TRAFFIC LIGHTS CONTROL SYSTEM FOR INDIAN CITIES USING WSN AND FUZZY CONTROL

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ABSTRACT: *The traffic light is the device responsible for ensuring the right of way by ordering the flow of vehicles with the goal of avoiding accidents. While the social geography of the urban centers changes over time, it imposes new restrictions to the vehicles flow. Such restrictions are often not reflected in the traffic lights programming leading to congestions at the urban centers. In this work, a traffic lights dynamic control system has been proposed that combines an IEEE 802.15.4 Wireless Sensor Network (WSN) for real-time traffic monitoring. The Zigbee based wireless transceiver system can be adopted for this purposes in which both transmitter and receiver blocks has been designed to transmit data from and to centralized control from the sensors required for counting vehicles. Multiple fuzzy logic controllers has been designed, one for each phase, that work in parallel. Each fuzzy controller addresses vehicles turning movements and dynamically manages both the phase and the green time of traffic lights. The proposed system combines the typical advantages of WSNs such as, easy deployment and maintenance, flexibility, low cost, noninvasiveness, and scalability with the benefits of using four parallel fuzzy controllers, one for each phase, instead of a single controller for all the phases which causes better performance, fault-tolerance, and support for phase-specific management. The work proposes a novel system that combines several technologies i.e. fuzzy logic and WSN in an original way so as to obtain a lightweight but effective solution. Simulation results demonstrate that the multi-controller approach here proposed outperforms related works in terms of reduction of the vehicle waiting times in the queues, especially under heavy traffic.*

Keywords: WSN, Zigbee, Traffic light control, fuzzy logic etc..

1. INTRODUCTION

Traffic lights at intersections are the main traffic flow control mechanism in urban road networks. Traffic lights were originally installed in order to guarantee the safe crossing of antagonistic streams of vehicles and pedestrians. With steadily increasing traffic demand, it was soon realized that their presence may also be used to regulate the efficiency of road network operations, hence there must exist an optimal control strategy leading to the minimization of the total time spent by all vehicles in the network [2].

The Traffic Light Control (TLC) problem aims at dynamically controlling the flow of traffic at an intersection through the timing of green/red light cycles with the objective of reducing congestion, hence also the delays incurred by drivers. The general problem involves a set of intersections and traffic lights with the objective of reducing overall congestion over an area covering multiple urban blocks. Control strategies employed for TLC problems are generally classified into two categories: fixed-cycle strategies and traffic responsive strategies. Fixed-cycle strategies are derived off-line based on historical demand and turning rate data for each stream; traffic-responsive strategies make use of real-time measurements to calculate and adjust in real-time the best signal settings [2].

The first one is widely used in our present urban traffic systems due to its easy implementation and low cost. The second one controls intersections based on inputs detected by physical sensors such as loop detectors or cameras. Its examples are SCOOT [3] and SCATS [1]. They apply real-time traffic data and determine the cycle time to achieve the optimal performance of traffic signal control
The IEEE 802.15.4 standard defines the Physical and MAC layers for LR-WPANs. The Physical layer is responsible for characterizing the Physical attributes and behaviors of LR-WPAN nodes. This includes turning hardware operation states, selecting RF channel, estimating the RF link quality (LQI), receiver energy detection, and clear channel assessment (CCA) for CSMA/CA operation in MAC layer. The RF communication at the Physical layer is supported in three licence-free ISM (Industrial, Scientific, and Medical) frequency bands including 2.4 GHz with 16 channels and a 250 kbps data rate, 902 to 928 MHz with 10 channels and a 40 kbps data rate and, 868 to 870 MHz with 1 channel and a 20 kbps data rate. The IEEE 802.15.4 standard supports a 64-bit long address and a 16-bit short

address, theoretically resulting in a single network being able to support a maximum of 216 nodes.

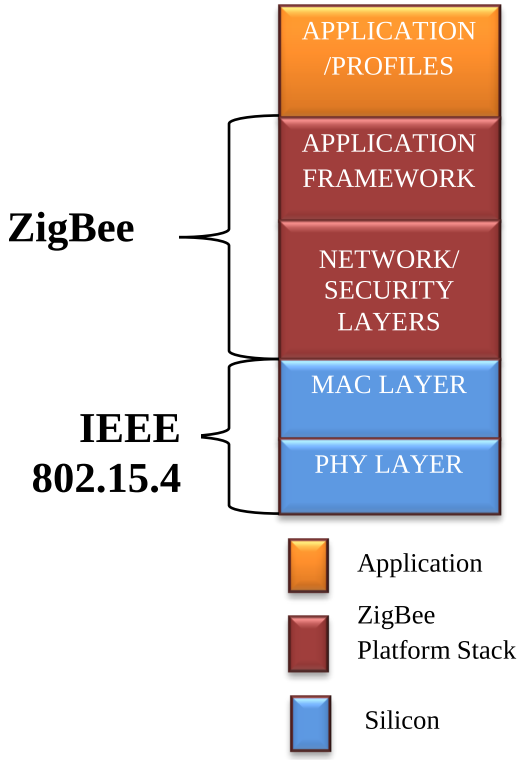

Fig-1: Network layers of IEEE 802.15.4 and ZigBee [4]

The ZigBee standard is implemented on top of the IEEE 802.15.4 Physical and MAC layers. Two more layers which are the Network and Application framework layers are added. The objective of the addition is to enhance the network organization ability and standardize the upper layers of the protocol stack.

2. LITERATURE SURVEY

Huang et al. [5] focus on the use of Timed Petri nets to model the preemption of emergency vehicles system. The advantage of the proposed approach is the clear presentation of traffic lights' behaviors in terms of conditions and events that cause the preemption of phase being changed. The resulting models allow one to identify and thus avoid urgent scenarios in such systems by conditions and events of the model that control the phase of traffic light alternations.

Al Sobky et al. [6] introduce a new application for using smartphones to measure traffic density and speed. The proposed system consists of two smartphones and two cars, with observer to count vehicles between the two cars. This count is utilized with tracking data to give "measured" density and "measured" speed. The travel speed and manual traffic counts were used to derive "calculated" density.

Bo Du et. al. [7] described the optimization scheduling of traffic lights in the actual large urban road network. The IOCAPSO method is proposed as a dynamic and real-time optimization method, which consists of ICM, the fitness function, and OCM. The optimization scheduling by the IOCAPSO method can achieve comprehensive phase scheduling of traffic lights, which includes the timing control, the phase sequence control and the special phase controls for different kinds of traffic problems, such as, IOCA-PSO method is compared with the PSO method and the RANDOM method under different traffic conditions of the Wuhan case.

Yi Sheng Huang et. al. [8] proposed a solution to regulate the problem of traffic congestion. For this purpose, their paper presents a dynamic control methodology. The dynamic traffic control methodology is constructed by the alternation of PIC and ROC sub-models. The two sub-models are successful in describing the dynamic situation. That is the GS can turn off to forbid incoming vehicles. And the GS can turn on when the traffic congestion is released.

Azzedine Boukercheet. al. [9] introduced a dynamic traffic light scheduling algorithm. This algorithm schedules the competing flows at any signalized intersection, to allow the more dense traffic flows to cross the intersection first. The assigned time for each phase is set based on the traffic distribution over its traffic flows. This algorithm is enhanced to handle the appearance of any emergency vehicle.

Abbas et al. [10] introduce a dynamic traffic light phase plan protocol for single-isolated intersections. The developed controlling method was compared with four other methods and showed a good performance in terms of reducing the average and maximum queue lengths, optimizing the given green time amount as needed, and increased the intersection's throughput (increased the given green time utilization).

Collotta et al. [11] propose a novel approach to dynamically manage the traffic lights cycles and phases in an isolated intersection. The target of the work is a system that, comparing with previous solutions, offers improved performance is flexible and can be implemented on off-the-shelf components. The proposed solution is a traffic lights dynamic control system that combines an IEEE 802.15.4 Wireless Sensor Network (WSN) for real-time traffic monitoring with multiple fuzzy logic controllers, one for each phase, that work in parallel.

Calderoni et al. [12]. In This infrastructure it consists of a network of smart cameras operating over an outdoor public lighting thanks to power line communication technology and equipped with a vehicle counting and classification algorithm.

3. RESEARCH METHODOLOGY

In this work a standard four lane traffic will be considered as shown in below figure.

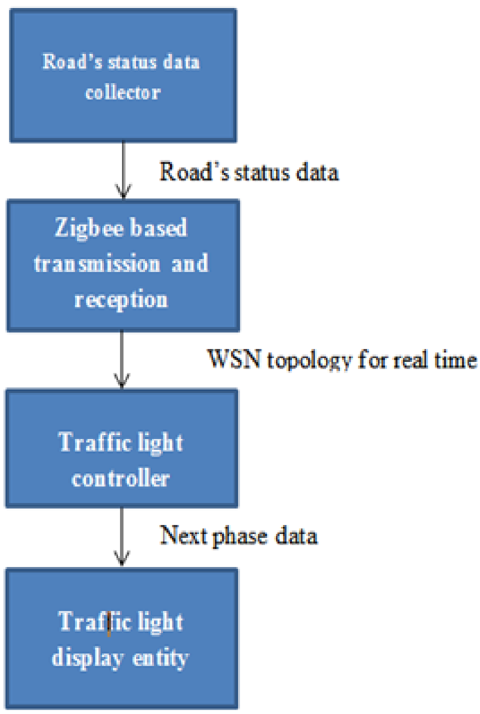

Fig-2: Work methodology

4. PRESENT WORK

4.1 System module for Traffic signal control system

Proposed control system is able to reduce the average waiting time of vehicles while managing the phase sequence, i.e., the time period during which it is possible, for a given set of lanes, to continue following the allowed direction. When dealing with highly crowded roads, it is really important to determine the correct phase sequence to ensure that the phases with the highest number of vehicles in queue will be executed with the highest priority and the longest green time. In this work a multi-controller system is envisaged, that consists of:

- A Wireless Sensor Network (WSN), for real-time traffic data acquisition.
- A Phase Sorting Module, for calculating the phase execution order according to the priority assigned to each phase on the basis of the number of enqueued cars in the lanes related to the specific phase.
- A fuzzy logic controller for each traffic lights phase, for calculating the appropriate green time duration of the relevant phase.

A traffic lights phase is the time period during which it is possible, for a given set of lanes, to continue following the allowed direction. In fixed-cycle traffic lights, each cycle can be approximated to a periodic task with period T, characterized by a fixed green time (Tg)

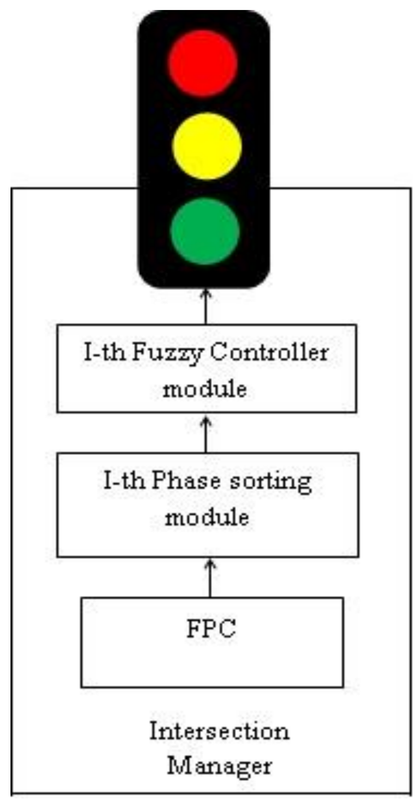

Fig-3: Modules of the intersection manager.

and a fixed yellow time (Ty). For the remaining time, the traffic lights are red (Tr) as described by Eq. (1).

$$T = T_g + T_y + T_r \quad (1)$$

Each lane is monitored by a node in order to detect the presence of vehicles through a magnetic sensor that measures the Earth's magnetic field distortion due to vehicles. The queue length is estimated based on the number of the road subsections in which the presence of cars is detected; therefore the queue length is expressed in terms of the number of enqueued cars. The approach here proposed envisages one fuzzy logic controller for each phase. An alternative design could have adopted a single controller working in a TDMA (Time Division Multiple Access) fashion on the different pairs of input variables corresponding to the different phases. However, the use of four parallel controllers instead of one not only improves fault-tolerance and performance but also flexibility, as it enables to apply phase-specific management. For this reason here one fuzzy logic controller for each phase is adopted to determine the optimal green light duration for that phase.

5. RESULTS AND DISCUSSIONS

This section contains the screenshots of the design and implementation of the proposed systems i.e. traffic light controller and ZIGBEE transceiver system and the experimental results at different steps of the proposed system. The implementation was built on Matlab/Simulink using fundamental components in Simulink to demonstrate how reliably complex modulation schemes can be built, cost effectively and efficiently. Fuzzy logic designer has been designed for selection of green light lane from all four lanes.

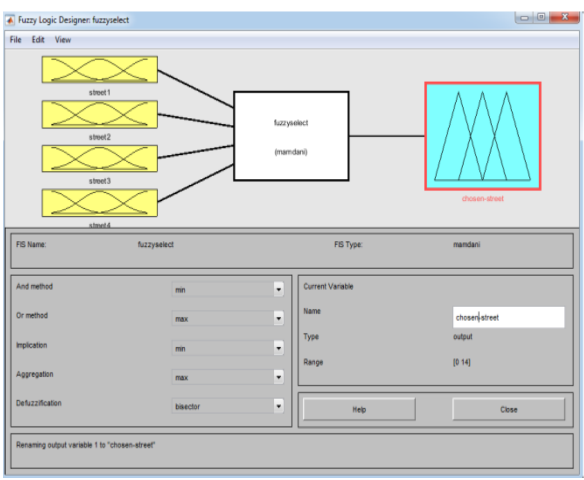

Fig-4: Fuzzy logic designer for lane selection

The membership functions for the output value (green time duration) are three (low, Medium, high). Considering that in current practice the minimum green time should be no shorter than 15 s and no longer than 60 s, the membership functions can be represented as in Figure 5.

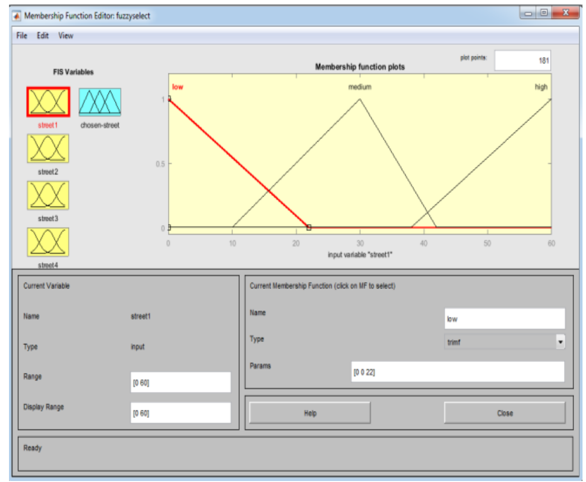

Fig-5: Membership function weightage for street one variable

So, for instance, in the case of Phase 1, Controller 1 will determine the green light duration by processing the queue length of the Lane 1 of Road A and that of the Lane 1 of Road C, respectively. Similarly, Controller 2 will determine the green time duration by processing the queue length of the Lane 1 of Road B and that of the Lane 1 of Road D, and so on. The fuzzy controller works in three steps. During the first step, called fuzzification, the input variables relevant to the two queue length values are converted from their analog value to a crisp value characterized by a certain degree of membership, from 0% to 100.

The second step of our approach is characterized by an inference mechanism through which the fuzzified information is correlated, following a linguistic approach based on the IF-THEN construct. If both the lanes of a phase are congested, i.e., their queue length is LONG, the phase needs the maximum green time duration in order to reduce the queues. On the contrary, if at least one of the two lanes is characterized by a NORMAL queue length, it is not advisable to allot the maximum green time duration to that phase.

The simulation blocks created are shown in fig -6

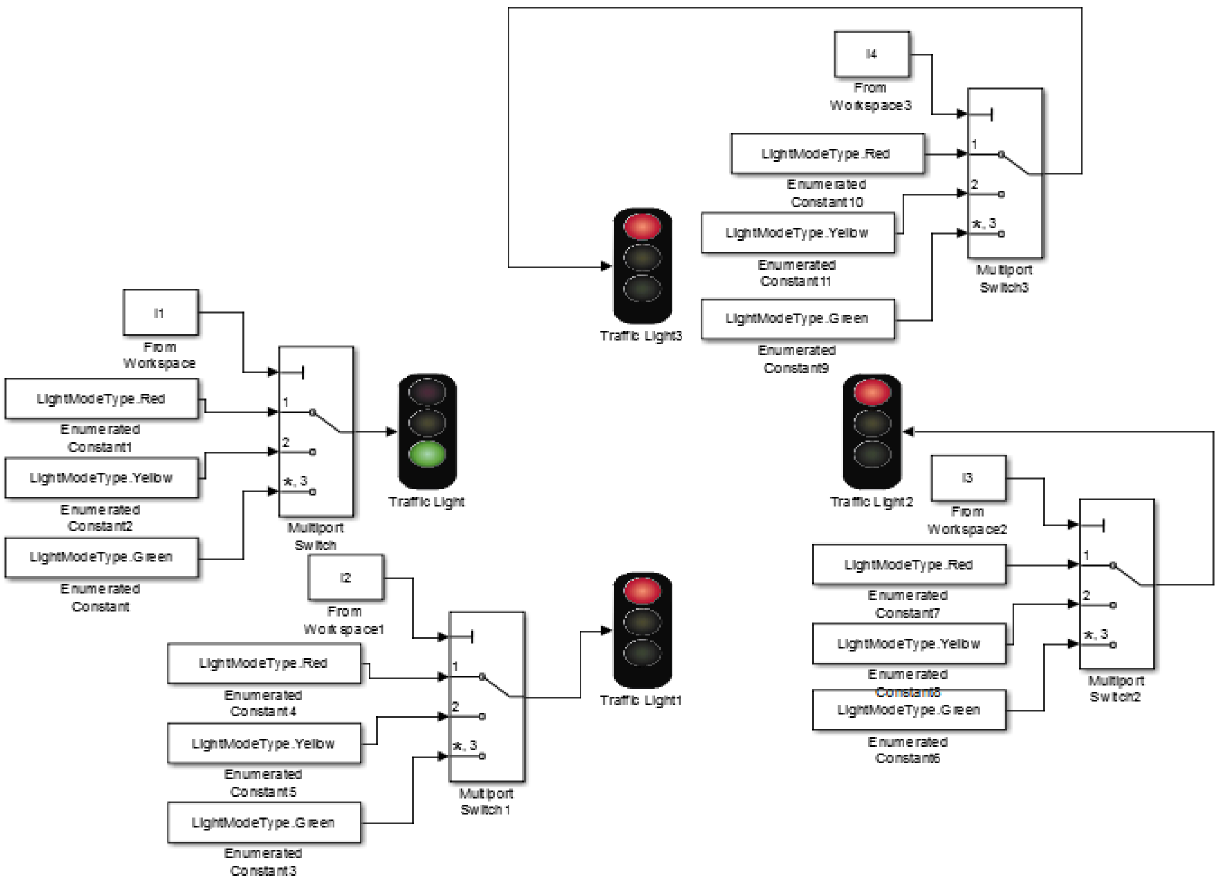

Fig-6: Simulation system for the proposed traffic light controller

After simulate this transceiver model we get the output which is exact as the input except a small amount of delay.

Table 1: Table shows total cars exit from all streets in 40 iterations of traffic light controller

Street Number	1	2	3	4
Total cars exit	120	204	132	216

The car counter has been visualized as under

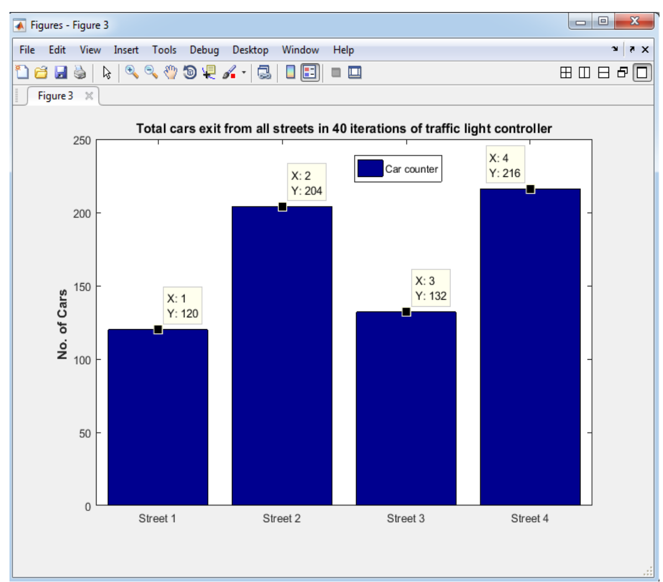

Fig-7: Total cars exit from all streets in 40 iterations of traffic light controller

6. CONCLUSION

With the growing number of vehicles, the phenomenon of traffic congestion has become a predominant problem. Hence it is imperative to improve the safety and efficiency of transportation. An efficient traffic control system can improve traffic flow and offer economic benefits. This is an important issue bearing on traffic light control in road-vehicle systems. Traffic light control systems exhibit a high degree of concurrency and there is the possibility of conflict to cause deadlock and overload. Proposed work addresses the dynamic control of traffic lights in an isolated intersection, i.e., an intersection whose incoming vehicle flows are not affected by the effects of upstream traffic lights. The main performance target here addressed is the reduction of the vehicle average waiting times in the queues. To achieve this goal, the paper proposes a traffic lights dynamic control system that combines an IEEE 802.15.4 Wireless Sensor Network (WSN) for real-time traffic monitoring with multiple fuzzy logic controllers, one for each traffic light phase, for dynamically determining the green time duration of each phase. The challenge here is to design a flexible, scalable and effective system that avoids complex and computationally expensive solutions, which would not be appropriate for the problem at hand and would impair the practical applicability of the approach in real scenarios. The proposed system works in two steps. In the first step , the number of queued vehicles estimated by the nodes of a WSN deployed nearby the traffic lights is sent to the WSN base station. Here, data processing is performed, with a twofold aim i.e. to sort the traffic lights phases according to a priority that depends on the number of queued vehicles and to select the phase to be executed first. In the second step, the green time duration of each selected phase is determined by the relevant fuzzy logic controller that exploits the information about the number of queued vehicles of the selected phase.

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