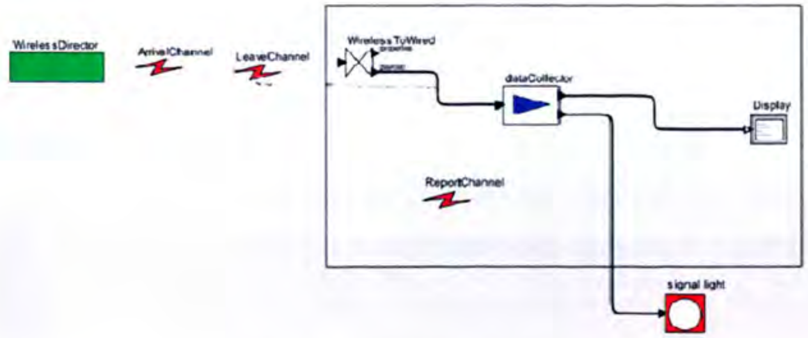

Figure 3.1: Structure of the node

3.3.1.2 RFID System Components

In this section, we shall explain the design of the RFID components that are important in this research: the tag and the scanner.

A. RFID Tag

In this research, the tag plays an important role to uniquely identify vehicles on the road and transmit information to them when necessary. The tag is the RFID component that stores the EPC and the *unique number plates*. For this research the number plates are used as a unique identification for each particular vehicle. We assumed that every registered vehicle has an RFID tag placed on top of it which will be scanned by the RFID Reader. Though there are different forms of tag and capability, in this research we propose the use of passive tags. The tag is associated with any vehicle and when read by the scanner the information associated with the tag in the traffic database can be retrieved at the TMC for necessary identification and communication. For this research, we propose the design of the tag as follows:

Figure 3.2: Design of tag

i. Header

The header identifies the EPC format used by the tag. It can be 96-bit, 64-bit or 256-bit. Based on the purpose of use, in our case we used the 96-bit.

ii. EPC Manager

The EPC Manager is 28-bit and its number identifies an organizational entity. That is, it will contain the South African traffic code that is responsible for the vehicle's number plate.

iii. ***Object Class***

The object class is a 24-bit field that refers to the exact type of product. In the case of our model the object class is used to identify a specific Traffic Database where each vehicle's owner information is stored depending on the specific province they come from.

iv. ***Serial Number***

The serial number is a 36-bit field. This is a unique number for each items (vehicle's number plate) within each Object Class (Traffic Database). These numbers must be unique for each vehicle and thus must to be assigned by a standards body such as EPC global Inc. The serial number will be used to query the database via internet to retrieve and update vehicle information.

In the model discussed in this research, the unique identification number system is the number plate of each vehicle. These number plates have unique identification information for each vehicle and it is saved in the tags' internal memory for identification purposes for vehicles. Is read-only (i.e. not changeable).

B. RFID Scanner

The RFID Scanner or reader we considered in our model is one that has wireless capability of reading tag information from about 50 meters away, and of objects in motion. It operates under EPC network using the internet. The design we proposed for this work is the type that can be placed overhead on the road, about 1 kilometre away from where the sensors that sense congestion are placed. In order not to overwhelm the server with incessant messages, the scanner is only active when the sensors send a signal indicating possible congestion on a particular route.

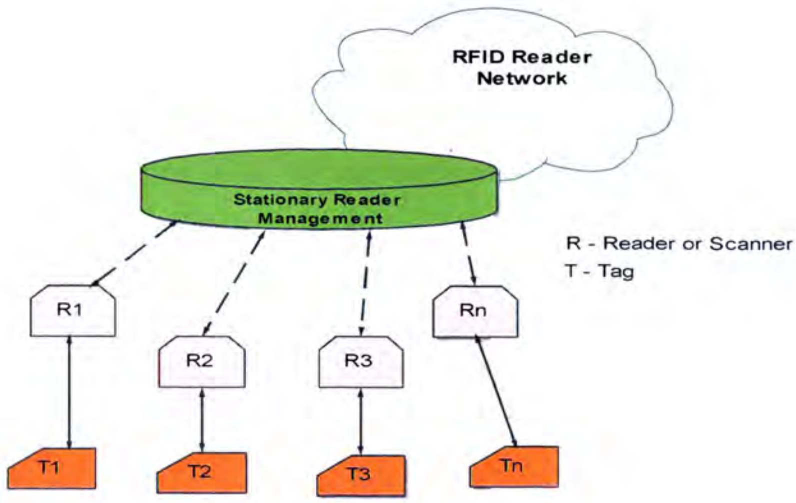

Figure 3.3: RFID reader network structure

As shown in Figure 3.3, the basic function of the scanner(R) is that, when once active, at a considerable speed it scans the tag(T) placed on the top of every registered vehicle and automatically transmits the EPC (i.e. *unique number plate)* through the RFID network to the EPC network's savant or middleware which in turn processes, filters, aggregates and communicates the filtered *unique number plate* over the internet that is used to query the traffic database where the driver's information is stored. When the database is queried, the driver's phone number is retrieved and the TMC uses it to send information from the GPS of possible shortest routes to the driver on the road on a real-time basis to avoid being affected by the congestion ahead.

3.3.1.3 The Global Positioning System (GPS)

Global Positioning System (GPS) is used to establish a position at any point on the globe and determine the location of any object (vehicle, building, person, areas, roads etc.). Furthermore; it evaluates a whole bunch of different routes and calculates a shortest or best route for vehicle users on the road. The GPS receiver first calculates the longitude/latitude position at which it is located. Translating that data into a street name or road name is done through automatic lookup in the local database of cities and streets. To calculate a route from that information, the GPS database must also include data such as the lengths of various roads, traffic flow rules and the locations of intersections. The local database can also include more detailed information, such as whether certain roads are highways or local streets, well-paved or one-lane gravel. The database can also include factors like the average speed on a given road at various times of a day, and any other number of variables that are relevant to route planning. The GPS does not attempt to evaluate every single possible route between two points, but tries to make a guess at which routes are most promising without congestion, and look at the cost of each leg of the route, the "cost" here being time or distance that will be taken using that specific road at that specific time. Two common methods that are used for calculating these kinds of problems are Dijkstra's algorithm and the A* search algorithm. The methods are used for:

•Faster Time: to calculate routes that are faster to drive but can be longer in distance.
•Shorter Distance: to calculate routes that are shorter in distance but can take more time to drive.
•Avoidances: select the road types you want to avoid on your routes.

For example, assuming a motorist is using a congested road and has an auto-routing GPS, or one that will navigate roadways. If it is in Automobile mode, the GPS will calculate the distance along a route using Data sent by the sensors to the TMC to determine the criteria (shortest route, fastest route, avoid congestion etc.) for routing the motorist. The GPS will take a position every second (or 5 seconds for some older units) and then calculate the distance between the two measurements. Normally it selects the generally fastest route between a user's current location and their destination. GPS generates directions by taking into account the state of the road with traffic activities (accidents, lane closures or severe weather). To increase the number of variables that the TMC computer system can consider when proposing a route, our model includes the ability to receive wireless live traffic data.

To incorporate data about ever-changing traffic and road conditions on the road networks, all vehicles using GPS units must be able to receive live information over the air. One way to do this is by radio transmissions over frequencies that are close to the frequencies used by the car stereo. By using "sidebands" or the Radio Data Service (RDS), providers such as MSN Direct and Navteq send digitised traffic (and often weather and news) information to the equipped GPS units from local radio transmitters.

Cars with built-in Sirius/XM satellite radio and GPS systems can also receive live traffic information in the background over the satellite radio signal. The information sent by the TMC will be automatically incorporated into the GPS system's route. Cellular phones equipped with a

GPS processor can often receive not just their position, but also live traffic information over the cellular network.

GPS based system deployment is widely used in developing countries and South Africa is one of them. GPS coverage in South Africa is wide and most urban roads are mapped to the GPS system. South African urban roads infrastructure is almost static, however new roads are being constantly built and the layout of old roads is frequently changed. This leads to the remapping of roads networks at regular intervals. With our novel model system for traffic monitoring using wireless sensor network (WSN) new roads and changes of old roads will simply require the reinstalling of a few sensors, or changes in their position on the roads. In this project we use GPS system in order to compute possible shortest routes close to congestion areas. This is to help the traffic officer in TMC regenerate message to the vehicle users on the roads.

3.3.1.4 Traffic Monitoring Centre (TMC)

Traffic Monitoring Centre (TMC) is a decision making centre where human operators take charge of continuous monitoring and data analysis from the systems in the field. TMC will decide the correct approach by analyzing the congestion information from the WSN system every second and decide if action is to be taken or not. In the case of congestion, the traffic officer at the TMC will immediately generate a message (i.e. Result of the GPS communication) and send it to the appropriate entity identified by RFID scanner on the road. The message sent is basically to inform vehicle drivers on the ground of alternative roads to take in order not to get stuck on the congestion ahead. However, for the TMC to function effectively, the following components are important: Computer system which will be used to access the traffic system interface (TraConSys) and the Central Traffic Database where all information about all registered motorists are stored.

Below is the description of components used in the TMC:

A. Computer System

Due to the nature of the system, we propose a desktop machine but with wireless connection capabilities. The machine supports batch 802.11- standard wireless LAN and GSM/GPRS wide-area wireless capabilities. The PC will run under windows platform but uses TraConSys software as interface.

B. Traffic Central Database

Basically, a database is an organised collection of data such that processes requiring the information are supported. With the nature of our novel model, the use of a database is indispensable. In the South African traffic system, all vehicles are identified by number plates or a registration number for their specific province. Therefore, we will create a national database called central database with sub-databases which are the provincial databases. See figure 3.4 below:

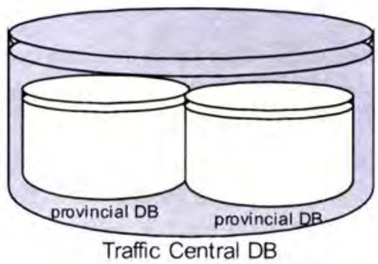

Figure 3.4: Traffic Central Database

The provincial databases are all directly connected to the system via the Central database on a real-time mode during traffic monitoring at the TMC. The real time connection to the central database is used for recording, storing, modification and retrieval of the vehicle's details where applicable for identification and verification purposes during congestion monitoring or in case of an accident. Access to this database will strictly be for two users: Traffic Officers (TOs) and Police Officers (POs). TOs will have both read-write access write while POs will have read-only access right.

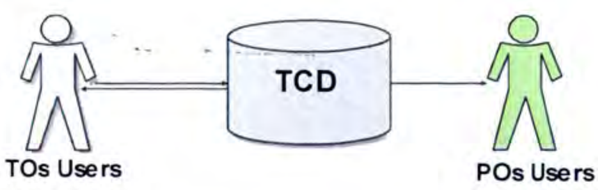

Figure 3.5: Structure of the node

During registration, the information that will be stored for a particular vehicle is shown in Figure 3.6.

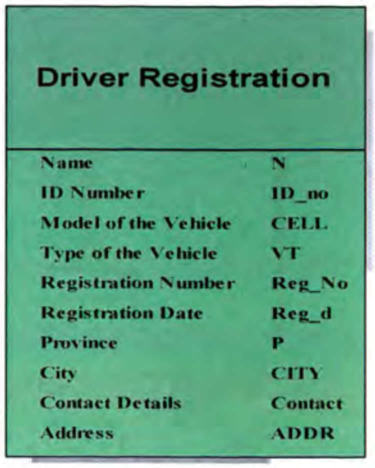

Figure 3.6: Structure of the node

All these attributes are fields in the central database. This information will be collected, stored and retrieved from the central database in their respective provincial database on real time mode. In this database, the registration number (Reg_No) will be used as the primary key to query the database by users and RFID reader.

3.3.2 Model Architecture

Wireless sensor networks is an information monitoring and transmitting network that can be applied to any type of traffic flow monitoring and forecasting system. To fully answer the questions in the above section about traffic monitoring in this project, we have presented our novel model for vehicle traffic monitoring based on WSN that can be appropriate to any type of urban city setting in South Africa, by means of investigating the current status of vehicle traffic monitoring networks, in the entire world in general and South Africa in particular; and combining wireless sensor network technology, RFID system and GPS technology to communicate with the road users. The architecture of the system is shown in Figure 3.7.

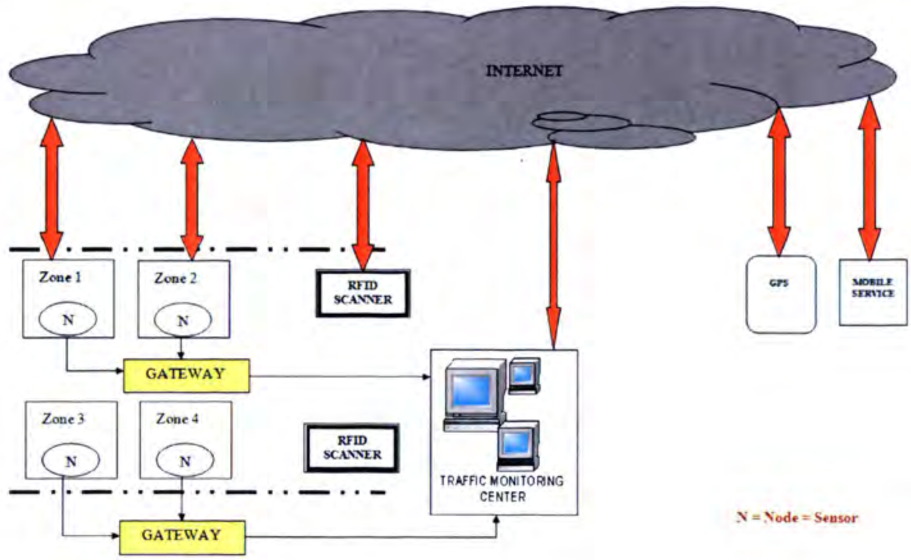

Figure 3.7: Model architecture

3.4 Model Functionality

The Novel Model shown in figure 3.7 consists of a wireless sensor network, GPS, RFID scanner, and mobile services. The sensor node installed on the road's junction will sense for congestion. Sensors will send information using (congestion images) gateway to the Traffic Monitoring Centre (TMC) if observed within route. The TMC will simultaneously communicate with GPS and RFID scanner. Communication with the GPS is for possible shortest route computation, while the RFID scanner immediately scans the RFID tag deployed on every moving vehicle from a distance of 1km. The output of such scan is a unique number (vehicle number plate in our case) which is used by the Traffic Monitoring Centre to communicate with the specific vehicle's driver in that specific congestion area. Immediately the scanned unique number is received, the traffic control Centre will generate a message (result of the GPS communication) and send it to the appropriate entity on the road to use the closest roads with no congestion. The gateway nodes in our proposed system work also as a collector that collects the data. If multiple nodes have sensed the same problem, they can pass the collected information to traffic monitoring centre; it will reduce the number of messages passing between the gateway and traffic monitoring centre system. This helps for system as it will remove the redundant data and transfers the useful data only. The image below illustrates one example of four (4) different roads:

Figure 3.8: Roads Intersection

In the above scenario, vehicles are traveling simultaneously. Some coming from R100 and R101 may be entering N1 or negotiating a turn from N1 into N12; as this movement goes on simultaneously it may cause a traffic jam (congestion) which may lead to a deadlock situation. The common possible solutions to this situation are avoidance, prevention, detection and recovery. This particular traffic circle in the road is a critical region, and only one vehicle is allowed to pass or negotiate the critical region per time. No two vehicles are allowed to pass through or negotiate the critical region at the same time as this may result in a deadlock (congestion) situation. In such a situation, using our novel model, the vehicle coming from N1 wanting to enter N12, R100 or R101 will be able to know the state of the road to avoid congestion on their specific direction.

The immediate reasons of congestion are various, as discussed in the previous section. The major ones are too many vehicles for a given road's design or intersection capacity, and dynamic changes in roadway capacity caused by lane-switching and car- following behaviour. However, we can identify two principal broad categories of underlying factors which can either be; micro-level factors (e.g. those that relate to traffic "on the road") and macro-level factors that relate to overall demand for road use. In this context, congestion is "triggered" at the "micro" level (e.g. on the road), and "driven" at the "macro" level by factors that contribute to the incidence of congestion and its severity. Basically, figure 3.9 shows the aspect of micro level congestion on the M40 to Johannesburg and figure 3.10 shows the macro congestion in the N1 Pretoria as the demand for the road increases.

There are no specific mechanisms related to the causing of congestion but they differ according to different types of roads. Congestion on continuous flow facilities such as highways does not occur in the same manner nor for the same proximate causes as congestion arising on intervallic flow facilities such as those found in dense urban centres.

Figure 3.9: Macro level congestion in M40 Johannesburg

Figure 3.10: Macro level congestion in N1 Pretoria

The images below shows different type of congestion that can occur in different type of roads networks in urban areas:

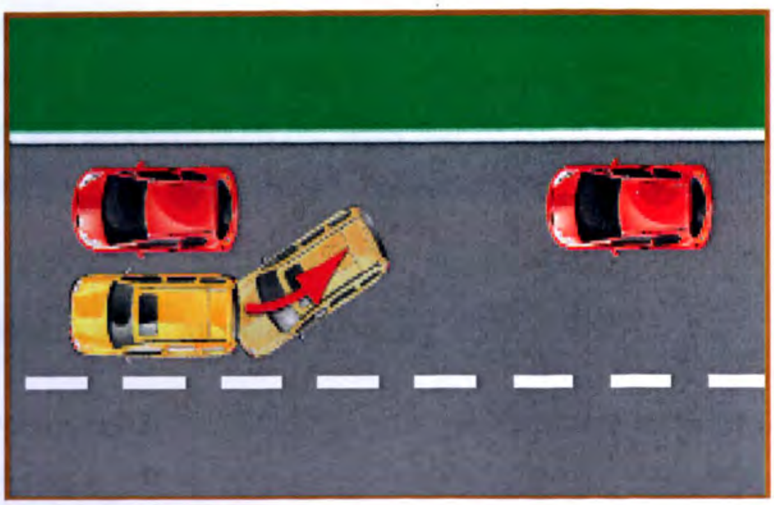

Figure 3.11: Traffic congestion caused by a break down vehicle

Many things can cause traffic congestion on the road netwoks, a vehicle breakdown may lead also to congestion as show in the above figure 3.11. Assuming our RFID is situated in 1km before each crossing as shown in the image, our novel model is able to quickly assist cars that are coming from different directions entering the main road under such a situation. The above scenario is different from the one that might happen at the roundabout as show in figure 3.12 below.

Figure 3.12: Traffic scenario at the roundabout

Figure 3.12 shows a congestion scenario at a roundabout which is an intersection where traffic travels around a central island in a counter clockwise direction. Vehicles entering or exiting the roundabout must yield to vehicles, bicyclists, and walkers. Compare to figure 3.8, here the rule for the road are totally different. To turn right at the intersection, Car A must choose the right-hand lane and exit in the right-hand lane to avoid congestion. To go straight through the intersection, Car B will be forced to choose either lane or exit in that lane and to turn left, Car C will choose the left lane, continue around, and then exit to avoid congestion.

3.5 Simulation tool for our Novel Model

Modelling of wireless networks requires sophisticated representation and analysis of communication channels, sensors, ad-hoc networking protocols, localisation strategies, media access control protocols and energy consumption in sensor nodes. Our novel model architecture is implemented and simulated using Visual Sense, part of PtolemyII [38], is recognised by its clear interface and its capability to simulate concurrence (multiple independent processes running in the same time interval), and is highly useful to simulate several independent wireless devices with processors existing in the same scenario and working concurrently.

VisualSense allows for wireless channel simulation taking variables such as delay and signal attenuation into account. VisualSense is a modelling and simulation framework for wireless and sensor networks that builds on leverages PtolemyII, it disposes a clear interface to model and simulate scenarios, as well as elements to visualize simulation results. Although simulation of energy consumption in the nodes is not optimally implemented, the elements (actors) in PtolemyII can be programmed using the Java programming language to achieve an extended functionality and provide a wider control over actors' behaviours. A basic simulation window constructed on PtolemyII, using VisualSense application is shown in figure 3.13 below, where we can appreciate four important actors as examples; a wireless director, a communication channel which takes into account the power loss of a signal, and two composite actors representing a transmitter and a receiver.

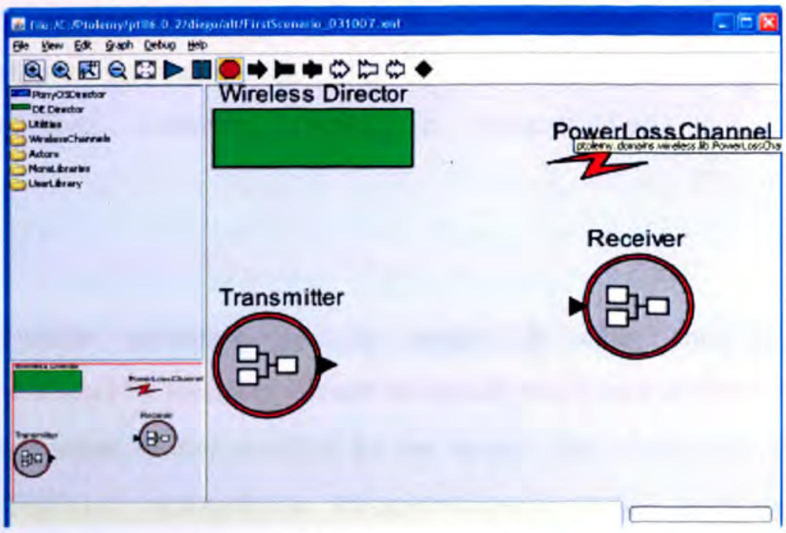

Figure 3.13: VisualSense Window

3.5.1 Software Architecture

VisualSense is constructed by sub-classing key in Ptolemy II. Basically, the extension to Ptolemy consists of a few new Java classes and some XML files. The classes are designed to be sub-classed by model builders for customisation, although non-trivial models can also be constructed without writing any Java code [52]. Executable components implement the Actor interface, and can be either atomic or composite. Atomic actors are defined in Java, while composite actors are assemblies of actors and relations. Each actor, whether atomic or not, contains ports, which are linked in a composite actor via relations. A top-level model is itself a composite actor, typically with no ports. Actors, ports and relations can all have attributes (parameters). One of the attributes is a director. The director plays a key role in Ptolemy II: it defines the semantics of a composite. It gives the concurrency model and the communication semantics. In VisualSense, the director implements the simulator. The Wireless Director is an almost completely unmodified subclass of the pre-existing discrete-event director (DEDirector) in PtolemyII. A node in a wireless network is an actor that can be a subclass of either TypedAtomicActor or TypedCompositeActor. The difference between these is that for TypedAtomicActor, the behaviour is defined in Java code, whereas for Typed- Composite Actor, the behaviour is defined by another Ptolemy II model, which is itself a composite of actors [52]. The default behaviour of Atomic-Wireless-Channel is represented by the following pseudo code:

```
Public void transmit(token, sender, properties) {
foreach receiver in range {
_transmitTo(token, sender, receiver, properties)
}
}
```

To determine which receivers are in range, it calls the protected method `_receiversInRange()`, which by default returns all receivers contained by ports that refer to the same channel name as that specified by the sender. The `_transmitTo()` method by default uses the `public transform Properties()` method to modify the properties argument and then put the token and the modified properties into the receiver. The `transform Properties ()` method applies any property transformers that are registered using the `register Property Transformer ()` method, but does nothing further.

3.5.2 Simulation Scenario in VisualSense

Basically, a simulation made in the Visual Sense platform in PtolemyII software is based on a *scenario* composed by *actors* interacting between them. An *actor* in PtolemyII could be defined as a single component in a scenario, where each element in a simulation is represented by an *actor*, being a minimal basic unit, or being a container for other actors and behaving as a black box. Examples of actors are the transmission media (wired and wireless), nodes (composite actors containing other actors), output interfaces for text and graphics (used to allow the user to visualize the data flux or the output data in a simulation). Among the simple actors we can find adders, file readers and logical comparators, useful to assemble a composite actor (which commonly represents a node or device) building a data flux diagram inside of it based on simple actors, where such diagram represents or "simulates" the internal functionality of an actor.

3.6 Advantages of the Novel Model

The use of WSN in the novel model gives us some advantages in managing the road efficiently in several urban areas in South Africa. In the literature review, we listed some of the advantages of using WSN in the novel Model and others derived by simulation of the novel model. Below are a few of the advantages that we are considering:

i. Making use of WSN in the Novel Model gives us the ability to monitor and evaluate roads automatically and continuously, with minimal human effort.
ii. The model through the use of WSN can work during the night even with poor weather conditions; i.e. when there is fog or presence of dust (pollution, volcanic ash) in the air.
iii. The Model through WSNs gives a low cost and power consumption.
iv. The Novel model allows the integration of video monitoring with magnetic or power sensors. In this way, it is possible to obtain complete and integrated information (video-images and traffic volumes information).
v. WSNs allow dynamic changes to network topology based on real needs and reports coming from sensors located along the road.

3.7 Chapter Summary

In this chapter we explained the hardware components of the novel model, their functionality and the software architecture used for the implementation of the simulation model. We explained how our novel model is used to avoid congestion in urban areas and finally we gave the advantages of using WSN in the design of the novel model. In the following chapter we discuss the results of the implementation of our novel model by using different experiments during the simulation.

CHAPTER 4

Model Implementation

4.1 Chapter Overview

In this chapter we present the results of the implementation of the model during the simulation. Based on the PtolemyII simulation environment, specifically in VisualSense different experiments were carried out during our simulation. The simulation of our novel model for traffic monitoring is carried out using specific hardware, a modular platform for WSNs, whose main feature is modularity.

4.2 Road Topology Simulation

Generally the design of a Wireless Sensor Network is a very specific task, especially because of the peculiarities of the deployment environment considered. Basically a WSN simulator consists of various modules namely events, medium, environment, node, transceiver, protocols, and applications. Each category is represented by an interface that defines its methods and events generated and consumed. In VisualSense simulation the main issue is in designing road topology as similar as possible to reality. In our road design we defined a 50 meter piece of road with a normal lane and one junction as show in the figure 4.1 below.

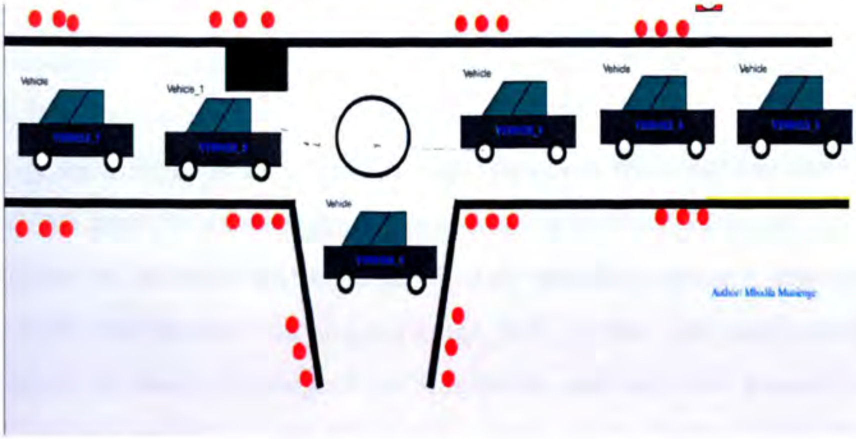

Figure 4.1: Road topology using VisualSense

In the simulation design of the road we deployed six (6) nodes randomly according to their specific sensing zone as explained in chapter two and chapter three. Basically the road topology during simulation is shown in figure 4.2 below.

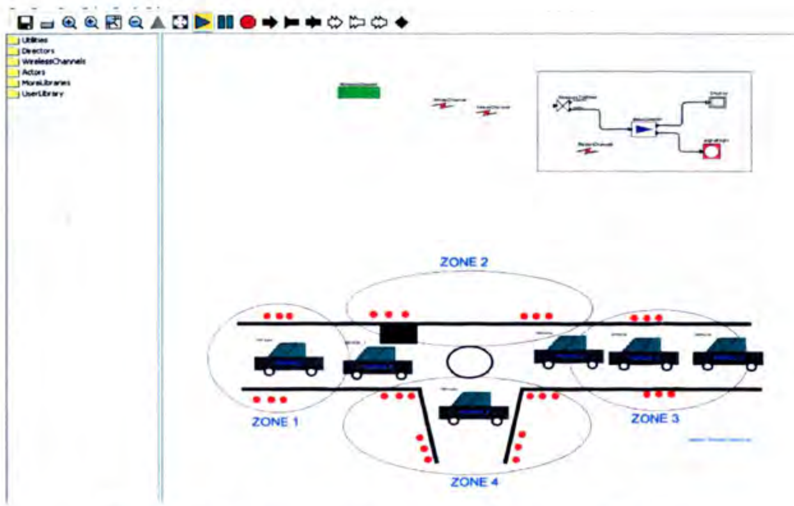

Figure 4.2: Sensors deployment in specific Zone

The image above shows also the distance of each node according to their specific zone as they are deployed on the road side; we used a distance of 10 meter approximately for simulation in each node, so the distance for each zone for sensing and communication purpose is 20 meters. The sensors are placed in groups called Zone 1-4 in such a way that if a vehicle cannot be sensed by one zone it will be able to be sensed by another zone.

4.3 Simulation of Vehicle's Traffic Monitoring

PtolemyII uses actors oriented; therefore it requires creation of composite actors according to the requirement. Our simulation made use of real life scenarios and was carried out in two types of roads topology for a duration of 2 minutes with respect to three different traffic scenarios. The collection of data used for these experiments was made between February 2013 and May 2013. In our simulation we assumed that all nodes in their specific zone sent data at the same rate on the gateway node and the data was analyze in the TMC so that road users could get information about the state of the roads. Although if our simulation used only two types of road network, our novel model can be used in any type of roads in urban areas in South Africa. The event in figure

4.3 shows that zone 2 was congested with a deadlock shown in red sensors and no vehicle was allowed to enter or negotiate those areas, but in zone 1, zone 3 and zone 4 as we can see, some of the areas are green and the road was still accessible to the users and motorists. In this case motorists using the sensing roads in zone 2, were advised by the TMC to avoid the roads and use an alternative road.

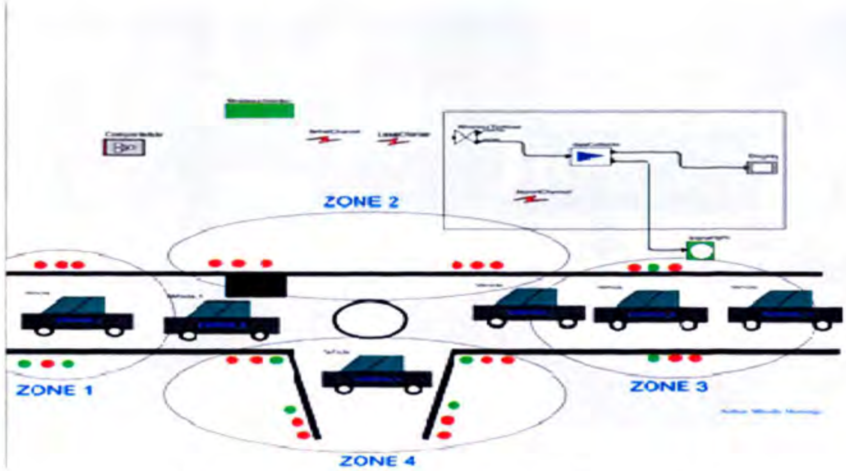

Figure 4.3: Vehicle monitoring (scenario 1)

Figure 4.4: Vehicle monitoring (scenario 2)

Figure 4.4 shows the result of the sensing zone. After sensing congestion in different zones, the sensors sends a message to the TMC showing congestion in different areas and the areas that are congestion free. Each sensor is defined by a specific number and that number defined the zone in which the sensor was deployed on the roadside. The nodes in red have an outcome as FALSE meaning there is congestion in those areas and the areas with no congestion as TRUE outcome as shown in the simulation above. Figure 4.5 below illustrates the implementation of the system between two cities during simulation.

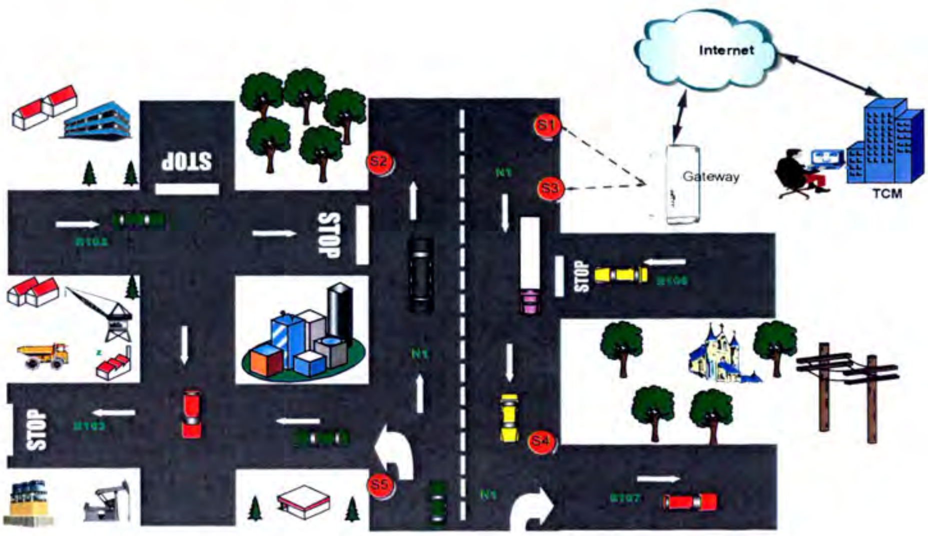

Figure 4.5: System implementation between two cities

Basically sensors are deployed on the road side N1, R103, R107, R102 and R106 to collect data from different directions, which is sent to the gateway so that the traffic officer in the TMC can make decisions and inform motorists about the road state.

4.4 The Occurrence of Traffic Congestion before our Model Implementation

Congestion control is the core issue of traffic flow control and management. The occurrence of the traffic congestion phenomenon is closely related to the design mechanism of traffic network. In such an environment, there may be a sufficient capacity to send vehicles in a given path. However, at some point on the road, the vehicles from different paths will be brought together, as we explained previously, and this leads to traffic congestion. By evaluating the scenarios in the previous chapter, before implementation the state was as shown in figure 4.6 below.

Figure 4.6: Congestion during peak hours (1)

The scenarios in figure 4.6 above and figure 4.7 below illustrated the state of the road monitoring before the simulation of our Novel system.

Figure 4.7: Congestion during peak hours (2)

4.5 Congestion Detection after our model implementation

Numerous methods for vehicles traffic monitoring are being used with different hardware using wireless sensor networks for congestion detection. Figure 4.8 and figure 4.9 shows the results obtained after the implementation of our novel model between PTA and JHB and JHB and PTA respectly.

Figure 4.8: RFID installation between PTA and JHB

Figure 4.9: RFID installation between JHB and PTA

It is also clear from our results shown on figure 4.12 the causes of congestion across different types of road networks are the extreme vulnerability of road demand in peak hours. When roads are operated at or near their maximum capacity, small changes in available capacity due to such factors as differential vehicle speeds, lane changes, and acceleration and deceleration cycles can trigger a sudden switch from flowing to stop-and-go traffic. Likewise, saturated intersections can quickly give rise to queues whose upstream propagation can bog local roads and intersections. These factors are shows in figure 4.10 and figure 4.11.

Figure 4.10: Saturated intersection

Figure 4.11: Stop-and-go traffic

In the next section we display the results of the simulated road using data collected between February 2013 and May 2013.

4.6 Simulation Results

In the following section we present the results for the simulation. During the simulation we were able to fulfill all the requirements for our model even though there were some limitations for the software. The results displayed on the graph in figure 4.12 were obtained after the implementation of our novel model.

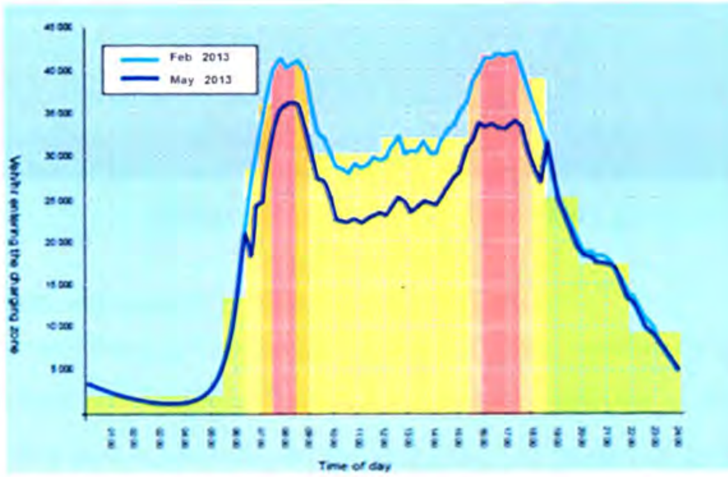

Figure 4.12: Road Monitoring before and after the Model simulation

It can be seen the graph before our model implementation, that vehicles entering the charging zone during peak periods were significantly high per day.

After our model implementation, it can be observed that the number of vehicles entering the same congestion zone during the peak period has reduced due to availability of congestion information supplied from the traffic monitoring center (TMC) developed by our model. Consequently, this information has helped motorists to take an alternative route for their journey during the peak period and therefore has drastically reduced the rate of congestion during these peak periods.

The reduction in traffic congestion after the implementation of our model results in a situation where the road traffic takes the form of the image shown below in figure 4.13.

Figure 4.13: Road after simulation

4.6.1 Successful delivery of data packets during simulation

During the experiments sensors placed on the road side are at a variable range between 10-20 m. The average range can be considered as 15 m. Successful delivery of data packets will be affected by range. We perform simulation for two values of packet sizes (500 bytes and 1000 bytes). As it is clear from Figure 4.14 the percentage of successfully delivered packets increases for large packet size.

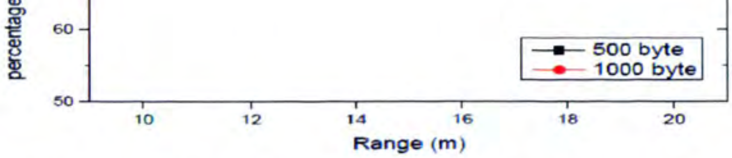

Figure 4.14: Sensing range on successful data packets

4.6.2 Delay in delivery of data packets during the simulation

The allowable speed limit for vehicles ranges between 40-100 km/h. For the purpose of this experiment, the average speed considered is 60 km/h, and the least delay in delivery of data packets is found within this speed. When the vehicle is too slow or speedy, the delay will be high. This implies that the higher the packet size, the higher the delay at any speed. The packet size considered here ranges between 500 – 1000 Bytes.

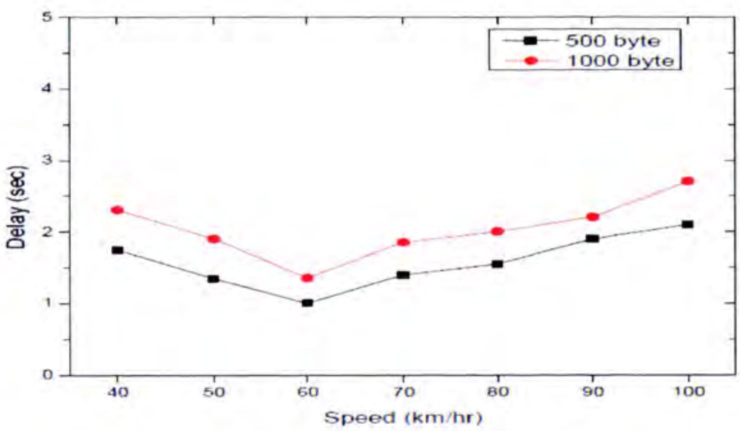

Figure 4.15: Sensing range on delay data packets

4.7 Chapter Summary

This chapter presents the simulation results of the novel model for vehicle traffic monitoring using wireless sensor networks. The simulation of the model was done using a software tool called VisualSense in Ptolemy II platform. The software is based on scenarios composed by actors interacting between them using a few new Java classes and some XML files. The results obtained in this simulation, show that the novel model can be used effectively to monitor traffic congestion in different cities in South Africa and other developing countries around the world.

CHAPTER 5

Summary, Conclusion and Future work

5.1 Summary

Cities and traffic have been developing alongside each other, dating back to the earliest large human settlements. The same common reason(s) responsible for inhabitants congregating in large urban areas are also responsible for sometimes intolerable levels of traffic congestion on urban streets and thoroughfares. Effective urban governance requires a careful balancing between the benefits of agglomeration and the disadvantages of excessive congestion. Urban growth results traffic congestion which ultimately requires traffic monitoring.

The road transport profile in South Africa is categorized by its sizeable dependence on cars, particularly in the highly developed urban areas, alongside cycling and public transport. Managing effective congestion requires an integrated strategy that goes beyond the visible incidence of congestion on the road and extends to the management of the urban area as a whole. Many strategies can help to improve travel speeds, increase system reliability and reduce the impacts of congestion in South Africa urban roads. With new technologies, the use of WSN in this research helps us to develop a cost effective model that reduces the level of congestion, and keeps the roads under control during congestion periods between two major cities in South Africa. The full report on which this summary is based aims to provide policymakers and technical staff with the strategic vision, conceptual frameworks and guidance on some of the practical tools necessary to manage congestion in such a way as to reduce its overall impact on individuals, families, communities and societies.

5.2 Conclusion

As the city road networks is growing day-by-day, the question of how to minimize traffic on the roads is becoming more and more challenging. In South Africa, the increasing congestion level an urban areas public road networks is a growing challenge. Therefore, the application of wireless sensor networks offers a promising platform for traffic monitoring that can compete with current technology in accuracy and lifetime. In this research dissertation, we have developed a novel model for vehicle traffic monitoring that uses WSN to monitor congestion between two major cities (Pretoria and Johannesburg). The model consists of RFID, sensor nodes, mobile service and GPS. Upon implementation, we demonstrated that the model is able to reduce traffic congestion in those urban cities. As a way of proffering a solution to the problems, we also suggested some important strategies to minimize congestion.

5.3 Future work and Recommendation

This section is explained in the following two sub-heading:

5.3.1 Future work

Because technology is advancing and road traffic congestion is on the increase, as future work, we shall explore the use of diverse congestion detection mechanisms that combine mobile sensor networks and multiple camera video surveillance as a single technology to combat the envisaged traffic increase in the next century.

5.3.2 Recommendations

Road traffic congestion poses a challenge for all large and growing urban areas. The success or failure cities experience in monitoring congestion will ultimately depend on how well they organise themselves to carry out the task they set for themselves. We must understand that congestion is one of the major pre-occupations of urban decision-makers, and that congestion takes on many faces, occurs in many different contexts and is caused by many different processes. Because of this, there is no single best approach to managing congestion – and therefore this report is not prescriptive about specific congestion management measures. However, there are many things that congestion management policies should take into account if they are to achieve the goals they set for themselves.

Monitoring road traffic is the cost paid as a result of congestion. Therefore, congestion management invariably reduces the road traffic cost associated with it. For the purpose of this research, we recommend the flowing ten (10) strategies to reduce congestion so as to enhance traffic monitoring.

i. Build new and modern infrastructure.
ii. Build express highways to be built.
iii. Promote private participation in road development.
iv. Modifying existing infrastructure by widening busy roads.
v. Implement mobility management by improving public transport systems.
vi. Expand and improve on railways network operation.
vii. Implement of Metro-rails in metros and big cities in South Africa.
viii. Improve urban planning and design.
ix. Improve traffic operation through improving traffic operation information to develop and monitor relevant congestion indicators.
x. Manage demand for road and parking space consistent with a shared vision on how the city should develop.

References

[1] B. Barbagli, L. Bencini, I. Magrini, G. Manes, and A. Manes, "A real-time traffic monitoring based on wireless sensor network technologies," *in 2011 7th International Wireless Communications and Mobile Computing Conference,* pp. 820–825, 2011.

[2] X. Laisheng, P. Xiaohong, W. Zhengxia, and X. Bing, "Research on Traffic Monitoring Network and its Traffic Flow Forecast and Congestion Control Model Based on Wireless Sensor Network V," pp. 142–147, 2009.

[3] R. Bhoraskar, N. Vankadhara, B. Raman, and P. Kulkarni, "Wolverine: Traffic and road condition estimation using smartphone sensors," *in 2012 Fourth International Conference on Communication Systems and Networks (COMSNETS 2012)*, pp. 1–6, 2012.

[4] G. Kamath, X. Ye, and L. A. Osadciw, "SAA 09-4 - Using Swarm Intelligence and Bayesian Inference for Aircraft Interrogation," *in 2008 IEEE Wireless Communications and Networking Conference,* pp. 3279–3284, 2008.

[5] A. Koutsia, T. Semertzidis, K. Dimitropoulos, N. Grammalidis, A. Kantidakis, K. Georgouleas, and P. Violakis, "Traffic Monitoring using Multiple Cameras, Homographies and Multi-Hypothesis Tracking," *in 2007 3DTV Conference*, pp. 1–4, 2007.

[6] D.J Cook, and S.K. Das, *Overview, in Smart Environments: Technologies, Protocols, and Applications* (eds D. J. Cook and S. K. Das), John Wiley & Sons, Inc., Hoboken, NJ, USA. doi: 10.1002/047168659X.ch, 2005.

[7] L. G. Feng Zhao, "Wireless Sensor Networks: An Information Processing Approach", Morgan Kaufmann (ISBN 1-55860-914-8), 358 pages, 2004.

[8] K. Romer and F. Mattern, "The design space of wireless sensor networks," *IEEE Wireless Communications,* vol. 11, no. 6, pp. 54–61, 2004.

[9] L. Xiao, X. Peng, Z. Wang, B. Xu, and P. Hong, "Research on Traffic Monitoring Network and Its Traffic Flow Forecast and Congestion Control Model Based on Wireless Sensor Networks," *in 2009 International Conference on Measuring Technology and Mechatronics Automation*, vol. 1, pp. 142–147, 2009.

[10] Y. S. Malik Tubaishat, "Adaptive traffic light control with wireless sensor networks", *IEEE,* vol. 11, pp187-197, *(2007).*

[11] C. Wenjie, C. Lifeng, C. Zhanglong, and T. Shiliang, "A Realtime Dynamic Traffic Control System Based on Wireless Sensor Network," *in 2005 International Conference on Parallel Processing Workshops (ICPPW'05)*, pp. 258–264, 2005.

[12] A. Koutsia, T. Semertzidis, K. Dimitropoulos, N. Grammalidis, A. Kantidakis, K. Georgouleas, and P. Violakis, "Traffic Monitoring using Multiple Cameras, Homographies and Multi-Hypothesis Tracking," *in 2007 3DTV Conference,* pp. 1–4, 2007.

[13] J. Yick, B. Mukherjee, D. Ghosal, "Wireless sensor network survey", *Computer Networks 52* (2008), pp 2292–2330

[14] I. Akyildiz, "Wireless multimedia sensor networks: A survey," *Wireless Communications, IEEE*, Vol: 14, no: 6, pp 32-39, *(2007).*

[15] K. Romer and F. Mattern, "The design space of wireless sensor networks," *IEEE Wireless Communications.,* vol. 11, no. 6, pp. 54–61, 2004.

[16] V. Katiyar, "An Intelligent Transportation Systems Architecture using Wireless Sensor Networks," *International Journal of Computer Applications*, 14(2), pp 22–26, 2011.

[17] A. Tiwari, P. Ballal, and F. L. Lewis, "Energy-efficient wireless sensor network design and implementation for condition-based maintenance," *ACM Transactions on Sensor Networks,* vol. 3, no. 1, p. 1–4, 2007.

[18] H. Arolka, K. Dhamecha and D. Pate, "Architecture for Accident Monitoring in BRTS Corridors Using Wireless Sensor," *International Journal of Enterprise Computing and Business Systems,* vol. 2, no. 1, 2012.

[19] J. Hwang, C. Shin, and H. Yoe, "Study on an agricultural environment monitoring server system using Wireless Sensor Networks.," *Sensors (Basel),* vol. 10, no. 12, pp. 11189–211, Jan. 2010.

[20] D. Pompili, T. Melodia, and I. F. Akyildiz, "Deployment analysis in underwater acoustic wireless sensor networks," *Proc. of ACM International Workshop on UnderWater Networks (WUWNet), Los Angeles, CA, 2006*

[21] J. Yick, B. Mukherjee, and D. Ghosal, "Wireless sensor network survey," *Computer. Networks*, vol. 52, no. 12, pp. 2292–2330, Aug. 2008.

[22] V. M. Geoff . and T. Y. Kheng, Wireless sensor networks: application-centric design, Rijeka, HR, InTech, ISBNs: 9789533073217, 504pp, eds.2010

[23] Q. Wang, "Wireless Sensor Networks - An Introduction," no. 187857, 1984.

[24] G. Anastasi, M. Conti, M. Di Francesco, and A. Passarella, "Energy conservation in wireless sensor networks: A survey," *Ad Hoc Networks*, Vol. 7 Is 3, pp 537-568, 2009.

[25] M.A. Rahman, E. Al-Shaer, P. Bera, "A Noninvasive Threat Analyzer for Advanced Metering Infrastructure in Smart Grid", *IEEE Transactions on smart Grid,* p(s): 273 - 287 Volume: 4, Issue: 1, March 2013

[26] M. Tubaishat, Y. Shang, and H. Shi, "Adaptive Traffic Light Control with Wireless Sensor Networks," *in 2007 4th IEEE Consumer Communications and Networking Conference*, pp. 187–191, 2007.

[27] H. Arbabi and M. C. Weigle, "Using DTMon to monitor transient flow traffic," *2010 IEEE Vehicle Networks Conference*, pp. 110–117, Dec. 2010.

[28] K. Romer and F. Mattern, "The design space of wireless sensor networks," *IEEE Wireless. Communications,* vol. 11, no. 6, pp. 54–61, 2004.

[29] G. Padmavathi, "A Study on Vehicle Detection and Tracking Using Wireless Sensor Networks," *Wireless Sensor Net*works, vol. 02, no. 02, pp. 173–185, 2010.

[30] V. Katiyar, "An Intelligent Transportation Systems Architecture using Wireless Sensor Networks," vol. 14, no. 2, pp. 22–26, 2011.

[31] T. S. K. Dimitropoulos and A. K. N. Grammalidis, "Video sensor network for real-time traffic monitoring and surveillance," *IET journals & magazine,* vol.4, Is.2, pp. 103-112, 2010.

[32] S. Hadim and N. Mohamed, "Middleware: Middleware Challenges and Approaches for Wireless Sensor Networks," *IEEE Distrib. Syst. Online*, vol. 7, no. 3, pp. 1–1, Mar. 2006.

[33] S. Toumpis and L. Tassiulas, "Optimal deployment of large wireless sensor networks," *IEEE Trans. Inf. Theory*, vol. 52, no. 7, pp. 2935–2953, Jul. 2006.

[34] Yick, J.; Bharathidasan, A.; Pasternack, G.; Mukherjee, B.; Ghosal, D., "*Wireless Communications and Networking Conference*", 2004. WCNC. 2004 IEEE, Vol. 4, pp 2486 – 2491, 2014.

[35] I. F. Akyildiz and E. P. Stuntebeck, "Wireless underground sensor networks: Research challenges," *Ad Hoc Networks (Elsevier)*, Vol. 4, No. 6, pp. 669-686, 2006.

[36] M. Li and Y. Liu, "Underground structure monitoring with wireless sensor networks," proceeding of *International Conference on Information Processing in Sensor Networks, pp.69-78, (IPSN'07),* April 25–27, 2007, Cambridge, Massachusetts, USA.

[37] J. Bohn, "Prototypical Implementation of Location-Aware Services Based on Super-Distributed RFID Tags," *Architecture of Computing Systems - ARCS* 2006, Lecture Notes in Computer Science Vol. 3894, pp 69-83, 2006.

[38] J. Schwieren and G. Vossen, "A design and development methodology for mobile RFID applications based on the ID-Services middleware architecture," *information Systems Frontiers*, Vol.15, Is.5, pp 529-539, 2010.

[39] "RFID Essentials - Bill Glover, Himanshu Bhatt - Bok (9780596009441) | Bokus bokhandel." [Online]. Available: http://www.bokus.com/bok/9780596009441/rfid-essentials/. [Accessed: 27-Sep-2013].

[40] R.Want, RFID: A key to automating everything. Scientific American, 290(1), pp.56-66, (2004, January). Retrieved 09-sept-2013 from MasterFILE Premier Database. [Online]

[41] D.M. Ward, March: RFID Systems. Computers in Libraries, pp.19-24, 2004.

[42] K. Ahsan, H. Shah, and P. Kingston, "RFID applications: An introductory and exploratory study," arXiv Prepr. arXiv1002.1179, 2010.

[43] K. Ahsan, "RFID Components, Applications and System Integration with Healthcare Perspective, ISBN: 978-953-307-380-4, in book: Deploying RFID - Challenges, Solutions, and Open Issues, Source: InTech 2006.

[44] A. Narayanan, S. Singh, and M. Somasekharan, "Implementing RFID in Library: Methodologies, Advantages and Disadvantages," *In International Conference on Academic Libraries (ICAL-2009)*, Delhi (India), pp. 300-306, 5-8 October 2009. [Conference paper]

[45] M. Brown, E. Zeisel, and R. Sabella, *RFID+ Exam Cram. Que*, 2006, pp. 336.

[46] R. Moroz Ltd. (2004, July). Understanding Radio Frequency Identification (RFID), (Passive RFID). Markham, Ontario: R. Moroz Ltd. Retrieved, 04-Sept-2013 from http://www.rmoroz.com/rfid.html.

[47] S. Shepard, RFID: *Radio Frequency Identification*. McGraw Hill Professional, Business & Economics, pp. 256, 2005.

[48] M.R. Rieback, B. Crispo, A.S. Tanenbaum. "The Evolution of RFID Security." *IEEE Pervasive Computing*, vol. 5(1):62-69, 2006.

[49] L. Wang, G. Wang., RFID-driven global supply chain and management. International Journal of Computer Applications in Technology, (2009), p35:1, 42, online publication date: 1-Jan-2009.

[50] Bohn, J., "Prototypical implementation of location-aware services based on a middleware architecture for super-distributed RFID tag infrastructures", *Personal Ubiquitous Computing, ACM*, Vol.12 (2), pp.155-166, 2008.

[51] M. Ward, R. Van Kranenburg, W. Marsterson, and A. Hopkinson, "RFID : Frequency, standards, adoption and innovation," JISC Technology and Standards Watch, 2006.

[52] "Ptolemy II Home Page." [Online]. Available:http://ptolemy.berkeley.edu/ptolemyII/index.htm. [Accessed: 17-Sep-2013].

[53] Global Positioning System, Standard Positioning System Service, Signal Specification, 2nd Edition, 1995, page18, http://www.navcen.uscg.gov/pubs/gps/sigspec/gpssps1.pdf

[54] D. Kaplan: Understanding GPS, Artech House, Boston 1996, ISBN 0-89006-793-7

[55] B.Parkinson, J.Spilker: Global Positioning System, Volume 1, AIAA-Inc. page 89, 1996.

[56] D. Tacconi, D. Miorandi, I. Carreras, F. Chiti, R. Fantaci, "Using wireless sensor networks to support intelligent transportation system ", *Ad Hoc Networks*, Volume 8, Issue 5, Pages 462–473, 2010.

[57] H. Sheikhi, M. Dashti, and M.Dehghan, "Congestion detection for video traffic in wireless sensor networks", International *Conference on Consumer Electronics, Communications and Networks (CECNet)*, pp.1127 – 1131, 2011.

[58] R. Fantacci and F. Chiti, Urban Microclimate and Traffic Monitoring with Mobile Wireless Sensor Networks, Wireless Sensor Networks: Application-Centric Design, Yen Kheng Tan (Ed.), ISBN: 978-953-307-321-7, 2010. InTech, Available from: http://www.intechopen.com/books/wireless-sensor-networksapplication-centric-design/urban-microclimate-and-traffic-monitoring-with-mobile-wireless-sensor-networks [access 10-novemember-2013]

[59] S. Kumar and R. Kumar, "Video Sensor Network for real-time Traffic Monitoring and Surveillance", *International journal of Enterprise Computing and Business Systems (online)*, vol.2, Is.2, 2012.

[60] T. Semertzidis K. Dimitropoulos A. Koutsia N. Grammalidis, "Video sensor network for real-time traffic monitoring and surveillance", *IET Intelligent Transportation Systems*, 2010, Vol. 4, Issue. 2, pp. 103–112

[61] F. Zhu, S. China and L. Li, "An Optimized Video-Based Traffic Congestion Monitoring System, Knowledge Discovery and Data Mining", *WKDD '10 Conference*, pp.150-153, 2010.

Appendix: Source Code

```
/* TraConSys interface */

import javax.swing.*;
import java.awt.*;
import java.awt.event.ActionEvent;
import java.awt.event.ActionListener;

public class main {
  JFrame myWindow = new JFrame();
  Container container = myWindow.getContentPane();
  JPanel panel = new JPanel() {
    ImageIcon image = new ImageIcon("C:/gps/images/gpsBGMain.png");
    public void paint(Graphics g) {
      Dimension d = getSize();
      for (int x = 0; x < d.width; x += image.getIconWidth()) {
        for (int y = -3; y < d.height; y += image.getIconHeight()) {
          g.drawImage(image.getImage(), x, y, null, null);
        }
      }
      super.paint(g);
    }
  };
  JButton btNavigation = new JButton("Navigation");
  JButton btWarning = new JButton("Warning");
  JButton btNotice = new JButton("Send Notifications");
  JButton btTraffic = new JButton("Traffic");
  JButton btMenu = new JButton("Menu");
  JButton btReload = new JButton("Reload");
  JButton btOFF = new JButton("QUIT");
  JLabel lbPic = new JLabel(new ImageIcon("G:/DOCUMENTS/PROGRAMZ/COM 3520
PROJECT/JavaImG/g2.gifl"));
  public main() {
    // myWindow.setUndecorated(true);
    // myWindow.getRootPane().setWindowDecorationStyle(JRootPane.FILE_CHOOSER_DIALOG);
    myWindow.setTitle("GPS");
    myWindow.setSize(800, 400);
    myWindow.setResizable(false);
    myWindow.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
    ADD(lbPic, 220, 63, 850, 200);
    ADD(btNavigation, 40, 20, 120, 100);
    NavigationButtonHandler NavigationHandler = new NavigationButtonHandler();
    btNavigation.addActionListener(NavigationHandler);
    ADD(btWarning, 40, 140, 120, 40);
```

```
    WarningButtonHandler WarningHandler = new WarningButtonHandler();
    btWarning.addActionListener(WarningHandler);
    ADD(btNotice, 40, 185, 120, 40);
    NoticeButtonHandler NoticeHandler = new NoticeButtonHandler();
    btNotice.addActionListener(NoticeHandler);
    ADD(btTraffic, 40, 230, 120, 40);
    TrafficButtonHandler TrafficHandler = new TrafficButtonHandler();
    btTraffic.addActionListener(TrafficHandler);
    ADD(btMenu, 40, 280, 120, 80);
    MenuButtonHandler MenuHandler = new MenuButtonHandler();
    btNavigation.addActionListener(MenuHandler);
    ADD(btReload, 700, 310, 80, 20);
    ReloadButtonHandler ReloadHandler = new ReloadButtonHandler();
    btReload.addActionListener(ReloadHandler);
    ADD(btOFF, 700, 340, 80, 30);
    OFFButtonHandler OFFHandler = new OFFButtonHandler();
    btOFF.addActionListener(OFFHandler);
    container.add(panel);
    panel.setOpaque(false);
    myWindow.setVisible(true);
  }
  public void ADD(Component c, int x, int y, int l, int b) {
    c.setBounds(x, y, l, b);
    container.add(c);
  }
  public class NavigationButtonHandler implements ActionListener {
    public void actionPerformed(ActionEvent e) {
      //code to be executed
      myWindow.setVisible(false);
      new main();
    }
  }
  public class WarningButtonHandler implements ActionListener {
    public void actionPerformed(ActionEvent e) {
      //code to be executed
      myWindow.setVisible(false);
      new myWarnings();
    }
  }

  public class NoticeButtonHandler implements ActionListener {
    public void actionPerformed(ActionEvent e) {
      //code to be executed
      //   myWindow.setVisible(false);
```

```
        // new ManagerLogin();
      }
    }
    public class TrafficButtonHandler implements ActionListener {
      public void actionPerformed(ActionEvent e) {
        //code to be executed
        //  myWindow.setVisible(false);
        // new CashierLogin();
      }
    }
    public class MenuButtonHandler implements ActionListener {
      public void actionPerformed(ActionEvent e) {
        //code to be executed
        //   myWindow.setVisible(false);
      }
    }
    public class ReloadButtonHandler implements ActionListener {
      public void actionPerformed(ActionEvent e) {
        //code to be executed
        myWindow.setVisible(false);
        new main();
      }
    }
    public class OFFButtonHandler implements ActionListener {
      public void actionPerformed(ActionEvent e) {
        //code to be executed
        myWindow.setVisible(false);
        new Trams();
      }
    }
    public static void main(String[] args) {
      new main();
    }
}

/* GPS detection */

//import com.mysql.jdbc.Connection;
//import com.mysql.jdbc.Statement;
import java.sql.*;
//import java.beans.Statement;
//import java.sql.Connection;
import java.sql.DriverManager;
import java.sql.ResultSet;
```

```
import java.sql.SQLException;
import javax.swing.JOptionPane;

public class UniversalConnectionClass {
   String dbName = "sars";
   String URL = "jdbc:mysql://localhost/" + dbName;
   String driver = "com.mysql.jdbc.Driver";
   String username = "root";
   String password = "";
   private Connection con;
   public Statement st;
   ResultSet rs;
   public UniversalConnectionClass() {
      try {
         Class.forName(driver);
         this.con = (Connection) DriverManager.getConnection(URL, username, password);
         this.st = (Statement) this.con.createStatement();
         //JOptionPane.showMessageDialog(null,"        CONNECTION STATUS\n\n\n\nConnected to
database : "+ dbName+"\n\n");
         System.out.println("\n\nConnected to database : " + dbName);
      } catch (Exception e) {
         System.out.println("Error :" + e.getMessage());
      }
   }
   public static void main(String[] args) {
      new UniversalConnectionClass();
   }
}

/* sending message state of the road */

import javax.swing.*;
import java.awt.*;
import java.awt.event.ActionEvent;
import java.awt.event.ActionListener;
import java.sql.Connection;
import java.sql.DriverManager;
import java.sql.ResultSet;
import java.sql.Statement;

public class mySend {
   UniversalConnectionClass dataBase = new UniversalConnectionClass();
   Connection c = null;
   Statement s = null;
```

```
ResultSet r = null;
JFrame myWindow = new JFrame();
Container container = myWindow.getContentPane();
JPanel panel = new JPanel() {
   ImageIcon image = new ImageIcon("C:/gps/images/gpsBGMain.png");
   public void paint(Graphics g) {
      Dimension d = getSize();
      for (int x = 0; x < d.width; x += image.getIconWidth()) {
         for (int y = -3; y < d.height; y += image.getIconHeight()) {
            g.drawImage(image.getImage(), x, y, null, null);
         }
      }
      super.paint(g);
   }
};

JButton btNavigation = new JButton("Navigation");
JButton btWarning = new JButton("Warning");
JButton btNotice = new JButton("Send Notifications");
JButton btTraffic = new JButton("Traffic");
JButton btMenu = new JButton("Menu");
JButton btReload = new JButton("Send");
JButton btOFF = new JButton("OFF");
JLabel lbPic = new JLabel(new ImageIcon("G:/DOCUMENTS/PROGRAMZ/COM 3520
PROJECT/JavaImG/g2.gifl"));
JTextArea myMsg = new JTextArea();
public mySend() {
   // myWindow.setUndecorated(true);
   // myWindow.getRootPane().setWindowDecorationStyle(JRootPane.FILE_CHOOSER_DIALOG);
   myWindow.setTitle("Send Notification");
   myWindow.setSize(800, 400);
   myWindow.setResizable(false);
   myWindow.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
   ADD(lbPic, 220, 63, 850, 200);
   ADD(myMsg, 223, 67, 475, 250);
   ADD(btNavigation, 40, 20, 120, 100);
   NavigationButtonHandler NavigationHandler = new NavigationButtonHandler();
   btNavigation.addActionListener(NavigationHandler);
   ADD(btWarning, 40, 140, 120, 40);
   WarningButtonHandler WarningHandler = new WarningButtonHandler();
   btWarning.addActionListener(WarningHandler);

   ADD(btNotice, 40, 185, 120, 40);
   NoticeButtonHandler NoticeHandler = new NoticeButtonHandler();
```

```
    btNotice.addActionListener(NoticeHandler);
    ADD(btTraffic, 40, 230, 120, 40);
    TrafficButtonHandler TrafficHandler = new TrafficButtonHandler();
    btTraffic.addActionListener(TrafficHandler);
    ADD(btMenu, 40, 280, 120, 80);
    MenuButtonHandler MenuHandler = new MenuButtonHandler();
    btNavigation.addActionListener(MenuHandler);
    ADD(btReload, 700, 310, 80, 20);
    ReloadButtonHandler ReloadHandler = new ReloadButtonHandler();
    btReload.addActionListener(ReloadHandler);
    ADD(btOFF, 700, 340, 80, 30);
    OFFButtonHandler OFFHandler = new OFFButtonHandler();
    btOFF.addActionListener(OFFHandler);
    container.add(panel);
    panel.setOpaque(false);
    myWindow.setVisible(true);
  }
  public void ADD(Component c, int x, int y, int l, int b) {
    c.setBounds(x, y, l, b);
    container.add(c);
  }
  public class NavigationButtonHandler implements ActionListener {
    public void actionPerformed(ActionEvent e) {
      //code to be executed
      myWindow.setVisible(false);
      new main();
    }
  }
  public class WarningButtonHandler implements ActionListener {
    public void actionPerformed(ActionEvent e) {
      //code to be executed
      myWindow.setVisible(false);
      new myWarnings();
    }
  }
  public class NoticeButtonHandler implements ActionListener {
    public void actionPerformed(ActionEvent e) {
      //code to be executed
      //  myWindow.setVisible(false);
      // new ManagerLogin();
    }
  }
  public class TrafficButtonHandler implements ActionListener {
    public void actionPerformed(ActionEvent e) {
```

```
        //code to be executed
        //   myWindow.setVisible(false);
        // new CashierLogin();
    }
}
public class MenuButtonHandler implements ActionListener {
    public void actionPerformed(ActionEvent e) {
        //code to be executed
        //  myWindow.setVisible(false);
    }
}
public class ReloadButtonHandler implements ActionListener {
    public void actionPerformed(ActionEvent e) {
        //code to be executed  public void actionPerformed(ActionEvent e) {
        //code to be executed
        try {
            String search;
            Class.forName("com.mysql.jdbc.Driver");
            c = DriverManager.getConnection("jdbc:mysql://localhost/sars", "root", "");
            s = c.createStatement();
            r = s.executeQuery("SELECT  *  FROM accounts ;");
            while (r.next()) {
                /*
                 * get column 1 and 2 from table cds
                 */
                Object[] row = {r.getString(1), r.getString(2), r.getString(3), r.getString(4)};
                /*
                 * remember add row to the model not the jtable, the model
                 * knows how to put data in the JTable
                  */
                String msg, comand;
                msg = myMsg.getText();
                comand = " UPDATE accounts SET note =  '" + msg + "';";
                //JOptionPane.showMessageDialog(null, comand);
                dataBase.st.executeUpdate(comand);
                JOptionPane.showMessageDialog(null, "Notification sent");
                myMsg.setText(null);
            }
        } catch (Exception er) {
            JOptionPane.showMessageDialog(null, "Error : " + er);
            er.printStackTrace();
        }
    }
}
```

```
  public class OFFButtonHandler implements ActionListener {
    public void actionPerformed(ActionEvent e) {
      //code to be executed
      System.exit(0);
    }
  }
  public static void main(String[] args) {
    new mySend();
  }
}

/* Warning message from the system */

import javax.swing.*;
import java.awt.*;
import java.awt.event.ActionEvent;
import java.awt.event.ActionListener;
import java.sql.Connection;
import java.sql.DriverManager;
import java.sql.ResultSet;
import java.sql.Statement;

public class myWarnings {
  UniversalConnectionClass dataBase = new UniversalConnectionClass();
  Connection c = null;
  Statement s = null;
  ResultSet r = null;
  JFrame myWindow = new JFrame();
  Container container = myWindow.getContentPane();
  JPanel panel = new JPanel() {
    ImageIcon image = new ImageIcon("C:/gps/images/gpsBGMain.png");
    public void paint(Graphics g) {
      Dimension d = getSize();
      for (int x = 0; x < d.width; x += image.getIconWidth()) {
        for (int y = -3; y < d.height; y += image.getIconHeight()) {
          g.drawImage(image.getImage(), x, y, null, null);
        }
      }
      super.paint(g);
    }
  };

  JButton btNavigation = new JButton("Navigation");
  JButton btWarning = new JButton("Warning");
```

```
JButton btNotice = new JButton("Send Notifications");
JButton btTraffic = new JButton("Traffic");
JButton btMenu = new JButton("Menu");
JButton btReload = new JButton("Reload");
JButton btOFF = new JButton("OFF");
JLabel lbPic = new JLabel(new ImageIcon("C:/g2.gifl"));
JTextArea myMsg = new JTextArea();

public myWarnings() {
  // myWindow.setUndecorated(true);
  // myWindow.getRootPane().setWindowDecorationStyle(JRootPane.FILE_CHOOSER_DIALOG);
  myWindow.setTitle("WARNIGS");
  myWindow.setSize(800, 400);
  myWindow.setResizable(false);
  myWindow.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
  ADD(lbPic, 220, 63, 850, 200);
  ADD(myMsg, 223, 67, 475, 250);
  ADD(btNavigation, 40, 20, 120, 100);
  NavigationButtonHandler NavigationHandler = new NavigationButtonHandler();
  btNavigation.addActionListener(NavigationHandler);
  ADD(btWarning, 40, 140, 120, 40);
  WarningButtonHandler WarningHandler = new WarningButtonHandler();
  btWarning.addActionListener(WarningHandler);
  ADD(btNotice, 40, 185, 120, 40);
  NoticeButtonHandler NoticeHandler = new NoticeButtonHandler();
  btNotice.addActionListener(NoticeHandler);
  ADD(btTraffic, 40, 230, 120, 40);
  TrafficButtonHandler TrafficHandler = new TrafficButtonHandler();
  btTraffic.addActionListener(TrafficHandler);
  ADD(btMenu, 40, 280, 120, 80);
  MenuButtonHandler MenuHandler = new MenuButtonHandler();
  btNavigation.addActionListener(MenuHandler);
  ADD(btReload, 700, 310, 80, 20);
  ReloadButtonHandler ReloadHandler = new ReloadButtonHandler();
  btReload.addActionListener(ReloadHandler);
  ADD(btOFF, 700, 340, 80, 30);
  OFFButtonHandler OFFHandler = new OFFButtonHandler();
  btOFF.addActionListener(OFFHandler);
  container.add(panel);
  panel.setOpaque(false);
  myWindow.setVisible(true);
}
public void ADD(Component c, int x, int y, int l, int b) {
  c.setBounds(x, y, l, b);
```

```
    container.add(c);
}
public class NavigationButtonHandler implements ActionListener {
    public void actionPerformed(ActionEvent e) {
        //code to be executed
        myWindow.setVisible(false);
        new main();
    }
}

public class WarningButtonHandler implements ActionListener {
    public void actionPerformed(ActionEvent e) {
        //code to be executed
        //  myWindow.setVisible(false);
    }
}
public class NoticeButtonHandler implements ActionListener {
    public void actionPerformed(ActionEvent e) {
        //code to be executed
        myWindow.setVisible(false);
        new mySend();
    }
}
public class TrafficButtonHandler implements ActionListener {
    public void actionPerformed(ActionEvent e) {
        //code to be executed
        //   myWindow.setVisible(false);
        // new CashierLogin();
    }
}
public class MenuButtonHandler implements ActionListener {
    public void actionPerformed(ActionEvent e) {
        //code to be executed
        //  myWindow.setVisible(false);
    }
}
public class ReloadButtonHandler implements ActionListener {
    public void actionPerformed(ActionEvent e) {
        //code to be executed  public void actionPerformed(ActionEvent e) {
        //code to be executed
        try {
            Class.forName("com.mysql.jdbc.Driver");
            c = DriverManager.getConnection("jdbc:mysql://localhost/sars", "root", "");
            s = c.createStatement();
```

```
            r = s.executeQuery("select * from accounts ");
            while (r.next()) {
               Object[] row = {r.getString(1), r.getString(2), r.getString(3), r.getString(4), r.getString(5),
r.getString(6)};
               String msg;
               msg = r.getString(6);
               myMsg.setText("\n\n\t" + msg);
         }
            r.close();
            s.close();
            c.close();
         } catch (Exception er) {
            JOptionPane.showMessageDialog(null, "Error : " + er);
            er.printStackTrace();
         }
      }
   }
   public class OFFButtonHandler implements ActionListener {
      public void actionPerformed(ActionEvent e) {
         //code to be executed
         System.exit(0);
      }
   }
   public static void main(String[] args) {
      new myWarnings();
   }
}
```