Intelligent Applications to Smart Cars Based on 5G MEC with Iot

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ABSTRACT
With the rise of 5G as a burgeoning computing method, MEC technology has gained traction. It gives a revolution in automotive field with its low latency and high response. The article introduces the concept of MEC and gives coordinate development status first. Compared to traditional network and cloud computing, the MEC can offer low latency and high computing power service. Then, three core technologies are discussed and analyzed in depth: sensor, digital twin, and V2X communication. The sensor contains three typical methods of object detection and the MEC will support the CNN algorithm to give precise results in hardware. The digital twin can also apply with MEC as effective tools in the manufacturing of the smart car. With MEC assistance, the V2X can reduce the delay and packet loss. Further examples of applications based on MEC are given. After that, the advantages and limitations of mentioned applications are analyzed. Finally, the conclusion gives a brief overview of the automotive industry that the MEC can decrease the latency and offering extraordinary computing power to integrate different parts. It also advises the practitioners to give further experiments in three key parts of smart car for their potential value and well feasibility. The further trend of MEC in the smart vehicle and the defects that need further work are reviewed.

Keywords: *Mobile Edge Computing, Digital Twin, Autonomous driving, Internet of Things (IoT), V2X Communication*

1. INTRODUCTION

With the telecommunication technology revolution, the 5G has been put up as a new infrastructure construction project globally. Mobile edge computing (MEC), as the core of 5G, is applied to various fields, especially the vehicle. According to the research of Martin Placek, the number of autonomous cars with at least Level 1 autonomy (driver assistance) is projected to grow between 2019 and 2024 from 31.4 million to 54.2 million as estimated [1]. In China and America, the car PARC is more than 280 million in 2021 and the worldwide car sales grew to around 66.7 million automobiles in 2021, up from around 63.8 million units in 2020[2]. It reveals giant needs for vehicles and high potentiality for the car to proceed to an intelligent era with applications such as autonomous driving, smart parking, and intelligent traffic. The implementations of relevant applications require low latency, fast response, and huge flow which can only be solved by the MEC based on 5G nowadays.

The article will discuss MEC technology development with its strength and drawbacks. In the use of MEC, several technologies in the manufacturing and driving fields of smart vehicles will be analyzed. This article can give a brief view of applications to smart cars based on 5G MEC and predict the future trend of the smart car which does help relevant practitioners.

2. MEC

2.1 Concept of MEC

Mobile edge computing (MEC) is a technology that is currently being standardized in the European Telecommunications Standards Institute (ETSI) Industry Specification Group (ISG). According to the ETSI Whitepaper, Mobile Edge Computing provides an IT service environment and cloud-computing capabilities at the edge of the mobile network, within the Radio Access Network (RAN) and in close proximity to mobile subscribers [3]. It fixes the weakness of clouds services with low latency, efficient network operation and service delivery.

In traditional network service, the end-users send requests to the clouds and get a coordinated response. The cloud service, which combines a large number of servers, can offer the significant computing power to the local device by computing the task from end-users and sending back the results. However, the cloud servers usually possess a long physical distance to the users' device which will cause latency. Besides, the explosion of requests number and long distances require more base stations to receive and transfer the data which will bear extra energy and infrastructure cost and transfer delays. In that case, the MEC is put forward to solve these problems. The users' requests will be managed in the local network edge instead of delivered to the remote core clouds server to maintain the low latency.

2.2 MEC Referenced Architecture

The MEC Architecture, as shown in figure 1, reveals the high-level functional compositions of MEC. It contains two parts which are Mobile Edge (ME) system-level and ME host-level.

On top of the whole architecture is the ME system-level management, which contains the operation support system (OSS) and ME orchestrator (MEO) as the basis to run the ME applications [4]. Beneath the top structure is the ME host-level. It consists of ME host and corresponding management composition. The ME host can be further divided into the ME platform, the ME applications and the virtualization infrastructure. The virtualization infrastructure will execute the rules received from the ME platform and organize the order between the applications, services, and networks in order to provide corresponding computing resources. Meanwhile, the ME platform supports the local domain system server to lead the user stream to ME applications. Moreover, the communications between ME platforms are based on the Mp3 reference point which is designed for procedures control. This interface can do help to build an inner network of different platforms. With the building of the virtualization infrastructure, the applications are able to interact with the ME platform over the Mp1 reference point, which controls the process of event switch locating and availability indicating.

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To give accurate and detailed management of application lifecycle, requirements, and elements, an ME platform manager (MEPM), which is a host-level entity, is put into use. The management then offers the instruction of corresponding events, which contains authorizations, stream rules, DNS configurations, and resolving issues, to the MEO over the reference point Mm3. It connects the ME system level and ME host level. The users' requirements and interactive functions mostly rely on the ME system level. For the customer-facing service (CFS) portal and user equipment (UE) application, they are designed to receive the users' requests and then passed to OSS through Mx1 and Mx2. OSS will ensure the integrity and authenticity of these requests and put forward the qualified requests to the MEO for the next process.

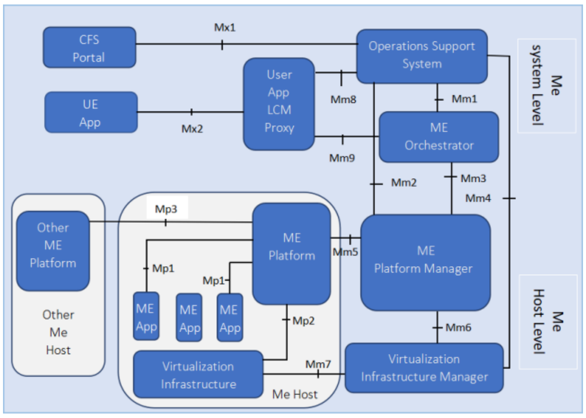

Figure 1. MEC Referenced Architecture

3. INTELLIGENT APPLICATIONS FOR SMART CAR

The sensors parts are the basic equipment of the smart car to implement intelligent functions such as automatic drive. With Vehicle to everything(V2X) communication, the smart car could communicate with other devices. Furthermore, the digital twin technology enables the more powerful function of the smart car. The following part will discuss these technologies and analyze how they implement with MEC.

3.1 sensors

Camera, Lidar, and Radar are three classic methods to implement vehicle detection. The radar is using the low-frequency radio wave to detect obstacles. It can work in bad weather conditions and will not be affected by the brightness of the environment and the status of the obstacles. However, it can not get more parameters like the shape of the target as Lidar does. Lidar is a system that emits a laser beam to detect the target's position, speed, and other characteristics. By emitting the laser beam to the target and receiving the signal (target echo) reflected from the target, the relevant information about the target can be obtained after processing the comparison between the echo and the original beam. The radar is using the low-frequency radio wave to detect obstacles. It can work in bad weather conditions and will not be affected by the brightness of the environment and the status of the obstacles. Lidar has the advantages of high precision and high resolution, as well as the ability to build 3D models of surroundings. However, its disadvantage lies in its weak detection of stationary objects such as median strips. While the Radar and Lidar can neither identify the colors nor give the visual picture to the driver as the camera does. The video camera can give precise detection of surroundings with the recognition algorithm, but it has bad robust to extreme weather conditions like rain and fog.

3.2 Digital twin

A digital twin (DT) is a digital mapping system to reflects the life process of a real object in the digital world by using the physical model, system simulation, digital prototyping and other related methods[5]. A DT system is consist of three main parts: physical entities, virtual models and services. The physical entities that serve as the foundation for virtual models are real-world objects or systems that adhere to reality's physical rules. Virtual models should be digital copy of physical entities, which reproduce the physical appearance, properties and behaviors followed related rules. With DT reflections to targets' shape, position, gesture, status, and motion[6], big data analytics and machine learning can be applied to obtain the assessment of present states, prediction of future trends as the service. By using the virtual models to do the test simulating reality, the cost of damage in the experiment can be saved and the security of participants can be ensured. Besides, some extreme conditions which hard to be achieved in the real world can be simulated in the digital world and implemented in the test. It is beneficial to many fields, such as manufacturing and smart traffic.

3.3 V2X communication

Vehicle to Everything(V2X) communication is a concept containing the Vehicle to Vehicle (V2V) communication and Vehicle to infrastructure (V2I) communication. V2I communication requires a wireless network where vehicles exchange the information such as speed, location, driving and directions based on the dedicated Short-range communications (DSRC) standards and cellular networks[7]. While the Vehicle to Infrastructure(V2I) replaces one communicatee from moving vehicle to the related infrastructure.

3.4 Implementation based on MEC

A smart car requires three significant parts: sensor, processor and communication. The sensors models allow the drivers to perceive the inner-vehicle status and outer-vehicle surroundings. The communication model enables the vehicle to interact with other devices and interment. By analyzing the data from sensors and communications, the processors make the final result and give back the decision to the vehicle to implement. While the achievement of the smart car requires enough computing power to support the three parts with low latency. The vehicle space is not enough to install powerful servers and the cloud service can not guarantee the transfer delay so the MEC is applied to offer high computing power with low latency.

In vehicle detection sensors, algorithms based on convolutional neural network(CNN) are implemented to help devices to get precise results, especially for camera detection. Since Ross Girshick put forward R-CNN in 2013, people have proposed Fast R-CNN, Mask R-CNN, SSD, YOLO and other algorithms in just a few years. The target detection method of two-step detection (R-CNN series) needs to generate a large number of candidate frames first and then classify and regressive candidate frames using CNN. Single-step detection methods (SSD, YOLO series algorithms) directly use regression method in the CNN to predict the location and category of the target in one step. Although the two-step detection has higher accuracy in most situation, it consumes a lot of time cost and huge computing power. In the most vehicle and pedestrian detection, the YOLO is the only choice. By applying the MEC, the YOLO algorithm can run much faster and implement more iterative layers in CNN to get preciser result. The MEC can overcome the computing power limitation with low latency, allowing R-CNN implementation in vehicle camera detection.

In the manufacturing of the smart car, the DT has been used to obtain the digital models of car parts. With DT models, experts can test the product status and make adjustments promptly. The value of DT models of car parts has been demonstrated by many enterprises like Tesla [8]. In the production process, the assembly lines require low latency and a fast response supervision system. The MEC can achieve the destination with enough available computing power and low latency in place of traditional network service. Another example is the digital twin in automatic driving. Wang et al put forward a digital twin paradigm using an advanced driver assistance system that supports cooperative ramp merging in cloud service, though there are communication delays and packet losses to some extent[9]. The MEC can solve problems which are revealed by B. Fan et al research. They suggest the sensing and computing capabilities of the automatic vehicle can be strengthened to guarantee real-time safety with MEC[10].

Furthermore, in communication, the MEC can reduce communication delay and increase response speed. M. Emara et al make researched MEC-assisted V2x communication and result that the deployment of MEC infrastructure can substantially prune the End-to-End communication latency[11]. More algorithms for the offloading in MEC-assisted V2X tasks have been put forward to optimize the MEC performance in V2X communication.

4. CONCLUSION

Mobile edge computing (MEC) is the key technology in the automotive field with the smart vehicle era coming under the flourishing development of 5G. Governments have begun to build the smart city and traffic with various infrastructures in the 5G trend which make it possible for the vehicle to step into the intelligent era. The MEC breaks the barrier in latency and bandwidth of traditional network and cloud services so that the core technologies in the automotive industry can be upgraded with 5G MEC. The sensors, V2X and digital are significant elements in autonomous driving. Industry 4.0, also requires sensors and digital twin technology to optimize the performance and reduce the production of waste. The key is to give high computing power with low latency which can be offered by MEC.

This article analyse three key parts of smart car design implementation based on the MEC with their advantages and drawbacks which reveals the feasibility and problems in implementation with several possible solution. The article gathers the sensors, communication and manufacturing technologies of the smart car and demonstrate how MEC improve their performances.

In automotive field, the productivity improvement from MEC ought to extend to more technologies to break the limitation of the original process. Relevant practitioners can dig into some areas which have not been applied to MEC yet to figure out their potential commercial utility value, though there are defects that remain. In sensors combined with CNN algorithms, the structure of neural networks based on MEC can still be improved to dig more efficiently. The V2X communications in offloading decision of MEC can be further adjusted to achieve a more reliable status. The algorithm used in digital twin needs to give more iterations and evaluations by experts to give a more precise prediction of the target.

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