IMPROVING VEHICULAR TRAFFIC LIGHT CONTROL IN A DEVELOPING COUNTRYUSING ON-ROAD WIRELESS SENSORS NETWORKS (WSN)

BY

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DEPARTMENT OF ELECTRONIC ENGINEERING

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APPROVAL PAGE

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A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF DEGREE OF MASTER OF ENGINEERING (M. ENG.) IN THE DEPARTMENT OF ELECTRONIC ENGINEERING, COMMUNICATION OPTION, UNIVERSITY OF NIGERIA, NSUKKA NIGERIA

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PROF.W. I. OKONKWO (CHAIRMAN, FACULTY POSTGRADUATE COMMITTEE)	SIGNATURE é é é DATE é é

CERTIFICATION PAGE

AdesinaAdewaleBolarinwa, a masterœs degree postgraduate student in the Department of Electronic Engineering and with registration number PG/UD/M.ENG/07/92 has satisfactorily completed the requirements for the award of Master of Engineering (M.ENG) in communication engineering.

PROF. C. I. ANI	DR. M. A. AHANEKU
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DECLARATION

I, ADESINA ADEWALE BOLARINWA, a postgraduate student in the Department of Electronic Engineering, University of Nigeria, Nsukka declare that the work embodied in this thesis is original and has not been submitted by me in part or in full for any other diploma or degree of this or any other university.

______________________________ ____________________

ADESINA ADEWALE BOLARINWA **DATE**

PG/UD/M.ENG/07/92

DEDICATION

This thesis is dedicated to God Almighty, the Creator of life, and Sustainer thereof

ACKNOWLEDGEMENT

First and foremost, I give thanks to God Almighty, my Creator and Sustainer; it is in Him that I live, move and have my being. Without the life He sustains, provision n of all that pertains to life, this research would not have seen the light of the day.

I thank Professor CosmasAni for giving me the opportunity, needed support, encouragement and never ending stream of ideas to pursue this research. His enthusiasms have been of immense benefit to me while under his supervision. I also thank lecturers for sharing from their wealth of knowledge and experience during the course of the programme. The support of administrative staff in the department and at the Digital Bridge Institute (DBI) cannot be quantified.

I acknowledge the contributions of all my previous teachers, lecturers and others in elementary andsecondary schools; universities and other institutions of learning where I have drank from the fountain of knowledge. These invested part of themselves individually in developing my ability to cope with the program and successfully conclude this research. I am immensely grateful for their contributions. In this wise, I recall with gratitude the sponsorship of the Papa ObafemiAwolowo Scholarship Board for my undergraduate studies. I am grateful to Mr.Isah Mohammed Haske, who was my immediate senior at work when the course commenced for his support and encouragement.

Finally, I appreciate my family members and colleagues at various offices I have worked during the period of this program and researchfor their invaluable presence, understanding and differs contributions.

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Abstract

Traffic situation in some cosmopolitan cities in Nigeria, such as Lagos, Port Harcourt and Abuja are becoming chaotic, and resulting in needless waste of man-hour and loss of lives. Traffic lights are installed at most intersections to control traffic by authorising rite of passage to routes in an orderly manner. The order ensures that the rite of passage is often granted equally to all routes in sequence. This arrangement has been seen to introduce delay, and consequently increased travelling time of road users. The delay is attributable to equal insensitivity to the conditions of traffic approaching the intersection. Wireless sensor network (WSN) application in target detection, among others, have been applied to the modern intelligent traffic system. This research seeks to deploy findings in WSN to improve vehicular traffic light control in a developing country using on-road sensors. `A unique feature of the system is the varying time slots allotted to each route subject to traffic conditions of the highway. Time allotted for each of the routes at any time of the day is determined based on the condition of the route at that period. The route with the highest traffic at the beginning of each period determines the time slot to be allotted to it, and the other routes in relation to their comparable volume of traffic. A simulated performance appraisal shows considerable improvement in the waiting period at the intersection, and subsequent reduction in travel time by travellers using the intersection to which the system applies.

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Traffic control relates to the supervision of the movement of people, goods, or vehicles to ensure efficiency and safety[1].Techniques and devicesused to facilitate traffic controlinclude Signs, Signals Markings, Licensing, etc. [2]. Traffic light is one of the popular techniques employed in support of traffic control. It tells road users what to do on approaching an intersection or along a road, i.e. stop or go, and when or how to turn, or move with caution. Its basic design included the tri-coloured Red to mean Stop, Amber (Yellow) to mean Get-Ready, and Green to mean Right of Way. The design remained in use till date. However, the basic design has been improved to incorporate automatic timers, motion sensors, LED, among others. Various technologies have been employed as motion sensors. These include wireless sensors.

Wireless Sensor Networks (WSN), as a technology, has been successfully deployed for use in a variety of applications and environments. It focused originally on designing efficient solutions for transfer of information from sensor nodes to a sensor network gateway.Recently the focus started to shift towards creating sensor network based communities, the Internet of Things, and defining the role and place of sensors and machines in the Future Internet [3]. The successful and promising outcome of such deployments in commercial, medical and industrial applications has led to increase in the interest of new users [4].

The main purpose of sensor networks is to monitor an area, including detecting, identifying, localising and tracking one or more objects of interest [5]. WSN is defined as a group of autonomous sensor nodes, mostly based on low power consumption, that send their sensed data to a main network gateway by using a radio frequency channel of communication [4]. Wireless sensor network (WSN) is a network which implements many autonomous sensors to monitor physical or environmental conditions and passes the collected data to a main location [6]

Traffic road network is increasing day by day in todayûs world [7]. Traffic jam and high number of accidents in urban and metropolitan areas become more and more stressful and lead to dramatic consequences on economy, human health, and environment [6].

Two main concerns regarding traffic on roads are congestion and safety [6]. In order to address these issues, intelligent transsportation systems are being developed and deployed. These systems acquire traffic information across road networks. Traffic Information acquisition Systems (TIS) in most places where available use wired power and communication, and require powerful computing resources to attain high detection accuracy. Such methodologies elevate the cost of construction and maintenance; consequently, the available detection area is narrowed. The high cost may be disincentive to adoption of (TIS), particularly in developing countries. Thus, the promise of low cost, highly scalable detection properties of WSN in applications such as traffic surveillance or monitoring make deployment of the technology in solving traffic problems an attraction.

The research is therefore motivated by desire to improve traffic control using on-road wireless sensors networks.

1.2 PROBLEM STATEMENT

Congestion on major road in urban areas results in traffic jam and high number of accidents. In order to ensure safe society, therefore, the need to resolve challenge of traffic congestion in the most effective and economical way is paramount to the development of the society. Effort at addressing the challenge requires acquisition of traffic condition on the road, and an effective control thereof. It is in search of the solution that this project seeks to consider effectiveness of the use of on-road WSN in traffic control.

1.3 OBJECTIVES OF STUDY

The aim of this thesis is to develop and analyzethe on-roads wireless sensor network prototype for improving traffic control in a given road network under real-time constraints. The following objectives are set to meet the requirements of the thesis:

- Collectionof vehicular movement record or traffic data using on-road wireless sensors network
- Design and development of the system prototype
- Cost effective deployment of on-road WSN

1.4 SIGNIFICANCE OF STUDY

Rising population in developing nations of the world are bound to give rise to increase in human and vehicular movement. This increase results in problems like congestion and possibly collusion with attendant loss of man-hour, lives and other resources. Design and development of road networks are expected to be carried out painstakingly taking into consideration human safety concerns. This study aims at developing and analysing on-road wireless sensor network for improving traffic control in a given road network under real-time constraints is therefore relevant in attaining the objective of design and development of road network.

Secondly, it is noted that various attempts and efforts have been put into solving the problems of road congestion and enhance road safety. However, being an evolving challenge, following dynamism of human society, solution requirecontinuous refinement. The focus of this thesis, which is devoted to improving on the existing solution, meets this requirement. The study, therefore, represents a significant contribution to knowledge.

1.5 SCOPE OF WORK

The project is intended to presentthe use of on-road wireless sensors networks for vehicular traffic control at a two-lane bi-directional intersection in a developing country.

1.6 OUTLINE

The document is structured in such that here in the introduction, WSN is introduced. The motivation for the study, its aims and objectives are clearly stated. The scope of the study is defined while the methodology adopted is enumerated. Then in the second chapter, theoretical backgrounds that are used for the realisation of the work are explained. It discusses related work carried out on the subject matter. Further on, in chapter three the design and implementation of the complete work, with the theoretical consideration in mind, is presented. The chapter describes the hardware and software platforms used for the reference implementation. Chapter four presented an evaluated implementation of the design in real time using a designated road network. And finally, the tests results are presented in chapter fiveto show the performance of the system. The concluding chaptersummarises the thesis, presents conclusion reached and recommendation for future research.

CHAPTER TWO

LITERATURE REVIEW

2.1 TECHNOLOGY BASE

A sensor is a device or transducer that is able to detect a given phenomenonsuch as motion or transform some physical process such as vibration within a specific location or environment into an electrical or optical signal,which can be measured by a digital processor [8]. Transducer converts energy from one domain to another [9]. The usefulness of sensors lies in their ability to communicate such detection or transformation to. Data gathered by sensors are obtained by users in different ways. These include physical change in their appearance, texture, size, taste, etc. The transformation can be transmitted to remote location by means of electrical or optical signals for processing or to initiate an action.

2.1.1 SENSOR NETWORK

A sensor network (SN) is composed of sensor nodes which are small in size, low in cost, and have short communicationrange. In general, someenvironmental conditions are measured by the sensor nodes deployed with a spatial densityand at a sampling rate specified by the application [8].A sensor node usually consists of four components or sub-systems:

a. A processor (microcontroller) or computing subsystem: this is responsible for functions such as execution of the communication protocols andcontrol of sensors,

b. A sensing subsystem: this subsystem is responsible forsensing the environmental characteristics, such as usingtemperature, humidity, or acoustic sensor,

c. A radio or communication subsystem: this consists of a short radio range used to communicate with neighbouringnodes,

d. A power source or power supply subsystem: this includes a battery whichprovides energy to sensor node. [10]

The sensing subsystem comprise of sensor(s) and analogue circuit [11]. Composition of a sensor node is depicted as in Figure 2.1. Figure 2.2 depicts three main types of deployment of sensors in any given facility or area, viz: - (a) triangular sensor deployment (b) square sensor deployment and (c) irregular sensor deployment.

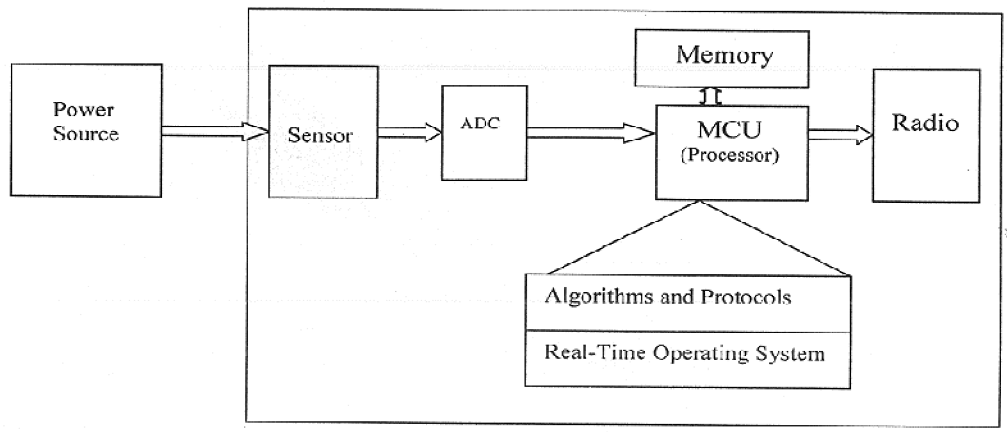


Figure 2.1 System architecture of a wireless sensor node [8]

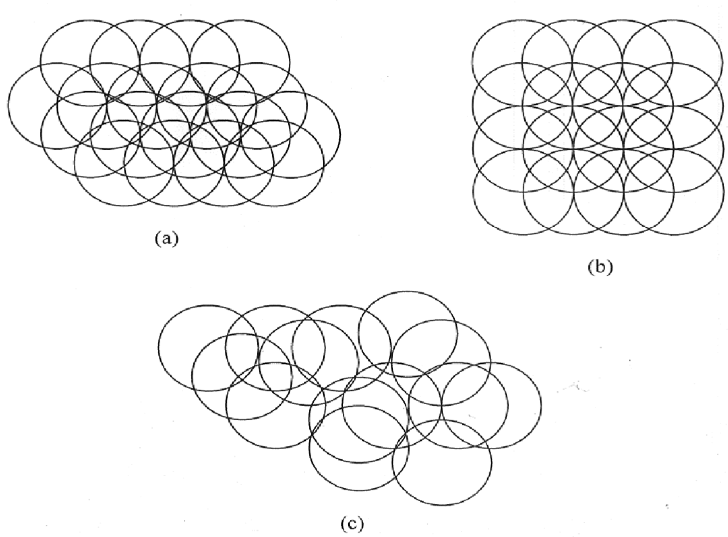


Figure 2.2 Main Types of Sensors Deployment (a) Triangular, (b) Square and (c) Irregular Networks [9]

Energy ratings of possible power sources and drawback in adoption of each presented in [8] reveals the following:

- Zinc-based batteries have high energy density but high leakage, so they are only good for use in short-duration applications
- Lithium batteries offer higher energy density with fewermemory effects[1], but require longer recharge times
- polymer-based batteries have excellent energy density with flexible form factor, but relatively expensive (e.g. $20 / 1500mAh)
- developing battery technology using micro fuel cell, has 10 times larger energy density than the commonly used alkaline battery
- active research aimed at collecting renewable energy from wind or solar panels on-going

2.1.2 TYPES OF SENSORS

Sensors in a sensing subsystem are made from the following sensing technologies [12]:

- Micro-electromechanical systems (MEMS) ï gyroscopes, accelerometers, magnetometers, pressure sensors, pyroelectric effect sensors, acoustic sensors
- CMOS-based sensors ï temperature, humidity, capacitive proximity, chemical composition
- LED sensors ï ambient light sensing, proximity sensing, chemical composition

The sensing subsystem/technologies are further classified as intrusive, non-intrusive and off-roadway technologies [8]. Intrusive technologies refer to those that require installation directly onto the pavements, in saw-cut, holes or tunnelling under the surfaces. Drawbacks include the disruption of traffic for installation and repair, failures induced by poor road conditions, and system reinstallation caused by road repairs or resurfaces. Examples include inductive loop,pneumatic road tube, and piezoelectric cable, among others.

Non-intrusive technologies do not need any installation on or under the pavement.The installation and repair of such a system can be done without disrupting the traffic. Examples include microwave radar, infrared, Video Image Processing (VIP), ultrasonic and passive acoustic array.Off-Roadway Technologies refer to others that do not require any hardware to be setup under the pavement or on the roadside. Example includes probe vehicle technologies with GlobalPositioning System (GPS) and mobile phones; Automatic Vehicle Identification (AVI); andremote sensing technologies that make use of images from aircraft or satellite

2.1.3 DATA TYPE

An extract from data obtained from the different sensors collated and tabulated for purpose of comparison is presented in Table 2.1 [8].

Data Type

Data Type / **Technology**	**Speed**	**Count**	**Classification**	**Occupancy**	**Presence**
Intrusive					
Inductive Loop	Y	Y	Y	Y	Y
pneumatic road tube	Y	Y	Y	N	N
piezoelectric cable	Y	Y	Y	N	N
Non-Intrusive					
WIM system	Y	Y	Y	N	N
Microwave Radar					
CW Doppler	Y	Y	Y	Y	N
FMCW	Y	Y	Y	Y	Y
Infrared					
Active	Y	Y	Y	N	N
Passive	Y	Y	Y	Y	Y
Video Image Processing	Y	Y	Y	Y	Y
Ultrasonic	Y	N	N	N	Y
Passive Acoustic	Y	Y	Y	Y	Y

Y: available, N: not available

Table 2.1 Data type available with different Sensor Technology [3]

2.1.4 NETWORK TOPOLOGY

In terms of connectivity of between the sensing subsystem and the gateway, WSN nodes are typically organised in one of three network topologies, viz:- star, cluster or mesh topologies [11]. In a star topology, data is routed from each node directly to the connected gateway. Communication between nodes in a cluster topology is between a lower node to node high up in a hierarchical nodes arrangement or cluster tree and then tothe gateway.Mesh topology offers increased reliability, by the possibility of one node to pass data through multiple other nodes in the system and thus able to pass data throughthe most reliable path available.Figure 2.3 depicts three common WSN network topologies.Communication between the nodes can be one way direction or bi-directional. Bi-directional, star and mesh technologies evolve after the initial one way direction networking protocol [12]

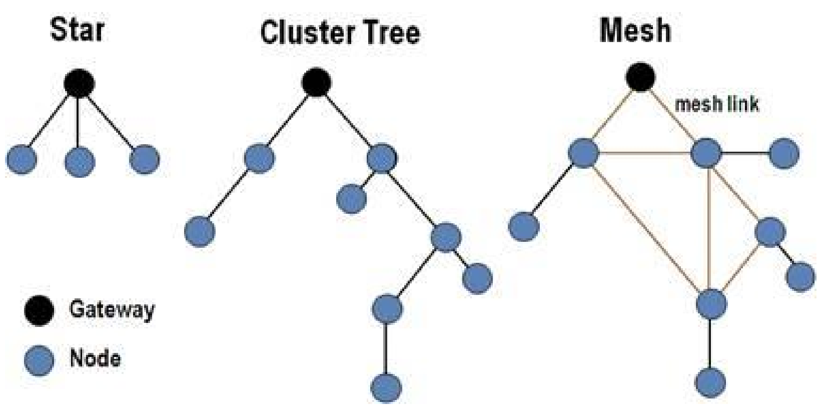


Figure 2.3 Common sensor nodes Network Topologies [10]

A Wireless Sensor Network (WSN) is a network of small sensor nodes communicating among themselves using wireless communication, to sense the physical world which combines distributed sensing, computation and wireless communication technologies [8]. It is described as a network which implements many autonomoussensors to monitor physical or environmental conditions and passes the collection data to a main location. The bi-directional nature of WSN enables control of sensor activities [13].WSN system incorporates gateway that provides wireless connectivity back to the wired world and distributed nodes [11].The first wireless network that bore any real resemblance to a modern WSN is the Sound Surveillance System (SOSUS)developed by the United States Military, which used submerged acoustic sensors ï hydrophones ï distributed in the Atlantic and Pacific oceans 1950s to detect and track Soviet submarines [12].

2.2 RELATED RESEARCHES

Literatures abound on research works previously carried out on traffic control ï vehicular, air, and pedestrian;evolutionand application of wireless sensors networks in various human endeavours, such as Target or Real-Time Object Tracking, vehicle detection, Space Environment,traffic control [4, 5, 6, 7, 8,9, 10, 12, 14, 15,16]. Also, refinement of technologies employed in wireless sensors network, such as Routing in Wireless Sensor Networks, secured integration into applications,power, and connectivity, sensing subsystems and processors or microcontrollers have been carried out [17, 18].

The literatures are primarily concerned with vehicle detection, traffic control using WSN, among others issues that form the focus of this study. For example, aWSN based vehicle detection system using small magnetic sensors to replace conventional inductive loop detectors was developed [6]. The system provides an avenue to collect traffic flow and speed information with high accuracy. It also presented analyses of acoustic and magnetic sensor signals that can potentially be used in sensor nodes. The first generation of sensor node prototype designed in the project named, ôTrafficDotö comprised of two magnetic sensors (HMC1051Z), a microcontroller with integrated radio (MICA2DOT), a battery (TL-5135) and a protective cover (SmartStud) made by high impact polycarbonate designed to be placed on pavement.

The system proved to be an excellent technique of intelligent traffic monitoring. However, to get an excellent linearity, a two or three dimensional measurement of the magnetic field passing through sensors is required. This would demand AMR sensors to be configured into two or three axis, which increased complexity and cost of the system.

In order to minimise power consumption and lower computational complexity, [15] modelled and analysed optimal power saving methodologies using ultrasonic data. This is in contrast to auto-resistive magnetic sensors and WSN for traffic monitoringused to monitor road network in [6]. Characteristics of ultrasonic waves and sensors were analysed. Power consumption of an ultrasonic sensor was discussed to provide detailed power-saving strategies.The detection algorithm developed took cognisance the importance of determining the detection interval for power saving in WSN-based traffic information acquisition systems that use ultrasonic sensors. It was described as novel ñwith low computational complexity and memory usage, while still providing an appropriate level ofperformanceò. However,the study demonstratedthat placing ultrasonic sensors on a bend or curved roads resulted in loss of detection. In effect, reliable vehicle detection is achieved with ultrasonic sensors placed on straight sections of the road.

2.3 RELEVANCE OF RELATED RESEARCHES

The studies on WSN-based applications on traffic information acquisition presented above are aimed at achieving objectives such as traffic monitoring, surveillance, safety, among others. The objectives form part of the requirements for or outcome of effective traffic control. A major disadvantage to the use of ultrasonic sensors for vehicle detection with minimal ultrasonic bursts, reasonably long detection interval (an overly long interval increases detection errors) is in the fact that detection error occurs if the detection interval goes below certain level as a result of new ultrasonic wave being emitted before the previous one has been received [14]. In addition, owing to the slow sampling rate of ultrasonic sensors, compared with magnetic and acoustic sensors, the detectable vehicle speed is lowerusing ultrasonic sensors, especially on a multi-lane road.

However, majority of the roads in developing countries are one or two lane roads, for which the vehicle detection algorithm developed may apply with reasonable level of accuracy, lower computing power and battery consumption with embedded memory reduction mechanisms [15].

2.4 CONCLUSION

It is obvious from the foregoing that traffic control in developing countries can be improved upon or enhanced with the use of wireless sensor networks in acquisition of traffic information and determination of which route approaching an intersection is granted right of way from time to time. The use of such system has potential to reduce traffic congestion, accidents and enhance safety on our roads.

CHAPTER THREE

IMPROVED VEHICULAR TRAFFIC CONTROL SYSTEM DESIGN

3.0 INTRODUCTION

Traffic situation in some cosmopolitan cities in Nigeria, such as Lagos, Port Harcourt and Abuja are becoming chaotic and resulting in needless wastage of man-hour and loss of innocent lives. The situation has further become worrisome in terms of economic loss to individuals and country at large. Government response to dealing with the situation included installation of traffic light at major intersections, provision of mass transport system, regulation of vehicular movement in certain areas and certain days, among others.

The use of traffic light to control vehicular movement aims at avoiding vehicular collision, orderly passage of vehiclesarriving the intersection from different routes. But it should also address concern of road users in terms of minimising travelling time by eliminating unnecessary delay. It relies on assignment of time slots to traffic approaching a given junction or intersection in sequence based on pre-programmed time allotment designed to allocate right of way to vehicles or pedestrians arriving the intersection from a particular route.An improvement desired is to alter the sequence and time allotment based on flow of traffic from different route. The system design takes cognizance of vehicle counts and speeds from different route, and allot right of way to vehicles arriving the intersection based on an adaptive algorithm.

3.1 DESIGN SPECIFICATION

Given the objectives of this design, which aim at improving vehicular traffic control in a developing country using on-road WSN, the design took into consideration the need to avoid vehicular collision or traffic jam, ensure safety of road users, eliminate or minimise delay at intersections or road junctions.

This is achieved by utilising the enormous potential of WSN to detect, count, compare or analyse the number of vehicles and the speed at which they are arriving a road junction from different routes to determine the right of way granted at the junction. In order to reduce travelling times, the algorithm for granting right of way must take cognisance of traffic conditions in adjoining intersections.

The requirements to be satisfied by the system proposed in this study include the following:

(a) an intersection of roads carrying traffic to and from four routes as depicted in Figure 3.1

(b) each of the routes has two lanes

(c) the routes are separated and protected such that traffic from one route cannot cross to the other route, whereas vehicles on a given route are free to change lane at any time.

(d) Right of way given to traffic from any route apply to vehicles on both lanes of the given route

(e) The right of way is such as to avoid vehicular collision or traffic jam, i.e. no two routes are given right of way in a manner that could lead to collision

(f) The right of way is given in a manner that reduces waiting time by vehicles approaching the intersection

(g) No route will be given right of way when no vehicle is approaching the intersection from that route, unless no vehicle approaches the intersection from any other route.

(h) The system will comply with the existing traffic indicators of Red to Halt traffic, Green to Move and Yellow to Get Set to either Move or Halt, and others such as Full Circle, Arrow Right, Arrow Left, Arrow Northward, etc

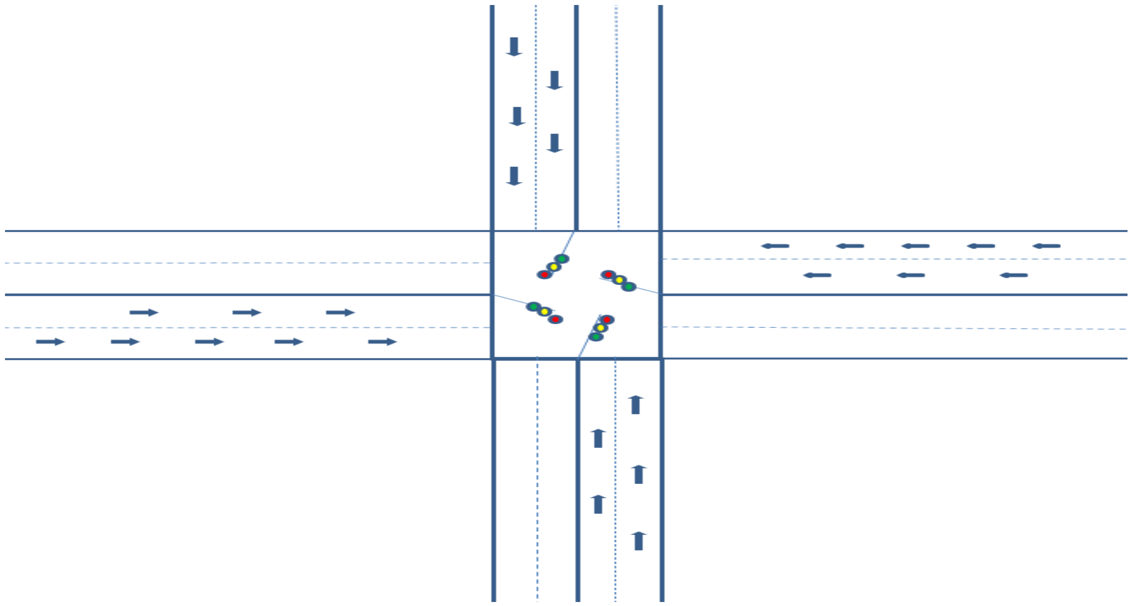


Figure 3.1 Typical Road Intersection with arrows showing direction of vehicular movement towards the intersection

3.2 DESIGN METHODOLOGY

In order to satisfy the afore-mentioned requirements, the proposed systems need to incorporate sensors for detecting vehicles along the routes simultaneously, power source for the sensors and other power consuming elements in the system, software for counting vehicles and computing speed at which they are approaching the intersection, a central server to integrate data from the different routes and adjacent intersections, appropriate communication system for conveying data to the central server from which users can obtain information to assist in deciding routes to ply based on traffic conditions at adjacent intersections. These are to be integrated into the existing traffic control display at the affected intersections.Whereas choices of materials to perform the various functions enumerated above are diverse, the decisions on which materials are chosen are influenced by the properties of various materials reviewed in chapter two of the thesis. Selected materials (hardware and software) for the proposed system are presented below.

3.2.1 WSN NODES

Ultrasonic sensors comprising of transmitters and receivers are chosen for the proposed system. The transmitter and receivers are to be placed alternately at equi-distance on both sides of all the roads leading to the intersection. Figure 3.2 depicts the position of the sensors on the road leading to chosen intersection. The starting and ending point of the sensors are to be chosen depending on approximate traffic density on the roads. The average traffic density may be pre-determined or computed after initial installation. Where the traffic density has not been determined, the starting sensor may be placed at an approximate 5 meters distance to the intersection, while others are positioned further away from the intersection. The number of sensors to be placed on each side of the road will also vary depending on traffic density. The number should be inversely related. The echoes from sound waves generated by the transmitters on passing vehicles are picked by the receivers. The signals is transmitted

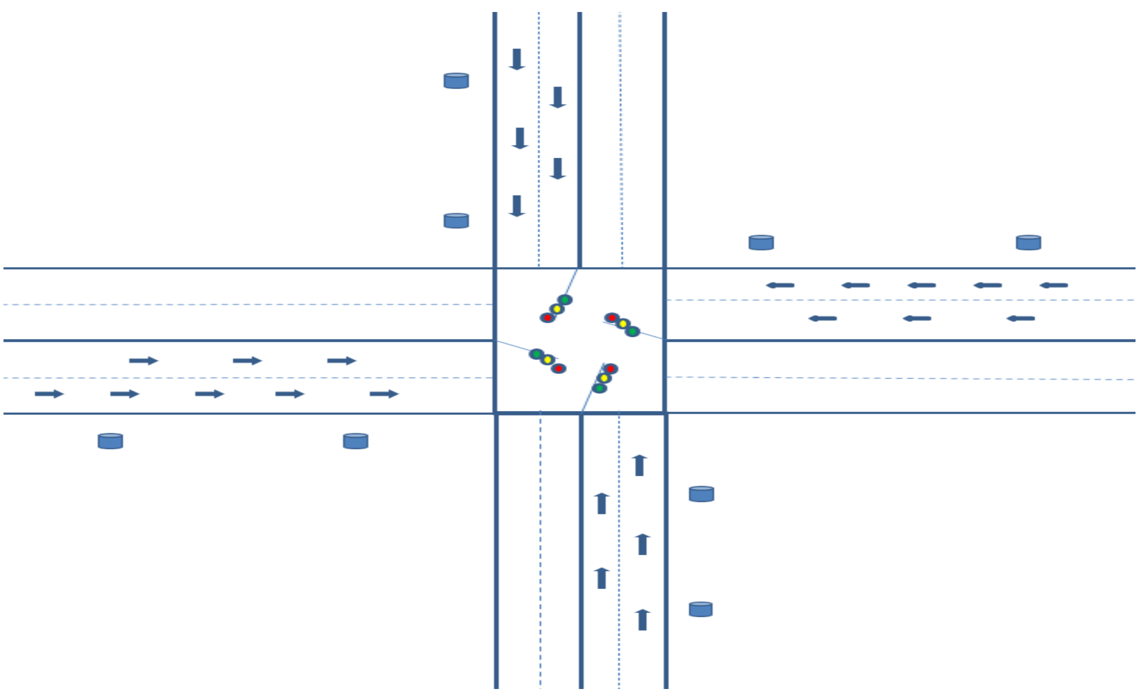


Figure 3.2 Road Intersection with Sensors placed along the routes

3.2.2 TOPOLOGY

A star topology is adopted for the design. Each sensing node is to communicate directly with the microcontroller. This is to improve reliability of the system, and avoid data loss that may arise from failure of one or more sensors in the event that a bus topology is adopted.

3.2.3 POWER SUPPLY

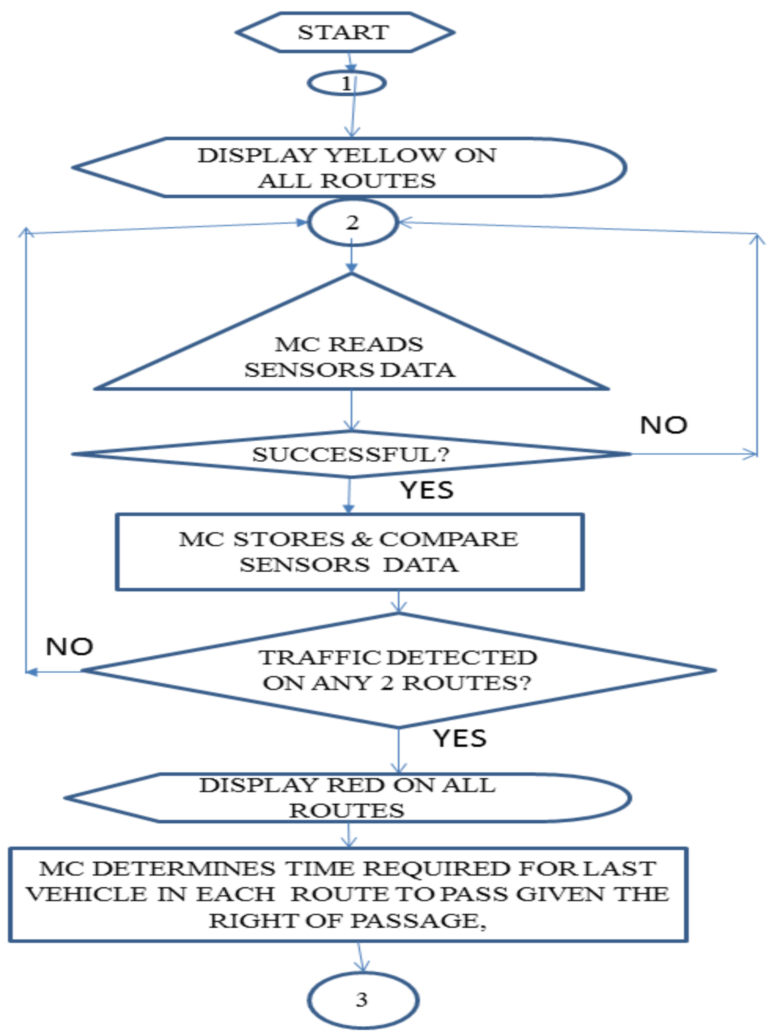
The Power supply for the sensing subsystem is to be provided by encased lithium batteries and solar charger due to higher energy density and fewer memory effect of the former. It is noted that lithium batteries require longer recharge times, but this can be accommodated due prevalent of solar energy, especially in the tropics with most countries being under-developed or developing.

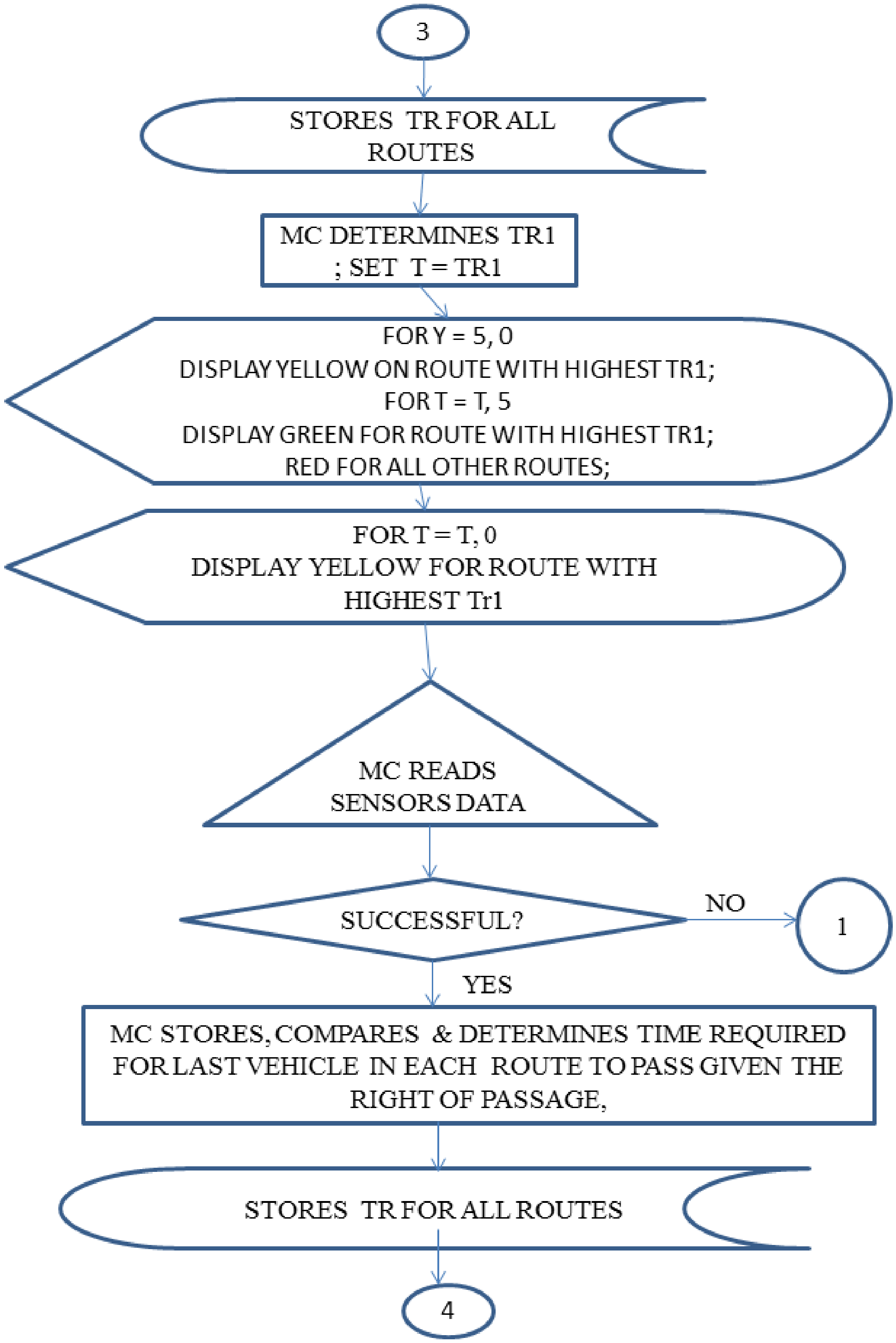
3.2.4 SOFTWARE

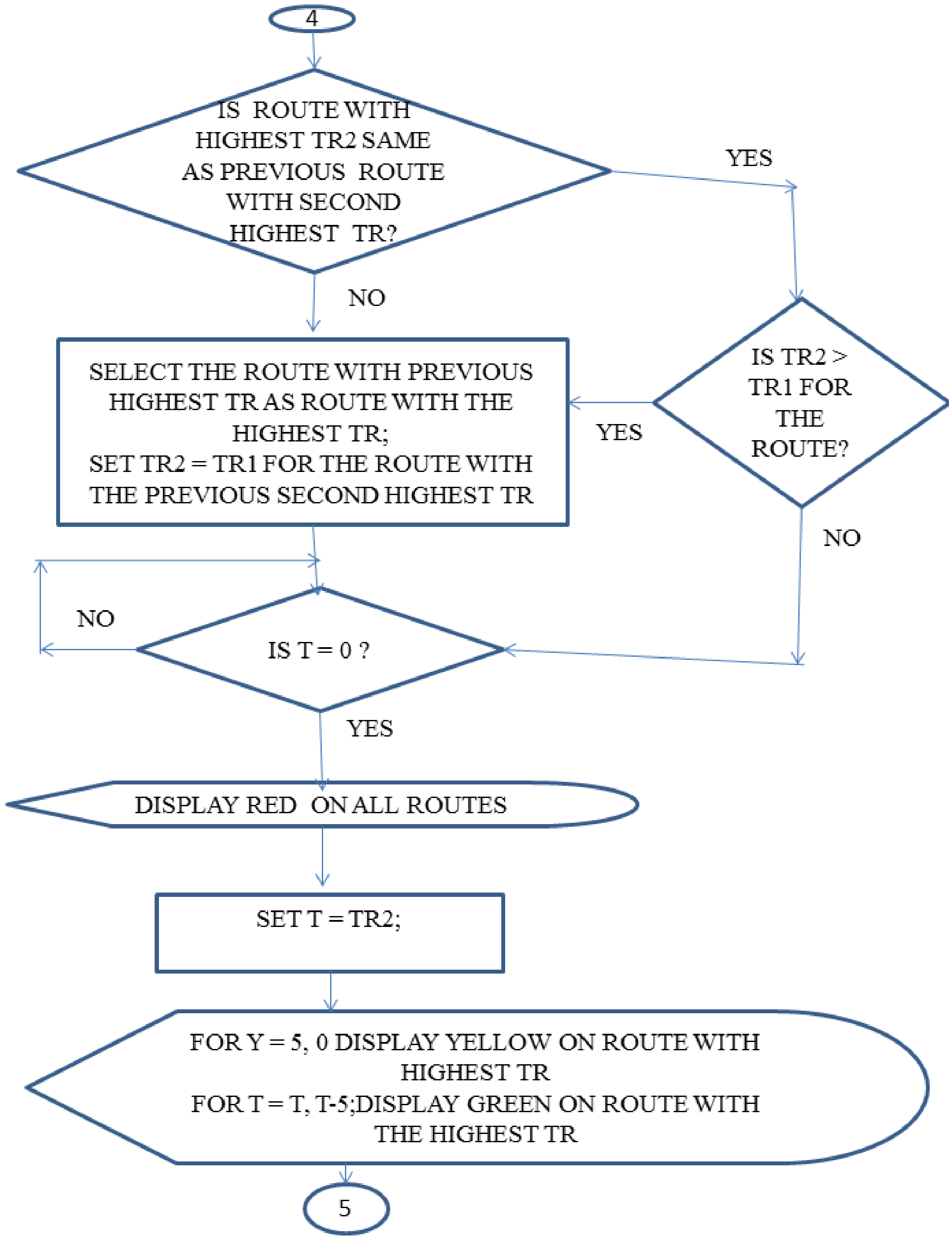
TinyOS, an open source operating system designed for low-power wireless devices such as embedded sensor networks, is employed to programme the sensing nodes, which themselves run MoteWorks. The tasks carried out at the nodes, which represents the states can be grouped into idle or sleep, and collecting/measuring. The nodes are in idle/sleep mode when no vehicles pass, but change state upon detection of ultrasonic wave signifying detection of vehicular movement. The new state, collection, reverts back to idle/sleep state, until another signal is detected. The signal is sent to server as soon as detection is made.

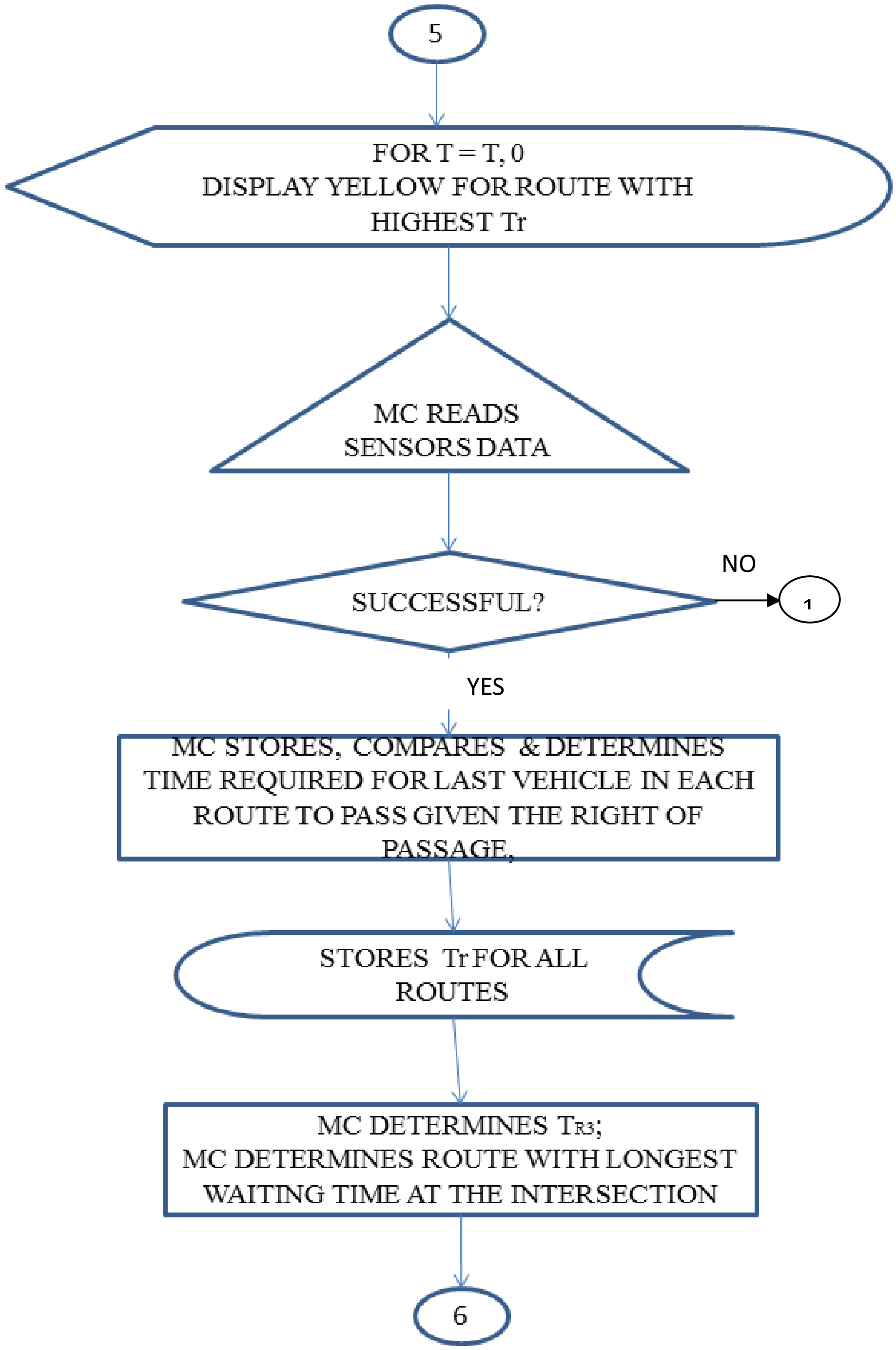
3.2.5 MICROCONTROLLER

The system is designed to incorporate an 8-bit microcontroller (MC), which activates all sensors for 5 seconds, to signal the commencement of the initial period. The activation action is initiated by the application of power to the microcontroller. The MC reads, stores and compares data received from individual sensors placed on all roads leading to the intersection. Where no traffic is sensed on all the routes, the system signals YELLOW on all routes. It continues to read the sensors until traffic is detected on at least two of the routes. Based on the volume of traffic recorded and in comparison with values from other routes, MC determines initial time slot, t_{i1}seconds, to be allotted, and then signals YELLOW followed by GREEN LEDs on the route with the highest volume of traffic.Figure 3.3 is a flow chart depicting the control process.

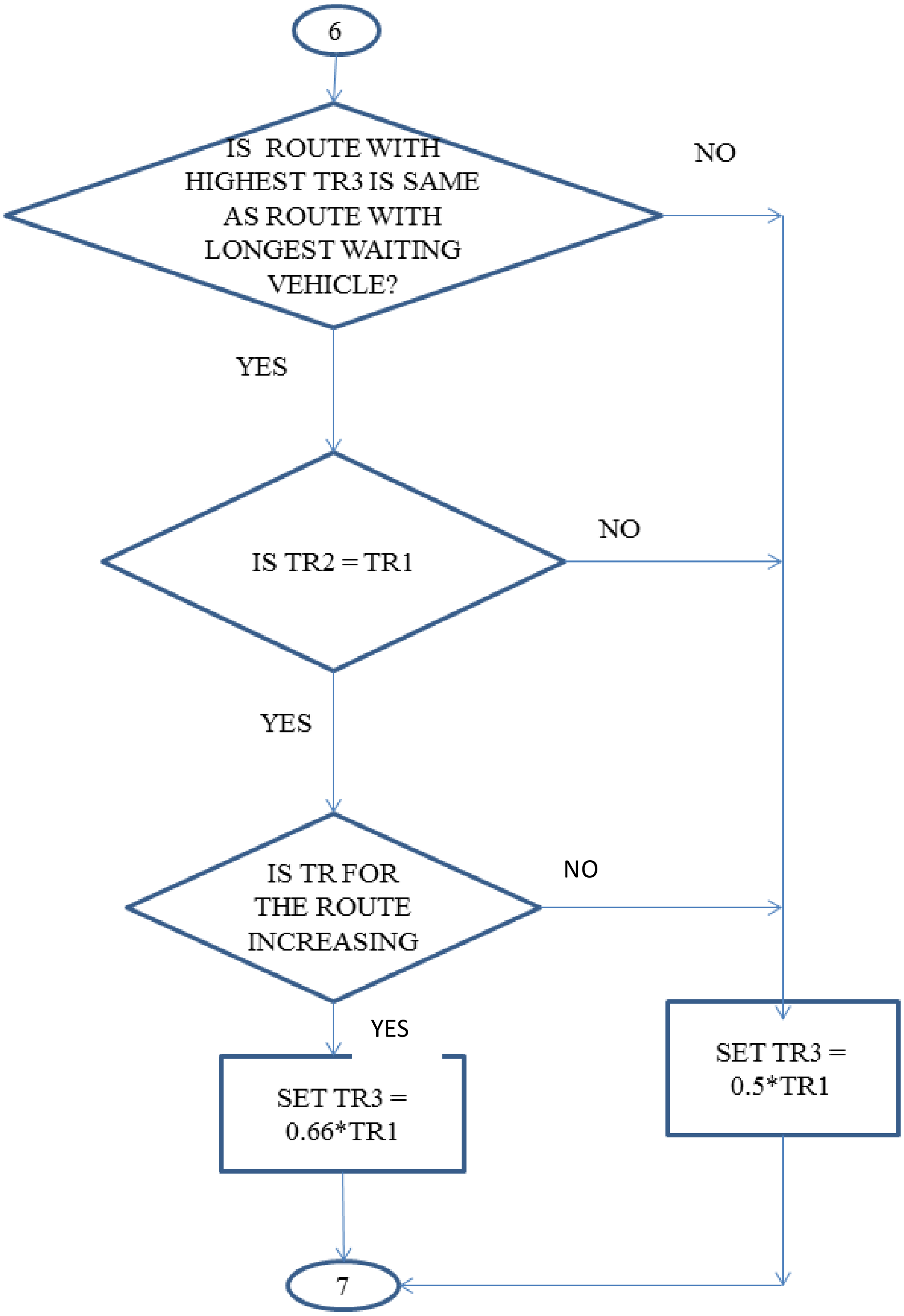


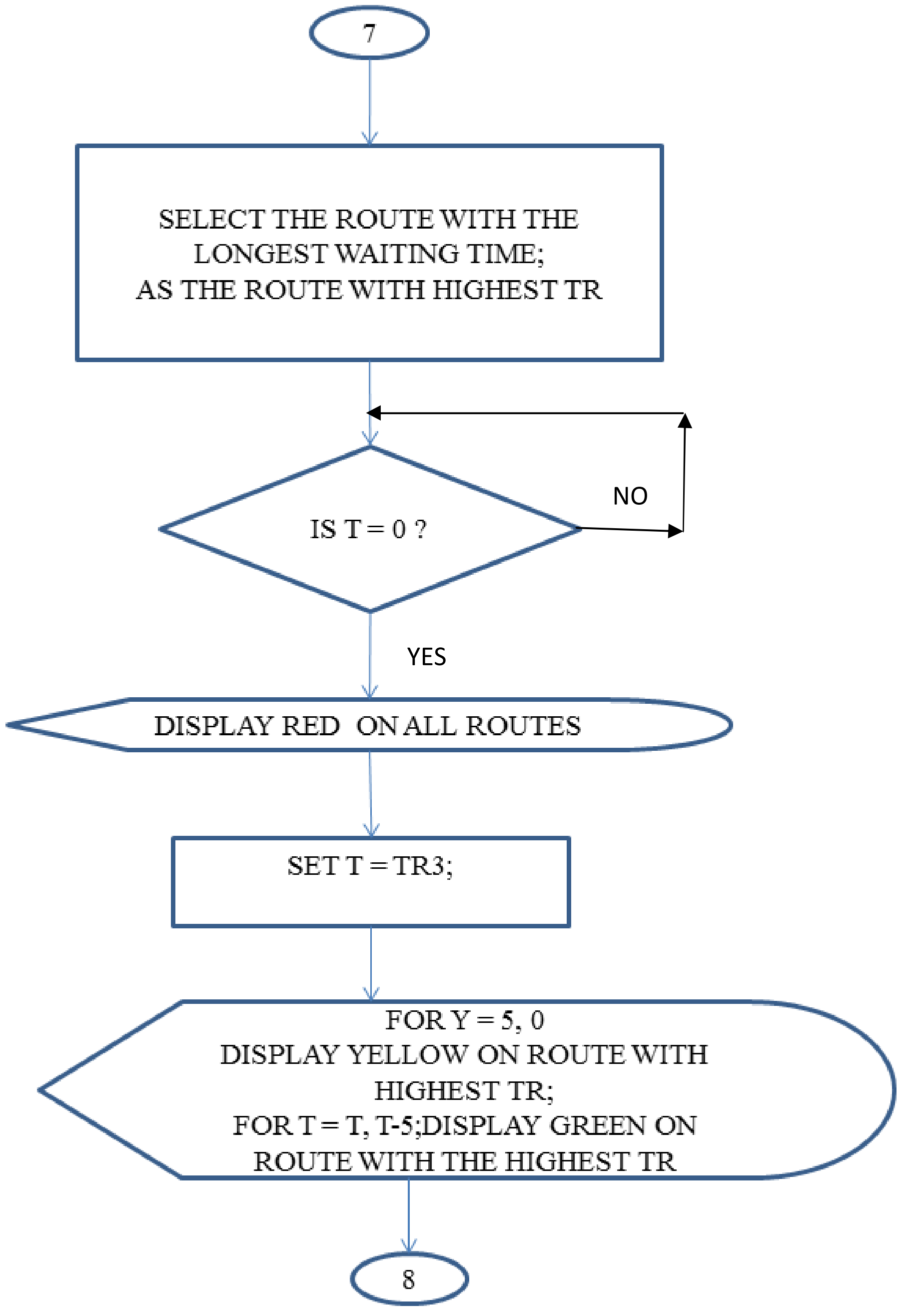

3
STORES TR FOR ALL ROUTES
MC DETERMINES TR1 ; SET T = TR1
FOR Y = 5, 0
DISPLAY YELLOW ON ROUTE WITH HIGHEST TR1;
FOR T = T, 5
DISPLAY GREEN FOR ROUTE WITH HIGHEST TR1;
RED FOR ALL OTHER ROUTES;
FOR T = T, 0
DISPLAY YELLOW FOR ROUTE WITH HIGHEST Tr1
MC READS SENSORS DATA
SUCCESSFUL?
NO
1
YES
MC STORES, COMPARES & DETERMINES TIME REQUIRED FOR LAST VEHICLE IN EACH ROUTE TO PASS GIVEN THE RIGHT OF PASSAGE,
STORES TR FOR ALL ROUTES
4

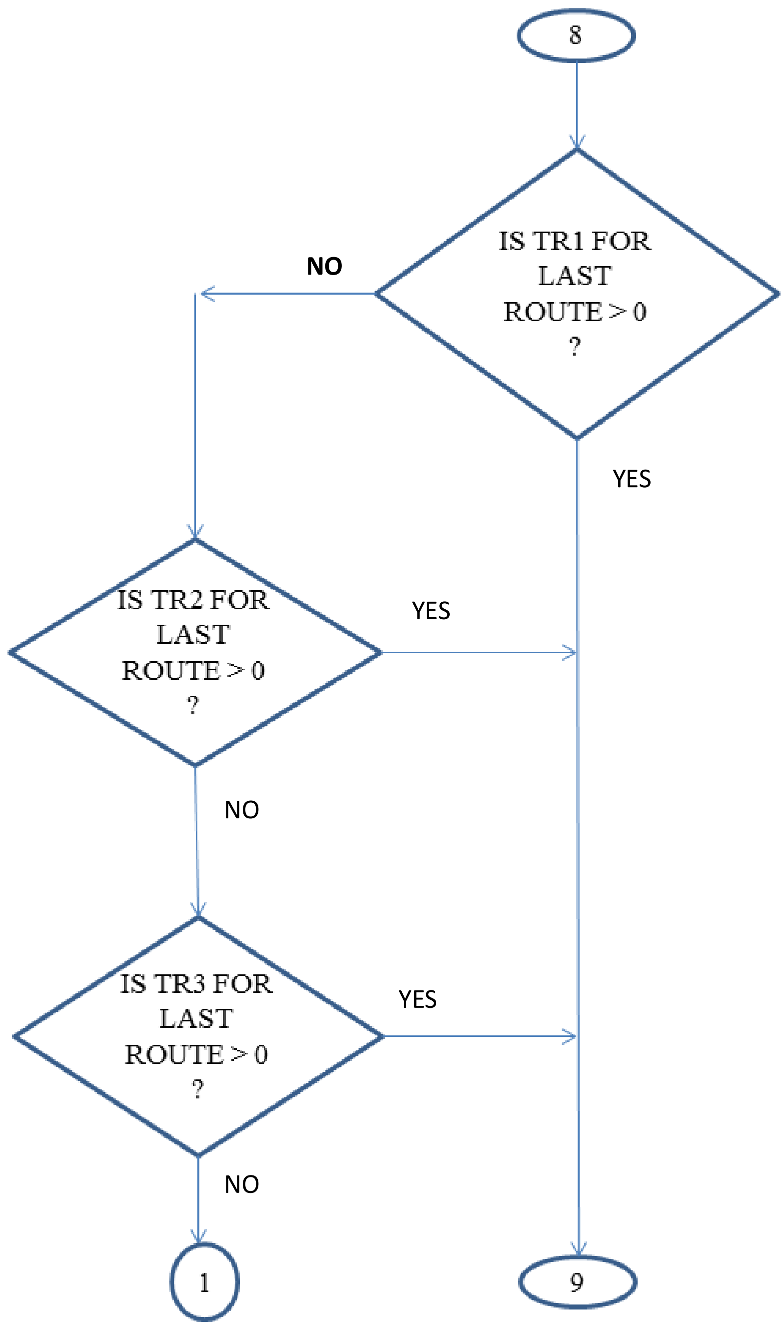

4
IS ROUTE WITH HIGHEST TR2 SAME AS PREVIOUS ROUTE WITH SECOND HIGHEST TR?
YES
NO
SELECT THE ROUTE WITH PREVIOUS HIGHEST TR AS ROUTE WITH THE HIGHEST TR;
SET TR2 = TR1 FOR THE ROUTE WITH THE PREVIOUS SECOND HIGHEST TR
YES
IS TR2 > TR1 FOR THE ROUTE?
NO
NO
IS T = 0 ?
YES
DISPLAY RED ON ALL ROUTES
SET T = TR2;
FOR Y = 5, 0 DISPLAY YELLOW ON ROUTE WITH HIGHEST TR
FOR T = T, T-5;DISPLAY GREEN ON ROUTE WITH THE HIGHEST TR
5

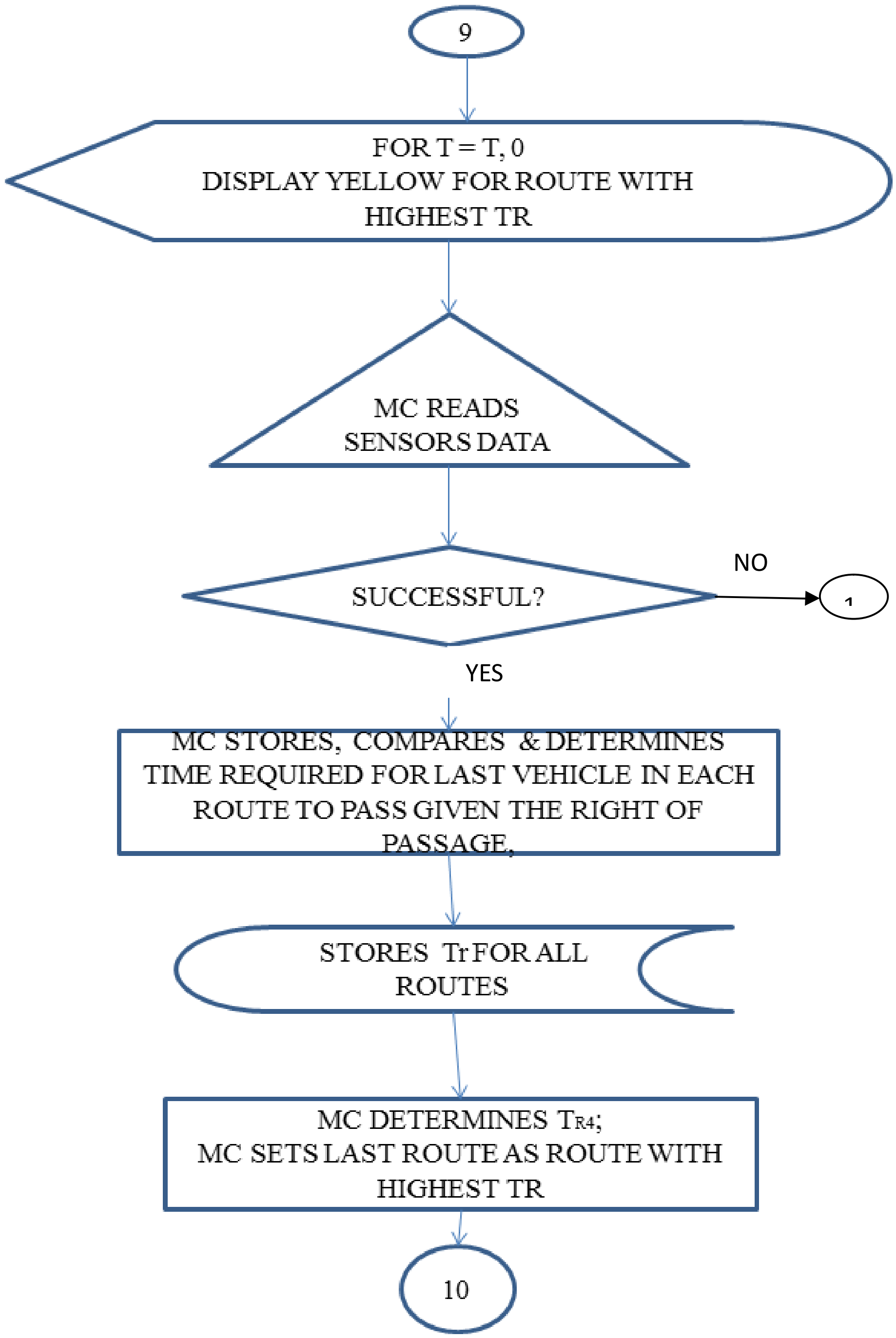

5
FOR T = T, 0
DISPLAY YELLOW FOR ROUTE WITH
HIGHEST Tr
MC READS
SENSORS DATA
SUCCESSFUL?
NO
1
YES
MC STORES, COMPARES & DETERMINES
TIME REQUIRED FOR LAST VEHICLE IN EACH
ROUTE TO PASS GIVEN THE RIGHT OF
PASSAGE,
STORES Tr FOR ALL
ROUTES
MC DETERMINES TR3;
MC DETERMINES ROUTE WITH LONGEST
WAITING TIME AT THE INTERSECTION
6

NO


6
IS ROUTE WITH HIGHEST TR3 IS SAME AS ROUTE WITH LONGEST WAITING VEHICLE?
NO
YES
IS TR2 = TR1
NO
YES
IS TR FOR THE ROUTE INCREASING
NO
YES
SET TR3 = 0.66*TR1
SET TR3 = 0.5*TR1
7


7
SELECT THE ROUTE WITH THE LONGEST WAITING TIME; AS THE ROUTE WITH HIGHEST TR
IS T = 0 ?
NO
YES
DISPLAY RED ON ALL ROUTES
SET T = TR3;
FOR Y = 5, 0
DISPLAY YELLOW ON ROUTE WITH HIGHEST TR;
FOR T = T, T-5;DISPLAY GREEN ON ROUTE WITH THE HIGHEST TR
8


8
IS TR1 FOR LAST ROUTE > 0 ?
NO
YES
IS TR2 FOR LAST ROUTE > 0 ?
YES
NO
IS TR3 FOR LAST ROUTE > 0 ?
YES
NO
1
9


9
FOR T = T, 0
DISPLAY YELLOW FOR ROUTE WITH
HIGHEST TR
MC READS
SENSORS DATA
SUCCESSFUL?
NO
1
YES
MC STORES, COMPARES & DETERMINES
TIME REQUIRED FOR LAST VEHICLE IN EACH
ROUTE TO PASS GIVEN THE RIGHT OF
PASSAGE,
STORES Tr FOR ALL
ROUTES
MC DETERMINES TR4;
MC SETS LAST ROUTE AS ROUTE WITH
HIGHEST TR
10

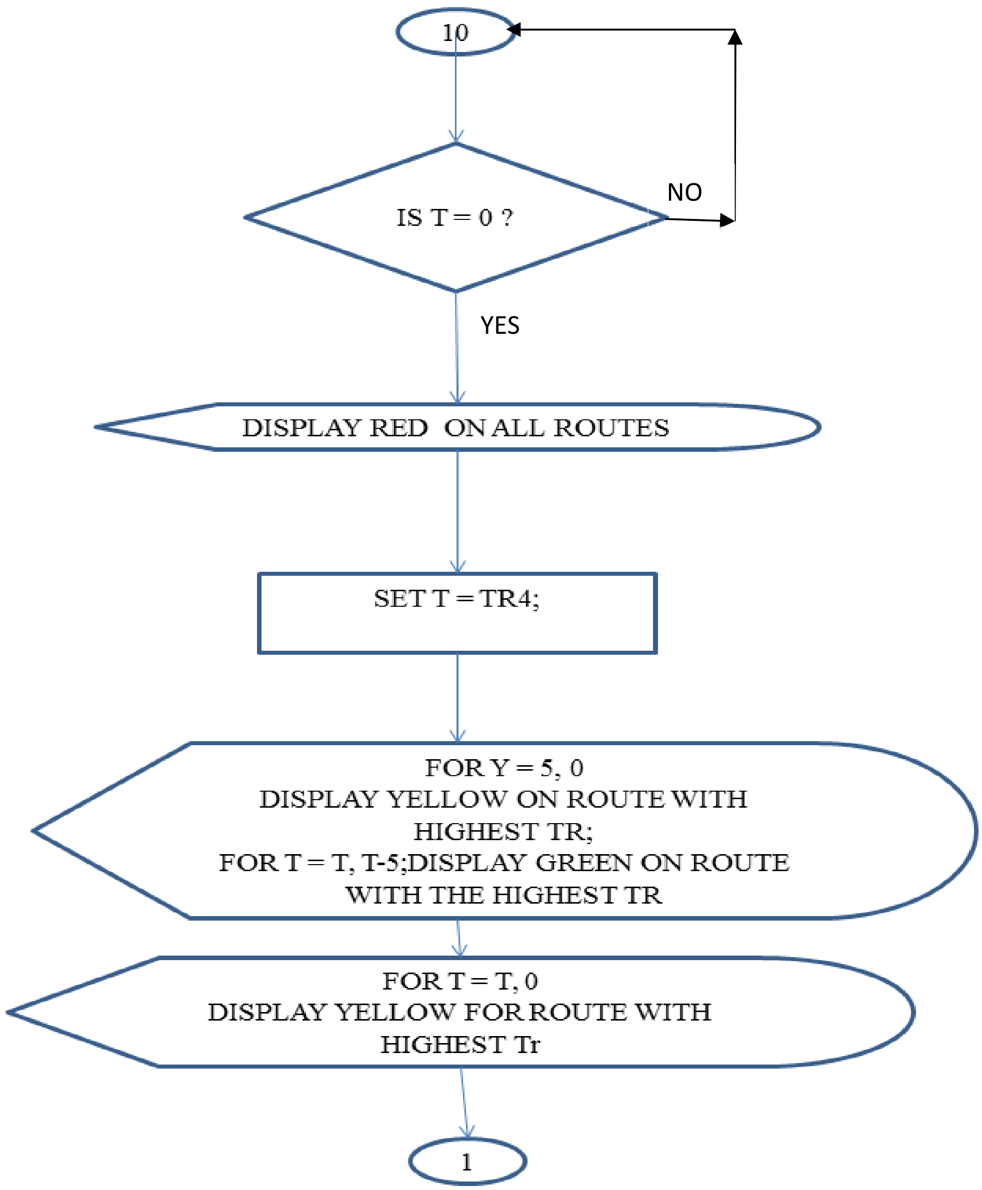


Figure 3.3 Control Process Flow Chart

The initial time slot is computed as the average time slot required for the last vehicle in each route to pass, as depicted in equation 3.1

$$\text{Initial Time Slot, } t_{ri} = (t_{r1A} + t_{r1B} + t_{r1C} + t_{r1D})/n_{ri} \quad . \quad . \quad . \quad 3.1$$

Wheret_{r1A} refers to Time required forthe last vehicle in Route A to pass

t_{r1B} ññ ñ ññ ñ ñ ñ ñ Route B ñ ñ

t_{r1C} ññ ñ ñ ñ ñ ñ ñ ñ Route C ñ ñ

t_{r1D} ññ ñ ñ ñ ñ ñ ñ ñ Route D ñ ñ,

iand n_{ri}refer to sequence number and number of routes with vehicles

The time required for the last vehicle in any route X to pass, t_{riX} is computed as the sum of time required for the first vehicle to cross the intersection, and product of sensor reading and average speed as shown in Equation 3.2

$$t_{riX} = t_c + \text{sensor reading} * \text{average speed} \quad . \quad . \quad . \quad 3.2$$

Where t_c refers to time for the first vehicle to traverse the intersection,

MC counts t_{r1} down until 5 seconds before 0, then activates,reads and stores sensor values on the roads. Time for the last vehicle on each route to pass is computed and stored as t_{r2A}, t_{r2B}, t_{r2C} and t_{r2D} for Routes A, B, C and D respectively. Eliminating Route previously passed, MC allots t_{r2} =t_{r1}seconds to the route with the highest value, provided that the route with the highest value remains the same as the route with the second highest value at the previous reading, otherwise, t_{r2} is computed as in equation 3.1, where t_{r2} replaces t_{r1}, and the route with the new highest route, apart from previously passed route is signalledYELLOW followed by GREEN when the count reaches 0.Similarly, MC counts down t_{r2} until 5 seconds before the counter reaches 0, activates, reads and stores sensor values. Time required for last vehicle on each route is computed as before. The MC determines the route with the longest waiting time at the intersection. This is done by comparing T_{ri} for the remainder of the two routes. The route with the higher T_{ri} route is selected next. Where T_{r1} for both routes are zeros, the route with the higher T_{r2} is selected. Eliminating the previous routes granted rite of way, the route with the highest value is compared with the previous values.

If the sensor readings signify increasing values and $t_{i2}=t_{i1}$, then MC set $t_{i3}=0.66*t_{i1}$, otherwise $t_{i3}=0.66*t_{i2}$. However, if the sensor readings remain constant, the MC set $t_{i3}=0.5*t_{i1}$. . With time t_{i3} set, the MC signifies YELLOW followed by GREEN LEDs to the selected route once the countdown counter reaches 0. When the countdown counter reaches 5 seconds, the MC set $t_{i4} = 0.5*t_{i1}$ for $t_{i1}=t_{i2}$, otherwise $t_{i4}=0.5*t_{i2}$. The process is repeated for $t_{(i+1)1}$, $t_{(i+1)2}$, $t_{(i+1)3}$ and $t_{(i+1)4}$, and the circles continues forever.

3.2.6 COMMUNICATION TECHNOLOGY

Communication between the sensors and the microcontroller is wireless. The system utilises the 2.45GHz frequencies.

3.2.7 TRAFFIC LIGHT DISPLAY

Existing traffic light display is maintained except that the sequencing of right of way granted to vehicles approaching the intersection is altered to reflect output of the microcontroller feeding on the ultrasonic sensors placed along the routes.

3.3 THE PROTOTYPE

The proposed system comprises of sensors, radio transmitters and receivers, traffic light panels, power supply units, microcontrollers, and server computer. They are composed of discrete items distributed over a geographical location. The specific materials used in each item are enumerated below:

3.3.1 SENSOR NODES

For the purpose of this study, MCS410, based on the Atmel ATmega128L ï low-power microcontroller, shown in Figure 3.3. It runs MoteWorks from its internal memory[1].

Figure 3.4 Picture of MCS410MICAz Sensor Node [19]

3.3.2 TRANSMITTERS AND RECEIVERS

The MICAz mote used for the system incorporate the CC2420 radio chip. Its signal transmission is based on IEEE 802.15.4 compliant RF transceiver. It is operated within the 2.4 to 2.48 GHz ISM band. Transmit (Tx) data rate is 250 kbps. RF power lies between -24dBm to 0 dBm.

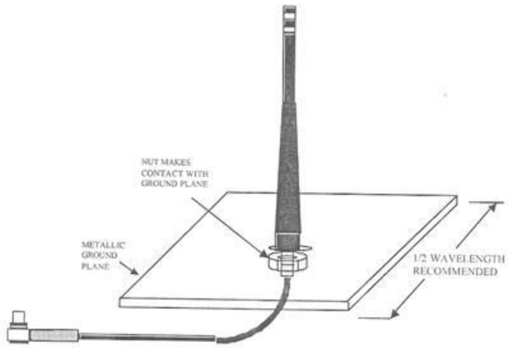


Figure 3.5 Illustration of an antenna option [20]

3.3.3 TRAFFIC LIGHT PANEL

An existing traffic light panel can be incorporated into the system. However, for the prototype, a TRF108-OER-012V panelcharacterised with very low power consumption (3W).Figure 3.5 depicts the traffic light display used for the prototype. The lamps can be retrofitted into existing traffic light housing.


Figure 3.6 Traffic light display panel[21]

3.3.4 POWER SUPPLY

The nodes by lithium batteries supplying 0V to 5V DC, while the traffic light LED receive power from 0V to 9V provided by Ni-Cd batteries charged by solar energy.

3.3.5 MICROCONTROLLER

Atmelôs manufactured 8 bit microcontroller (AT89C51-12PA) was selected for the system, although other comparable microcontrollers may be used. It is a low-power, high performance CMOS microcontroller with 4 Kbytes of Flash Programmable and Erasable Read Only Memory (PEROM). Figure 3.6 depicts its Pin configuration, while Figure 3.7 shows its block diagram.

Pin	Name	Description	Pin	Name	Description
1	GND	Ground	27†	UART_RXDO	Uart Receive
2	VSNR	Voltage (battery	28†	UART_TXDO	Uart Transmit
3	INT3	GPIO	29	PWO	GPIO/PWM
4	INT2	GPIO	30	PW1	GPIO/PWM
5	INT1	GPIO	31	PW2	GPIO/PWM
6	INT0	GPIO	32	PW3	GPIO/PWM
7†	BAT_MON	Battery Voltage Monitor	33	PW4	GPIO/PWM
8†	LED3	Green LED	34	PW5	GPIO/PWM
9†	LED2	Yellow LED	35	PW6	GPIO/PWM
10†	LED1	Red LED	36†	ADC7	GPIO/ADC CH7, JTAG
11	RD	GPIO	37†	ADC6	GPIO/ADC CH6, JTAG
12	WR	GPIO	38†	ADC5	GPIO/ACD CH5, JTAG
13	ALE	GPIO	39†	ADC4	GPIO/ADC CH4, JTAG
14	PW7	GPIO	40	ADC3	GPIO/ADC CH3
15	USART_CLK	Usart Clock	41	ADC2	GPIO/ADC CH2
16††	PROG_MOSI	Programmer Pin	42	ADC1	GPIO/ADC CH1
17††	PROG_MISO	Programmer Pin	43	ADC0	GPIO/ADC CH0
18††	SPI_CLK	Radio Clock	44	THERM_PWR	GPIO
19	USART1_RXD	Usart1 Receive	45	THRU1	Thru User Connect
20	USART1_TXD	Usart1 Transmit	46	THRU2	Thru User Connect
21	I2C_CLK	I2C Bus Clock	47	THRU3	Thru User Connect
22	I2C_DATA	I2C Bus Clock	48††	RSTN	Micro Processor Reset
23	PWMIO	GPIO	49	PWM1B	GPIO
24	PWMIA	GPIO	50	VCC	Voltage (battery)
25	AC+	GPIO	51	GND	Ground
26	AC-	GPIO			

†OK to use but has shared functionality

Figure 3.7 Pin Diagram of AT89C51-12PA [20]

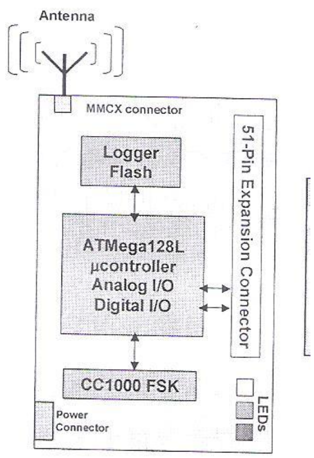


Figure 3.8 Block Diagram of AT89C51-12PA [20]

Other features of the microcontroller include 128 bytes of RAM, 32 I/O lines, two 16-bit timer/counters; a five vector two-level interrupt architecture, a full duplex serial port, on-chip oscillator and clock circuitry. In addition, it has a Power Down mode which saves the RAM contents and freezes the oscillator, disabling all other chip functions until the next hardware reset.It is packaged as a 40 lead, 0.600ò wide, Plastic Dual Inline Package (PDIP). Figure 3.8 depicts its schematics.

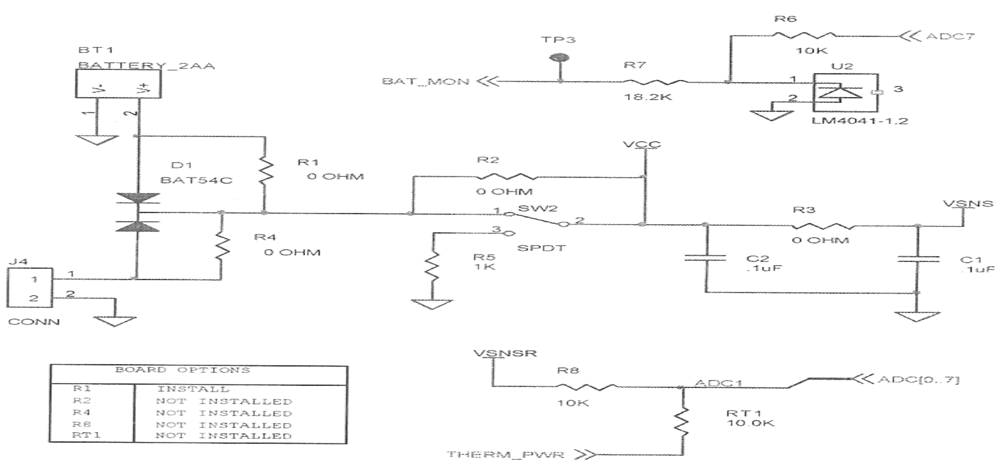


Figure 3.9 Schematics or circuit diagrams of AT89C51-12PA [20]

CHAPTER FOUR

IMPLEMENTATION AND SYSTEM TESTING

The system design was subjected to test vide partial implementation and simulation control. The KashimIbrahim /Aminu Kano intersection at Wuse II district of Abuja, the Federal Capital Territory (FCT) of the Federal Republic of Nigeria was selected for the purpose. Figure 4.1 describes or depicts the sketch of the intersection with sensors positioned along the routes. The choice of the road is influenced by observed flow of traffic, which when compared with other two lane roads in the area, records high levelof vehicular movement.

Figure 4.1 Google Map of Selected Intersection

Traffic light control at the intersection was observed to determine current operations of existing system at the intersection.The observation was repeated over a period of five (5) days and at different periods (including peak and off-peak) of the days to ascertain consistency of operation. Peak period is defined to be the period during which the intersection witness high volume of traffic while the off peak period refer to other times of the day other than the peak period.Figure 4.2is a state diagram or graphical representation of record of observation made with the existing system.

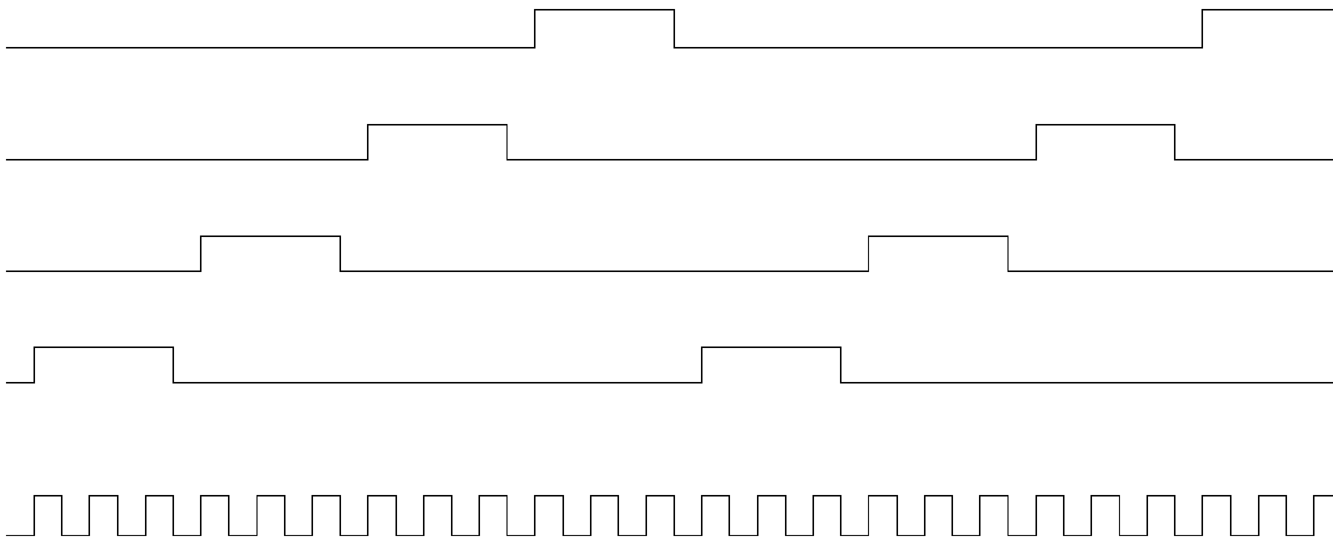


Figure 4.2 State Diagram/Observed pattern of Right of way of the existing system at the selected intersection

It was observed that the existing system allots fixed amount of time to passing traffic in each route, and selection of route followed in a circular direction. Thus, it is possible to predict specific time a vehicle waits at the intersection, given start up time. This arrangement makes it possible for vehicle on a one route to be kept waiting while right of way is granted to a route without traffic. The system, therefore, encourages travellers to attempt to beat traffic and lead to avoidable accident while assuming no vehicle is coming from the route granted right of way.

The proposed system was thereafter positioned along the routes as described in chapter three.However, the existing light display panel was not tampered with due to municipal regulations which forbid tampering with the system without authority or approval, and bureaucratic delays encountered in a bid to secure approval of same. An associated traffic light display was positioned besides each of the existing/installed traffic light display panel. A record of right of way granted to vehicles from the routeson the system traffic light display panel or a typical state diagram of the proposed system is shown inFigure 4.3.

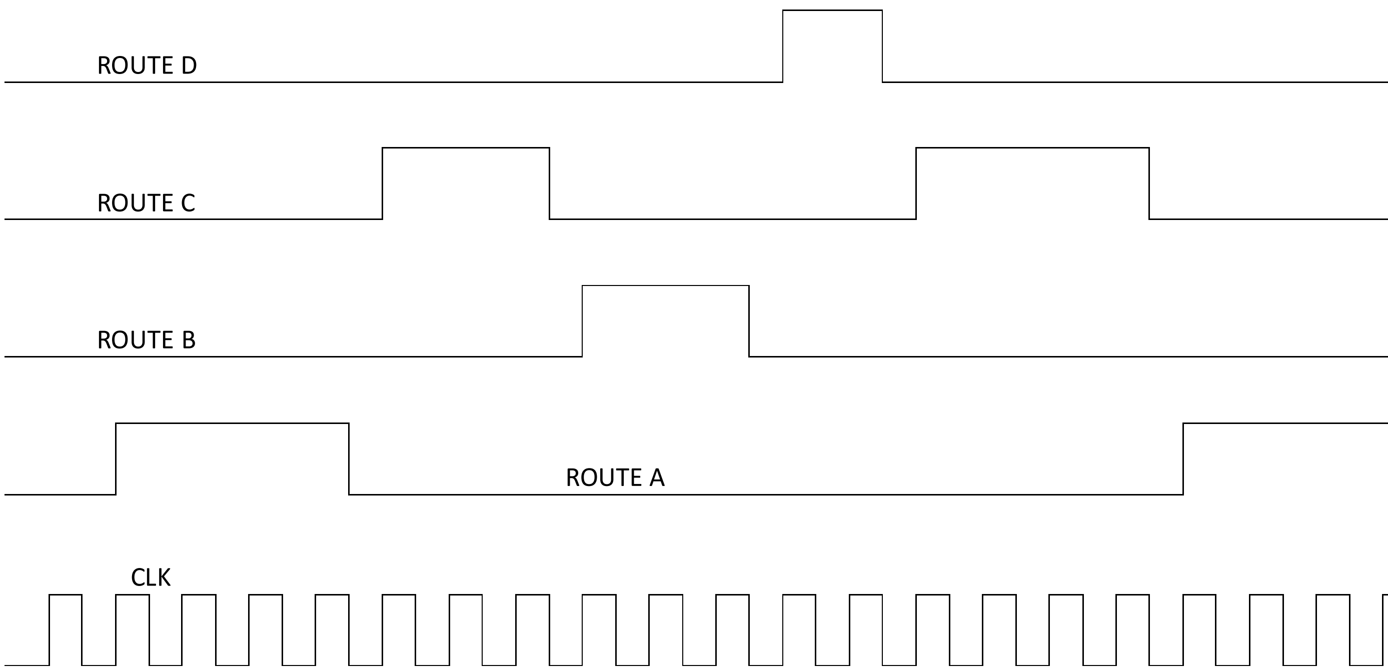


Figure 4.3 State Diagram/Observed Pattern of Right of Way of the proposed system at the selected intersection

4.1 DISCUSSION OF RESULT

The study shows that the existing system arbitrarily determines the first route to be granted Right of Way, whether there are vehicles or not. This contrastswith the proposed system which first senses traffic on all routes, determines thatthe first route to have the Right of Way is the route with the highest volume of traffic.It was also observed that the existing system grants Right of Way in a predetermined sequenceamong the routes. Figure 4.2shows that the existing system allots equal period of time for all routes in their respective GREEN or RIGHT OF WAY state. This is without regards to traffic conditions on other routes. Thus a vehicle that arrivedthe intersection from Route designated D at the commencement of the signal controlwould have to wait at leastthrice allotted time in the existing system. However, the vehicle's waitingperiod in the proposed system is dependent on the conditions of traffic on other routes. The proposed system adapts to traffic condition of the routes to determine the sequence. For, instance, such vehicle may have to wait for about half of waiting time in the existing system.

In addition, variabletime slot is allocated to the routes. For instance, comparing Figures 4.2 and 4.3, it can be seen that the proposed system granted Right of Way to Route C, instead of Route B granted same in the existing system after Route A. Also, leading vehicle on Route D waited for 50s in the proposed system compared with 80s in the existing system, implying about 30% improvement. This level of improvement is without prejudice to the possibility of higher or lower value subject to varying traffic condition. For instance, a simulated implementation, as presented in Table 4.1 below, shows that improvement can be as high as over 50%where traffic from Routes B and C are significantly low, or as low as 5% otherwise.

Table 4.1 Reading from Simulated Exercise

i	t_{riA}	t_{riB}	t_{riC}	t_{riD}	t_{ri}	t_i	Waiting time Route C
1	25	0	15	0	20	20	25s against 50s in the existing system
2	15	5	20	10	12.5	20	
3	30	15	24	28	24.25	13.2	
4	30	20	24	10	21	10	

4.2 CHALLENGES/CONSTRAINTS

The Researcher encounters limitations that negatively affected effective implementation of the system design. These challenges or constraints include funding/financial, duration or time available to carry out the research, municipal approval requirement, among others.

4.2.1 FUNDING

The research work is limited in implementation due to inability of the researcher to raise support fund to procure necessary materials needed to put the design to test. These include research materials such as previous studies carried out in the subject area, hardware and software, as well as study tours and travels.

4.2.2 MUNICIPAL APPROVAL REQUIREMENT

Existing law vested responsibility for roads works and maintenance in government agencies and parastatals. Any modification of the road infrastructure requires consent of such municipal authority. Effort of the researcher to obtain needed approval was not successful to the point of writing this report.

4.2.3 TIME CONSTRAINT

The time available to design and implement the project is inadequate in view of the afore-mentioned challenges and constraints. Were there to be sufficient time, some of the other challenges encountered could have been bridged. For instance, the researcher could bridge challenge of access to literature by visiting several libraries across the country.

4.2.4 LIMITED ACCESS TO RELEVANT LITERATURE

It is no secret that research work is a continuous activity, and that scientific knowledge is incremental in nature. The above statement implies that a successful research project feeds on previous work carried out in the subject area. Accessibility to some of these resources requires finance which funding of the research project could have provided for.

CHAPTER FIVE

CONCLUSION AND FUTURE WORK

5.0 CONCLUSION

The study have shown that it is possible to improve on the existing vehicular traffic light control using on-road wireless sensor network (WSN) thereby enhance safety, minimise accidents and loss of lives, reducing travel time of road users, and contribute to economic development of the developing nations.

5.1 RECOMMENDATION FOR FUTURE WORK

The need to put the design to work cannot be over-emphasised. The design can be improved upon to link adjacent intersections, such that traffic conditions in adjacent conditions are taken into consideration in determining routes that are granted right of way. The effect of this will further improve vehicular traffic and safety.

A GSM module and a sever may be integrated into the system to provide road users traffic situations ahead of each intersection with a view to taking decisions as to which direction to follow to achieve maximum reduction in travel time.

5.2 CONTRIBUTION TO EXISTING KNOWLEDGE

This study has made significant contribution to existing through the introduction of a unique algorithm to determine the best route to grant rite of way at any particular intersection, with the attendant improvement over the existing system.

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