Key Technologies of MEC Towards 5G-Enabled Vehicular Networks

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Abstract. Mobile edge computing (MEC) can satisfy the communication requirements of ultra-high reliability and ultra-low latency in 5G-enabled vehicular networks, since it provides Internet service environment and cloud computing capability for wireless access network. In this paper, the architecture and characteristics of MEC for unmanned driving are explored. Meanwhile, the key technologies of MEC are discussed. With the assist of clustering, we propose the scheme of mobile vehicle cloud (MVC)-aided communication, and examine the network performance including computing resource allocation by MEC and link performance. The numerical results show that the network performance is improved effectively.

Keywords: 5G vehicular networks · MEC · MVC-aided communication Clustering · Network performance

1 Introduction

With the advanced technologies, unmanned driving has been widely concerned by mainstream carmakers and internet firms, such as Mercedes Benz, Ford, TOYOTA, Volvo, and Google. Unmanned driving requires more thorough awareness, more comprehensive ability of interconnection and deeper wisdom in vehicular networks so as to build a new mobile wisdom space. Up to data, vehicular networks are mainly facing the challenge of integration of computing, communication, network and application, which has greatly restricted the development of complete automation of intelligent transportation system (ITS). At present, it is generally believed that mobile edge computing (MEC) technology is expected to break through the bottleneck of communication in unmanned systems, and catalyze the deployment of unmanned vehicles. For instance, in 2017, a vehicular network prototype was demonstrated built on top of the virtualized MEC platform at Mobile World Congress.

L. Wang et al. (Eds.): QShine 2017, LNICST 234, pp. 153–159, 2018.
https://doi.org/10.1007/978-3-319-78078-8_16

The network architecture of 5G vehicular networks is about to transform from connection-centeric to content-centeric, with the aid of emerging MEC technology. As shown in Fig. 1, the traditional cloud architecture is divided into three parts: mobile vehicle cloud (MVC), mobile edge cloud (MEC) and remote central cloud (RCC). MVC is formed to improve routing utility in ad hoc networks through the communication between vehicles with on-board units. The edge cloud nodes include base stations and roadside units, which can communicate through backhaul with each other, in MEC. As a variant of RCC, MEC integrates infrastructure with Internet business. The content-centeric architecture relaxes the traffic pressure in wireless networks, which facilitates system to evolve towards Software Defined Network (SDN), Network Function Virtualization (NFV) and network open capability [1].

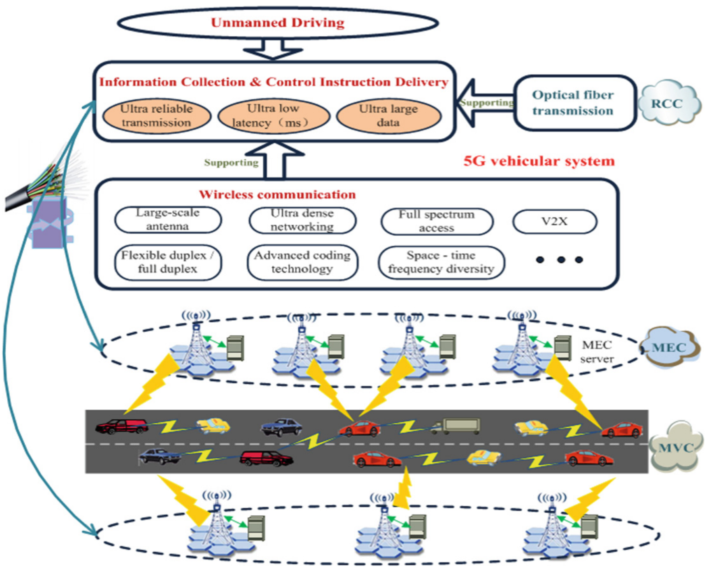

Fig. 1. MEC-based 5G vehicular network system architecture

In this paper, we first look into the architecture in MEC-based 5G vehicular networks. MEC is beneficial to realize the flattening of vehicular network architecture. Thereafter, we attempt to find the characteristics of MEC in the context of vehicular networks, and then the related key technologies are analyzed. On basis of the above research, we propose a MVC-aided communication scheme, where the communication capability of MVC is fully exploited according to the clustering of vehicles. With the scheme, the communication performance is improved significantly.

The remainder of this paper is organized as follows. Section 2 introduces the architecture, characteristics and technologies key of MEC in 5G-enabled vehicular networks. The scheme of MVC-aided communication is presented and verified in Sect. 3. Finally, we conclude the paper in Sect. 4.

2 MEC in Vehicular Networks

With the development of a variety of communication modes, such as vehicle-to-vehicle (V2V), vehicle-to-roadside unit (V2R), vehicle-to-pedestrian (V2P), and so on, big data analysis and sharing are getting more and more important. MEC technology is expected to realize the big data analysis and sharing among vehicles, infrastructures and pedestrians.

2.1 Architecture of Distributed MEC

MEC is mainly located near the management layer in the terminal-management-cloud framework [2], and sinks to the wireless access network. As shown in Fig. 2, the information transmission process includes four parts: wireless access network layer, data sensing and forwarding layer, MEC layer and cloud computing layer.

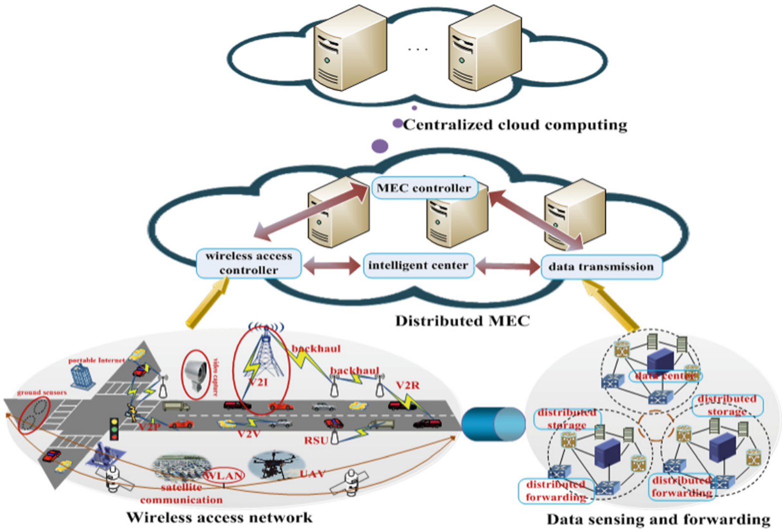

Fig. 2. Distributed information transmission scheme of MEC

In MEC layer, the decision-making center, MEC controller is mainly responsible for network source scheduling and computing task offload. The wireless network access and data transmission are completed by wireless access controller, which can realize the seamless connection of various heterogeneous resources and the cross layer cooperation between communication resources and computing resources. The data filtering and preliminary analysis are completed by the intelligent center, while the control and storage of data delivery are completed in the data transmission controller. The safety of unmanned vehicles depends on the period of the information update, i.e., with the faster information update, the driving will be safer. The deployment of MEC can accelerate the data update cycle in the network and alleviate the congestion of packets.

In vehicular networks, MEC servers are often deployed near RSUs, so that the deployment and performance of MEC will be limited by RSUs. Due to the unique nature of MEC towards vehicular networks, the characteristics of MEC deserve to be noticed. The first is the finiteness. Since the data in the MEC server is derived from RSUs, the service scope of the MEC server is limited. Meanwhile, the computing ability of MEC will also be reduced to a certain degree. Another important property is heterogeneity. Because of the different network environments and communication technologies, MEC should support a variety of hardware and software devices to satisfy the demand of safety. In addition, the transmission management and server selection of MEC must adapt to the mobility of the vehicle, in order to achieve low latency and security in high-speed mobile environments.

2.2 Key Technologies of MEC

MEC provides three functions: data storage, computing and wireless access. Based on this, there are three main key features in 5G-enabled vehicular networks: network functional virtualization, the collaboration among MVC, MEC and RCC, and multi-layer heterogeneous network. Therefore, the key technologies of MEC are divided into the following three aspects.

(a) MEC networking
There are three schemes of MEC networking: independent deployment as an element, integration in RSU, MEC combination with SDN/NFV. When MEC is independently deployed, there are some difficulties in deployment, maintenance and update. The scheme of integration shortens the physical communication distance, whereas the complexity of proprietary hardware integration and operation limits the development of MEC. Based on the virtual platform, MEC is combined with SDN/NFV, which contributes to network programmability and flexibility, and reduces the running time of business maturity. In the virtual platform, NFV focuses on network function and SDN focuses on the separation of control plane and user plane. However, there are still some difficulties to be overcame in the integration of multiple technologies.

(b) Collaborative management of resources
In order to realize the cooperation among vehicles, roads and people, resource managements have to combine MVC, MEC and RCC. However, vehicle mobility requires major changes to collaborative management of resource to ensure real time. Therefore, the rapid and reasonable scheduling is the key of resource collaboration.

(c) Heterogeneous network
With the increasing of applications in ITS, mobile heterogeneous computing and seamless connection are the significant challenges for MEC in heterogeneous network. In heterogeneous networks, we can take RCC as the root node, MEC as the intermediate node, and MVC as the leaf node. Generally speaking, at the network layer the separation of user plane and control plane can satisfy the requirement of fast data transmission in mobile scene. Due to the high-speed mobility of vehicles, the link layer protocol is changed to adapt the constant change of topology at the link layer.

3 MVC-Aided Communication

As a technology to achieve the integration of computing and communication, MEC plays a pivotal role in the wireless access network. Up to now, the researches about MEC especially focus on the offloading with the optimization of minimum energy consumption or maximum service efficiency within the maximum tolerable delay range [3–5]. However, these studies didn't consider the ability of MVC. It is well known that platoon model based on the clustering of vehicles can achieve ultra-low latency in vehicular networks [6]. Consequently, we especially examine the action of MVC on study of MVC-aided communication. Due to the clustering of vehicles, the vehicles that can communicate directly with each other by one hop are divided into one platoon, which is a MVC.

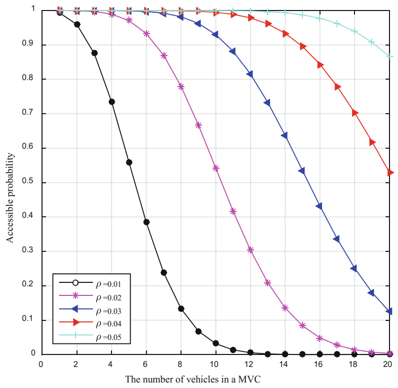

Fig. 3. The number of vehicles in a MVC

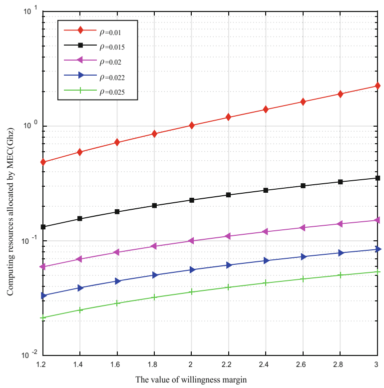

Fig. 4. Resource allocation of MEC

The process of MEC-aided communication is divided into the following phases:

(1) The target vehicle node which attempts to run an application becomes the leader of MVC and recruits members. The target vehicle establishes a MVC member list with members' IDs, position information and corresponding task assignment information.

(2) The adjacent vehicle willing to share resource sends hello packets including the geo-information and computing capability to the leader. Then adjacent vehicle is labeled as member of MVC and recorded in the leader's list. In MVC, every member can communicate with each other, which guarantees the link performance of MVC ad hoc network.

(3) According to the communication ability and the computing resource block quantity of every node, the application is split into several task blocks, and the target vehicle offloads the task blocks to MVC members.

(4) Due to the mobility, the MVC list is updated in real time and maintains the corresponding entries. When there is member joining or leaving the MVC, some task blocks need to be reallocated according step 3.

(5) Judging whether the resources of the MVC satisfy the needs of the running application. If yes, jump to step 7. Otherwise, jump to step 6.
(6) The leader of MVC offloads the rest of the task blocks to MEC, according to the projected consumption of time and energy.
(7) The output results of MVC members and MEC are transmitted to the target node.
(8) The target node processes the collected results to obtain the output content, and saves/publishes it.
(9) When target vehicle no longer uses the resource of MVC or is unable to connect with members, MVC is dismissed.

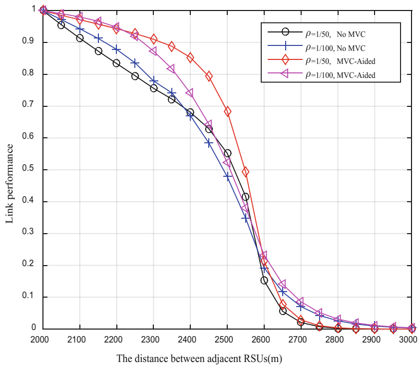

Fig. 5. Link performance based on MVC

Assuming the transmission radius of vehicles is 500 m and ρ represents the vehicle density measured in vehicles per meter. As shown in Fig. 3, the number of vehicles in a MVC under different densities is obtained according to [7]. Figure 3 reflects the relationship between the node number within the MVC and the network access probability under different vehicle densities. According to [8], the willingness margin value is introduced to study the significance of MVC for offloading in the paper. As shown in Fig. 4, the vehicle computing resources within the MVC can be fully utilized and the computational power of MVC is enhanced as the increasing of vehicle density. Thanks to MEC, it is not necessary to access Internet through the core network when the vehicle requests the network service, which greatly reduces the transmission delay. It means that there is a large channel competition in the network, with the vehicle density increasing. MVC can effectively manage the transmission in the network, and consequently, the channel contention between vehicle and RSU is reduced. In this article, the communication between two adjacent RSUs is considered as a network, where the transmission range of RSU is 1000 m. As shown in Fig. 5, the link performance based on MVC is improved because of the reduction of data collisions probability. MVC plays a significant role especially in computing tasks and network performance. In conclusion, with the increase of vehicles number, there are more available resources in a MVC. Therefore, the leasing of resources of MEC is reduced. And under the management of MVC, the link performance is improved.

4 Conclusion

MEC provides an effective integration solution of computing, storage and Internet. Up to now, with the development of technological advancement, the challenges of MEC in vehicular networks focus on mobility management and resource scheduling in heterogeneous networks. Based on the study of MEC, we look into the MEC-aid communication, considering the traffic load, computing and storage capacity, energy consumption and delay. In this paper, we prove that the resource leasing of MEC is reduced and the network communication is effectively managed, while the capability of MVC is fully taken advantage of. Under the research background of new generation communication technology, this paper provides the direction and ideas for the research of MEC in vehicular networks.

Acknowledgments. This work was supported in part by the National Natural Science Foundation of China (61471031, 61661021), the State Key Laboratory of Rail Traffic Control and Safety (Contract No. RCS2017K009), the Key Technology Research and Development Program of Jiangxi Province under Grant No. 20171BBE50057, the Open Research Fund of National Mobile Communications Research Laboratory, Southeast University (No. 2017D14), Science and technology project of Jiangxi Provincial Transport Bureau (No. 2016D0037), Training Plan for the Main Subject of Academic Leaders of Jiangxi Province (No. 20172BCB22016), and Natural Science Foundation of Guangdong Province under Grant No. 2015A030313844.

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