Application of 5G Communication Technology in IOV

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Abstract. With the development of IOV (Internet of Vehicles) and wireless communication technology, the application of IOV has become a key solution to realizing future intelligent transportation. Communication technology is the core technology of IOV, which determines many of its key performance of IOV. However, traditional communication technology cannot meet the signal requirements of IOV communication, so the application of communication technology for 5G in IOV is crucial. This paper firstly introduces the principle and requirements of the IOV communication system, 5G communication technology and its protocols, and then focuses on the difference between 5G communication technology and traditional communication technology. From re-analysis of a vehicle grouping algorithm applied to D2D, it is concluded that the greater the distance between units, the smaller the relative speed difference between vehicles and the more stable the signal transmission channel. This algorithm can effectively solve the contradiction between the environment of a vehicle moving at high speed and the stability of signal transmission. Finally, the development of 5G communication technology applied to vehicle networking is anticipated.

Keywords: IOV · D2D · 5G communication technology · communication protocol

1 Introduction

With the development of the Internet, smart car applications have gained popularity. While it brings convenience to life, it also highlights many problems, such as traffic congestion and inefficient travel. Based on the urgent needs of automobile users and the pressure of transportation system, researchers began to apply Internet of things technology to automobiles, so as to form an intelligent and efficient interconnected automobile system.

IoT is the application of IoT in transportation systems. The main idea of IoT is to form a network of physically unconnected objects through a network, and it is applied to intelligent transportation to establish data exchange between vehicles and vehicles, vehicles and people, and vehicles and the surrounding environment. Based on the actual traffic system requirements, the IoT technology needs to have the following characteristics: the ability to adapt to the changing road environment, large communication network

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coverage, etc. Therefore, there are many difficulties in its implementation. One of the main difficulties is the transmission of signals between vehicles and other communication units. IOV communication requires extremely high signal requirements, and high quality and high transmission rate signal interaction is the basis of IOV communication. While the existing 5G communication technology has this advantage, the research of Suresh Borkar [1] focuses on how 5G networks work, showing that 5G communications can provide wider bandwidth and apply higher frequencies, therefore ensuring high fidelity transmission of signals. And the research of Sreekrishna Pandit [2] in which a model of a 5G connected vehicle is built and the working principle is described, demonstrates the feasibility of 5G technology applied to vehicular networking.

The author focuses on the working principles of 5G communication technology in vehicular networks and elaborates on the communication quality and time delay problems in conventional technology. The application of 5G-based D2D communication technology in vehicular networks is proposed, and the algorithm cases in existing research are analyzed. The above research can further improve the transmission quality of signals in IOV communication, which helps to ensure the safety and reliability of intelligent vehicles and traffic systems, reduce social traffic pressure and reduce the probability of traffic accidents, provide efficient and reliable auxiliary tools for existing traffic, and provide ideas for further development of related fields in the future.

2 Architecture of IOV

Based on intra-vehicle network, inter-vehicle network and in-vehicle mobile network, advanced sensors, controllers and actuators are configured for vehicles. The equipment side incorporates positioning technology, information processing technology, wireless communication technology and intelligent decision control technology built based on algorithms to integrate the above facilities to build a highly collaborative IOV ecosystem.

2.1 System Levels and Functions of IOV

According to the network architecture, the IOV architecture can be divided into three layers: the perception layer, network layer and application layer, as shown in Fig. 1.

The role of the sensing layer is to provide feedback to the driver from all kinds of collected information. Through the joint sensing of in-vehicle sensors, in-vehicle radar, and positioning systems, the driver can get status information inside and outside the car, such as road environment information, car driving status, and so on. The driver makes decisions according to the feedback information, so as to realize the function of IOV assisted driving.

The role of the network layer is to analyze the data collected by the perception layer. Combined with the Internet and wireless communication networks, it realizes the functions of network access, data analysis, data transmission and node management for vehicles. The network layer also provides real-time information to users and enables the allocation of wireless resources.

The application layer is the highest increase in the IOV architecture and can provide different services to users, including but not limited to emergency assistance, in-vehicle entertainment facilities, remote collaboration, etc.

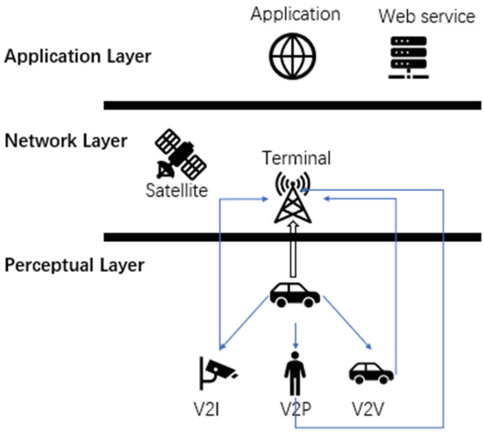

Fig. 1. IOV System Levels (original)

In the future, 5G communication technology will have more flexible application methods, which will add new system elements to the IOV architecture. In addition to the information interaction of V2X in the in-vehicle network, inter-vehicle network and in-vehicle mobile Internet value, 5G IOV may also realize the interconnection of mobile terminals, base stations and clouds. The resulting information interaction efficiency will be improved, and the signal time delay will be reduced, facilitating communication channel switching.

2.2 5G-Based IOV Communication System

In IOV, there are various scenarios of interaction between connected vehicles and transportation systems, including V2V (Vehicle-to-Vehicle), V2I (Vehicle-to-Infrastructure), V2N (Vehicle-to-Network) and V2P (Vehicle-to-Pedestrian). The four categories can be collectively called "V2X". In particular, researchers are now developing cellular mobile communication-based solutions to make up for the shortcomings of traditional dedicated short-range communication, so that 5G technology can be used in V2X in a new way. In Yiming Huo's study [3], the key and low-cost cellular-WIFI multiplexing technique is analyzed and the advantages of this technique for smart mobile devices are described. The paper describes the solution to the blocked condition during signal transmission and the circuit design. Xiaohu You [4] also mentioned that the key technology of 5G mobile communication is the ultra-high performance wireless transmission technology, which has high system spectrum efficiency, allowing multiple users in the network to share resources in the frequency band and communicate with the base station at the same time. This will enable 5G to be extended to play a transmission and interaction role in the field of intelligent transportation.

The 5G communication system consists of three main components, namely the core network (Core Network), macro base stations (MBS) and micro base stations (SBS).

The main role of the core network is to control the system and transmit information data, which can dock requests or data from different ports to the corresponding network.

Macro base stations are connected to the core network through optical fiber or microwave, and transmit information to macro base stations, micro base stations and users in different areas through wireless communication. Macro base stations are characterized by high transmitting power (usually more than 10 W) and a coverage radius of 200 m or more. Micro base stations are a generic term for small base stations, which have been used in the 4G era. Although the transmitting power is low and the coverage area is small, the coordinated coverage of a large number of micro base stations can effectively increase the density of wireless connections and ensure the signal strength of the responsible area. 5G communication system has the advantage of a high communication rate, but it still has an upper-speed limit, which is determined by Shannon's formula.

$$C = W \log_2\left(1 + \frac{S}{N}\right) \tag{1}$$

The above equation illustrates that the information transmission rate is jointly influenced by several factors such as channel bandwidth and signal-to-noise ratio, where C is the transmission rate maximum; W is the channel bandwidth; S is the signal power; N is the noise power; and S/N denotes the signal-to-noise ratio.

As applied to IOV, the 5G mobile communication network can be considered a two-layer network, including the macro-cellular layer and the device layer. The macrocellular layer requires the participation of a base station to achieve device communication. While in the device layer communication, the main component of the 5G mobile communication technology is D2D (device-to-device), which is a direct terminal-to-terminal information interaction without the use of any network infrastructure.

2.3 Legacy Model - DSRC-Based V2X Communication Architecture

2.3.1 The Concept of DERC

DSRC, which has also become Dedicated Proximity Service, is a core technology that enables V2V, with dedicated frequency bands allocated in several countries. It works by establishing a communication link between the vehicle and the roadside unit to establish microwaves, enabling vehicle information identification without the need to stop the vehicle. It works in the 5.9 GHz band with a bandwidth range of 75 MHz and a communication distance of around 1000 m. The standard of DSRC is IEEE802.11, using the MAC protocol, which allows distributed operation and mainly applies to point-to-point communication mode. The DSRC band can be used only for a single channel or divided into multiple channels (Fig. 2).

2.3.2 The Application of DSRC in V2X

According to the research found by Kaiming Ren [5], DSRC can be applied to a variety of scenarios in V2X. For example, in the highway toll booths, the use of DSRC technology can realize fast electronic toll collection to improve road traffic efficiency. What's more, based on Yuanfu Mo's paper [6], traffic information transmission guarantee technology built on DSRC technology is becoming increasingly mature, and the problem of information blockage in the high-density communication environment of IOV has

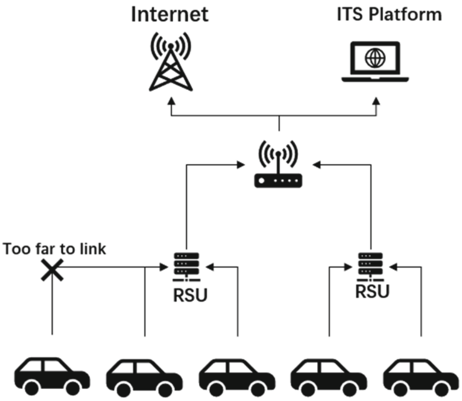

Fig. 2. The constructure of DSRC (original)

been improved. As Liu Fuqiang [7] concluded his study, he specified the application of DSRC to intelligent traffic management, including fleet management on highways, safe overtaking, etc. The principle can be seen in the figure below. The common characteristics of these scenarios are the high delay and reliability requirements of communication connection, and the characteristics of DSRC dedicated short-range service meet these two requirements.

However, the disadvantages of this technology are also very obvious. As the vehicle moves at a high speed during the driving process, and this characteristic makes the connection time between the vehicle and the RSU short, forcing the in-vehicle communication network to switch channels continuously, there is a high possibility of short communication interruptions. In addition, when the density of road vehicles is high, the data transmission rate to be carried by each channel will be greatly improved, so that the channel competition between vehicles will become more intense, and the V2V communication quality will be greatly reduced.

3 Solution – D2D Based IOV Communication System

3.1 The Structure of D2D System

D2D communication basis is also known as device pass-through technology. While traditional cellular communication systems must communicate through a base station, D2D technology allows direct communication between devices on both the transmitting and receiving sides, making it an efficient way to communicate over close distances with low time delays and low power consumption. D2D is also a high-performance communication method with a high data transfer rate. The schematic of the D2D system is shown in Fig. 3.

3.2 Four Categories of D2D Technology and Functions

Terminal forwarding over the base station control link. In environments with incomplete signal coverage, D2D technology allows the terminal device to communicate with the

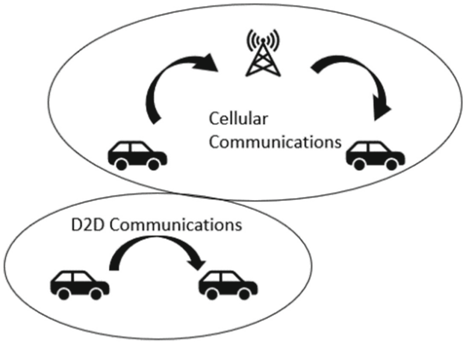

Fig. 3. D2D communication schematic (original)

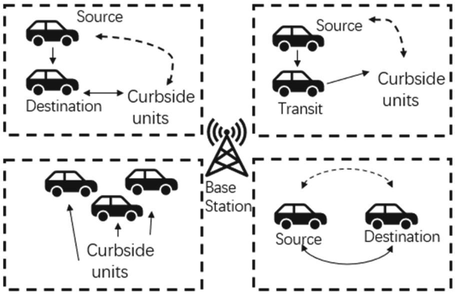

Fig. 4. 5G IOV architecture based on D2D communication (original)

base station through the information forwarding equipment of nearby terminal devices. In this process, the communication link is controlled by the base station and the relay device, which allows the terminal device to have a high quality of service (QoS).

Direct communication of terminals with the base station-controlled link. In this communication method, the interaction of information does not require the assistance of the base station, but the link needs to be established under the control of the base station.

Terminal forwarding of terminal control link. The establishment of the communication link and information exchange are independent of the base station, and the communication between the source and the receiver is coordinated and controlled by the relay equipment.

Terminal direct communication of terminal control link. The communication between each terminal is not assisted by external equipment and can control the establishment of the link by itself, which is conducive to reducing the interference caused by the introduction of external equipment on the communication quality.

Figure 4. Shows the logic of all those four structures. From the overall structures of the communication network, D2D technology cannot be achieved without network connectivity. Before the birth of 5G technology, relying on Wi-Fi, Bluetooth and other technologies, it is impossible to realize large-scale D2D connection. At the same time, for IOV applications, when the vehicle and road environment data are accessed on a large scale, D2D communication relying only on the Internet cannot guarantee the system's

performance. With the development of 5G mobile communication technology, D2D is transformed from Internet-based to a new generation of the mobile communication systems. Based on the large bandwidth, high data transmission rate, large-scale access capability and data processing capability provided by 5G mobile communication, the information processing capability of D2D technology has been greatly improved, and it can realize the large-scale access of network terminal devices, which can be applied in IOV to realize the stable interconnection of vehicles and road terminals.

3.3 Protocols for 5G Communication Technology

The IEEE802.11 standard is mentioned above in DSRC [8], which is a global universal IOV communication standard designed by the IEEE organization to study the US 5.9 GHz band DSRC standard. It is applicable to V2X communication and introduces various advanced mechanisms such as data transmission, mobile interconnection and identity authentication. The standard also standardizes the physical layer and the medium access control layer of the DSRC standard. The use of orthogonal frequency division multiplexing (OFDM) in the physical layer aims to reduce information interference caused by the Doppler shift. In addition to this, the DSRC bandwidth range is divided into seven sub-channels, where the control channel is responsible for delivering secure messages and the six service signals are responsible for the transmission of the rest of the information. The standard CSMA/CA is still used in the medium access control layer, but the access control method and other aspects are optimized.

In addition to communication standards, routing protocols are also an important basis for communication technology, which determines the network communication capability of the IOV, and are mainly divided into the following three types: on-demand routing protocols, hierarchical routing protocols and geolocation-assisted routing protocols. Among them, geolocation-assisted routing protocols can be better adapted to the communication requirements of IOV based on their characteristics for using geolocation information.

The greedy algorithm in this protocol is an approximate method that can solve the optimization problem. In a 2017 study, Dwi Ann Ratna Wati [9]. Proposed combining the greedy algorithm with geolocation information by having a node periodically wave data containing its own identifier and current geographic coordinates, which other nodes analyze and build a list of nodes after receiving the information. This process omits the exhaustive process in traditional algorithms and is more efficient. Besides, anchor routing protocols can import the topology of roads into routers according to the distribution pattern and relative stability of traffic networks in space and time. This process allows information to be transmitted along the road topology, which can effectively reduce the interference of the traffic environment on the communication quality.

3.4 The Challenges of D2D Technology

According to Wanlu Sun [10], there are several advantages to applying D2D communication to V2X. Firstly, the scenario of V2X communication is just right for D2D to achieve direct communication of devices within a certain range. Meanwhile, the hop gain of D2D communication can just meet the low delay requirement of V2X communication. Finally, the proximity gain of D2D communication can meet the high reliability requirement of V2X communication.

However, D2D communication technology also has some drawbacks. Like DSRC, it is difficult to establish communication links between vehicles and devices when the traffic density is high. At the same time, D2D technology has the risk of illegal listening in terms of information security, so this kind of communication technology needs more complete communication protocols.

3.5 Vehicle Grouping Algorithm

TO solve the error brought by the high-speed movement of vehicles in the D2D communication system, a vehicle grouping algorithm is discussed comprehensively [11]. This algorithm groups vehicles in a large fleet into clusters, considering that vehicles within close range and traveling in the same direction are in the same cluster. It is assumed that the vehicles within this cluster can efficiently transfer information among themselves, including sharing speed, motion trajectory and in-vehicle services, while sending different operations of the vehicles during the driving process to other vehicles through D2D communication. This communication mode is helpful to assist vehicles in driving safely. If there are a total of N vehicles on the current road, they are divided into M groups (M $<$ N). The vehicles in the group are represented as periodically reporting their key information to the designated unit, and at the same time, the vehicle speed and the expected travel distance are defined as the reference elements for the consistency of the movement within the group factor.

$$\eta_{k,i} = \alpha_k \left| \frac{v + \overline{v}_k}{\overline{v}_k} \right| + \beta_k \frac{1}{d} \tag{2}$$

$$\overline{v}_k = \frac{1}{w_k} \sum_{j=1}^{w_k} v_{kj} \tag{3}$$

where v_k is the average speed of the k group, vi is the speed of the i vehicle, and the factors before each calculation equation are weighting factors that can be dynamically adjusted according to the actual situation. The smaller N is, the higher the probability of receiving vehicle u. Therefore, the larger d is, the smaller the relative difference between the average speed and the vehicle sub-velocity, and the longer the group members can sustain D2D communication, thus solving the communication instability caused by vehicle movement.

4 Conclusion

This paper focuses on the 5G-based IOV architecture and communication model. The network layering of the IOV and the functions corresponding to each layer is highlighted in the IOV architecture, which leads to the IOV communication system. In the elaboration of the communication system, the advantages and disadvantages of DSRC and D2D are compared to illustrate the applications and drawbacks of D2D in the context of 5G, and a vehicle grouping algorithm is proposed to solve the communication interference problem due to the high-speed movement of vehicles. The aim is to provide solutions for future 5G vehicular communication systems.

At the same time, there are certain shortcomings in this paper, which are mainly divided into two aspects. On the one hand, this paper only considers the communication between vehicles and stationary roadside units and ignores the interaction between vehicles and moving objects, such as pedestrians, other vehicles, etc. Therefore, the algorithm can also set the speed for the interacting units to analyze the communication conditions of V2X. On the other hand, this paper can sample data on traffic flow and average vehicle speed in cities and under different road types to refine and validate the environmental conditions for algorithm analysis. In the future, a scaled-down physical model can be built to validate the different algorithms and investigate the vehicle's behavior patterns so that the theoretical improvements can be applied in practice.

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