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Survey on Resource Allocation in V2X Cellular Communication System

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Abstract

We are in an era of rapid development of communication technology. With the gradual landing of 5G mobile communication technology, 6G mobile communication technology has begun to develop. 6G will integrate a series of disruptive technologies, including larger-scale information exchange, high-precision Environmental awareness, adaptive allocation and self-regulation of network resources, edge computing based on deep learning, etc. Under this network, autonomous driving technology will also usher in a new leap to achieve smarter and more efficient transportation. This paper investigates the existing work and challenges of LTE to support efficient V2X communication. First, we show the motivation of cell based V2X communication. Secondly, the LTE V2X architecture and operation scenarios under consideration are summarized. Thirdly, the challenges of existing LTE supporting V2X communication are discussed, and recent solutions to these challenges are investigated. We further discussed the challenges and possible solutions of on-board communication. Finally, the open research issues and directions of cellular based vehicle communication are discussed.

Keywords

V2X, Edge Computing, Resource allocation, Machine Learning, NOMA-V2X.

1. Introduction

The guidance for the construction of National Standard System for Internet of Vehicles pointed out that "by establishing a perfect intelligent automobile standard system, we will guide and promote the development of intelligent automobile technology and product application, and build a safe, efficient, healthy and intelligent future automobile society.". "Made in China 2025" also points out that "the realization of the intelligent scenario of the future automobile industry is the ultimate practice of the eternal pursuit of the manufacturing industry", which shows that the intelligent automobile is an important development direction of the future transformation, innovation and upgrading.

Although the current development potential of the Internet of vehicles is huge, its current theoretical level is still in a relatively unmatched state with production and application.On the one hand, the transmission rate of the traditional network is difficult to support the data transmission of the above-mentioned large-scale tasks. On the other hand, the mobility of vehicles poses a great challenge to the realization of low-latency iot communication scenarios The existing Macro Base Stations (MABS) are an integral part of iot scenarios and are used for data transmission infrastructure. However, the physical distance between MABS and the cloud is relatively long, which makes it difficult to timely feedback the result of task request in the iot scenario. To address these challenges, a high-performance computing paradigm, namely edge computing, is adopted in the iot scenario to enable vehicles to experience high-quality services in real time[1]–[4].

With the rapid development of social economy and automobile industry, the number of automobiles in China has increased rapidly, which has led to more and more serious traffic problems, such as road traffic safety, traffic congestion and air pollution. These problems have reduced the quality of life of social residents, and are not conducive to economic development. However, traditional technologies have been unable to effectively solve the current traffic pressure. The cell based V2X technology is applied to the communication technology in the field of Internet of Vehicles. Its main purpose is to connect the mobile vehicle with other terminals or users. In the application of C-V2X technology, road safety is one of its important fields, which can not be ignored in reducing the accident rate, ensuring the safety of users and reducing property losses[5]. Industry and other organizations have conducted a lot of research to solve the communication capability between vehicles and traffic infrastructure, mainly including vehicle to vehicle (V2V), vehicle to infrastructure (V2I), vehicle to pedestrian (V2P) and vehicle to network (V2N) communication, which are collectively referred to as V2X communication. V2X communication can improve the safety and efficiency of the transportation system[6]. For a long time, V2X communication, together with existing vehicle sensing functions, has supported enhanced security applications, passenger infotainment and vehicle traffic optimization. In addition, V2X communication shall support various use cases, such as no pass warning, forward collision warning, queuing warning, parking discovery, optimal speed recommendation and curve speed warnin. V2X communication supports various use cases by using various wireless communication technologies (such as DSRC and cellular network technology) to exchange messages between infrastructure, vehicles and pedestrians.

Edge computing is a key way to solve the current prominent problems of the Internet of Vehicles. Through end-to-end collaboration, application delay can be reduced, bandwidth utilization can be improved, and network performance can be improved to improve the quality of user experience. Therefore, it requires very low latency, efficient processing and mass storageIn the scenario of Internet of Vehicles, the importance of edge computing is self-evident. Specifically, existing MABS and Road Side Units (Rsus) can be upgraded to edge nodes[7]–[9]. All resource-sharing applications running on vehicle nodes will be assigned to edge nodes to complete data processing, encryption and decision-making, and provide real-time and reliable data communication. In addition, the edge-computation-based edge-side collaborative approach can also prevent potential attacks from traditional data transmission, thus improving data integrity and security. Considering the variety of in-car apps or mobile apps that users have a amount of computing power required is growing. Superior solutions are needed to meet this challenge.In this case, assigning the task to the edge server and returning the results is the ideal solution. Take advantage of the edge server power ability to perform local processing, reduce the computing pressure of the application side and fast feedback results, reduce transmission delay and reduce service waiting time to improve user service quality and economic benefits.

2. LTE V2X Model and Architecture

LTE V2X communication mainly involves V2V, V2I, V2P and V2N communication, as shown in Figure 1. Relevant information or roadside units can be exchanged between similar vehicles directly or by means of infrastructure. The roadside units can broadcast information related to emergency or traffic conditions to a group of user equipment. The evolution packet core of LTE network can be connected to the intelligent transportation system server to provide various vehicle services. Figure 1 shows the general LTE-V2X model with intelligent vehicles running on the road. Each vehicle is equipped with on-board sensors that can detect vehicle traffic information. M RSUs are randomly distributed along the road. Each RSU is equipped with a MEC server to provide computing and caching services for vehicles. Each vehicle has computing and

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caching capabilities, and can be used as an agent to collect data independently to achieve collaborative decision-making. Both the vehicle and RSU have communication capability, and can distribute and collect vehicle driving information through V2V and V2I technology. In the multi-dimensional information fusion model, the travel information generated by CAV usually has spatio-temporal characteristics, and only reflects the state of vehicles in a specific time or space. For example, vehicles with road planning needs to collect geographic information of the current region, which is only applicable to the region where the current vehicle is located. Once the vehicle enters other areas, the previously collected geographic information will be invalid. Therefore, the status acquisition task must be completed before the data becomes invalid. This paper assumes that the vehicle driving information is only valid within the same RSU, and the vehicle must complete the data collection task before leaving the RSU coverage area[10].

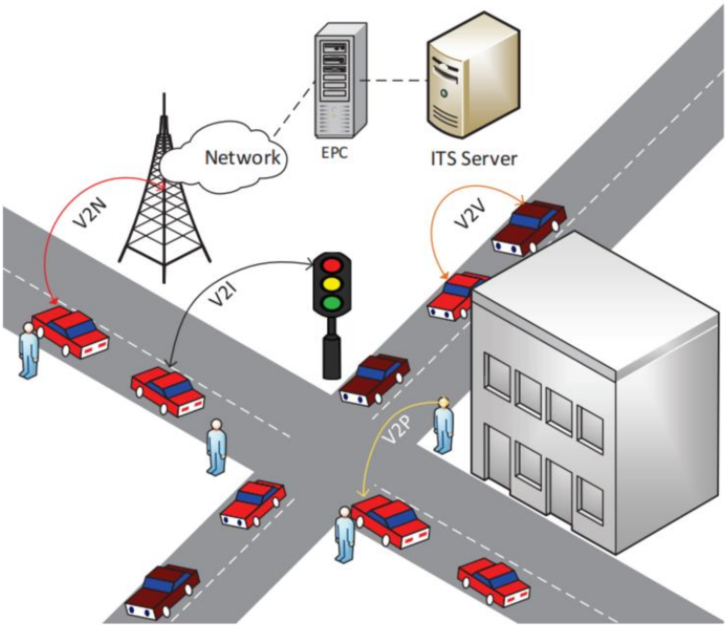

Figure 1. Generic LTE V2X Communication Model

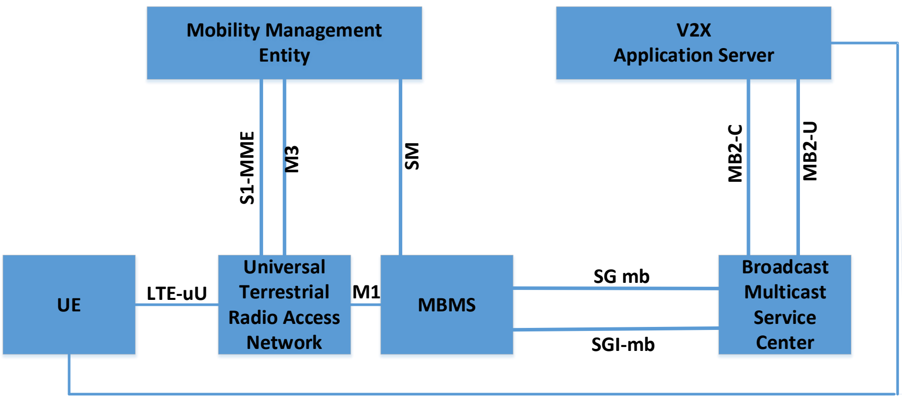

Figure 2 LTE V2X architecture based on eMBMS and LTE uU

As is shown in Figure 2, In the V2X architecture based on PC5 and LTE Uu, there are 8 reference points. In LTE V2X, functional entities include V2X control function, mobility management entity (MME), V2X application server, service gateway (S-GW) and packet gateway (P-GW).

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When e-UTRAN is in service or not, the V2X control function provides the UE with the necessary parameters for V2X communication. Due to the large number of concurrent transmissions in dense vehicle traffic scenarios, available resources must be used. In LTE D2D, for centralized scheme, downlink control information is used for resource management, while for distributed scheme, random resource selection method is used. Compared with vehicle traffic scenarios, many concurrent transmissions are low, so LTE D2D resource allocation may not be applicable to V2X traffic. Due to the high mobility and dense vehicle users in LTE V2X communication, D2D centralized resource allocation may lead to additional signaling overhead, because UE needs to connect to eNB frequently, and resource conflicts may occur with resource allocation. The solution is a semi persistent resource allocation scheme for centralized resource allocation and technology. The MBMS with high interleaving requirements for communication is also considered. Resource allocation can be broadly divided into centralized resource allocation and distributed and autonomous resource allocation[11].

Firstly, the problems existing in the resource scheduling of end-to-end collaboration under the Internet of vehicles environment are analyzed. Secondly, the key technologies used in the first research point are described: multi-objective optimization algorithm and multi-objective attribute decision technology, which provides a theoretical basis for the subsequent batch task oriented resource scheduling method. Finally, the key technologies used in the second research point: deep learning, deep reinforcement learning, early exit and model segmentation are described and analyzed, providing a theoretical basis for the subsequent research on resource scheduling methods oriented to deep learning applications.Analysis model of C-V2X mode 4 communication performance under various multichannel propagation models to verify different transmission parameters and different communication multi-objective optimization algorithm.There are two optimization objectives of resource scheduling for batch processing under the environment of Internet of vehicles, which need to achieve multi-objective linkage Joint optimization. Therefore, this problem should be constrained to a multi-objective optimization problem, and this kind of problem can get multiple solutions to form the solution set of the multiple objective equilibrium is also called the Pareto optimal solution set. Those that satisfy the following definition are called Pareto optimal.

3. V2X Network with Edge Computing

With the rapid development of 6G mobile network and artificial intelligence technology, some new intelligent mobile applications have also increased dramatically, such as intelligent navigation, high-performance computing, virtual reality, automatic driving and other emerging technologies continue to enter people's daily life, and these new applications have increasingly increased the demand for computing task processing time delay and energy consumption, According to the relevant data estimated by the Data Center of Prospective Industry Research Institute, the market number of intelligent terminal devices in China's future mobile networks may exceed 500 billion. Due to the limitations of its own resources and computing capabilities, mobile devices often face insufficient capabilities in processing computing intensive and delay sensitive applications. However, the computing offload technology in Mobile edge computing (MEC), which offloads computing tasks from mobile terminals to the edge of mobile network, can effectively solve such problems. Compared with the computing offload in mobile cloud computing, MEC solves the problems of high latency, network load and resource occupation. MEC has certain computing power, can provide low latency services, and supports mobility. In addition, MEC can continuously manage and control the information in the end users. In terms of server distribution, MEC servers are mainly deployed in the base stations near the network edge of the terminal devices. By unloading the tasks of the terminal devices to the edge servers for execution, more and more new mobile applications will benefit from MEC.

With the continuous development of digital technology, the EU issued the General Data Protection Regulation in 2016 to ensure people's privacy. However, technologies such as deep learning and big data are data trends, which often require a large amount of data to train or analyze a qualified model. Due to the improvement of people's privacy awareness, more and more fields have the crisis of data islands, such as health care, finance and education industries. Federated learning provides a privacy protected cooperative machine learning framework for distributed terminal devices. Its original intention is to solve the problem of mobile end users updating their learning models on their mobile phones. In the design, fully consider the information security issues in the data exchange process, ensure that terminal data and personal privacy will not be disclosed, and comply with laws and regulations, and on this basis, develop an efficient machine learning framework with multi participation as far as possible. Federated learning can not only use deep learning, but also use other machine learning algorithms, such as deep forest.

Embedding artificial intelligence at the edge of the network will be a key technology to ensure future service performance, such as large-scale Internet of Things communication, haptic Internet, robotic surgery, enhancement and virtual reality. Now there are some researches that combine artificial intelligence and edge computing to achieve better performance. Reference designed that the UAV network can obtain assistance from adjacent MEC servers with computing resources. However, recent MEC servers do not always guarantee optimal computing performance and communication efficiency. In order to solve this problem, the author proposes to use machine learning algorithm to analyze the computing unloading system from UAV to MEC server, so as to find the optimal MEC server to unload tasks. From the above research, it can be seen that edge intelligence can expand the UAV network and reduce the computing cost and improve the computing efficiency. Secondly, the combination of intelligent algorithm and UAV network can solve the problems of connection management and resource scheduling in the UAV network, so that the UAV network can adapt to the dynamic network environment and make optimal decisions.

Edge computing based on UAVs refers to the combination of edge computing architecture and UAV platform. UAVs can be used as user nodes to unload computing intensive tasks to edge servers located in ground base stations, or as airborne edge servers to provide computing unloading services for multiple ground user nodes. Traditional edge servers are usually installed in fixed location cellular base stations, which makes them unable to effectively provide computing offload services for IoT mobile devices when they are damaged by natural disasters or faced with sudden large-scale outdoor activities. With the continuous breakthrough and improvement of UAV technology, it is a good way to equip the edge server on the UAV. Compared with the traditional architecture, the UAV that builds the edge server can provide more efficient computing unloading services for mobile devices of the Internet of Things with its advantages such as fast deployment, strong scalability, flexibility and so on.

4. NOMA-V2X Network

The effect of signal propagation channel on network performance, and the significant resource impact of perception-based semi-static scheduling protocol was identified. In sudden problems and dense mobile environments, it is difficult to guarantee user access rates. To solve this problem, in Non-orthogonal multiple access technology is introduced in V2X network. With the help of random geometry mathematical tools, a Poisson line based crossing technique is established. Checks and Heterogeneous NOMA-V2X Network Analysis Model Based on Poisson Line Cox Point Process to Study Heterogeneous Networks. Performance parameters such as average network coverage and spatial frequency efficiency are used for the design and deployment of future V2X network systems. From the practical application point of view, a two-

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way human-vehicle-home interconnection system is designed based on V2X technology to solve the problem.Resolve the technical problem that the automobile and home smart home equipment can not be interconnected, further highlight the uniform of the smart networked automobile.

For the current C-V2X mode 4 communication performance evaluation, it is limited to specific aspects as well as a single or small number of Mathematical formulas are used to quantify errors caused by half-duplex transmission. Errors caused by receiving signal power below detection power threshold, errors caused by propagation effects, and grouping conflicts Four performance analysis parameters, error, are combined with transmission power level, transmission channel model and modulation and decoding scheme. The transmission parameters, the performance analysis model of C-V2X mode 4 under multi-channel propagation model is designed, and the parameter pair for communication is explored. The impact of performance, whether the communication performance can be further improved by adjusting parameters[12]. Results from the analysis model comparing with the results obtained by the simulator simulation, the analysis results show that the analysis model can more accurately model. The communication performance of C-V2X mode 4 is proposed, and the perception-based semi-static scheduling protocol is identified as having significant resource impact. The sudden problem points out the direction for further design and optimization of V2X network.

To solve the resource conflict problem and ensure the user access rate of vehicle users in dense scenarios, use V2X network Non-orthogonal multiple access is introduced as a more spectral efficient wireless access technology[13]. For V2X network characteristics, use different Poisson point process modeling is a heterogeneous N0MA-V2X cellular network composed of vehicles, roadside units and cellular macro base stations. Loop uses two-dimensional Poisson point process to model cellular macro base station location distribution, and uses Poisson line process for road system layout. Roadside units and vehicle nodes are located along roads based on a two-dimensional Poisson point process. Vehicle nodes served by specific roadside units using NOMA technology are also restricted along roads. Next, it deduces that a typical user is connected to the nearest user Distance Distribution Function and Laplace Transform of Disturbance for Near Side Cell or Cellular Macro Base Station; Ultimately. Based on the full probability formula, the theoretical expression of the average coverage of the network in both cases is obtained. The simulation results verify the validity of the Correctness of NOMA-V2X network analysis model. The numerical analysis results show that the isomeric NOMA-V2X network is flat. Overall coverage is better than V2X network based on orthogonal multiple access technology. The analysis results can be deployed for NOMA-V2X. It provides some theoretical support.

In previous studies, vehicle nodes were simply assumed to be any bit within the network coverage area. Considering the practical application scenarios of vehicles in road system, and combining with random geometry theory, a two-layer heterogeneous model is constructed.NOMA-V2X cellular network model. Using Poisson Line Cox Point to better match the actual distribution scenario distance modeling, using Poisson line processes to simulate the spatial layout of the road system, vehicle nodes and roads on the road system. The locations of side units are represented by independent Poisson point processes, and side units are located on roads based on one-dimensional Poisson point processes On-line, vehicles served by a given roadside unit using NOMA technology are also restricted to the road line, and a final derivation is obtained. Mathematical expressions for network coverage and spatial spectral efficiency of NOMA-V2X networks under the most recent selection strategy[14], [15]. The simulation results verify the correctness of the theoretical derivation and model. The numerical analysis results show that the comparison is based on orthogonality V2X network with multiple access technology, heterogeneous NOMA-V2X cellular network has better network coverage and space spectral efficiency. By introducing the concept of NOMA technology in V2X network, network coverage can be improved a better balance with spatial spectral efficiency can be achieved by choosing an appropriate roadside unit deployment density to meet different requirements network coverage and spatial spectral efficiency requirements.

5. Future and Challenges

In the next decade, with the development of communication technology and neural network, more and more devices will be unmanned, which poses challenges to existing systems. With the integration of UAV and automatic driving technology, future vehicles will have a higher dimension of environmental awareness. The future automatic driving network will have higher flexibility and heterogeneity, and also need to have stronger disaster tolerance. SDN technology can well meet this demand. At the same time, data security and privacy issues in the network also deserve attention, How to use blockchain technology to ensure the security performance of the system is also worth looking forward to. Due to the limitation of UAV's own energy characteristics, it is particularly important to improve the energy efficiency of the system. Joint edge computing and deep learning will be deeply integrated with the system to balance the dynamic requirements of the system.Combining the latest V2X, Internet of Things technology, front-end and back-end development technology, a V2X-based technology is designed. The "person-car-home" two-way interconnection system is designed to break the technical barriers between car and home scenarios.

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