5G network slicing: applications and benefits within industry

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***Abstract*—Network slicing is a network architecture which is applied in 5G systems by dividing the physical network infrastructure into multiple logical isolated network parts, so called slices. Different requirements of performance can be fulfilled simultaneously, which introduces new business models, technologies and opportunities. This paper discusses technical background, benefits, requirements, and architecture of network slicing. The applications of 5G network slicing in industry are also covered, mainly within the automotive sector and AR/VR applications, since these areas benefit greatly from network slicing in terms of improved performance and availability. Lastly future challenges of this promising technology are described.**

***Index Terms*—5G, AR/VR, automotive, network slicing, virtual network**

I. Introduction

The development of communication technologies has been one of the most important factors in the growth of modern society and business. Therefore, it will make a huge impact on future developments that are yet to come.

The amount of improvement in this mobile generation is extensive and enables wide varieties of use cases [1]. However, different application scenarios correspond to different network requirements. To accommodate these requirements for quality of service (QoS), the 5G network divides the network resources and functions to form network slices according to the requirements from customers. Network slicing is therefore one of the key technologies in achieving flexible and scalable networks. The purpose of this paper is to demonstrate the use cases derived from this technology and how they are implemented. This is achieved by discussing requirements of the network system, rather than in-depth analysis of the enabling technologies.

A. Goal of Network Slicing

According to the capabilities of network slicing, there are several requirements for the 5G network to ensure the implementation of network slicing [2]:

- Ensure that every network slice is isolated from others.
- Dynamically assign and manage network slices.
- Keep service security.
- Ensure network slices are transparent to customers.
- Support the end-to-end resource management.

B. Technical background

A network slice consists of different parts, for example hardware and software, to fulfill the assigned functions in a flexible and secure way [3]. The important performance metrics and network demands include: latency, security, data rate, reliability, coverage and bandwidth [4]. Because network slicing aims to simultaneously meet different types of needs, it constantly optimizes the services, while serving the customers [4].

Network slices can be created in different ways. One possible way to design a network slice is by designating an end-to-end part of a physical network as one slice [5]. This would however be very inefficient as this slice type is fixed to one physical network. Therefore, the physical infrastructure should instead be used to create multiple different slices for multiple different users. This is impossible to realize only by hardware and therefore virtualization is introduced. Different techniques for managing and changing these slices can be used but dynamic slicing is preferred due to its possibility to reconfigure the network continuously according to different requirements [6].

C. Benefits and necessity

5G will enable new services and business, which are impossible to realize by using the existing network, such as 4G [2]. 5G combined with network slicing permits business users to customize the network capabilities based on their specific requirements [7] that comply with service level agreement with mobile operators. However, there are dedicated networks that cater to specific use cases. They are costly and their performance too inflexible to support the new services in the 5G network [8]. Therefore, it is necessary to implement a flexible, efficient, low cost, reliable and low latency technique, which is network slicing. After implementation, network slicing will be beneficial for both service providers and customers [2]. For example, 5G is expected to support fast moving autonomous vehicles and simultaneously serve numerous devices. It can be realized by network slicing, since the service provider could dynamically configure the slice based on the consumers' needs.

II. Network slicing architecture

Slices can consist of many different segments of the physical network and they can span over both the core network and radio access network, using dedicated or shared process power, storage, and bandwidth, while they are still isolated from other network slices using the same resources [7], as shown in figure 1.

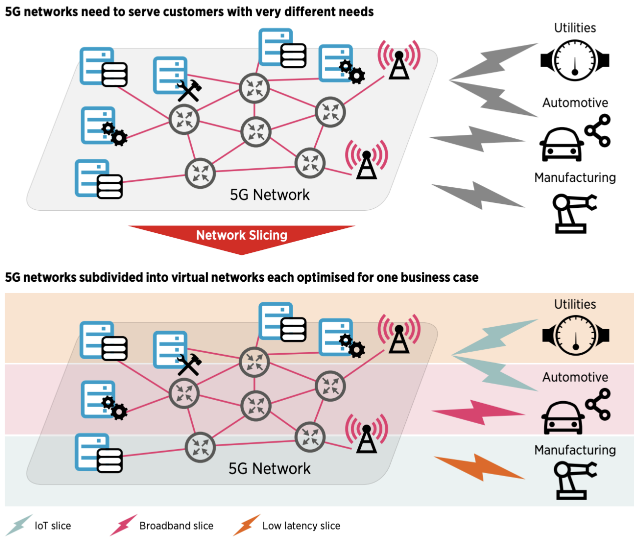

Fig. 1. Difference between networks with and without network slicing. Illustrates how resources can be optimized and shared between different businesses and users. From [7].

It is noticeable from figure 1 that different sectors with different needs can coexist by sharing different slice functions. For example, the figure above demonstrates how the 5G network provides the same service for utilities, automotive and manufacturing. After slicing 5G network into several virtual networks, the automotive and utilities could share the same internet of things (IoT) slice, which is distributed by customer requirements and reflects the efficiency of network slicing, since it can simultaneously serve multiple and diverse requirements. Whereas, this puts some constraints on security as different slices under different security environments sharing the same medium. Furthermore, by attacking one slice, another slice is possible to be affected [9]. Different pieces of user equipment (UE) can also use different slices. Therefore, the security of one slice can be compromised by accessing the slice through the UE. Above all, extra inter-slice security is needed [9] and common standards should be developed.

To realize the requirement of programmability and resource sharing needed, network function virtualization (NFV) and software defined networking (SDN) is used [6]. By virtualizing the physical network into smaller functionality-oriented ones, different services can be fulfilled by orchestrating slices in the background. SDN is the network configuration, which unlike traditional management, it is dynamic and uses cloud computing to improve network performance [10]. NFV is instead more connected to the actual physical infrastructure's functions and is the virtualization of TCP protocols, virtual private networks and hardware communication. This makes it easier to change and allocate resources for slices as changes can be done by the operators rather than consumers [11].

It is important that these slices are always developed and optimized on the basis of the mutable requirements from users. Efficient management of slices is therefore of great importance. For example, optimizing slice resources and regularly performing life cycle assessments [3].

III. Applications of network slicing

People's daily work and life are increasingly dependent on connectivity. Due to the benefits of network slicing, it is widely applicable for various business, such as: industry automation, massive IoT, enterprise network, and healthcare.

The international telecommunication union (ITU) has defined three main uses of 5G: enhanced mobile broadband (eMBB), ultra reliable low latency communications (URLLC), and massive machine type communications (mMTC) [12]. As illustrated in figure 2, various services require different network performance. This section aims to exemplify and mainly focus on the automotive sector and AR/VR live broadcast. Other possible future implementations are also briefly discussed.

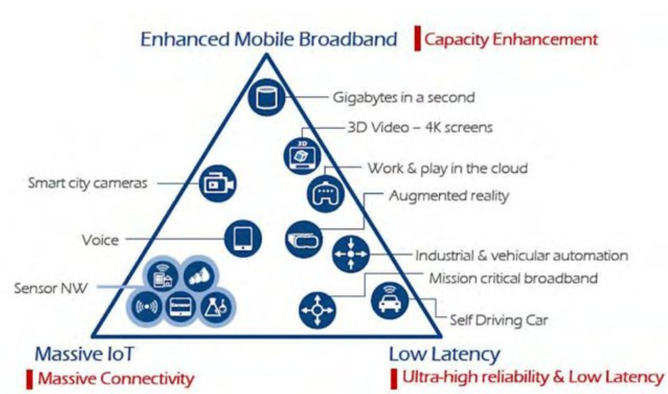

Fig. 2. The triangle of 5G services. Showing the most important requirements, i.e. benefits of 5G, for different sectors. From [13].

A. Automotive sector

There is a growing demand for mobile communications in vehicles [9] and it is not possible to fulfill the changing requirements of vehicle-to-x (V2X) services with the current long term evolution (LTE) networks [14]. Hence, many different types of network slicing technology are needed, both in manufacturing and for driving automotive vehicles, such as, car sensors, entertainment, autonomous driving, massive IoT in factories and vehicle platooning to name a few.

This paper focuses on three technologies used while driving to improve safety, efficiency and comfort, namely: traffic safety and efficiency service, infotainment in vehicles, and technologies to enhance/help autonomous driving [14]. These different use cases expect different types of properties and performance. Hence, illustrate the distinguishing features and benefits of network slicing; flexibility and multi-tenancy [6].

Firstly, by sending data between different vehicles and other structures in the traffic environment, accidents can be avoided (by sharing positions and observations etc) and efficiency increased (by e.g. platooning) [3]. The key is that the received information needs to be up to date, therefore low latency is very important, especially for autonomous driving. Coverage and reliability will also become very important for autonomous cars' navigation systems, since they need to be driverless and reliable everywhere (rural areas) but also to work in dense areas (city center). Infotainment services are not as important as safety features, which can tolerate latency but requires high data rates. However, the relevance of this area becomes more important as media consumption is likely to increase proportionally with autonomous vehicles [3].

Figure 3 illustrates the three prior mentioned use cases' requirements on performance and showcase how different they are. For example, some need very high latency or data rate while some require almost none. By dividing the network into multiple logical ones, resources can be shared to be able to reliably cater to all these needs simultaneously.

Service category	Traffic safety and efficiency service	Autonomous driving related service	Vehicular internet and infotainment service
Communication mode	V2V,V2P,V2I	V2V,V2I,V2N	V2N
Maximum latency	100 ms [3]	10 ms [11]	Low latency is not critical for media streaming [2]
Reliability requirement	About 99 percent [2]	99.999 percent [11]	Not a concern
Data rate	About 1 Mb/s [2]	10 Mb/s [11]	0.5 Mb/s for web browsing, up to 15 Mb/s for HD video [2]

Fig. 3. Examples of typical QoS requirements for different automotive service categories[2] [14].

One downside with network slicing in the automotive sector is that the networks used are already very complex. Thus, adding network slicing on top of that would make the network management even more complicated, making today's traditional model-based networks ineffective [14]. Deploying machine learning (ML) or artificial intelligence to the network would utilize the history and properties of the network and in advance allocate resources [4] which would streamline and optimize network slicing. If ML or other smart systems are used, the main problem is however 5G coverage [15], since many of these technologies will heavily rely on real-time data, for example autonomous driving.

The development of automotive systems will benefit of 5G network slicing since it enables extended usage and coverage while reducing costs [15]. The dynamic reconfiguration opportunities combined with its possibly to fulfill various requirements of latency, data rates and coverage will benefit all V2X services and lead way for other future opportunities as well. Specific applications which were not further discussed here but which will benefit greatly on network slicing, include road warnings, information sharing (e.g. see-through vehicles) or cooperative driving [15].

[2]Other sources claim other values (but similar in magnitude of order).

B. AR/VR sector

Augmented reality (AR) and virtual reality (VR) are two of the most emerging industries in the world [16]. AR is a technology that merges virtual information with the real world. VR is used to construct a virtual environment, and provides a fully immersive experience of virtual reality based on user's sensory inputs, such as, sound, touch and sight. There is no doubt that the development of 5G plays a role in promoting AR/VR technologies. To implement AR/VR, they have similar requirements of tight synchronization and high-capacity network environment. This section discusses how to address these requirements.

Table I shows the example requirements for VR implementation. Various degrees of VR experience and different video resolution bring distinct requirements on the data transmit speed and latency. Higher interactivity means the higher data rate should be provided.

	Experience stages	**Resolution/format**	**Speed requirement**	**Latency requirement**
Limited interactivity	Basic VR experience	8K, 2D, 3D	40Mbps - 60Mbps	20ms - 30ms
	Advanced VR experience	12K, 3D	340Mbps	20ms
	Highest VR experience	24K, 3D	2.3Gbps	10ms
High interactivity	Basic VR experience	8K, 2D, 3D	120Mbps - 200Mbps	10ms
	Advanced VR experience	12K, 3D	1.4Gbps	5ms
	Highest VR experience	24K, 3D	3.4Gbps	5ms

Table I. VR experience requirements [17]

To fulfill the performance requirements of synchronization, the idea of network slice designing should conclude the consideration of network condition (e.g., interference), frame rates and bandwidth of videos [15]. Therefore, these applications depend on deterministic traffic. Meanwhile, network slicing helps to deliver the packets and tries to minimize the inter-packet delay. To further achieve the requirements of synchronization, a delay tolerance is proposed. This means that a certain traffic flow should reach the end-user within a certain latency. The level of delay tolerance can be flexible due to different application scenarios which exemplifies the flexibility of network slicing.

Also, both AR and VR rely on video computing and processing. Therefore, AR/VR technology requires high density computing to deal with AR/VR video processing. To meet these requirements, the transport network can be divided along a spatial dimension, which is called spatial division multiplexing (SDM). Resources will then be assigned to different services according to the difference in space. Also, the resource isolation must be realized at the same time, which is known as slice isolation technique. Since different slices require different security measures, slice isolation is necessary to prevent depleting slice resources [12].

Above all, 5G within network slicing provides conditions to implement AR/VR. Remote surgery can be an example use case of AR [16]. This allows doctors to remotely perform operations even in unsafe conditions. VR can be applied in many fields as well, such as VR education, VR museum visiting and VR games. Users can deploy multiple slices to support AR/VR effectively, one slice for voice conversation and another slice for video handling. By using network slicing, high capacity and low latency is provided and consumers are able to experience steady and smooth connections anytime.

C. Impact on society and environment

Sustainability and environmental impact must always be considered when developing and implementing new technologies. It is therefore important to consider using energy efficient designing and especially renewable energy [5].

One significant cause for the development of 5G technologies is the need for higher data rates, coverage and an increased number of users. The large difference in performance is not compatible with today's systems and upgrading them would come at a great expense since the investment of new devices and the increased energy consumption would be to large [9]. To be sustainable economically, the core of the network operations must be able to change and adapt to consumers' needs. One way to do this is by using network slicing. This not only enables the possibility to cater to the needs of every user, but also uses the network as efficiently as possible.

Since more data will be processed in cloud networks in the future, many new opportunities arrive. To make it sustainable and efficient, the usage of ML will be very important, as previously discussed in section III-A.

By having multiple virtual logical networks exist within the same physical network, network slicing improves efficiency and is therefore more economically sustainable than current networks [7]. Network slicing makes network infrastructure much more responsive to changing external factors from the different users and can be customized, enlarged, and improved, without large effects on the other users.

D. Possible future applications and challenges

This technique has potential to be implemented in many other business when 5G is widespread and fully developed, for example, industry automation. This service is relied on machine to machine communications. Operator offers URLLC slice to factories, so that the robots can be remotely controlled and monitored to work in the factories [7]. This service requires sub-ms latency for closed control loops and near real-time communications [6]. These use cases take time to be implemented in practice since they require a high level of 5G network development. Nonetheless, they are worth waiting for.

As a potential technology, network slicing is immature and plenty of knowledge is still at a theoretical stage and has not been practiced yet. This section briefly concludes the possible challenges in the future applications and researches.

Efficient transfer: To realize near real-time latency, transfer efficiency has to be increased. However, research of this problem is still at the theoretical level. Once there are achievements applied in the field, the customisation ability of network slicing will be magnified. Furthermore, the automotive and AR/VR fields will be promoted. Since both of these two fields require high throughput and real-time communication, in order to guarantee users' experience, efficient transmission is the goal of next step.

Security: Security is one of the advantages in network slicing. Nowadays, there are many platforms which provide services to meet data security and privacy requirements beyond current network capabilities. Therefore, security is one of the most important features in future development.

IV. Conclusion

This paper illustrates the benefits of network slicing and the technology behind specific applications. By dividing the physical network into logical slices, different performance in terms of scalability and flexibility of different slices can be achieved. Network slicing will be beneficial for automotive vehicles and AR/VR technologies, since it improves usage opportunities and performance of their service. As a new technology and extension of 5G, it is not mature enough to be widely implemented, but as it is tested and implemented, it will gain a wider audience. One downside with network slicing is that it complicates the already complex network architectures. It is however needed to be able to widen the usage of 5G and one solution to simplify the process is by using ML to autonomously update the network structure. Above all, 5G brings numerous use cases to a new stage and network slicing lets them be practical.

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