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A FRAMEWORK FOR FOG VIRTUAL TRAFFIC LIGHT SYSTEM

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ABSTRACT

Traffic congestions at intersections inside urban cities gain a considerable research interest. Traditional physical traffic light systems become unable to manage traffic congestions efficiently due to a vast increase on the number of vehicles on the roads. Recently, Virtual Traffic light (VTL) system technology based vehicular communications has attracted research community and industry. The emerging field of Fog computing and vehicular networks make replacing traditional physical traffic light systems by VTL system is cost-effective. Hence, the main contribution of this paper is divided into two parts. First part is to provide a taxonomy of the research on traffic light systems and traffic congestions based different vehicular communications. The second part is to design a new framework to implement VTL system based on fog computing architecture namely F-VTL. In contrast to traditional VTL system, the algorithm that operates the F-VTL dynamically manages vehicles passing unsignalized intersections. In F-VTL system, a fog node is responsible to collect and processes data from vehicles on a regular base to control F-VTL system. Simulation experiments show that F-VTL has better performance compared to the traditional VTL system.

Keywords: *Fog computing, Virtual Traffic Light, Vehicular communication, Traffic Congestions.*

1. INTRODUCTION

Vehicular traffic congestion has direct negative consequences impacts on our surrounding environment. Traveling through congested roads imposes extra travel time and decreases transportation sector efficiency dramatically. As a result, degrading air quality by increasing fuel consumptions and CO2 emissions from vehicles moving on the congested routes. For example, vehicular congestions cost of $166 billion per year in USA caused people to travel an extra 8.8 billion hours and consume an extra 3.3 billion gallons of fuel [1]. Commonly, traffic congestions are deducted in terms of traffic density by estimating number of vehicles per unit area [2]. Several important parameters are used in traffic density estimation techniques such as vehicle position, speed, direction, difference time between entering and leaving observed area [3] [4] [5]. The most promising approach to mitigate traffic congestions is using vehicular communications to guide drivers to non-congested routes, or to adjust traffic signals adaptively according to traffic conditions. In this paper, we cover some important protocols suggested to handle traffic congestions problem and optimize traffic light signaling time using Vehicular Ad hoc Networks (VANTEs) communications. This including Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure(V2I), hybrid of V2V/V2I.

Nowadays, cloud computing technology is widely used to store and process a range of data volume from small to tremendous amount of data, and to serve several domains and aspects including VANETs. However, effective and evolved versions of VANETs require a smaller number of jumps to the cloud, higher bandwidth and lower latency[6]. Therefore, cloud computing has been emerged to produce a modern cloud technology such as Edge and Fog computing. The main purpose of these technologies is to balance and resolve the drawbacks of cloud computing. Fog computing aims to perform data processing task near the vehicle (workstation) to reduce the latency time, and Edge computing objectives is to process the data on closer data center than the original cloud system [7].

Managing traffic congestions at intersections by physical traffic light systems are still in widespread use today. However, traffic lights deployment and maintenance cost many resources and cover a limited number of intersections. For instances, as reported in [8], traffic light intersections coverage is nearly 0.5% in USA and 25% in Dublin. Hence, the VTL system is considered as a promising approach to eliminate physical traffic light systems while monitoring intersections effectively [8]. In the VTL system, traffic management and coordination at intersections are fully rely on vehicles themselves. Taking advantages of existing Fog computing, operating VTL system becomes more realistic and visible. Vehicles running VTL system send their data to a fog node, where available at each intersection. The fog node collects and processes this data on a regular base to control VTL system operations between vehicles. In addition to this, fog nodes in a particular area can exchange traffic information to deduct congested routes and inform drivers to avoid them. The main contribution of this paper is to provide an overview of traffic congestion detection and traffic light systems using VANET, and to propose a new concept of VTL based on fog computing.

The remainder of this paper is organized as follows. Section 2 presents an overview of the literature. Section 3 presents VANETs solution to optimize traffic light systems. Our proposed solution presents in section 4. Section 5 presents the performance evaluation of the proposed solution and results discussion. Section 6 discuss some open research issues and challenges. Finally, Section 7 discusses the conclusions and future work.

2. TRAFFIC CONGESTIONS USING VANETS

VANETs approach shows an important role for reducing and handling vehicles congestion around the globe. The literature shows several architectures for VANETs such as V2V, V2I, and a hybrid approach which combines both (V2V/V2I).

2.1 Vehicles-to-Vehicles (V2V) approaches

Several V2V monitoring techniques have been proposed in literature, which are explained in this section in turns. In this category, each vehicle is responsible to exchange traffic information to other surrounding vehicles periodically.

Contents Oriented Communication (COC), is a real-time traffic based V2V communication systems proposed to monitor vehicular accidents and congestions immediately [3]. In COC, once an accident or a spot of congestion is found, vehicles are exchanged three types of information; position, vehicles density and information about a particular group of vehicles such as (front and tail location of group). Each vehicle analyses traffic situation from broadcasted information to take a proper decision about current road condition. Similarly in traffic View technique, each vehicle collects speed and position information of ahead vehicles [4]. In A Self-Organizing Traffic Information System (SOTIS) [9], a periodic report for each road segment includes traffic information is disseminated by each vehicle every five second to surrounding neighbors, and it is stored in a database. Beside the periodic report, an emergency report is proposed in SOTIS to handle emergency cases with a high priority. In [10] traffic condition such as free flow, pre-jammed and jammed area is determined by applying pattern recognition techniques such as a Weight of evidence on a snapshot of the traffic information over a period of time. The VOTING protocol was proposed in [11], to determine a congested highway area at a given time, by comparing the current moving speed with the maximal allowed speed. If most vehicles vote for slow-moving, this means that a congested has occurred. In this paper [12] a cluster method for Sharing Traffic Jam (STJ) information is suggested to estimate arrival time for each vehicle. A highway is divided into small zones. Every vehicle estimates and exchanges information of its entering and leaving time to the zone and with each other. Which helps to predict congestion spot in advance for ongoing vehicles. Chou et al.[13] proposed a Virtual Data Sink (VDS) technique to mitigate traffic congestions and to estimate traveling time for vehicles a long road segment. VDS also succeed to control excessive number of broadcasted messages by using a new global broadcast methodology. A location based group concept is suggested in Infrastructure-Free Traffic Information System (IFTIS) [14], to estimate a traffic density on both road directions to choose free congested route for vehicles. In IFTIS a group leader which is selected according to its position of the cell group, is responsible to disseminate data packet density information at each intersection. Recently, V2V-based fuzzy logic has been proposed for the detection of road traffic congestions [15]. A fuzzy controller uses vehicle speed and traffic density as the input to determine level of local traffic and the level of regional traffic congestion. An INtelligent protocol of CongestIon DETection (INCIDEnT), based on a neural network was suggested in [16], to deduct and classify congestion levels, and suggest alternative routes to avoid congested area. Based on the average speed and the density of vehicles three levels of congestions are classified: free, moderate and congested, and are disseminated by all vehicles through periodic broadcasted messages.

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Table 1: A taxonomy of traffic congestions protocol

Protocol	Architecture	Type of traffic collected information	Simulator/tools
COC	V2V	Position and density	Computer based simulation model
TrafficView	V2V	Speed and position	Ns2
SOTIS	V2V	Speed	Ns2
Traffic pattern	V2V	Speed, position and direction	MATLAB
VOTTING	V2V	Speed	JIST/SWANS [17][18]
STJ	V2V	Density and speed	Visual C++
VDS	V2V	Density and direction	NCTUns [19]
INCIDEnT	V2V	Speed and density	OMNeT++ [20]
Fuzzy controller	V2V	Speed and density	OMNeT++ [20]
IFTIS	V2V	Density	QualNet [21]
StreetSmart	V2I	Speed	RoadMap[22] / Linux based laptops
V2X	V2I	Speed	VSimRTI [23]
Lattice	V2I	Traveling time	Private simulator
TraffCon	V2I	Velocity and acceleration	STRAW[18]
Fife Proactive	V2I	Position speed and direction	TraCI[24]
CHIMERA	V2I	Speed and density	TraCI [24]
NRR	V2I	Traffic volume	TraCI [24]
ECODE	V2V/V2I	Density, speed and location	Ns2
EcoTrec	V2V/V2I	Traffic volume	iTETRIS [25]
V2X-d	V2V/V2I	Density and roadmap topology	NS2

Table 2: A taxonomy of traffic light protocols

Protocol	**Architecture**	**Type information needed**	**Simulator/tools**
VTL	V2V	Position and direction	DIVERT [26]
Co-exist VTL	V2V	Position and road characteristics	SUMO [27]
AVTL	V2V	Speed, density and direction	NCTUns [19]
VTL	V2C	Speed, density and direction	Framework
DVTLA	V2V	Position and direction	Real life testbed
VTL	V2V	Position and direction	Android-based smartphones
SATL	V2I	speed, location, direction	Simulink/MATLAB
IRTSS	V2I	Speed, time and position	OPNET [28]
V2I based cooperation	V2I	Speed, direction and position	MATLAB

2.2 Vehicle-to-Infrastructure (V2I) approaches

StreetSmart Traffic technique deploys clustering tool and epidemic communication to exchange a summarized traffic information of a congested area only [11]. Each vehicle can estimate high congestion level zones from the summery statistic collected by local vehicles. Another technique namely V2X-Based traffic congestion recognition and avoidance [12], employs an algorithm based on GPS to calculate routes circumnavigating congested roads. It calculates the average speed for a road segment which be used by vehicle to find a new route with a shorter travel time. A V2I mechanism is proposed to address vehicle traffic congestions problem [13]. It employs traffic information sharing and route selection procedures to select a congestion free route, based on the traveling time information from moving vehicles. This information is collected and then is broadcasted by Road Side Unit (RSU) to target vehicle to take a proper route for their journey. A traffic management system namely (TraffCon), based on a client-server architecture is introduced to optimize the usage of the road capacity and reduce vehicle trip times. All vehicles act as clients and gather traffic information vehicle such as, velocity and acceleration. A server is responsible to collect this information from vehicles and to inform them about best route. A proactive system which includes five re-routing strategies was proposed in [14], to monitor and decrease the traffic congestion of vehicle. The five proposed strategies are : (1) the dynamic shortest path (DSP), (2) the A∗ shortest path with repulsion (AR∗), (3) the random k shortest path (RkSP),(4) the entropy-balanced kSP (EBkSP), and (5) the flow-balanced kSP (FBkSP). These strategies use real-time data information about traffic conditions, such as position, speed and direction which are collected by a roadside system. An intelligent traffic system namely CHIMERA was proposed in [15], to deduct and control traffic congestion in urban centers. In CHIMERA, vehicles send their information such as, ID, current position, route and destination) to a nearest RSU. CHIMERA uses K-NN (k-nearest neighbors) for congestion detection and traffic classification and uses the K-Shortest Path-based algorithm for the route choice. To mitigate unexpected traffic congestions, Next Road Rerouting (NRR) strategy was proposed in [16]. In NRR, a re-route decision for a driver is calculated based on a heuristic technique and a cost function that takes into account several traffic information such as distance to target destination, traffic conditions and travel time. This information is collected by the intelligent Traffic Light (iTL) to decide and to inform vehicles if whether any of its intersection roads is congested.

2.3 Hybrid V2V / V2I approaches

In [5], a hybrid Efficient congestion detection (ECODE) protocol of reactive and provocative broadcasted scheme is used to allocate traffic congestion of any road segment in any urban grid-layout topology. An ADVertisement (ADV) message is sent to surrounding vehicles using V2V communication which includes information such as ID, Speed, location, direction, destination and timestamp. Then, a Traffic Monitoring Report (TMR) that includes information such as the average speed, the density and the estimated travel time for vehicles, is created based on aggregated ADV messages and a Neighbor Report table (NR). TMR is sent to any closest RSU by vehicles, which it's in turns rebroadcasts it to all vehicles inside its transmission rage. Doolan et al. [29] proposed a (EcoTrec) routing solution using VANET to reduce the CO2 and decrease time wasted due to traffic congestion. For this purpose, three type of models are used in EcoTrec: The Vehicle Model which represents the important characteristics, The Road Model which allows each vehicle to query our update the road characteristics, and The Traffic Model which includes real-time traffic condition that can be used by vehicles on each road segment. The Traffic Model is maintained at a central server and updated regularly with information that collected from vehicles. In [30], a V2X-d approach was proposed to estimate traffic density using V2I and V2V communication. In V2I communication traffic density is estimated by the average number of packets received by each RSU, and the ratio between streets and junctions of the studied map. In another hand, traffic density in V2V communication is collected using the number of neighbors that are reachable by one-hop messages.

3. VIRTUAL AND PHYSIYCAL TRAFFIC LIGHT SYSTEMS

3.1 Vehicles-to-Vehicles (V2V) approaches

So far the VTL systems are implemented using V2V communications, where the first investigation of VTL system was proposed in [8]. VTL system works by electing one vehicle as a leader among group of vehicles that approaching an intersection. This leader will act as a temporary virtual infrastructure for the intersection and undertake the responsibility for managing and broadcasting the traffic light messages to its group. Authors In [31], are assumed that not all vehicles are capable to

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interact with the VTL system. Hence, they have proposed a new model that makes vehicles equipped with the VTL system able to co-exist with vehicles that do not have the VTL system. An Adaptive Virtual Traffic Light (AVTL) is suggested in [32] to adapt the cycle of traffic lights according to traffic conditions through smart cycle function; planning, management and operating functions. In the planning function general vehicles information such as position, traveling time and speed are collected to elect a group leader. In the management function, after the leader is selected, it creates and maintain its own AVTL system at each intersection. Finally, in the operating function the selected leader broadcasts traffic signals to its group members. A framework of the VTL system is implemented by using cloud and mobile communication technologies in [33]. Vehicles information such own geo-location, speed and heading data are sent to cloud server system, then it disseminates information message to all VTL vehicles at a given intersection. In [34] A Distributed Virtual Traffic Light Algorithm (DVTLA) is proposed for the intersections where a physical deployment of a traffic light is not cost-effective. It aims in the first phase to: define the first priority for vehicles when come to an empty intersection, based on the first coming, first crossing principle. In the second phase of the DVTLA, a vehicle which holds the previous priority switches it to the next vehicle. The concept of the VTL system in [35], is implement using smartphone application such Android and IOS, where colors of the VTL are represented as a user interface on Android-based smartphones.

3.2 Vehicles-to-Infrastructure (V2I) approaches

A Self-Adaptive Traffic Light Control system (SATL) is proposed in [36], to adaptively adjust the light timer of the traffic signal based on average vehicles speed. Each vehicle sends its own speed once it passes the intersection, then the traffic light adjusts the signal time for each direction in real time accordingly. A new Intelligent Road Traffic Signaling System (IRTSS) system based on V2I communication was proposed in [37]. IRTSS assumes that each vehicle is equipped with OBU system based IEEE802.11p, and able to communicate with RSU via Dedicated Short-Range Communication (DSRC). The RSU collects traffic information from OBU such as speed, position and time to reach the intersection, and broadcasts the signaling information based on received traffic information active OBUs within its range. a V2I based cooperation technique is implemented in [38] between traffic signal and approaching vehicles at intersections to optimize both traffic signal change timing and vehicle speeds.

4. PROPOSED FRAMEWORK

4.1 Overview

In this section, a fog architecture base VANETs, is presented as in figure 1. Vehicles can communication with cloud nodes via wireless communication interfaces, such as 3G or 4G. This communication form is called *Vehicles-to-Cloud (V2C)* communication. Cloud nodes can send traffic information to fog nodes in advance in terms of *Cloud-to-Fog (C2F)* communication model, to predict road condition and make early decision. Fog nodes are installed at intersections to manage traffic congestion, and capable to communicate with each other via either cloud nodes, or directly if they are in the same transmission range. The F-VTL system management is organized between vehicles via *Fog-to-Vehicle (F2V)* communication to assign priority for each intersection and manage the VTL system zone. The communication between F2V is made by using IEEE 802.11p wireless communication standard. All Vehicles are assumed to be autonomous and equipped with wireless devices such as a GPS and an On-Board Unit (OBU), that allows DSRC communications with other OBUs or fog nodes.

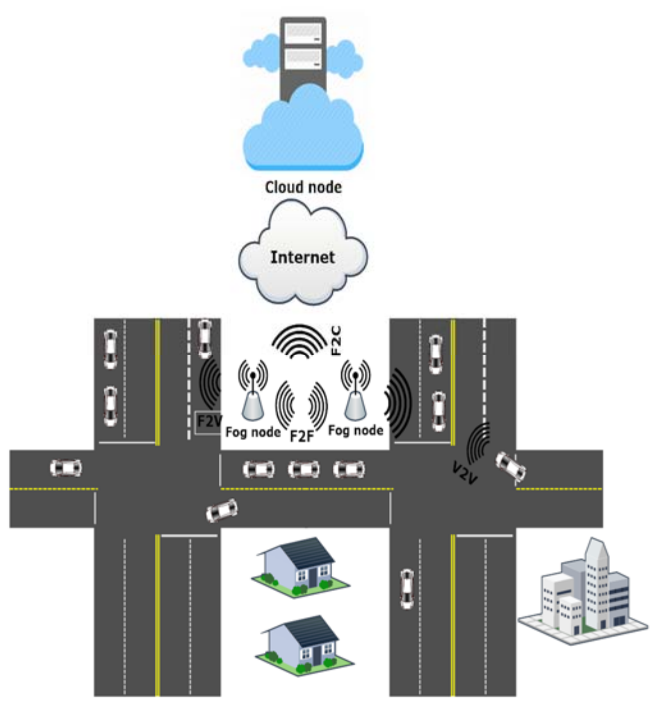

Figure 1: system architecture of fog computing.

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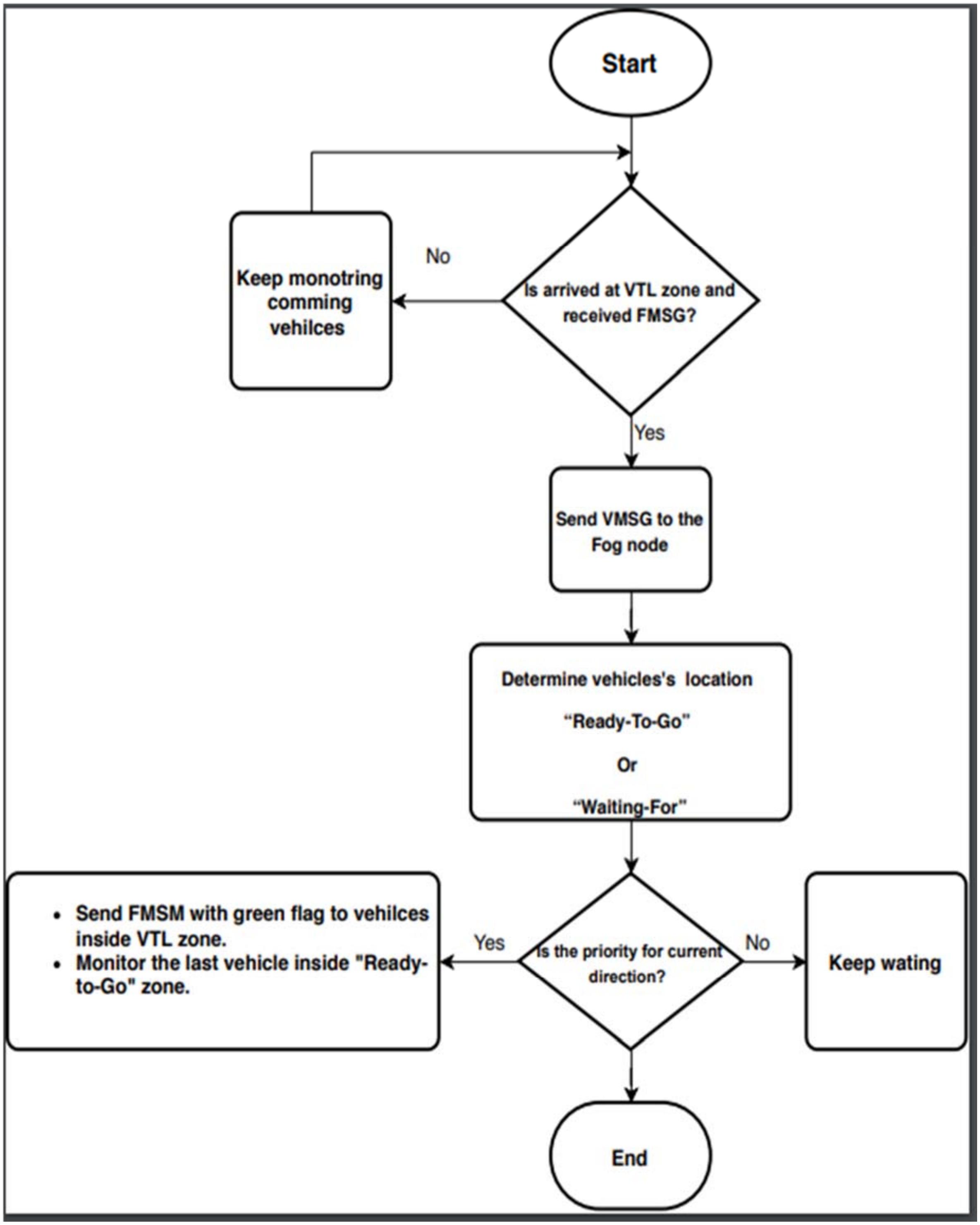


Figure 2: Flowchart of VTL producer.

4.2 Proposed framework architecture

In the traditional VTL system vehicles at the same intersection should elect leader candidate to act as a cluster leader. The elected leader must be the closest vehicle to the intersection and must acknowledge by all other cluster leaders. It serves as VTL operator and responsible for creating and dissemination traffic light information to its follower vehicles. In this paper leader election process and responsibly is replaced by F-VTL technology. In F-VTL, cluster leaders are not necessary, and their roles are assigned to fog nodes.

In the proposed F-VTL framework, the fog node sends information message (FMSG) to neighboring vehicles at its intersection periodically. FMSG includes (fog ID, longitude, latitude and color flag) as described in the table 3. In the other hand, vehicles do not need to send Vehicle Message (VMSG) to its neighbors periodically. The V2F communication takes place one-demand and when the vehicles are located inside the fog node's transmission rage. This can reduce the total network overhead and increase its performance. When vehicle i approaches the fog node, it disseminates VMSG including the information listed in the table 4. Each fog node maintains a V2F list (L_{V2F}) which is updated as follows. When a fog node j receives VMSG from vehicle i and it is not in the list, it adds Vi information (vid, v, din, dout, rid, t) to L_{V2F}. Otherwise, it is discarded.

In the F-VTL framework, road segment near to an intersection is called VTL zone and it is divided into two zones; "*Ready-To-Go*" and "*Waiting-For*" zones. Dimension of each zone (length and width) is predefined and stored in a spatial database in the fog node. Upon vehicle arriving at the VTL zone and receiving FMSG, it should announce itself to the fog node by broadcasting VMSG. Based on its position at VTL zone, the fog node can identify vehicles on "*Ready-To-Go*" and "*Waiting-For*" zones. Priority of passing the intersection is given based on the total number of vehicles inside VTL zone. The intersection which it's VTL zone are fully congested or have a total number of vehicles more than other intersection is privileged to grant a priority. Two color signals are available in the F-VTL framework; green signal and red signal. Fog nodes geocast a green signal to vehicles queued at the "*Ready-To-Go*" area only. The fog node is responsible to monitor vehicles movement until they all passed the intersection. It's simply done this by knowing position of the last vehicle in "*Ready-To-Go*" zone. After that, the fog node sends FMSG with Red flag to vehicles inside VTL zone and grants the priority to another intersection direction. This framework

Table 3:The fog node message information.

Fid	the unique identifier of the fog nod
long	longitude
la	latitude
Color Flag	Red or Green

Table 4: The vehicle message information.

Vid	the unique identifier of the vehicle
S	Vehicle speed
P	Position
Din	Direction of vehicle moving to the fog node
Dou	Direction of vehicle leaving of the fog node
T	Arrival time

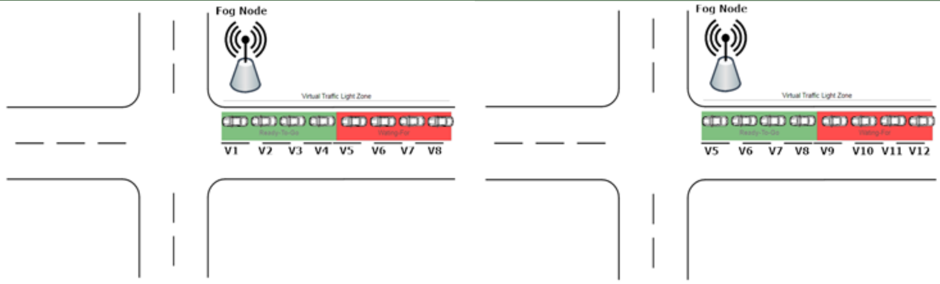
does not use signal cycle time for each color to allow vehicles pass the intersection, but the time required for each cycle is equal to the number of selected vehicles that privilege to pass. Figure 2 draws a flowchart for working process of F-VTL.

In some emergency cases, emergency vehicle must travel very fast to reach the target area. Hence, it is very crucial to inform fog nodes in the trajectory of emergency vehicle. Since an emergency vehicle can only contact a nearby fog node where decision of VTL framework is made locally. Therefore, emergency vehicle must send its own information including its (speed, direction, type and destination) to the cloud node. Then, the cloud node guides the emergency vehicle via free-congested routes and informs all fog nodes ahead to free intersections before approaching them.

4.3 Priority management at intersections

Average waiting time waiting factor at each intersection is considered to manage traffic priority between vehicles on intersections. We suppose that each intersection has four direction (East, Waste, North and South). When a vehicle arrives at fog node, its arrival time is recorded, and average waiting time is calculated for all vehicles to estimate the priority for each direction. Suppose that Vi is the waiting for a vehicle just arrived at VTL zone, n is the number of total vehicles at VTL zone, then the Average Waiting Time (AWT) is calculated as follows:

$$AWT = \sum_{i=1}^{n} Vi \qquad (1)$$



scenario (a) **scenario (b)**

Figure 3 : Show how F-VTL manage west direction between vehicles located at VTL zone

The fog node calculates AWT for each direction and grants the priority for the direction that has the larger AWT. However, in emergency cases the priority is assigned to the direction of emergency vehicles.

4.4 Illustrated scenario

Figure 4 illustrates how F-VTL works in a real-life based scenario. In scenario (a), when vehicles v1, v2, v3, v4, v5, v6, v7 and v8 at west direction, enter at the fog node communication rage they immediately send VSMG containing information in the table 3. If the current priority to pass intersection is not for west direction, the fog node should send FMSG with Red flag to all vehicles that queue inside "*Ready-To-Go*" and "*Waiting-For*" zones. Once priority is given to the west direction, fog node sends FMSG with Green flag to all vehicles from 1 to 8. However, since vehicles inside "*Ready-To-Go*" zone are privilege to pass the intersection, the fog node will keep monitoring position of the last vehicle, (i.e. v4) until leaving "*Ready-To-Go*" zone. when the fog node makes sure that all previous vehicles in "*Ready-To-Go*" zone have passed the intersection, it sends FMSG with Red flag to all current vehicles inside "*Ready-To-Go*" and "*Waiting-For*" zones. Scenario (b) shows that vehicles inside "*Waiting-For*" from scenario (a) zone, are currently waiting inside "*Ready-To-Go*" zone, and new vehicles are entering "*Waiting-For*" zone. The fog node updates L_{V2F} and repeats this process for all direction with same steps.

5. SIMULATION ENVIRONMENT AND PERFORMANCE EVALUATION

The performance of F-VTL framework is evaluated using the OMNeT++ 5.01 simulator [20]. SUMO is used to simulate mobility model [27], and TraCI (Traffic Control Interface) [24] to manage traffic provided by it. Size of simulation area is about 1000 x 1500 meters with four intersections.

A fog/RSU node is installed at each intersection. IEEE 802.11p is MAC protocol, and 250-meters transmission range is set for each vehicle. In this paper, the total number of vehicles moving in the simulation is randomly set between 200 to 800 vehicles with random speeds between 5 and 60 km/h. The following metrices are used to compare F-VTL framework and traditional VTL system:

- **Average waiting time**: represents the total waiting time for all vehicle at intersections.
- **Average speed time**: shows the average speed for all vehicles

Figure 4 shows average waiting time for all vehicles at intersections. When number of vehicles on the road increases, average waiting time also increases dramatically. This is due to increase number of waiting vehicles at the F-VTL zone. It is clearly that F-VTL incurs less waiting time than VTL system, as it explicitly determines the number of vehicles that must pass the intersection. For instance, when the number of vehicles is high, the F-VTL reduces average waiting time about 64% compared to traditional VTL system.

Results in figure 5, confirm the superiority of the F-VTL over its counterpart by increasing average speed of all vehicles over all traffic densities. Normally, as vehicle densities increases speed of vehicles decrease due to high traffic congestions at intersections. However, the F-VTL performs better than the VTL system and improves average speed of vehicles about 29% and in low traffic densities (i.e. 200 vehicles) and 50% in high traffic densities (i.e. 800 vehicles). Figure 6 also shows that F-VTL allows emergency vehicles moving faster than traditional VTL system. This is due to the fact that F-VTL gives the priority to all directions that emergency vehicles will pass. For instance, in a high traffic density (i.e. 800 vehicles), the F-VTL and the VTL system allows emergency vehicles move with speed 30km/h and 20km/h, respectively.

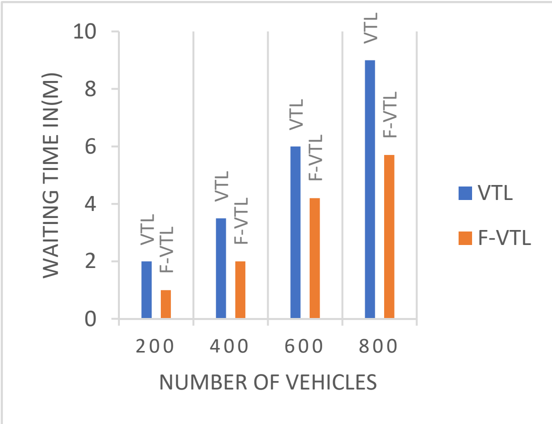


Figure 4: Waiting Time vs Number of Vehicles

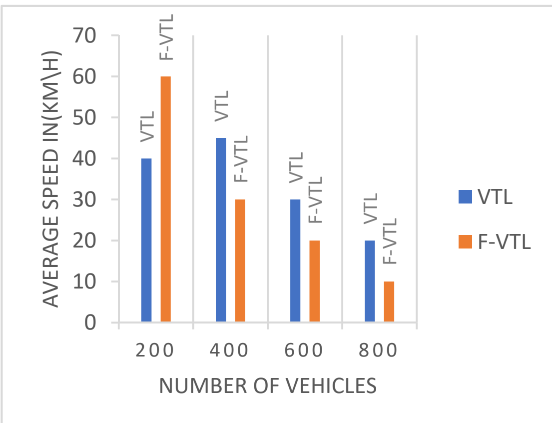


Figure 4: Number of Vehicles vs Average Speed

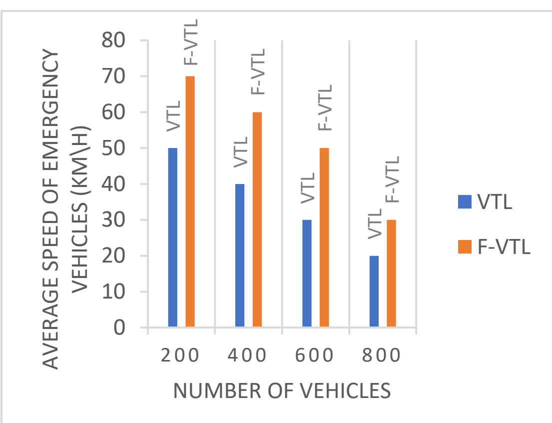


Figure 5: Number of vehicles vs average speed of emergency vehicles.

6. OPEN RESEARCH ISSUE

So far implanting an efficient VTL system is still an open research question. The following issues need further investigation to improve the VTL performance system and to increase its visibility:

- The fog node must be able to know in advance the direction of each vehicle at the intersections. Hence, the need for an efficient algorithm to address this issue is very important to organize and manage priority of passing intersection for vehicles.
- The F-VTL framework does not use fixed timer for all vehicles to pass the intersection, it depends only on the predetermined number of vehicles at "*Ready-To-Go*" zone. Therefore, how to determine the area of the F-VTL zones is still not clear and requires more investigations.
- Since some vehicles will not be equipped with the VTL system, a new scheme must be developed to work with various types of vehicles and complex scenarios.

7. CONCLUSION AND FUTURE WORKS

This paper has identified a clear taxonomy of mitigate traffic congestions and control traffic light systems using vehicular communications. Then, it sheds light on benefit of using VTL system in the near future instead of using physical traffic light systems. The rapid advances in deployment of fog computing technology in smart cities, has opened new horizons for research community to make the VTL system more visible in the real-life applications. Therefore, in this paper we introduced a framework of VTL system based on fog computing which is so-called F-VTL framework. The F-VTL framework divides road segment near to an intersection into two zones; "*Ready-To-Go*" and "*Waiting-For*" zones. Based on a position of each vehicle at VTL zone, the fog node can easily identify vehicles on "*Ready-To-Go*" and "*Waiting-For*" zones. Priority of passing the intersection is given based on the total number of vehicles inside VTL zone. The fog node organizes vehicles passing intersection by gecasting VSMG with green/red flag to vehicles at VTL zone, while monitoring vehicles movement inside both zones. Simulation experiment shows that F-VTL outputs traditional VTL system under different traffic densities in terms of average waiting time and average speed time. For instance, when the number of vehicles is equal to 800, It reduces average waiting time up to 64% and increases average speed time up to 50% compare to VTL system.

For the future the work, we will implement F-VTL in the realistic to investigate its performance further. It can be also extended to manage non-VTL vehicles and bicycle drivers by exploring fog node features.

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