SCR: a Smart Cross Road Management System Based on IoT

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Abstract
In Smart cities traffic management solutions are addressing more and more problems of urban transportation. The cities expansion and the road infrastructure planning are becoming a serious challenge for governmental planner. The traffic lights control which creates green waves in most arterials is used to reduce traveling time depending on traffic flow.
Nowadays, avoiding congestion, reducing traveling time and budget saving are needed with growing traffic and modern cities expansion. For planners, making adjustments to the road network organization is necessary to improve the traffic flow. All traffic light sequencing, timing, and road network objects placement, have a direct influence on traffic flow and capacity. Road network planning and organization have a direct influence on the economic consequences unforgiving real world testing. That is why it is important to find optimal solutions.
In this paper we dress a study of Traffic Road Management time optimization and control using IoT solutions. We present the vision of the next generation of traffic optimization, where navigation and traffic management are made closer as a highly integrated system, shifting travel diagram in the city.
Keywords:
Traffic Light Automation, Road Management, IoT, Smart City.

1. Introduction:

Smart City is an environment that provides new level of innovation and interactive services for all over the social activities in the urban area such as transport organization, energy saving, health care, monitoring of environment, commerce, business, and emergency responses. In point of view of technologies, Smart City uses information, communication and IoT in an effective and secure manner to access the road physical objects, buildings, as well as city resources status and location. IoT is the network of physical objects that features an IP address for internet connectivity, the communication between these objects and other systems that have internet accessibility. It has major role in smarter urban management for Cities and countries. In smart cities, traffic related problems are controlled by using IoT in right way. Reservation-Based System, Connected and Automated Vehicles and smart parking system are proposed as a part of traffic management using IoT. Sensing and classifying roadway obstacles provide accident free environment and also a smooth drive to the vehicles.

The monitoring of traffic vehicles have been becoming a serious issue in several countries in the world due to population increasing census leading to add new roads and bridges and building several concentric rings around the cities. In addition, they are restricting big vehicles through peak hours. So the necessity for organizing traffic vehicles needs accurate applications that can control and simulate the traffic lights using classical fixed-time, automated controllers and examination of other factors such as waiting time, density and cost.
Developing intelligent transportation systems pass through understanding the road traffic evolution in space and time. Also the interactions between traffic participants and structured elements present in the environment should be considered. Most of existing analysis methods focus on the space in the vicinity of a vehicle [3], or consider road traffic as a collective entity [4]. For a global environmental view, a model which incorporates data gathered at different levels of detail is needed.
However this paper focuses on the traffic management effectiveness evaluation. The output traffic lights control system achieves globally optimal routes and traffic light schedules. We make, in this paper, the following contributions:

- ✓ We envisage a traffic lights system to minimize globally travel time;
- ✓ We conduct a pilot experimental study by simulation to verify the opportunities offered when traffic lights control is used,
- ✓ We identify key research challenges in realizing such system.

The rest of this paper is organized as follow:
A brief literature overview presentation is given in the paragraph three, and in the section four we study the most used traffic lights models proposed in the literature. The study of the crossroad management and control system modeling is given in section five. Simulations and results are discussed in the paragraph six. Then this paper is ended by conclusion, future works and references.

2. Literature overview.

In smart cities traffic related problems are controlled by using IoT in right way. Reservation-based system,

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Connected and Automated Vehicles (CAV) and smart parking system are proposed as a part of traffic management by using IoT. Sensing and classifying roadway obstacles provides accident free environment and also a smooth drive to the vehicles.

We review relevant studies on traffic control systems, Time-dependent navigation optimization. Since more than half of century the traffic flow optimization has been deeply studied starting with the recognized fluid dynamic based traffic flow modeled by Lighthill and Whitham in 1955 [1]. Then it was followed by Traffic modeling such as Biham-Middleton-Levine (BML) model in 1992 [2].

To enhance traffic light control system performances many studies have been done. In [5], E. Brockfeld et al. studied traffic light cycle time effects on network capacity. They show that the optimal cycle time's derivation can be reduced to a single street flow optimization simpler problem, with one traffic light.

Furthermore a study of self-organizing traffic light using multi-agent learning algorithms has been done. In [6], M. Tubaishat et al. achieved an adaptive decentralized traffic light control study through wireless sensor networks.

In other hand, many researchers proposed a traffic light queue behavior model using a queuing theory. The traffic light adaptation leads to the Fixed-Cycle Traffic Light (FCTL) queue model proposed by Beckmann et al. [7]. Since many improvements have been done using Poisson arrivals model [8], general arrivals model [9], etc…

A model which combines theoretical formulas with simulations making it semi-empiric has been proposed by Webster et al. [10]. Therefore the virtual traffic light concept has been proposed in [11, 12].

With the assumption that cars are controlled by agents, a reservation based system for traffic congestion at intersections has been developed by K. Dresner [13]. In [14] he describes an autonomous intersection management system.

A framework was designed for cyber cars by A. de La Fortelle [15]. This work is an improuvement of a previous one that demonstrated the feasibility of such a reservation algorithm.

A reservation-based approach was designed and evaluated by S. Huang [16] and K. Zhang proposes a universal state-based action model [17]. Y. J. Zhang studies minimizing fuel consumption solution [18].

In [19] Y. Geng developed a Stochastic Flow Model (SFM), including roads with finite vehicle capacity.

In a follow-up study, Demiryurek et al. propose in [20] an efficient time-dependent network shortest path algorithm for online path computation. This study did not consider collaborative path optimization among multiple drivers or coordination with traffic lights.

Jeong et al. consider collaborative path optimization and propose a self-adaptive navigation system named SAINT [21]. In this system, a centralized navigation server monitors all navigation requests and traffic conditions reported by drivers. By knowing real-time drivers' trajectories and traffic conditions, the navigation server can predict the traffic condition for the near future, and suggest paths adaptively to the drivers. Coordination with traffic lights is still not considered in this study.

The traffic light controlling is an extensively studied area. Hardware sensors at intersections to detect vehicles and help optimizing traffic light control have been widely deployed. Many recent studies consider detecting vehicles with vehicular ad-hoc networks (VANET). For example, Maram Bani Younes and Ezzedine Boukerche [22] proposed an algorithm for traffic light controlling using VANET. They consider optimizing an individual traffic light based on its surrounding real-time traffic monitored via a VANET. Their simulation study shows that the traffic fluency of a road network can be improved using a coordinated traffic light control algorithm compared with using isolated traffic light control algorithms. This study verifies the potential of traffic optimization via a coordinated traffic light controller system based on real-time traffic.

Kőhler and Strehler [23] take a maximum network flow approach for traffic light optimization. They show that the optimization of traffic lights in order to synchronize with path assignment is NP hard. They focus on traffic light optimization and assume that path assignment has been done independently. They adapt a classic maximum flow algorithm, the maximal dynamic flow algorithm, to solve the optimization problem. Their assumption of fix-time traffic lights is restrictive and loses optimization opportunities to vary duration of a traffic light. How to optimize traffic lights and navigation together remains unexplored.

In summary the studies above show the potentials in traffic optimization via optimizing navigation and traffic light controls independently. They have not make use of the optimization opportunities arise from unifying navigation and traffic light control together. To realize such a unified system, a blocking issue is the unpredictable nature of human drivers' behaviors. An optimization made based on a certain navigation assignment may be invalidated by drivers deviating from the assigned paths. In the forthcoming era of self-driving cars, we envisage that this may not be an issue any more, or has been much alleviated and becomes manageable. There are still open challenges to be addressed for a unified traffic optimization system. For example, navigation instructions and traffic conditions need to be communicated between the traffic optimization system and all cars on road in real time. This will create a high volume of network communication data. Further, coordinating all cars and traffic lights will be computationally expensive. These challenges bring research opportunities to communities in the areas of spatial-temporal data management, computer networks, transportations, etc. We detail them in Section 4.

3. Cross Road Traffic light Modeling:

In this section, we focus on the modeling techniques cited in the literature. Some researchers propose a model based on graph theory, some others used the queuing theory or Numerical and Simulation Models. The probabilistic and graphical models were used like Bayesian Networks for vehicle environment modeling [24].
Another category of research is based on object oriented models [25]. The classify road objects into different classes without defining spatial relations between them. There are other models based on graph theory present in the literature, as in [26, 27]. These models take into consideration vehicles information and road lanes but they don't consider other types of objects in the road network.

3.1 Modeling Using Graph Theory,

Graph theory model is qualitative. It aims to understand urban spatial evolution of road traffic. The definition of this kind of models take in consideration various objects which affect the traffic flow and the spatial relations between them. The model input consists of many different data type and qualitative knowledge at microscopic and macroscopic levels. The use of quantitative data improves the model robustness. Mathematical graphs formalization at different levels of granularity is introduced on [35].

3.2 Queuing theory modeling,

Road traffic flow is considered as queueing networks and modeled as servers. With the assumption of exponential service times, Poisson arrivals and preemptive-resume polling the FIFO exponential polling and priority are analyzed. The distribution of queue length is analyzed for each serving discipline, and for all models except the green wave priority polling with low priority for the green wave. The individual queue length distributions expressions are derived. [34].

3.3 Numerical Simulation Models,

Any road network and traffic flow can be subject of simulation. Running a simulation model for any given time leads to a signal lights optimum timing. The simulation actuates data traffic for the computation. It checks for each iteration the demand of number of vehicles available for any direction and computes the signal light timing based on that real time demand. Therefore the simulation adopts an on time traffic signal light adjustments. The flow patterns can be improved to avoid congesting junctions according to future predicted flow patterns. The vehicle flow patterns can be defined as distributions and using an hourly flow can be given as either a constant value or a stochastic one. It helps to input current traffic flow patterns in a realistic way [28].
The literature contains many traffic simulation models which analyses the single junction signal light timing. Most available multi-junction models use traffic flow patterns single numbers. Developed simulation templates overcome both of these barriers [29].

3.4 Algebraic Modeling.

The Algebraic model is based on the macroscopic first order model, with triangular fundamental diagrams. The dynamics of vehicle pelotons moving through road sections is described in [1, 30]. It assumes that only pelotons are observed. Moreover, the density of pelotons is considered to be binary, in the sense that, at a given time, the density on a given section is equal to 1 if any peloton of vehicles is moving on, and it is equal to zero otherwise. This microscopic representation of the traffic dynamics is convenient to describe the traffic in urban networks.
In [31] Nadir Farhi et al. present two models. The first one describes the traffic inflowing to and out-flowing from an intersection with two entry roads and two exit roads where one of the entry roads has priority with respect to the other one. The second model considers that the intersection is controlled with a traffic light, see fig. 1.

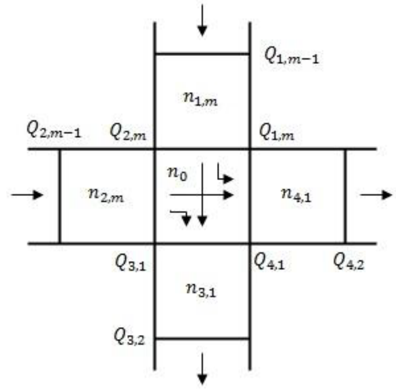

Fig. 1 Intersection model with a priority rule.

3.5 Traffic Modeling based on SUMO simulator.

SUMO traffic simulator uses two Intelligent Transportation Systems solutions. It uses the combined Traffic Signal Control Strategy effects (TSC) and Variable Message Sign (VMS) evaluation. Macroscopic flow variables are used for dynamic selection strategy. TSC and VMS are tested through microscopic approach. The main focus of this simulation is based on reference to fuel consumption estimations and pollutant emissions [32].

3.6 Fuzzy Logic modeling.

Traffic signal control is a measure used to minimize vehicular traveling times and delays. All signal timing parameters are calculated and kept constant for fixed time control using historical traffic data. Fuzzy logic allows qualitative and quantitative modeling of complex systems. It is widely used to develop adaptive traffic signal controller. Many researchers used fuzzy logic for analyzing traffic signal control systems [33].

4. Smart Cross Road Management and Control System Modeling and simulations:

Dynamic Cross Road Management is one of the major pre-occupation of urban and governmental decision-makers. Nowadays most cities are dressing policy statements highlighting the importance of road congestion and crowding.

Due to the recent development and sensors multi-functionalities, WSNs are utilized for a wide variety of applications. Environment monitoring, building surveillance, traffic flow managing are privileged area of applications. Moreover, WSNs can provide high capacity of gathering information.

In the other hand, the traffic flow control in big cities becomes a serious problem for decision makers. The traffic congestion is the main source of losing time and energy, especially in rush hours.

Traffic flow in urban cities is highly affected by road management systems. When traffic control system fails road management, drivers' loose time and waste energy. A smart traffic lights controller can save money and human life.

We focus on the new technologies increasing such as communication and sensor networks, as well as the use of more sophisticated algorithms for setting smart traffic lights controller.

SCR, as a smart control system traffic road, improves cars fluidity and optimizes the average waiting time of vehicles in road network. Thus, the crossroad will have a smartness behavior and will be able to take decision according to the number of vehicles in each side.

The smart traffic light measures the queue length and decides which lanes are to be put and for how long time it will kept on green.

This system manages the vehicles queue and assigns green light time in each side of crossroad proportional to the size of waiting vehicles queue. Moreover, it can synchronize many crossroads to avoid long time waiting green light and then saving energy and time. It can also prevent accidents and facilitate emergency in that case. Fig. 2 presents both crossroad with and without sensors' detection.

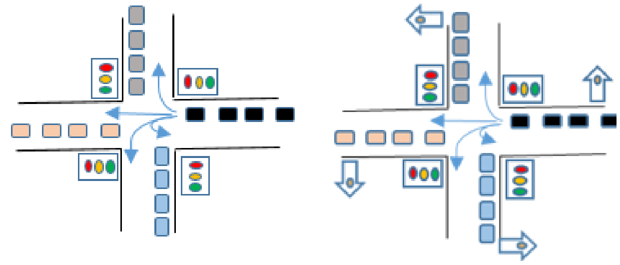

Fig. 2 Crossroad with and without sensor detection.

5. Simulation and results discussion:

A road green light timing experiment based on dynamic queuing state is done using simulations. It consists of an extendible framework that is formed by crossroad and car objects. Each crossroad has four incoming queues and four outgoing queues each for a road: North, South, West and East. The incoming queue North, South, West, East roads respectively is the outgoing queue South, North, East, and West respectively of the neighbor crossroad in the South, North, East, and West.

The sensors in the smart traffic light count the number of cars in each queue waiting to cross the crossroad which gives the length of the queue. The lanes are put on green in an anticlockwise. The time spent on green for each lane depends on the ratio of the number of cars that are waiting in this lane upon the number of all cars that are waiting to cross the crossroad. To reduce the starvation phenomena, a threshold time is set which cannot be exceeded.

The simulation has the following components:

a. The car:

The car class in Fig. 3 has a speed, location in the road, a source and destination crossroads, waiting time, current crossroad, a Boolean that is used to track the car, and a carKind that is used now to either keep the car always in the system or not. It may be used later to distinguish between cars that need specific processing (ambulance, police car, truck).

```
struct car
        {
                int speed;
                int carID;
                int carKind; // neverQuitCar or
canQuitCar (used only for raodMap)
                int currentSpeed;
                int location; // to headed
Crossroads
                struct crCoord current;
                struct crCoord destination;
                bool TRACK;
                //***********statistics
                long int waitingTime;
                int perCrossWaitingTime;
                int CrossroadsNbr;
                struct car *next;
        };
```

Fig. 3 Car class

b. The road:

A class Route Fig. 4 is simulating the road that is maintaining some parameters like the maximum number of cars it can have, the current number of cars it contains, the distance, the number of cars that are waiting to go over a crossroad, and the maximum speed allowed in this road. It also contains a Boolean that indicates if this road is an end route so any car that reaches this road gets out of the system. This road is a queue of cars that is manipulated by two functions such as carIn() and carOut().

```
    class Route
    {
    public:
        int numberOfCars;
        int maxNumberOfCars;
        int distance;
        int fromCrossroad;
        int toCrossroad;
        int waitToCross;
        int maxSpeed;
        bool endRoute;

        struct car *route, *head, *tail;

    public:
        Route (int fI, int fJ, int tI, int tJ, int
dist, int mxC);
        Route ();
        Route (bool endroute);
        void carIn(car *c, int speed);
        void Route::carIn(car *c, int speed, int
distance);
        car *carOut();
```

Fig. 4 Route Class

c. The crossroad:

The crossroad given in Fig. 5 has a light status that gives which is on green, the light time which is set to the number of cars that can cross when it is green. This time is depending on the total number of cars waiting to cross in all roads getting to the crossroad. To not get a starvation a maximum total light time is set. In the peak time (rush hours), when all roads are crowded, this process is leading the normal traffic light functionalities.
The crossroad is attached to eight roads four incoming from and four outgoing to North, West, South, and East neighbor crossroads' roads.

```
class Crossroads
{
private:
        int light [4];
        int lightTime [4];
        int maxTotalLightTime;
        int minTotalLightTime;
public:
        Route *NI, *SI, *WI, *EI, *NO, *SO, *WO,
*EO;
        Crossroads(Route *Ni, Route *Si, Route
       *Wi, Route *Ei, Route *No, Route *So,
                   Route *Wo, Route *Eo, int
         maxTLTime=100, int startLight=0);
        Crossroads();
        void greenLight();

        void setRoutes(Route *Ni, Route *Si, Route
*Wi, Route *Ei, Route *No, Route *So, Route *Wo,
Route *Eo);
        void track(int id, int i, int j,char *s,
char *d);

};
```

Fig. 5 Crossroad Class

This system can be formed by a simple main road with two crossroads until a city with NxM crossroads. The cars can be sent from all the incoming roads getting into the city. To maintain the traffic running for a longtime and get trusted results some cars can be specified as never leave the system. These latter, as soon as they are in end route, they make a U-turn and get in the system again.
The number of cars going over the crossroad is divided in four with a set of probabilities for going U-turn: pu, going Straight: ps, going Left: pl, and going Right: pr where pu+ps+pl+pr = 1.
We start with only one main bidirectional street that connects two crossroads like it is shown in Fig. 6; we send cars from West to East in peak time while cars are getting in the system from other directions in very less frequency. There are two types of cars: those getting in the system and never leave and those getting into system and leaving. These latter, are used to measure the performance of our

proposed solution. We check the impact introduced in the entire system and compare it with the normal system using equal scheduled time.

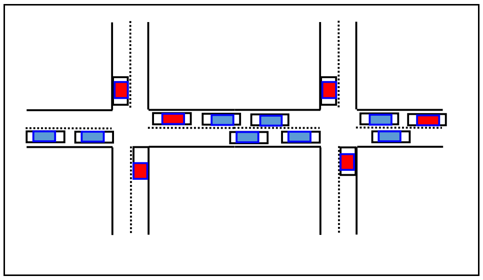

Fig. 6 Traffic between two crossroads

We send cars from one side (say from left to right) the total waiting time is zero in all crossroads as all other roads are not given the chance to have the green light unless those returning back from the second crossroad reach the first before all initial cars cross it. If the number of sent cars is N, pu1, ps1, pl1, pr1 are the probabilities of the directions while going over the first crossroad and pu2, ps2, pl2, pr2 are those while going over the second crossroad then Table 1 summarizes the traffic between the two crossroads.

Table 1: Traffic between two crossroads

N: total number of cars
p_{u1*}N: number of cars making U-turn and leaving the system
p_{l1*}N: number of cars turning left and leaving the system
p_{r1*}N: number of cars turning right and leaving the system
p_{s1*}N: number of cars getting strait to the second crossroad
$p_{u2*}p_{s1*}$N: number of cars making U-turn in the second crossroad and returning back to the first crossroad etc
p_{l2*} p_{s1*}N: number of cars turning left in the second crossroad and leaving the system
p_{r2*} p_{s1*}N: number of cars turning right in the second crossroad and leaving the system
p_{s2*} p_{s1*}N: number of cars getting strait in the second crossroad and leaving the system

We define idle time IT as the time spent in the crossroad without any traffic crossing while there are some cars waiting to cross. In our proposed solution the idle time is always zero while in normal traffic system, where the cross time given to all is the same, IT for one green light round is given in the equation 1.

$$IT = 4*C - (C_N+C_W+C_S+C_E) \quad (1)$$

For simplicity we consider that in a unit of time only one car can cross and then we use number of cars to measure the time. In the equation 1, C is the number of cars that can cross when the green light is on in one lane in a normal traffic system, CN, CW, CS, CE, are the number of cars going over the crossroad in all directions North, West, South, and East respectively. IT is part of the cross delay (CD) which is the time a car is waiting to cross. In case where the number of cars waiting to cross are less or equal to the maximum number of cars that can cross in the time allowed to cross in normal traffic management, the cross delay of our proposed solution CDP is given in the equation 2.

$$CD_P = CD_N - IT \quad (2)$$

Where CD_N is the Corss Delay in normal traffic system for a crossroad.

Fig. 7 gives the number of cars waiting to go over the crossroads CR1 and CR2 when initially 100 non-leave cars are sent in each of them. These counts are taken in different 5 instances while the system is running. The fact that the total number of cars in both crossroads is not generally equal to the total cars in the system returns to the fact that the cars that are leaving the crossroad may not be waiting to cross in the other crossroad.

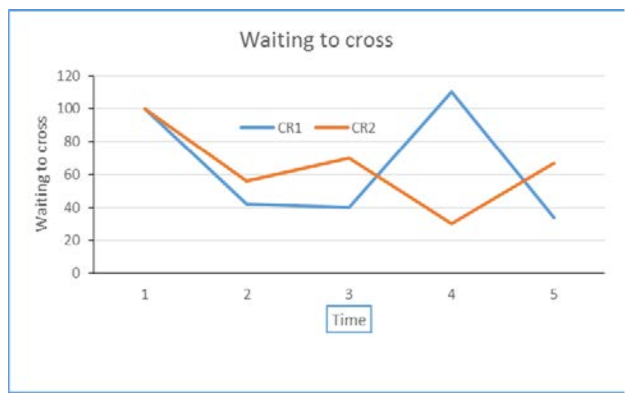

Fig. 7 Number of cars waiting to cross

Initializing the system with non-leaving cars will give the random aspect of the traffic which brings the results close to reality.

Fig. 8 presents the architecture for a small city 4x8 crossroads. Our experiments are conducted with different cities' and different traffic's sizes.

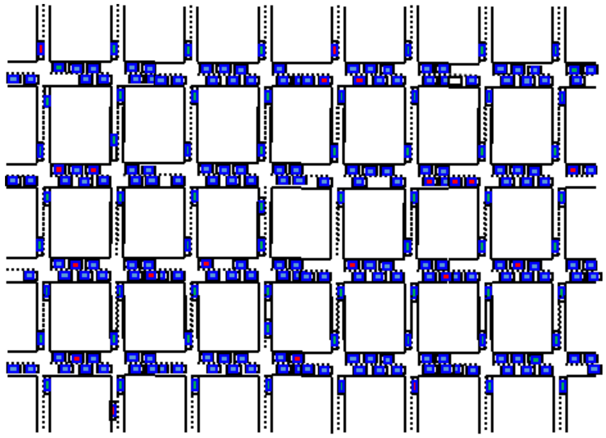

Fig. 8 City 4x8 traffic

In the experiments we measure the total delay for a car to cross different crossroads from source to destination, the average delay caused by the traffic over the city, and the idle time that is wasted in normal traffic system. All these are done for different city sizes. Fig. 9 gives the average car delay (ACD) in each of 4 chosen crossroads with different traffic sizes.

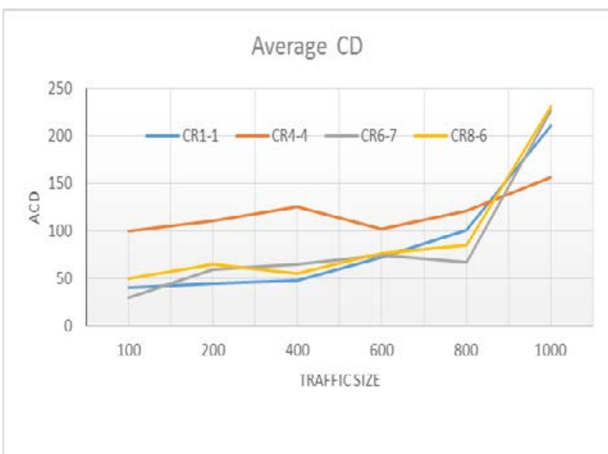

Fig. 9 Average car delay in some crossroads

Fig 10. presents a comparison between the average CD of the 4 crossroad chosen in Fig. 9 and the calculated CDP in the normal traffic management in worst case (CDNW) where the car arrives in the big interval just while the light is going to red and in the average (CDNA) when the car arrives in the mid time of all the cycle. In all cases, our proposed technique outperforms the normal traffic light management. However, in some rare cases, when the system is overloaded, a car may come to the crossroad slightly after the system counts the proportions and then be delayed while in the normal case it can cross in the idle time.

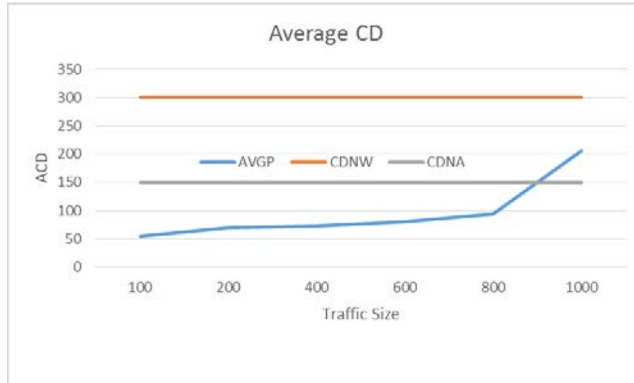

Fig. 10 ACDP vs CDN

6. Conclusion:

We proposed a new traffic management system based on IoT using sensors communications that detect the number of cars getting into a road and communicate the information to the headed crossroad system. The traffic light switch depends on the proportion of the number of cars waiting to cross in the different roads getting into the crossroad. To eliminate the possibility of starvation a maximum time is given to each lane. In case of traffic peak in all directions (rush hours), our proposed system will act like a normal traffic light system as all lanes will be given the same maximum time. Our experiments results show that in all cases our proposed system outperform the normal traffic management system. The main gain comes from the fact that there is no idle time in our proposed system. In the future work, we will concentrate on adding the communication between the crossroads using Ad-Hoc networks to prevent the bottleneck which may result to huge delay.

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References.

[1] Lighthill, M.J. and Whitham, G.B. (1955), A Theory of Traffic Flow on Long Crowded Roads. Proceedings of the Royal Society of London A, 229, 317-345. http://dx.doi.org/10.1098/rspa.1955.0089.

[2] Middleton, Alan; Biham, Ofer; and Levine, Dov, "Self Organization and a Dynamical Transition in Traffic Flow Models" (1992). Physics. Paper 208. http://surface.syr.edu/phy/208

[3] Karl Granstrom, Marcus Baum, Stephan Reuter, Extended Object Tracking: Introduction, Overview and Applications,

Journal of Advances in Information Fusion, Volume 12, Number 2, Pages 139-174, December 2016, ISSN 1557-6418.

[4] LiLi and All, Expanding the role of reactive transport models in critical zone processes, Earth-Science Reviews, Volume 165, February 2017, Pages 280-301. https://doi.org/10.1016/j.earscirev.2016.09.001

[5] E. Brockfeld, R. Barlovic, A. Schadschneider, and M. Schreckenberg. Optimizing traffic lights in a cellular automaton model for city traffic. Phys. Rev. E, 64:056132–1–056132–12, Oct 2001.

[6] M. Tubaishat, Y. Shang, and H. Shi. Adaptive traffic light control with wireless sensor networks. In Consumer Communications and Networking Conference, 2007. CCNC 2007. 4th IEEE, pages 187 –191, jan. 2007.

[7] M. J. Beckmann, C. McGuire, and C. Winsten. Studies in the economics of transportation. Yale University Press, 1956.

[8] H. Mine and K. Ohno. Traffic light queues as a generalization to queueing theory. Journal of Applied Probability, 8(3):480–493, 1971.

[9] G. F. Newell. Approximation methods for queues with application to the fixed-cycle traffic light. SIAM Review, 7(2):223–240, Apr. 1965.

[10] F. Webster. Traffic signal settings. Tech. Paper 39, Road Research Lab, H.M.S.O., London, UK, 1958.

[11] O. Tonguz. Biologically inspired solutions to fundamental transportation problems. Communications Magazine, IEEE, 49(11):106 –115, november 2011.

[12] M. Ferreira, O. Tonguz, R. Fernandes, H. Conceicao, and W. Viriyasitavat. Methods and systems for coordinating vehicular traffic using in-vehicle traffic control signals enabled by vehicle-to-vehicle communications, Patent WO 2012/009620, January 2012.

[13] K. Dresner and P. Stone, "Multiagent traffic management: A reservation based intersection control mechanism" in Proc. 3rd Int. Joint Conf. Auto. Agents Multiagents Syst., 2004, pp. 530-537.

[14] K. Dresner and P. Stone, "A multiagent approach to autonomous intersection management," J. Artif. Intell. Res., vol. 31, pp. 591656, Mar. 2008.

[15] A. de La Fortelle, "Analysis of reservation algorithms for cooperative planning at intersections," in Proc. 13th Int. IEEE Conf. Intell. Transp. Syst., Sep. 2010, pp. 445-449.

[16] S. Huang, A. W. Sadek, and Y. Zhao, "Assessing the mobility and environmental benets of reservation-based intelligent intersections using an integrated Simulator," IEEE Trans. Intell. Transp. Syst., vol. 13, no. 3, pp. 1201-1214, Sep. 2012.

[17] K. Zhang, A. de La Fortelle, D. Zhang, and X. Wu, "Analysis and modelled design of one state-driven autonomous passing-through algorithm for driverless vehicles at intersections," in Proc. IEEE 16th Int. Conf. Comput. Sci. Eng., Dec. 2013, pp. 751-757.

[18].Y. J. Zhang, A. A. Malikopoulos, and C. G. Cassandras, "Optimal control and coordination of connected and automated vehicles at urban traffic intersections," in Proc. Amer. Control Conf., 2016.

[19].Y. Geng and C. G. Cassandras, "Multi-intersection traffic light control with blocking," J. Discrete Event Dyn. Syst., vol. 25, N. 12, pp. 730, Jun. 2015.

[20] Ugur Demiryurek, Farnoush Banaei-Kashani, Cyrus Shahabi and Anand Ranganathan. Online Computation of Fastest Path in Time-dependent Spatial Networks. In International Symposium on Spatial and Temporal Databases SSTD 2011 pp 92-111

[21] Jaehoon Jeong, Hohyeon Jeong, Eunseok Lee, Tae (Tom) Oh, and David H.C. Du. SAINT: Self-Adaptive Interactive Navigation Tool for Cloud-Based Vehicular Traffic Optimization. IEEE TVT 65, 6 (2016), pp:4053–4067.

[22] Maram Bani Younes and Azzedine Boukerche. Intelligent Traffic Light Controlling Algorithms Using Vehicular Networks. Transactions on Vehicular Technology IEEE TVT Vol. 65, Num. 8, pp: 5887–5899. 2016. ISSN: 0018-9545, URL: http: //ieeexplore.ieee.org/xpl/mostRecentIssue.jsp?punumber=25.

[23] Ekkehard Köhler, Martin Strehler. Traffic signal optimization using cyclically expanded networks. Networks International Journal Vol: 65, Issue: 3 (2015), pp: 244–261. https://doi.org/10.1002/net.21601.

[24] Kuhnt F., Kohlhaas R., Schamm T., Zöllner J. M. (2015). Towards a unified traffic situation estimation model—street-dependent behaviour and motion models. In Information fusion (fusion), 2015 18th international conference on,p.1223–1229.

[25] Rieken J., Matthaei R., Maurer M. (2015). Toward perception-driven urban environment modeling for automated road vehicles. IEEE 18th international conference on Intelligent transportation systems (itsc), 2015, p. 731-738.

[26] Ulbrich S., Nothdurft T., Maurer M., Hecker P. (2014). Graph-based context representation, environment modeling and information aggregation for automated driving. In Intelligent vehicles symposium proceedings, 2014 ieee, p. 541–547.

[27] Knaup J., Homeier K. (2010). Roadgraph-graph based environmental modelling and functionin dependent situation analysis for driver assistance systems. In 13th international ieee conference Intelligent transportation systems (itsc), 2010, p. 428-432.

[28] Kasun N. Hewage Janaka Y. Ruwanpura. Optimazation of traffic signal light timing using Simulation, Proceedings of the 2004 Winter Simulation Conference, Pages 1428-1436 ISBN:0-7803-8786-4.

[29] G. Brettia, R. Natalini, B. Piccoli. Numerical algorithms for simulations of a traffic model on road networks. Journal of Computational and Applied Mathematics Vol: 210, pp: 71-77, 2007, www.elsevier.com/locate/cam.

[30] Richards, P. I. Shockwaves on the highway. Operations Research, 1956.

[31] Nadir Farhi, Habib Haj-Salem, Jean-Patrick Lebacque An algebraic approach for modeling and simulation of road traffic networks, 2014, arXiv:1406.6929v1 [math.OC].

[32] Stefano de Luca, Roberta Di Pace, Silvio Memoli, Luigi Pariota. Matching macro-and micro-scopic approaches for the evaluation of traffic management impacts. IEEE International Conference on Environment and Electrical Engineering and IEEE Industrial and Commercial Power Systems Europe (EEEIC / I&CPS Europe) 2017.

[33] Rahib H. Abiyev, Mohammad Ma'aitah, Bengi Sonyel Fuzzy Logic Traffic Lights Control (FLTLC), 9th

International Conference on Education Technology and Computers Pages 233-238, Barcelona, Spain, December 20 - 22, 2017, ISBN: 978-1-4503-5435-6.
[34] Sebastiaan Vermeulen, Modeling road traffic flow with queueing theory, July 15, 2016, http://www.science.uva.nl/math
[35] Kamaldeep Singh Oberoi, Géraldine Del Mondo, Yohan Dupuis, Pascal Vasseur. Spatial Modeling of Urban Road Traffic Using Graph Theory. Spatial Analysis and GEOmatics, Nov 2017, Rouen, France. <hal-01643369>.

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