

Study on Static and Dynamic Traffic Control Systems

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Abstract: The purpose of this paper is to study different types of traffic control systems in the vehicle atomic network (VANET). Several attempts have been made to improve the efficiency of the Traffic Control System (TCS) over the last few years. Traffic pollution in urban networks adversely affects economic, environmental and quality of life. Consequently, extensive analysis has been conducted to generate each-action through traffic-based operating routes. These techniques are intended to provide automated regulations of traffic through different regulatory approaches. Our study focuses on both static and dynamic traffic control systems.

Keywords: Traffic control system, Adaptive traffic control system, Congestion.

I. INTRODUCTION

Expanding urbanization and congestion in traffic creates many problems in day to day life. So our Traffic Control System (or) Transportation System works with higher performance and maximum efficiency. Congestion in traffic has been creating numerous discriminating issues and difficulties in many modern countries and urban cities. Congestion means lost time, missing opportunities and barriers. As traffic volume continues to expand, the road gets extra and additional incomplete. Traffic signal management is one of the most well-known cost-effective measures for managing this problem. Traction signal reminder and coordination of existing signals have been proven to achieve significant reductions in traffic delays, thereby expanding and expanding the periods of brooding sink, travel time and extensive security.

II. TYPES OF TRAFFIC CONTROL SYSTEM (TCS)

There are two types of signalization present in the traffic control system. First type of signal is Static traffic control system and the second type is Dynamic signal Control system. The Fig.1 shows how the traffic signal types are grouped.

III. STATIC TRAFFIC CONTROL SYSTEM

The static traffic control system (TCS) is split into four types

1. Pre-timed signaling
2. Solid state Pre-timed signaling
3. Pre-timed actuated Signaling
4. Webster Method

A. Pre-timed signaling

The operation of the signal control system [5] may be coordinated before the vehicles can be stopped or sanctioned without the realization of a predetermined "fixed cycle" length and "division between different methods of ore." Vehicle demand. With the setting of the signal reference unit shown, the signal's time-connection is also pre-selected for typical signals. Any of these features can be changed according to specific needs.

In the previous time signal control system [5] operation, the signal system range is controlled by the signal policy, the request of the frame signal interval. The amount of time each given a break in a signal arrangement is specified by a temporary order setup. Determined locally or remotely by the start time and / or signal plan programs in the specific temporary order and / or the end time of the clock or equivalent device.

Traffic volumes may use pre-timed control [5] at broken crossing points in unexpected places. Alternatively, the establishment should soon be provided with neighboring divisions.

The simplest type of signalization is pre-timed control [5]. In pre-timed signal control, the cycle length, stages, and non-adaptive times and spaces are all in advance to modify. This defined cycle is updated in cycle length, phase, and unprecedented times, and temporarily adjusts the stationary request. About Controller Instrumentation, some preemptive timing models can be used. Multi-dial controllers have distinct timing plans that are released from time to time in the preceding days. For example, three-dial controllers typically have different signal timing arrangements for AM, Off-Crest, and PM conditions.

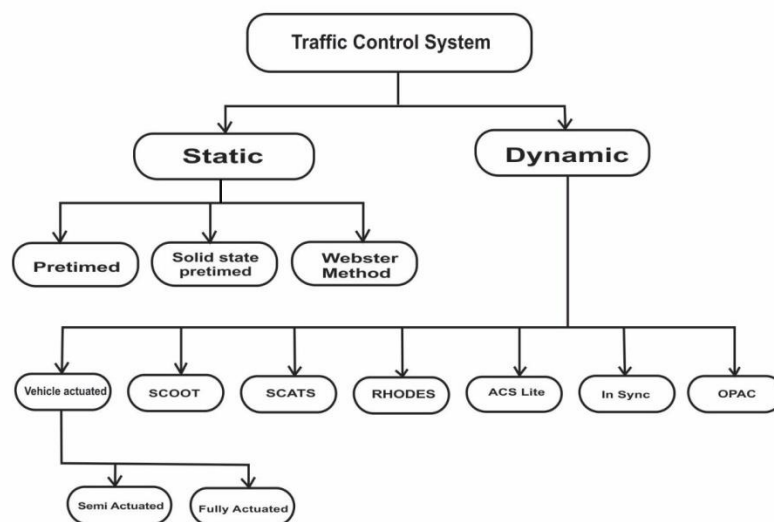


Fig.1 Types of Traffic Control System

B. Solid-state Pre-timed Control

In the early 1980s, the producers began releasing early time controllers in view of solid state circuits. Dial motors and cam shafts of electromechanical controllers have been replaced with software-driven

devices. Timings are specialized by the use of time settings set in time. Cam shafts are cut with signal arrangements in prom chips. Fresher models of the controllers will not bother that the program is sold. The required efficiencies of electromechanical have been copied, but this is done digitally. Many additional features like Additional time arrangements, signal plans and detention recognition capabilities are included. Solid-state pre-time controllers are not suitable for manufacturers.

C. Pre-timed actuated control

The front-controlled control [5] uses the same controller as shown in the first section, which can wire in the hardware control of the vehicle intensity. Identification methods include the controller in the most indicated portion until a vehicle is detected. This type of operation is a central point to allow the controller to adhere to the green condition and be the largest in the primary street. Any disadvantage controller should complete the flag break and do not effectively allow time to break up. Solid-state controllers, traffic control plans In addition, the world's time arrangements are gradually adjusted in the city, no doubt beyond the brands, almost fully controlled controller.

D. Webster Method

Webster Method [18] is designed for the simplest pre-timed signal control. He conducted an experiment about the pre-timed isolated control in 1950's. From this strategy he designed two phases, which was the signal phase and, the split phase. He proved that Webster method minimizes the delay. The system should have critical phase timings and equal degree of saturation. The Webster method derived two equations, one was for cycle length shown in Eq.(1) and another one was delay equation shown in Eq. (2).

$$C_0 = \frac{1.5L+5}{1-Y} \quad (1)$$

Where,

C_0 - Optimum minimum cycle length.

L - Total lost time within the cycle

Y - Sum of critical phase flow ration

The Delay Equation is given by

$$d = \frac{d(1-\lambda)^2}{2(1-\lambda x)} + \frac{x^2}{2q(1-x)} - 0.65 \left(\frac{c}{q^2} \right)^{\frac{1}{3}} x^{(2+5\lambda)} \quad (2)$$

Where,

d – Average Delay per vehicle for particular lane or one iteration

c – Cycle Length in seconds

q – Flow vehicles in Seconds

λ – Proportion of the effective green with respect to cycle length

x – Degree of the saturation

IV. DYNAMIC TRAFFIC CONTROL SYSTEM

Dynamic Traffic Control System [25] tracks the rate of traffic every second, which makes the traffic rate easier to receive and changes traffic timing according to the traffic rate. Dynamic traffic signal control is also called positive traffic signal control.

V. ADAPTIVE TRAFFIC SIGNAL CONTROL

The fig.2. shows that Adaptive Traffic System works. It sensors the vehicle rate used by sensors. According to the trajectory, the traffic system naturally assesses timing arrangement, split, queue assessment and phase optimization.

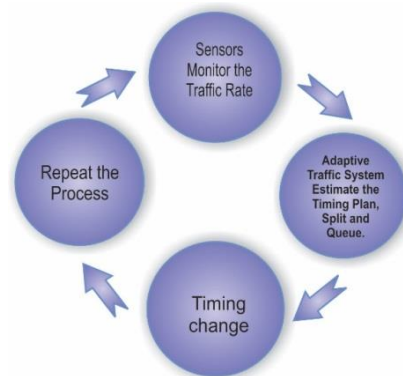


Fig.2. Working of Adaptive Traffic Signal Control

Off chance, when the traffic rate is high, then the system cycle timing increases. Traffic signal control [1] [4] [10] techniques adjust traffic signal according to traffic rate. The Benefits of the Adaptive Traffic Control Systems are:

- Automatically adjust to sudden changes in traffic conditions.
- Improve time period dependableness.
- Reduce the traffic congestion and fuel utilization.
- Prolong the viability of stoplight timing arrangements of action.
- Make stoplight operations proactive by watching and reacting to crevices

A. Working Methodology of Adaptive Traffic control System

By collecting the data from the sensors to optimize a green signal timing settings, Adaptive signal control [1] [4] [10] innovations can focus when and to what extent lights ought to be green. Adaptive Signal Controls Technologies helps to enhance the QoS (Quality of Service) that explorers encounter on our neighborhood streets and highway roads.

The procedure is simple. To begin with, traffic sensors gather the data. Next, traffic data was assessed and signal timing arrangement improvements were developed. At long last, the adaptive signal management innovation actualized signal worldly request upgrades. The strategy was perpetual every jiffy to finish what had been started streaming swimmingly. Traditional signal re-timing would possibly solely repeat this method each three to five years.

B. Need of Adaptive Signal Control Technologies

- Adaptive sign control technology [1] [4] [10] conveyedan enhanced Quality of Service (QoS) to road users. Obsolete stoplight timing arrangement of action without further ado represented more than 10% of all activity delays. Average, adaptive signal management

advancements improved the period of time by more than 10%. In areas with significantly obsolete signal temporal arrangement, an enhancement was 50% or a lot of.

- Adaptive signal management technologies conjointly react to surprising events, like crashes and special events. By adjusting stoplight temporal arrangement in period to replicate actual conditions on the road, travelers relished an additional reliable trip.
- By determination traffic issues as they occurred, adaptive signal management will scale back the traveler's complaints. Adaptive signal management technology may be a proactive step that signal operators will fancily improve the services.
- Adaptive Traffic signal control technologies [16] provide value.
 - The cost of congestion and delay to road user area unit substantial and adaptive signal management technology delivered advantages to users the way outweigh its value.
 - Adaptive signal management technologies are valuable to signal operators. By enlarging the effect of lightweight temporary setup schemes, direct savings by manually reducing the frequency of recurrence signals by enforcing positive signal management technologies.

C. Adaptive Traffic signal control Technologies

- Vehicle Actuated Method
 - Semi Actuated
 - Fully Actuated
- SCOOT
- SCATS
- RHODES
- ACS Lite
- OPAC
- InSync

i) Vehicle Actuated Method

Actuated Signals [3] [5] had the capacity to react to the vicinity of vehicles or pedestrians at the convergence. Activated Traffic signal control comprises of intervals that were called and stretched out in light of vehicle detectors. The traffic signal controllers were equipped for not just fluctuating the cycle length & green times because of distinguishing or exertion, however of settling the request and arrangement of stages. Adaptive Traffic Control Systems (ATCS) [24] have a place with the most recent era of signalized crossing point control. ATCS over and again recognize vehicular traffic volume; ideal signal timings backed this distinguished volume and in the meantime execute them. Responding to those volume varieties commonly winds up in diminished deferrals, shorter queues and bated travelling times.

Vehicle-Actuated Signals obliged activation by a vehicle on one or more methodologies in place for specific phases or traffic to be adjusted. The control frameworks were outfitted with identifiers and the essential control rationale to react to the requests put on them. Vehicle Actuated control utilizes

information on present requests and operations, acquired from locators inside the crossing point, to change one or extra parts of the signal temporal arrangement on a cycle- by-cycle premise.

ii) Semi Actuated Signal

Fig.3. Demonstrates that the design of Semi Actuated control. The identifiers or detectors laid in the minor methodologies. Semi-actuated control [5] utilized recognition just for the minor developments at an intersection.

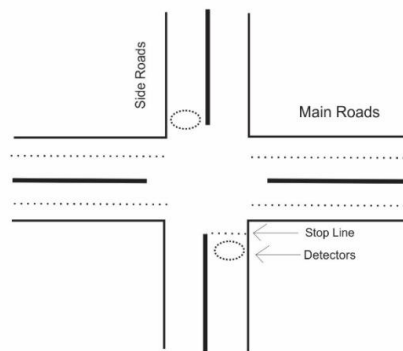


Fig.3. Layout of Semi Actuated Control

The phase sequence was identified by the significant street through developments were working were "non-impelled." That was, these stages didn't appear to be given location information. Amid this kind of operation, the controller was customized to abide inside the non-impelled segment and, alongwith these lines, maintain an unpracticed evidence for the best stream developments (typically the key road through development). Semi-actuated administration was ideally equipped for application at convergences that were a piece of a facilitated arterial street system. Semi-actuated control might likewise be suitable for confined convergences with a low-speed real street and lighter junction volume. Semi-actuated control had a few advantages. Its primary benefit was that it can be utilized adequately as a part of a facilitated signal system. Likewise, in respect to Pre-timed control, it lessened the deferral acquired by the real street through developments (i.e., the developments connected with the non-incited stages) amidst times of light activity. Finally, it needn't bother with indicators for the real street through development stages and thusly, the operation wasn't bargained by the disappointment of those locators. The significant detriment of semi-actuated operation is that nonstop request on the stages connected with one or more minor developments can result in an intemperate postponement to the real street through developments if the most extreme green and the section time parameters were not fittingly situated. An alternate drawback was that finders ought to be utilized in the minor methodologies, so obliging installation and in advancement upkeep. Semi-actuated operation conjointly needed additional guiding than that needed for pre-timed administration.

iii) Fully Actuated control

Fully-actuated [3] [20] control alluded to crossing points for which all phases were roused and along these lines. It needed discovery for all activity developments. Fig.4. represents Fully-actuated control was preferably suited to confine crossing points where the traffic requests and examples shift generally amid the course of the day.

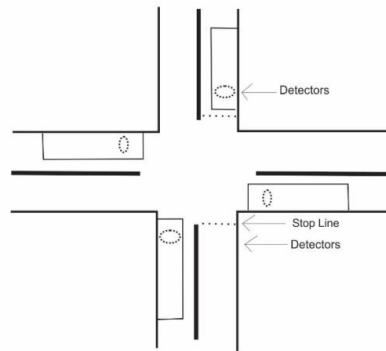


Fig.4. Layout of Fully actuated control

Most current controllers in facilitated sign frameworks can be modified to work in a completely impelled mode amid low-volume periods where the framework is working in a "free" (or non-coordinated) mode. Fully-actuated control can likewise enhance execution at convergences with lower volumes that are placed at the limit of a facilitated framework and didn't affect traffic of the framework. Fully-actuated control had likewise been utilized at the crossing point of two arterials to improve green time distribution in a discriminating convergence control strategy. There are a few focal points of Fully-actuated control. Initially, it diminished delay in respect to Pre-timed administration by being amazingly mindful to activity request and to change in traffic design. Likewise, recognition, information allows the process duration to be speedily assigned on a cycle-by-cycle premise. At long last, it grant phases to be skipped if there was no involve administration, along with these lines, allowing the controller to allot the unused time to an ulterior part.

The significant disservice of Fully-actuated control is that its cost (beginning and support) is higher than that of other control sorts because of the measure of discovery needed. It might likewise bring about a higher rate of vehicles halting in light of the fact that green time is not held for upstream units.

iv) SCOOT

SCOOT [2] [9] was nothing but Split Cycle Offset Optimization Technique. SCOOT is maybe the most broadly utilized adaptive traffic control systems with more than 200 implementations all through the world.

Fig.5. represents the SCOOT [19] framework partitions a system into "locales", every containing various "hubs" (signalized convergences and walker intersections which run at the same process duration to permit coordination). Hubs may be "twofold cycled" (i.e. Work at a large portion of the framework cycle length) at passerby intersections of under-soaked convergences. Provincial limits were placed at long connections where coordination may not be attainable. The execution of SCOOT altogether depended on traffic stream information acquired from the detectors. The framework obliges an expansive number of identifiers spotted at foreordained areas on every connection. The area of finders was discriminating, normally set at the upstream end of the methodology join.

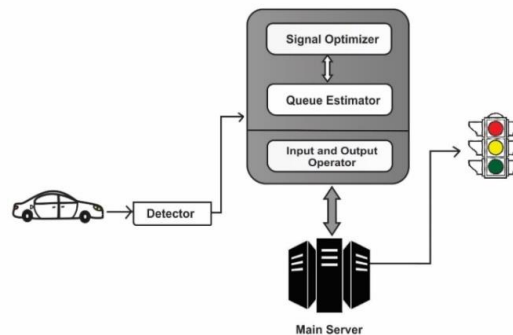


Fig.5. Architecture of SCOOT

SCOOT has three improvement modes: Split Optimizer, Offset Optimizer, and Cycle Time Optimizer. The computational vehicle has been criticized for criticism and has stopped on each connection and measures the execution of the frame of the action taken into consideration. From the general breach of the system, SCOOT [24] has changed the pre-determined signal timing arrangements. Before the path modes changes, be sure to look at the red and green parts present, whether brief or similar, to see if the split optimizer parts are expanded. The split optimizer received additional expectations from one to four seconds. As explained by the activity stream changes in different time periods, analysts described above, SCOOTs can really change the time scheduler settings. It may take over day by day traffic stream drifts over the long run and keep up a proceeding with coordination of the sign system

v) SCATS

SCATS [7] were Sydney Coordinated Adaptive Traffic signals. SCATS are presumably the most exceptional and generally adaptive traffic control system. SCATS were created by the Roads and Traffic Authority of New South Wales, Australia. As a real time adaptive traffic control system, SCATS [23] will change the signal transient request because of variances in signal temporal order and framework limit. Fig.6 demonstrates the Architecture of SCATS. The SCATS were planned with three control levels: central, regional and local. For each convergence, SCATS conveyed processes between a regional computer at the activity operations focus and the field controller. The central level was worked by the focal framework that corresponds with option levels inside the progression, basically for recognition capacities.

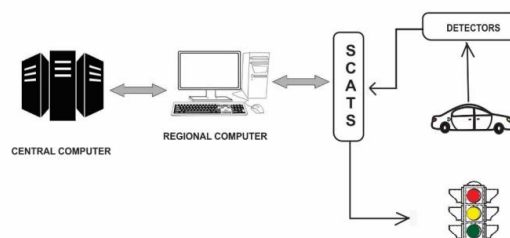


Fig.6. Architecture of SCATS

SCATS consolidated adaptive traffic signal control with routine control methodologies to furnish clients with a framework that can meet different operational needs. Control methods include: versatile operation, time of day and day of week coordination, and secluded sign operation. With constant reporting devices, the framework permits traffic engineers to screen framework operations. Persistent convergence checking rapidly alarms administrators of any uncommon conditions or supplies disappointments.

vi) RHODES

RHODES [8] [17] was a real-time traffic adaptive control system with a various leveled structure. RHODES will take information from varying sorts of locators or detectors and, bolstered what future traffic conditions are anticipated, create upgraded signal control plans.

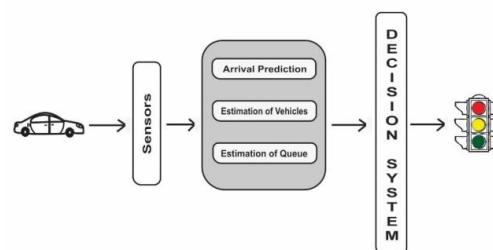


Fig.7. Architecture of RHODES

Fig.7. represents to the System Architecture of RHODES. The RHODES has three noteworthy framework peculiarities were noted by the advancement group that makes RHODES a reasonable and successful adaptive signal control system. To begin with, recent new innovations and systems were decently received in RHODES to verify the system iselited in exchanging, preparing, foreseeing traffic information and sign control. Second, RHODES took into thought the irregular way of activity stream varieties. Third, expressed forecast of individual vehicle arrivals, platoon arrivals and traffic stream rates were completely thought-about in RHODES.

vii) ACS LITE

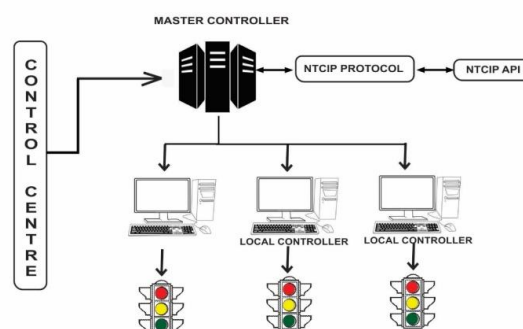


Fig. 8.Architecture of ACS Lite

The ACS Light [6] [12] framework provides a low effort traffic control framework that works continuously with small and medium-sized groups, altering and facilitating signal timing to neglect to change the traffic model. ACS Light uses new traffic signals or re-enforces existing activity signals. 90% of the traffic signal frameworks in the United States are intended to provide cycling-by-cycle control for close-up close loop frames, assessing or assessing the possibilities of two balance settings in upstream and downstream conversion. This death penalty may be directly a surrogate for vehicle breaks and instrumentation, which is not directly measured from point detectors. In particular, the acquisition or sophisticated vehicle flow is in the center of the cycle reproducing green around the traffic phase, at the point given at the point given at the point at which the measurement of flow (living-seconds residence space) is at the base. The algorithm system reflects the flow of control over each method, assessing totally different talent by reducing the total amount of acquisition and choosing the balance.

Fig.8 demonstrates the construction modeling of ACS Lite Traffic Control System. ACS Lite had two controllers Master Controller and Local Controller. The Master Controller controls the Local controllers and neighborhood controller control all the activity signals. The NTCIP conventions (National Transportation Communication and ITS convention) benchmarks are utilized to exchange the data between the ACS Lite framework and the traffic activity controllers

viii) OPAC

OPAC [15] is one of the Adaptive Traffic Control Technology. It was discovered in 1970's. OPAC [21] is only Optimized Policies for Adaptive Control. It was a real time and distributed traffic control methodology. More than once adjusted signal timings to diminish an executive capacity of aggregate deferral of vehicles and stops more than a pre-specified horizon. Optimization of any or all part intended to weaken downright convergence postponement and/or stops. The gimmicks of OPAC were it underpins for section, skipping within the absence of demand, various sets of setup parameters for altering the subsequent temporal arrangement to wait beyond any doubt developments for uncommon circumstances or by time of day, Configurable to answer to changes in left turn lead/slack staging by time of day, extraordinary attentiveness toward the part transient request inside the vicinity of clogging (high finder inhabitance). Numerous forms were accessible in the OPAC System they are OPAC – I, OPAC – II, OPAC – III, OPAC – RT, OPAC – IV.

ix) InSync

The InSync [13] [14] Adaptive Traffic control system, invented by Rhythm Engineering, is associate Intelligent Transportation that allows traffic signals to adjust to real traffic request. As of March 2012, traffic organization in 18 U.S. states has hand-picked InSync to be utilized at more than 650 convergences.

InSync may be a plug and play framework that works with existing cabinet controls and controllers. Its two principle equipment components have utilized one us IP based camcorders and a processor, by and large named as "the eyes" and "the cerebrum" of the framework, severally. Mounted camcorders confirm the amount of vehicles arrived and then to what extent the vehicles are holding up (additionally alluded to as postponement). The processor, a state machine, dwells inside the traffic controller bureau controller at the convergence. The framework rings the light expresses that best serves the genuine interest, while arranging its call with option convergences. The Insync framework has divided into two streamlining method, they are nearby enhancement and Global improvement. Neighborhood Optimization InSync uses coordinated computerized sensors to comprehend the exact mixture of autos thorough administration at a partner crossing point and the way long they've been holding up. Methodologies square measure given staging need upheld this line and deferral learning.

InSync's dynamic staging and element unpracticed parts adjust the traffic signals to utilize unpracticed time speedily. Worldwide Optimization InSync makes traffic in a complete way by exploitation "green passages." Platoons of vehicles assemble and square measure then free through the path. By human activity with each other, the signs expect the unpracticed burrow's entry, subsequently vehicles experience while not hindrance down or ceasing. The unpracticed burrows' length and recurrence will fluctuate to best bolster activity conditions. Between unpracticed passages, the local change serves the perspective roads and left turns

VI. COMPARISONS OF ADAPTIVE TRAFFIC CONTROL SYSTEM

Table.1Shows a comparison of the adaptive traffic control system. Different parameters have been taken for comparison. Parameters such as detector layout, arrival prediction, queue evaluation, split optimization, offset optimization. Cycle optimization, face sequence optimization, saturation status. Matching shows, what are the benefits and risks of the adaptive traffic control system. There are various types of ASCTs developed or developed. This shows some of them, including their operational goals. Each system has the ability to generate better levels of operation and specifically the management of traffic controls.

VII. CONCLUSION

To conclude that, this paper has focused on aa comprehensive overview of developments in the area of traffic control systems. The coverage are wide and current developments in the areas of traffic – responsive control such as static traffic control system, dynamic traffic control systems have been summarized. The Adaptive Traffic Control System mainly reduces the traffic, fuel consumption. Congestion in the vehicles, travelling time of the passengers. The ATCS increase the traffic rate, average flow speed of the vehicle. The popular ATCS are SCOOT, SCATS, RHODES, ACS Lite, OPAC and Insync. Adaptive Traffic Control System increases the traffic fluency when compared withOther static traffic control system.

TABLE.1 COMPARISON OF TRAFFIC CONTROL SYSTEMS

Traffic Control System	SCOOT	SCATS	RHODES	ACS Lite	OPAC	InSync	Pre Timed	Vehicle Actuated	Webster
Goal	Minimize the Performance Index	Minimize the delay in stops or maximize the throughput	Minimize cumulative delay	Maximized total amount of captured amount flow	Optimization of any or all section splits designed to reduce total intersection delay and/or stops	InSync optimizes traffic control based upon delay of individual movements	Minimize the delay	Detect vehicular traffic volume and compute optimal signal timings	To minimize Traffic delay and maximize the efficiency
Detector Layout	Upstream (Detectors deployed at 300 m from the stop bar)	At Stop Bar	Upstream (Detectors deployed at 400 – 600 m from the stop bar)	Both upstream and stop bars	Upstream Detectors	Upstream Detectors	At the Intersection	At stop bar	Upstream detectors
Arrival Prediction	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes
Queue Estimation	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes
Split Optimization	One third of total optimization affected by optimization	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
Offset Optimization	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
Cycle Optimization	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
Phase Sequence Optimization	No	No	No	No	Yes	Yes	No	No	No
Saturated Condition	Good	Good	Good	Good	Good	Good	Poor	Poor	Poor

References

- [1] Aleksandar StevaflOvic, Adaptive Traffic Control Systems: Domestic and Foreign State of Practice, National Cooperative Highway Research Program.
- [2] Hunt, P. B., Robertson D. I., Bretherton R. D... and Winton, R. 1.. "SCOOT – Traffic Responsive Method of Coordinating Signals". Laboratory Report 1014. Transport and Road Research Lab, Crowthorne, Berkshire, U.K., 1981.
- [3] Jin-yi Guo, Bao-hua Mao, Ming-Jun Liu, Li-Ping Ga, "Study on actuated signal controlled system in isolated intersection" IEEE Control and Decision Conference, 2008, Page(s): 2261–2265.
- [4] Kartik Pandit, Dipak Ghosal, Michael Zhang, and Chen-Nee Chuah "Adaptive Traffic Signal Control with Vehicular Ad hoc Networks" IEEE transactions on vehicular technology. Vol. 62, no. 4, May 2013.
- [5] Li-Wen Chen and Thea-Yin Hu. Flow Equilibrium Under Dynamic Traffic Assignment and Signal Control—An Illustration of Pre-timed and Actuated Signal Control Policies. IEEE Transactions on Intelligent Transportation Systems. VOL. 13.No.3. September 2012.
- [6] Luyanda, F., Gettman, D., Head, L., Shelby, S., Bullock, D... and Mirchandani, P... "ACS Lite Algorithmic Architecture: Applying Adaptive Control System Technology to Closed-Loop Traffic Signal Control Systems", Transportation Research Record 1856, pp 175-184, 2007.
- [7] M. Besley, R. Akeelik, and E. Chung, "An evaluation of SCATS master isolated control." in Proc. 19th ARRB Transp. Res. Conf, May 1998, pp. 1—24.
- [8] Mirchandani, P. and Head, L., "RHODES: A Real-Time Traffic Signal Control System: Architecture, Algorithms, and Analysis". Transportation Research Part C, 9(6). pp 415-432. 2001.
- [9] Robertson, D. I.; Bretherton, R. D. Optimizing Networks of Traffic Signals in Real-time - the SCOOT Method. IEEE Transactions on Vehicular Technology, 40 (1991), pp. 11- 15.
- [10] Shelby, S. G., "Design and Evaluation of Real-time Adaptive Traffic Signal Control Algorithms". Ph. D. Dissertation, The University of Arizona. 2001.
- [11] Sims, A. G. and Dobinson, K. W., "The Sydney Coordinated Adaptive Traffic (SCAT) System Philosophy and Benefits". IEEE Transactions on Vehicular Technology, 29(2), 1980.
- [12] Stallard, C., Ghaman, R. S., Li Zhang; McHale, G, "The role of traffic simulation in traffic signal control system development "Intelligent Transportation Systems, 2003. Proceedings. 2003 IEEE, Page (s): 872 - 877, Vol. 1
- [13] Kevin Fehon, P.E., PTOE and Jim Peters, P.E., PTOE, "Adaptive Traffic Signals, Comparison and Case Studies" Intelligent Transportation System.
- [14] The InSync Traffic System Developers <http://rhythmtraffic.com/>
- [15] Gartner, Nathan H. et al., "Implementation of the OPAC adaptive control strategy in a traffic signal network" Intelligent Transportation Systems, 2001. Proceedings. 2001 IEEE, pp. 195 – 200.
- [16] Deng, L.Y., Hsu Chun Liang; Chin-Thin Wang; Ching-Sheng Wang et al., "The development of the adaptive traffic signal control system" Parallel and Distributed Systems, 2005. Proceedings. 11th International Conference on Vol. 2, pp. 634 - 638
- [17] Markos Papageorgiou, Christina Diakaki, Vaya Dinopoulou, Apostolos Kotsialos, and Yibing Wang, "Review of Road Traffic Control Strategies", PROCEEDINGS OF THE IEEE, VOL. 91, NO. 12, DECEMBER 2003.
- [18] Rachmadi, M.F, Al Afif, F.; Jatmiko, W.; Mursanto, P. et al., "Adaptive traffic signal control system using camera sensor and embedded system" TENCON 2011 - 2011 IEEE Region 10 Conference pp. 1261 – 1265.

- [19] Taale, H, Fransen, W.C.M & Dibbitts, J. (1998). "The second assessment of the SCOOT system in Nijmegen." IEE Road Transport Information and Control, 21-23 April 1998. Conference Publication No. 454.
- [20] Maslekar, N. ; Boussedjra, M. ; Mouzna, J. ; Labiod, H. "VANET Based Adaptive Traffic Signal Control" Vehicular Technology Conference (VTC Spring), 2011 IEEE 73rd, 2011, pp. 1 – 5.
- [21] M.Amin, S. Jalili "Urban Signal Control using Intelligent Agents" in eProceedings of Applied Artificial Intelligence, pp. 811-816.
- [22] Z.Liu "A Survey of Intelligence Methods in Urban Traffic Signal Control," in International Journal of Computer Science and Network Security. vol. 7, July 2007, pp. 105-112.
- [23] Gartner, Nathan H. ; Pooran, F.J. Andrews, C.M. "Implementation of the OPAC adaptive control strategy in a traffic signal network" Intelligent Transportation Systems, 2001. Proceedings. 2001 IEEE, 2001, pp. 195 – 200
- [24] Bhuvaneswari, P.T.V, Raj, G.V.A. ; Balaji, R. ; Kanagasabai, S. "Adaptive Traffic Signal Flow Control Using Wireless Sensor Networks" Computational Intelligence and Communication Networks (CICN), 2012 Fourth International Conference on 3-5 Nov. 2012, 85 – 89.
- [25] Heydecker, B.G, Chen Cai; Wong, C.K. "Adaptive Dynamic Control for Road Traffic Signals "Networking, Sensing and Control, 2007 IEEE International Conference, 15-17 April 2007, pp. 193 - 198

