GTI
5G Network Slicing White Paper V2.0

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Version:	V2.0
Deliverable Type	□ **Procedural Document** √ **Working Document**
Confidential Level	√ **Open to GTI Operator Members** √ **Open to GTI Partners** □ **Open to Public**
Working Group	XXX
Task	5G eMBB Architecture – Network Slice
Source members	ZTE,Huawei,Nokia
Support members	ZTE,Huawei,Nokia
Editor	ZTE,Huawei,Nokia
Last Edit Date	31-01-2019
Approval Date	DD-MM-2019

Document History

Date	Meeting #	Version #	Revision Contents
12-02-2018		V1.0	Initial first version of GTI 5G Network Slicing White Paper
31-01-2019		V2.0	Update GTI 5G Network Slicing White Paper

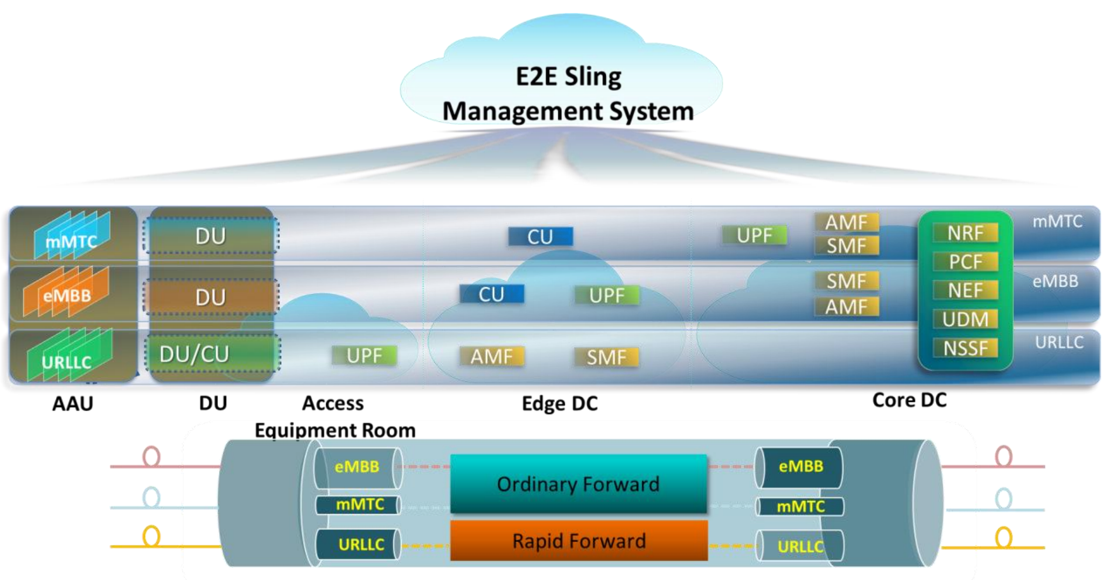
Table of Contents

1 Network slicing conceptual architecture

Network Slice is a logical network that provides specific network capabilities and network characteristics. It realizes multiple network services in a unified physical facility and provides multi-level isolation and security, reducing the cost of network construction for operators and satisfying the needs of multiple industries in the vertical industry.

5G end-to-end network slicing is flexibly allocated according to network resources, and network capabilities are combined on demand. Based on a 5G network, multiple logical subnets with different features are virtualized. Each end-to-end slice is composed of a core network, a wireless network, and a transmission network sub-slice, and is managed by an end-to-end slice management system.

Figure 1-1 Slicing Concept Architecture



Different Slice (e.g. mMTC,eMBB, URLLC) can contain slice specific NFs(e.g. AMF,SMF,UPF etc.) or slice shared NFs(e.g. AAU,DU,CU). CN slice subnet can be virtualized and distributed in Edge DC or Core DC .TN slice subnet can provide rapid or ordinary forwarding channel for different SLA requirement. AN slice subnet can provide different network slices by resource scheduling. Different communication services are provided by service provider through using different slice. User can access different services based on different slices.

2 Driving force of Network slice

2.1 Trends and Demands of the Vertical Industry

Vertical Industry worldwide is undergoing a tremendous digital transformation featuring the convergence of information/communications technology and operation technology in various segments. Industry digitization involves the connection of massive numbers of machines and people, with open data sharing and a generic ICT infrastructure to support them. 5G will be a major technology in growing industrial digitalization, creating and enhancing industry digitalization use cases. We categorize the vertical industry 5G serving as following according to the basic 5G service/slice types eMBB, mIoT and URLLC:

Figure 2-1 5G Vertical industry

	vertical industry				
eMBB	Smart City(e.g. surveillance)	Remote Education	Tele- medicine□		
mMTC	utility(Smart Meters & sensors)□	Collabora-tive robots	eHealth monitoring		
uRLLC	Remote Surgery	UAV control	Manufacturing	Utilities	Robotics

Here we will take a representative vertical industry as insight for the trends and demands in some vertical industry.

Table 2-1 Trends and demands in vertical industry

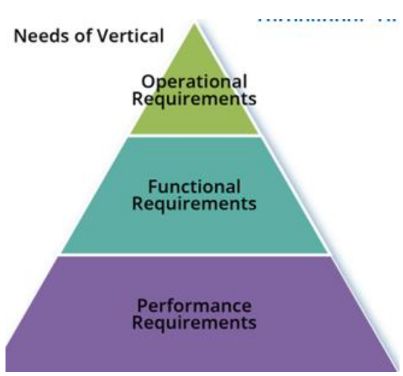
Manufacture	Hyper competition with no sustainable competitive advantages. Increasing volatility from business cycles and product lifecycles. The smart factory is advancing from developments in the internet of things and automation
Healthcare	Increasing consumer attention on wellbeing Increasing cost to fit with social demographic changes Increasing demand on quality, patient safety and data storage. Changing consumer behavior, freedom of choice and alternative service provider.
automotive	Autonomous driving and connected traveler with telematics. Car sharing and changing commuter habits Electric mobility with decreasing battery costs and a green agenda

	Digital enterprise and connected supply chain Digital vehicle ecosystem Infotainment on the move Urbanization and inter mobility Environmental awareness---CO2 emissions and public spaces Urban lifestyle and growing expectations on public transport
Energy utility	Oil supply imbalance and instability and carbon constraints Structural shifts with increasing retiring assets New decentralized business models Electrification and renewable energy generation

Requirement of the vertical industry

5G is addressing the more stringent and business critical requirements of the vertical industries, such as real-time capabilities, latency, reliability, security and guaranteed Service Level Agreement (SLA)'s. Here we set three hierarchy of requirements for vertical industry including 'Operational Requirements', 'Functional Requirements' and Performance Requirements'.

Figure 2-2 5G Needs of Vertical



Type 1: Performance requirements: latency, throughput, availability and resilience, reliability, coverage and mobility.

The target of very low latency combined with high reliability of 5G will enable many applications to be untethered, supporting a larger number of use cases that today require fixed line connectivity. High availability is essential to ensure minimal service accessibility to critical infrastructures or service providers in case of a disaster. Reliability is defined as the probability that a certain amount of data to/from an end user is successfully transmitted to another peer within a predefined time frame, i.e., before a certain deadline expires.

Type 2: Functional requirements: Security and Identity Management, Isolation.

Security communications need to guarantee that personal or confidential data must not reach the public domain and not be modified or replayed by unauthorized parties. Identity management relates to the management of devices and user identities .5G will connect a huge variety of devices and users which have subscriptions to vertical service providers. This demands for a new device-user identity management and related lifecycle management, which will complement the universal SIM (USIM). While using a shared network infrastructure, the different vertical industries (and optionally the various services), need to be isolated one from another. That means that each virtual network belonging to different vertical customers are protected, preventing their resources from being accessed by network nodes of others.

Type 3: Operational requirements

Verticals will be able to timely deliver their service to their own customers by ordering a network slice it in a simple way, e.g. through a simple user interface. Several industries may rely on the Mobile Network Operator (MNO) for the deployment and management of their own network slice while other industries may want to do it independently. Depending on assets and business, multiple models are needed for managing service/applications and customers of the verticals. In one model the vertical industry customer has their own customers but no network resources. The vertical requests a network slice via a North Bound Interface (NBI) of the MNO, realized e.g. though a dashboard-like web service. Another model is the one of a vertical who owns part of network resources and designs and customizes own service. In this case the vertical provider may need part of the network (for example the RAN) of the MNO according to a given SLA via the NBI as in the case above.

By 5G network slicing based on SLA business service agreement signed with customers, CSP can provide isolated and functional network services for different vertical industries, different customers and different services. In the future, the 5G network slice will have a broad market application prospect for consumer market and vertical industry. However, due to the different maturity of the 5G industry chain applied by different industries, the scale application of the 5G network slice will be divided into three stages.

- The first outbreak will be eMBB business with the most mature industry chain and clear market prospects, such as 4K / 8K HD video live broadcast, 360 degree VR watch, VR /

AR / MR cloud game, as well as smart city HD video surveillance, car entertainment, distance education, etc.;

- Then URLLC business closely related to the vertical industry, based on its ultra-low latency, ultra-high reliability, combined with eMBB, will fully enable digital transformations in industry, energy, transportation, healthcare, education, agriculture, etc., such as robotics, smart energy, autonomous driving, networked drones, telemedicine diagnostics, etc.;
- Finally, mMTC business may have a low commercialization due to the lag of the mMTC standard, the high initial terminal cost, and the competition of existing IoT and other IoT technologies such as 3G / 4G / NB. Typical applications include smart homes, asset tracking, smart city environment monitoring, smart water meters, and more.

2.2 Insight into the value of network slicing

Until now, telecom network design has been largely static and based on creating a one-size-fits-all infrastructure. However, the arrival of 5G brings about a new focus on specific use cases and how they can be supported. Network slices will create virtual instances of a network, using the same underlying hardware, to meet each use case's needs.

Why network slicing is important

1. Industry digitization will be fueled by customized communication solutions that are dynamic and open. Through Network Slicing, redefine information sharing in a wide variety of industrial scenarios, ranging from ultra-reliable low-latency machine communications to the small-packet burst transmission of operations data.
2. 5G slicing technology in particular, will help make pervasive networks of intelligent objects, machines, and people a reality. There is a growing number of opportunities for new business models bringing artificial intelligence, robotics and autonomous control to networks of industrial machines, devices and systems. This is re-defining the need for a new type of secure, robust and customer managed communication.
3. Future industry will be characterized by rapidly evolving service requirements and innovations. Correspondingly, the sustaining network technology should also be flexible and scalable to adapt to ever-changing business/service needs. 5G Network Slicing for Cross Industry Digitization is expected to help connect, move and process information at speeds.

4. The network slicing with next generation communication fabric will provide effective mechanisms to allow dynamic provision of communication services for different tenants (industry users) with proper independence.

The true value of network slicing

Operators face great pressing on business model transformation: They need to change business from traffic management to differentiated services for vertical industries. In addition to the traditional B2C business model, it is necessary to seek new business models such as B2B or B2B2C. Network slicing offers operators a way to provide premium services to multiple customers. There are two revenue opportunities for operators that Network slicing can creates:

- ✓ Serving existing high-end customers with higher grade service: services tailored to the needs of a current customer or customer segment are more valuable and can win a premium Average Revenue Per User (ARPU)
- ✓ Reaching new customers for whom premium service is critical: new customer segments can be addressed, creating completely new, additional revenue streams.

From Bell Labs Consulting's result (Unleashing the economic potential of network slicing), with network slicing, operators have a new means of expanding their business and winning new revenue by delivering premium services focused on the requirements of customer segments, such as high network performance in key areas or to meet specific regulatory or compliance needs. By applying automation to control network slice operating costs, operators have the potential to use network slicing to win business in many new areas. Network slicing delivers higher operating margins.

- ✓ Network slicing has the potential to reach new customer segments and generate substantial extra revenue for an operator. These customer needs cannot be met with single, one-size-fits-all networks
- ✓ End-to-end network slicing opens further customer segments with costs that scale more or less in line with the additional demand, making them commercially viable
- ✓ Implementing automation effectively brings down the operational costs of network slices, enabling an operator to address more customers profitably. With full automation, the TCO of even high numbers of network slices becomes acceptable

The accurate preparation of network slices and their operation is critical to ensure that premium services are supported by the network.

3 Key Technologies of E2E Slicing

3.1 Enabling Technologies of the Network Domain

3.1.1 Core Network

The Core Network (CN) is considered as the most critical and essential part in network slicing. The CN provides the network services for the tenants and their end users, for instance control plane functions (mobility management, session management, policy control, and charging) and user plane functions (data forwarding). To meet the diversified demands of vertical industries, the network service customization and on-demand deployment are the key concepts that need to be reflected in the CN design. The CN is envisioned to have the following attributes:

Cloudification:

Cloud native technology adoption will enable the future CN to support a large number of NSIs over common infrastructure, which is based on a three-tier DC networking mode. The bottom layer is the edge DC that is close to or on the access sites. The second layer is the local DC, and the upper layer is the regional DC. Taking advantage of cloudification and virtualization, it is possible to let the NSIs “breathe”, in the sense of scaling the resources up and down according to the real traffic needs.

Service-Orientation:

In 5G, CN will apply service-based architecture to realize flexible orchestration of network functions, services as well as capabilities, which aims to satisfy diverse requirements from different tenants with high network operation efficiency.

As illustrated in Figure below, the CN architecture defines the services provided by different network entities and their corresponding relationships. Such services include control plane and user plane services. The CN defined for 5G should allow the coexistence of logically isolated NSIs for different tenants on a common infrastructure. The CN makes the decision of NSI selection for a terminal that attaches to the network, which could be based on the assistant from the terminal. Each NSI has its specific network topology, network functions, and allocated resources. The CN adopts a service-based architecture design methodology, which includes a unified database to enable a coherent view, and a programmable user plane to support network slicing. The CN architecture promotes the simplification of signaling interactions, enables the distribution of network functions, and allows customized network function placement (e.g., close to the AN to reduce latency). In order to consolidate wireless and wireline access using the same CN, it is also relevant to consider "access-agnostic" in the design of CN functions and architecture.

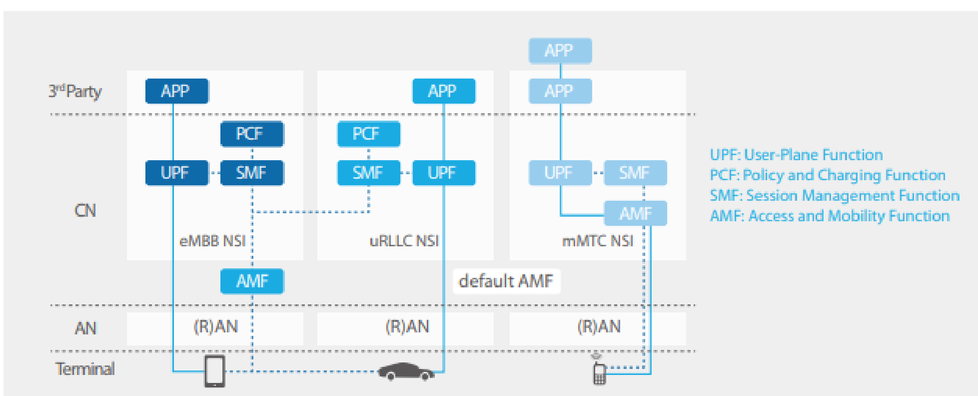
Modularization:

Compared to the 4G CN, the control plane and user plane functions will be further split and partitioned into fine-grained functional modules. These modules can be customized and flexibly combined in an NSI in order to meet specific functional and/or performance requirements.

On-demand function customization and dynamic orchestration:

Service-based architecture (SBA) and service-based restructuring of the software architecture enable network orchestration capabilities on 5G networks. To meet diversified network requirements of different industries, on-demand orchestration capabilities on 5G networks provide different network capabilities specific to each application. Additionally, 5G networks allow services to be deployed in different locations to meet different latency requirements.

Figure 3-1 Core network (CN) architecture with network slicing support example



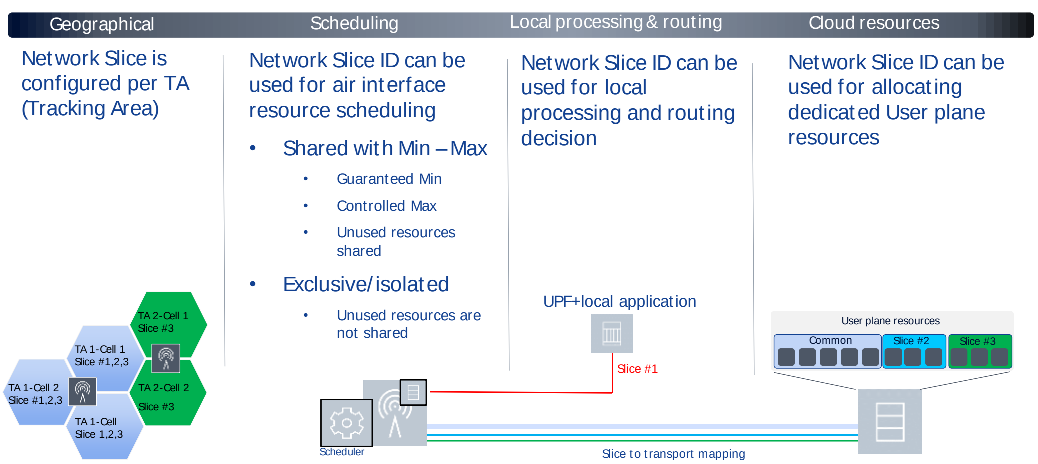
3.1.2 Wireless

The NG-RAN is preconfigured with the slicing support information, which includes the list of TAI Slice Support List per PLMN ID, configuration for each network slice, etc. The configured slicing information enables the NG-RAN supports a differentiated handling of traffic for different network slices. This allows the slice aware and slice optimized scheduler in the NG-RAN node.

In case of CU-DU split RAN architecture, the CU control and user plane (CU-CP, CU-UP) resources can be dedicated to certain slices, or common to several slices. This allows implementing a high-throughput CU user plane instance, for example, for an eMBB slice. It also allows the flexible deployment of CU-CP and CU-UP resources based on the needs of a given slice. For example, the CU user plane location can be geographically close to the DU for URLLC slices (although one CU-UP can still serve many DU), while CU control plane is centralized.

The NG-RAN supports resource isolation between slices. NG-RAN resource isolation may be achieved by means of RRM policies and protection mechanisms that should avoid that shortage of shared resources in one slice breaks the service level agreement for another slice. It should be possible to fully dedicate NG-RAN resources to a certain slice.

Figure 3-2 RAN slicing implementation options



The required support for network slicing in the NG-RAN includes following aspects:

AMF Instance and NW Slice Selection

During the initial Registration procedure, the UE conveys the NSSAI over RRC in the explicitly indicated format by the upper layer. The NSSAI consists of one or a list of S-NSSAIs (i.e. up to 8 S-NSSAI), where an S-NSSAI is a combination of:

- mandatory SST (Slice/Service Type) field, which identifies the slice type and consists of 8 bits (with range is 0-255);
- optional SD (Slice Differentiator) field, which differentiates among Slices with same SST field and consist of 24 bits.

Based on the assistance information (i.e. NSSAI) and GUAMI, the NG-RAN selects the AMF.

Table 3-1 AMF Selection

Temp ID	Assistance Info	AMF Selection by NG-RAN
not available or invalid	not available	One of the default AMFs is selected (NOTE)
not available or invalid	present	Selects AMF which supports UE requested slices
valid	not available, or present	Selects AMF per CN identity information in Temp ID

NOTE: The set of default AMFs is configured in the NG-RAN nodes via OAM.

The initial NAS is routed to the selected AMF, which performs validation of the UE rights to access a network slice.

UE Context Handling

During the initial context setup procedure, the AMF provides the Allowed NSSAI and additionally contains the S-NSSAI(s) as part of the PDU session(s) resource description, to the NG-RAN node. In case of CU-DU split, the gNB-CU provides the S-NSSAI per DRB during the F1AP UE Context Setup/Modification procedure. The NG-RAN supports policy enforcement between slices as per service level agreements. It should be possible for a single NG-RAN node to support multiple slices. It is up to the NG-RAN implementation to apply the best RRM policy for the SLA in place to each supported slice.

PDU Session Handling

During the PDU session establishment procedure, the 5GC indicates one S-NSSAI per PDU session, so NG-RAN is enabled to apply policies at PDU session level according to the SLA represented by the network slice, while still being able to apply (for example) differentiated QoS within the slice. The NG-RAN node allocates resources for a PDU session associated to a certain NW slice based on the given service level agreement, and dynamically shift resources from one slice to another, if there is the need and possibility.

Mobility

To make mobility slice-aware in case of Network Slicing, S-NSSAI is introduced as part of the PDU session information that is transferred during mobility signalling. This enables slice-aware admission and congestion control. During the admission control, if the target RAN node receives a PDU session resource associated with a non-supported slice, it shall reject that PDU session resource.

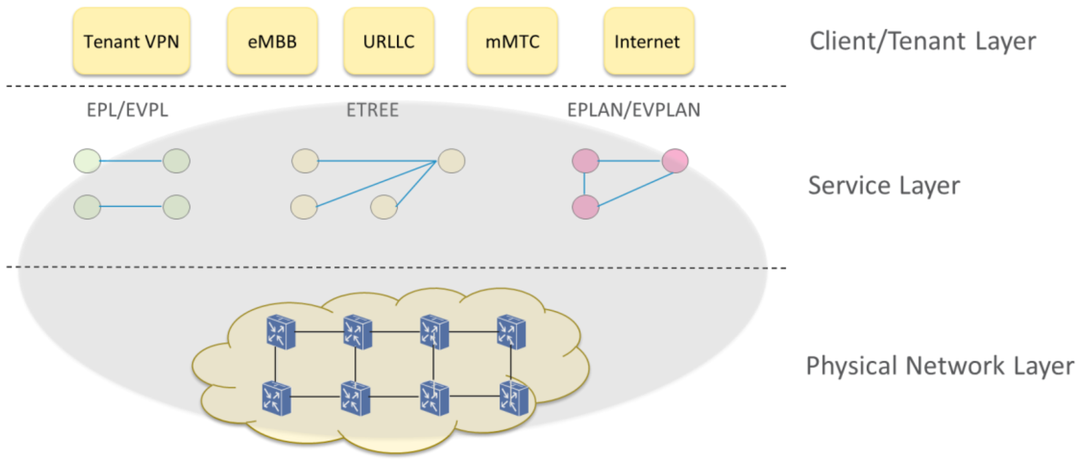
Overload Control

To enabled network slicing based overload control, the AMF indicates the related S-NSSAI(s) to the NG-RAN node, which allows the NG-RAN node to reduce the signalling where the Requested NSSAI at AS layer only includes the indicated SNSSAI(s) indicated by the AMF.

3.1.3 Bearer

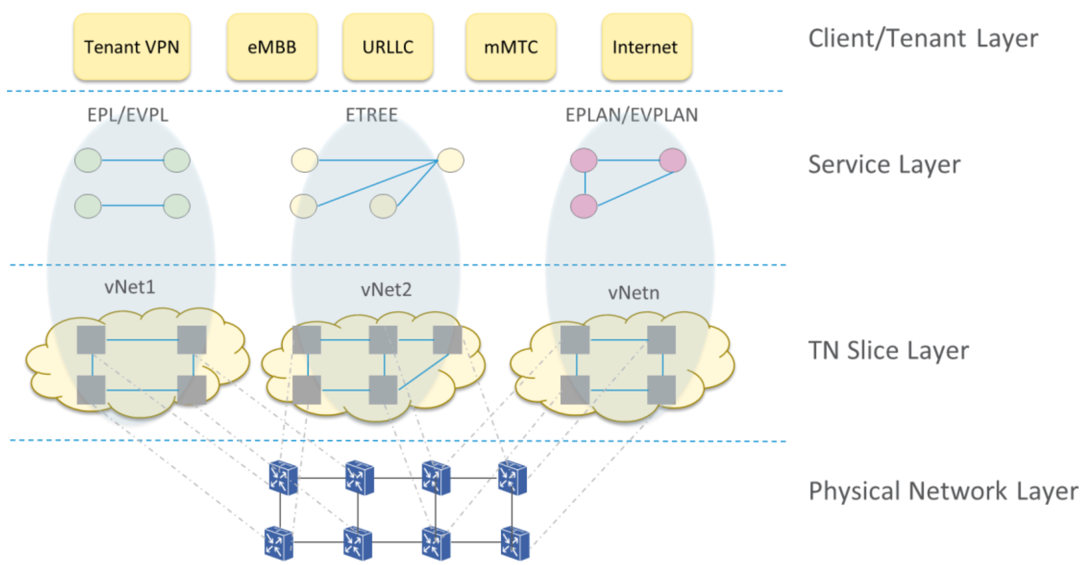
The traditional transport network can be divided into the client/tenant layer, the service layer and the physical network layer, as shown in Figure 3-3. Services such as L2VPNs and L3VPNs can be deployed directly on the physical network to form a business layer to transport upper-level client/tenant services (such as 5G services). In this architecture, various services on the service layer share physical network resources. Because of no isolation mechanism, there is a resource competition problem, and it is difficult to manage and control on-demand isolated clients/tenants according to different service scenarios (such as 5G services). The architecture does not manage or control future 5G traffic transmissions efficiently, so the transport network needs to introduce new layering techniques and layered architectures.

Figure 3-3 System and Architecture of Traditional Transport Network



The transport network architecture of layered slices is shown in Figure 3-4. Compared with the traditional non-slice network structure, a new virtual network layer (also called slice layer vNet) is built between the physical network layer and the service layer. The physical network is divided into vNet1, vNet2...and vNet n. vNet has similar features to physical networks, including independent management planes, control planes, and forwarding planes. Each vNet can independently support a variety of services, such as EPL/EVPL and EPLAN/EVPLAN.

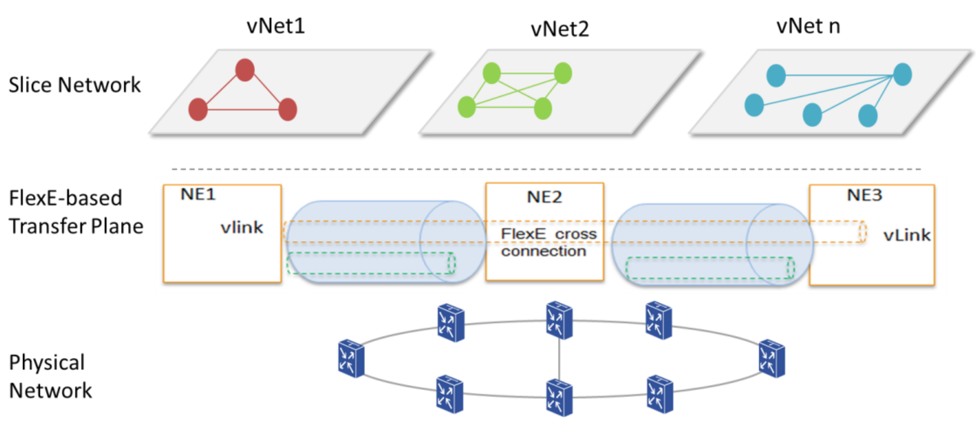
Figure 3-4 Technology Architecture of Transport Network



There are two isolation techniques for transporting network forwarding plane slices: soft isolation technology and hard isolation technology. Soft isolation is a Layer 2 or higher layer technology based on statistical multiplexing, such as SR/IP/MPLS based tunneling technology and VPN/VLAN based virtualization technology. Hard isolation is a Layer 1 or optical slice based technology based on physically rigid pipes such as FlexE, OTN and Wavelength Division Multiplexing (WDM).

FlexE technology supports physical layer based forwarding and provides tight pipe isolation and flexible bandwidth allocation. The introduction of three key technologies, such as FlexE switching, OAM and protection, can successfully extend FlexE to the network-level technology, namely FlexE tunneling technology. The FlexE channel based on the FlexE switch can form a new vLink between the NEs in the fragmented network to reconstruct the fragmented network topology, as shown in the figure.

Figure 3-5 FlexE Tunnel Based Forwarding Plane Slice

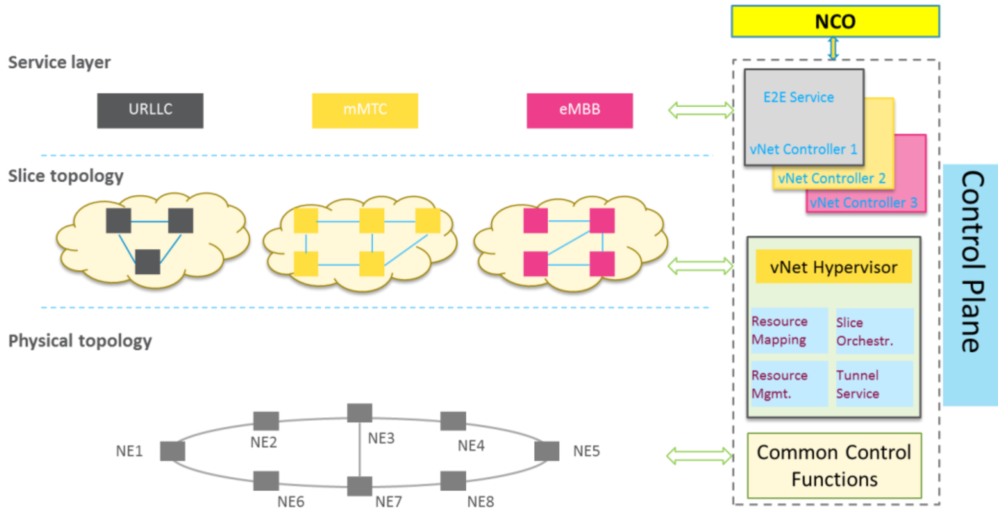


SDN-based control plane slicing technology

SDN decouples the control plane from the forwarding plane, making the physical network open and programmable, and supporting future new network architectures and services. The control plane can achieve functions such as network topology and resource unified management, network abstraction, path calculation, and policy management. It can abstract physical forwarding resources into virtual device nodes and virtual network connections, and manage these virtual resources according to policies to form a separate logical slice vNet.

The SDN-based control plane slicing architecture consists of the following information of the physical network, including the public control function, the vNet management program, the vNet controller, and the NCO, as shown in Figure 3-6.

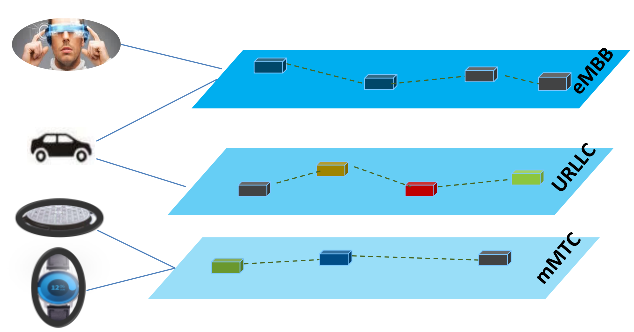
Figure 3-6 SDN-based Control Plane Slices



3.1.4 Terminal

5G terminals are rich in variety, including high-end terminals with rich features (such as smart phones, V2X car terminals, and VR terminals) as well as low-cost, and IoT terminals with low power consumption (such as smart meter reading terminals, smart manhole cover sensors, and intelligent street light switches).

Figure 3-7 Terminal Slice Access Example



The 5G terminal supports slicing and needs to have the following features:

1. One UE terminal can access one or more slices at the same time. For example, a V2X terminal can simultaneously access eMBB and URLLC.

2. UE can configure the slice type set Configured NSSAI that is expected to be accessed, or obtain the Configured NSSAI from the network side. Upon registration, the slice sets Allowed NSSAI that allows access can be obtained from the network side.

3. You can select different slices for different APP applications according to the NSSP (Network Slice Selection Policy) delivered by the PCF.

3.2 Slicing O&M Management

5G end-to-end slicing involves multiple network devices such as access network, transport network and core network, so the deployment and management of slices are facing enormous challenges.

Slice operation and maintenance management needs to support the following key technologies:

1) On-demand customization of the slice: The system needs to customize the network slice design according to the needs of different industry users to quickly meet a variety of application scenarios and diverse customer needs. The WYSIWYG slice design is achieved through template-based modification and drag-and-drop visualization.

2) Automated slice deployment: The network slice deployment is automatically completed based on user service and subscription and SLA (Service-Level Agreement) requirements to achieve fast delivery of user services.

3) SLA monitoring and assurance: End-to-end network slicing integrates multiple network sub-slices, which need to meet and guarantee the SLA of slices to meet the needs of vertical industry applications. Therefore, during the running of the slices, it is necessary to collect and monitor the SLA of the network slice to ensure its performance. E2E slice SLA monitoring and strategy closed-loop control is a complex closed-loop feedback control system involving key processes such as slicing SLA data collection, policy decision making, policy execution and feedback.

4) Automated service provisioning and activation: Full automation is made from patching, orchestration, deployment to activation. The system can automatically select the sub-slice deployment template preset by a suitable Access Network (AN), a Transport Network (TN), or a Core Network (CN) according to the SLA requirements of the customer, and automatically splits the AN/CN/BN latency, bandwidth, and user capacity according to the preset template. According to the split SLA requirements, the slice VNF/PNF is automatically deployed, and the slice configuration is automatically activated.

5) Intelligentization and automation: The system can realize the intelligentization and automation of slice operation and maintenance by introducing technologies such as automatic closed-loop assurance, root cause analysis, ZSM (Zero touch Service and Management) and AI.

3.3 Slicing Isolation and Security

Slicing isolation and security contains three fundamental layers: the infrastructure, network slice, and network management layer. Each layer must consider its individual security risks and protection mechanisms. Moreover, it is necessary to consider all domains together as an organic whole to provide overall security. In general, there exist the following three aspects in a holistic framework of network slice security

Infrastructure Isolation and Security

As Network Slice Instances (NSIs) are sharing the same infrastructure, proper isolation between NSIs must be enforced to avoid adverse cross-effects and information leakage, especially when NFV is used. For example, different virtual machines or containers are used for different network functions and the virtual links connecting VNFs dedicated for different NSIs should be logically isolated.

Network Management Security

Security risks exist in every phase of the NSI lifecycle management in the network management layer. Malicious attacks may use malware to compromise a network slice template, threatening all subsequent NSIs. Attacks may also pass through configuration interfaces during the runtime phase of an NSI. Confidential data could be obtained during the decommissioning phase, if the NSI is handled improperly. Therefore, the security considerations should cover each single step of the lifecycle management of NSIs. As some network capabilities and interfaces are exposed to tenants, the capabilities granted to a particular tenant are defined by the operator. Tenants must be authenticated and authorized before being allowed to access these capabilities and interfaces.

Network Slice Instance (NSI) Isolation and Security

To guarantee security for the network services provided by an NSI, it requires embedding the security mechanism and security provisioning entity (e.g. security anchors and security functions) into the logical network architecture of the NSI.

Security isolation: Without security isolation, malicious attacks with access to one NSI may use that NSI as a launching pad for attacking other NSIs by, for instance, illegally occupying resources of another NSI. In addition, it may also result in breaches of data confidentiality and integrity attacks.

Slice access control: A terminal should be authenticated and authorized to access a specific NSI. The communication between the terminal and the allocated NSIs should be protected against attacks.

Customized security mechanisms: Terminals may require different levels of security protection. Terminals accessing the eMBB type NSI have strict security requirements on authentication and encryption/decryption, which can be similar to the mechanisms used in LTE. Terminals like low-cost sensors accessing the mMTC type NSI require only lightweight authentication and encryption/decryption algorithms due to limited computing capability. Terminals accessing the URLLC type NSI require quick access authentication and strong encryption algorithms.

4 End-to-end Slice Deployment and Evolution

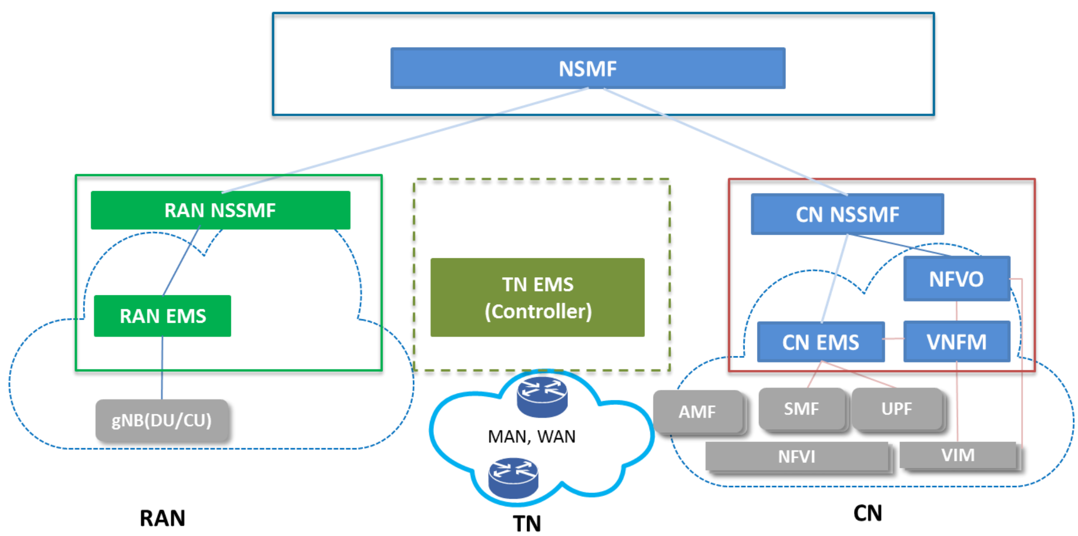
The introduction of the 5G network slicing business needs to consider the maturity of standard technologies and industrial development. Operators need to introduce network slicing in stages. According to the deployment requirements of slicing, it can be divided into rapid deployment and target deployment.

The first stage is a minimalist 5G network, focusing on eMBB for rapid deployment

According to the overall deployment pace of 5G network, in order to quickly launch 5G services, the initial focus is on typical eMBB slicing, such as high-definition video, AR/VR, and 3D., and appropriate cooperation with the deployment of the core network user plane to the edge to achieve partial super low latency service needs.

At the same time, the layout of slices is simplified. CN sub-slices are deployed by using the cloud technology, providing CN NSSMF for sub-slice scheduling and deployment. RAN and TN sub-slices are configured to dispatch and isolate slice resources.

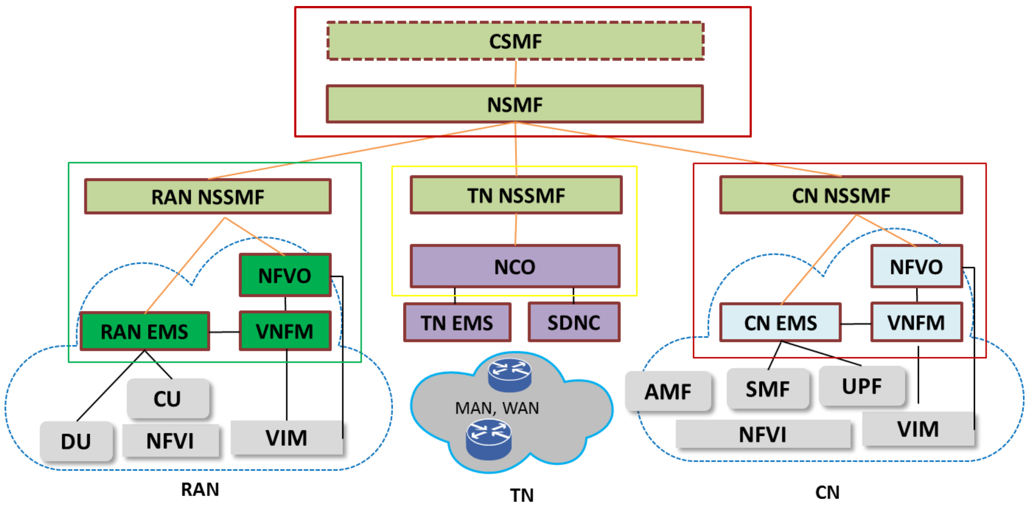
Figure 4-1 Rapid Deployment



The second phase is to gradually realize the 5G target network to support E2E orchestration

On the basis of eMBB, different types of slices such as URLLC and mMTC are gradually introduced. RAN supports separation of DUs/CUs and cloud deployment of CUs. TN supports the FlexE-based hard-slice vNet, providing ultra-low latency forwarding. It supports RAN, TN and CN end-to-end slicing management, and gradually realizes automatic exposing and intelligent protection of slices together with automation and AI technologies.

Figure 4-2 Target Deployment



5 Foresight Technologies and Trends of Network Slicing

1. Mobility management aspect

Mobility management is very important topic in 5G network slicing and need further study. There are few key actions to answer:

1) How user move between 4G to 5G networks and keep the same SLA level (is it even possible?)

2) How the radio will react in case many users with high SLA plan will handover (e.g. Stadium case,

3) Business area during rush hours etc.)

4) How slices SLA will be kept in case transport network is chocked or underperforming?

5) How fast a user will hand over from 5G to 4G and vice versa and what will be the service

6) degradation during the handover process

7) How about roaming, is national roaming mandatory for some use cases where service continuity

8) is required

9) RAN slicing (3GPP rel.16 study items)

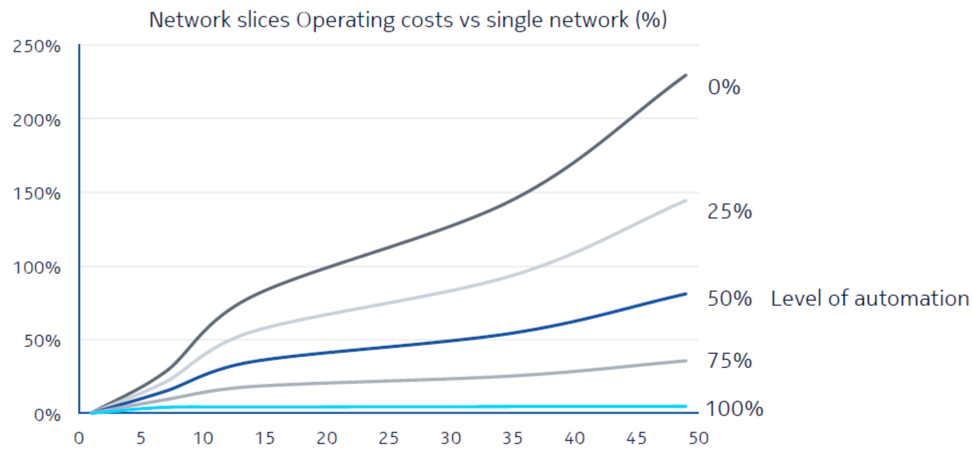
2. The need for automation

Network management automation is critical to minimize operational costs and enable more network slices to capture more connections and thus customer revenues.

Network slice management can split to three vertical layers; Service instance layer, network slice instance layer and resource layer. The service layer contains different end user services or business services which are supported by the network. The network slice instance layer provides the network characteristics which each service instance requires. The resource layer offers all physical and virtual network functions and resources (computing, storage etc.) for an access Network (radio and fixed), a transport network and core network used to implement each slice instances.

Currently each dedicated network is managed and orchestrated as a single network, mostly manually. In case of 5G network slice management, automated orchestration is a key and its role is even increasing when we talk about on-demand network slicing. According to Bell Lab Consulting‘s research, increasing the level of network management automation can substantially reduce the OPEX for each network slice. At 100 percent automation, there is virtually no cost increase with the number of slices. Granted this is a long-term goal and impractical in the short to medium term, yet even 50 percent automation will bring very significant benefits.

Figure 5-1 Automation is essential to minimize the costs of operations and enable higher numbers of network slices



3. Development of slice malls

Slicing is one of 5G's innovative technologies, which will lead to a new business model. It needs to further improve the slice-level operation technology, such as online ordering, slicing and billing, to support Network Slicing as a Service (NSaaS) such as wholesale and online sales of slice malls, and slice markets. To provide operators with new business models and support operators to be able to directly sell chips to enterprises or sell them to powerful partners in batches, and then retail segments for industry users to create a new 5G business ecosystem.

6 End-to-end Use Case

1. Automotive

For automotive industry, a number of representative 5G network slicing use case families /classes are presented in the following subsections.

Infotainment

Such services normally focus on providing a more pleasant driving experience both for driver and passengers, so they are not safety-critical and can be delivered using mobile broadband (MBB) connectivity. Examples include: music, movies, live TV streaming, audio/video conference streaming (office-in-car), online gaming, web browsing.

Telematics

This type of use case also requires direct data exchange between vehicle and application servers via a mobile system, which are normally provided by automotive manufacturer (or their authorised third-party service provider). It provides services to assist the driving experience. Example use cases are navigation provisioning, remote health monitoring of the vehicle, precise position provisioning, parking slot discovery, automated parking, etc. An automotive manufacturer could also use the connectivity to schedule a control module firmware and software update over mobile system for selected range/type of vehicles.

Basic Safety Services

Basic safety services support the driver with additional information to improve road safety and efficiency.

- Road Warning: These services provide information to the driver about imminent dangers such as red light violation, hazard warning, forward collision warning, intersection collision warning, traffic jam warning, etc. Such information could help the drivers to take remedial actions (e.g. lane changing, deceleration). Being different from the driving experience assistance mentioned in Telematics, these use cases normally are triggered by a specific event (e.g. based on real time road situation detection) and the actions are taken by driver, hence it is not strictly delay-sensitive, but it is preferred to be delivered as fast as possible.
- Information (Sensor Data) Sharing: Perception of surrounding environment for driving condition analysis is a very crucial aspect to improve driving safety. Real-time information could be exchanged among vehicles, e.g. on-vehicle sensor or information captured by the vehicles like traffic information. Such information could be used for collective perception of environment to avoid potential dangers. Information sharing is also one of the essential factors to enable autonomous driving services mentioned below.

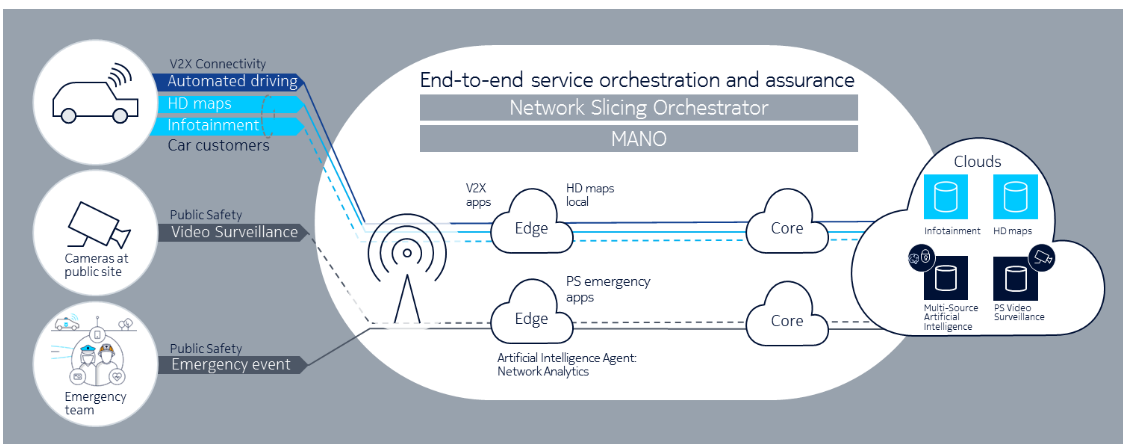
Advanced Driving Services

Advanced driving services enable semi-automated or fully automated driving.

- Cooperative Driving: Information (on-vehicle sensor data and driving actions like braking and accelerating) can be exchanged among vehicles for cooperative collision avoidance. Another example use case is cooperative lane merging, where vehicles exchange information on their intended trajectories and perform automated lane changing manoeuvres to avoid collisions and to improve traffic flow.

- Platooning: This use case class describes operating a group of vehicles in a closely linked manner so that the vehicles move like a train with virtual strings attached between vehicles. To keep the vehicles as close as possible with safety assurance, the vehicles need to share status information (such as speed, heading) as well as their driving intentions (such as braking, acceleration). By doing this, the overall fuel consumption could be lowered down, and the number of required drivers can also be reduced.
- Tele-Operation:This use case class describes the scenarios where a driver could directly control an autonomous-capable vehicle from a remote location such as a control centre in certain periods of time. The remote driver receives a video stream taken from the cameras on the vehicle. The real-time video provides elaborate perception of the environment to the driver so that the diver can operate the vehicle as if he/she is personally inside the vehicle. Advanced video technology (e.g. VR) could further improve the experience of a remote driver.

Figure 6-1　E2E orchestration and assurance



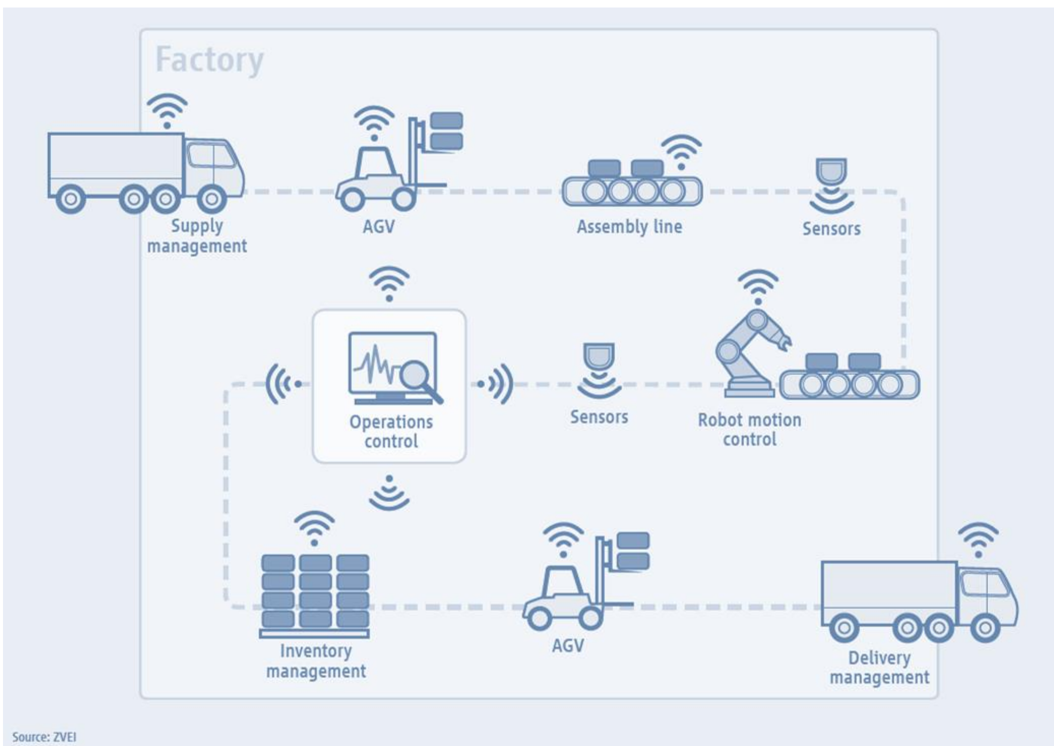
2. Industry 4.0

Industry 4.0 revolution is big part of network slicing business potential and will be the next phase in the digitization of the manufacturing sector, it has the potential to provide (wireless) connectivity for a wide range of different use cases and applications in industry. In the long-term, it may actually lead to convergence of the many different communication technologies that are in use today, thus significantly reducing the number of relevant industrial connectivity solutions. Just as there is an ongoing trend towards Time-Sensitive Networking

(TSN) for established (wired) Industrial Ethernet solutions, 5G is likely to become the standard wireless technology of choice, as it may for the first time enable direct and seamless wireless communication from the field level to the cloud.

The figure below illustrates different examples of where 5G may be used to advantage in a factory in the future. Promising application areas range from logistics for supply and inventory management, through robot and motion control applications, to operations control and the localization of devices and items. Interestingly, 5G is likely to support various Industrial Ethernet and TSN features, thereby enabling it to be integrated easily into the existing (wired) infrastructure, and in turn enabling applications to exploit the full potential of 5G with ease.

Figure 6-2 examples of where 5G may be used to advantage in a factory in the future



3. Media& Entertainment Industry

5G network slicing will serve new applications such as 4K/8K video streaming, virtual and augmented reality and gaming use cases which require higher bandwidth, greater capacity, security, and lower latency.

TV & Video

Already today video consume 50-70% of mobile networks capacity, the expectations is that it will continue to grow and enhanced with new features such as:

- Higher quality formats (4K/8K) which will be consumed on any device from a TV to a mobile phone
- TV personalization platform – content will be streamed based on user preferences followed by personalized advertisement which will create additional revenue source to operators
- Operators own content – operators will increase the ARPU with content
- 5G XCast - Broadcast and Multicast Communication Enablers For the Fifth Generation of Wireless Systems

The assumption is that operators will create a premium video slice with SLA to broadcast premium quality content (it will be mandatory in case of Fixed Wireless Access)

Digital Engagement

Digital Engagement is a cornerstone of almost any brand's marketing. Operators can benefit from this opportunity by providing edge computing and its use cases as key enablers of breakthrough digital experiences in relevant locations, such as, stadiums, temporary event locations, malls, airports, stations, etc. A dedicated slice for AR/VR will be created and AR/VR content can be stored and broadcast from operator Edge Cloud

- Augmented Reality (AR) - is a technique where the real-world view is augmented, or assisted, by a computer-generated view, this can be in single or multi-sensory modes including, auditory, visual, and haptic. AR requires low latency and moderate bandwidth – one application which demonstrated by Nokia is Way-Finding which is an indoor navigation software which use pictures to identify location and provide guidelines
- Virtual Reality (VR) is the technology to construct a virtual environment, which may be based on the real environment within which people could have real-time interaction. There are a number of key technologies used together to enable VR, i.e. 360-degree panorama video, Freeview-point, computer graphics, light field, etc. Many applications are derived from VR, for instance, VR gaming, VR broadcasting, VR simulated environment for education, healthcare, military training, etc. Moreover, the mutuality of the Cloud capability (e.g. rendering in cloud, edge computing) as well as pervasive network infrastructure deployment will bring VR applications to a new dimension.

Gaming

5G could change the video game industry forever, long seen as one of the last frontiers of consumer cloud services, companies have been attempting to bring video games to the cloud. Soon, world-class gaming could be streamed to any new device, anywhere.

Cloud Gaming - means that the game engine and graphic processing is done in the cloud and users can play any game at any time from any device. Any cloud gaming solution highly depends on high quality customer experience and gamers community are not compromising on quality. Cloud gaming is streamed in 4K 60FPS quality, to provide gamers with top quality experience it will require about 50Mbps bandwidth and less than 18ms latency. Three main steps is envisioned in cloud gaming for 5G:

- Create a “Gamers Slice” with a dedicated SLA for cloud gaming, this has to be in collaboration with gaming companies and operators
- Edge Cloud – move game engines to run from operators’ edge cloud
- APIs – between operators and game developers for: user experience, charging, upsell, promotions etc. …

7 Summary and Prospective

5G network slicing is an innovative technology for 5G network. Network slicing provides a logical network of E2E on a unified physical infrastructure. It can fully adapt to the SDN/NFV infrastructure to achieve flexible matching of service requirements to network resources, so as to meet the specific functional requirements of different vertical industries in the future 5G network in the form of network slicing.

For operators, 5G network slicing will provide new business models and new profit growth points. In addition to supporting B2C slicing services, it also supports Network Slicing as a Service (NSaaS), providing new operating modes such as slicing mall and slice fair. It will extend its operations from traditional services such as voice, data and messaging to vertical industries such as IoV, smart grid and VR/AR.

For the vertical industry, the differentiated network capability provided by the slice can make the competitive business more convenient and quicker, and the deep cooperation and symbiosis with the operator can promote a new business form. In the future, 5G slicing technology will penetrate into all walks of life, agriculture, education, medical care, industry and other industries with the support of cloud native, automation, hardware and software acceleration, AI, Big Data and other technologies.