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Survey of Traffic Congestion Detection using VANET

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ABSTRACT
Traffic congestion is a major problem in modern societies where around the world millions of hours and gallons of fuel are wasted everyday by vehicles stuck in traffic. Traffic congestion estimation using vehicular ad hoc networks can have many interesting applications. This survey summarizes the research on traffic information systems based on vehicular ad hoc networks. Two classes of such systems are studied: Infrastructureless solutions based on inter-vehicle communication and infrastructure-based solutions. Systems within Infrastructureless class are briefly introduced and their strengths and weaknesses are analyzed.

General Terms
Traffic Congestion, Vehicular Ad Hoc Networks (VANET), Traffic Information System.

Keywords
Congestion Detection, VANET, V2V.

1. INTRODUCTION
A vehicular ad hoc network (VANET) [1] 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). Many applications have been proposed on VANETs for different purposes such as safety, infotainment, financial, navigational aid etc. [2].Traffic congestion has been studied extensively in traffic flow theory for various reasons such as road capacity planning, estimating average commute times etc. Congestion information can be useful for many VANET applications also, such as for route planning or traffic advisories. Typically, congestion information is collected as the number of vehicles passing a point per unit time by some roadside equipment and transmitted to other places for broadcasting to vehicles. Moreover, the congestion information [3] is usually available only at a single macroscopic level for all vehicles and is not customized for the requirements of each vehicle.

Road traffic congestions [4] [5] results an important economical and productivity losses, as well as an increasing environmental impact. To reduce their negative effects, novel Intelligent Transportation Systems (ITS) are currently being investigated [6]. Simply extending the road network is not suited to fight congestion due to spatial, financial and environmental constraints. Recent progress in the area of information and communication technology, however, promises to make today’s transportation systems not only more efficient, but also safer, more reliable and more convenient. Vehicular Ad Hoc Networks (VANETs) [7] are considered a central part of these Intelligent Transportation Systems (ITS) [8]. VANETs enable all actors in traffic (e.g., vehicles, traffic lights or road side units) to exchange information and to coordinate their behavior. As no underlying infrastructure is required and message exchange is carried out with low latency times, we consider VANETs as an excellent tool to reduce congestion in the context of ITS [9]. Congestion detection algorithms are designed to detect areas of high traffic density and low speeds. Each vehicle captures and disseminates information such as location and speed and process the information received from other vehicles in the network. Multiple approaches have been proposed to implement congestion detection in VANETs [10] [11] [12] [13]. Congestion detection is only one of many applications of VANETs and it is not designed to be used as means for automated driving but rather as a tool to deliver information to the driver that will help him/her make decisions to avoid heavy traffic. Developing a traffic congestion detection system will have tremendous impact on the economy, the environment and society in general allowing us to spend less time stuck in traffic and more time doing more productive and enjoyable activities.

The contributions of this survey are: 1) Discussing the definition of traffic congestion; 2) Identification of Traffic Information System approaches; 3) Classification of the most valuable traffic congestion techniques. The reset of this survey is organized as follows: Section 2, why we need to avoid road traffic congestion; Section 3, Different Approaches of Traffic Information System; In Section 4, Discussing Infrastructureless Information Systems; Section 5, General discussion and open points; and conclusion in Section 6.

2. ROAD TRAFFIC CONGESTION
Traffic congestion is now considered one of the biggest problems around the world. Traffic problems will be also much more widely increasing as an expected result of the growing number of transportation means and current low-quality infrastructure of the roads. There are many factors causing traffic congestion such as rush hour, road construction, accident and even bad weather. All this factors and many other can cause traffic congestion, Drivers who are unaware of congestion eventually join it and increase the severity of it. The more severe the congestion is, the more time it will take to clear once the cause of it is eliminated. The ability for a driver to know the traffic conditions on the road ahead will enable him/her to seek alternate routes saving time and fuel. When many drivers have this ability, traffic congestions will be less severe and only the vehicle in the center of congestion area will be affected. This [15] would lead to a much more efficient use of road infrastructure. In order to face Traffic congestion there is a need for a system that provide drivers with useful information about traffic conditions, Information such as congestion type, location and boundaries. Traffic Congestion system must relay this information to drivers within the congestion and those heading towards it.

For vehicles within the congestion to form their own picture of congestion they need to collaborate using Vehicle-to-Vehicle (V2V) or vehicle-to-infrastructure (V2I) [16] communication. Once a clear picture of the congestion has formed, this information needs to be relayed to vehicles away from the congestion so that vehicles heading towards it can take evasive actions avoiding further escalation its severity [17]. The improvement of traffic flow and congestion reduction can be achieved by means of traffic information systems (TIS). In general, their aim is to capture, evaluate and disseminate traffic-related information. TIS [18] have two main approaches **Infrastructure-based** and **Infrastructureless approaches** Nowadays the main object of researchers is to work in Infrastructureless approach that based on V2V communication, because Infrastructure-based approach depend on V2I communication that already exists as a commercial solutions. In the following section, we will discuss in some details different approaches of TIS also most important techniques of traffic congestion detection that uses V2V communication.

3. DIFFERENT APPROACHES OF TRAFFIC INFORMATION SYSTEMS

Most current navigation systems are static and do not provide traffic information. Route selection is based solely on static map data which leads to the system that fails to give the driver the most efficient route to his/her destination. In the last year or so, some of these devices have incorporated “real-time” traffic information to aid in route selection. Such “real-time” traffic systems such as the services provided from NAVTEQ [20] and other commercial services today [21] [22] rely on humans and/or road infrastructure like traffic cameras and radars to maintain a central database of current traffic condition based systems.

Traffic Information Systems (TIS) are one of the key non-safety application areas of VANETs. As such, TIS are much less delay sensitive compared to safety applications, which have recently attracted a lot of attention in VANET research. In general, TIS can be classified as either Infrastructureless or Infrastructure-based [23] as shown in figure (1).

Infrastructure-based TIS can rely on client-server or peer-to-peer (P2P) models of data storage and communication that based on centralized architecture [24]. Most traffic information systems are based on a centralized architecture focused around a traffic management centre that collects data from the street network, via sensing devices, and processes them.

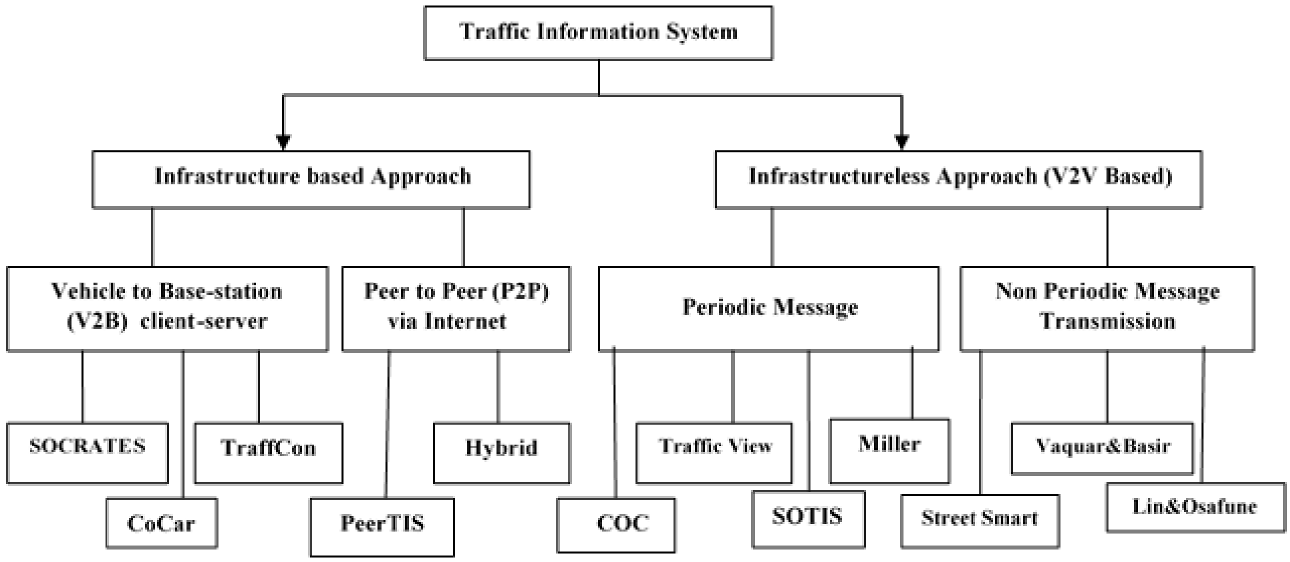

Fig 1: Traffic Information Systems Classification

The resulting traffic information is made available to the drivers via broadcast service or alternatively on demand via cellular phones. The centralized approaches are dependent on fixed infrastructure that demands public investments from government agencies or other relevant operators to build maintain and manage such infrastructure: a large number of sensors are needed to be deployed in order to monitor the traffic situation.

The traffic information service is then limited to streets where sensors are integrated [25]. Besides centralized designs, having the disadvantage of being rigid, difficult to maintain and upgrade, require substantial computing/communications capabilities, and are susceptible to catastrophic events (sabotage or system failures).Moreover, such systems require much lower market penetration compared to infrastructure-less approaches [26]. There are many systems have been established depending on this approach such as SOCRATES [27] system, TraffCon system[28], CoCar system[29], PeerTIS system[30]] and Hybrid system[31].

Infrastructureless approaches [32] typically apply data aggregation techniques to limit bandwidth use and maintain scalability. Usually, with increasing distance, observations regarding a given area become less precise. Thanks to store-and-forward techniques, traffic information can be disseminated in multiple partitions of VANETs. As the information is a subject of interest to many vehicles in a given geographical area, the broadcast nature of V2V communication fits very well the objectives of Infrastructureless TIS. However, such systems have two main drawbacks in long distance information dissemination. Firstly, they have a relatively high delay and secondly the information is limited in its details (due to the distance-based data aggregation). Another problem is that several overlapping aggregates for the same area may exist, making it difficult to compare them. Therefore, the quality of V2V communication based approaches greatly depends on the quality of the aggregation techniques. There are many systems that use this approach such as Contents Oriented Communication (COC) [33], TrafficView [34],SOTIS[35],Miller[36], StreetSmart [37], Vaqar and Basir [38] and Lin and Osafune [39].

To overcome the disadvantages of Infrastructure-based approach, initiatives towards decentralizing traffic information systems (Infrastructureless approach) began to appear. So where the main motivation of nowadays researches’ is towards Infrastructure-less approach so this paper will focus on this approach and the most famous traffic congestion systems that use it.

4. INFRASTRUCTURELESS TRAFFIC INFORMATION SYSTEM

The existing traditional ITS[40] traffic information systems are based on a centralized structure in which sensors and cameras along the roadside monitor traffic density and transmit the result to a central unit for further processing. The results will then be communicated to road users. These systems require substantial public investment in sensing, processing and communication equipments. Moreover, such systems are characterized by long reaction times and thus are not useable by all the applications requiring reliable decision making based on accurate and prompt road traffic awareness.

Infrastructureless approach of TIS provides a completely decentralized mechanism for the estimation of traffic density in city roads. This decentralized approach is based on traffic information exchanged, updated and maintained between vehicles in the roads. The estimated road traffic density information is useful for several ITS-related applications. Particularly, this schema is suitable for integration to real-time traffic congestion warning systems. It may also be used as a critical metric for determining optimal vehicular data routing paths in Vehicular Ad Hoc Networks (VANET).

Infrastructure traffic information systems depends mainly on V2V (Vehicle-to-Vehicle) communication[41] ,This kind of architecture allows vehicles to send information between each other via multi-hop communication.V2V is better suited for safety applications because the vehicles can almost immediately detect collision or congestion warning that is transmitted within the affected area. the main advantage of this type of communication is low cost of deployment where there is no infrastructure or road side units also less delay than infrastructure to vehicle communication so it is suitable for sensitive application such as traffic congestion detection and collision avoidance and detection[42]. In the following, we will discuss in some details, those systems used for traffic congestion detection based on V2V communication.

There are many vehicle traffic congestion techniques have been developed recent years based on V2V communication. Those techniques are classified according to how the messages between vehicles are send. Techniques that send ***Periodic traffic information messages*** such as Content Oriented Communication (COC), TrafficView, SOTIS and Miller's all those techniques vehicles send periodic messages to each other so vehicles can then detect congestion from comparing exchanged traffic information. Other types of techniques are based on ***Non periodic message transmission*** so vehicles sends messages to only situation of unexpected or abnormal traffic conditions. Techniques transmit such messages are Street Smart, Vaqar and Basir, Lin and Osafune. Later this survey will discuss some details about those techniques and make little comparison between them.

4.1 Periodic Message Techniques

1) Contents Oriented Communication (COC)

COC [33] is a technique where vehicles estimate road traffic density from received beacon messages, and periodically transmit this information to other vehicles. Vehicles can then detect traffic congestion conditions by comparing the exchanged traffic density estimates with average density values for the road segments under evaluation. With COC, each vehicle collects original information that each vehicle has by communicating each other, and creates contents which may be useful for drivers, by analyzing original information [43]. COC deliver the analyzed contents to other vehicles. The simulation results show that COC provide timely information of vehicular accidents and congestion to drivers. This technique is seen to be one of very good ways to estimate traffic congestion and accidents. COC gets the content that is the local information immediately after dangerous events like terrorism, the situation information immediately after generation of catastrophe, or the local information of vehicular accidents and congestions. COC exchanges the information that consists of own status each other and acquired by surroundings. COC analyzes the situation in the surrounding in real-time. Moreover, COC 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.

2) TrafficView technique

A technique called ***TrafficView*** is presented in [34]. Its main objective is to gather and disseminate information about the position and speed of vehicles. The information is restricted only to the vehicles positioned ahead of the current vehicle. 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. Whenever a vehicle receives a report, it updates its stored information, and sends the updated report in the next broadcast period. Although the average size of the stored records is very small (on the order of 50 bytes) data aggregation is performed in order to fit all information in a single packet [44]. Performance evaluation of TrafficView was carried out using the ns-2[45] network simulator and the CORSIM [46] vehicular traffic simulator.

The main drawbacks of this techniques it very costly and provide a great overhead to the network also this technique don't 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 (e.g. through nearby road side units or cellular links).

3) SOTIS technique

A Self-Organizing Traffic Information System (SOTIS) is proposed in [35]. It works within an approximate radius of 50 to 100 km of an individual user, even if as few as only 2% of all vehicles are using it. The precision of the information it provides decreases as the distance to the area of interest increases. The authors propose a distributed receive-analyze-send algorithm. The information received from other vehicles is first analyzed, and only results of the analysis are transmitted. Roads are divided into variable size segments, and the information is exchanged on per segment basis. Each vehicle stores information for every segment of the road in its local database called Knowledge Base (KB). A GPS-based time-stamp is used to determine the accuracy of the information: more recent reports are assumed to be more accurate, and thus replace older ones. The reports are exchanged between vehicles travelling in both directions. The system was evaluated using the ns-2 network simulator [45] and a simple vehicular traffic simulator based on cellular automata. SOTIS is a good technique for aggregating traffic information these systems cannot be deployed in the near future, as one has to wait until the necessary market penetration of V2V communications technologies has been reached [47]. The drawback of this approach is that the selection of the cluster head usually generates additional signaling overhead. In addition, it is important to emphasize that the definition of road segments is usually challenging. In fact, many techniques define road segments based on the vehicle's transmission range, but this might significantly vary, in particular when applying transmits power and congestion control protocols.

4) Miller Technique

In the ***Miller technique*** or V2V2I [36] architecture, the transportation network is broken into zones in which a single vehicle is known as the Super Vehicle. A zone can be as granular as desired, though it assume that the zones consist of sections of a freeway or individual lanes of sections of a freeway. 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. That technique represent the freeway system as a graph with edges consisting of sections of a freeway system and the weights of the edges being determined by the amount of time to traverse that section of the freeway with current speeds. They perform an analysis using FreeSim [48] to determine how accurate the represented freeway system is. This technique proposes [49] that only one vehicle in each road segment is in charge of collecting and aggregating road traffic data. This information is then transmitted to adjacent road segments. However, the selection of the vehicle responsible for the data aggregation usually generates additional signaling overhead. The techniques previously described require the periodic exchange of packets different from the beacon messages already included in the IEEE802.11p/WAVE or ITSG5A standards [50].

4.2 Non Periodic Message Techniques

1) Street Smart

The ***Street Smart*** Traffic technique introduced in [37] proposes to aggregate traffic information using distributed clustering algorithms with an epidemic diffusion model. It is designed to perform well even if only a small fraction of vehicles participates in the system. Moreover, the system does not require constant connectivity. Each vehicle records its speed and on this basis builds a local traffic map. Vehicles that are close to each other exchange their speed maps. Data aggregation is performed using clustering techniques, which combine related recordings of an unusual speed. The system was evaluated using the authors own simulator of Manhattan's grid of highways and a random way point mobility model. Street Smart obviously reduce the overhead generated by traffic messages than other techniques discussed previously where Street Smart [51] limits the exchange of traffic information to only situations of unexpected or abnormal traffic conditions, e.g. traffic jams. 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.

2) Vaqar and Basir Technique

In this technique [38] 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. This snapshot is considered as a pattern in time of the current traffic conditions. The pattern is analyzed using pattern recognition techniques. A weight-of-evidence-based classification algorithm is presented to identify different road traffic conditions. The algorithm is tested using data generated by microscopic modeling of traffic flow for simulation of vehicle or node mobility in ad hoc networks. Test results are presented depicting different percentage levels of vehicles equipped with communication capability. The mechanism reported by Vaqar and Basir reduces [52] 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.

3) Lin and Osafune Technique

The technique [39] relates to traffic condition detection by vehicle-to-vehicle communication systems. More particularly, the present technique relates to a method and apparatus for detecting and diffusing traffic condition information by distributed vehicle-to-vehicle communication systems. This system achieved by the method and apparatus according to the present invention as defined by the independent claims. The dependent claims relate to preferred embodiments of this technique .The present technique proposes a Wireless communication system [53], such as a Wireless vehicle-to-vehicle communication system, by which a traffic condition can be determined. Exemplary traffic conditions that can be determined are free flow of traffic, traffic jam, and complete halt and/ or restricted flow of traffic. This technique makes a voting procedure so that neighboring vehicles exchange their traffic estimates and try to reach a consensus decision. The work reported in [54] also proposes a cooperative detection process that calculates the number of vehicles in a traffic jam using a tree based counting algorithm. However, the formation and management of the tree requires the exchange of a large number of packets, with the consequent risk of overloading the communications channel.

Table 1. Traffic Monitoring Techniques

Technique	Congestion Detection	Detection correlation	Congestion Level	Traffic Jam Length	Limited Overhead	Dissemination
COS	Yes	Yes	Yes	Yes	No	No
Traffic View	Yes	Yes	Yes	Yes	No	No
SOTIS	Yes	Yes	Yes	Yes	No	No
Miller	Yes	Yes	Yes	Yes	No	No
Street Smart	Yes	Yes	Yes	Yes	Yes	No
Vaquar &Basir	Yes	No	Yes	No	Yes	No
Lin & Osafune	Yes	Yes	No	No	Yes	Yes

5. DISCUSSION AND OPEN POINT

As we can see all the presented techniques are aimed to face vehicle traffic congestion and monitoring traffic conditions. All proposed techniques are based on V2V communication that performs Infrastructureless approach of Traffic Information System. These techniques are COC, SOTIS, TrafficView, Miller, StreetSmart, Vaquar and Lin. All mentioned techniques can be classified into two main categories according to type of message transmission: Periodic message transmission and Non periodic message transmission.

Table 1 summarizes the previous discussed techniques, gives some metrics for comparing their performance, and reviews the existing V2V-based traffic congestion techniques based on their detection capabilities and the type of traffic information they provide. *Congestion detection* indicates the capability of the technique to monitor traffic conditions and detect congestion situations. *Detection correlation* refers to whether individual congestion estimates are correlated or not among several vehicles to reach a consensus decision. *Congestion level* and *Traffic jam* length refer to the technique's capability to classify the detected traffic jam's congestion level (or intensity) and quantify its length. *Limited overhead* indicates whether the technique is capable to limit the generation of communications overhead to only situations of abnormal traffic conditions (e.g. traffic jam). Finally, *Dissemination* indicates whether the technique includes the capacity to select the vehicle that will be in charge of disseminating the detected traffic congestion conditions to approaching vehicles or road authorities (e.g. through nearby road side units or cellular links).

This capacity would avoid the possibility that multiple vehicles detecting the same traffic congestion conditions generate redundant messages that could overload the communications channel.

1) The technique provides traffic information such as the vehicles' speed and/or traffic density. However, it does not classify the congestion level based on the collected traffic measurements.

2) The technique has been designed to monitor road traffic conditions, but is currently not able to explicitly detect congestion situations.

3) The detection correlation is based on a voting process carried out among vehicles located in the one-hop neighborhood; no multi-hop correlation is applied.

4) The technique does not explicitly provide the traffic jam length. Such length could be indirectly inferred from the locations of the jam header and tail, but this would require an evolution of the original proposal.

There other metrics must be taken in account when we discussing any techniques, those metrics effect on the design and performance of each technique or system. Such metrics are Ease of deployment and cost effectiveness, Reliability, Privacy and Security.

- ***Ease of Deployment and Cost Effectiveness***
  As we discuss technique based onV2V communication so they don't use any infrastructure such as roadside units or any centralized points so it much cheaper for deployment than infrastructure based techniques. For techniques such as COC, TrafficView and SOTIS they depend completely on V2V communication so it's inexpensive for deploying. Also (Vaqar and Basir) technique and (Lin and Osafune) technique. On other hand Miller and StreetSmart they use some kind of servers for getting more accuracy in measurements they cost more and more complicated to be deployed in real world.
- ***Reliability***
  Reliability is the ability of the system component to function under stated conditions. For our techniques where they based on distributed approach (Infrastructureless) approach so if one or more node (vehicle) failed will not affect on the whole systems. For Miller and StreetSmart techniques, they are not reliable like other techniques such as COC, TrafficVIEW, SOTIS where in their architecture depend on some servers so if one server failed the whole system will be affected. Although Miller technique uses both V2V and V2I communication together when a failure occurs the systems use only V2V communication.
- ***Privacy and Security***
  When new cooperative networks systems such as VANETs are deployed, a major concern for users is the loss of privacy, after all nobody wants his/her vehicle to be telling everybody where it is at all times. Most academic work on congestion detection in VANETs ignore this important fact and use unique vehicle IDs that persist over time making it possible for a malicious node to track the location of a vehicle, for this reason, the solution proposed in this work does not require vehicles to maintain unique IDs. Along with privacy, security is a legitimate concern for real-world systems. Preventing users from abusing or sabotaging the system is paramount. Several initiatives have been developed in recent years to provide secure V2V communications [55] [56] [57] [58]. Techniques such as SOTIS, StreetSmart and Miller have no IDs for vehicles but techniques such as COC, TrafficView, Vaqar and Basir and Lin and Osafune each vehicle has its own ID.

5. 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. Vehicular congestion estimation shall not only provide a basis for development of traffic monitoring application but also aid in development of other applications which can exploit traffic congestion information for other goals in VANETs such as disseminating information, suggesting alternate driving route etc. So this survey discusses different approaches of traffic information systems and how the Infrastructureless approach is the more one to be used in transportation system. Then it discusses different techniques and systems developed by many researchers for traffic congestion and monitoring systems. So for building traffic system to detect congestion and allow drivers to avoid it, the most powerful option is Infrastructureless system that based only on V2V communication without any infrastructure. Those systems don't require large investment so can be easily deployed.

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