IEEE Access
Multidisciplinary | Rapid Review | Open Access Journal

SPECIAL SECTION ON ADVANCED BIG DATA ANALYSIS FOR VEHICULAR SOCIAL NETWORKS

Received November 25, 2018, accepted December 4, 2018, date of publication December 17, 2018, date of current version January 7, 2019.

Digital Object Identifier 10.1109/ACCESS.2018.2887075

Emergency Message Dissemination Schemes Based on Congestion Avoidance in VANET and Vehicular FoG Computing

ATA ULLAH[1,2], (Member, IEEE), SHUMAYLA YAQOOB[2], MUHAMMAD IMRAN[3], (Member, IEEE), AND HUANSHENG NING[1,4], (Senior Member, IEEE)

[1]School of Computer and Communication Engineering, University of Science and Technology, Beijing 100083, China
[2]Department of Computer Science, National University of Modern Languages, Islamabad 44000, Pakistan
[3]College of Applied Computer Science, King Saud University, Riyadh 11681, Saudi Arabia
[4]Beijing Engineering Research Center for Cyberspace Data Analysis and Applications, Beijing 100083, China

Corresponding author: Huansheng Ning (ninghuansheng@ustb.edu.cn)

This work was supported by the Fundamental Research Funds for the Central Universities under Grant FRF-BD-18-016A.

ABSTRACT With the rapid growth in connected vehicles, FoG-assisted vehicular ad hoc network (VANET) is an emerging and novel field of research. For information sharing, a number of messages are exchanged in various applications, including traffic monitoring and area-specific live weather and social aspects monitoring. It is quite challenging where vehicles' speed, direction, and density of neighbors on the move are not consistent. In this scenario, congestion avoidance is also quite challenging to avoid communication loss during busy hours or in emergency cases. This paper presents emergency message dissemination schemes that are based on congestion avoidance scenario in VANET and vehicular FoG computing. In the similar vein, FoG-assisted VANET architecture is explored that can efficiently manage the message congestion scenarios. We present a taxonomy of schemes that address message congestion avoidance. Next, we have included a discussion about comparison of congestion avoidance schemes to highlight the strengths and weaknesses. We have also identified that FoG servers help to reduce the accessibility delays and congestion as compared to directly approaching cloud for all requests in linkage with big data repositories. For the dependable applicability of FoG in VANET, we have identified a number of open research challenges.

INDEX TERMS Congestion, FoG computing, messages storm, social vehicular network, VANET.

I. INTRODUCTION

Vehicular ad hoc network (VANET) comprises of vehicles with wireless connectivity to exchange information among each other [1], [2]. Vehicles act as mobile nodes in VANET to collect and disseminate information including current position, travelling rate per unit time and density [3] at central repositories of Big Data. Vehicular networks ensure driving safety, organize traffic and timely report emergency conditions in cases of health issues, road accidents, land sliding, and slippery road segments. It should also consider the social behavior and response to emergency conditions that may vary from region to region. Social vehicular networks can also inform the nearby vehicles in a specific region to avoid further hazards by extracting data about road and area conditions from big data repositories. In this condition, other vehicles may change the route as per destination to avoid traffic jamming. Vehicles can also transmit messages to nearby collection points or servers to share data with Intelligent Transportation System (ITS) [4]. Smart vehicles can also automatically detect the road conditions and hazards to reduce speed and also intimate the vehicles behind it to slow down as per runtime distance calculation from the emergency area. Mainly dissemination can be categorized as one-hop and multi-hop. In former, messages are only deliver to nearest neighbors while the latter is more similar to real road situation to forward messages to next neighbors [5]. In this scenario, long delays should be avoided where high traffic density can affect the performance of information dissemination models [6].

Cellular networks are also utilized in social networks [7] and vehicular networks [8] but now both network entities are becoming interdependent on each other which is getting growing interest. It arises the need for vehicular social networks (VSNs) along with challenging requirements for information exchange among huge number of users. Vehicular clouds are the solution to provide central data repositories for big data. It can help to control and minimize unsafe driving and related hazards [9], [10]. Moreover, detection of traffic region is also challenging in social networks. In [11], crowd source data in temporal and spatial segments is used in order to model traffic conditions. After analyzing various results, it is stated that traffic is consistent in social network. In the similar vein, 5G achieves low latency based reliable communication. Existing generations face limitations in accessibility and coverage [12].

FoG computing is the middle layer at the edge of the network to provide data computation, data storage, and networking between end users and cloud servers [13], [14]. It reduces the latency and delays that occur due to accessing cloud from cellular network. Due to mobility, vehicles have to rely on unknown intermediaries that may breech security [15]. The term "FoG computing" was invented by Cisco [16]. In this scenario, vehicles can act as communication hubs or intermediaries to share local resources, instead of sending redundant bulk of big data to cloud servers [17], [18]. FoG servers can refine the data obtained from social networks and vehicular networks to predict the possible interdependencies. It includes both local decision making and geo distribution characteristics in order to bring less delay [19]. Figure 1 illustrates two ways to access FoG server like vehicles and transportation systems access via road side units (RSUs). In second scenario, users and smart devices access via internet or the base station (BS) respectively. FoG server has concept of distribution for load balancing and task sharing among different local FoG servers.

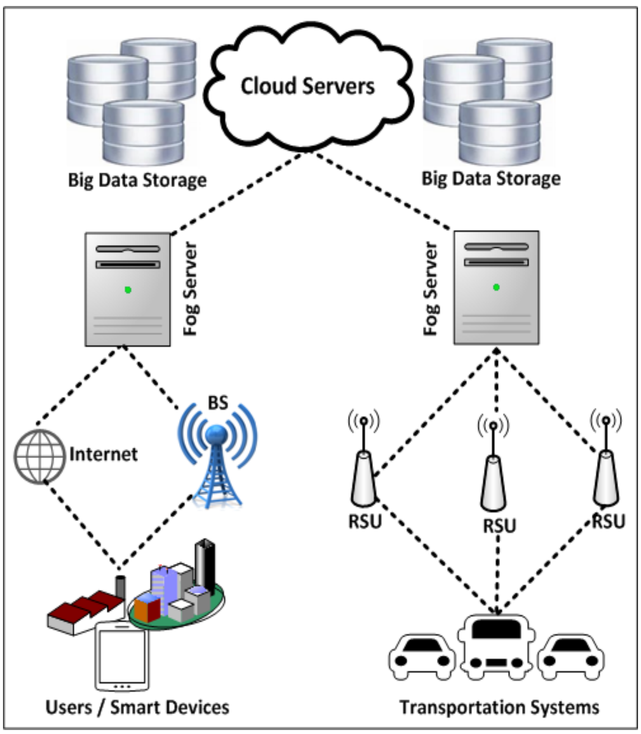

FIGURE 1. FoG server based architecture for transportation systems, users and smart devices using RSUs.

Existing techniques are proposed in 3G and 4G cellular networks [20] in conjunction with roadside units (RSUs) [21]. However, these are not sufficient for cellular networks in order to provide unlimited communication. To overcome existing limitations, FoG computing, Software Defined Networks (SDN), and Fifth-Generation (5G) networks may support in a better way. It arises a large set of challenges for researchers to providing efficient and reliable solutions to optimize communication, computation and energy overhead. Currently, VANETs are most widespread networks where vehicles have rich energy, storage, and communication capabilities. Moreover, network topology changes frequently due to rapid mobility. Vehicles can communicate in following two scenarios: Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I), which is collectively referred as V2X communication [13], [22]. In [8], it is also defined as Infrastructure to Vehicle (I2V) to send messages from servers to vehicles.

Existing surveys present enormous literature for VANET and its communication scenarios along with message sharing schemes. Indeed, several detailed review of message dissemination schemes in VANET including [2], [3], [5], [6], [23]–[26] have been given in literature. However, message dissemination in VANET is a critical constraint for smooth communication. Secondly, researchers have highlighted advantages of FoG computing [27]–[29] towards strengthening the term and its use for future directions. But no one has discussed about dominating aspects of FoG in VANET for message dissemination. We have identified this gap and presented the related message dissemination schemes and their challenges for advancements towards FoG assisted VANET. Major contributions of our work are as follows:

1) We have explored VANET and FoG based architectures and challenges. After that, we have explored the existing surveys to identify the research gap as summarized in table 1 which highlights the need to survey the congestion avoidance schemes.
2) Next, we present an extensive review of existing schemes on the efficient message dissemination and congestion avoidance. We present a comprehensive taxonomy of message congestion avoidance schemes. After that, we have presented a comparison of congestion avoidance schemes in literature.
3) As the final contribution, we have identified a number of open research challenges that should be considered for designing dependable solutions using FoG assisted VANET.

The rest of paper is organized as follows; Section II provides VANET architecture along with applications and challenges. It also covers the type of messaging in VANET.

TABLE 1. A summary: focused areas of message dissemination in VANET and FoG computing conducted by existing surveys.

Focused topic of VANET and FoG Computing	Description
Adaptive approaches for message dissemination in VANET	Kayhan Zrar et al. [2] surveyed the adaptive beaconing approaches that focused on transmission power, window size adjustment and hybrid techniques for information dissemination in VANET only.
Single hop based information dissemination protocols in VANET	S. Panichpapiboon et al. [3] presented a detailed review of one-hop and multi-hop protocols for information dissemination. Mostly schemes considered protocols that assume single road without dense environments. Moreover, comparative overview of schemes is not highlighted explicitly.
Survey for data dissemination based approaches in VANET	M.Chaqfeh et al. [6] thoroughly surveyed the PUSH and PULL model based approaches for data dissemination in VANET. The key opportunities, limitations and requirements for each approach are not clearly explored.
Review and comparative study of message dissemination schemes in VANET	A. Sanguesa et al. [5] presented an overview of single and multi-hop based message dissemination schemes in detail. Schemes are compared but future directions and requirements are not highlighted explicitly.
Opportunities and network based challenges of FoG architecture.	Shanhe Yi et al. [13] discussed about opportunities and challenges of FoG computing but how it can be useful for VANET challenges is not discussed.
Routing for data dissemination in VANET	Bihari Dubey et al. [23] surveyed probability based routes for data dissemination in VANET which is not suitable in real dense environment.
Inter-Vehicle communication in VANET	M. Sichitiu et al. [25] surveyed thoroughly about possible ways for inter vehicle communications but did not highlight the hurdles in communication in case of congestion.
Strength of FoG computing over cloud	Redowan Mahmud et al. [29] discussed strength of FoG computing over cloud as well its challenges are highlighted but how it can be helpful for VANET challenges is not highlighted clearly.

Section III discusses about message dissemination schemes. In Section IV, a FoG assisted architecture is explored to manage congestion avoidance. We have also presented a taxonomy of message congestion avoidance schemes. Section V explores a comparison of schemes in literature and Section VI presents the open research challenges. Section VII concludes our work.

II. VANET ARCHITECTURE AND CHALLENGES

In this section, we have explored the architectures, communication pattern and standards in VANET. After that, we have highlighted the key challenges.

A. ARCHITECTURE OF VANET

VANET architecture can be categorized into three types including WLAN or cellular, ad-hoc and hybrid architectures. WLAN is a wireless technology that follows following standards; in Europe and Japan, vehicle protocol stacks are consistent in automotive industry. In America, IEEE 1609 Wireless Access in Vehicular Environments protocol stack builds on IEEE 802.11p WLAN [30]. In case of infrastructure, WLAN/cellular or a WIMAX access point is involved. Cellular networks cover large area and huge set of users that can strengthen vehicular communication system [25]. In this case, vehicles and RSUs can interact with WLAN and cellular networks by using access points. In VANET, permanent cellular gateways and access points can be deployed at road junctions to exchange traffic related information. It can improve connectivity to vehicles but it adds infrastructure cost [31]. WLAN is less expensive, but its communication range is limited [32]. In case of ad-hoc networks, vehicles communicate without access point. Hybrid architectures involve infrastructure and ad-hoc as well. It avails minimum cost of IEEE 802.11p and maximum coverage due to cellular technologies along with low-latency [33] but it faces transitions among wireless systems.

Global Positioning System (GPS) is also key component of VANET along with Onboard Units (OBU) [30], [34]. OBU are integrated with sensors to detect accidents [5]. In-Vehicle equipment (IVE) is an OBU for communication without infrastructure [25]. For reliable communication and information sharing, ITS plays a vital role. It integrates traffic information from different regions using data aggregation techniques in a secure manner where RSU acts as router to exchange data [23]. Mostly, RSUs are placed in the intersection of roads in order to cover more area [32] and transfer information from vehicles to server. Vehicles move at high speed and interact with RSU for short interval when passing nearby RSU region [4]. VANET supports safety driving to reduce accidents and traffic blockage [35].

B. CHALLENGES IN VANET

Although VANET overpowered the world with its enhanced advantages but still there are many challenges of recent research fields. These challenges needs to be explored in order to achieve smooth traffic and road safety. In smooth traffic it needs to avoid road blockage by using efficient traffic signals. Road safety needs to avoid accident rate inform to rescue timely. VANET based application for information distribution among vehicles need to focus on bandwidth of network. Some of the challenges including latency, throughput, routing, security, availability, congestion, node mobility and time constrain can be improved using FoG computing.

1) LATENCY

Data latency means time period between transmission time from one source vehicle and receiving time at destination vehicle. It can be improved by using local servers of FoG computing. A key parameter in sending and receiving a data packet is transmission time, by using it throughput rate can be calculated. To calculate transmission time delay, the following phases are applied [36]. Bit-Rate = Data Size/ Transmission Time Delay Transmission Time Delay=Data Size/Bit-Rate Data size = User Data + Header.

2) THROUGHPUT

It is based on rate of communication per time unit like bits per second. Throughput is linked with packet delivery ratio which is the ratio of the number of packet received by the destination to the number of packet sent by the sender. Basically it is the major point that is to be consider in packet forwarding. Several essential factors such as packet size, action range, mobility of nodes and cluster size affect it. The robust message broadcast is described as the 100% packet distribution [36].

3) CONGESTION

It can be categorized into two types including physical congestion of vehicles on the road and network congestion which occurs during beaconing, message reporting and V2V communication [32], [37]. Communication among vehicles is the main issue as we have seen in above discussion. Weak vehicle communication leads to road accidents and delay in identification of accidents. It may also lead to poor reporting about accidents. For above mentioned challenges, VANET has a main server that takes more time and high chance of break down. This leads to high delay and less availability [26]. It can be resolved using FoG assisted VANET. Local servers can reduce delay and provide less chance of information loss.

4) AVAILABILITY

In safety applications as post-crash warning, the wireless broadcast signal has to be accessible for vehicles communication in order to receive the warning messages. If the radio channel goes out (jamming), then the warning cannot be broadcast and the application itself becomes useless. In case of message congestion, the system is also not fully available for smooth communication and more packet drops can occur. Hence high availability of communication systems is quite challenging [26].

5) ROUTING

It is quite challenging to find best path from source to destination vehicle. In vehicular networks, the topology rapidly changes due to excessive and unpredicted mobility of vehicles. In this case, the end-to-end path is not discovered and next-hop vehicle is selected as per direction, speed and position of vehicle towards destination. Efficient position based routing can ensure less delay in packet delivery. It leads to optimal path by having less hop connection in order to transfer data. Routing overhead involves the number of packet transmitted per route [31].

6) SECURITY

Security for VANET is important research era in the sense to avoid attacks. There are several attacks such as bogus attack on IVC based on direct communication among vehicles to fulfil the application requirements such as collision avoidance [25]. One of the major problems of these system is the security assurance of transmitted data and authentication for user accessibility [38], [39]. In vehicular social networks, secure message dissemination for emergency messages can be done using QR code based authentication by preparing topology from active users of social network in that area [40]. A trust model is also mandatory to ensure the data collection [41].

III. MESSAGE DISSEMINATION SCHEMES

This section includes schemes about message dissemination and congestion avoidance in VANET and FoG computing. These schemes are organized in a taxonomy where dynamic schemes are included to manage congestion. In this section, we have also focused on network connectivity which is a basic issue for enabling information dissemination in V2V communication. FoG computing supports geo-distribution, location awareness and support mobility so that it is an appealing research field for vehicles. Several schemes have been studied about VANET and FoG assisted VANET for providing efficient and smooth communication. We select the FoG assisted VANET which takes moving vehicles as communication nodes in order to establish better network connectivity. To the best of our knowledge, no exiting work considered message congestion resolution in FoG assisted VANET. ITS needs to manage few things like traffic management, passenger's information and public safety messages [35]. There are 2 types of public safety messages [26], [42].

- PERIODIC BEACON MESSAGES: Beacon known as basic safety message (BSM) in US or cooperative awareness message (CAM) in Europe [42] are transmitted to test the connectivity of devices. It ensures that a particular vehicle is in range of an RSU or other server level node. Basically beacon messages consist of current position, vehicle speed and its direction [5], [26], [43]. Its priority is less than event driven messages.
- Event Driven Messages: Event-driven safety message or decentralized environmental message in Europe 42] are generated at the time of event occurrence like query initiation, data collection, emergency reporting and accident alerts [44]. These messages can either be sent to RSUs via V2V communication or V2I.

In VANET, nodes exchange *EMs* called beacons with their neighbor vehicles. A beacon message holds information about state of vehicle such as position of vehicle, velocity, heading information, and other emergency or safety based information [45]. Risky situations can be avoided through *EMs* alerts. V2X communications allow vehicles to collect information of moving vehicles and then prevents possible

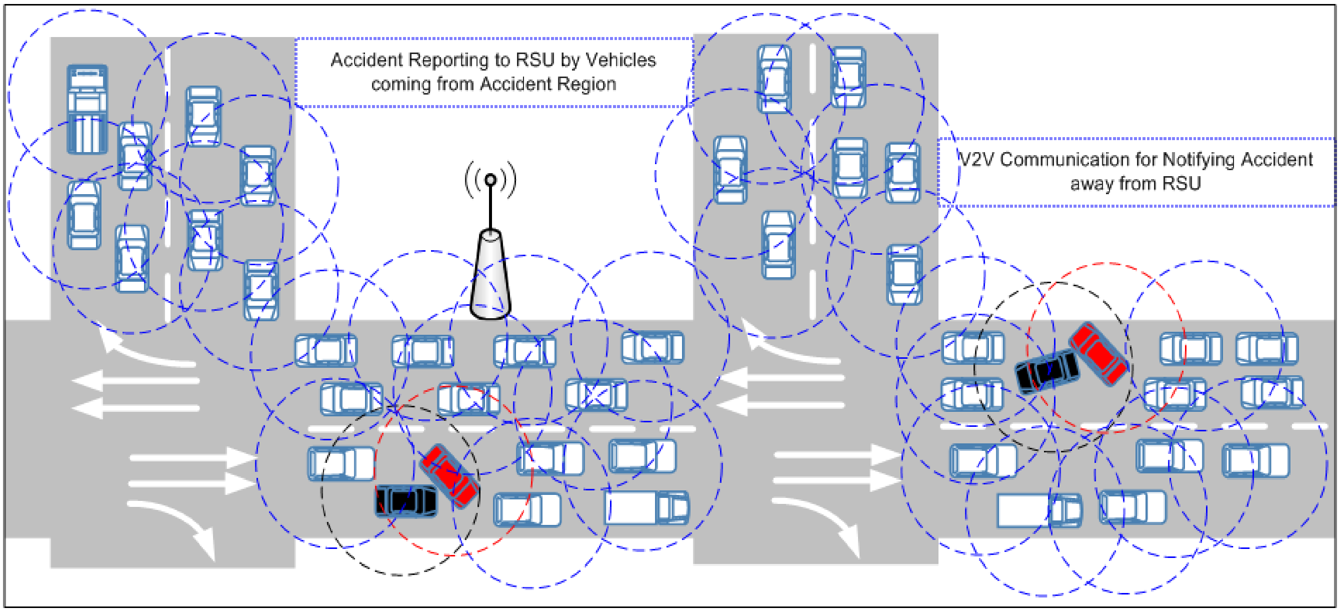

FIGURE 2. Message Congestion in VANET for the scenarios when RSU is located nearby or far away from the accident region.

transportation accidents or dangers happened on the ahead roads [23], [46]. Vehicles that near to the abnormal vehicle (AV) where accident happened receive the real-time *EMs* in order to take proper reactions immediately, e.g. to slow down the speed. The author has introduced a smartphone based protocol GoSafe in [47] to improve road safety and road management. This protocol is used to report warnings messages about an accident by using voice commands to server. It can send alert messages to emergency centers and can also receive *EMs*. Vehicle request the server for nearby events regularly in order to get emergency alerts. In [48], a guidance system is proposed to detect accident and ask service for portable devices. It uses the GSM cellular network in order to communicate among portable device and the central Server. It presents a system where a set of information from the user is associated with a location using a GPS Tracking system and creates an accident report [48]. It sends GPS coordinates of the person, displays the coordinates on a map and computes the shortest route to accident site. The system also automatically detects an accident. The author proposed new approach in [49] to improve vehicle communication by giving emergency alert before collision of vehicles. It focuses on the congestion of network which was handled by transmission rate and transmission power control methods while in controlling DDOS Attack in [50]. Many schemes improve Low-latency in order to overcome this issue but still there are few aspects which need to be improved for the betterment. Mostly, when an abnormal event occurs, mostly there are many vehicles affected by the scenario. Need to send messages in order to intimate about the natural emergency situations.

During messaging between network devices, congestion occurs on some paths when a large number of packets are transmitted through certain intermediate or bridging nodes. During congestion, network is overcrowded or blocked where reliable communication is not possible. Figure 2 illustrates that when single or multiple abnormal vehicles continuously exchange emergency messages (*EMs*) to nearby passing vehicles in order to inform RSU then *EMs* are flooded and congestion arises. In this scenario, neighboring vehicles further disseminate *EMs* to more vehicles and RSUs in the traveling region. A number of vehicles keep on flooding the message in the region that results in congestion. It causes information loss, poor communication and weak road safety. It may result in packet collisions [3], [6] that leads to packet loss in *EMs* delivery. To resolve these issues, a number of schemes have been proposed by researchers to focus on congestion detection and congestion avoidance. We have focused on latter approach which is more demanding.

IV. MESSAGE CONGESTION AVOIDANCE SCHEMES

Congestion avoidance is major concern for ITS to timely manage packet transmissions during emergency scenarios. Incorporating social awareness to ITS by analyzing social habits and responses on traffic hazards. It should also consider several obstacles in message delivery including channel fading, delay, congestion and packet collision [26] and security attacks [40]. Congestion arises when a bulk of messages are exchange with V2V communication towards a nearby RSU or any other collector. Chris et al. proposed that smartphone can detect an accident by using acceleration and 3G data connection by sharing information to server [51]. The information is processed by server then the authorities got informed.

Congestion avoidance schemes can be sub divided into static and dynamic schemes where former scheme uses fixed

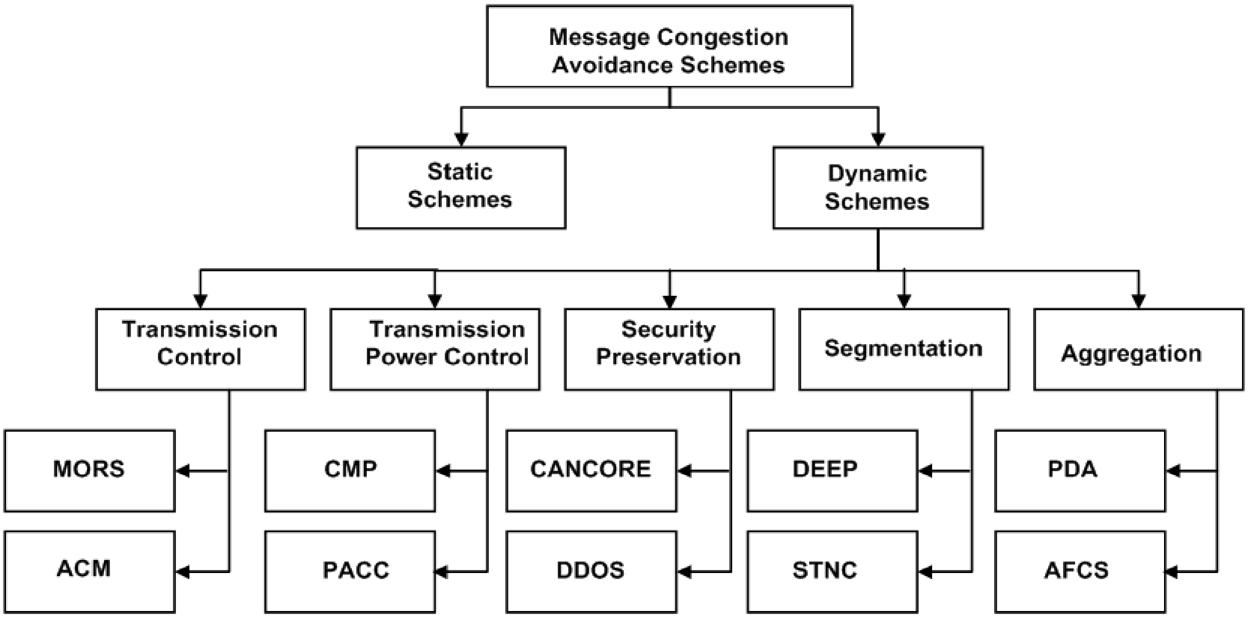

FIGURE 3. Taxonomy for message congestion avoidance schemes.

segment slots that are not efficiently applicable in VANET. Static road segments disturb the actual situation on roads as large segments result in accuracy loss and small segment results in high communication load. Therefore, dynamic schemes should be considered in order to collect data from vehicles. Dynamic schemes are accurate and reliable to collect data in VANET, instead of predefined designs. A general and flexible design can be used for several applications like management of traffic lights, detection of road conditions and accident avoidance. Dynamic schemes are sub divided into transmission control, transmission power control, Security preservation, segmentation and aggregation based schemes that are further sub divided as shown in figure 3. Analysis of each scheme explore strength and limitation where limitation leads to future work. After analyzing individual scheme comparison is done to explore research areas.

A. FOG ASSITED VANET ARCHITECTURE

In this section, a FoG assisted VANET (FAV) architecture is explored that manages the message congestions and message storms caused due to excessive communication in busy hours or emergency conditions. With gradual advancements, VANETs have taken a paradigm shift towards cloud along with big data support like in VANET-based clouds [52] and Vehicular Cloud Computing (VCC) [34], [53]. It supports a massive amount of information that is related to storing road condition parameters, healthcare records of people or patients in vehicles, analytic learning and training parameters based on social behavior and response of peoples on road emergencies. It helps to take better decisions as per near to realistic conditions at road emergency region as well. FoG servers can handle resources in an optimized way in order to improve overall round trip time, data transfer cost and bandwidth utilization and optimistic resource allocation and utilization [54] along with infrastructure support. Due to multi-hop nature and mobility, new connections should be continuously established [55], [56]. In this case, cell phones bear delays in communication when directly accessing to the cloud or VCC. It is not suitable for emergency conditions and busy hours when a large number of vehicular users interact with network. FoG assisted VANET provides ensures real-time and distributed services for geo location. It results in better communications than VCC with less time delay and less cost for vehicles with position information [57] in Vehicular FoG Computing (VFC) as well [58].

In Vehicular Social Network (VSN), floating vehicles like taxi and public transport can play a vital role to disseminate information and identify emergency situations. But, it is hard to generate pure mobility data set for the validation of VSN. Therefore, this scheme generates mobility data set by considering floating vehicles' data. It predicts origin destination (OD) by detailed analysis of datasets for floating cars. Still it is unable to highlight accurate spot of social vehicles at some places like airport and railway station [59]. Our scheme can further improve this limitation. In existing setup for vehicular networks, RSUs are used to manage delays and routing tasks especially in case of emergency. Similarly, FoG servers are also commonly used for reducing delays caused due to direct data exchange with cloud servers. In FAV, BS in existing cellular networks can be utilized for alternate connectivity to communicate on long distances. It greatly improves the delays as compared to V2V communication.

In FAV architecture, we have considered VFC [58] along with cell phones and RSUs. Cell phones can communicate via base station to approach the FoG server for efficiently intimating about emergency conditions without delay.

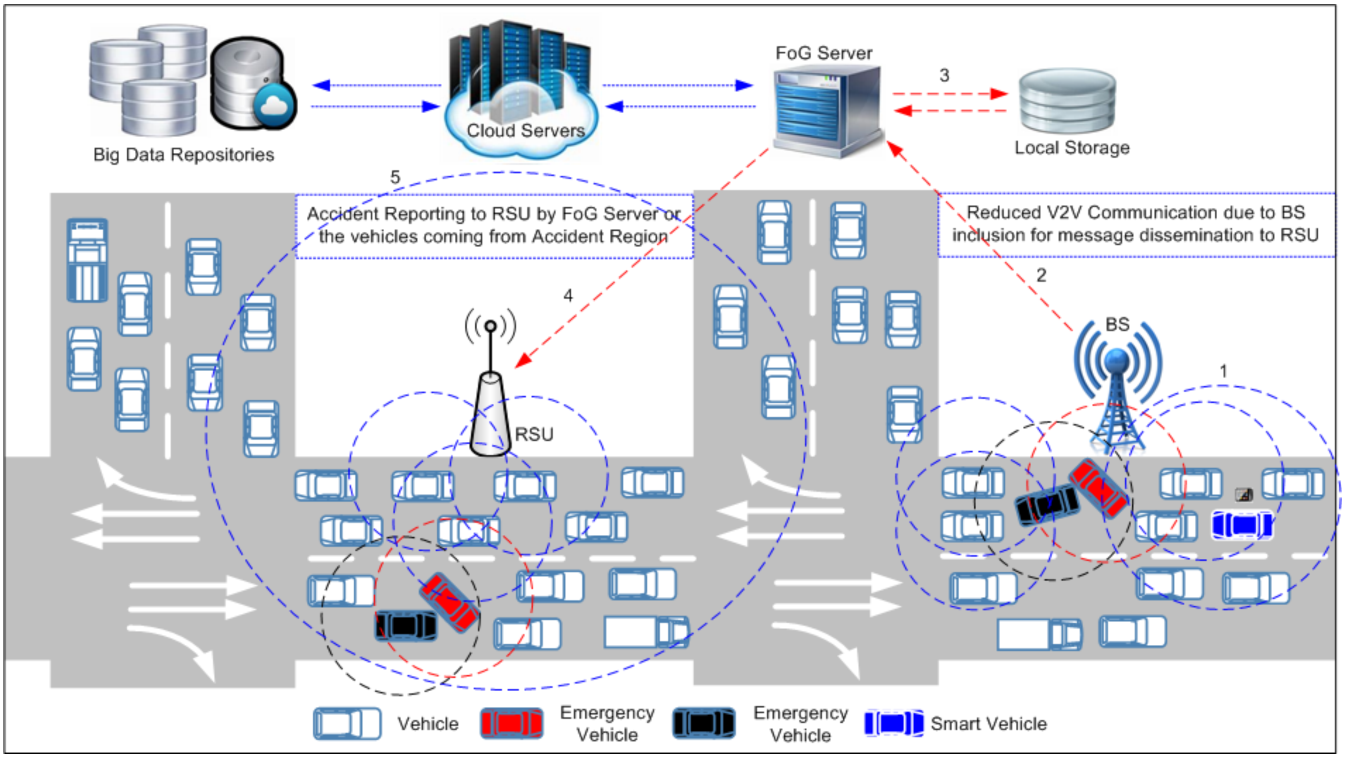

FIGURE 4. Congestion management based on communication in FoG assisted VANET (FAV) architecture where cell phones or smart vehicle can communicate to BS as well in addition to RSU for reporting to FoG server about emergency events.

Figure 4 elucidates that the emergency event can be reported via cell phone to BS for exchanging with regional FoG server that informs to nearby RSUs to intimate only the vehicles approaching that region. It will help to eliminate the chances of further collapses and damages. FoG server extracts the position parameters shared by smart vehicle to further acquire details from local storage about the RSUs mounted in the nearby region on that road as illustrated in step 3. Next, FoG server identifies direction and lane number of vehicles based on pre-assigned road segments of that region. Finally, it informs about emergency to RSU and precautionary measures to only those vehicles that are near to approach emergency area as illustrated in steps 4 and 5. RSU also exchange the messages with reporting vehicles to restrict further sharing with next RSUs. It also informs vehicle that is actually in emergency, to stop intimating about emergency condition as the event is already noticed by servers and rescue efforts are initiated. It reduces communication overhead and avoids message congestion as compared to flooding the messages in already congested area.

In this scenario, the vehicle to vehicle communication is very limited and even next RSU will also be informed about the event even before the vehicles from emergency region report to RSU. It just ensures the RSU about the verification of the event but RSU does not need to wait for such confirmations and acts as instructed by FoG server. But in this case, we have considered junction based communication scenarios where the anchor nodes near the junction can guide about next-hop selection in the direction of nearby RSU during V2V communication when cellphone and internet both option are not available.

FoG server also alerts the RSU by considering the chances of human interaction and crowding as per training data, previous history of that region and existence of populated residential or commercial areas. It also considers the time factor for the human involvement like in late night there may be very less chances of crowd. FoG servers may communicate with cloud server to upload or access data from big data repositories related to region, road, segment and vehicle direction identification along with social factors associated with that region. Vehicles with only mobile phones can first access BS to communicate with FoG server. Normal vehicles without any smart device or internet approaches FoG server through RSUs, firstly send message to RSU then it transfers to FoG server. Basically, purpose of this architecture is reliable communication, if RSUs are not available in that area then the message can be transferred through other vehicles by using V2V communication. Suppose there is no RSU in the range of normal vehicle then it gives message to nearby vehicles in one hop unless it reaches to FoG server. FoG server also replies to that smart vehicle, in order to inform abnormal vehicle as well. It achieves better communications with less time delay and less cost. We have also considered that some of the vehicles or cell phones may have direct access to internet to approach FoG servers or related emergency servers. In this case, the cell phone must know about the identity of supported

TABLE 2. Use cases of real –time FoG computing and their network specification for message dissemination.

Area	Application	Network Scale	Specification for Network Requirement
Transportation	Real time traffic lights Management [61], driver and vehicle safety [24] [58], Message Congestion Avoidance, Timely *EMs* delivery, Reliable route estimation.	Several number of vehicles	Time span, enormous data, event driven and beacon messages
Smart City	Smart devices for social connection [27] [24], Real time crowd detection and control, Home safety by using smart locks.	Smart Phones, Cameras and smart tablets, smart safety locks	Enormous data flow in each sphere
Forces	Safe communication in all forces like Army Navy and Air force, Task computation in distributed manner [27] [28] [29], Marine detection in NAVY.	Smart Phones, Army soldiers, smart devices	Huge confidential data, Weapons tracking and safety
Healthcare	Real time health monitoring [13] [62], Data Storage	Smart instruments, No. of Patients	Time span and immense data
Tragedy Management	Early alerts about flood arrival and timely earth quake detection	Smart devices, People in affected region	Lack of infrastructure, enormous data

FoG server for that region. We have considered the existence of such vehicles that may have acquired the identity of supported FoG server to support in timely transmitting information for emergency events including accidents, slippery roads, floods, traffic jams, fire and road sinkholes.

For the implementation of proposed architecture, most of the implementation is required at the RSU side which is core component of vehicular networks. RSU should implement the procedures to receive the commands from BS and interpret as per enumerated value which is further used to execute the programming code in appropriate switch case. RSU will also interpret commands from FoG server. In the similar vein, FoG server will also implement the procedures to interpret the commands sent from the RSU and BS as well. In this case, BS does not need any amendments because the existing functionality of sending short messages or GPRS based data messages can be transmitted as per existing format. The RSU and FoG servers can interpret and extract the message or data accordingly.

During message dissemination, motion of vehicles provides good message carriers to transmit information by making new connections continuously. Due to these communication hubs, the FoG is shaped instead of sending meaningful data to cloud servers. FoG server share communication resources locally, that includes both local decision making and geo distribution characteristics in order to bring less delay. In the similar vein, we have presented a collection of use cases in table 2 for real-time FoG computing assisted message dissemination scenarios that can utilize our architecture as per the application scenario.

B. TRANSMISSION CONTROL BASED SCHEMES

In these schemes, metrics are measured locally to reduce the amount of control messages. It discusses two main issues about VANETs; one is broadcast storms and the other is high speed of data transfer that causes disconnection problems of network. A broadcasting storm occurs when multiple messages are sent at the same time so it causes poor network performance. Dissemination delay can be resolved by using high data rates [60].

Broadcasting storms leads to harmful effects when the network is near to its capacity fullness. The network disconnection issue occurs when forward messages need node through which data travel on specific area of the road. This type of dissemination loss is related to vehicles velocities. It causes hurdle in order to deliver safety message [60]. In [16], a new ACM scheme is proposed with three types of mobility design: stationary nodes nearly, nodes that move in arbitrary designs, and the nodes which move in known designs with preassigned trajectory. It can exchange message with different nearby vehicles in range. Moreover, a Multi-hop broadcast mechanism for emergency messages dissemination (MBM-EMD) involves two phases; i) selection of optimal relays including nearby vehicles to reach till destination by involving vehicles' density, motion, direction and channel quality; ii) Broadcast the messages on identified optimal relay and initialize a rebroadcast on next best available relay [63].

Classification of mobility designs based on SDN controller in order to communicate with the whole network from a global side. Basically SDN is used to separate the network structure from data [4]. It consists of three layers where one layer based on controller. There is a campus scenario where a school bus act as moving node that has a known mobility design. In the same way, a moving car and a stationary car represent an unknown moving node and a quasi-stationary node, respectively. The controller is responsible to manage the parameters in the structure of network state information (NSI). In this case, mobility information is required to minimize control message overhead. Every wireless node is responsible to send and receive beacon messages occasionally, in order to keep recent connection information. The number of control messages maximizes with the number of nodes. If nodes mobility design is quasi-stationary or known, we can minimize the reporting frequency as the controller is able to predict the nodes position. On the contrary, NSI is also useful for recovery. Seongjin Park et al. explores the connection failure between the FoG server and the nodes. As the link is wireless between the nodes and the connected vehicle, the networks may suffer from frequent disconnection, which effects whole network performance. Here the controller predict connection is lost or not between a FoG server and a wireless node, by using the nodes mobility design and the link quality. The controller is also responsible to decides disconnected nodes link will recover soon or not. When the controller forecasts a connection loss, it is classified as either a temporal or a severe failure. The controller is responsible to manage the network by keeping NSI [16]. There is a recovery process from FoG server failure. The vehicle that was in connection to the failed FoG server was not able to use its resources until the connection is recovered. For fast recovery of services and resources, a fast fail-over scheme is needed. Basically this noval approach is utilizing the network state information (i.e., the nodes mobility patterns and link quality) to overcome unstable communication in the FoG computing and SDN-based connected vehicle environment [16]. There are few confronts to run an SDN controller on FoG servers. Although FoG servers take mobile nodes as the clients. It should also take the nodes information about mobility in the mobile environment for communication [64].

C. TRANSMISSION POWER CONTROL BASED SCHEMES

The authors proposed Control Message transmission Power (CMP) scheme to handle congestion of messages [65]. Congestion is a result of higher transmission power that leads to high number of nodes in argument for single channel like 802.11 network. A scenario has several number of nodes like vehicles at certain distance from each other for transmission. For example, 50 adjacent nodes sending 250bytes packet at five packets per second in order to generate load more than available bandwidth in VANET. In the same way transmitting 250 byte packets can lead to the same result. To keep an eye on congestion for beacon-based safety need to manage transmission rate. So variable message size can be another possible way to gain the congestion. In this scheme all nodes need to be informed about their channel status timely. Whenever a signal reaches to its saturation level a vehicle node is able to sense congestion instantly. Special concern is required for handling transition between both approaches as increasing or decreasing power level smoothly. At the same time event driven messages propagated simply through remaining bandwidth with large penetration.

Soufiene and Yacine [43] proposed a priority assignment, congestion detection and congestion control based scheme (PACC). This scheme adjusts the transmission power with the rate of beacon transmission. Basically this approach is based on three stages: Priority assignment to message in order to transmit, detect the congestion created by several messages at a time and finally adjust the beacon messages load. To handle this load transmission power is integrated with the rate of message transmission.

D. SECURITY PRESERVATION BASED SCHEMES

The author has proposed new scheme called Context-Aware Network COded REpetition (CANCORE) to improve effectiveness and security of applications [45]. CANCORE has two major goals: First one is broadcast the *EMs* from front vehicles extensively by using network coding. Second is to avoid unnecessary reporting growth caused by repetition of coded *EMs*.

$$Score = \sum_{i=0}^{M-1} d_i^A - \sum_{i=0}^{N-1} d_i^B \qquad (1)$$

Beacon scores are updated regularly by using equation (1) where each vehicle prepares a coded packets like P1 and P2. It calculates the distance d between sender and receiver A and B respectively by considering direction as well. Score involves exchanging M beacons at A and N beacons at B. These packets are based on two native beacons and selected by following two rules; Rule 1 is used to reduce overhead by permitting large number of vehicles to have only one of P1 and P2 at the receiving time. Rule 2 is used to keep beacons as active as possible. In first rule, select one simple packet from each direction with highest score. While in second if there is the same score between beacons, the beacon arrived earlier is preferred. If P1and P2 are far away from each other, probably receivers obtain beacons via intermediaries. So, CANCORE bound the distance among the sender and the source of a selected beacon in order to meet situation. Grover and Mittal [50] identify the Distributed Denial Of service (DDOS) attack in the network and give good path for the safe V2V communication. Its objective is to reduce the communication delay and communication loss. Firstly, the work model created the controlled clusters and apply the several limits based analysis to identify the attack. Though, safe communication take place over the network.

E. SEGMENTATION BASED SCHEMES

Density-aware Emergency message Extension Protocol (DEEP) broadcasts EMs in VANETs. Basically, it is used to resolves the EMs broadcast storm issue, in order to obtain less delay in distribution and reliability. The technique delivers EMs timely and ensure all nearby vehicles receive the messages by using recovery mechanism [66]. A scheduling scheme titled Space Time Networking Coding (STNC) is presented for message dissemination among vehicles. Basically it is based on segments where it divides time slots along transmission in order to improve delay. It works better in dense network than sparse. It is based on the concept that channel is accessed randomly. Random access message dissemination strategies lead to the issue of interaction among vehicles for message transmission. This scheduling scheme included control node in order to select relay node and highlights transmission frame. Firstly, identifies the transmission frames then all nodes transmit data according to frames order. All nodes include vehicles and RSUs. Finally, vehicle send beacon message to RSU for scheduling next distribution cycle. Beacon message sends the speed, velocity and position information [67]. In a Trinary partitioned black-burst-based broadcast protocol (3P3B), two main mechanisms are proposed as follows; i) assign priority value to EMs for early processing as compared to normal messages; ii) a trinary partitioning of transmission region into small sectors in an iterative manner for approaching distant vehicles [68].

F. AGGREGATION BASED SCHEMES

A Probabilistic Data Aggregation (PDA) framework is presented to manage *EMs* broadcast storm [69]. It reduces broadcasting rate by minimizing repeated *EMs*. Basically less bandwidth rate leads to improves data dissemination. Proposed framework is local knowledge based in order to save the decisions for data aggregation. This scheme enables dynamic fragmentation for road safety requirements. By using this scheme, efficient VANET data aggregation is possible without predefined or static approach. In [22], an Adaptive forwarding message and cooperative safe driving (AFCS) scheme is proposed for smooth messaging by reducing message storm. Basically this scheme is based on aggregation or grouping concept, where message sent to group leader then that is responsible to forward message V2V in a group. This scheme consists of two segments Adaptive Forwarding Message (AFM) and AFM including cooperative active safe driving (AFM-CSD). This approach improves end-to-end delay and connectivity.

V. COMPARISON OF CONGESTION AVOIDANCE SCHEMES

Message congestion avoidance schemes are reviewed in order to evaluate the suitability for FoG based environments. We have explored the strengths and limitations of these schemes and evaluated for metrics including congestion, delay and bandwidth as illustrated in Table 3. These limitations lead to future research work. We have evaluated these metrics in terms of High (H), Medium (M) and Low (L). Here one major point to remember is that, message congestion avoidance schemes should be in multi-hop environment because single-hop is not suitable in urban areas [63]. Message forwarding load and accuracy of destination should be considered. Moreover, message beaconing frequency is also quite challenging work in traffic aware network [2]. We have highlight the schemes that lead to reliable communication in VANET by analyzing several *EMs* transmission schemes. DEEP [66] reduces message congestion using small segments for rural areas. It needs to be extended for urban areas. ACM [16] is also used to avoid message congestion but only for fixed and known mobility patterns, it needs to extend for unknown mobility pattern. CANCORE [45] is used to control message storm with high cost due to encryption and decryption. CMP [65] scheme highlights message congestion avoidance but it needs dynamic algorithm with more cost. DDA [69] avoids message storm using data aggregation which losses throughput.

In VANET, energy consumption should be reduced for efficient and green vehicle communication. More energy is consumed when network is not able to send the data in given or specific time and retransmissions are increased. Another challenging reason is unnecessary message retransmissions when next-hop vehicle is moving in the opposite direction to destination. Delayed messaging should be improved under the constraint of vehicle's speed, connectivity and sudden change in vehicle motion [8]. Low delay rate leads to reliable communication. In STNC [67], time slots are divided for transmission to improve delay. Researchers should propose novel schemes that manage delay, throughput, latency and position based routing in order to improve energy efficiency. DEEP, CANCORE, CMP and DDA are used for message congestion avoidance by reducing congestion rate but all these suffer from high delay. DEEP has segments that leads to high delay. CANCORE faces high delay by encoding/decoding the packet. CMP controls message transmission power which leads to delay by sending packet in limited power that leads to high delay in order to reach the destination. DDA suffers from high delay due to aggregation time. In fact, dynamic mobility information based protocols are required to improve delay performance in VANET [15]. Moreover, density independent scheme also improves the delay and average message dissemination speed. It manages to assign a time critical priority to EMs and also minimize contention period jitter that results in a smooth period of device contention [68].

ACM [16] consumes high bandwidth for unknown mobility pattern because of frequent messages transmitted repeatedly. DEEP [66] also has high bandwidth because of high transmission rate but ACM and DEEP reduced message congestion at some extent. PACC [43] controls the message beaconing by managing transmission power. AFCS [22] achieves smooth messaging by reducing message storm. Moreover, throughput is based on rate of communication per time unit which should be utilized efficiently to improve energy utilization. DDA [69] has low throughput due to dynamic data aggregation. It needs to gain high throughput by using new dynamic algorithms. In the similar vein, packet delivery ratio is the ratio of the number of packet received by the destination to the number of packet sent by the sender. Therefore, delayed messages or packet loss should also be reduced to achieve better energy utilization. In [63], a rebroadcast mechanism on available set of relays or short paths independent of sender or receiver utilizes more bandwidth but achieves better delivery ratios. In [68], the communication range is portioned in an iterative manner to reach until distant vehicles with better delivery ratios. Several essential factors such as packet size, action range, mobility of nodes and cluster size affect influence it.

VI. FOG ASSISTED DESIGN CHALLENGES FOR MANAGING CONGESTION AVOIDANCE: OPEN RESEARCH CHALLENGES

This section explores a number of open research challenges that should be considered to develop reliable congestion avoidance schemes by utilizing FoG servers in conjunction

TABLE 3. Comparison of message congestion avoidance schemes.

Technique	Methods	Strength	Limitation	Congestion	Delay	Bandwidth	Remarks for suitability in FoG assisted VANET
DEEP: Density-aware Emergency message Extension Protocol [66]	Segmentation (Set length and width of block size)	Control broadcast storm of *EMs*	Deliver *EMs* to a specific area.	M	H	H	Need QoS Need to extend for Complex environment
CANCORE: Context-Aware Network COded REpetition scheme [45]	Coding & Decoding	Broadcast the *EMs*. Avoid unnecessary reporting growth caused by repetition of coded *EMs*.	Computation overhead due to complex operations. High Delays during transmission Limits the distance.	L	H	L	High delay due to coding /decoding. Needs to be generalize without distance limitation.
ACM: Adaptive Control Messages [16]	FoG, SDN & 5G	Reporting frequency can be reduced for known mobility pattern and quasi-stationary nodes.	Unknown mobility pattern nodes report their mobility information frequently.	L	L	H	Needs to control Frequent EMs for unknown mobility pattern.
CMP: Congestion Mitigation Process [65]	Transmission Power control	*EMs* congestion control	Structural congestion control scheme	M	H	L	Need to Develop suitable mobility based algorithm
DDA: Dynamic Data Aggregation [69]	Data Aggregation	Congestion control dynamically	Less Throughput	M	H	M	Disseminate data efficiently using more throughput.
AFCS: Adaptive Forwarding message & Cooperative Safe driving [22]	Grouping/Data Aggregation. Identify group leader	Efficient Messaging in mobile society & 5G world by controlling message storm.	Need to improve speed synchronization interval. Absence of ITS.	M	M	L	Need to communicate with ITS. Need to synchronize speed dynamically in order to message congestion rate.
PACC: Priority Assignment for Congestion Control [43]	Adjustment of transmission power along message transmission rate.	Congestion detection and handle it for efficient messaging	Difficult to deploy	M	M	M	Need dynamic algorithms for integration to reduce delay and easy deployment
STNC: Space Time Networking Coding [67]	Scheduling: Made transmission frames.	Safely message dissemination. Avoid Collision.	Not good in sparse environment. Random access leads to issue of interaction among vehicles.	L	L	M	Need to improve interaction for message distribution in sparse environment.
MBM-EMD: Multi-hop broadcast mechanism – for *EM* dissemination [63].	Identify relays towards destination, Rebroadcast on available set of optimal relays, Involves density, motion, direction and channel quality	Improved packet delivery ratios, Availability of alternate relays/short paths, Involves a metric for optimal relay selection, Sender and receiver independent relays	Computational overhead due to Dynamic relays identification, Communication overhead for rebroadcasting	M	M	H	Needs to manage relays rebroadcast as per change in topology, Multi-hop based broadcasting needs a control over communication cost
3P3B: Trinary partitioned black-burst-based broadcast protocol (3P3B) [68]	Dynamically partitioning transmission region, Priority for *EMs*	Density Independent, Reduces delay and improves jitter for contention period	Dynamic change in topology increases computational cost in partitioning	L	L	M	Need to incorporate the direction of moving vehicles in each sector of transmission range

with VANET and ITS [70], [71]. More innovative schemes are needed to present dependable solutions to mature the applicability of FoG computing in various application scenarios in linkage with ITS. There are several challenges in different extent and research domains but few of the relevant one are explored as follows;

A. CONTINUOS CONNECTIVITY SUPPORT

FoG assisted architecture enhances connecting with vehicles, that helps in resolving the major issue of connectivity in vehicular network [72]. In FoG environment router and vehicles act as nodes in order to provide better network connectivity. It helps to avoid collision and data loss by using the concept of V2X. Moreover, smart vehicles along with in-built hardware for auto detection of emergency events and driving conditions. However, cellular network also enables the support for BS based accessibility or using mobile data for online accessibility of transportation services. It results in variety of connectivity options that are effective for continuous communication and data sharing among any two distant vehicles as well.

B. REAL-TIME DATA STORAGE SUPPORT

FoG server maintains the mostly accessible and recent content to manage real-time transportation, traffic, emergency events and road situations [9], [10]. FoG assisted considers sufficient amount of storage in terms of local repositories at FoG server and Big Data repositories at cloud. Big Data repositories help to access existing decision making and record keeping content for previous similar conditions. It can help to maintain a history of previously processed cases that can be accessed in near future. It can also maintain captured video streams to identify traffic violations and accidents. It also interprets video frames for the tasks like data mining and tracking. FoG server keeps the record of collected data that can be used in several novel applications. FoG server is also directly linked with cloud that allows a much large storage capacity for VANET related information. With the growth of communication parties in a variety of scenarios, we have considered that the vehicles can perform multiple communications across networks. In this scenario, a vehicle may access multimedia content from FoG or other servers, news and TV channel streaming, social network connectivity, interaction with RSUs and FoG servers, acting as an intermediary for forwarding messages from neighboring vehicles or RSUs. A single vehicle can be involved in many such communications that can result in shortage of temporary and permanent storage at vehicle. Moreover, processing capabilities can become a bottleneck to smoothly perform these operations. FoG assisted VANET needs to manage resources in order to utilize computation nodes and storage resources. Nodes can be vehicles, base stations, RSU and router. Computation nodes should be cheaper in cost for V2V communication in order to send message to nearby vehicle. Several protocols and algorithms have to be planned to detect idle resources and utilize them efficiently among vehicles. However, future research needs to explore new algorithms and techniques to share resources among nodes efficiently. Researchers should present novel load balancing and other solutions to resolve these issue.

C. REDUCTION IN REAL-TIME COMPUTATION AND COMMUNICATION OVERHEAD

FoG servers are placed at the edge of the networks that are near to source vehicles as compared to clouds [34]. It improves the computational responses to vehicles for timely analysis of road conditions, social vehicular analysis, road predictions and related data mining based queries. Edge network involves smart devices, base station and RSUs. It helps vehicles to take intelligent decision making as per road and traffic conditions in upcoming regions. It involves FoG server to analyze and take more accurate decisions by consulting local repositories. It also supports vehicles as infrastructure in order to avail best usage of communication and computation properties [58] to enhance the available resources for the sake of best capacities. In some cases, FoG server can exchange data with cloud servers to request for verification or data extraction from the big data repositories that already contains decision for current situations as per region. It greatly reduces redundant computations at FoG server and store the concrete decision about a certain emergency or demanding situation for further inquiry by the vehicles approaching that region. By adopting FoG assisted architecture, vehicles can access the current positions of road junctions and analyze the direction of packet movement towards destination nearby a certain junction point. It reduces massive amount of communication overhead as compared to V2V communication with huge packet drop probabilities that occurs due to wrong next-hop vehicle selection in opposite direction to the destination. It results in less energy consumption to achieve green computing.

D. LOW LATENCY

FoG assisted VANET reduces the latency by processing tasks on the edges [27], [34]. Basically it leads to low latency caused due to accessibility of cloud from RSU or the cellular network. Vehicles can access the cloud services for availing live feedback regarding weather, global positioning and tracking the fellow vehicles. FoG server actively reduces the latency to access the data of these services by maintaining local backup using local repositories. Reduced V2V communication and involvement of more smart vehicles in the network results in much more improvement in latency.

E. MOBILITY AND POSITION TRACKING MANAGEMENT

FoG assisted VANET handle mobility of end nodes (vehicles) such as track the vehicle location, tune the expected traffic light and give *EMs* alerts to nearby vehicles dynamically [13]. FoG assisted architecture provides high mobility tracking support by available RSUs that are maintaining vehicle positions. Secondly, anchor vehicles near RSU are also maintaining the positions, speed and direction of vehicles. Moreover, cellphones are also trackable in cellular networks to identify the position of driver as well. In future smart cities, signals can also be linked with RSUs and FoG servers to act as anchor points a well for predicting about passing by vehicles in that region. It can help to draw a trajectory of a vehicle form one location till the demanded location to track the route and travelling time. FoG server also maintains the communication request transmitted by a particular tracking vehicle on the move on a certain path.

FoG assisted VANET introduced mobility among vehicles by using geo distribution concept for known pattern of vehicles. Mobility is a major challenge in VANET and other wireless networks [15] where network topology changes dynamically on every moment. FAV architecture can manages it by dynamically utilizing the real-time information regarding anchor nodes and road junctions. It can achieve much better results in terms of reducing delay and packet drop ratio and improve the energy consumption and packet delivery ratios. But, it becomes extremely challenging when there is no internet, cellphone and RSU nearby a vehicle in emergency situation and no other vehicle is available within direct communication range. In this scenario, no vehicle cannot act as next-hop or the intermediary to forward the message. The only solution for this problematic vehicle is to wait and perform V2V communication when any vehicle is approaching its region. It may result in unbearable delays, dis-connectivity and exclusion of vehicle from current sessions at FoG server. It opens a challenging scenario for the researchers to propose innovative solutions for possible communication.

F. SCALABLE VEHICULAR NETWORK FOR DISTANT COMMUNICATION SUPPORT

VANET researchers used to concentrate on scalable data dissemination by avoiding information repetition [6]. FoG assisted VANET supports high scalability instead of waiting for new updates in the system [34]. Being FoG nodes vehicles are capable to setup high scalable and distributed FoG environment [27], [29]. It ensures the scalability support to enable short and long distance communication among vehicles based on RSUs, BS and FoG servers. In [63], rebroadcasting the message on optimal relays to reach until distant nodes. It adopts short time relays that are not directly linked with sender and receiver but utilizes next-hops of neighbors as well. In [68], a distant vehicle is approached by iteratively extracting the sectors of a communication range for source vehicle.

G. GEOGRAPHIC DISTRIBUTION OF VEHICLES AND ROAD SEGMENTS

FoG assisted VANET provides best features for fast, slow and stationary vehicles as per geographic distribution like clustering of neighboring vehicles [58] that also avoids message storm [33], [73]. Geographical addressing is the most promising and complex element in transportation [8] like identify the count of vehicles and pedestrians [24], [61]. Involvement of social interaction by human beings in vehicular network is a challenging aspect. Its deployment provides real scenario of interactions including V2V and V2I [24] similar to FAV architecture. To further differentiate the direction of vehicles and deeply analyze the lanes, each road is divided into road segments. It greatly helps to identify the road segment of emergency vehicle and take decision about chances of vehicle passage from side by road lanes. It also allows to identify the exact region or segment of road where some emergency event has happened. In this case, FoG servers can inform RSU to communicate with nearby vehicles or intimate about any emergency situation like accidents, slippery road segments and road sink holes. Connection of vehicles is real and vital network in order to deal with transportation issues and road hazards. FoG assisted VANET gives the opportunity of traffic light management to avoid accidents. Video cameras and sensors are used to senses the emergency events. After sensing the emergencies, FoG servers can manage to change traffic lights at entry point of this road. Other traffic is routed to alternate paths in order to avoid congestion on the road.

H. SOFTWARE UP-GRADATION IN VEHICLES

Before FoG vehicles need to bring repair shops in order to install recent software packages which leads heavy cost [28]. This type of software/hardware updating was limited due to delay and other constraints to cloud. FoG assisted VANET provides software/hardware updating on edges without facing delay and bandwidth constraints. It is linked with the ITS for authentication to download or install the client side software for continuous and reliable communication. It also manages the fail-safe state to avoid possible accidents in case of crashing the software modules or any real-time exceptions.

I. SECURE COMMUNICATION

FAV architecture achieves better security as compared to security solutions in existing V2V and V2I communication scenarios. FoG servers can actively recognize and track objects as per multiple attributes of vehicle [39], [61]. Secondly, involvement of human beings for interacting with the vehicles has resulted into merger of social and vehicular networks as VSN. It arises the chances of security attacks and message modification attacks [40]. However, FAV architecture is capable of providing vehicle's security by recognizing the vehicles identity, access permissions and authentication along with tracking based on session as well. FoG servers can act as sink for storing secured information from different vehicles scattered in large areas to provide real-time sensor readings. FoG server can also play the role of a central certification authority to assist in cryptographic operations. FoG servers manage the distributed vehicular network in a large region where a vehicle can communicate with a large number of intermediate vehicles to approach the infrastructure like RSU, BS or FoG servers. It is also challenging to manage security for several servers, in order to authenticate the data on different FoG servers and gateways [61]. It becomes more challenging to manage non-delay tolerant cyclic data transmissions for busy hours or emergency scenarios. In this scenario, vehicles have to trust on any of the vehicle which can act as intermediary to transmit data towards destination vehicle or nearby RSU. We have considered the trust management based solutions for vehicles to communicate with others vehicle, RSU and FoG server but it still needs innovative and dependable solutions. The main reason is the distributed attack scenarios using vehicles as bots to extract the data from vehicles. It arises the need for a dependable intrusion detection system that can detect malicious vehicles and inform the nearby vehicles in the region to abstain from such attacks. It demands a solid effort by the researchers to present innovative solution to further ensure the V2V communication.

J. DYNAMIC VEHICLE TYPE IDENTIFICATION

In FAV architecture, a vehicle can act as a normal vehicle with limited communication support for wither V2V or V2I. Secondly, a vehicle with only cell phone or additionally can access internet as well. Moreover, there exist chances for vehicles with strong hardware like OBU to auto-detect road situations along with auto-driving capabilities. It is quite challenging to identify the real-time capabilities of the vehicle like a vehicle may not have internet support at any specific time but RSU assigned a task to notify using internet due to its previous state. Similarly, it is quite challenging to maintain record for recent and available capabilities of vehicle and assign and dynamically update the vehicle type in local and global repositories. It should also ensure the temporal and spacial consistency for the vehicle specific information. Researchers should present dependable solutions to resolve this challenge.

K. DETECTION AND SYNCHRONIZATION WITH FOG SERVER AND RSU

In case of vehicle with WLAN support or only internet support to directly access the FoG server via internet. For these vehicles, it is quite challenging to dynamically detect the FoG server in a new region where vehicle also cannot directly communicate with RSU to request for address of FoG server. In this scenario, new solutions are needed to efficiently approach the nearby RSU using limited V2V communication support or by approaching some alternate online contact points to access FoG server address. It opens a new direction for future research. Moreover, it is also challenging to remain synchronized with RSUs with a rapidly changing high speeds of vehicle where multiple RSUs can be crossed in little durations. It demands a smooth handoff for complete synchronization for continuous communication for certain events. It becomes more challenging when there is no next RSU in the chain. In this case, the nearby smart vehicles can play a role to assist in message dissemination. Another option could be to utilize nearby cell phones carried by human beings but it can be challenging to share vehicular data with cellular network or social network user if it does not support messaging format to interpret the destination to forward the packets.

L. QUALITY OF SERVICE

Quality of service (QoS) is quite challenging to ensure services asper expected requirements [34]. To manage quality, delay should be minimized. Secondly, fault tolerance with QoS requirements is a challenging task in this environment [29] . FAV architecture can handle the fault tolerance and also manages the fail-safe strategy. The delay should also considered on priority basis by utilizing FoG servers, RSU and BS for different type of vehicles as per capabilities. But, QoS services still needs improvement for V2V communication to reduce delays and ensure smooth and reliable message dissemination in busy hours and emergency scenarios to avoid congestion.

VII. CONCLUSION

FoG computing can play a vital role in vehicular networks to improve the communication capabilities among vehicles for sharing road and traffic conditions. It is quite challenging when information is disseminated in peak hours or emergency scenarios when congestion can badly affect smooth communications. In this paper, we have explored message dissemination schemes and presented a taxonomy of messages congestion avoidance schemes. It includes a collection of dynamic schemes that are suitable for VANET due to mobility support. We have also explored the FoG assisted architecture for VANET to avoid congestion during peak hours or emergency conditions. Moreover, a comparison of congestion avoidance schemes is presented to highlight the strengths and limitations of dominating schemes in literature. Our main focus is to identify the advancements of VANET towards FoG assisted VANETs along with key opportunities and challenges. Finally, a number of new open research challenges are identified. We have created a need of presenting novel and dependable solutions by considering identified challenges for congestion avoidance in FoG assisted VANET.

REFERENCES

[1] M. Khabazian, S. Aissa, and M. Mehmet-Ali, ‘‘Performance modeling of message dissemination in vehicular ad hoc networks with priority,’’ *IEEE J. Sel. Areas Commun.*, vol. 29, no. 1, p. 61–71, Jan. 2011.

[2] K. Z. Ghafoor, J. Lloret, K. A. Bakar, A. S. Sadiq, and S. A. Ben Mussa, ‘‘Beaconing approaches in vehicular ad hoc networks: A survey,’’ *Wireless Pers. Commun.*, vol. 73, no. 3, pp. 885–912, Dec. 2013.

[3] S. Panichpapiboon and W. Pattara-atikom, ‘‘A review of information dissemination protocols for vehicular ad hoc networks,’’ *IEEE Commun. Surveys Tuts.*, vol. 14, no. 3, pp. 784–798, 3rd Quart., 2012.

[4] S. P. Warghane and S. Choudhary, ‘‘Data dissemination in software defined vehicular ad hoc network: A review,’’ *Int. Res. J. Eng. Technol.*, vol. 4, no. 1, pp. 1–4, 2017.

[5] J. A. Sanguesa, M. Fogue, P. Garrido, F. J. Martinez, J.-C. Cano, and C. T. Calafate, ‘‘A survey and comparative study of broadcast warning message dissemination schemes for VANETs,’’ *Mobile Inf. Syst.*, vol. 2016, Mar. 2016, Art. no. 8714142.

[6] M. Chaqfeh, A. Lakas, and I. Jawhar, ‘‘A survey on data dissemination in vehicular ad hoc networks,’’ *Veh. Commun.*, vol. 1, no. 4, pp. 214–225, Oct. 2014.

[7] R. Hussain, W. Nawaz, J. Lee, J. Son, and J. Seo, ‘‘A hybrid trust management framework for vehicular social networks,’’ in *Computational Social Networks—CSoNet* (Lecture Notes in Computer Science), vol. 9795, H. Nguyen and V. Snasel, Eds. Cham, Switzerland: Springer, 2016.

[8] G. Karagiannis *et al.*, ‘‘Vehicular networking: A survey and tutorial on requirements, architectures, challenges, standards and solutions,’’ *IEEE Commun. Surveys Tuts.*, vol. 13, no. 4, pp. 584–616, 4th Quart., 2011.

[9] A. Kamouch, A. Chaoub, and Z. Guennoun, ‘‘Mobile big data in vehicular networks: The road to Internet of vehicles,’’ in *Mobile Big Data* (Lecture Notes on Data Engineering and Communications Technologies), G. Skourletopoulos, G. Mastorakis, C. Mavromoustakis, C. Dobre, and E. Pallis, Eds. Cham, Switzerland: Springer, 2018.

[10] J. Contreras-Castillo, S. Zeadally, and I. J. G. Ibañez, ‘‘Solving vehicular ad hoc network challenges with big data solutions,’’ *IET Netw.*, vol. 5, no. 4, pp. 81–84, 2016.

[11] X. Kong, X. Song, F. Xia, H. Guo, J. Wang, and A. Tolba, ‘‘LoTAD: Long-term traffic anomaly detection based on crowdsourced bus trajectory data,’’ *World Wide Web*, vol. 21, no. 3, p. 825–847, 2018.

[12] S. A. A. Shah, E. Ahmed, M. Imran, and S. Zeadally, "5G for vehicular communications," *IEEE Commun. Mag.*, vol. 56, no. 1, pp. 111–117, Jan. 2018.
[13] S. Yi, C. Li, and Q. Li, "A survey of Fog computing: Concepts, applications and issues," in *Proc. ACM Workshop Mobile Big Data*, 2015, pp. 1–6.
[14] K. Sandeep and C. Er, "Survey Paper on Fog Computing," *Int. J. Sci. Res. Comput. Sci., Eng. Inf. Technol.*, vol. 2, no. 3, pp. 420–422, 2017.
[15] C. Fang, H. Yao, Z. Wang, W. Wu, X. Jin, and R. F. Yu, "A survey of mobile information-centric networking: Research issues and challenges," *IEEE Commun. Surveys Tuts.*, vol. 20, no. 3, pp. 1–19, 3rd Quart., 2018.
[16] S. Park and Y. Yoo, "Network intelligence based on network state information for connected vehicles utilizing Fog computing," *Mobile Inf. Syst.*, vol. 2017, Feb. 2017, Art. no. 7479267.
[17] X. Kong *et al.*, "Big trajectory data: A survey of applications and services," *IEEE Access*, vol. 6, pp. 58295–58306, 2018.
[18] B. Liu, D. Jia, J. Wang, K. Lu, and L. Wu, "Cloud-assisted safety message dissemination in VANET–cellular heterogeneous wireless network," *IEEE Syst. J.*, vol. 11, no. 1, pp. 128–139, Mar. 2017.
[19] F. Xia, J. Wang, X. Kong, Z. Wang, J. Li, and C. Liu, "Exploring human mobility patterns in urban scenarios: A trajectory data perspective," *IEEE Commun. Mag.*, vol. 56, no. 3, pp. 142–149, Mar. 2018.
[20] G. Hampel, K. L. Clarkson, J. D. Hobby, and P. A. Polakos, "The tradeoff between coverage and capacity in dynamic optimization of 3G cellular networks," in *Proc. IEEE 58th Veh. Technol. Conf.*, Orlando, FL, USA, Oct. 2003, pp. 927–932.
[21] W.-H. Kuo, Y.-S. Tung, and S.-H. Fang, "A node management scheme for R2V connections in RSU-supported vehicular adhoc networks," in *Proc. Comput., Netw. Commun. (ICNC)*, Jan. 2013, pp. 768–772.
[22] B.-J. Chang, Y.-H. Liang, and Y.-D. Huang, "Efficient emergency forwarding to prevent message broadcasting storm in mobile society via vehicle-to-X communications for 5G LTE-V," in *Proc. Int. Comput. Symp. (ICS)*, Dec. 2016, pp. 479–484.
[23] B. B. Dubey, N. Chauhan, and P. Kumar, "A survey on data dissemination techniques used in VANETs," *Int. J. Comput. Appl.*, vol. 10, no. 7, pp. 5–10, 2010.
[24] F. Bonomi, R. Milito, J. Zhu, and S. Addepalli, "Fog computing and its role in the Internet of Things," in *Proc. 1st Ed. MCC Workshop Mobile Cloud Comput.*, 2012, pp. 13–16.
[25] M. L. Sichitiu and M. Kihl, "Inter-vehicle communication systems: A survey," *IEEE Commun. Surveys Tuts.*, vol. 10, no. 2, pp. 88–105, 2nd Quart., 2008.
[26] M. Y. Darus and K. A. Bakar, "A review of congestion control algorithm for event-driven safety messages in vehicular networks," *Int. J. Comput. Sci. Issues*, vol. 8, no. 5, pp. 49–53, 2011.
[27] A. V. Dastjerdi, H. Gupta, R. N. Calheiros, S. K. Ghosh, and R. Buyya. (2016). "Fog computing: Principles, architectures, and applications." [Online]. Available: https://arxiv.org/abs/1601.02752
[28] M. Chiang and T. Zhang, "Fog and IoT: An overview of research opportunities," *IEEE Internet Things J.*, vol. 3, no. 6, pp. 854–864, Dec. 2016.
[29] R. Mahmud, R. Kotagiri, and R. Buyya, "Fog computing: A taxonomy, survey and future directions," in *Internet of Everything: Algorithms, Methodologies, Technologies and Perspectives*, 1st ed. Singapore: Springer, 2018, ch. 5, pp. 103–130.
[30] A. Malathi and N. Sreenath, "A comparative study of clustering protocols in VANET," *Int. J. Emerg. Trends Technol. Comput. Sci.*, vol. 6, no. 1, pp. 11–20, 2017.
[31] R. Kumar and M. Dave, "A comparative study of various routing protocols in VANET," *Int. J. Comput. Sci.*, vol. 8, no. 4, pp. 643–648, 2011.
[32] L. Le, R. Baldessari, P. Salvador, A. Festag, and W. Zhang, "Performance evaluation of beacon congestion control algorithms for VANETs," in *Proc. Global Telecommun. Conf. (GLOBECOM)*, 2011, pp. 1–6.
[33] S. Ucar, S. Ergen, and O. Ozkasap, "Multihop-cluster-based IEEE 802.11p and LTE hybrid architecture for VANET safety message dissemination," *IEEE Trans. Veh. Technol.*, vol. 65, no. 4, pp. 2621–2636, Apr. 2016.
[34] V. G. Menon, "Moving from vehicular cloud computing to vehicular Fog computing: Issues and challenges," *Int. J. Comput. Sci. Eng.*, vol. 9, no. 5, pp. 1–5, 2017.
[35] A.-H. Syed *et al.*, "An efficient channel access scheme for vehicular ad hoc networks," *Mobile Inf. Syst.*, vol. 2017, Jun. 2017, Art. no. 8246050.
[36] R. K. Kamini, "VANET parameters and applications: A review," *Global J. Comput. Sci. Technol. GJCST*, vol. 10, no. 7, pp. 1–6, 2010.
[37] N. Taherkhani and S. Pierre, "Centralized and localized data congestion control strategy for vehicular ad hoc networks using a machine learning clustering algorithm," *IEEE Trans. Intell. Transp. Syst.*, vol. 17, no. 11, pp. 3275–3285, Aug. 2016.
[38] H. Liu, H. Ning, Y. Zhang, and M. Guizani, "Battery status-aware authentication scheme for V2G networks in smart grid," *IEEE Trans. Smart Grid*, vol. 4, no. 1, pp. 99–110, Mar. 2013.
[39] C. Dsouza, G.-J. Ahn, and M. Taguinod, "Policy-driven security management for Fog computing: Preliminary framework and a case study," in *Proc. Int. Conf. Inf. Reuse Integr. (IRI)*, Redwood City, CA, USA, Mar. 2014, pp. 16–23.
[40] A. Paranjothi, M. S. Khan, M. Nijim, and R. Challoo, "MAvanet: Message authentication in VANET using social networks," in *Proc. IEEE 7th Annu. Ubiquitous Comput., Electron. Mobile Commun. Conf. (UEMCON)*, New York, NY, USA, Oct. 2016, pp. 1–8.
[41] X. Yao, X. Zhang, H. Ning, and P. Li, "Using trust model to ensure reliable data acquisition in VANETs," *Ad Hoc Netw.*, vol. 55, pp. 107–118, Feb. 2017.
[42] X. Ma, G. Kanelopoulos, and K. S. Trivedi, "Application-level scheme to enhance VANET event-driven multi-hop safety-related services," in *Proc. Workshop Comput., Netw. Commun. (CNC)*, Durham, U.K., Jan. 2017, pp. 860–864.
[43] S. Djahel and Y. Ghamri-Doudane, "A robust congestion control scheme for fast and reliable dissemination of safety messages in VANETs," in *Proc. IEEE Wireless Commun. Netw. Conf., Mobile Wireless Netw.*, Apr. 2012, pp. 2264–2269.
[44] R. Patni and G. Jain, "Traffic congestion detection and management using VANET," *Int. J. Adv. Res. Innov. Ideas Edu.*, vol. 2, no. 3, pp. 1274–1280, 2016.
[45] H. Kang, H. Yoo, D. Kim, and Y.-S. Chung, "CANCORE: Context-aware network coded repetition for VANETs," *IEEE Access*, vol. 5, pp. 3504–3512, 2017.
[46] S. Schwarz and M. Rupp, "Society in motion: Challenges for LTE and beyond mobile communications," *IEEE Commun. Mag.*, vol. 54, no. 5, pp. 76–83, May 2016.
[47] O. Tahan, R. Rima, S. Bakri, Z. Merhi, and S. El Deek, "GoSafe: A power-efficient android application for road events signaling and notification," in *Proc. IEEE Electrotech. Conf. (MELECON)*, Lemesos, Cyprus, Apr. 2016, pp. 1–5.
[48] A. Fanca, A. Puşcaşiu, and H. Vălean, "Accident reporting and guidance system: With automatic detection of the accident," in *Proc. Control Comput. (ICSTCC)*, Sinaia, Romania, Oct. 2016, pp. 150–155.
[49] X. Yang, L. Liu, N. H. Vaidya, and F. Zhao, "A vehicle-to-vehicle communication protocol for cooperative collision warning," in *Proc. IEEE 1st Annu. Int. Conf. Mobile Ubiquitous Syst.*, Boston, MA, USA, Aug. 2004, pp. 114–123.
[50] S. Grover and P. Mittal, "A novel model based on group controlled observation for DDOS attack detection and prevention in VANET," *Indian J. Sci. Technol.*, vol. 9, no. 36, pp. 1–6, 2016.
[51] C. Thompson, J. White, B. Dougherty, A. Albright, and D. C. Schmidt, "Using smartphones to detect car accidents and provide situational awareness to emergency responders," in *Mobile Wireless Middleware, Operating Systems, and Applications (MOBILWARE)*. Berlin, Germany: Springer, 2010.
[52] R. Hussain, Z. Rezaeifar, and H. Oh, "A paradigm shift from vehicular ad hoc networks to VANET-based clouds," *Wireless Pers. Commun.*, vol. 83, no. 2, pp. 1131–1158, 2015.
[53] K. Kai, W. Cong, and T. Tao, "Fog computing for vehicular ad-hoc networks: paradigms, scenarios, and issues," *J. China Univ. Posts Telecommun.*, vol. 23, no. 2, pp. 56–65 and 96, 2016.
[54] D. Sharma, "A detail review on cloud, Fog and dew computing," *Int. J. Sci., Eng. Technol. Res.*, vol. 5, no. 5, pp. 1–9, 2016.
[55] M. Li, K. Zeng, and W. Lou, "Opportunistic broadcast of event-driven warning messages in Vehicular Ad Hoc Networks with lossy links," *Comput. Netw.*, vol. 55, no. 10, pp. 2443–2464, 2011.
[56] H. Madsen, B. Bernard, G. Albeanu, and F. Popentiu-Vladicescu, "Reliability in the utility computing era: Towards reliable Fog computing," in *Proc. Int. Conf. Syst., Signals Image Process. (IWSSIP)*, Bucharest, Romania, Jul. 2013, pp. 43–46.
[57] P. Hu, S. Dhelim, H. Ning, and T. Qiu, "Survey on Fog computing: Architecture, key technologies, applications and open issues," *J. Netw. Comput. Appl.*, vol. 98, pp. 27–42, Nov. 2017.

[58] X. Hou, Y. Li, M. Chen, D. Wu, D. Jin, and S. Chen, "Vehicular Fog computing: A viewpoint of vehicles as the infrastructures," *IEEE Trans. Veh. Technol.*, vol. 65, no. 6, pp. 3860–3873, Jun. 2016.
[59] X. Kong *et al.*, "Mobility dataset generation for vehicular social networks based on floating car data," *IEEE Trans. Veh. Technol.*, vol. 67, no. 5, pp. 3874–3886, May 2018.
[60] O. Chakroun and S. Cherkaoui, "Enhancing safety messages dissemination over 802.11p/DSRC," in *Proc. 7th IEEE LCN Workshop User Mobility Veh. Netw.*, Oct. 2013, pp. 179–187.
[61] I. Stojmenovic and S. Wen, "The Fog computing paradigm: Scenarios and security issues," in *Proc. Fed. Conf. Comput. Sci. Inf. Syst.*, vol. 2, Sep. 2014, pp. 1–8.
[62] V. Stantchev, A. Barnawi, S. Ghulam, J. Schubert, and G. Tamm, "Smart items, Fog and cloud computing as enablers of servitization in healthcare," *Sensors Transducers*, vol. 185, no. 2, pp. 121–128, 2015.
[63] S. Li and C. Huang, "A multihop broadcast mechanism for emergency messages dissemination in VANETs," in *Proc. IEEE 42nd Annu. Comput. Softw. Appl. Conf. (COMPSAC)*, Tokyo, Japan, Jul. 2018, pp. 932–937.
[64] B, N. Truong, G. M. Lee, and Y. Ghamri-Doudane, "Software defined networking-based vehicular adhoc network with Fog computing," in *Proc. IFIP/IEEE Int. Symp.*, May 2015, vol. 7, no. 6, pp. 1202–1207.
[65] B. M. Mughal, A. A. Wagan, and H. Hasbullah, "Efficient congestion control in VANET for safety messaging," in *Proc. Symp. Inf. Technol. (ITSim)*, vol. 2, Jun. 2010, pp. 654–659.
[66] M. Chuang and M. C. Chen, "DEEP: Density-aware emergency message extension protocol for VANETs," *IEEE Trans. Wireless Commun.*, vol. 12, no. 10, pp. 4983–4993, Oct. 2013.
[67] X. Shen, X. Cheng, L. Yang, R. Zhang, and B. Jiao, "Data dissemination in VANETs: A scheduling approach," *IEEE Trans. Intell. Transp. Syst.*, vol. 15, no. 5, pp. 2213–2223, Oct. 2014.
[68] C. Suthaputchakun, M. Dianati, and Z. Sun, "Trinary partitioned black-burst-based broadcast protocol for time-critical emergency message dissemination in VANETs," *IEEE Trans. Veh. Technol.*, vol. 63, no. 6, pp. 2926–2940, Jul. 2014.
[69] R. Kumar and M. Dave, "A framework for handling local broadcast storm using probabilistic data aggregation in VANET," *Wireless Pers. Commun.*, vol. 72, no. 1, pp. 315–341, Sep. 2013.
[70] Y. Bi, "Neighboring vehicle-assisted fast handoff for vehicular Fog communications," *Peer-Peer Netw. Appl.*, vol. 11, no. 4, pp. 738–748, Jul. 2018.
[71] L. M. Vaquero and L. Rodero-Merino, "Finding your way in the Fog: Towards a comprehensive definition of Fog computing," *ACM SIGCOMM Comput. Commun. Rev.*, vol. 44, no. 5, pp. 27–32, 2014.
[72] H. Zhao, S. Chen, D. Li, and H. Zhu, "The establishment of the network connectivity model in VANET," in *Proc. 8th IEEE Int. Conf. Wireless Commun. Signal Process. (WCSP)*, Yangzhou, China, Oct. 2016, pp. 1–6.
[73] E. A. Feukeu and T. Zuva, "Mitigation of a broadcast storm problem in a vehicular ad hoc network (VANETs)," in *Proc. IEEE Int. Symp. Parallel Distrib. Process. Appl., IEEE Int. Conf. Ubiquitous Comput. Commun. (ISPA/IUCC)*, Guangzhou, China, Dec. 2017, pp. 1289–1295.

ATA ULLAH received the B.S. and M.S. degrees in computer science from COMSATS Islamabad Pakistan, in 2005 and 2007, respectively, and the Ph.D. degree in computer science (in the area of wireless network security) from IIUI, Pakistan, in 2016. From 2007 to 2008, he was a Software Engineer with Streaming Networks Islamabad. He joined NUML Islamabad Pakistan, in 2008, and was an Assistant Professor of the Head Project Committee, Department of Computer Science, until 2017. Currently, he is on leave from NUML and has been working as a Research Fellow with the School of Computer and Communication Engineering, University of Science and Technology Beijing, China, since 2017. He has supervised 110 projects at under graduate level and has won One International and 45 National Level Software Competitions. He was awarded ICT funding for the development of projects. He has published several papers in ISI indexed impact factor journals and international conferences. He is also a reviewer and guest editor for conference and journal publications. He remained a faculty partner for industrial collaboration in software development. He has programming expertise in C, C#, Java, PHP, and NS2. His areas of interests are WSN, the IoT, cyber physical social thinking space, health-services, NGN, VoIP, and their security solutions.

SHUMAYLA YAQOOB received the B.Sc. degree in computer science from the Virtual University of Pakistan, in 2011, the M.C.S. degree from the National University of Modern Languages (NUML), Islamabad, Pakistan, in 2014, and the M.S.C.S. degree from the Department of Computer Science, NUML. She was a participant of 3MT presentation and has won two National Level Software Competitions. She served in the Army Public School and College System as a Lecturer, from 2015 to 2017. She was a Junior Web Developer with Sharp-itech, Rawalpindi. She is currently a Visiting Lecturer with NUML. Her research interests include vehicular ad-hoc networks, data dissemination, artificial intelligence-based games, and media files conversion.

MUHAMMAD IMRAN has been an Assistant Professor with the College of Computer and Information Sciences, King Saud University, since 2011. He was a Post-Doctoral Associate on joint research projects between KSU, The University of Sydney, and Iowa State University, USA. He is a Visiting Scientist with Iowa State University. He has published more than 80 papers in refereed international conferences and journals. His research interests include mobile ad hoc and sensor networks, WBANs, M2M, the IoT, and fault tolerant computing. His research is financially supported by several grants. He has received a number of awards such as the Asia Pacific Advanced Network Fellowship. He has been involved in a number of conferences and workshops in various capacities such as a chair, co-chair, and technical program committee member. These include IEEE ICC, Globecom, AINA, LCN, IWCMC, IFIP WWIC, and BWCCA. Recently, European Alliance for Innovation (EAI) has appointed him as a Co-Editor-in-Chief for *EAI Transactions on Pervasive Health and Technology*. He also serves as an Associate Editor for *Wireless Communication and Mobile Computing Journal* (Wiley), *IET Wireless Sensor Systems*, and *International Journal of Autonomous and Adaptive Communication Systems* (Inderscience). He served/is serving as a Guest Editor for the *IEEE Communications Magazine*, *Computer Networks* (Elsevier), the *International Journal of Autonomous and Adaptive Communications Systems*, and the *International Journal of Distributed Sensor Networks*.

HUANSHENG NING received the B.S. degree from Anhui University, in 1996 and the Ph.D. degree from Beihang University, in 2001. From 2002 to 2003, he worked in Aisino Co. From 2004 to 2013, he was an Associate Professor with the School of Electronic and Information Engineering, Beihang University. Since 2013, he has been a Professor and the Vice Dean with the School of Computer and Communication Engineering, University of Science and Technology Beijing. He has published more than 70 journal/conference papers. His research interests include cybermatics, the Internet of Things, and cyber-physical social systems. He is an IEEE Senior Member, the Founder and Chair of Cybermatics and Cyberspace International Science and Technology Cooperation Base, the Co-Founder and Co-Chair of the IEEE Systems, Man, and Cybernetics Society, Technical Committee on Cybermatics, and the Co-Founder and Vice Chair of the IEEE Computational Intelligence Society, Emergent Technologies Technical Committee Task Force on Smart Word. He has presided over many research projects including the Natural Science Foundation of China, National High Technology Research and Development Program of China. He has served as an associate editor of many well reputed journals.