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Research and Application of Network Slicing in the Internet of Vehicles Scenario

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Abstract: Driven by advanced capabilities of fifth-generation (5G) mobile networks, vehicle-to-everything (V2X) communication is transitioning from theoretical concept to practical implementation. However, the inherent characteristics of vehicular environments—high mobility, dynamic topology and dense traffic scenarios—pose significant challenges in meeting the stringent and diverse quality-of-service (QoS) requirements for V2X applications. This article explores the application of network slicing technology, supported by Network Function Virtualization (NFV) and Software Defined Networking (SDN). The requirements for network slicing in the context of the Internet of Vehicles are analyzed. In response to these needs, the article further studies the specific applications of network slicing technology in these scenarios. Finally, the article discusses the challenges faced by network slicing in the Internet of Vehicles and looks forward to future prospects such as intelligent management, cross industry cooperation, and standardization. The findings reveal that effective implementation of network slicing can significantly enhance the performance and reliability of V2X communication, paving the way for safer and more efficient vehicular networks.

Keywords: Network slicing, Vehicle networking scenarios, network resource, NFV, SDN

1. Introduction

Network slicing technology, as a key 5G technology, can create multiple virtual end-to-end networks on a shared physical network to meet the needs of different business scenarios. With the development of 5G technology, network slicing is widely used in fields such as vehicle networking. The Internet of Vehicles (IoV) technology is based on the mobile communication network, and realizes the information transmission between vehicles, routes, people and vehicles and the Internet through vehicle terminals, so as to improve the vehicle perception. Network slicing ensures reliable communication in the Internet of Vehicles and meets business needs such as autonomous driving [1]. However, there are still gaps in research, such as efficient network management, addressing differentiated needs, and performance optimization.

To further study its application, this paper aims to explore how network slicing technology serves as a critical enabler for transitioning vehicle networking from theoretical frameworks to large-scale commercial applications. It investigates the potential of network slicing to provide "on-demand services" in complex vehicular environments, facilitated by advancements in intelligent algorithms and industry collaboration. The study seeks to assess how these developments can promote the efficient, safe, and sustainable evolution of intelligent transportation systems, providing

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a reference for the future development of the Internet of Vehicles and promoting the widespread application of 5G technology within the industry.

2. Overview of network slices

Network slicing is a revolutionary technology that cleverly divides network resources into multiple logically independent virtual networks using the power of virtualization technology. This technology not only greatly improves the utilization of network resources, but also gives operators unprecedented flexibility. Network slicing allows operators to create highly customized virtual networks based on different business needs. These virtual networks can flexibly configure and optimize network resources based on specific application scenarios, user needs, or service quality requirements. In this way, including real-time communication applications requiring low latency and high bandwidth, or financial transaction applications emphasizing data security and privacy, network slicing can provide customized network services to ensure smooth business operations. In addition, network slicing also has high scalability and adaptability. With the changes in business requirements and technological evolution, operators can easily adjust and optimize network slicing to meet the constantly changing market demands. This flexibility not only reduces network operating costs, but also improves the overall quality of network services and user satisfaction. Network slicing, as an innovative network architecture solution, provides operators with unprecedented business flexibility and market competitiveness.The logical architecture of 5G network slicing is shown in Figure 1, which divides physical network resources (computing, storage, bandwidth, etc.) into multiple independent virtual slices through virtualization technology. Each shard can be customized to specific business needs, enabling operators to dynamically allocate resources and optimize network performance to suit different vehicle-connected scenarios [2]. It will help operators better meet user needs in a complex and ever-changing market environment, and promote the continuous upgrading and innovation of network services.

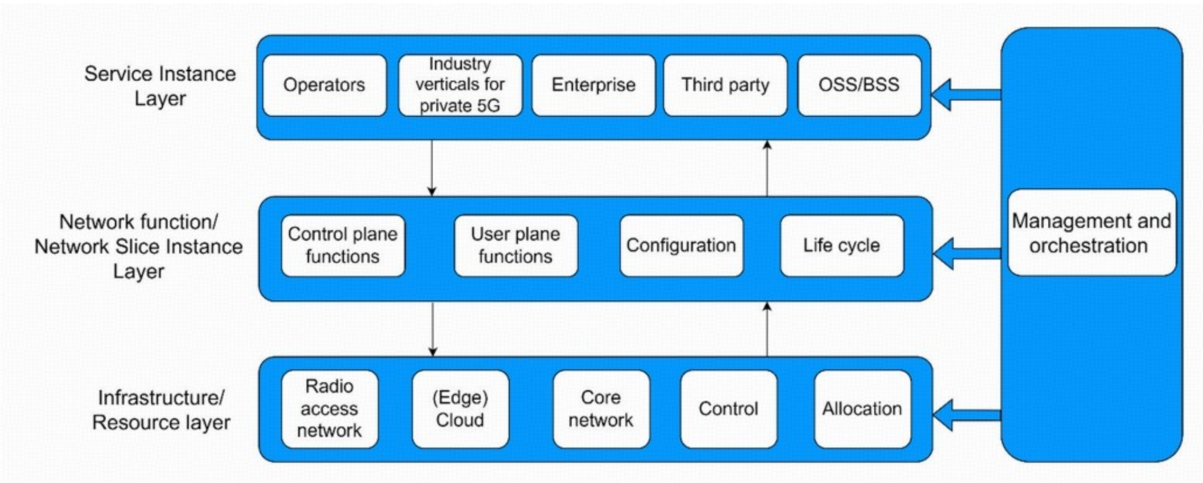

Figure 1: Concept of 5G network slicing [2]

3. Technology enablers

3.1. Technology enablers1(NFV)

NFV, as a revolutionary technology, is leading a profound transformation in network architecture. By implementing software based network functions, NFV enables flexible scheduling and efficient utilization of network resources, marking a significant breakthrough in traditional network

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architecture. NFV transforms the network functions that used to run on hardware devices into software that runs on general-purpose servers. This transformation enables network functions to be rapidly deployed, upgraded, and configured like applications. Compared to traditional hardware devices, software based network functions not only have higher flexibility, but also achieve more efficient resource utilization. This transformation not only brings significant economic benefits, greatly reducing the cost of network construction and maintenance, but also enhances the flexibility and scalability of the network. With the continuous changes in network demands, NFV can quickly respond and meet the needs of various emerging application scenarios. As one of the important technical supports for network slicing, NFV enables slicing to have fast, flexible, and scalable characteristics. Network slicing can quickly generate, deploy, and optimize network resources according to different business needs, thereby meeting the modern network's demand for efficient, reliable, and intelligent services. This feature makes NFV play a crucial role in the construction of 5G networks, laying a solid foundation for future network development.

3.2. Technology enablers 2 (SDN)

SDN is a revolutionary technology that separates the network control plane from the data plane, enabling centralized and intelligent network control. The core concept of SDN is to achieve efficient utilization and optimization of network resources through centralized and intelligent network control [3]. Through SDN technology, operators can obtain a global view of network resources, thus possessing the ability to finely control and manage network resources. This technology not only greatly improves the efficiency and flexibility of network management, but also provides powerful automation and intelligent support for end-to-end orchestration and management of network slicing. SDN technology achieves automated scheduling and optimization of network resources through intelligent algorithms and strategies, significantly improving network performance and stability. The application of SDN enables operators to respond more quickly to market demand and provide more flexible, reliable, and efficient network services. Through SDN technology, operators can achieve intelligent scheduling and load balancing of network traffic, improving network bandwidth utilization and transmission efficiency. Meanwhile, SDN can also help operators quickly deploy and configure new network services to meet the diverse needs of users. SDN technology plays a crucial role in network competition. By introducing SDN technology, operators can achieve comprehensive control and optimization of network resources, improve the quality and competitiveness of network services, and thus occupy an advantageous position in fierce market competition.

4. Requirement analysis of network slicing in the context of connected vehicles

4.1. Requirements for Augmented Reality (Ar) driving scenarios

Augmented reality driving scenarios have become a hot topic in the current field of intelligent driving. By overlaying virtual information onto the real driving environment, this technology can provide drivers with more intuitive and rich driving information, greatly improving the driving experience and safety. It can not only enhance the driver's perception ability, but also provide timely driving assistance at critical moments, effectively reducing the occurrence of traffic accidents. In such scenarios, network slicing plays a crucial role. In order to ensure real-time updates and high-definition display of AR information, network slicing must meet a series of strict technical requirements. Low latency is a key element of network slicing, which ensures that the AR information seen by drivers is synchronized with the actual driving environment, avoiding security risks caused by information lag. In addition, high bandwidth is a necessary condition for supporting high-definition image and video transmission. Only by meeting this requirement can drivers enjoy a

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more realistic and immersive AR experience. At the same time, network slicing also needs to ensure the stability of basic driving communication and avoid interference from the transmission of AR information on normal driving. This requires network slicing to have excellent resource scheduling and conflict avoidance capabilities to ensure that AR information and basic driving communication can coexist harmoniously and do not interfere with each other in complex and changing driving environments. The demand for augmented reality driving scenarios is not only reflected in real-time updates and high-definition displays of AR information, but also involves ensuring the stability and safety of basic driving communication. With the continuous advancement of technology and the increasingly widespread application, it is reasonable to believe that augmented reality driving scenarios will become one of the important development directions in the field of intelligent driving in the future.

4.2. Requirements for autonomous driving scenarios

Autonomous driving technology is undoubtedly one of the most challenging applications in the field of connected vehicles and an important direction for the future development of intelligent driving. Against the backdrop of continuous breakthroughs in this technology, the implementation of autonomous driving scenarios places extremely high demands on the reliability, latency, and security of network slicing. In order to achieve precision and efficiency in autonomous driving, network slicing must be able to provide ultra reliable low latency communication (URLLC), which is a necessary condition to ensure that autonomous vehicles can perceive and process surrounding environmental information in real time [4]. URLLC technology can significantly reduce network delay, improve the reliability and stability of data transmission, and thus ensure the normal operation of the auto drive system. At the same time, autonomous driving also needs to ensure the security and privacy protection of data transmission, which is an important means to prevent risks caused by hacker attacks and data leaks. Network slicing must adopt advanced encryption techniques and security protocols to ensure the integrity and confidentiality of data transmission. This includes not only the communication security between vehicles, but also the communication security between vehicles and infrastructure, ensuring that autonomous vehicles will not be subject to any form of interference or attack during operation. The implementation of autonomous driving technology relies on the support and guarantee of network slicing. Figure 2 illustrates the management and orchestration process of the autopilot slice. It includes key modules such as resource allocation, redundancy design and security monitoring. The workflow starts with the creation of a dedicated slice for self-driving cars, followed by dynamic resource scheduling based on real-time requirements, such as URLLC requirements. Redundant resources are configured in advance to ensure system stability in the event of network failure. In addition, the slice integrates encryption protocols and intrusion detection mechanisms to protect data transmission from network threats [5]. Only when network slicing can provide stable, reliable, and secure communication services, can autonomous driving technology truly realize its potential and bring more convenient, efficient, and safe experiences to people's travel.

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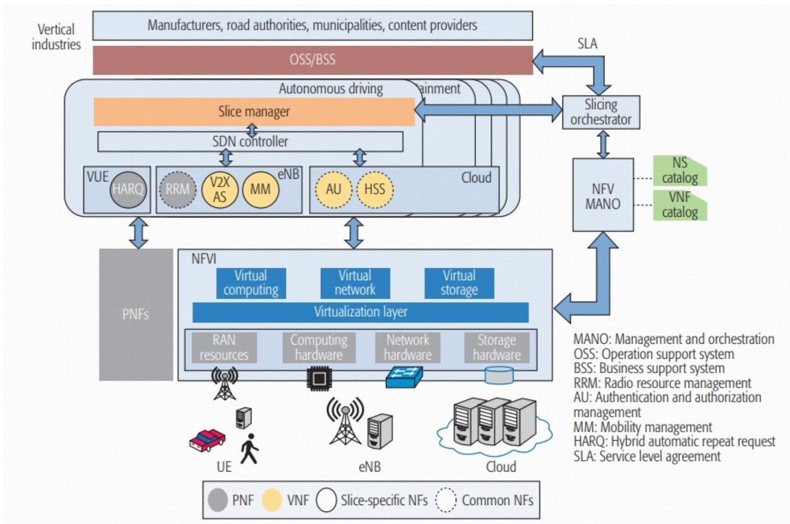

Figure 2: The case of autonomous driving slice: management and orchestration [5]

4.3. Requirements for in car social networks

As an important application scenario in the field of connected vehicles, in car social networks are gradually changing the mode of transportation. It allows vehicles to exchange real-time information, share road conditions, and enjoy various entertainment services while driving, providing drivers and passengers with a more convenient, fun, and colorful travel experience. In such scenarios, the application of network slicing is particularly important, requiring high requirements for flexibility, scalability, and user experience. In order to meet the diverse social and entertainment needs of different user groups, network slicing needs to support high concurrency connections and dynamic resource scheduling. High concurrency connections can ensure that multiple vehicles can simultaneously exchange information and provide entertainment services during peak hours without network congestion or latency [6]. Meanwhile, dynamic resource scheduling can adjust the allocation of network resources based on real-time conditions, ensuring that each user can obtain the best network experience without affecting service quality due to insufficient resources. In addition, network slicing also needs to provide stable and reliable network connections and high-quality user services to meet users' high-quality needs for in car social networks. For example, Collaborative Federated Learning (CFL) can be introduced. CFL allows vehicles to interact directly with model parameters, reducing reliance on a central server, local data processing through distributed training, and reducing the risk of sensitive information transmission [7]. This method not only ensures high concurrent connection, but also dynamically allocates network resources, effectively copes with the fluctuation of the number of users, and simultaneously takes into account the quality of service and privacy security. In this way can in car social networks truly play their due value and become important assistants in travel and daily life.

5. Application research of network slicing technology in the context of vehicle networking

5.1. Network slicing for Ar driving scenarios

For AR driving scenarios, network slicing is undoubtedly a crucial innovation. By optimizing resource allocation strategies, it can ensure low latency and high bandwidth for AR information transmission, thereby significantly improving the driving experience. Specifically, this technology can achieve priority processing and fast transmission of AR data by dynamically adjusting the transmission path and bandwidth resources in network slices. In order to optimize real-time

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performance, the AR data stream can be classified into dedicated RAN slices and the rendering task can be processed near the edge server to prioritize high-priority spectrum resources and reduce transmission latency [8]. This means that complex road information, real-time traffic conditions, and other important driving assistance information can be presented to drivers at the fastest speed possible. Furthermore, network slicing can intelligently allocate resources based on real-time network conditions and the priority of AR information. It can identify which information is currently most needed by the driver, and then prioritize the transmission of this information to ensure that it arrives in the shortest possible time. This intelligent resource allocation method not only improves the efficiency of information transmission, but also ensures the accuracy and real-time performance of information. For drivers, this means they can drive with more focus and confidence. Because they can obtain the most accurate and timely driving information in real time, thus making more informed driving decisions. This improvement not only enhances driving safety, but also allows drivers to enjoy unprecedented smoothness and comfort during the driving process.

5.2. Network slicing for autonomous driving scenarios

In the context of autonomous driving, the importance of network slicing design is self-evident. It needs to pay more attention to reliability and safety to ensure the stable and safe operation of autonomous driving technology. To this end, various technological measures can be taken to enhance the reliability and security of network slicing. When designing the network slice, people need to pay attention to the redundancy design, that is, configure multiple backup resources in the network, so that when the main resources fail, it can be quickly switched to the standby resources, so as to ensure the continuous and stable operation of the auto drive system. In addition, it is necessary to establish a comprehensive fault recovery mechanism that can quickly locate and repair network faults in a short period of time, thereby avoiding autonomous driving accidents caused by network problems. In order to ensure the security of autonomous driving data transmission, advanced encryption and authentication technologies are needed to encrypt the transmitted data and authenticate the identity to prevent security risks such as hacker attacks and data leaks. At the same time, it is also necessary to strengthen the security monitoring and early warning of the network slice, timely discover and deal with potential security threats, and ensure the reliability and safety of the auto drive system [9]. The design of network slicing in the context of autonomous driving requires comprehensive consideration of multiple factors and the adoption of various technical means to ensure the reliability and security of the network, providing solid support for the popularization and development of autonomous driving technology.

5.3. Network slicing for in car social networks

In the context of in car social networking, the design of network slicing should focus on its flexibility and scalability to cope with constantly changing user needs and network environments. With the booming development of in car social networks, users' demand for the network is also increasing day by day, which requires network slicing design to have high flexibility and scalability. To meet this demand, it is necessary to introduce intelligent resource scheduling algorithms. Through this algorithm, slice resources can be dynamically adjusted based on users' real-time needs and network load conditions to ensure efficient network operation [10]. This not only enables high concurrency connections, but also provides users with a high-quality user experience. At the same time, network slicing design also needs to have strong scalability. With the continuous expansion of network scale and changing user demands, slicing resources must be able to flexibly adjust to adapt to these changes. This flexible and scalable network slicing design not only meets the growing needs of users, but also provides more stable and efficient network support for in car social

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networks. Flexible and scalable network slicing design is the key to the development of in vehicle social networks. It will bring users a smoother and more stable social experience, driving the continuous development of in car social networks.

6. Challenges and prospects of network slicing in the internet of vehicles

6.1. Challenges faced

First, efficiently allocating network resources to meet the needs of different businesses in a dynamic connected vehicle environment is an extremely complex and requires further in-depth research. With the continuous enrichment and diversification of vehicle networking application scenarios, the demand for network resources is also increasing. How to optimize resource allocation and achieve efficient utilization of resources while ensuring network service quality is one of the key issues that urgently need to be addressed in the current field of connected vehicles [11].

Second, network slicing, as one of the important technologies for 5G and future communication networks, has broad application prospects in the field of vehicle networking. However, the lifecycle management of network slicing, including the creation, configuration, deployment, maintenance, and deletion of slices, requires more intelligent solutions. How to achieve efficient and flexible management of network slicing to adapt to the rapid changes in vehicle networking application scenarios is another major challenge facing the current vehicle networking field.

Third, the Internet of Vehicles involves collaboration in multiple fields, such as traffic management, communication operators, etc. The information silos and data barriers between different fields have brought great difficulties to cross domain network slicing management. How to achieve cross domain information sharing and collaborative work, and promote the widespread application of vehicle networking slicing technology, is one of the key issues that need to be focused on in the current vehicle networking field.

6.2. Future prospects

With the continuous development of artificial intelligence and machine learning technology, intelligent management will become an important direction for the development of vehicle networking slicing technology. By introducing artificial intelligence and machine learning algorithms, efficient and automated management of network slicing can be achieved, further improving the dynamic management and resource allocation efficiency of network slicing [12]. The development of vehicle networking slicing technology requires joint efforts from multiple industries such as communication and transportation. In the future, strengthening cross industry cooperation will become an important way to promote the application and development of vehicle networking slicing technology. Promote the application and development of vehicle networking slicing technology in different fields through joint research and development, standard setting, and market promotion. Standardization is the key to promoting the widespread application of vehicle networking slicing technology. In the future, it is necessary to strengthen the standardization of vehicle networking slicing technology, develop unified technical standards and specifications, and promote interoperability between different systems. At the same time, it is necessary to actively participate in the formulation and promotion of international standards to enhance the international competitiveness of China's vehicle networking network slicing.

7. Conclusion

Network slicing, as one of the key technologies for 5G and future communication networks, has enormous potential for application in the field of connected vehicles. With the support of

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technologies such as NFV and SDN, network slicing can achieve software based network functions and centralized control planes, providing efficient, flexible, and scalable network services for vehicle networking scenarios. However, the application of network slicing in the Internet of Vehicles also faces many challenges, such as resource allocation optimization, dynamic management, and cross domain collaboration.

However, this paper has limitations, including a lack of comprehensive empirical data to support the proposed applications and challenges of network slicing in the Internet of Vehicles. Looking ahead, future researches can focus on intelligent management algorithms. Additionally, it is essential to promote cross-industry cooperation and standardization efforts to facilitate the widespread application and advancement of vehicle networking slicing technology. With the continuous advancement of technology and the expansion of application scenarios, network slicing is expected to play a more important role in the field of connected vehicles, bringing people a more convenient, efficient, and secure travel experience.

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