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ADAPTIVE PRIORITY BASED SCHEDULING ALGORITHM FOR INTELLIGENT TRAFFIC CONTROL IN URBAN CITIES USING MULTI-AGENT SYSTEM

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ABSTRACT : Efficient management of traffic flow in agglomerate cities has been a subject of great concern in the recent time. The continuous variations of vehicular flow and the need to dynamically prioritize emergency service vehicles (ESVs) contribute greatly to this challenge. Adaptive traffic control systems usually referred to as Intelligent Transportation Systems (ITSs) have been adopted in most urban cities to remedy this challenge. These ITSs use-Traffic Signal Control (TSC) and Dynamic Route Guidance (DRG) to realize congestion control in urban cities. However the challenge of dynamically prioritizing the flow of ESV in these agglomerated cities has not been efficiently handled by these systems. This paper proposes a dynamic vehicle prioritized traffic control system, using multi agent system for urban cities with coordinated flow splits. The proposed algorithm gives preference to like: fire trucks, ambulances, safety cars and police cars that are required to travel through the traffic network during rush hours. The prioritized scheduling approach adopted for this system will be modeled as a packet switched network which supports different traffic type with different quality of service requirement (QoS) literally representing the different ESV flow. Simulation was carried out using MATLAB 2014 and results obtained were analyzed using Microsoft Excel 2010.Results obtained from the analysis shows that the APS out performance the FITC in the area of average network delay and intersection utilization by 0.35% and 0.56% respectively. In the area of fairness the APS is not fair to all class of traffic as it gives more preference to the EVS than NV.

Key Words: ESV, ITS, TSC, DRG, Multi Agent System, VRA

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1. INTRODUCTION

Managing traffic congestion is a crucial challenge in most urban cities. Many of the congestion experienced in these cities are mostly caused by improper control of traffic lights around the cities. This is basically brought about by inadequate information of the current traffic condition around the neighboring road junctions in the cities [1]. The continuous and dynamic variations in vehicle traffic flow in these cities also contribute greatly to congestion experienced in them. These variations in traffic flow, adds to the other troubles of traffic control. In view of this, traffic control requires an adaptive system to remedy this challenge [2]. Unfortunately, the urban vehicle traffic flow is a large scale system and the traffic control systems deployed in most cities are time dependent. As such many of the approaches adopted in classical control systems are useless to hire in this dynamic agglomerated cities [3]. Often, in agglomerated areas vehicles usually wait in queues to cross the intersections or cross roads. This usually causes great delay to the flow of emergency service vehicles (ESVs) such as: fire trucks, ambulances, safety cars and police cars. However in recent times, there have been some amendment to the regular traffic control system; this is with the aim of accommodating ESVs that requires high priorities while traveling through the traffic network during rush hours [2, 4]. In most recent traffic control systems, the presence of these ESVs is usually signaled to traffic controllers that can change the phases order or quite preempt the intersections thus giving preference to these ESVs in the traffic network [3]. The adaptive traffic control system currently in use in most urban cities usually referred to as Intelligent Transportation System (ITS), uses: Traffic Signal Control (TSC) and Dynamic Route Guidance (DRG) in realizing congestion control [4]. However, the challenge associated with dynamically prioritizing the flow of ESV during rush hour is not efficiently catered for by this system. Thus in this paper, we propose an adaptive priority based intelligent traffic control system using multi agent system for urban cities with coordinated flow splits. The proposed algorithm gives preference to ESVs that are required to travel through the traffic network during rush hours. The rest of the paper is organized as follows: Section II gives an overview of the art in the area of traffic control systems and the different technologies that have been deployed over time in this area. Section III discusses the multi-agent systems and then, the system architecture of the proposed dynamic vehicle prioritized traffic management system using multi agent system. Then we describe the modeled system and carryout analysis of the results obtained from the simulation. Comparison of the result obtained from the simulation against that of the current application will be presented in section IV. Finally, Section V concludes and makes recommendations for future work.

2. STATE OF THE ART

The problem of traffic control has been studied in the area of intelligent transportation system for many years. The first one is the method of Vehicle Actuated Signal Control [5]. This method controlled traffic lights by considering the number of cars waiting in the queue to be serviced by a traffic light. Sensors are placed at a short distance from the junction in order to detect cars and count the number of passing cars. When the current green light is going to be changed to red, but the sensor can detect that some cars have come in that range of distance, the duration of the green light is extended further. This scenario can be repeated until no more cars have arrived in that range or the maximum duration for the green light has been reached. Some approaches employed machine learning methods, such as reinforcement learning and genetics algorithm [6], to learn traffic patterns of different time in a day and used them to control the traffic lights. This seems feasible when all the commuters behave normally. However, in real life condition, it is hardly to be so. Other approaches used Fuzzy controllers [7] to adjust only the duration of green light of each traffic light to match the current traffic condition, but not to change the signal patterns.

This is not capable to control the traffic patterns. In [8], green wave system was discussed, which was used to provide clearance to any emergency vehicle by turning all the red lights to green on the path of the emergency vehicle, hence providing a complete green wave to the desired vehicle. A ‘green wave’ is the synchronization of the green phase of traffic signals. With a ‘green wave’ setup, a vehicle passing through a green signal will continue to receive green signals as it travels down the road. In addition to the green wave path, the system will track a stolen vehicle when it passes through a traffic light. Advantage of the system is that GPS inside the vehicle does not require additional power. The biggest disadvantage of green waves is that, when the wave is disturbed, the disturbance can cause traffic problems that can be exacerbated by the synchronization. In such cases, the queue of vehicles in a green wave grows in size until it becomes too large and some of the vehicles cannot reach the green lights in time and must stop. This is called over- saturation. In [9], the use of RFID traffic control to avoid problems that usually arise with standard traffic control systems, especially those related to image processing and beam interruption techniques are discussed. This RFID technique deals with multivehicle, multilane, multi road junction areas. It provides an efficient time management scheme, in which, a dynamic time schedule is worked out in real time for the passage of each traffic column. The real-time operation of the system emulates the judgment of a traffic policeman on duty. The number of vehicles in each column and the routing are proprieties, upon which the calculations and the judgments are done. The disadvantage of this work is that it does not discuss what methods are used for communication between the emergency vehicle and the traffic signal controller. In [10], it proposed a RFID and GPS based automatic lane clearance system for ambulance. The focus of this work is to reduce the delay in arrival of the ambulance to the hospital by automatically clearing the lane, in which, ambulance is travelling, before it reaches the traffic signal. This can be achieved by turning the traffic signal, in the path of the ambulance, to green when the ambulance is at a certain distance from the traffic junction. The use of RFID distinguishes between the emergency and non-emergency cases, thus preventing unnecessary traffic congestion. The communication between the ambulance and traffic signal post is done through the transceivers and GPS. The system is fully automated and requires no human intervention at the traffic junctions. The disadvantage of this system is that it needs all the information about the starting point, end point of the travel. It may not work, if the ambulance needs to take another route for some reasons or if the starting point is not known in advance. In [11], currently video traffic surveillance and monitoring systems have been commissioned in many urban cities. The operation involves a manual analysis of data by the traffic management team to determine the traffic light duration in each of the junction. It will communicate the same to the local police officers for the necessary actions. In recent time, some works have adopted the multi-agent approach. For example, [12] adopted case-based reasoning to control traffic lights. The agent observed traffic condition at a junction and used this information to match with candidate cases from its case-base;

consequently it applied the solution of the selected case to control the traffic lights. An Agent proposed in [13] used some properties of the current states of all traffic patterns as the criterion to determine which will be the next pattern.

3. MULTI-AGENT SYSTEMS ARCHITECTURE FOR DYNAMIC VEHICLE PRIORITIZED TRAFFIC CONTROL SYSTEM.

Multi-agent systems technology is used with success in the case of distributed systems. Distributed systems in this case are those systems in which their components can make their own decisions, where each component performs a task so that the entire system can achieve its main goal. In such systems the cooperation between system components to achieve the goal of that system, becomes very important. Distributed systems environment is dynamic and continuously changing. The technology used to model such a system must cope with unpredicted situations that appear in the system [12]. Until now the most appropriate technology to resolve such situations is the multi-agent systems technology. Building applications using this technology improves the system's flexibility and capacity to resolve these unpredicted situations. Multi-agent systems have seen a proliferation in recent years, being used in applications in various domains. Examples of such domains are: transportation, industry, healthcare, military etc. The architecture of multi-agent systems varies depending on the application it is used in. In making such architecture it is important to know where the intelligent agents are placed and the purpose of each agent. They will have the ability to make their own decisions based on the conditions of the environment to which they belong. Another important point is the coordination of the agents. Each agent must be capable to communicate with other agents. Thus the decisions of each agent will be in accordance with the needs of the entire system. The multi-agent system's architecture depends on the application in which it is used. In order to create such architecture, it is important to know the place where the intelligent agents are in the system, and each agent's goal. The agents will have the ability to make their own decisions according to the state of their environment at a given time. The architecture proposed in this article is that of an agglomerated urban traffic control system. The proposed architecture seeks to keep the systems entities autonomy (i.e. they have the capacity to make their own decisions) without necessarily using a central coordinator. In the same time it seeks to increase the system's flexibility (to make easier adding or deleting agents) in other to cater for future expansion of modeled urban city. Each vehicle existing in the monitored area is considered an agent. The agents are mobile because they are moving on the road and in intersections network. The inherent advantages in this choice of adopting the mobile agents are: reduced overall network latency, reduced network load, easy of executing asynchronous and autonomous actions, improved adaptive nature of the system and ease of dynamically developing new software components in the system [13]. Beside mobile agents in the system architecture an agent who will detect the incidents that appeared in the controlled area is introduced. This agent is called Incident Detection Agent and is doing globally the incident detection. This is necessary because for every mobile agent (car) to detect the incidents that appear in traffic, a big number of messages transmitted between the agents is needed. The delays appeared at message transmission will lead to important detection delays. When a specialized agent is used to detect the incidents, the sent messages number in the network decreases. However, the disadvantages of using incident detection at the agents level are: the number of messages sent between agents is growing (this situation can lead to network overhead), and that the agents don't have a global image of the system (to have a more complete global image the agent needs to receive a lot of massages from the other agents) [14]. Without a complete system image it becomes very hard to detect all the incidents which can influence the agent's behavior. The Incident Detection Agent receives information about agents and about the environment. Based on this information the agent generates the incident information. This information is sent back to the agents. Each agent plans its own route based on the detected incident information. Planning the new routes is necessary only if on its road an incident appears. The new plans have to be generated in a short time, so that the agent can avoid the blocked area. The part involving changing the agent's behavior will be done at each agent level. This will be done locally because the agents have different goals (origin points, intermediary points and destination points). This data is known at the local level, a big computational effort being necessary if each route is to be calculated globally and then the resulted routes to be transmitted to each agent.

4. SIMULATION MODEL AND ANALYSIS

The urban traffic network system is modeled by a set of traffic arcs representing the roads network. The arcs are connected by a set of intersections. A combination of vehicles (i.e. normal vehicles and emergency service vehicles) run on the arcs in the global network and is served at various bus stops. Each arc is characterized by a set of parameters: its length (L) in meters, its capacity (C) in private car unit (PCU), the maximum possible flow, referred to as the saturation flow (D) in pcu/time unit, the number N of vehicles present on the arc, that is incremented and decremented when a vehicle enters or leaves the arc, the corresponding status of traffic. The system is controlled by an agent container (the agent network) which is responsible for initiating the multi-agent simulation in parallel with the vehicular traffic. Four types of agents are intended to regulate the bimodal traffic (i.e. traffic due to normal vehicles flow and emergency service vehicles flow) on the network: Vehicle agent (VA) represents emergency service vehicle; Vehicle Route agent (VRA) supervises Vehicle agents, it particularly monitors the regularity of Vehicle. Intersection agent (IA) generates and monitors traffic light signal plans; and finally the Stage agent (SA) computes the green time needed to evacuate vehicles on the arcs concerned by the stage. It

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cooperates with Intersection agent to establish the traffic light plan. The various agents of the system interact and communicate together to achieve their goals. We thus describe the internal architecture of each agent and protocols of collaborations between the agents in realizing the dynamic vehicle prioritized traffic control system.

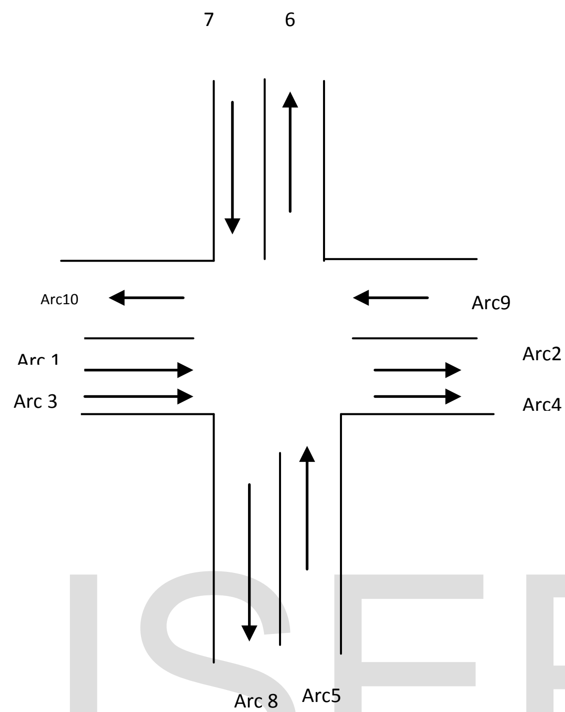


***Figure 1: Crossing system with 8 branches*.**

In Figure 1 above, the number of arcs on each branch depends on the number of lanes. Each lane is represented by an arc.

- **Vehicle Agent (VA):** The goal of VA is to minimize the time it takes emergency service vehicles (ESVs) to navigate the network during rush hour. It ensures that these vehicles have a regular time interval with its predecessor at each intersection. To achieve these goals, it communicates with the IA in order to get the right of way at traffic lights and the priority that the given ESV carries at the given time. In view of this, VA's are injected into the network by the VRA at a given frequency. When a given VA enters an arc, it retrieves the necessary information on the length of the current arc, the number of vehicles on the arc, the capacity of the arc and its flow. Then it calculates a period (i.e. a space time) it will request to the IA of current information about the next intersection in order to avoid a stop at red light when the ESV arrives. The time interval requested by the VA is specified by a start time (T_{begin}) and an end time (T_{end}). The start time indicates the moment when the special vehicle will arrive at the traffic lights and the time required by the green traffic light to evacuate all vehicles which enter the arc before the ESV.

This time is calculated as thus:

$$T_{begin} = T_0 + 3.6 *(L/V - N/D) \quad (1) \quad [13]$$

$$T_{end} = T_{begin} + (N/D) + T_{eva} \quad (2) \quad [13]$$

Where: L is the length of the arc,

N the number of vehicles in the arc,

V the speed of the special vehicle in km / h,

D the saturation flow of the arc,

T_0 the current time system

T_{eva} is the time required to get the special vehicle from an arc to another.

Whenever the VA perceives a bus stop in the network, it contacts directly its VRA.

- **Vehicle Route Agent (VRA):** A vehicle route consists of several vehicles moving on the same roads and serving the same bus stops. The role of a VRA is to manage all the VA which belongs to the same vehicle route. The VRA has a global view on the route it manages. It affects a priority index to each vehicle in the route. This priority varies based on the level of emergency attached to the services delivered by these vehicles.
- **Intersection Agent (IA):** The IA is the key agent in the proposed system. Each agent is responsible for monitoring its intersections and generating traffic light plans to regulate traffic. To achieve its objective, it needs to be assisted by the Stage Agent .They work together to establish an evacuation plan that maximizes the capacity of the intersection while trying to better satisfy the reservations of VA. When the IA receives a request from the VA it saves it in its database. And then carry out a check to decide the manner execution to adopt. In case of two reservations in the database that may overlap during their execution, the agent delays the reservation with the lowest priority. All bookings are then sorted and stored; they will be deleted after execution. It's important to note that reservations can be executed over several cycles in case of network congestion. The ultimate goal of the IA is to satisfy the entire requests it get
- **Stage Agent (SA):** The SA is the agent that manages the various stages of the intersection. Each agent is responsible for calculating the optimal duration for discharging the intersection, contributing to the development of plans to control traffic lights to maximize the ability of the crossroads and satisfy SV reservations. The agent has a process which calculates the green time required after the request of the IA. The optimal duration of green light is the largest evacuation time of one of the arcs of the stage. It is calculated by this formula:

$T = \max \{T_i\}$ with i=1...m, where m is the number of arcs entering in this stage and T_i the necessary time to evacuate every arc

$$T_i = \frac{Ni}{Di} + \left(\frac{Ni}{Di} * \frac{Li}{Vi}\right) \quad (3)[13]$$

N_i is the number of cars in the arc, D_i the flow, L_i the length and V_i speed of the vehicles.

Stage index urgency determines the importance of the stage and lets the IA computes an order for the stages in the establishment of the traffic light plan; the longer the lapse of time, the more urgent the stage.

The urgency index is measured by the following formula:

$$I_j = \sum_{i=1}^{m} e^{wi} + e^{bi} \quad (4)\ [13]$$

Where $w_i = N_i / C_i$ is the measure of the degree of congestion in the arc,

b_i the number of buses present,

m the number of entering arcs,

and e the constant of Euler strictly greater than 1.

The system chart of operation is given in Figure 2.

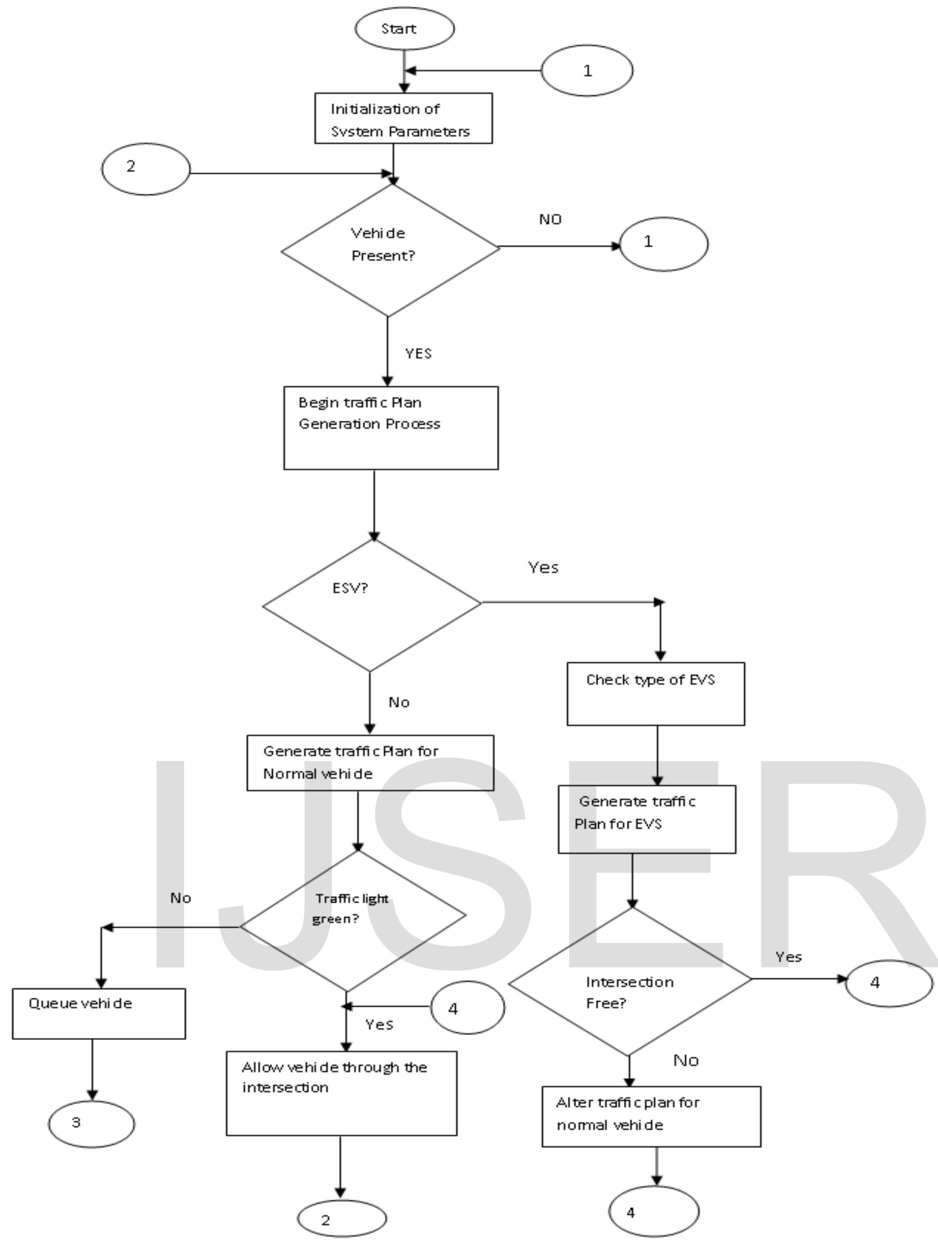


Figure 2: System flow chart of operation

5. SIMULATION RESULT AND DISCUSSION

In order to analyze the performance of the proposed Adaptive Priority Based Scheduling Algorithm for Intelligent Traffic Control (APS), the proposed model was developed in Matlab Simulink Environment with the following simulation parameters as shown in table.1. The analysis of the model was carried out side by side with a typical Fixed Intelligent Traffic Control (FITC) Model for urban cities using the same simulation parameters as in table 1.

Table1: Simulation Parameters

N_{max}: maximum number of vehicle per arc	40	
T_{Eva}: Average evacuation time	30ms	
Number of intersections	4	
Average vehicle speed	50km/hr	
Length of arc	1000m	
Priority of emergency service vehicles (ESVs)	Vehicle	Priority
	Hospital ambulance	0.5
	Fire service truck	0.3
	Police vehicle	0.2

The results obtained from the simulation model are analyzed as thus:

5.1. Overall Network delay against Number of vehicle for APS and FITC: The result from the simulation as presented in figure 3, shows that the when the network deploys the proposed Adaptive Priority Based Scheduling Algorithm (APS) for traffic control, vehicles in the network experiences reduced delays as against the situation where the Fixed Intelligent Traffic Control (FITC) was deployed for traffic control in the network. This can basically be attributed to the fact that the APS uses agents in coordinating the traffic flow and each agent can take logical decision in the network thus reducing the delay experience by vehicles in the network. It is also observed that emergency service vehicles experience least delay relative to normal vehicle transversing the network. This is attributable to the facts that the agent in the network gives more preference to ESVs and such they can at any time these vehicles appear in the network interrupt the traffic signal just to give way to these ESVs. By so doing, this ESVs experience very little delay in the network.

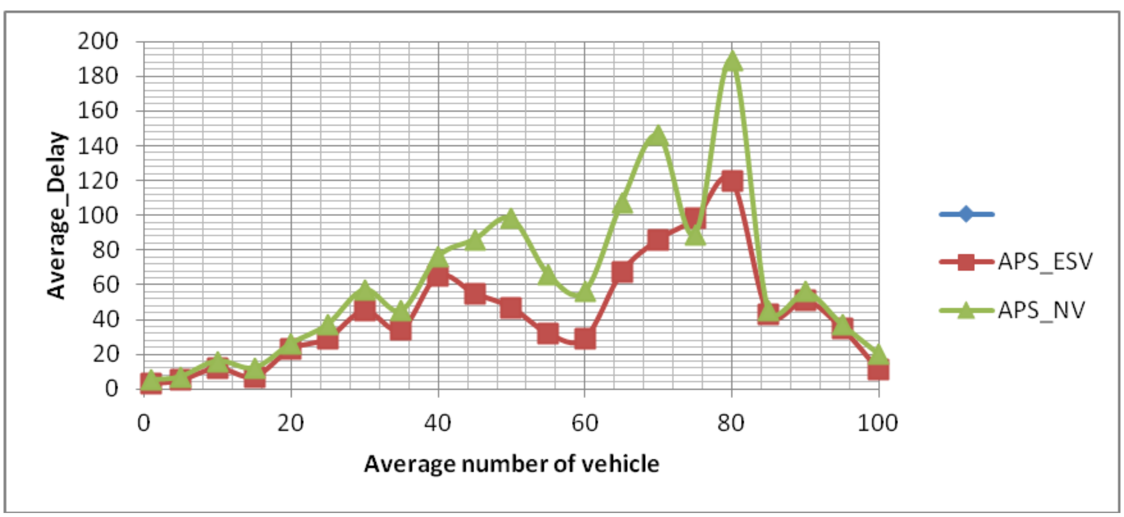


Figure 3: Overall Network delay against Number of vehicle for APS and FITC

5.2. Average Intersection Utilization against Number of vehicle for APS and FITC: From the simulation result as shown in figure 4, it is seen that the APS ensures better utilization of the intersections at every point in time. This is because the agents in the network, work together in ensuring that information about the condition of each intersection are transmitted to every IA, thus enabling them take coordinated decisions on the traffic plan at each intersection.

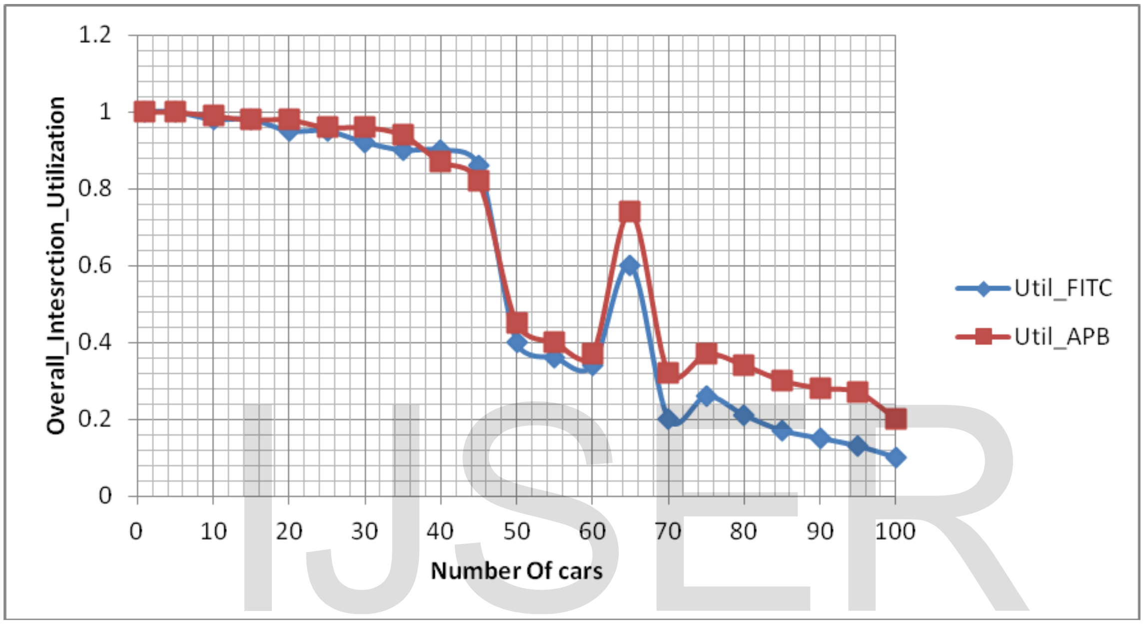
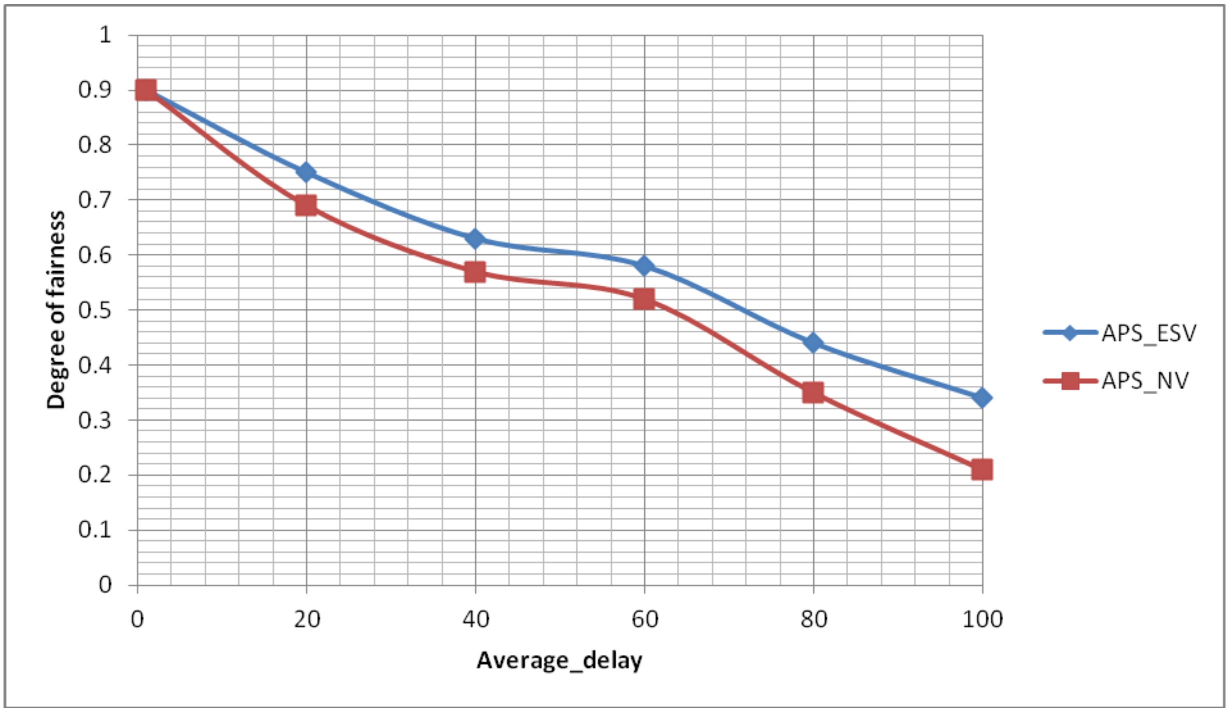


Figure 4: Average Intersection Utilization against Number of vehicle for APS and FITC

5.3. Fairness of Adaptive priority based scheduling scheme to ESV and NV: It is seen from the plot in figure 5, that the developed APS is not totally fair in it distribution of road traffic resources. It gives more preference to ESV than NV as it does not take into cognizance the degree of occurrence of ESVs at an intersection. The resultant effect is that some vehicles (NVs) tend to spend more time at intersection.



6. CONCLUSION

The development of an intelligent traffic model that is fair in the provisioning of road traffic resource in urban cities has been a great challenge. In this work we propose an Adaptive Priority Based Scheduling Algorithm for Intelligent Traffic Control (APS). The proposed APS ensures that road traffic resource is dynamically distributed to different road users/vehicles based on the priority allotted to the type of vehicle. It is seen that even though the APS out performs the conventional FITC used in urban cities in the area of delay and utilization, it is not totally fair in it distribution of road traffic resources. It is seen that some vehicles will starve in the distribution of resources as IA does not take into cognizance the occurrence of ESVs in an intersection. The resultant effect is that some vehicles (NVs) tend to spend more time at intersection.

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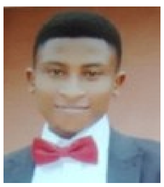

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