Real-Time VANET Applications Using Fog Computing

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Abstract The main objective of vehicular ad hoc networks (VANETs) is to improve driver safety and traffic efficiency. Most of VANET applications are based on periodic exchange of safety messages between nearby vehicles and between vehicles and nearby road side communication units (e.g., traffic lights, roadside lights etc.). This periodic communication generates huge amount of data that have typical storage, computation, and communication resources needs. In recent years, there have been huge developments in automotive industry, computing, and communication technologies. This has led Vehicular Cloud Computing (VCC) as a solution to satisfy the requirements of VANETs such as computing, storage, and networking resources. Fog computing is a standard that comprehends cloud computing and related services to the proximity of a network. Since VANET applications have special mobility, low latency, and location awareness requirement. Fog computing plays a significant role in VANET applications and services. In this paper, we present real-time applications of VANET that can be implemented using fog computing.

Keywords Fog computing · VANET · Cloud computing

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1 Introduction

Due to large-scale improvement in computation and wireless communication technologies, vehicles are being equipped with communication devices in order to communicate with other vehicles and take appropriate actions based upon received messages. Such communication creates new opportunities for enhancing road safety. VANET has emerged as a solution to many road safety problems by providing safety information to drivers on time [1]. VANET is a special class of mobile ad hoc network (MANET) [2, 3]. Main characteristics of VANET that distinguish it from MANET are high mobility of nodes, scalability, and frequent topology changes. VANETs use short range radios [4] in each vehicle, which allows various vehicles to communicate with other vehicles and roadside infrastructure. Safety and traffic management applications require real-time information and can play significant role in life and death decisions.

In VANET, vehicle to vehicle (V2V) and vehicle to roadside (V2R) communication is used to propagate safety information to nearby vehicles on time. Apart from the communication unit, each vehicle is also equipped with high computation and storage unit. But most of the time, these units are underutilized. Vehicular cloud computing (VCC) is the paradigm [5] emerged to utilize VANET resources efficiently by taking advantages of cloud computing. It serves the drivers of VANET with a pay as you go model. In VCC, group of vehicles cooperates with each other to dynamically share computing, sensing, and communication resources for decision-making on the road in order to improve traffic management and road safety. Some examples of VCC applications are:

1. Local traffic condition can be collected from nearby vehicles for route planning.
2. Current transportation system can be improved by big data processing of traffic information by local traffic authorities.
3. Collaborative image of critical events can be reconstructed such as car accident, congestion on the road, etc.

VCC is a very promising solution to share the computation and storage resources among the vehicles and roadside units in order to implement these applications. But VCC is not sufficient for many VANET applications due to mobility of vehicles and the latency sensitive requirements imposed by these. It is difficult to meet the Quality of Service (QoS) requirements using VCC. So, a new approach is designed that comprehends cloud computing with VANET applications named as fog computing. Fog computing leverage computation infrastructure that is closer to the network edge to compliment cloud computing in providing latency sensitive applications and services. Fog computing is similar to cloud computing but the only difference is that time sensitive applications can be implemented at the network edge rather than sending huge amount of data to remote cloud. The idea of fog computing [6, 7] is to place cloud-like facility at the proximity of application users. It provides storage, computation, and application services to the edge of network (nodes within proximity), thereby reduces burden on the cloud and facilitates real-time VANET applications implementation. In VANET, any node having communication, computation, and storage resources can become fog nodes. Fog computing is very useful to implement VANET applications as these are time sensitive and real time which is the prime agenda of Intelligent Transportation system (ITS) [4].

This paper discusses various applications of VANET which can be implemented using fog computing. The rest of the paper is organized as follows. Section 2 provides overview of cloud computing and its emergence with VANET. It also discusses the concept of VCC. Fog computing and its related work in relation with VANET is discussed in Sect. 3. Some of the VANET real-time applications which can be implemented using fog computing are discussed in Sect. 4. Finally, concluding remarks with future work are covered in Sect. 5.

2 Vehicular Cloud Computing

Cloud computing is an Internet-based computing technique that provides shared computer processing resources and data to computers and other devices on demand. It enables the users with various capabilities to store and process their data in privately owned or third party data centers that may be located far from user (in different city or country). Cloud computing provides high computation power, cheap cost of service, high performance, scalability, accessibility, availability, etc.

Inspired by the success of cloud computing integrated with mobile communications, authors [5, 8, 9] have introduced the concept of vehicular cloud computing (VCC). Figure 1 describes vehicular cloud environment in VANET.

Huge advancements in automotive industry, computation, and communication technologies have led the dream of smart cars true. Ford has announced the manufacturing of four million vehicles with SYNC systems (having integrated in-vehicle communication system, GPS and Radar, etc.). Recently, Google has also tested a self-driving car which is equipped with computation and communication device, radar sensors, GPS and video camera, etc.

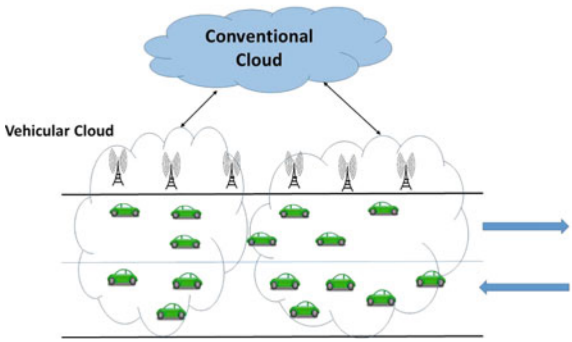

Fig. 1 Vehicular Cloud environment for Vehicular Ad Hoc Network

Nowadays, vehicles are just more than transportation machines because these have high computation and storage capability. People can get different types of services (such as navigation, weather, and entertainment, etc.) when they are driving. Most of the time (especially when vehicles are parked in offices, shopping malls etc.), computing and storage resources of these vehicles are untapped. These vehicles could be the potential resources for vehicular cloud (VC). The main issue in implementing VC is due to the dynamic behavior of vehicles. VC services can be switched to traditional cloud placed nearby in the case of vehicles move in/out a specific area.

3 Fog Computing

Fog computing is defined as a platform where large number of heterogeneous, ubiquitous, and distributed devices communicate and cooperate by forming a network in order to perform storage and processing functions without the intervention of third parties. These functions can be providing support to new applications that can run in sandboxed environment. Most of VANET applications are area specific and needs to be handled locally such as navigation, infotainment and safety information, etc. In these cases, fog computing just fits in because it allows the contents and application services as close as possible to drivers on the road in particular road segment. Fog computing addresses the limitation of location awareness of cloud computing. For example, a person visiting a new city would like to seek information on the places of interest, news, and weather conditions of this city rather than interested in other city information. Fog computing is well suited for these types of applications. However, Firdhous et al. [12] mentioned that fog computing paradigm needs extensive research before its practical deployment.

Cloud computing is the central portal of information and does not have location awareness. Fog computing overcomes this issue by providing localized services to specific deployment sites. Bonomi et al. [13] have presented the basic architecture of storage, computing, and networking for cloud and fog computing. Fog computing is a most suitable approach that can control critical resources like energy, traffic, health care, etc. Vaquero et al. [15] presented a border and integrative view of fog computing. Concept of smart building and software-defined networking (SDN) is also presented using fog computing in [6]. Different authors presented their different perception of fog computing, Yi et al. [14] strongly differentiated the fog computing from related technologies. Sarkar et al. [17] have shown that for a scenario where 25% of applications demand real-time low latency services, means energy expenditure in fog computing is 40% less than conventional cloud computing model. This analysis motivates the research and academia to explore fog computing more extensively.

As can be seen from Fig. 2, fog computing is overlaid onto cloud computing in VANET scenario. It creates a distributed computing platform for VANET components to tackle with data processing and storage services. The role of fog computing

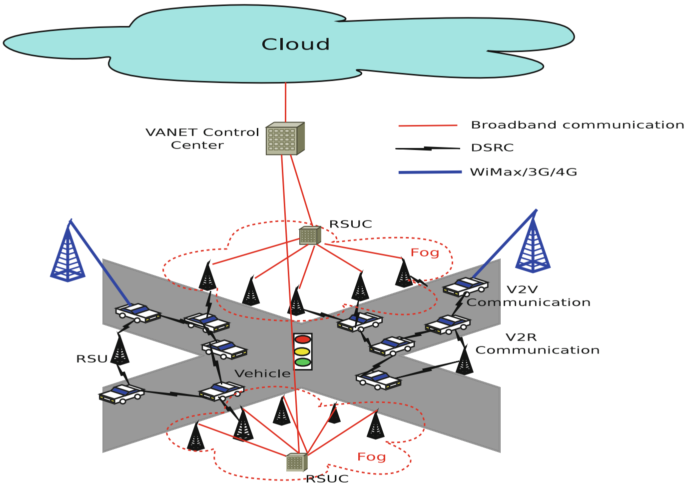

Fig. 2 Architecture of Fog Computing for VANET

is like near-end computing proxies between the front-end devices and the far-end servers. There are three types of connections made by fog server in VANETs:

- **RSU to Fog Server**: In VANET, V2V and V2R communication is used to propagate safety/non-safety information. RSUs are also able to communicate with each other. Hence RSUs act as a backbone of fog. There is wired/wireless connection between RSU and fog server. In Fig. 2, **RSUC** is the fog server.
- **Fog Server to Fog Server**: Fog servers at different locations manage a pool of resources for localized area. There can be direct wired/wireless communication between peer fog servers, or these can be connected via vehicular control center. It allows the collaborative service provision and content delivery among peered fog servers, thereby improving the performance of entire system.
- **Fog Server to Cloud**: The cloud is the central controller of fog servers deployed at different locations. Each fog server provides services to users at specific locations. Cloud aggregates the information received from fog servers and performs centralized computation and fog servers convey the information received from cloud to application users.

Luan et al. [10] summarized the differences between fog and cloud computing. Some of the main features of fog computing compared to cloud computing are:

1. It simplifies the development model for huge number of decentralized heterogeneous devices.
2. Fog computing enhances service quality with increased data rate and reduced service latency and response time.
3. It avoids the back-and-forth traffic between cloud and users. This saves the network bandwidth and reduces the energy consumption.

4. Fog users can use the resources of fog or of cloud reactively based on their demands.

4 Fog Computing for VANET Applications

Applications of fog computing in vehicular scenario are not as much as for VCC. Giang et al. [16] argued that traditional cloud computing is not sufficient for many VANET applications due to mobility of vehicles and their real-time applications. Fog computing leverage computation infrastructure that is closer to the network edge, thereby supports applications with low latency requirements. Some of the applications are listed below:

4.1 Smart Traffic Lights

A Dynamic Traffic Light System (DTLS) is an important application of VANET that optimizes traffic at traffic light junctions efficiently by using the concept of fog computing. As this application is distributed (location proximity specific and time sensitive), centralized solution such as VCC cannot be used. Different fogs can be used at traffic light junctions to compute the duration of each signal based on the traffic around the junction. The current system of traffic lights allots a dedicated time towards each direction, thereby making the whole system static. The limitation of this system is that traffic from one side has to wait for the green light even if there is no vehicle crossing the road in the current direction of green light. A dynamic

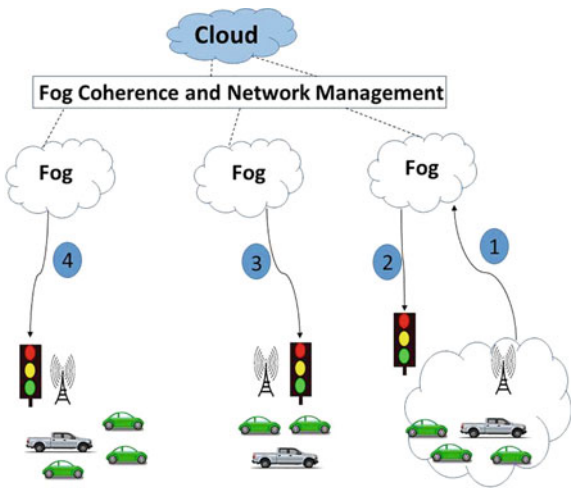

Fig. 3 Smart Traffic Light System using Fog Computing

DTLS allots the time of each signal based on the traffic present around the junction. A sample smart traffic light system is shown in Fig. 3.

Traffic lights can serve as fog devices to send warning messages to approaching vehicles in particular direction. The interaction between vehicle and RSUs is based on Dedicated Short Range Communication (DSRC). RSUs can communicate with each other to form a fog and send the aggregated perceived safety information to traffic signal. Traffic lights can be switched from one mode to another as number or type of vehicles approach towards them.

DTLS is one of the main applications of fog computing. Communication range of each RSU is generally 500–1000 m and it is a usual norm that each vehicle sends beacon packets periodically (Please refer [18]). Hence, RSUs are able to estimate the traffic on particular road segment. Based upon the computed information, RSUs can propagate the information to fog servers and thereby duration of traffic light can be decided accordingly. Now, we discuss different scenarios of DTLS.

1. If there is heavy traffic on one side of road segment and other side of the road is free, traffic signal can be turned green for the heavy traffic side and red for the free road. This can be implemented using fog servers collecting information from RSUs and timely making decision by performing computations.
2. In a scenario, where emergency vehicle such as an ambulance is approaching towards road junction. Nearby RSUs can identify ambulance by information sent by it. Video cameras deployed in RSUs are also able to recognize flashing lights. RSU observing the event spread this information in the fog. Neighboring smart lights serving as fog can coordinate and create green light signal in addition to sending warning signals to approaching vehicles.
3. Roadside lights can also detect the presence of vehicles and measures the speed and distance of nearby vehicles. Sensors deployed on fog servers can facilitate turning on these lights on identification of vehicles and vice versa. Smart lights along the road side serve as fog devices can collaboratively make efficient use of resources.

4.2 Parking System

Finding an empty parking space in rush hour is really a big problem in urban areas. Kim et al. [11] have presented their work on solving parking problems to relieve the traffic congestion, reduce air pollution, and enhance driving experience. They have shown how fog computing and roadside clouds can be used to find a vacant spot. They assume that unused public and private parking slot (e.g., in hotels, parks, universities etc.) can be shared for the vehicles. Matching theory is used to solve the parking problem by bringing profit to the owners of these places.

4.3 Content Distribution

Fog computing can be used for distribution of any type of information (safety or non-safety). For example, if a particular section of a road is blocked due to some accident or natural hazard. This information can be conveyed by the fog servers to vehicles approaching towards this site.

4.4 Decision Support System

Safety of drivers can be improved by using intelligent decision support system (DSS) using fog computing. Different fog servers can exchange their localized conceived information with each other and form DSS in order to monitor traffic violation and safety system for drivers.

VCC has vast number of applications as compared to fog computing. But fog computing fulfills the service requests on localized information, thereby reducing the service latency and response time.

5 Conclusion

In this paper, we have discussed how fog computing can be used in implementing real-time VANET applications. We have also presented the architecture of VCC and fog computing in VANET environment. Fog computing has the potential to handle the data generated by VANET components and take appropriate actions in order to implement desired VANET applications. The features of fog computing like mobility, proximity to end users, low latency, heterogeneity, location awareness make it best suited for implementation of some applications of VANET. We also have discussed different real-time applications of VANET that can be implemented using fog computing. In our future work, we would like to design the layout and implementation of these applications using fog computing in VANET.

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