Intelligent Traffic Light Control with Wireless Sensor Networks

Shreyta Kulkarni, Vikesh Dass and Aseem Sharma

Abstract — **In this paper, the design of a system that utilizes and efficiently manages traffic light controllers is presented. The main motto is the real-time adaptive control of the traffic lights. The existing methods for traffic management and control are not adequately efficient in terms of performance, cost, maintenance, and support. We present an adaptive traffic control system based on a new traffic infrastructure using Wireless Sensor Network (WSN) and using new techniques for controlling the traffic flow sequences. These techniques are dynamically adaptive to traffic conditions on both single and multiple intersections. In the system architecture, the main focus is on use of wireless sensor network in place of pneumatic road tubes, inductive loop detectors and micro loop probs. The wireless sensors are deployed on the lanes going in and out the intersection. The simulation proposed by us shows the efficiency of the proposed scheme in solving traffic congestion in terms of the average waiting time and average queue length on the single intersection and thus in turn efficient global traffic flow control on multiple intersections.**

Keywords: Intelligent traffic signal control, intelligent traffic control agents, smart signals, wireless sensor networks.

I. Introduction

In today's era, there is continuous and huge amount of increase in the congestion level on public roads which leads to traffic jam, especially at rush hours. This is major concern in many countries leading towards a critical situation of congestion. Most of the methods were proposed for solving the illusion of traffic jam. In addition, over the ground sensors like videos, and radars were used. These systems are also high cost and their accuracy depends on surrounding conditions of the environment. The methods which are there already used for traffic management and control are not adequately efficient in terms of the cost and the effort needed for maintenance as well as for the performance. For providing solution to this problem, a intelligent road system is developed. In this particular system, the total trip time for a vehicle is minimum. This is achieved by minimizing the average waiting time on traffic lights. This paper presents a real-time adaptive system based on wireless sensors that has the potential to establish a new era traffic control and surveillance because of its low cost and potential for large scale deployment. The system consists of the wireless sensor network and the intersection control agents.

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Traditionally, each intersection is managed statically. For eg. Suppose 10 vehicles are approaching at intersection. Traditional approach says that approximately 9^{th} or 10^{th} vehicle will have to wait for net turn of green light. Here, at this point, the order and durations of the green lights is increased so that 9^{th} or 10^{th} vehicle should not have to wait for the next turn of green lights. This is done mainly using Wireless Sensor Networks (WSN).The intersection control agent collects the information from the sensor nodes to analyze traffic conditions and take actions such as adjusting the traffic light durations or exchanging information with other intersection agents for better optimization of traffic flow. This is done using Network Simulation Tool (NS2).

II. Related Work

The system proposed by Malik Tubaishat, Yi Shang and Hongchi Shi in 'Adaptive Traffic Light Control with Wireless Sensor Networks'[1] , it consists mainly of the wireless sensor network and the intersection control agents.The wireless sensor network are composed of nodes in groups, each comprising of a processor, some sensors, a radio and a battery. They traffic information is generated such as speed, cars in numbers, and the vehicle length, based on processing of the sensor data in Green Light District (GLD) [1] simulator to test their model. They used PEDAMACS (Power Efficient and Delay Aware Medium Access Protocol for Sensor Networks) [1] for their traffic system. PEDAMACS is a Time Division Multiple Access (TDMA) scheme that discovers the topology of the network and keeps the nodes synchronized to validate the execution of a TDMA schedule.

While in the system that we have adopted, we have used Loss Monitor UDP Protocol which removes the delay of acknowledgement packet thereby removing the delay related problems occurred in their system.

In System proposed by Victor Gradinescu in 'Adaptive Traffic Lights Using Car-to-Car Communication' [2] they examine the possibility of deploying an adaptive signal control system based on a system that can base its control decision on information coming from cars, by adding short-range wireless communication capabilities to vehicles, the devices form a network allowing cars to exchange information about road conditions and nearby traffic while in our system we are making use of a centralized controller for every intersection which will take decisions based on the traffic details obtained from the wireless sensor nodes present/deployed on the road.

In Sanjay S. Dorle system proposed in 'Design Approach for Dynamic Traffic Control System Based on Radio Propagation Model in VANET' [3] the dynamic vehicular flow creates traffic jams, congestion at the intersection.

Vehicular Ad hoc Network (VANET) is a common part of Intelligent Transport System (ITS) which is directly involved in handling problems and aims to make journey more comfortable. The traffic flow depends also on the driver behavior and and is influenced by traffic control and environmental factor.

This paper describes a working a VANET environment and then a brief study of dynamic traffic system based on radio model of propagation. This traffic system uses a clustering algorithm at the intersection. While in our system as already described above Loss Monitor UDP Protocol is adopted which works with the wireless sensor network described below and its much more efficient than these previous systems proposed.

III. WIRELESS SENSOR NETWORKS

Wireless sensor Network (Wireless Node): The wireless nodes are already present in NS2 tool and for their actual implementation this section gives the wireless sensor network and its hardware that will detect the vehicles on the road.

A. Sensor Node hardware:

The microprocessor is Atmel ATmega128L with 128kB of programmable memory and 512kB of data flash memory. The node is protected and can be glued on anywhere on the pavement.[1]

*B. **Vehicle Detection:***

We use magnetometer sensor for vehicle detection. The sensor detects distortions of the ground field caused by a large ferrous object like a vehicle. Since the distortion depends on the ferrous material and the orientation, a signature which is magnetic is induced corresponding to the vehicles shape.[1]

*C. **Communication protocol :***

We adopt Loss Monitor UDP Protocol. The delay of acknowledgement packet causing data loss and delay convergence is removed and overcome in this protocol. The data at the sensor nodes in the WSN is periodically updated and transferred to ICA.

D. ***Road Intersection Configuration:***

We use intersections controlled by the traffic lights corresponding to each road. The traffic light is responsible for controlling traffic on its corresponding lanes. We assume the right lane turns right only, centre lane goes straight or left and left lane goes left only. We deploy sensor nodes on every lane. We place the sensor nodes where they can monitor the traffic before entering the intersection and after leaving the intersection. We use the nodes placed after the intersection to locally determine the direction of the vehicle within one intersection.

IV. INTERSECTION CONTROL AGENT (ICA)

Intersection control Agent (ICA) will be used to control and monitor the traffic light activities on the intersection for which the ICA is established.

The main aim is to reduce the old methods of vehicle detection and promote the use of wireless sensor node hardware that is the use wireless sensors to detect the vehicles and tell the ICA of that intersection about the traffic on that lane of the road. In this way all the Crossing roads in an intersection will be maintained by Intersection control agent (ICA).

There are 4 message types

1) ***Sensor Nodes to ICA****:*

Sensor nodes count number of vehicles approaching an intersection. Every node monitors one lane. The message sent from the sensor nodes to the intersection control agent includes number of vehicles, time duration of the collected data and the number of lanes.

2) ***ICA to Sensor Nodes***:

After the information is received from all the nodes monitoring a specific intersection, the intersection agent decides the best flow model (policy) for the vehicle flow.

3) ***Greedy ICA to ICA****:*

Intersection control agent can exchange information with other intersection control agents in its vicinity to improve the flow of vehicles in a wider area. This is because the agent can select a better policy depending on more information collected. We call this situation greedy policy because each agent satisfy its intersection flow without paying attention of other intersections flow.

4) ***ICA to ICA with Coordination:***

This is the same as the previous one except that the agents coordinate among themselves to achieve even better flow. The intersection control depends not only on the analysis one agent but on the coordination of multiple agents[1].

V. SIMULATION

We test our model using Network Simulation Tool Version 2.NS2 is a discrete event simulator in simple terms it aids in simulating the concepts in wired and wireless networks. NS is a public domain simulator containing a rich set of internet protocols including terrestrial , wireless and satellite networks. It is the most popular choice of simulator used in research papers appearing in selected conferences like Sigcomm. The Simulator can virtually show the road and traffic simulation on the road using NAM (Network animator). NS together with NAM form a very powerful set of tools for teaching network concepts. NS contains all IP (internet protocols) typically covered in ever expanding user base. With NAM these protocols can be visualized as animations.

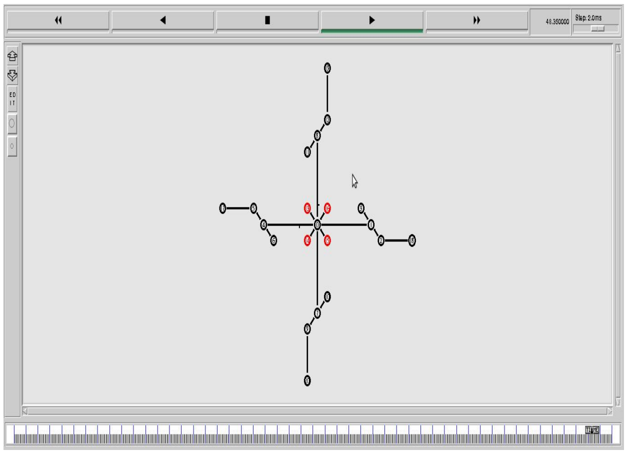

Fig. 1 Screenshot taken from NAM(Network Animator)

VI. PROPOSED SYSTEM ARCHITECTURE

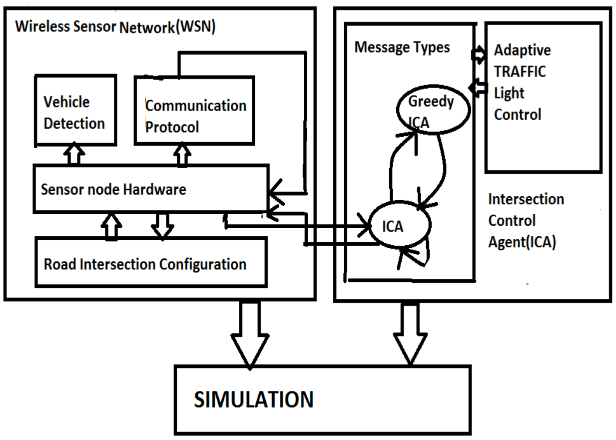

Fig. 2 System Architecture.

A. *Algorithm*

Let Input be N, λ, μ and Qi, i =1, N
Output: Guarantee successful communication between all the components of the traffic control system in order to set the time duration for all the traffic signals using the traffic control box.
Here Traffic Base Station means the Intersection Control Agent.
TSTMA means traffic signal time manipulation algorithm.
Operations:

1. The traffic base station that is running, it sets the listening period (L) to read from TSNs.
2. The traffic base station sends an "Operating Message" which Turn-ON all the TSNs, putting them
   in the communication node.
3. Each TSN identifies itself as either an arrival detecting vehicles or departure detecting vehicles sensor node.
4. Each TSN selects randomly a time slot within " L " to send its traffic status i.e information (λ , μ and Qi) to the Traffic Base Station.
5. The traffic base station applies the TSTMA, which returns the time durations of traffic signal various directions.
6. The traffic base station sets the dynamic durations obtained on the traffic signals using the traffic control box.

B. *Single Intersection Base Model Formulation*

A Mathematical queue model is used to model the lanes in multiple intersections with random arrival times. The length of the mathematical queue can be computed as stated below. Assume that each traffic signal is to be associated with a certain lane.

$$\mathbf{QL(j) = QL(j-1) + \lambda(G) - \mu(G) + \lambda(R)}$$

Terminologies:
λ = Rate with which the arrivals follow Poisson distribution with constant average
P0 = ideal proportion of the time the traffic signal (server)
P = busy proportion of time the system
QL(j-1) = Remaining from the previous cycle.
λ(G) = Vehicles arrive in green time.
μ(G) = Vehicles departure in green time .
λ(R) = Vehicles arrive in red time.
j = the traffic cycle number,
QL (j) = the expected queue length of one lane for the next cycle j,
Hence, the queue length equation is given by:
$\mathbf{QL = \rho 2/(1 - \rho)}$
And using Little's Law, the AQL is given by:
QL = λW
(where 'W' is the average time spent in the system)

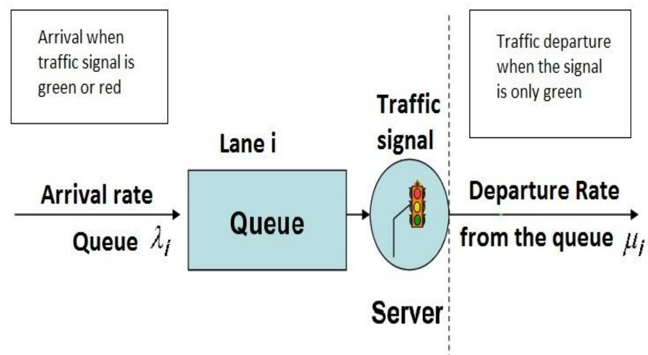

Fig. 3 Traffic signal queue flow.

VII. EXPECTED RESULTS

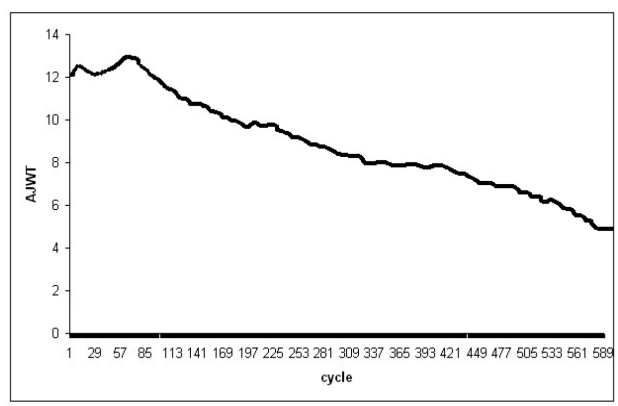

Fig. 4 Average junction waiting time.

Expected result: Figures 4 shows the average junction waiting time. Traffic lights will be set such that the setting will let the most number of vehicles pass. This will be the best setting for each junction, because junctions do communicate and users on the lanes would be able to proceed because the decision about that lane at the next traffic light is planned according to the decision taken by the ICA which communicates with its neighbor ICA's. Thus the above graph in Fig. 4 shows no major ups and downs in waiting time

VIII. CONCLUSIONS

In this paper, the design of an intelligent traffic control system, utilizing and efficiently managing WSNs, is presented. An adaptive traffic signal real time scheduling algorithm based on a new traffic infrastructure using WSNs is proposed on a single and intersections on multiple roads. The proposed system with its algorithms is proved to play a major role in alleviating the congestion problem when compared to inefficient classical traffic control systems. The advantage of information collected from the wireless sensor network has two folds: 1) improve the localized flow model in the intersection and 2) improve the coordination among the neighbor traffic lights. Furthermore, the traffic control system can be easily installed and attached to the existing traffic road infrastructure at a low cost and within a reasonable amount of time. The system is configured such that it operates in real-time to detect traffic states and exchange information with other nodes via a wireless communication with self-recovery function. In addition, no traffic disruption will be necessary when a new traffic sensor is to be installed.

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