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A new Algorithm for Traffic Congestion Detection using Vehicular Ad hoc Networks

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ABSTRACT

Traffic Congestion in Egypt roads is the same problem facing many cities around the world where traffic congestion is a well-known economic and social problem generating significant costs and safety challenges, and increasing pollution in the cities. Current Conventional infrastructure based solutions to detect traffic congestion, such as surveillance cameras and road surface inductive loops, have the limitations of high deployment costs and limited coverage. This paper contributes towards the development of distributed and cooperative vehicular traffic congestion detection by proposing a new vehicle-to-vehicle (V2V) congestion detection algorithm based on the IEEE 802.11p standard.
The new algorithm allows vehicles to be self-aware of the traffic in the city roads, performing congestion detection based on speed monitoring and exchanging traffic information with the surrounding vehicles. Exchanging is achieved using adaptive single-hop broadcasting which depends on the level of congestion. The paper presents the congestion detection algorithm and the cooperative communication in detail, and presents performance evaluation using large-scale simulation in Veins framework based on OMNeT++ simulator and SUMO vehicular mobility simulator. Results show that precise congestion detection and quantification can be achieved using a significantly decreased number of exchanged messages allowing more vehicles to be aware of congestion and be able to avoid it.

General Terms

Traffic Congestion Detection, Vehicular Ad Hoc Networks, Traffic Information System, V2V**.**

Keyword

1. INTRODUCTION

During the last decades, worldwide road traffic density has been increasing year after year. This case has led to the fact that traffic congestions are one of the most common phenomena that drivers have to face in their trips. Millions of hours and gallons of fuel are wasted everyday by vehicles jammed in traffic due to increase of traffic intensity.

Traffic congestion management is currently done via conventional traffic monitoring solutions based on infrastructure which provide fixed-point traffic information. These solutions include various types of infrastructure from traditional traffic lights, to smart video cameras. Fixed point solutions provide traffic estimates based on measurements taken at a specific location where they are placed. Because of that, such systems might not provide an accurate representation of the traffic conditions over larger road segments. Additionally, they would have to be installed at every intersection in order to cover the area of the whole city and the cost of such solutions is extremely high and deploying them at every intersection is not practically feasible.

One of the infrastructure based traffic monitoring and management are those systems designed with using Vehicular Ad hoc Networks (VANET) [1]. A vehicular ad hoc network (VANET) is an ad hoc wireless communication system setup between multiple vehicles (vehicle-to-vehicle or V2V) or between a vehicle and some roadside infrastructures (V2I).

This kind of networks are self-configuring networks composed of a collection of vehicles and elements of roadside infrastructure connected with each other without requiring an underlying infrastructure, sending and receiving information and warnings about the current traffic situation. Since V2I communications also require supporting infrastructure, V2V [2] communications are the only completely distributed way of exchanging the traffic related information.

Various researchers are working on VANET to find the solution for current crucial congestion problem. In paper [3] we have proposed a survey of different approaches of traffic information systems and how the Infrastructureless approach is the more one to be used in transportation system. Also we have discussed different techniques and systems developed by many researchers for traffic congestion and monitoring systems. We have mention from that survey the importance of V2V communication in new systems of traffic congestion detection.

In this paper we propose the algorithm which contributes towards distributed traffic congestion detection in Egypt environment based on Vehicle-to-vehicle (V2V). This algorithm enables each vehicle to determine traffic conditions surrounding it and then share this information with other vehicles. The result of such exchanging approach is in reducing the number of broadcasting nodes, at the same time having available the information about traffic congestion. The rest of the paper is organized as follows: In section II presents problem definition while in section III, we present literature overview of most of systems related to congestion detection and our proposed technique. Our proposed in details for traffic congestion detection is described in section IV. Performance evaluation and simulation results of our proposed and the others are discussed in section V. Finally, section VI concludes this work and illustrates directions for future work.

2. PROBLEM DEFINITION

Traffic congestion detecting using VANETs has been one of the hot research topics recently. Most of the work so far focused on solving this problem by V2I communications and such work is not presented here. On the other hand, we found a number of papers which used V2V communications for traffic congestion detection, management and forecasting and some were presented previously in this paper. Although, all of the presented techniques are based on V2V communications, they still have certain limitations. These include:

- Some techniques designed only for the high way scenario and not effective in solving congestion problem of real world traffic.
- Most of presented techniques depend on periodic messages to exchange traffic information this may cause network overload and broadcast storm.
- Some techniques depend on extra information about traffic flow from such traffic center or any information provider to be able to perform traffic analyzing.

Therefore, we propose the mechanism which contributes towards distributed V2V traffic congestion detection in Egypt roads independent of any additional information and relying on broadcasting algorithm. This mechanism enables each vehicle to determine its traffic condition and then through cooperation share this information with other vehicles. The result of such cooperative approach is in reducing the number of broadcasting nodes while at the same time having available the information about traffic congestion. Our technique has been simulated and applied on real map also we have applied three techniques SOTIS, VOTING and Lin and Osafune on the same map and conditions to compare the performance of those three techniques and our proposed technique TCD.

3. LITERATURE OVERVIEW

Traffic congestion detection and management using VANETs has recently become very important topic in transportation systems. Focus so far has been on the highway scenarios mostly considering V2I communications, which rely on supporting infrastructure such as roadside units (RSUs). But due to many limitations in deploying such systems, and how they require expensive infrastructure. In V2V communication has two types of messages used to exchanges traffic information between vehicles, first type is ***event-driven messages***, whose transmission depends on the occurrence or non-occurrences of a certain well-defined events at a node. This type of inform neighboring vehicles about abnormal or dangerous situations such as traffic jam or accidents [4]. Second type ***Beacon messages***, these messages are sent periodically by all vehicles and inform other vehicles about their presence, position, speed, acceleration and services information. Most of algorithms developed for congestion detection use only beacon or periodic messages to collect and distribute traffic information and some algorithms use both periodic and non-periodic messages. On the other hand, our proposed algorithm depends only non-periodic messages to exchange all traffic information between vehicles, this allow us to overhead on communication channel. Many researchers have developed different algorithms based on Vehicle to Vehicle communications.

One of the first papers dealing with distributed traffic congestion detection and management ***COC (Contents Oriented Communication)*** [5] is a technique where vehicles estimate road traffic density from received beacon messages, and periodically transmit this information to other vehicles. COC analyzes the situation in the surrounding in real-time, and shares the analyzed information among vehicles. In a word, people can recognize the vehicular accidents and congestions in real-time by using COC. This capability is obtained at the expense of overloading the communications channel through the continuous exchange of traffic density estimates so appear the need for better techniques such as Traffic View and SOTIS. A technique called ***TrafficView*** is presented in [6]. Its main objective is to gather and disseminate information about the position and speed of vehicles. The approach for message exchange is very similar to that used in SOTIS: vehicles periodically broadcast reports (contained in a single packet) about themselves and other vehicles they know about. The main drawbacks of this techniques it very costly and provide a great overhead to the network. This technique does not have the capacity to select the vehicle that will be in charge of disseminating the detected traffic congestion conditions to approaching vehicles or road authorities.

In the ***Miller technique*** or V2V2I [7] architecture, the transportation network is broken into zones in which a single vehicle is known as the Super Vehicle. Only Super Vehicles are able to communicate with the central infrastructure or with other Super Vehicles, and all other vehicles can only communicate with the Super Vehicle responsible for the zone in which they are currently traversing. This technique proposes [8] that only one vehicle in each road segment is in charge of collecting and aggregating road traffic data. However, the selection of the vehicle responsible for the data aggregation usually generates additional signaling overhead. The ***Street Smart*** Traffic technique introduced in [9] proposes to aggregate traffic information using distributed clustering algorithms with an epidemic diffusion model. Each vehicle records its speed and on this basis builds a local traffic map. Data aggregation is performed using clustering techniques, which combine related recordings of an unusual speed. Previous VANET congestion systems had limited scope. The TrafficView project focused the congestion of the road directly ahead. The TrafficView project was able to demonstrate that it is possible to monitor vehicle congestion using a real VANET. The idea was extended to both sides of the road by SOTIS. this technique the first to address the problem of discovering traffic on a road network.

In technique **Vaqar and Basir technique** [10] the traffic information gathered by a node in an ad hoc network is viewed as a snapshot in time of the current traffic conditions on the road segment. The pattern is analyzed using pattern recognition techniques. The mechanism reported by Vaqar and Basir reduces the risk of communications overload by only estimating traffic congestion locally at each vehicle using pattern recognition techniques that exploit the beacon messages received from nearby vehicles. However, the lack of mechanisms to validate or correlate the traffic congestion estimates among various vehicles may lead to unreliable detections. To evaluate our proposed technique (TCD) capability to accurate detects and characterizes road traffic congestion conditions. Its performance is compared against that obtained with the three techniques SOTIS, VOTING and Lin and Osafune. Those techniques have chosen as they the most famous V2V based solutions that are able to detect traffic congestion based only on the traffic measurements collected by the vehicle itself. Those three techniques are discussed in some details in the next subsections.

A. SOTIS technique

Self-Organizing Traffic Information System (SOTIS) [11] is one of the techniques we will deal with in some details for comparing it with our proposed technique. SOTIS is completely different proposal to establish a powerful traffic information system depends only on vehicle to vehicle communication (V2V) without any additional infrastructure. All vehicles are part of a Self-Organizing Traffic Information System (SOTIS): Each vehicle monitors the locally observed traffic situation by recurrently receiving data packets with detailed information from other vehicles. All currently available traffic information of a node is stored in the Knowledge Base (KB), e.g. in form of a database containing roads and information for each segment of the road. The algorithm for the distribution of traffic information consists of three parts: ***Receive*****:** each vehicle send periodic message contains some basic information such as velocity and position. ***Analyze:*** The second part of the distribution algorithm perform the traffic analysis based on the information in the KB. The average velocity of all vehicles for an analyzed road segment is calculated, based on the velocity information received from vehicles in transmission range. The result is the estimated road condition for that road segment at the current time. ***Send:*** The third part of the distribution algorithm determines the time schedule to transmit the next SOTIS packet and the traffic information that will be included. In SOTIS project in order to evaluate the performance they used a simplified model was implemented within the network simulator ns-2[12]. The ns-2 simulator is extended with a movement model based on a simple traffic simulation using a cellular automaton approach. It additionally allows passing, if safety conditions are not violated. The scenario presented for this project simulates a regular highway with two lanes per direction and all packets are transmitted as broadcast. SOTIS is such good technique for detecting traffic congestion but may have some limitation in network overhead due to periodic messages also SOTIS simulation used to simulate it in simple high way with two lanes only.

B. VOTING technique

Vehicular over-the-air information gathering (VOTING) [13] is a technique based on a simple idea: decision by majority. In VOTING the whole system depends on three main parts the first is that all vehicles broadcast their current location, speed and direction at fixed time intervals. Secondly, a vehicle that is going “slower than normal” considers itself to be in congestion. A vehicle that believes to be in congestion will validate its congestion area with data received from other vehicles. This is where the name VOTING comes from: If the information received is consistent with the congestion, it is said to be in agreement. When the number of vehicles in agreement surpasses those in disagreement by a certain margin, and the congestion reaches a certain size, the congestion is then validated and broadcasted. Finally, Vehicles that are not in congestion limit their participation to broadcasting their own information (location, speed and direction) and the congestion information they have received from other vehicles. They do not make any changes to congestion information. For simulating such system Java in Simulation Time (JiST) [14] and the Scalable Wireless Ad hoc Network Simulator (SWANS) are used SWANS supports the concept of mobility models. A mobility model controls how network nodes move overtime. The author also developed a visualization [15] tool that allows researchers to determine the strengths and weakness of a particular congestion detection algorithm by showing them how the system is behaving under a particular situation. Simulation has been developed for simple high way of two lanes this may introduce some limitation when applying this technique for real world traffic.

C. Lin and Osafune technique

Lin and Osafune [16] is a method for detecting and diffusing traffic condition information by distributed vehicle-to-vehicle communication systems. Lin and Osafune is a technique based on both voting mechanism and speed estimation between vehicles all this information is used to determine traffic congestion and inform other vehicles to avoid the area of congestion. This technique can be described in two step procedure. In first step vehicles exchange periodically position data among each other in the communication range. By receiving the position data from other vehicles each vehicle keeps a table of position data and historical movement of other vehicles. The second step is detecting the position of traffic congestion also its beginning and end positions. For achieving this voting process inside vehicle to vehicle network can be established. Based on the first step each vehicle has its own estimation about traffic condition so vehicle congestion will broadcast a voting message to other vehicles in the communication range and requests the other vehicles to answer with their own estimation results. If most of the vehicles replay with the same traffic conditions so this area be a traffic congestion area. After all the steps of traffic estimation Lin technique provides an additional way to determine the beginning and the ending position of the traffic congestion. So the host vehicle divides the replay messages into two groups based on their position. Vehicles replied are divided into upstream vehicle and downstream vehicles this represent vehicles replied behind and a head of the host vehicle. If 80% of received replies are from downstream vehicles, then host vehicle be in or near the end of the congestion area. On the other hand, if most of replies are from upstream then host vehicle be at the beginning of the congestion area. Lin and Osafune technique is a very good theoretical systems depend on periodical messages and voting technique, this system define the beginning and the ending of traffic congestion but can't indicate length or intensity of traffic congestion.

D. Our proposed technique

Traffic **C**ongestion **D**etection (TCD) is our proposed technique for detecting traffic serious situations specially congestion on city roads. This technique based on each vehicle participating in the system which will collect and analyze traffic conditions. After analyzing traffic surrounding it the vehicle send warning message to all vehicles on its communication range. Traffic analysis in TCD depends on vehicle's speed, if a vehicle gets slower than certain limit it can consider itself in congestion. TCD allow less processing for the vehicle and less load on the communication because of non-periodic messages sent between vehicles. All the process of our proposed will be discussed in details in the next section.

4. OUR PROPOSED TECHNIQUE

To enable vehicles to determine traffic status similar to human judgment, we have proposed a technique that allows each vehicle to collect and analyze traffic status around it then when detecting any traffic congestion, a vehicle can share its information with other vehicles. To achieve the efficiency in traffic management with the help of vehicular communication, our approach is based on the following points:

1. Warning messages are generated and broadcasted by affected vehicle itself which contains decision message.
2. Based on decision vehicles adapt the driving behavior and helps in controlling congestion.

In proposed technique the warning messages will be generated in case of event occurrence only. This further reduces the packet flooding problem of broadcasting as periodically data packets are not transmitted. Messages are broadcasted to all neighbors in reception range, so receiving vehicles will rebroadcast the messages only for new warning. This technique is very suitable for us here in Egypt because it can be implemented with no need for additional infrastructure.

As assumption each vehicle is occupied with a GPS device that provides vehicle's current location, a real-time clock and a wireless communication device such as a two-way radio that allow it to communicate with other vehicles around. Congestion detection techniques are designed to find areas of high traffic density and low speeds. Each vehicle disseminates the information it has obtained from its own hardware and from other sources then process the information received from other nodes in the network.

Simply our proposed technique is based on Vehicle-to-Vehicle (V2V) communication by equipping vehicles with relatively simple devices that allow them to communicate with nearby vehicles; we can effectively turn them into data collectors. Each vehicle involved in the communication called node. These nodes have a mobile nature so while selecting the communication pattern this mobile nature must be considered.

For wireless access in vehicular network there are greater challenges in wireless traffic patterns. In our proposal will depend on wireless standard called Dedicated Short Range Communication DSCR/WAVE [17] which is a 75 MHz licensed spectrum at a 5.9 GHz band allocated by the US Federal Communications Commission (US FCC) in 1999, to be used solely for vehicle to vehicle and vehicle to infrastructure communication. DSCR is based on IEEE 802.11p, which originated from IEEE 802.11a and was amended for low overhead operation in the DSRC spectrum. At present DSRC [18] based on the Wi-Fi standard is widely used in VANETs. it connects infrastructure to vehicles and also vehicles to- vehicles using two ways short range radios which is of lower costs compared to other wireless standards available. DSRC/WAVE [19] systems fill a gap in the wireless infrastructure by facilitating low latency, geographically local, high data rate, and high mobility communications.

Simply our proposed technique called **TCD** representing **T**raffic **C**ongestion **D**etection. This technique based only on vehicle to vehicle communication where vehicles are responsible for collecting traffic information and processing it to make a decision about congestion areas on the road and send warning message to other vehicles around to avoid those areas.

We can summarize our proposed algorithm in five steps as follows:

- ***Congestion occurrence,*** there are many factors that can cause congestion as predictable causes like road construction, rush hour or bottle-necks and some factors are unpredictable like accidents, weather and human behavior.
- ***Speed Monitoring,*** vehicle collect traffic information and forwarding it to other neighbor vehicle, at this stage after the vehicle has been affected by the congestion occurrence, it will check for its speed if it's really affected so it will be able to make a decision about congestion.
- ***Vehicle Decision,*** As the vehicle received the event also collected traffic information about its position and speed then it will make a decision. The decision depends on vehicle speed if its speed is below a certain predetermined limit and/or stopped for more than predetermined threshold time then it consider itself to be in congestion area.
- ***Broadcasting,*** After the vehicle check for congestion conditions, if it considers itself in congestion area then vehicle will broadcast warning message to all other vehicle. Warning message contains road id this will help other vehicles to avoid this closed road and less vehicle will join the congestion.
- ***Congestion Detection,*** at this stage when a vehicle received warning message from another vehicle in congestion first it checks if this is a new warning or not. Each vehicle has a table where it saves warning messages received and this table updated continuously. So for warning message received if it is not in the table then it will be a new warning and the vehicle rebroadcast it to other vehicles in its range. After all steps have been done most of vehicles on the route are informed about the congestion and its position so they can change their route far from this traffic congestion.

For our proposed solution (**TCD**) there are many characteristics that distinguish it from other solutions and techniques used for traffic congestion detection with vehicular networks. We can summarize those characteristics as follow:

- ***Distributed Approach,*** our approach based on V2V communication that means there is no central infrastructure used for building the network, where we depend on vehicles itself. This provides a greater degree of reliability and does not require a major investment in infrastructure as the costs are distributed among many drivers where each vehicle works to collect data and broadcast it.

- ***Reliability,*** by putting the devices on each vehicle, the reliability of the network as a whole is increased as the likelihood of many nodes failing all at once is less than that of a central component failing. As our system does not require the entire vehicle to participate in the algorithm so if some vehicles not equipped this will not affect the result.

- ***Ease of Deployment and Cost Effectiveness,*** this one of the most important characteristics that our proposed solution is very suitable to be applied here in ***Egypt*** where no need for expensive infrastructure or road side stations. Deploying of a distributed network can be made gradually; devices can be installed in vehicle factories or can be sold as after-market products such as today's GPS navigation systems.

- ***Bandwidth Utilization,*** where there is no periodical data transmission only data transmitted when event occurs. In our technique no packet flooding problems like other systems build on periodical data transmission that requires large bandwidth.

5. PERFORMANCE EVALUATION

A. Simulation Setup

In order to evaluate the congestion detection mechanism and its impact on vehicular communication we developed simulation environment based on Veins simulation framework [20]. This framework is based on OMNeT++ [21] network simulator bi-directionally coupled with SUMO traffic simulator [22]. Both simulators are well-known and have been used for simulations by many authors. We have used Veins (Vehicles in Network Simulation) hybrid simulator to achieve the bidirectional coupled simulation. Veins incorporate all the benefits from state-of-the-art simulation techniques of both the network simulation and the road traffic micro simulation domains. It uses OMNeT++ as the network simulator and SUMO (Simulation of Urban Mobility) as the road traffic simulator.

Evaluation of our technique is based on two simulations which are bi-directionally coupled: the network simulation and the road traffic simulation, responsible for vehicle's mobility. Since we are interested in managing traffic congestion in Egypt roads, we have used (Open Street Map) OSM [23] map for our provincial capital Shebin El-Kom then use SUMO for simulating it. For more accurate performance measuring of all techniques, we have used a traffic density in simulation of 100 vehicles only.

We implemented our technique as application layer module in Veins and we compared it to the broadcasting application layer with fixed broadcast interval. Since most of the VANETs applications will be based on exchanging both beacons and data packets, both of applications we simulated are based on sending beacons and data as well. This simulation is not only for our proposed technique TCD but also for other three techniques discussed before VOTING, SOTIS and Lin to compare the performance of all.

B. Evaluation Metrics

In order to check the performance of both our proposed technique and the other three techniques discussed before many metrics can be used. During the simulation we recorded and evaluated some important parameters such as number of vehicles aware of congestion, average number of warning messages, total busy time of the node and total number of lost packets

1) Number of vehicles aware of congestion: After applying different techniques under the same simulation parameters we have recorded number of vehicles become aware of congestion for each technique this metrics shows haw efficient the technique in helping drivers to know about congestion position and avoiding it.

2) Number of warning messages sent: Each vehicle on the simulation send warning message, for our proposed algorithm TCD are non-periodic messages only for other techniques there is periodic and non-periodic packets as well.

3) Total number of lost packets: As the number of packets exchanged between vehicles increase also number of lost packets will increase due to overhead on the communication network.

4) Total busy time: During simulation time OMNET++ simulator record total busy time for each node.

C. Simulation Results

1) Number of vehicle aware of congestion

Simulation shows that our congestion detection technique precisely quantifies the level of congestion of each vehicle. As soon as speed becomes lower than threshold our technique starts calculating the congestion level.

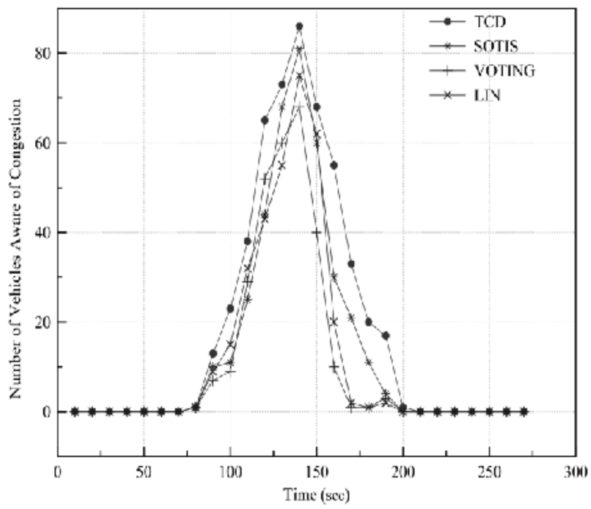

Fig 1. Number of vehicles aware of congestion versus simulation time for VOTING, SOTIS, LIN, and TCD.

Once the congestion detected a vehicle broadcast warning message for other vehicles in the same communication range. Figure 1 shows number of vehicles aware of congestion for each technique in both scenarios of 100 and 500 vehicles. As shown in figures above the performance of our proposed technique is more stable and efficient than other techniques discussed. Our proposed technique provides more awareness about congestion between vehicles, also under increasing number of vehicles so provide more scalability. As density of traffic increases, number of vehicles aware of congestion increase.

2) Total number of warning messages

After the examination of congestion detection technique, we tested its impact on the communication parameters and the network as well.

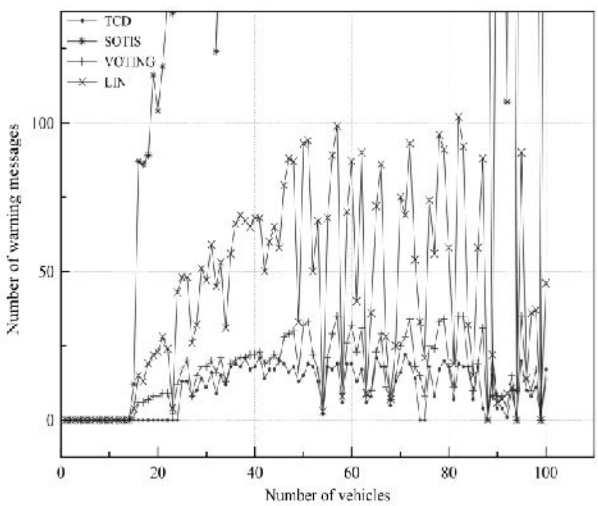

Fig 2. Number of warnning messages sent during simulation time versus number of vehicles for VOTING, SOTIS, LIN, and TCD.

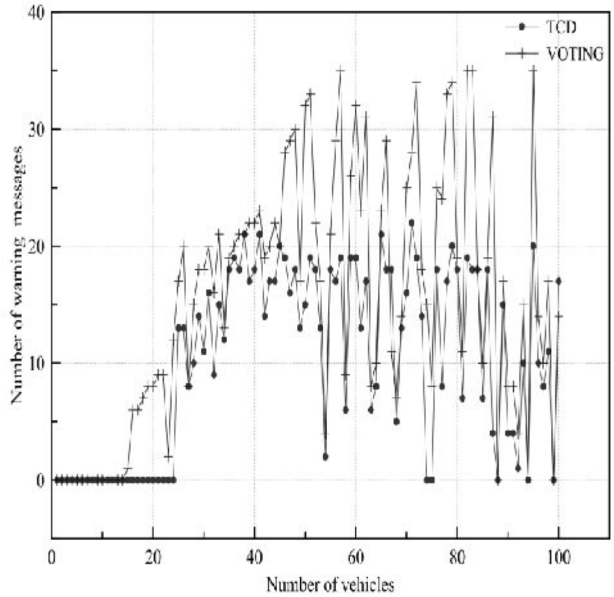

Fig 3. Number of warnning messages sent during simulation time versus number of vehicles for VOTING and TCD (Zoom).

In order to see how congestion detection technique impacts the adaptation of data broadcasting we recorded several parameters during simulation, including number of sent warning messages, total time while node was busy and total number of lost packets as well. Figure 2 and 3 shows number of sent warning messages by each vehicle during simulation time for each technique applied. It’s clear that even though in SOTIS technique vehicles send more warning messages than other techniques, SOTIS has less awareness of congestion between vehicles. On the other hand, our proposed techniques have less number of warning messages sent but more awareness of congestion so less overhead on the network. In our proposed technique, vehicles send warning messages only under a certain condition and can’t rebroadcast repeated messages. This concept provides less messages exchanged between vehicles. Other techniques use periodic messages so along with time more and more messages sent offering load on the network.

3) Number of lost packets

Figure 4 and 5 show number of lost packets from each node in the network and it is obvious that technique with more sent messages has more lost messages. SOTIS technique has recorded the largest number of lost packets during simulation due to large number of periodic messages exchanged between vehicles, other techniques VOTING, LIN and our proposed TCD recorded less lost packets specially TCD technique where vehicles exchange messages only for important traffic conditions.

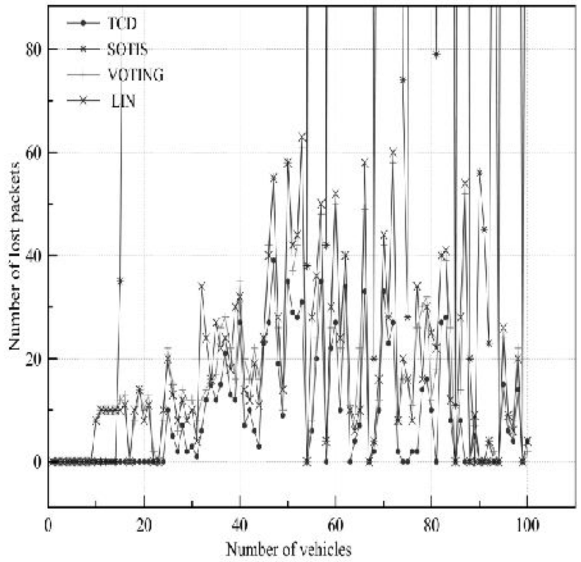

Fig 4. Number of lost packets for 100 vehicles during simulation time for each technique

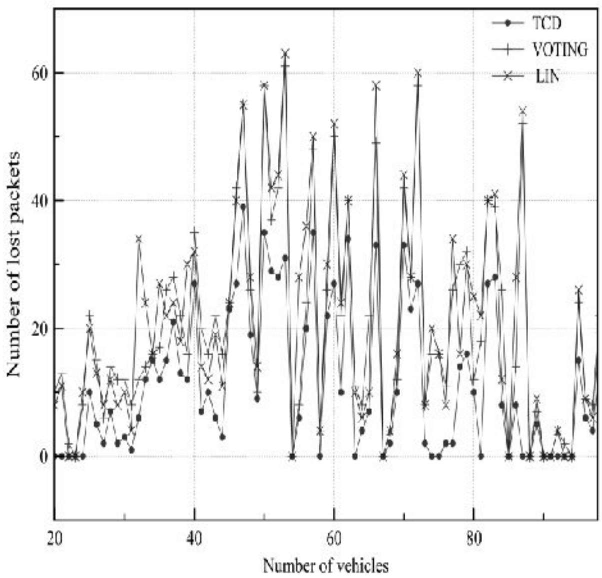

Fig 5. Number of lost packets by 100 vehicles during simulation time for TCD, VOTING and Lin techniques

4) Total busy time

Finally, in order to understand how our proposed technique impacts busy time for each node in the network. Our proposed results reducing largely in busy time than all other technique compared with it because of our principal of non-periodic messages that present very efficient performance of the communication network. Figure 6 and 7 shows busy time of each node during simulation time for each technique. It is clear that even though number of vehicles in the network increased, total busy time of our proposed still small fraction of simulation time. TCD technique provides stable performance over small and large number of vehicles in city highways.

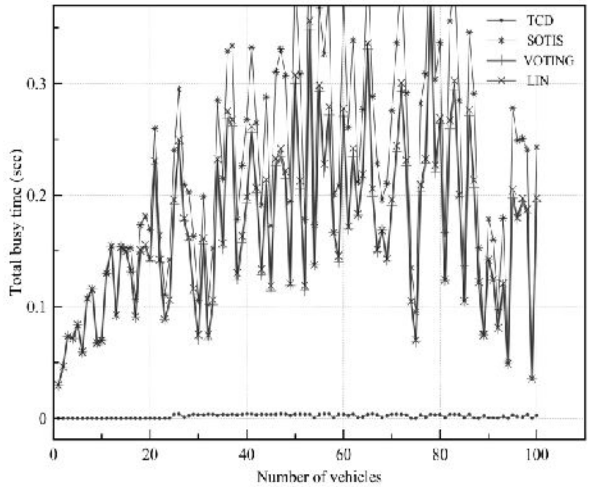

Fig 6. Total busy time versus Number of vehicles during simulation time.

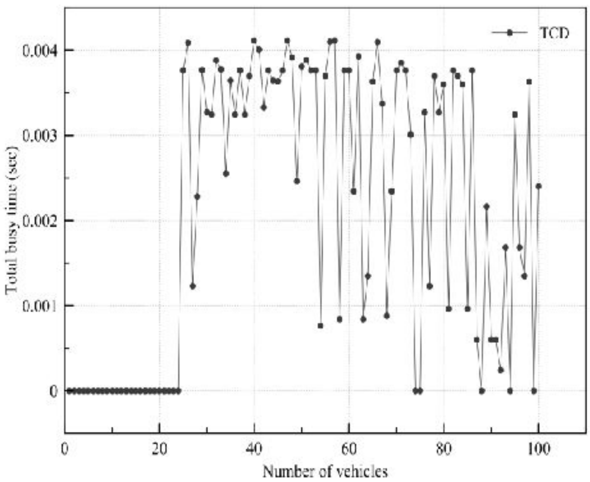

Fig 7. Total busy time versus Number of vehicles during simulation time for TCD (Zoom)

As a conclusion of all those results evaluated, our proposed technique TCD has many advantages over other technique we compared our performance with, these advantages are summarized as:

- All three techniques SOTIS, VOTING and LIN are designed for highway scenarios but our proposed technique TCD are designed for real world traffic.
- TCD uses only non-periodic messages to collect and distribute traffic information, other techniques use both periodic and non-periodic messages so they have more overhead on communication channel and as a result they have more lost packets and busy time than ours.
- No communication of any kind is needed in the detection stage, since our model takes data from a single vehicle as input. As a result, there are no new security or privacy issues caused by our proposed approach. In practice any device that uses our proposed technique can predict the current traffic state by itself with only velocity information from its GPS

- Our proposed model for congestion detection mechanism can be applied in many devices including all types of vehicles.
- Our proposed technique provides more stable and good performance as number of vehicles increase than other techniques whose performance changed after vehicles numbers increased.
- TCD provide more awareness about congestion for vehicles in city roads than other techniques.

6. CONCLUSION

Vehicular traffic congestion is a major problem associated with vehicular traffic which has been attracting the extensive attention of research in the field of VANETs. In this paper we presented a technique designed to detect and quantify the level of traffic congestion which is based on V2V communication and 802.11p standard. The main contribution of the proposed mechanism is it detects and quantifies the level of traffic congestion in completely distributed way, independent of any supporting infrastructure and additional information such as traffic data from local authorities. It relies only on observation of traffic conditions by each vehicle and information obtained from other vehicles. Results show that congestion detection performed by each vehicle corresponds to actual vehicle's speed is correct. Finally, the technique ensures that less amount of data is sent which contributes towards reducing the network load, especially important for VANETs since there will be many different applications running on limited number of channels. Our future work will include development of more advanced cooperative solutions for distributed congestion detection and management.

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