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Original Article

Vehicle's Traffic Flow Control Using Cloud Based IoT

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Abstract

This paper proposes Smart Adjustable Traffic light Time System (SATTS), a cloud-based IoT network model with a central management architecture by using cloud based IoT. The model innovates an algorithm to gather data from IoT devices connected to the sensors network to enable efficient traffic management in smart city appliances. SATTS scheme adjusts the green light period at intersections to alleviate traffic congestion and minimize delays and keep vehicle's traffic conservation. The mentioned model has been proposed to modifying the timing of green lights at the four ways intersection based on the vehicles arrival rate. The results verified by comparing SATTS with Fixed time Traffic light System (FTS) and Variable Traffic light System (VTS) models, and showed that the proposed schemes can effectively decreases delay and traffic congestion. On average, there is a reduction in the rate of number of waiting cars compared to the arriving cars of 33% in cycle 2 and 50% in cycle 3 for VTS, and 52% in cycle 2 and 75% in cycle 3 for SATT compared to FTS. SATTS minimizes delay time between the four lines of the intersection.

Keywords: *Internet of Things, Cloud based IoT, Energy Efficiency, Centralized Management Architecture, Dynamic Traffic Flow Control, Smart Cities.*

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1. Introduction

The rapid expansion of the internet has actually accelerated the evolution of the internet of things. A common factor contributing to this evolution is the ease with which IoT devices are accessible, affordable, and useful in everyday life. Because of the rapid development of wireless communication technologies, developers have produced extremely affordable IoT nodes that provide data gathering, information analysis, and wireless transfer [1][2][3]. IoT is essentially a network of connected devices along with sensing units that permits data sharing over the Internet. Because of the resource constraints of IoT devices, tasks with high computational complexity and large information storage space in the IoT context are constantly managed by the cloud, which considerably enhances their effectiveness [4][5][6]. Cloud computing is a pattern that provides for a large memory area and high computational capability at a low cost. [7][8][9].

The growing urban population, as well as substantial immigration from rural areas to major cities, increases transportation demand and traffic congestion. Traffic congestion is regarded as the primary civic issue. The problem has persisted due to the traditional existing traffic management system, such as the limited road's traffic capacity with the periodic traffic light [10][11][12].

In this paper, it has been considered how to propose traffic system which is dedicated for the vehicle's traffic intersections strategy that minimizes the vehicle's traffic congestion based on the queuing estimation. Therefore, smart traffic flow control system is introduced as smart solution that enhances limitations of the traditional traffic system. In this study, the (FTS) model was introduced to handle traffic congestion issues, in addition to the comparison with (VTS) and (SATTS) models to achieve less delay and reduce intersecting line traffic congestion in the cloud-based IoT networks. That would lead to smoother traffic flow, and fewer sudden stops and starts, thus lowering accident risks

The main contributions of this paper are summarized as follows:

• Developing a model to virtualize a IoT network of a smart city with four ways crossings with cloud-based IoT devices.
•Optimizing priority-based traffic lights and reducing intersection wait times.
• Reducing road accidents.
• Reducing fuel consumption.
• Reducing CO2 emotions and environmental pollutants.
• Cost and time saving.

The remaining of the paper is organized as follows: related research is discussed in Section 2. network optimization model of cloud based IoT is presented and discussed in Section 3. Section 4 presents objectives of the proposed model. Results evaluation and conclusion are introduced in sections 5 and 6.

2. Related Works

In order to address transportation issues, scientists are exploring the potential of new technologies such as the Internet of Things, artificial intelligence, and cloud computing to create innovative solutions for enhancing the effectiveness of transportation systems. The subsequent is a structured summary of the various available methods for overseeing urban traffic on roads:

The study [13], proposes a trajectory rejection scheme, which is based on multi-agent reinforcement learning. This method combines system and user perspectives to alleviate traffic congestion and decrease both Travel Time (TT) and Travel Distance (TD). In a paper by [14], it has proposed to implement an adaptive area-based system for controlling and managing traffic congestion using fog computing and the internet of vehicles. The fog servers utilize the established regional traffic correlations in the divided management areas to regulate the signal lights in real time and efficiently direct the traffic flow through the coordination between these areas. In [15], a proposal is made for a vehicular end-edge-cloud computing framework to facilitate vertical and horizontal cooperation among vehicles in a large area with multiple unsignalized intersections. The framework utilizes a two-stage reinforcement learning approach to achieve the best policy for vehicle control.

The Spatio-Temporal Multi-Agent Reinforcement (STMARL) framework, introduced in [16], aims to understand the spatio-temporal correlation among multiple interconnected traffic lights and manage them in a coordinated manner using the deep Q-learning approach. The purpose of this study [17] is to enhance traffic signals through the creation of a centralized traffic light control system using a distinct wireless communication network. The ambulance-to traffic light controller in [18] facilitates the exchange of information between ambulances and traffic light controllers along the rescue route. This information, comprising of speeds, locations, and emergency routes, enables traffic light controllers to activate a prioritized green traffic light as needed.

In [19], a smart routing algorithm based on deep reinforcement learning is developed to alleviate network congestion and distribute network load to support various smart city services with significant disparities. The algorithm aims to viable the distributed computing and communication infrastructure while meeting the latency requirements of service requests from the public. In [20], vehicular fog computing (VFC) holds potential for delivering real-time and location-specific network responses. As the concept and application of VFC are still in their early stages, this publication initially develops a three-tier VFC model to facilitate decentralized traffic management, aiming to reduce the response time for citywide events gathered and relayed by vehicles. A proposal in [21] outlines a traffic management plan aimed at reducing traffic congestion in a network of interconnected signaled lanes/roads. It focuses on providing efficient and timely routing for emergency vehicles. The control of inlet traffic flows by network gates and the adjustment of traffic lights throughout the network are achieved using model predictive control. Smart traffic system in paper [22] uses self-learning algorithms that dynamically permits traffic to pass by learning current traffic density. This is accomplished through (You Only Look Once) object detection method that detects and counts the total number of vehicles on the routes surrounding a traffic light intersection to reduce the overall delay at the intersection. A two-layer framework in paper [23] is used to properly manage signal and vehicle controls. In the first layer, autonomous intersection manager receives trained data through machines learning and generates a list of best green times for each intersection phase. In the second layer, connected autonomous vehicles computes the optimal speed values to optimize intersection efficiency while minimizing vehicle average delay and fuel usage. To capture the spatial-temporal features, that makes ensure accurate traffic flow prediction, a spatial-temporal Chebyshev graph neural network model (ST-ChebNet) for traffic flow prediction is proposed in paper [24]. The spatial and the temporal features are fused for assurance the traffic flow prediction for better urban traffic planning, traffic control, and traffic guidance.

3.Network Optimization Model of Cloud based IoT

According to the assumption made in this paper, a cloud network has been proposed, represented by nodes in a cloud-based IoT system. Where a simulation heuristic has been used. The sensors of IoT devices have been distributed across a physical grid, such as in a smart city at intersections, where they are connected by a physical network at four-way intersections, as depicted in Fig. 1. The connected node of the traffic light signal at each intersection serves as a gateway to collect data and send it to the cloud, as illustrated in Fig.1. Each IoT device is connected to its neighboring devices through a physical plan, and each IoT device possesses processing, storage, and functionality capabilities. It is assumed that each IoT device is capable of performing two of the following functions: (i.e. speed, density, climate, processing …etc.). planning, traffic control, and traffic guidance. Architecture of cloud based IoT network structured into three primary layers, each serving a distinct function within the system: sensing layer, this foundational layer comprises physical devices such as sensors and actuators. Network Layer acting as the intermediary, where the logical tasks allocation into IoT devices is performed. Application Layer situated at the top, this layer delivers application-specific services to end-users.

4. Objectives of the Proposed Model

The objective is to fulfill intersection traffic flow with least delay and with less negative effect of intersection lines to each other. This is accomplished by creating a number of parameters, first (TF_R) which indicates the traffic flow rate per each line and measured by cars per minute, (N_arr) which represents the number of arrived cars per each line during the red traffic light period and measured by cars per minute, (N_w) which is the number of waiting cars after green light traffic flow and (T_G, T_R) that is the period of Green , Red traffic light consequently.

Table (1): Related Work

Ref.	Technology	Approach	Methodology	Achievement
[13]	high adaptive learning	Traffic Route Guidance by a trajectory rejection scheme	multi-agent reinforcement learning	alleviate traffic congestion and decrease both Travel Time (TT) and Travel Distance (TD) Under Diverse Traffic Scenarios
[14]	Fog computing	adaptive area-based system for controlling and managing traffic congestion	utilize regional traffic correlations	to regulate the signal lights in real time and efficiently direct the traffic flow through the coordination between these areas
[15]	edge-cloud computing	a two-stage reinforcement learning	facilitate vertical and horizontal cooperation among vehicles	achieve the best policy for vehicle control
[16]	deep Q-learning	Spatio-Temporal Multi-Agent Reinforcement Learning	Cooperative Traffic Light Control	understand the spatio-temporal correlation among multiple interconnected traffic lights
[17]	wireless communication network	Smart traffic light system	a centralized traffic light control system	enhance traffic signals
[18]	communication technology	Ambulance-to-Traffic Light Controller Communications	a communication mechanism among ambulances and infrastructures (e.g., traffic light controllers)	enhance the efficiency of rescue missions
[19]	deep reinforcement Learning	design routing strategies	smart routing algorithm	alleviate the network congestion and balance the network load for supporting smart city services
[20]	fog computing	integration of fog computing and vehicular networks, vehicular fog computing (VFC)	a three-layer VFC model to enable distributed traffic management	achieve real-time and location-aware network responses
[21]	by means of network gates	model predictive traffic control scheme	an efficient and timely routing for emergency vehicles	alleviate traffic congestion in a network of interconnected signaled lanes/roads
[22]	edge machine learning	a Dynamic Traffic Light System (DTLS)	a vision-based DTLS is proposed using the YOLO	minimize the overhead incurred in both computations of traffic and in communication networks
[23]	Internet of Things	leverage the capabilities of both autonomous intersection manager (AIM) and connected autonomous vehicles (CAVs)	A two-layer framework is adopted to handle signal and vehicle controls effectively	optimize intersection efficiency and minimize vehicle average delay and fuel consumption
[24]	Internet of Things, intelligent transportation system and Neural Network	traffic flow prediction to capture the spatial-temporal features	spatial-temporal Chebyshev graph neural network model (ST-ChebNet)	ensure accurate traffic flow prediction for better urban traffic planning, traffic control, and traffic guidance.

In order to evaluate the performance of the model, it has been run for three scenarios. The first, Fixed time Traffic light System (FTS), involves fixing (T_G and T_R) period per each line, The values of model parameters are as follow: it is considered that the period time for the red light on is (90 seconds) in each line, hence, the period time for the green light on is (30 seconds) in each line which allows (TF_R= 10) cars to passthrough to any other line [25][26].

Whilst the second scenario is Variable Traffic light for Single line (VTS), where total intersection time has been increased to (150 s) to solve the delay problem, and (T_G) is increased by (30 s) for the highly congested line while fix it for other less congested lines. And for third scenario, Smart Adjustable Traffic light Time System (SATTS), in which the period of (T_G) needed for each line is specified based on line arrival rate. Since (T_G) is variable that necessitate varying period of red on signal (T_R) in each consecutive cycle.

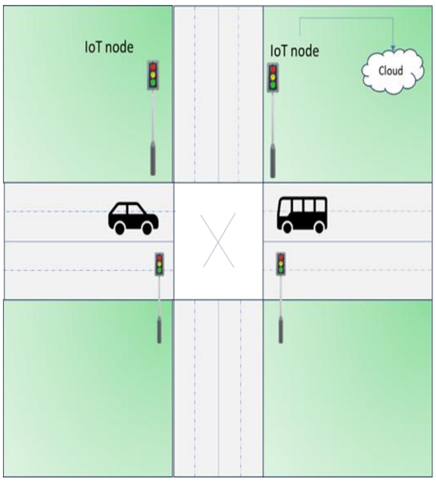

Figure 1. Physical network of smart city of four-way intersection

5. Results Evaluation

Three metrics have been identified, ((TF_R), (N_arr), and (N_w)) to compare the three scenarios, the model has been run for up to three cycles to show the effect of the proposed scenarios through presented metrics. Fig. 2,3 and 4, display the traffic congestion in one line of intersection for (FTS) scenario, when traffic light periods (green and red) are fix for all lines for three consecutive cycles. Fig. 2., demonstrates the number of arriving cars and number of waiting cars for first cycle (the initial state) of one line of intersection. From figures above, it can be observe that the percentage of the number of waiting cars increases as the number of the arriving cars increases in the consecutive cycles, where it is (50%) in cycle1, while it grows up to (75%) in cycle 2 and (83%) in cycle 3. Which means that the delay time by which the (N_w) have to wait till the next green traffic light signal is also increased due to more cars has been accumulated from previous cycles. To solve this issue, it has been proposed (VTS) model, its results are shown in Fig. 5,6 and 7, they display the traffic congestion in one line of intersection that has longer (T_G) for three consecutive cycles. From figures above, it is revealed that the number of arriving cars has been decreased significantly compared to (FTS) scenario due to longer (T_G) given to the highly congested line. Also, the rate of (N_w/N_arr) is reduced where it is (33%) in cycle 2 and (50%) in cycle 3. Taking into consideration, other lines will not suffer much delay since their (N_arr) is already less than the targeted congested line so there will be no high (N_w) in these lines.

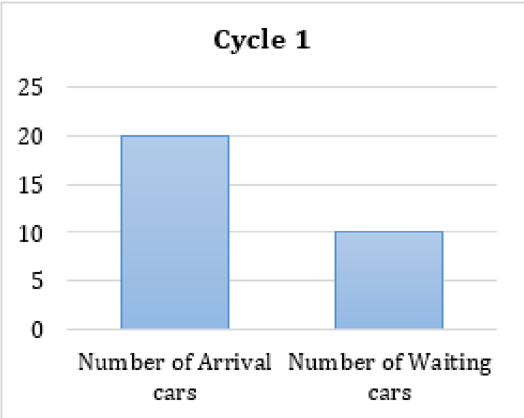

Figure 2. Traffic congestion in one line of intersection when traffic light periods are fix for all lines in the initial cycle

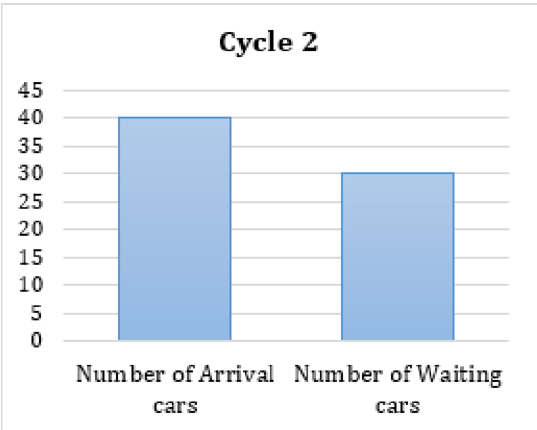

Figure 3. Traffic congestion in one line of intersection when traffic light periods are fix for all lines in the second cycle.

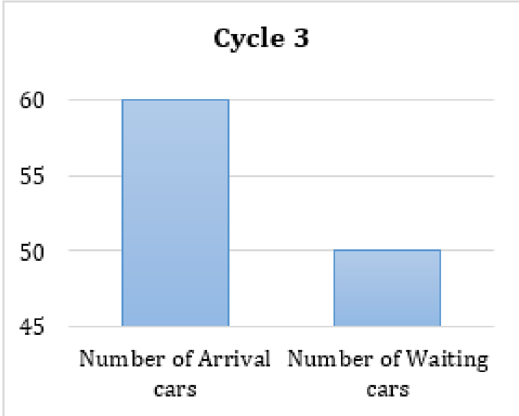

Figure 4. Traffic congestion in one line of intersection when traffic light periods are fix for all lines in the third cycle.

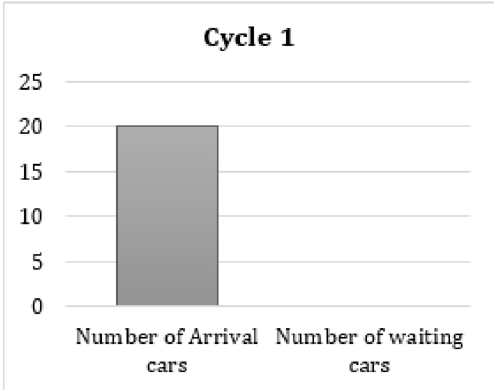

Figure 5. Traffic congestion in one line of intersection when traffic light periods are fix except for one line in the initial cycle.

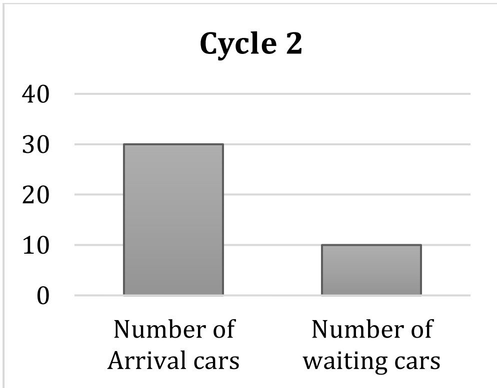

Figure 6. Traffic congestion in one line of intersection when traffic light periods are fix except for one line in the second cycle.

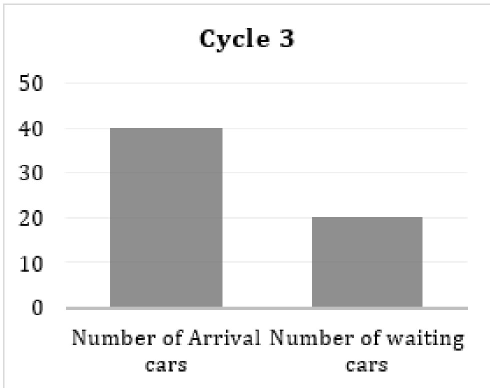

Figure 7. Traffic congestion in one line of intersection when traffic light periods are fix except for one line in the third cycle.

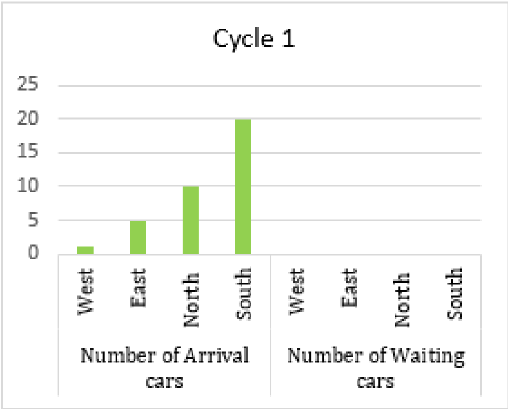

Figure 8. Traffic congestion in four lines of intersection when traffic light periods are variable for all line in the first (initial) cycle.

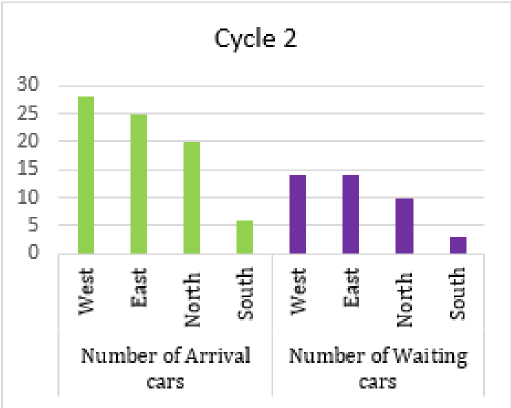

Figure 9. Traffic congestion in four lines of intersection when traffic light periods are variable for all line in the second cycle.

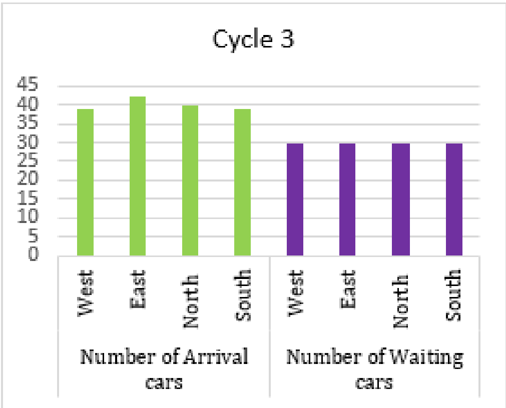

Figure 10. Traffic congestion in four lines of intersection when traffic light periods are variable for all line in the third cycle.

Last proposed scenario to deal with delay problem is (SATTS), where (T_G) presents variable time adjusted for all lines of the intersection using the same parameters of the first scenario by giving variable (T_G) for each line depending on the obtained congestion. Fig. 8,9 and 10, depict the traffic congestion in four (West, East, North and South) lines of intersection when traffic light periods are variable for all line in three consecutive cycles respectively. In cycle 1, (T_G) is enough for each line to fully pass the waiting cars, in cycle 2, together current arriving cars during the varied red on signal with assembled cars from previous cycle express the number of arriving cars (N_arr) and the same goes for cycle 3. The rate of (N_w/N_arr) is steady on average of (52%) in cycle 2 and (75%) in cycle 3, which are even better percentage than in (FTS) scenario. In these figures, it can be noticed that the delay of the four lines is almost convergent and it is the same in cycle 3 when traffic raises up, this is what is gained when treating four lines of intersection simultaneously, i.e. reducing congestion and being the delay nearly equally for each line.

5. Conclusion

In this paper, (FTS) model has been presented to address traffic congestion issue, besides to (VTS) and (SATTS) models to achieve less delay and reducing intersection lines traffic congestion in the cloud based IoT network. (VTS) schemes decreases the number of arriving cars in single congested line significantly to certain percentage and reducing delay in three consecutive cycles by extending total time of intersection. Nevertheless, (SATTS) scheme uses adjustable (T_G) green traffic light period in the four lines of intersection to overcome traffic congestion and further reduces delay. The results indicate that the proposed schemes can significantly reduce delay and hence traffic jam with an average (N_w/N_arr) percentage of (33%) in cycle 2 and (50%) in cycle 3 for (VTS) and (52%) in cycle 2 and (75%) in cycle 3 for (SATT), compared to (FTS). While (SATT) shorten the gap of the delay time between the four lines in the intersection.

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