# VANET Based Four Way Road Intersection Traffic Light Control Model

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# VANET Based Four Way Road Intersection Traffic Light Control Model

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## Master of Technology

*in*

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*by*

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# Certificate

This is to certify that the work in the thesis entitled *VANET Based Four Way Road Intersection Traffic Light Control Model* by **Alok Ranjan** is a record of an original research work carried out by him under my supervision and guidance in partial fulfillment of the requirements for the award of the degree of Master of Technology with the specialization in Computer Science in the department of Computer Science and Engineering, National Institute of Technology Rourkela. Neither this thesis nor any part of it has been submitted for any degree or academic award elsewhere.

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Finally, at this moment I surrender everything what I have is an outcome of the support and constant believe of my beloved parents. I am dedicating my thesis to my family especially to my mother, Renu Sinha for always standing next to me irrespective of her own compromises and my father, A.K Sinha for his encouragement and supports both financially and mentally that made me possible to finish my study.

*Alok Ranjan*

# Abstract

Traffic lights are responsible in maintaining the smooth passage of traffic in urban scenario. To enhance the efficiency of traffic control system we are utilizing the concept of Vehicular Ad-hoc Network (VANET) along with our proposed VANET Based Four Way Road Intersection Traffic Light Control Model. The proposed model facilitates more number of vehicles to cross the intersection simultaneously; reduces the vehicles waiting time at intersection. The dynamic cycle traffic control provides an adaptive mechanism to adjust the timing behavior of traffic signal in accordance to traffic demand. Traffic density estimation and traffic density analysis are the two major phases of the proposed traffic signal control. The proposed system comprises of estimation of vehicle density in different lanes approaching the intersection. The density estimation is carried out using (V2I) Vehicle to Infrastructure and (V2V) Vehicle to Vehicle communication. Further the assessment and analysis of obtained data from the estimated density part is carried out by the traffic signal controller to adjust the traffic signal cycles in accordance with the traffic requirement such that unnecessary traffic waiting time can be minimized.

The proposed model and proposed Green Light Allocation algorithm is evaluated against the existing static and dynamic cycle control system using Matlab. We found that our proposed system is giving better performance by allowing more traffic volume to cross through the intersection in each cycle. Also our proposed system is reducing the waiting time of vehicles at intersection by frequently switching the Green Light among the phases of same signal cycle.

**Keywords:** *Traffic Controller; Four Way Road Intersection Model; Traffic Clustering; V2V and V2I Communication; Road Side Unit*

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# Chapter 1

# Introduction

Traffic lights have been utilized since 1868, to schedule and control the competing traffic flows at each road intersection using light cycle schedules. They provide safe scheduling that allows all traffic flows to share the road intersection. The queuing delay at each road intersection decreases the traffic flow fluency and then decreases the traffic efficiency all over the road network [1].

Traffic management especially at road intersections in urban areas is a major issue nowadays. There are a lot of problems occur in our daily life because of traffic congestion. An intelligent traffic system (ITS) should be designed which can handle the time varying traffic density at the intersection in the city. ITS systems are the automatic road traffic management system which manages the road traffic designed for improving traffic safety and optimizing the flow of traffic [2] [3].

In urban area traffic lights are the only way to handle the road traffic. Followings are the terminology involved in the traffic light control system:

- CYCLE LENGTH: It is the time taken to complete one set of all four phases.

- PHASE: Each signal cycle is divided into a set of phases. A phase comprises a possible road-signal combination. Each incoming road gets a signal during a phase such that a specific group of traffic can cross through in that phase.

- INTERVAL: The amount of time for which the traffic signal for their respective road remains unchanged.

The traffic signal control can mainly be divided into two categories:

1. Fixed-time cycle control system

2. Real-time or dynamic cycle control system

Fixed-time cycle controlling utilizes the predetermined measured phase timing plan; conversely the real-time cycle controlling determines an adaptive phase and cycle timing by considering the traffic density near the intersection. Implementation of real-time traffic signals have commonly be included by using the sensors like loop detectors, video-cameras, microwave detectors, etc. Detectors are connected to traffic signal controller to send information regarding the density measurements and their noticeable drawbacks are excessive maintenance cost, great deal of human intervention and most significantly the deficiency of accurate route prediction because of their limited covered local area. On the other hand, in recent decade utilization of VANET in ITS concept has greatly reaped attention of academia. According to this study real-time traffic signal controlling technique which takes traffic density information by V2V and V2I communication as described in the dedicated short-range communications also called wireless access in vehicular environments which works in the spectral range of 5.855.95 GHz. We suggests an efficient algorithm for generating adaptive traffic signal timing which is qualified for central urban scenarios.

## 1.1 Problem Definition

Traditional traffic light control system which works on fixed cycle time technique is inefficacious in handling the increasing traffic at the intersection. The advance traffic light control system based on VANET has registered their efficiency in handling traffic but is sometimes incapable in handling traffic at peak hours. According to our study, we noticed that the traffic coming from all the various incoming lanes has a tendency to move towards a common destination especially during peak hours. The existing adaptive traffic light controller doesn't take into account

this biased behavior of traffic movement and hence vehicles suffer from prolonged waiting at the intersection.

So we require to develop a system that is intelligent and adaptive enough to work in accordance to the traffic behavior.

## 1.2 Motivation

Traffic control is a rapidly evolving subject, with the increase in number of vehicles the traffic congestion has worsened dramatically over the last 4-5 years, in spite of the introduction of automated traffic lights. Expensive and drastic measures, such as the flyovers, have been implemented to control traffic jams. Although various studies have been conducted in this area, concluded to the development of ITS. In New Delhi and other cities of developing nations, present traffic situation is quite unlike that of developed countries. As a result of improper planning and land management, only about 12% of the urban area consists of road space in New Delhi (compared to 20% required ideally).

With advancement in technology human traffic control system had been replaced with a new generation signal controller with the good intent of bringing discipline in traffic. In spite of optimistic predictions, it has visually perceived that traffic congestion has become even worst. The traditional fixed cycle traffic signal control utilizes the predetermined quantified phase timing plans. As per a recent survey it is required bring modernization in this area so to handle the traffic congestion especially at intersections. There is a need to develop such system which can speedup the traffic movement at intersection by switching the Green light between various lanes at intersection as per traffic demand.

## 1.3    Objectives

The objectives of the thesis are enumerated as follows:

- To increase the traffic handling capacity of roads.

- To decline the vehicles waiting time at intersection.

- To increase the traffic volume crossing the intersection in each signal phase.

- To reduce driver frustration and 'road rage'.

- To develop cost effective and efficient system to control traffic flow.

## 1.4    Thesis Organization

The rest of the thesis is organized as follows:

**Chapter-2** Literature review where we have taken a brief survey of the work report in the area of VANET based traffic light control system.

**Chapter-3** Introduction to VANET technology that includes a brief description about communications in VANET, VANET Protocols, applications and challenges of VANET.

In **Chapter-4** Proposed Four Way Road Intersection Model is given along with its comparative analysis.

**Chapter-5** Proposed traffic signal control system gives a detail about how vehicles communicate with each other and with the RSU. In this chapter we have proposed a Green Light Allocation algorithm which allocates green signal to lane as per their demand.

# Chapter 2

# Literature Review

The VANET based adaptive four ways road intersection traffic light control is based on facilitating high traffic density to cross the intersection simultaneously. Also it provides adaptive green signal timing in accordance to the traffic density for specific lane.

Several algorithms have been introduced using Vehicular Ad-hoc Networks technology over past many years to enhance the traffic control signal efficiency. VANET enables the utilization of real time traffic characteristics, which further enable real time decision making related to traffic controller. In this section, we give a brief about some adaptive real time traffic controller that have been introduced using VANET as key technology over the last few years [2].

In [3] , an adaptive traffic signaling system based on VANET is deployed in the intersections. Wireless communication and GPS system helps in spreading the information related to the traffic to the nearby vehicles. Freely available TIGER files are used to as input to maps. The system control is dependent on a wireless node located in the intersection for determining the optimum values for the traffic lights interval. However in V2I approach the compulsion to process a large number of broadcasted messages by the RSU and distinguishing the duplicate packets lead to slower the data processing at RSU.

In [4], an adaptive traffic light control system based on car-to-car communication which decreases the waiting time of traffic at the intersection. They proposed a data dissemination method called Direction based clustering algorithm for data dissemination so, to collect the information about the traffic density approach-

ing the intersection. This approach utilizes the concept of both V2I and V2V communication for grouping of vehicles to create clusters. At the intersection vehicles form cluster based on their direction of movement. The first vehicle in each direction is selected as the head of the cluster also called group leader.

In [5], author introduced an Intelligent Traffic Light Controlling (ITLC) algorithm. The introduced algorithm aims at increasing the traffic flow rate by decreasing the waiting time of traffic resulting in increased number of vehicles crossing the road intersection per second. The road segment with the largest traffic density is scheduled first. The area around the road segment where vehicles are ready to cross the intersection is known as ready area. The ready area is proposed to guarantee fair utilization of the road intersection. In terms of the average delay taken for each vehicle to cross intersection, ITLC decreases the delay by 25% and increases the throughput of each road intersection by 30%.

In [6], the proposed system uses both V2I and V2V communication schemes for traffic density estimation. Vehicles heading towards a common direction form their cluster by exchanging a sequence of packets followed by the process of cluster header selection. The proposed system also helps in controlling the traffic flow of adjacent intersection by maintaining an extra field in vehicle reply packet called subsequent direction field. Further the traffic signal cycle is adjusted adaptively in accordance to the traffic density using modified Websters equation.

In [7], the authors proposed a dynamic traffic control method based on virtual traffic light (VTL). In their framework, each vehicle can have its willthe desire of moving forward and share among one another its "will "–value. The virtual traffic light is capable in switching the signal adaptively in accordance to the information gathered by the traffic controller. One of the vehicles is considered as the leader out of many, heading to the same intersection. Further the selected head will be treated as the traffic light infrastructure for that moment. Information regarding traffic light will be generated and announced by the selected cluster head. In this method, the traffic light control schedule can be frequently altered to meet the traffic demand in the crossroad based on the current situations. If some drivers are

not in a hurry, they can lower their will-value and let others who have something urgent go first. Also it guarantees that the vehicles in sparse lanes will not suffer from starvation.

# Chapter 3

# Background of VANET

VANET, is a form of MANET (mobile ad-hoc network). It enables communications among nearby vehicles and between vehicles and RSU (road side unit). A VANET equipped vehicle need only a small electronic device generally known as OBU (onboard unit), which provides connectivity to the vehicles in Ad-hoc network environment. Each VANET enabled vehicle will be treated as a node in the Ad-Hoc network. This environment is widely used for designing intelligent traffic control system. Basically it consist of mobile nodes, a fixed infrastructure as RSU, output unit connected and placed within a vehicle as OBUs and wireless transmission links.

1. OBU: It is an output device which display output and provides instruction to the user present in the vehicle. It is also used to transmit or receive data in ad-hoc network.

2. RSU: It is a device which works like a router and placed anywhere within the network. It is used to extend the network range. It provides connection to OBU's and forwards data.

3. Transmission link: This is a link used to transmit data packet/information within network. Vehicles communicate through wireless communication. The communication is same as described in the dedicated short-range communications (DSRC)/wireless access in vehicular environments (WAVE) standards operating in the spectral range of 5.855.95 GHz.

## 3.1 communication in VANET

1. All vehicles communicate with each other through some RSU. This architecture may resemble wireless local area networks (WLAN).

2. Vehicles directly communicate with each other and there is no need of any RSU. This can be classified as Ad-hoc architecture.

3. Some of the vehicles can communicate with each other directly while others may need some RSU to communicate. This can be referred as hybrid scenario.
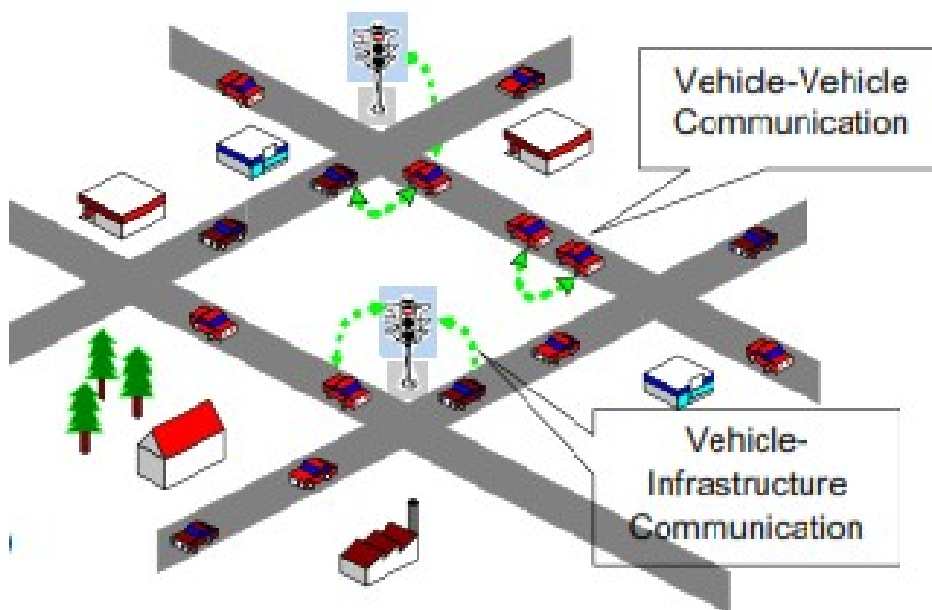


Figure 3.1: Communication in VANET

## 3.2 VANET vs. MANET

Similarity between the MANET and VANET are as follows:

1. VANET is a subgroup of MANETs

2. Both are characterized by the self-organization and movement of the nodes.

3. Both MANET and VANET are more prone to physical security threats in compare to the infrastructure based networks.

MANET provides voice and infotainment services to passengers but they are not well suited directly to V2V and V2X communication.

Differences between MANET and VANET are as follows:

1. MANET contains nodes which have un-controlled moving patterns. In VANET, movement of vehicles is restricted by factors like roads, traffic regulations. Nodes propagation model in VANET is not assumed to be free space because of presence of obstacles in the form of buildings, trees, vehicles etc.

2. Services of vehicles in VANET are supported by Fixed Roadside Infrastructures. Fixed infrastructures are deployed at certain locations in network.

3. Vehicles communicate with each other with DSRC standard that uses IEEE 802.11 standard for wireless communication.

4. Vehicles are not subject to be strict energy, space and computing capability which are normally adopted in MANETs. Nodes are assumed in VANET to have ample energy and computing power.

5. High speed vehicles (up to 250 km/h) and large dimension of the VANET are more challenging problems.

6. Due to high speed of nodes, network topology changes very frequently. Vehicles are moving at the speed of 50-75 kmph and if radio range between two vehicles is 125m then the link between the two vehicles would be functional for a maximum of 10 seconds.

7. In VANET, frequent disconnection of network occurs due to link between vehicles changes quickly. This problem is further worsening due to difference

of vehicles density in highway and urban scenarios. Also, vehicles frequency decrease in non-rush hours causes frequent disconnectivity.

## 3.3  Applications

Vehicles in VANET with the avail of network protocol stack and system integration, provide a number of applications. A vehicular generic class of applications most liable of carrying a homogeneous protocols and methods in the network stack due to homogeneous application characteristics and performance requisites. Network designers should be able to maximize the re-usability of mundane mechanistic 'building modules' for a categorical class of applications with homogeneous application characteristics and performance requisites. Research on VANET has driven network support of sundry application development. Research on deployment of RSUs are carried out by DSRC research community availing future deployment in V2X applications to provide safety/warning applications and highway traffic management for commercial applications. Applications of VANET are roughly organized into three major categories predicated on costumers benefit of applications.

It can be categorized and relegated the applications predicated on the application cognate characteristics. There are different relegation of applications like the entities participated in the application, the geographical region in which the application works when the applications will be triggered, end-to-end communication, the network protocol utilized, and kind of security used etc. The message packet format varies with the type of applications. Mundane safety and accommodation applications use lightweight concise messages while commercial applications on the other hand, generally prefer the traditional heavyweight IP format to be compatible with subsisting commercial Internet accommodations. Application relegation is conducted at sundry levels, depending on design granularity. High caliber relegation is auxiliary to distill the major concepts and identifying the synergy among sundry applications.

V2V/V2I applications classification based on network design are mainly di-

vided in two parts:

1. Short Message Communication: Applications using short message communication use both broadcast and unicast communication. Broadcast communication are used for event-driven, scheduled and On-demand applications while unicast is used for secure and non-secure routing.

2. Large-Volume Content Download/ Streaming: These applications generally use unicast communication. It is generally used for file download and video streaming.

## 3.4 VANET Protocols

There has been improvement in ITS, due to investment from the government, academia, and industry, leading to the development of safety and traffic management technologies in vehicle and road infrastructure. There has been proposed different protocols to meet the standard to support ITS but recently proposed WAVE standards on the dedicated short range communications (DSRC) is the only standard that meet the requirement for road safety messaging and control. But still there are several social and technical challenges with DSRC protocol to dealt with large scale deployment.

WAVE system supports two classes of devices: OBU and RSU. It supports two classes of communication, V2V and V2I. In the united state , 75 MHz of spectrum in the 5.9 GHz frequency band has been allocated for DSRC applications. This 75 MHz frequency band is divided into seven 10 MHz channel and the rest 5 MHz is reserved as the guard band. In seven channels available spectrum is configured into one control channel (CCH) and six service channels (SCHs). The CCH is reserved for high-priority short message or management data, while others are transmitted on the SCHs [8].

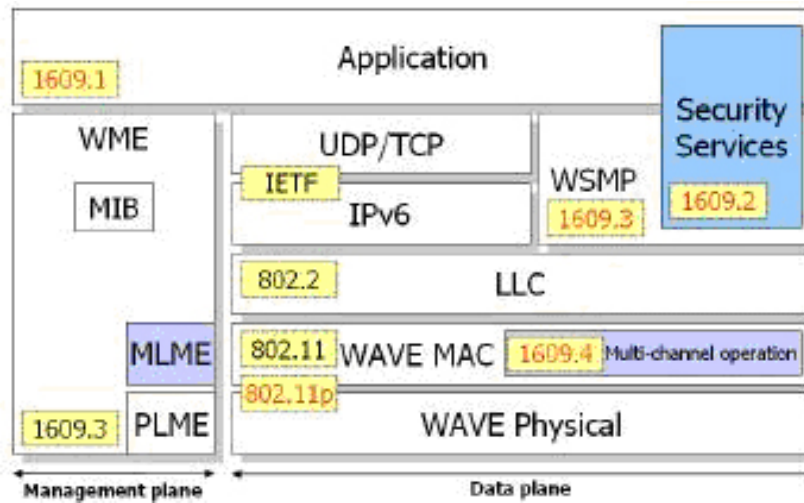The IEEE 1609 family, IEEE802.11p and the society of Automotive Engineers

Figure 3.2: WAVE Protocol Stack

(SAE) J2735 collectively form the key parts of the WAVE protocol stacks. The major component of WAVE protocol stack and its associated standards are shown in figure.
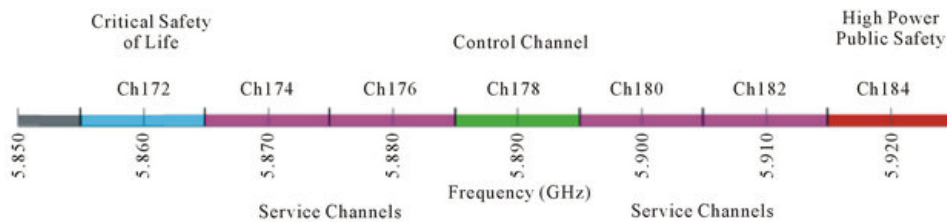


Figure 3.3: The DSRC Frequency Allocation

## 3.5 VANET Challenges

The major challenges of VANET can be divided into Technical challenges and Socioeconomic challenges [9].

### 3.5.1 Technical Challenges

First and central challenges of VANET is that no communication coordinator can be assumed to be possible. In all the area of the network roadside infrastructure deployment is very difficult. Although some applications are needed infrastructure

like traffic signal violation warning, toll connection and optimal path selection.

Design of the medium access control (MAC) layer is the key issue in the design of the VANET. Now, the main focus of VANET on using the IEEE 802.11 carrier sense multiple access (CSMA)- based MAC for VANETs. This is due to availability and cost considerations and accepts the random elements of such a MAC. The bandwidth of frequency channel varies in the range of 10 to 20 MHz and with such a high vehicular density, these channels easily could suffer from channel congestion. If more than one channel used then it leads to multi-channel synchronization problem especially in the case of a single transceiver per vehicle and co-channel interference problems.

Other challenges of VANET are the highly dynamic network topology due to high speed movement of vehicles and the consequences of it the environmental impact on their radio propagation. The lower antenna heights and attenuation/reflection of all the moving vehicles' metal bodies make the condition worse. VANET should work in large area, for sparse and dense vehicles traffic region and should be scalable. Adaptive transmission power and rate control is strongly needed to achieve a reasonable degree of reliable and low latency communication.

In VANET, achieving security and privacy is also a major challenge. Receiver must sure and trust the source of information, privacy requirement of a sender and, data must be confidential.

### 3.5.2   Socioeconomic Challenges

Market adoption is also a major challenge. Convincing costumer to purchase the vehicles equipped with VANET technology is difficult job. If number of vehicles equipped with VANET technology will be very less on roads then the benefits of it cannot be achieved. Deploying RSUs is also a costly approach in initial stages. Still various major issues are yet to solve before deployment like backhaul connectivity, IT-management issues, road operators etc.

# 3.6    Mobility Modeling

In VANET, there is a vigorous interaction between the network protocol and vehicular mobility. After several years of research, now an immensely colossal number of mobility models are available from most nugatory to authentic ones. But, still it is arduous to cull a good mobility model because of their arduousness in understanding of each model's characteristics and their benefits and drawbacks.

The mobility model is customarily relegated in two types as macroscopic or microscopic. Macroscopic mobility model are subsidiary to probe gross qualities of interest, such as vehicular density, mean velocity etc. Microscopic modeling considers each conveyance as a distinct entity, which result the demeanor in a more precise way but computationally more expensive way. The Microscopic modeling model are auxiliary in identifying functional block like kineticism constraints, traffic generator, and time and external influences. Microscopic simulation model deals with properties like the inter-vehicular distance, expedition, breaking, overtaking. Mobility model intended to engender authentic kineticism patterns includes the building block like precise and authentic topological maps, obstacles, conveyances characteristics (speed, expedition, deceleration, speed compatibilities), trip kineticism, path kineticism, smooth deceleration and expedition, human driving patterns, time patterns, external influence etc [10] [11].

# Chapter 4

# Proposed Four Way Road Intersection Model

In a typical four way intersection the roads are divided into two categories as shown in figure 4.1.
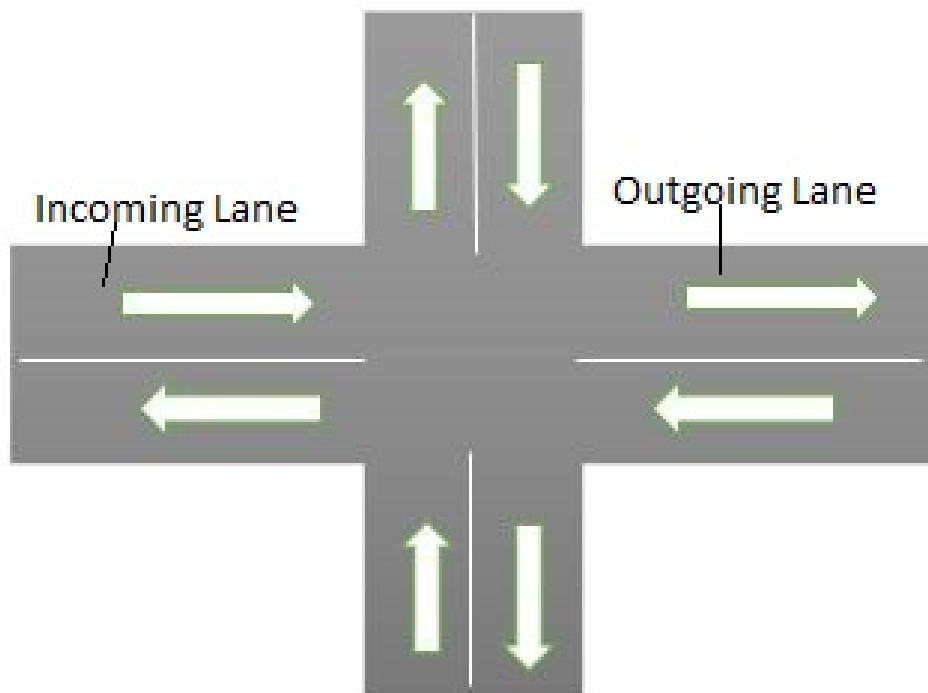


Figure 4.1: Typical Four Way Intersection

The traffic light signal of the proposed four way road intersection model is based on the traffic density of the out-going lanes. In the four way road intersec-

tion model we modified the existing road intersection such that the vehicles can cross the intersection simultaneously heading towards the same out-going lane. Each lane is subdivide into four parts (straight, left, right, U-turn) and the outgoing lanes will be having one extra physical separation which offers a collision free passage to the vehicles crossing the intersection.
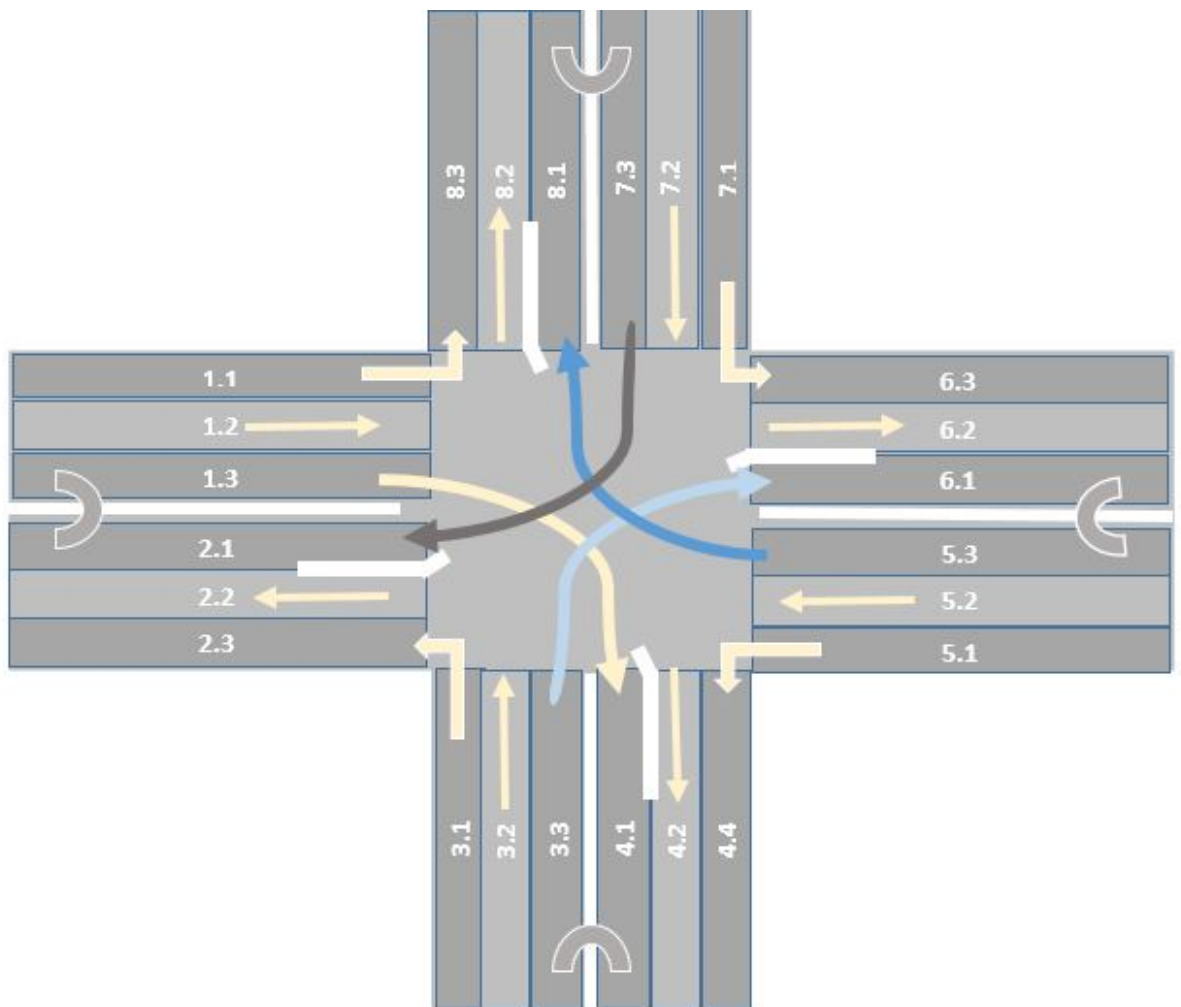


Figure 4.2: Proposed Four Way Road Intersection Model

In Figure 4.2 we can see that every outgoing lane is separated into three parts along with one U-turn, facilitating the easy passage to vehicles coming from all the four incoming lanes at a time. Consider if we want to permit traffic flow through lane-6, traffic coming from 7.1 can cross through 6.3, traffic from 1.2 can cross through 6.2 and at the same time traffic coming from 3.3 can cross the intersection through section 6.1. Also the model allows vehicles coming from section 5.3 to go through the same outgoing lane using the U-turn. Similarly the other outgoing lanes also provide an easy passage to traffic coming from all four incoming lanes simultaneously.

The vehicles can cross the intersection following their traffic light. The traffic light depends completely upon which outgoing lane is considered for that particular phase. In accordance to the outgoing lane the traffic light will be adjusted for all incoming lanes; so there are four possible phases for which the traffic signals need to be adjusted as follows:

| Incoming Lane | Straight | Left | Right | U-Turn |
|---------------|----------|-------|-------|--------|
| Road-1 | Green | Green | Red | Green |
| Road-2 | Red | Green | Red | Green |
| Road-3 | Red | Green | Red | Green |
| Road-4 | Red | Green | Green | Green |

Table 4.1: Phase 1

| Incoming Lane | Straight | Left | Right | U-Turn |
|---|---|---|---|---|
| Road-1 | Red | Green | Green | Green |
| Road-2 | Green | Green | Red | Green |
| Road-3 | Red | Green | Red | Green |
| Road-4 | Red | Green | Red | Green |

Table 4.2: Phase 2

| Incoming Lane | Straight | Left | Right | U-Turn |
|---|---|---|---|---|
| Road-1 | Red | Green | Red | Green |
| Road-2 | Red | Green | Green | Green |
| Road-3 | Green | Green | Red | Green |
| Road-4 | Red | Green | Red | Green |

Table 4.3: Phase 3

| Incoming Lane | Straight | Left | Right | U-Turn |
|---|---|---|---|---|
| Road-1 | Red | Green | Red | Green |
| Road-2 | Red | Green | Red | Green |
| Road-3 | Red | Green | Green | Green |
| Road-4 | Green | Green | Red | Green |

Table 4.4: Phase 4

## 4.1   Comparitive Analysis

This comparison is carried out considering both the systems are following Fixed-time cycle control technique. The traffic density in terms of traffic count per cycle for incoming lanes are given as:


**IN1** for Road1

**IN2** for Road2

**IN3** for Road3

**IN4** for Road4



Now, let the fractional value of traffic density for different direction is:

| Direction | Road-1 | Road-2 | Road-3 | Road-4 |
|-----------|--------|--------|--------|--------|
| Straight | $\alpha 1$ | $\beta 1$ | $\gamma 1$ | $\delta 1$ |
| Left | $\alpha 2$ | $\beta 2$ | $\gamma 2$ | $\delta 2$ |
| U-turn | $\alpha 3$ | $\beta 3$ | $\gamma 3$ | $\delta 3$ |
| Right | $\alpha 4$ | $\beta 4$ | $\gamma 4$ | $\delta 4$ |

Table 4.5: Fractional traffic density

For Existing system the total density of traffic crossing the intersection in 1 cycle can be calculated as, Phase 1: (Road-1 assigned Green Signal)

Traffic density$= IN1 + IN2(\beta 2 + \beta 3) + IN3(\gamma 2 + \gamma 3) + IN4(\delta 2 + \delta 3)$

Phase 2: (Road-2 assigned Green Signal)

Traffic density$= IN1(\alpha 2 + \alpha 3) + IN2 + IN3(\gamma 2 + \gamma 3) + IN4(\delta 2 + \delta 3)$

Phase 3: (Road-3 assigned Green Signal)

Traffic density= $IN1(\alpha2 + \alpha3) + IN2(\beta2 + \beta3) + IN3 + IN4(\delta2 + \delta3)$

Phase 4: (Road-4 assigned Green Signal)

Traffic density= $IN1(\alpha2 + \alpha3) + IN2(\beta2 + \beta3) + IN3(\gamma2 + \gamma3) + IN4$

Therefore, the total traffic density crossing the intersection in 1 cycle can be given as,

**Total Traffic density**= $(IN1+IN2+IN3+IN4)+3IN1(\alpha2+\alpha3)+3IN2(\beta2+\beta3) + 3IN3(\gamma2 + \gamma3) + 3IN4(\delta2 + \delta3)$

For Proposed system the total density of traffic crossing the intersection in 1 cycle can be calculated as,

Phase 1: (Road-1 assigned Green Signal)

Traffic density= $IN1(\alpha2 + \alpha3) + IN2(\beta2 + \beta3 + \beta4) + IN3(\gamma1 + \gamma2 + \gamma3) + IN4(\delta2 + \delta3)$

Phase 2: (Road-2 assigned Green Signal)

Traffic density= $IN1(\alpha2 + \alpha3) + IN2(\beta2 + \beta3) + IN3(\gamma2 + \gamma3 + \gamma4) + IN4(\delta1 + \delta2 + \delta3)$

Phase 3: (Road-3 assigned Green Signal)

Traffic density= $IN1(\alpha1 + \alpha2 + \alpha3) + IN2(\beta2 + \beta3) + IN3(\gamma2 + \gamma3) + IN4(\delta2 + \delta3 + \delta4)$

Phase 4: (Road-4 assigned Green Signal)

Traffic density= $IN1(\alpha2 + \alpha3 + \alpha4) + IN2(\beta1 + \beta2 + \beta3) + IN3(\gamma2 + \gamma3) + IN4(\delta2 + \delta3)$

Therefore, the total traffic density crossing the intersection in 1 cycle can be given as,

**Total Traffic density**$= IN1(\alpha1 + 4\alpha2 + 4\alpha3 + \alpha4) + IN2(\beta1 + 4\beta2 + 4\beta3 + \beta4) + IN3(\gamma1 + 4\gamma2 + 4\gamma3 + \gamma4) + IN4(\delta1 + 4\delta2 + 4\delta3 + \delta4)$

Now,

$\alpha1 + \alpha2 + \alpha3 + \alpha4 = 1$

$\beta1 + \beta2 + \beta3 + \beta4 = 1$

$\gamma1 + \gamma2 + \gamma3 + \gamma4 = 1$

$\delta1 + \delta2 + \delta3 + \delta4 = 1$

Therefore,

**Total Traffic density**$= (IN1 + IN2 + IN3 + IN4) + 3IN1(\alpha2 + \alpha3) + 3IN2(\beta2 + \beta3) + 3IN3(\gamma2 + \gamma3) + 3IN4(\delta2 + \delta3)$

Hence the Proposed System allows the same number of traffic to cross the intersection in 1-cycle as that of Existing System.

## 4.2    Simulation and Results

The proposed Four Way Road Intersection model is evaluated using Matlab-R2013a. We have taken standard data from [12] and [13] related to the number of vehicles crossing the intersection with their direction of movement respectively. There has been 40 sets of data for 4o different signal cycles considered for the evaluation.

Table 4.6: Evaluation Key Parameters

| Parameter | Value |
|---|---|
| Number of Signal Cycles | 40 |
| Maximum Traffic per lane in one Cycle | 100 |
| Maximum Vehicle Speed | $50Km/h \approx 14m/s$ |
| Start Point | 150 m from Intersection |

At first we calculated the number of vehicles crossing the intersection in all four phases of signal cycle but in fixed time interval scenario. For the existing system we equally divided the cycle time into four parts but for the proposed system we divided the cycle time in accordance to the vehicle count for a particular phase as shown below:

**K** $= 1/$(sum of traffic crossing intersection)

Therefore,

**Tg1** $= k * d1 * t$

**Tg2** $= k * d2 * t$

**Tg3** $= k * d3 * t$

**Tg4** $= k * d4 * t$

Where **Tg1** is the Green interval for outgoing lane-1, **d1** is the traffic density heading towards outgoing lane-1 and **t** is some fixed cycle time. Similarly **Tg2,**
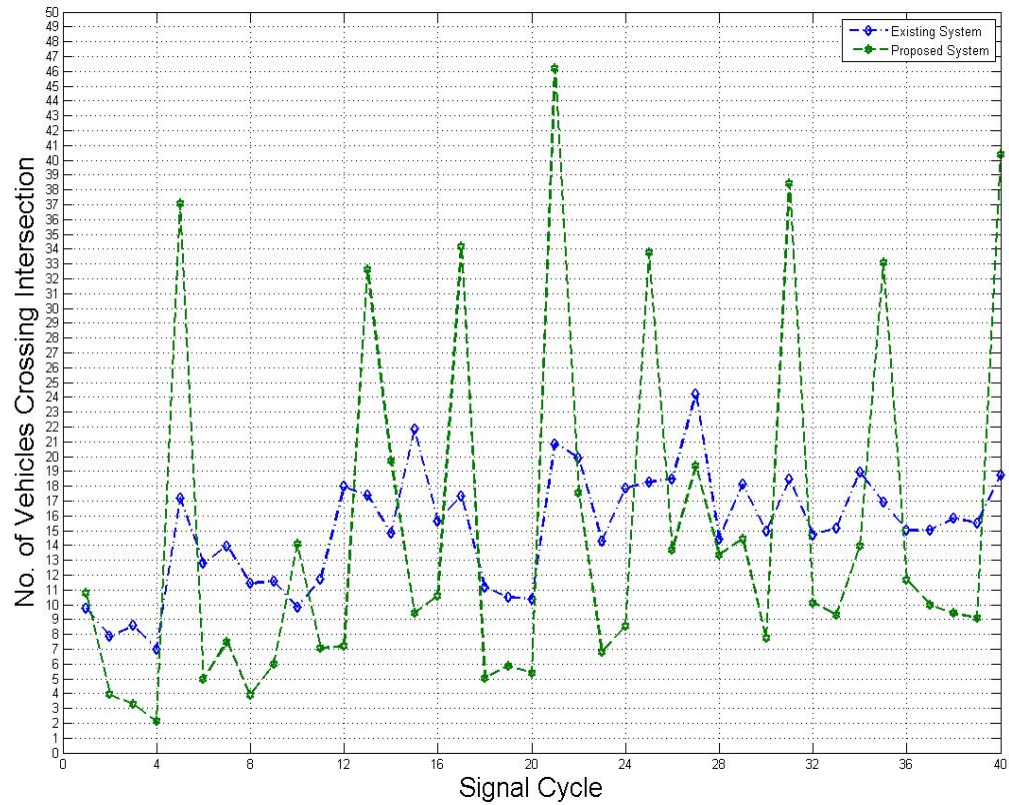
**Tg3, Tg4 and d2, d3, d4** are defined.



Figure 4.3: Comparison of Traffic Density Crossing Intersection

Since we used fixed cycle time therefore the performance gain in 4.3 is achieved for the phase having highest traffic density but the rest three phases are involve in compensating the extra time consumed by the phase which allowed highest traffic to cross through. This problem is solved by applying dynamic or real time cycle.

# Chapter 5

# Proposed Traffic Signal Control System

This part focuses on applying VANET to calculate the traffic density and calculating the optimum green signal duration for each incoming lane. The entire process is divided into two phases:

1. Traffic density estimation

2. Assessment and analysis of data obtained from first phase

## 5.1 Traffic Density Estimation

This is the phase in which the traffic density is estimated using VANET. The vehicles register their count to the nearest RSU using the OBU and other VANET components. The process of registration of vehicle count is carried out using clustering [6] [4]. Each RSU broadcasts the Initiation Packet for its corresponding lane. This process starts only when at least one out of four signals i.e. Straight, Right, Left, U-turn is RED. The structure of Initiation-Packet is shown in Figure 5.1.

Since there are only two such directions (straight and right) for which signal switches between RED and Green and for the rest two (left and U-turn) signal remains Green all the time. So, the Initiation-packet consists of only two direction fields 'Straight Bit' and 'Right Bit'. If the signal for straight direction is Red

| RSU ID | Straight Bit | Right Bit | RRL Duration |
|--------|--------------|-----------|--------------|

Figure 5.1: Structure of Initiation Packet

implies the 'Straight Bit' will be set i.e. '1'. Similarly 'Right Bit' is set in case if the right direction signal is Red. Vehicles waiting for the Green signal on receiving the Initiation-packet checks if the direction field is set and is the same as their direction of movement; sets their timer equal to the 'RRL Duration' field of the Initiation-packet. The 'RRL Duration' gives the remaining Red light duration for that specific lane but 2 seconds less than the real time duration. The modification of real RRL by 2 seconds helps in flawless transfer of traffic density information packet from cluster head to RSU, which we will see later in the description part of 'Density Packet'.

After receiving the Initiation-packet vehicles start participating in the cluster head selection process. Each vehicle transmits Cluster Header-packet to the RSU. The structure of Cluster Header-packet is shown in Figure 5.2 .

| RSU ID | Vehicle ID | Straight Bit | Right Bit |
|--------|------------|--------------|-----------|

Figure 5.2: Structure of Cluster Header Packet

In the above structure the 'vehicle ID' is the unique ID useful in identifying the vehicle. In general vehicle registration number is used in place of vehicle ID, so to assist the social security aspects. The vehicle whose Cluster Header-packet is received first by the RSU becomes the cluster head of its direction. On receiving the Cluster Header-packet the RSU acknowledges the cluster head and informs rest of the vehicles about selected cluster head for their group. The structure of

RSU Acknowledgment-packet is shown in Figure 5.3 .
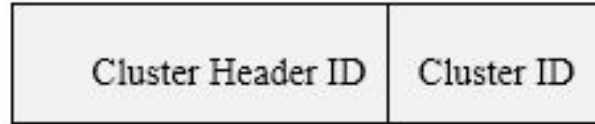
| Cluster Header ID | Cluster ID |
|---|---|

Figure 5.3: Structure of RSU Acknowledgment Packet

By receiving the Acknowledgment-packet and successful completion of cluster head selection process, vehicles stop transmitting the Cluster Header-packet, while the selected cluster head starts broadcasting the Cluster-packet. The purpose of Cluster-packet is to form the cluster of vehicles having same direction of movement. Each vehicle moving towards the same outgoing lane adheres to the respective cluster and hence the cluster head accounts for the count of vehicles with same destination. The structure of Cluster- packet is shown in Figure 5.4.

| Cluster Header ID | Cluster ID | Straight Bit | Right Bit | RRL Duration |
|---|---|---|---|---|

Figure 5.4: Structure of Cluster Packet

The cluster head calculates the current RRL duration and updates the RRL Duration field of Cluster Header-packet before transmission.

Further on receiving the Cluster Header-packet the vehicle replies back to cluster head by sending the Reply-packet. The structure of Reply-packet is shown below in Figure 5.5.
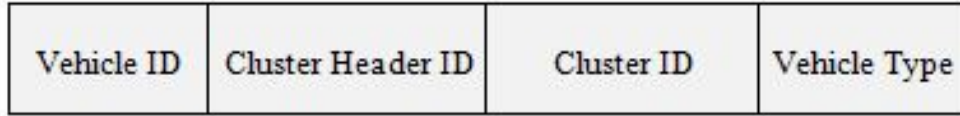
Figure 5.5: Structure of Reply Packet

The 'Vehicle Type' field gives the type of vehicle as Freight vehicle or Passenger vehicle. While calculating the traffic density each freight vehicle is considered as equivalent to two passenger vehicles.

The cluster head sends the Density Packet to the respective RSU when its RRL timer expires. The Density-packet possesses the information regarding the traffic count moving towards same direction or towards the same outgoing lane. The structure of Density-packet is shown in Figure 5.6.
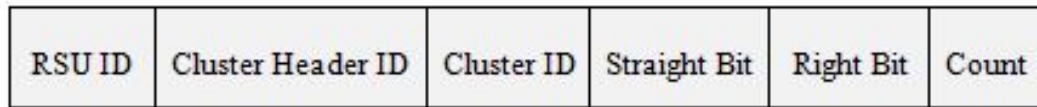


Figure 5.6: Structure of Density Packet

In Figure 5.6 the 'Count' field specifies the number of vehicles in the cluster. The cluster members terminate the cluster as their RRL timer elapse. Density estimation phase also terminates here and all the four RSU's share their density information with the traffic controller to complete the assessment and analysis phase.

**Note**: In case if the RRL timer expires and the lane doesn't get Green signal, the above process starts anew and the RSU transmits the Initiation-packet again for the same lane.

## 5.2    Traffic Density Analysis

The data gathered at the four RSUs are transferred to the central server for further analysis and calculating the optimum Green light interval. The proposed Green light allocation (GLA) algorithm allocates the green light as per the traffic demand. This algorithm assures deadlock free and starvation free movement of traffic through the proposed four ways road intersection. The traffic density heading towards the four outgoing lanes are stored in an array named *'Ocount'* on central server as shown in Figure 5.7 . *'Ocount'* is a two dimensional array with two rows *Tcount* and *Status*. The *Tcount* stores the traffic count while the *Status* consists of flag bit which help in assuring that the recently assigned lane would not get the Green light in continuation.
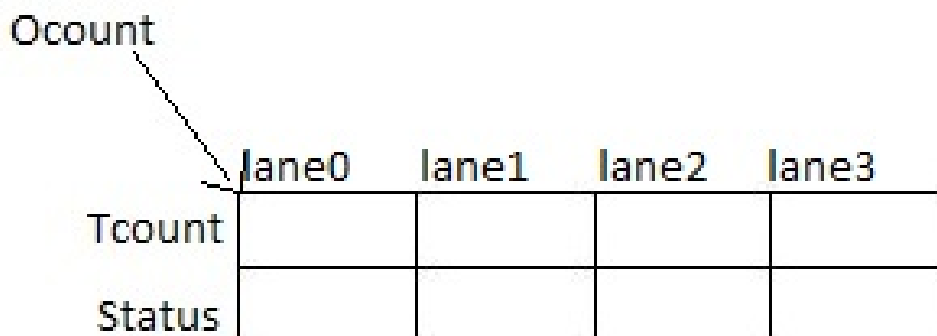
Figure 5.7: Ocount Array

## 5.3    Proposed GLA Algorithm

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**Algorithm 1** GLA Algorithm

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   **Initialize** $Tcount_i$ and $Status_i$ to 0, for $i = 0$ to 3
   **for** k=0 to 3 **do**
     **for** i=0 to 3 **do**
       Find the value of $Tcount_i$ for corresponding $lane_i$ and store it in Ocount
     **end for**
     $M =$Find max value of Tcount having $Status = 0$
     $S = \sum\limits_{i=0}^{3} Tcount_i$
     $Tmax = S * 0.63 * t/4$
     $Tg = \lfloor t/4 \rfloor * M$
     **if** $Tg <= Tmax)$ **then**
       Allocate Green Light for Tg interval to the corresponding lane for which Tcount is maximum and set its Status to 1
     **else**
       Allocate Green Light for Tmax interval to the corresponding lane for which Tcount is maximum and set its Status to 1
     **end if**
   **end for**
   **Repeat above steps for each Signal-cycle**

---

- **Input**: Traffic density of corresponding lane

- **Output**: Green light interval with Signal table

In Algorithm1 *'t'* is average time a vehicle takes to cross the intersection successfully and *Tmax* is the upper limit of Green light interval, so to avoid starvation and deadlock situation.

Note: if in case two or more elements of *Tcount* are equal, we invoke **LRU** (least recently used) approach.

The value of $t$ can be calculated as,

**t = (Total Distance)/(Average Speed)**

Now, let $d$ in meter is the distance of each lane from the starting point to the center point of the intersection. In our approach we are considering the average

speed of the vehicles while crossing the intersection is **14m/s**$(\approx 50km/h)$ .

Therefore,     **t = 2d/14** *seconds*

In the proposed Green light allocation method the value of *Tmax* is taken 0.63 times of the total cycle time, on the basis of our research work. This assures a smooth and deadlock free system in almost every situation.

## 5.4    Simulation and Results

The proposed **GLA** algorithm is applied on the proposed **Four Way Road Intersection Model** and further performance is evaluated using Matlab-R2013a. We have taken standard traffic data from [12] and [13] of intersection which includes the number of vehicles crossing the intersection with their direction of movement. There has been 40 sets of data for 40 different signal cycle taken for the evaluation.

Table 5.1: Evaluation Key Parameters

| Parameter | Value |
|---|---|
| Number of Signal Cycles | 40 |
| Maximum Traffic per lane in one Cycle | 100 |
| Maximum Vehicle Speed | $50Km/h \approx 14m/s$ |
| Start Point | 150 m from Intersection |

In the Figure 5.8, we compared our proposed system with the one having static or fixed cycle time control. It can be easily noticed that the proposed system is frequently changing the phase interval as per traffic demand while the static system is having the same phase interval for each cycle.
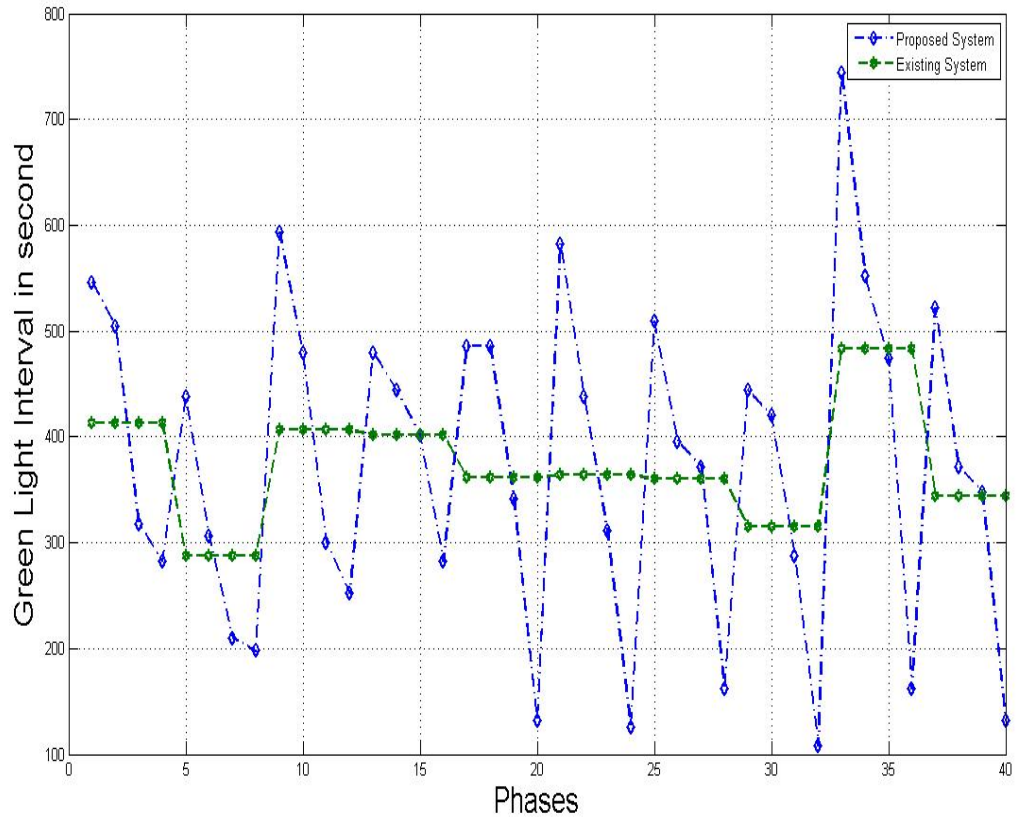


Figure 5.8: Comparison of Green Light Interval

In Figure 5.9 the proposed system is compared with the existing VANET Based Adaptive system. The total traffic volume crossing the intersection is greater in each cycle in the proposed system which implies our proposed system reduces the waiting time of the vehicles at intersection.
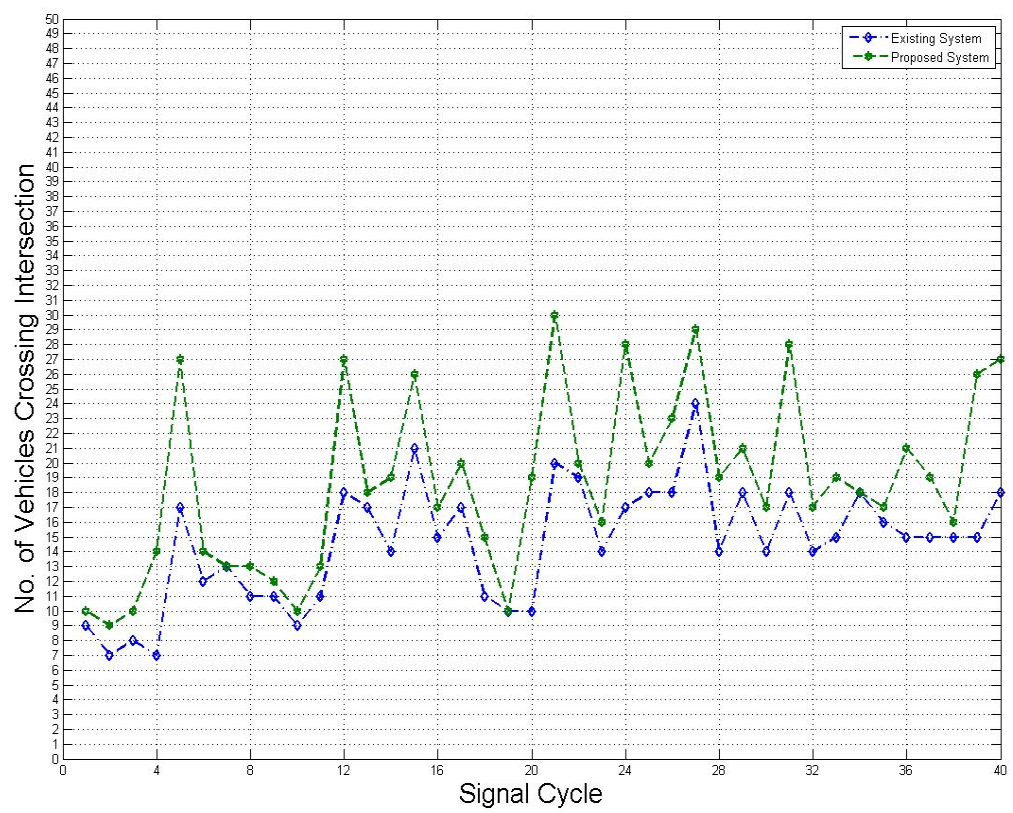
Figure 5.9: Comparison of Traffic Density Crossing Intersection in Each Phase

# Chapter 6

# Conclusions and Future Work

In the proposed system we tried to minimize the traffic waiting time at the intersection. On the basis of our study we found the biased nature of traffic towards a particular outgoing lane. In order to provide more Green light interval to such lane as well as allowing incoming traffic irrespective of their lane to cross the intersection simultaneously through a common outgoing lane, we proposed a **Four Way Road Intersection Model**. The proposed **GLA** algorithm helps in adaptively assigning the Green light as per traffic demand but without deadlock and unnecessary starvation of waiting vehicles. Initiation packet, Cluster Header packet, RSU Acknowledgment packet are involve in assisting the process of Cluster Head selection. Cluster packet, Reply packet are responsible for clustering of vehicles having common destination. Finally the Density packet informs about the traffic density to the respective RSU to help traffic controller in calculating the optimum Green light interval.

The evaluation results show that the proposed system is better than the existing one as it utilizes the Green light more efficiently by allowing more number of vehicles to cross the intersection in one signal cycle. Also the proposed system frequently switches the Green light among four lanes, so it reduces the waiting time of traffic as well.

Further we extend our work in simulating the proposed packets for vehicular communication at the intersection and analysing the result with the existing schemes.

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