Network Slicing

Use Case Requirements

April 2018

Future Networks Programme

The GSMA's Future Networks is designed to help operators and the wider mobile industry to deliver All-IP networks so that everyone benefits regardless of where their starting point might be on the journey.

The programme has three key work-streams focused on: The development and deployment of IP services, The evolution of the 4G networks in widespread use today, The 5G Journey developing the next generation of mobile technologies and service.

For more information, please visit the Future Networks website at: www.gsma.com/futurenetworks

Document Editor

Kelvin Qin, Senior Project Manager

Michele Zarri, Technical Director – Networks

This is a Non-binding Permanent Reference Document of the GSMA

Executive Summary

Creating smart 5G networks

Network Slicing is set to be a prominent feature of 5G to allow connectivity and data processing tailored to specific customers' requirements. Mobile communications provided by smart networks will enhance the efficiency and productivity of business processes and will open up opportunities for operators to address the Business to Business segment more effectively.

The Business Opportunity size

In the 5G era, different industry verticals are seeking to leverage the power of technology to boost productivity across swathes of the economy. Network Slicing builds on this expectation, and together with the promise of Massive IoT and ultra-reliable/low latency services, will support the digital transformation and mobilisation of industry vertical customers.

The GSMA estimates that in combination with other enablers and capabilities, Network Slicing will permit operators to address a revenue opportunity worth $300bn by 2025.

Understanding the customers' needs

The possibility of tailoring mobile network properties to the needs of the business through the configuration of a large set of parameters offers unsurpassed flexibility. However, with such a diverse range of possible requirements from verticals, operators will need to manage risks from excessive complexity in the service offering and cumbersome management, leading to higher costs.

In this paper, the GSMA sets out to understand the service requirements expressed by business customers from different vertical industries in several key sectors including energy, IoT, automotive, manufacturing and many more.

Requirements for each use case were analysed, quantified where possible and categorised into performance, functional and operational requirements.

Defining a common starting point

This paper proposes the adoption of a "generic slice template" that the industry can use as universal description. A generic slice template provides a universal description of a network slice type that can be used by infrastructure vendors, mobile network operators and slice buyers. When populated with values for all or a subset of the attributes, the generic slice descriptor can serve many purposes:

- Infrastructure vendors, can use the descriptor to define the features of their products
- The slice buyer can use the descriptor as a reference for SLA/contractual agreements with the operator
- Operators can exchange slice descriptors with their roaming partners facilitating the support of service continuity when moving between networks.

The generic slice template will also serve as a baseline for the definition of a set of standardised service/slice types.

This study has also been used to identify the use cases that can be served by the same network slice type as well as use cases that are likely to require simultaneous support, something referred to as a “network slice bundle”. A network slice bundle describes the family of network slice types required to serve a group of use cases, for example a network slice bundle for a vehicle will include slices supporting; a high-reliability telemetry service, a high bandwidth infotainment service, a low latency “vehicle to network to X” service, a super low latency vehicle to vehicle, etc.

Acknowledgement

Special thanks to the following GSMA Network Slicing Taskforce members for their contribution and review of this document:

- AT&T Mobility
- BlackBerry Limited
- China Mobile Limited
- China Telecommunications Corporation
- China Unicom
- Cisco Systems
- Deutsche Telekom AG
- Emirates Telecommunications Corporation (ETISALAT)
- Ericsson
- Gemalto NV
- OPPO
- Hong Kong Telecommunications (HKT) Limited
- Huawei Technologies Co Ltd
- Hutchison 3G UK Limited
- Intel Corporation
- Jibe Mobile Inc.
- KDDI Corporation
- KT Corporation
- Kuwait Telecom Company (K.S.C.)
- MediaTek Inc.
- Metaswitch Networks
- Nokia
- NTT DOCOMO Inc.
- Orange
- Qualcomm Incorporated
- Radiomóvil Dipsa
- S.A. de C.V.
- Samsung Electronics Co Ltd
- SK Telecom Co. Ltd.
- Sprint Corporation
- Starhome Mach
- Syniverse Technologies Inc.
- Telecom Italia SpA
- Telefónica S.A.
- Telenor Group
- Telia Finland Oyj
- United States Cellular Corporation
- Verizon Wireless
- Vodafone Roaming Services
- ZTE Corporation

Contents

1

Introduction

1. Introduction

5G networks, in combination with Network Slicing, permit business customers to enjoy connectivity and data processing tailored to their specific business requirements. It is expected that providing tailored services to business customers has significant commercial potential.

The main purpose of this document is to provide a comprehensive overview about the service requirements expressed by business customers from different vertical industries - consumers are purposefully not addressed. These requirements have been collected through discussions and interviews as well as analysis of available white papers. In addition, these requirements were analysed in detail and industry recommendations are deviated thereof. The paper also provides an overview of the standardisation landscape of Network Slicing, business model considerations and regulatory needs. Security, privacy and liability have also been covered in this paper. Finally, the generic slice template concept is briefly introduced which contains all the potential attributes a network slice could have. This gives us a baseline for all network slices offered to customers by specifying the values that each parameter would take for a given slice instance.

This document is the successor of previous documents [1], [2] which are written from the customer perspective and which define what Network Slicing is and what Network Slicing could offer to the customers.

The document is structured as follows:

- Chapter 1 introduces the paper and provides a brief summary of the Network Slicing definition coming from the previous papers and the terminology used throughout the document.
- Chapter 2 explores the business cases for Network Slicing, which could potentially change the way network operators do their business and to enable new business models.
- Chapter 3 gives a snapshot of the standardisation landscape with respect to Network Slicing and covers vertical industry organisations, telecom industry organisations as well standards developing organisations.
- Chapter 4 summarises the results of the study the GSMA conducted on the service requirements analysis for different vertical industries.
- Chapter 5 represents the core part of this document, which aims to analyse the service requirements and provides recommendations towards the industry. It also discusses the idea of the generic slice template.
- Chapter 6 provides an overview about the policy aspects around Network Slicing such as net neutrality.
- Chapter 7 concludes the document and provides details about the planned next steps.

1.1. High-level view on Network Slicing

From a mobile operator's point of view, a network slice is an independent end-to-end logical network that runs on a shared physical infrastructure, capable of providing an agreed service quality. The technology enabling Network Slicing is transparent to business customers for whom 5G networks, in combination with Network Slicing, allow connectivity and data processing tailored to the specific business requirements. The customisable network capabilities include data speed, quality, latency, reliability, security, and services. These capabilities are always provided based on a Service Level Agreement (SLA) between the mobile operator and the business customer.

A network slice could span across multiple parts of the network (e.g. access network, core network and transport network) and could be deployed across multiple operators. A network slice comprises of dedicated and/or shared resources, e.g. in terms of processing power, storage, and bandwidth and has isolation from the other network slices.

It is anticipated that mobile network operators could deploy a single network slice type that satisfies the needs of multiple verticals, as well as multiple network slices of different types that are packaged as a single product targeted towards business customers (a business bundle) who have multiple and diverse requirements (for example a vehicle may need simultaneously a high bandwidth slice for infotainment and an ultra-reliable slice for telemetry, assisted driving).

1.2. Abbreviations

Term	Description
3GPP	Third Generation Partnership Project
3GPP RAN	Third Generation Partnership Project Radio Access Network
3GPP SA	Third Generation Partnership Project Service & Systems Aspects
4G	4th Generation Mobile Network
5G	5th Generation Mobile Network
5GAA	5G Automotive Association
AMF	Access and Mobility Management Function
APEC	Asia-Pacific Economic Cooperation
API	Application Programming Interface
AR	Augmented Reality
AN	Access Network
BBF	Broadband Forum
C2C	Control-to-control
CN	Core Network

CV2X	Cellular vehicle-to-everything
D2D	Device to device
DiffServ	Differentiated services
E2E	End-to-End
EPS	Evolved Packet System
ETSI	European Telecommunications Standards Institute
EU	European Union
FMC	Fixed mobile convergence
eMBB	Enhanced Mobile Broad Band
GDP	Gross Domestic Product
GPS	Global Positioning System
GST	Generic Slice Template
HMI	Human-machine interface
ICT	Information and Communication Technologies
IEEE	The Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IoT	Internet of Things
IntServ	Integrated Services
IIC	Industrial Internet Consortium
IP	Internet Protocol
IPR	Intellectual Property Rights
ISG	Industry Specification Group
ISP	Internet Service Provider
ITU	International Telecommunication Union
ITU-T	ITU Telecommunication Standardisation Sector
KPI	Key Performance Indicator
L3VPN	Layer 3 VPN
LPWA	Low Power Wide Area
LTE	Long Term Evolution
MANO	Management and Orchestration
MBB	Mobile Broadband
MCPTT	Mission Critical Push to Talk
MDM	Multiple Dedicated Networks
MEC	Multi-access Edge Computing
MEF	Metro Ethernet Forum
mMTC	Machine Type Communications
MTC	Machine Type Communication
NB-IoT	Narrow Band IoT
NC	New Core
NFV	Network Function Virtualisation
NF	Network Function
NGFI	Next Generation Fronthaul Interfaces
NGMN	Next Generation Mobile Network
NR	New Radio
NSI	Network Slice Instance
OEM	Original Equipment Manufacturer
OSM	Open Source Management and Orchestration (MANO)
ONAP	Open Network Automation Platform
OTT	Over The Top

PRD	Permanent Reference Document
PPDR	Public Protection and Disaster Recovery
QCI	Quality of Service Class Identifier
QoS	Quality of Service
RTT	Round-trip Time
SDN	Software Defined Networks
SDO	Standards Developing Organisation
SLA	Service Level Agreement
SLR	Service Level Reporting
SR	Segment Routing
SST	Service Slice type
TN	Transport Network

TETRA	Terrestrial Trunked Radio
UE	User Equipment
UPF	User Plane Function
URLLC	Ultra Reliable Low Latency Communications
V2X	Vehicle to X (e.g. Vehicle, Infrastructure, Pedestrians)
VoLTE	Voice over LTE
VPN	Virtual Private Network
VR	Virtual Reality
WG	Working Group
ZVEI	Zentralverband Elektrotechnik und Elektronikindustrie - Germany's Electrical Industry

1.3. References

Ref	Title
[1]	Smart 5G networks: enabled by Network Slicing and tailored to customers' needs
[2]	An Introduction to 5G Network Slicing
[3]	http://5gaa.org/
[4]	https://www.zvei.org/en/
[5]	http://www.iiconsortium.org/
[6]	https://www.tmforum.org/
[7]	https://www.broadband-forum.org/
[8]	http://www.etsi.org/technologies-clusters/technologies/nfv
[9]	https://portal.etsi.org/tb.aspx?tbid=862&SubTB=862
[10]	5GPPP Project 5GCAR, "Deliverable D2.1: 5GCAR Scenarios, Use Cases, Requirements and KPIs".
[11]	5G-PPP White Paper on Automotive Vertical Sector, "5G Automotive Vision", Oct. 2015
[12]	3GPP TR 22.886 V15.1.0, "Study on enhancement of 3GPP Support for 5G V2X Services"
[13]	3GPP TS 22.186 V15.2.0, "Enhancement of 3GPP support for V2X scenarios"
[14]	3GPP TS 22.185 V14.3.0, "Service requirements for V2X services"
[15]	5GPPP White paper, "5G and Energy", Sep 2015
[16]	3GPP TS 22.261 V16.1.0, "Service requirements for the 5G system"
[17]	Perspectives on Vertical Industries and Implications for 5G", 06/2016. https://www.ngmn.org/fileadmin/user_upload/160610_NGMN_Perspectives_on_Vertical_Industries_and_Implications_for_5G_v1_0.pdf
[18]	3GPP TS 22.804, "Study on Communication for Automation in Vertical Domains"
[19]	What is the Internet of Things https://www.gsma.com/iot/wp-content/uploads/2016/09/What-is-the-Internet-of-Things.pdf
[20]	3GPP Low Power Wide Area Technologies https://www.gsma.com/iot/wp-content/uploads/2016/10/3GPP-Low-Power-Wide-Area-Technologies-GSMA-White-Paper.pdf
[21]	ETSI Multi-access Edge Computing (MEC) http://www.etsi.org/technologies-clusters/technologies/multi-access-edge-computing
[22]	ONAP https://www.onap.org/
[23]	OSM: https://osm.etsi.org/
[24]	ETSI ISG "MEC support for network slicing https://portal.etsi.org/webapp/WorkProgram/Report_WorkItem.asp?WKI_ID=53580
[25]	Zero-touch Network and Service Management – Introductory White Paper, December 7, 2017 https://portal.etsi.org/TBSiteMap/ZSM/OperatorWhitePaper

[26]	NGMN Alliance, “5G End-to-End Architecture Framework”, 10/2017.
[27]	Huawei iLab, “Cloud VR–oriented Bearer Network White Paper”, 2017.11.02
[28]	3GPP TS 33.501, 0.7.0, “Security architecture and procedures for 5G System”
[29]	http://www.ieee802.org/1/pages/802.1as.html
[30]	https://standards.ieee.org/findstds/standard/1588-2008.html
[31]	5G Network Slicing for Vertical Industries https://gsacom.com/paper/5g-network-slicing-vertical-industries/
[32]	China Telecom, China’s State Grid, and Huawei, “5G Network Slicing Enabling the Smart Grid”, January 22, 2018

1.4. Terminology

- **Network Slice:** A network slice is a logical network that provides specific network capabilities and network characteristics in order to serve a defined business purpose of a customer. Network Slicing allows multiple virtual networks to be created on top of a common shared physical infrastructure. A network slice consists of different subnets, example: Radio Access Network (RAN) subnet, Core Network (CN) subnet, Transport network subnet.
- **Network Slicing provider:** Typically a telecommunication service provider, is the owner or tenant of the network infrastructures from which network slices are created. The Network Slicing provider takes the responsibilities of managing and orchestrating corresponding resources that the Network Slicing consists of.
- **Business customer:** A business customer tenants the network slice, e.g. customers from vertical industries. For instance, a business customer could be an enterprise or specialised industry customer (often referred to as “verticals”).

2

Network Slicing: exploring the business case

2. Network Slicing: exploring the business case

2.1 Sizing the Network Slicing opportunity

Network Slicing is integral to unlocking the enterprise opportunity ($300bn by 2025) for the 5G era. Already, the industry expects the enterprise segment to be the most important source of incremental revenue opportunity in the 5G (Figure 1). Network Slicing is one of the 5G era tools and enablers that will support operators to unlock the enterprise opportunity.

In the 5G era, different industry verticals are seeking to leverage the power of technology to boost productivity across swathes of the economy. Network Slicing builds on this expectation, and together with the promise of Massive IoT and ultra-reliable/low latency services, will support the transformation of vertical industries.

To unlock this opportunity, Network Slicing will enable operators to create pre-defined, differing levels of services to different enterprise verticals, enabling them to customise their own operations.

However, the opportunity could become even bigger. Automation and the ability to quickly create slices could pave the way for operators to dynamically package and repackage network capabilities for different customers. This is the end goal of Network Slicing.

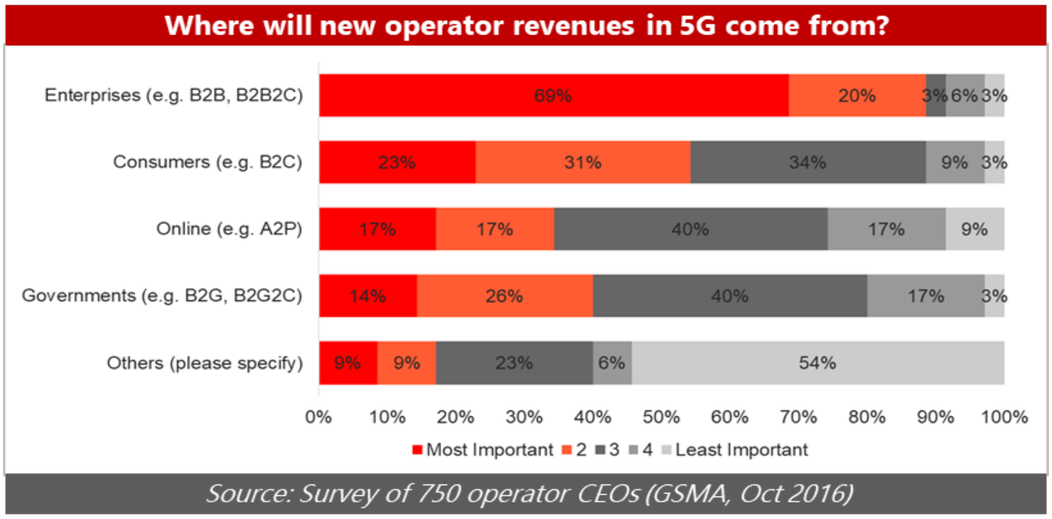

Figure 1: New incremental revenue opportunities in 5G to come from the enterprise segment

2.2 Network Slicing is part of the investment case for 5G

There are three considerations about the investment case for Network Slicing, especially given the potential complexity and cost of the required automation.

Firstly, ongoing industry activities to standardise Network Slicing should gear towards minimising the complexity of the technical solution so that adoption can be made relatively easy.

Secondly, the GSMA is working with its members to streamline the commercial deployment scenario for Network Slicing in order to drive economies of scale and reduce unitary cost of deployment.

Thirdly, operators and their vendors are working to make the cost of deploying Network Slicing marginal to the broader investment case for 5G. This is an important consideration because building a new investment case to retrofit an already deployed network is difficult and slow. That is the lesson learned from the past where VoLTE launches were decoupled from LTE launches (compared to 2G/3G voice services).

Figure 2: The role of collaboration in the investment case for Network Slicing

2.3 Go-to-market Strategy

There are three stages to the Network Slicing go-to-market strategy. These stages deliver value across the Value Chain, and may happen in parallel depending on local market conditions:

Deploy Network Slicing for internal use: This will prove the validity of Network Slicing by using the solution to serve internal customers within an operator or the operator's sister companies. This option offers a low risk opportunity to experiment and to validate the proposition in order to refine it ahead of rollout to commercial customers.

Upsell Network Slicing capabilities to existing enterprise customers: This will prove value to existing enterprise customers and based on the typical buying behaviour of business customers, upselling Network Slicing capabilities to these customers ought to be an easier opportunity than targeting new customers. These customers can then become proof points and advocates for the new capabilities.

Sell to new enterprise customers: When commercially ready, slicing will be made more broadly available to enterprise customers who often require a proven solution and seek market validation before they buy.

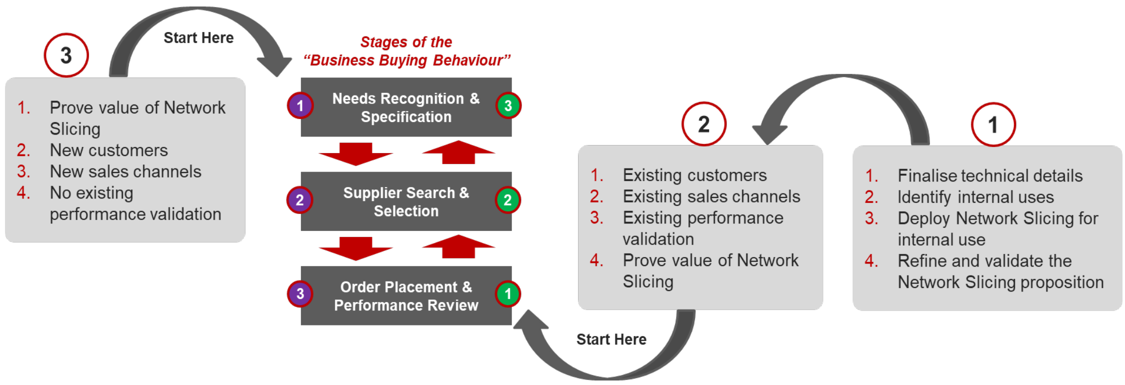

Figure 3: Stages of the Network Slicing go-to-market strategy

2.4 Avoiding the commercial shortcomings of previous QoS type solutions

The telecoms industry has had a history of creating technical solutions that can offer differentiated service levels to different customers e.g. DiffServ, IntServ, QCI etc. Yet despite fully developed technical solutions, there is no evidence of widespread commercial use of any of these solutions in the industry.

If Network Slicing is to avoid the same shortcomings, the industry needs to move fast to overcome the technical, commercial and regulatory factors that could impede progress.

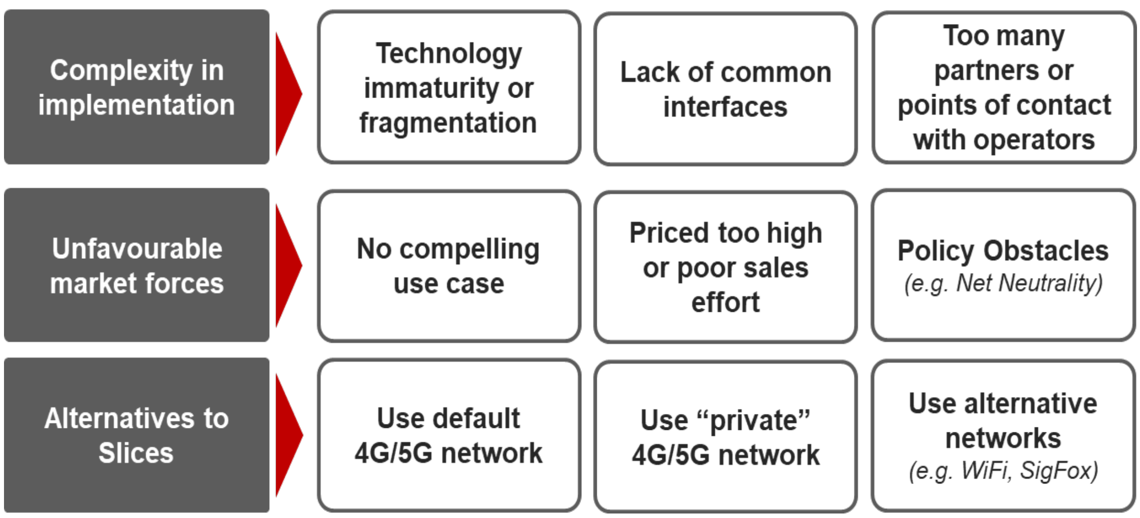

Figure 4: Factors that could impact commercial adoption of Network Slicing

3

Standardisation landscape

3. Standardisation landscape

Network Slicing is a concept for running multiple logical customised networks on a shared common infrastructure complying with agreed Service Level Agreements (SLAs) for different vertical industry customers (or tenants) and requested functionalities. To achieve this goal, Network Slicing needs to be designed from an End-to-End (E2E) perspective, spanning over different technical domains (e.g., access network, core network, transport network and network management system) as well as administrative domains (e.g., pertaining to different mobile network operators). Figure 5 illustrates a snapshot of various groups and organisations relevant to Network Slicing development.

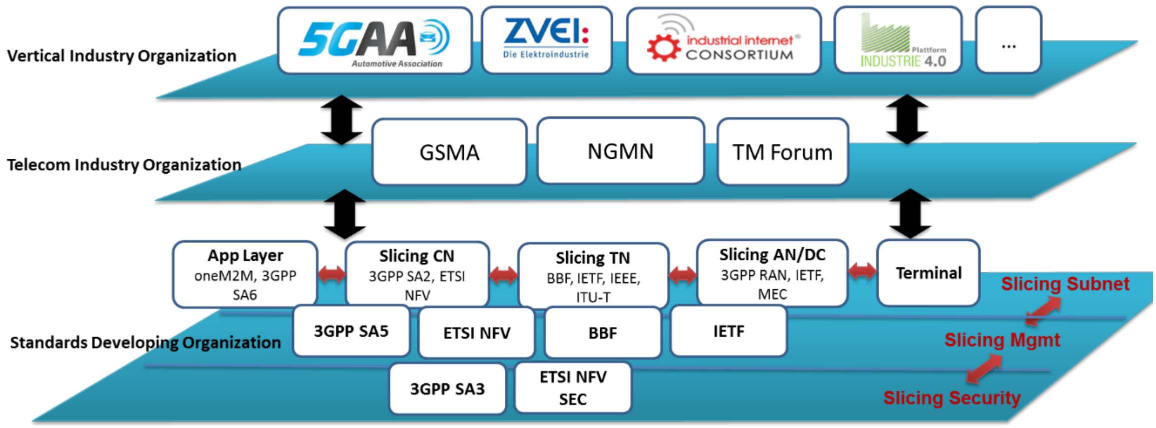

Figure 5: Network Slicing Relevant Industry Groups and SDOs Landscape

Even though many organisations are tackling Network Slicing issues as discussed above, they also notice that Network Slicing issues cannot be resolved in a single entity. Therefore, they should be liaised between them. The relationship among different industry platforms and SDOs is shown in Figure 6.

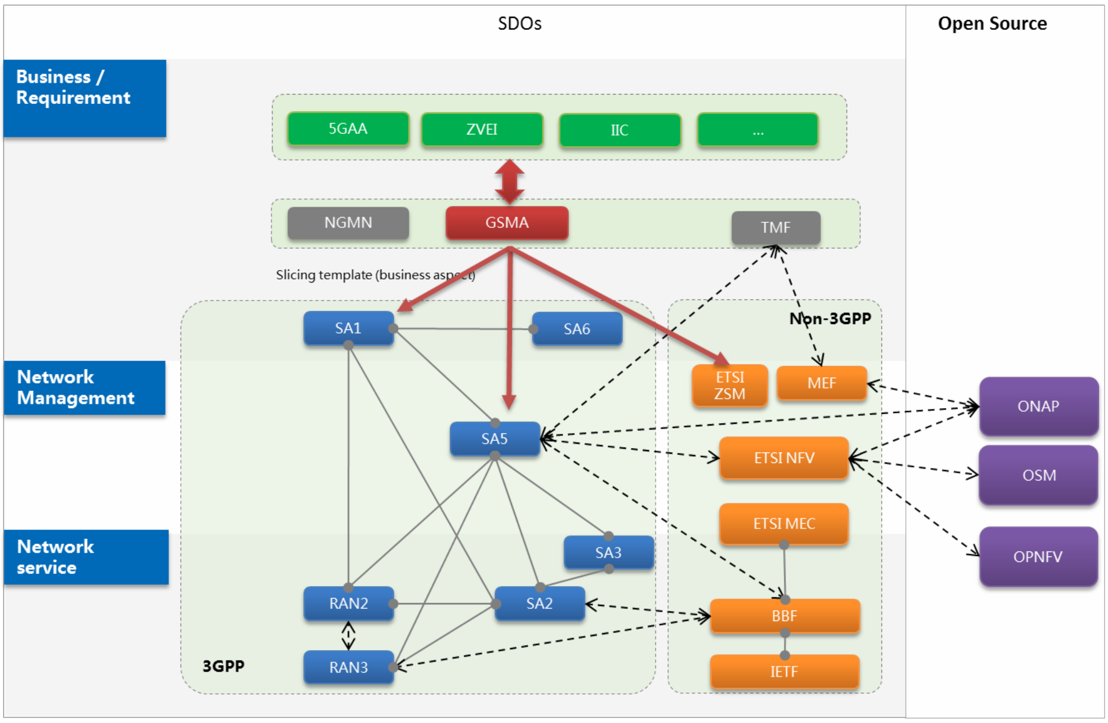

Figure 6: SDO relationship figure

In the following sections more details about the vertical industry and telecom industry organisations as well as the standards developing organisations will be provided.

3.1 Vertical Industry Organisation

Network Slicing aims to support various vertical industries in the 5G era, hence the direct requirements from vertical industries are essential for Network Slicing designs. 5G-awareness has been developed among different vertical industries. For instance, 5G Automotive Association (5GAA), created in September 2016, aims at a global, cross-industry Organisation of companies from the automotive, technology, and telecommunications industries (ICT), working together to develop end-to-end solutions for future mobility and transportation services [3]. In Nov 2017, the first Network Slicing workstream was established in 5GAA WG5 to understand the business aspects of Network Slicing in automotive industry. Manufacturing industry organisations like Zentralverband Elektrotechnik und Elektronikindustrie (ZVEI) [4] and Industrial Internet Consortium (IIC) [5] also started to engage with 5G for next generation smart manufacturing solutions.

3.2 Telecom Industry Organisation

Telecom Industry Organisations like the GSMA and NGMN (Next Generation Mobile Networks) describe the business drivers, concepts, and high-level requirements of E2E Network Slicing from the operator’s point of view. The GSMA has initiated the Network Slicing Taskforce (NEST) project to harmonise slicing definition, identify slice types with distinct characteristics and consolidate parameter and functionality requirements. The NEST aims at generating a Permanent Reference Document (PRD) to guide future Network Slicing standards.

The NGMN Alliance is developing, consolidating and communicating requirements to ensure that customer needs and expectations on mobile services are fulfilled. The Alliance actively drives global alignment and convergence of technology standards and industry initiatives with the objective to avoid fragmentation and to guarantee industry scale.

TM Forum ZOOM project [6] has started a workstream to analyse Network Slicing business models and business scenarios of high interest to service providers, vertical industries, and other potential Network Slicing consumers. A number of user stories have been generated, and respective requirements have been derived and mapped to TM Forum Assets.

3.3 Standards Developing Organisation

Various technologies and innovations from different technical domains have substantially contributed to the Network Slicing progress in different Standards Developing Organisations (SDO). Currently, technical specifications of those domains are defined in corresponding SDOs, namely, Radio Access Network (RAN) and Core Network (CN) by 3GPP, Transport Network (TN) by BBF and IETF, etc. ITU-T(GSTR-TN5G), IEEE(NGFI 1914), MEF and other SDOs are working on this topic as well. The major SDOs will be introduced in the following sections.

3.3.1 3GPP

3GPP could be considered as the forefront ambassador for Network Slicing. There are many Working Groups in 3GPP related with Network Slicing. In 3GPP SA1, Network Slicing related use cases and requirements are defined. In 3GPP RAN1/2/3, the RAN slicing-awareness features are discussed. In 3GPP SA2, the fundamental system architecture choice to support Network Slicing is specified. For instance, the fundamental network functions and procedures to support slice selection/access, session management within network slices, as well as the terminal behaviour, e.g. a UE could support maximum eight slices in parallel, and a common core network function is defined, i.e. AMF, for one UE to be capable to use all slices.

The 3GPP SA5 Working Group are responsible for completing the creation and management of slices in the 3GPP realm and for driving the coordinating with other relevant SDOs to generate complete E2E network slices. SA3 Working Group [28] are responsible for security capabilities of E2E Network Slicing that require triggering and coordination with ETSI ISG NFV on isolation of Network Slices.

3.3.2 BBF

BBF's [7] main scope in Network Slicing is to clarify the requirements for 5G bearer networks and defines the related TN slicing management architecture. The BBF should establish formal cooperation with 3GPP to facilitate the transmission requirements from 3GPP and coordinate the interface requirements between the 3GPP slicing management system and Bearer slicing management system, including corresponding slicing creation and management processes. The technical definition for a specific interface is not within the scope of the BBF standardisation, but they can recommend the potential options.

3.3.3 IETF

To support Network Slicing, the IP router should be enhanced, which will extend existing protocols, such as Segment Routing (SR) and L3VPN. Furthermore, potentially DetNet is a candidate technology for transporting traffic of URLLC slice type. Extension or new mechanism may be standardised to meet such requirement.

Another work in IETF is primary to define the interface between the 3GPP slicing management system and TN slicing management system. For the IP transport network, this interface is the northbound interface of TN slicing management system defined in BBF.

3.3.4 ETSI

3.3.4.1 ETSI ISG NFV

The ETSI NFV ISG (Network Function Virtualisation) [8] is responsible for providing technical solutions for resources such as computing and storage for Network Slicing. They consider NFV is a key enabler for the 5G infrastructure. However, further work is still required to understand how NFV technology supports Network Slicing, analyses the impacts to the current NFV architecture and standardises the NFV slicing resource layer. Including security and reliability-related features such as virtualisation level security isolation scheme, function orchestration of virtual border gateway (such as firewall), deployment and configuration strategy.

3.3.4.2 ETSI ISG ZSM

In Dec 2017, ETSI created the Zero touch network and Service Management Industry Specification Group (ZSM ISG) [9]. This initiative aims to resolve the 5G E2E Network Slicing management issue. Their vision is to enable full automation in terms of delivery, deployment, configuration, assurance, and optimisation of network services.

4

Vertical Requirements

4. Telecom Industry Organisation

This chapter briefly summarises different vertical industries, their most important use cases and their most important service requirements. The intention is not to provide very detailed information, but instead give an idea about the biggest challenges for each vertical industry. References to more detailed information are provided where available.

It should be noted that the list of verticals is not complete but can be considered as a snapshot of the current status. In addition, the status of the different verticals is different while some have very concrete ideas about use cases and requirements with concrete values associated to them some have vague ideas with initial indications. More discussions and analysis are required in the future to complement the list of verticals as well as details about the requirements and use cases.

4.1 AR/VR

It should be noted that AR/VR is not a vertical industry in itself. Instead AR/VR use cases can be found in almost all of the vertical industries. However, these use cases are so important that they are discussed in a separate section.

4.1.1 Overview

Augmented Reality (AR) is a technique where the real world view is augmented, or assisted, by a computer generated views, this can be in single or multi-sensory modes including, auditory, visual, and haptic.

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.

4.1.2 Use cases

Strong-Interactive VR: Audio-visual interaction

Audio-visual interaction is characterised by a human being interacting with the environment or people, or controlling an UE, and relying on audio-visual feedback. In order to achieve the VR environments with low motion-to-photon requirements, the 5G network slice should have the capability of motion-to-photon latency in the range of 7-15ms while maintaining the 250Mbps user data rate and motion-to-sound delay less than 20ms.

During voice conversions, there exists some interactive tasks, 5G Network Slicing is required to have the capability to support 100ms one-way mouth-to-ear low-delay speech coding for interactive conversational services.

Furthermore, audio components and video components are usually handled separately, so in order to avoid having a negative impact on the user experience, the communication system will also have to cater for the VR audio-video synchronisation. The audio-video synchronisation thresholds is 5-125ms for audio delayed and 5-45ms for audio advanced.

Strong-Interactive VR: Low-delay speech and video coding

Current speech codecs have an inherent coding delay of 20-40ms. In a 4G network, such coding delay is not a problem during a phone call because even a 400ms one-way delay between speakers does not seriously impair an interactive discussion. However, when the speech voice is used in a highly interactive environment, e.g., a multiplayer game or a virtual reality meeting, the requirements on the speech coding delay become tougher to meet, and current coding delays are too high. To support interactivity, the one-way delay for speech should be 10ms (or lower). These scenarios have a critical requirement on transfer bandwidth and delay to guarantee good user experience compared to current video service.

In order to fulfil the performance requirements of low-delay speech and video coding, the design of the network slice should consider different aspect of video codec, e.g. frame rates, resolution and bandwidth. The higher the frame rate (fps - frames per second) the better the video quality, virtual reality may require the capability of displaying content at frame rates of 120 fps or more.

Strong-Interactive AR: Use Cases

Assisting with complex tasks: Use of AR to overlay instructions can speed up fault finding and repairs by utilising heads up display with connected glasses.

Connecting remote workers: Allowing remote experts to see exactly what the worker sees and direct them to complete tasks. Enabling a deeper level of assistance and guidance to be conveyed.

Accelerated Learning: AR training packages can facilitate vastly more effective training. Supervisors are able to mentor and assess capability, resulting in higher-quality work with less mistakes.

4.1.3 Summary of requirements

In order to understand VR applications’ requirements for Network Slicing, VR applications could be classified into two categories according to how an end user interacts with the virtual environment: weak-interactive VR (wi-VR) and strong-interactive VR (si-VR). According to the technology maturity, VR use cases may experience three different stages:

- entry-level VR (now-2 years)
- advanced VR (3~5 years)
- ultimate VR (6-10years).

Weak-interactive VR

For wi-VR, end users do not have direct interaction with the virtual environment, the VR content is pre-planned and end users may be possible to select the observation point and location. Therefore, end users' experience for wi-VR is passive.

	Entry-Level VR (FOV,8K 2D/3D)	Advanced VR (FOV,12K 3D)	Ultimate VR (FOV,24K 3D)
Data rate	40Mbps（2D） 63Mbps（3D）	340Mbps	FOV：2.34Gbps
Typical RTT	30ms（2D） 20ms（3D）	20ms	10ms
Packet loss	2.40E-5	1.00E-6	1.00E-6

Table 1: Network performance requirements from wi-VR[27]

Strong-Interactive VR

With the progression of VR technology, end users could interact with the virtual environment via specific user interface (software or hardware) and the virtual environment will provide real-time response, which brings the interactive and immersive user experience. The VR content may be different according to user's input; hence, the content may be not planned in advance.

	Entry-Level VR (FOV,8K 2D/3D)	Advanced VR (FOV,12K 3D)	Ultimate VR (FOV,24K 3D)
Data rate	120Mbps（2D） 200Mbps（3D）	1.40Gbps	3.36Gbps
Typical RTT	10ms	5ms	5ms
Packet loss	1.00E-6	1.00E-6	1.00E-6

Table 2: Network performance requirements from si-VR[27]

4.2 Automotive

4.2.1 Overview

Cellular vehicle-to-everything (CV2X) is considered as one of the most prominent use cases for 5G, and the automotive industry has been one of the first verticals that engaged with the communications technology industry. CV2X aims to enable communication amongst vehicles (referred to Vehicle to Vehicle or V2V) as well as communication between vehicles and an infrastructure. Not only CV2X will create new business opportunities for OEMs, e.g. providing in-car infotainment service, but will also increases road safety. To support performance critical type of services (e.g. autonomous/semi-autonomous/assisted driving), CV2X communication also includes other connected-vehicle technology, e.g. in-car sensors, cameras and radar systems.

Providing support for V2X services using operator's 5G public network, not only will significantly reduce deployment cost compared to running V2X services on a dedicated network, but will also offer a better coverage. Moreover, CV2X can benefit from support of critical performance (e.g. ultra-reliable and low latency communication) and customised network services (e.g. network function could be tailored according to customers' requirements) that are included by design in 5G.

However, for a successful deployment of CV2X, 5G operators need to have a full understanding of the use cases and requirements of the automotive industry.

4.2.2 Use Cases

5G CV2X use cases have been well studied by many research programs (e.g. 5GPPP [10][11]), standardisation (e.g. 3GPP [12][13]) and industry oraganisations (e.g. 5GAA [3]). A number of representative use case families/classes are presented in the following sub-sections.

4.2.2.1 Infotainment

This type of use cases requires direct data exchange between vehicle and application servers via mobile systems. 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.

4.2.2.2 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). Being different from the above category, it provides services to assist the driving experience. Example use cases are navigation provision, 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.

4.2.2.3 Road Safety and Efficiency

4.2.2.3.1 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. One typical use case is “See-Through”, which refers to camera and/or radar data sharing to improve/extend driver’s visibility. For instance, by receiving a video stream captured by the front truck can help the driver behind to make an overtaking decision. Information sharing is also one of the essential factors to enable autonomous driving services mentioned below.

4.2.2.3.2 Advanced Driving Service

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 amount 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.

4.2.3 Summary of requirements

Automotive use cases have huge business potential, however, they also impose stringent performance requirements for the mobile system. Support of the CV2X requirements has been introduced for LTE in 3GPP Release 14 [14], while with regards to 5G, the plan is to develop technical solutions as part of Release 16 is expected to be completed at the end of 2019. In parallel to the 3GPP activity, 5GAA is working on gathering relevant use cases and requirements working directly with automotive industry partners. The scale of the challenge should not be underestimated: to support advanced driving services, the mobile system should provide ultra-high reliable and low latency communication between the vehicles and the network, as well as between vehicles and vehicles, exceptional mobility management performance and seamless service continuity even when moving at high speed. Furthermore, the mobile system should provide “predictive QoS”, that is inform the vehicle of changes in the quality of the connectivity going to be provided in the future so that the vehicle could decide to switch from autonomous driving mode to manual driving mode. Examples of factors that the network may use to predict future quality of service include weather conditions,, road situation, network availability at the position where the vehicle is travelling etc.

5G may have geographic coverage limitations (especially at the initial deployment stage). It is therefore useful for 5GAA and other relevant industry associations to specify vehicle (or the device) behaviour in case the network performance is not going to meet the minimum requirements.

4.3 Energy

4.3.1 Overview

The energy vertical has some very specific requirements on the supporting communication solutions that go beyond what current LTE can provide. The business potential of introducing 5G Network Slicing in the energy domain is exceptionally high, as it is expected to provide the necessary support not only to the critical machine type communication (MTC) applications of energy grid protection and control, but also to the massive volume of MTC type applications of the emerging smart metering.

4.3.2 Use Cases

Energy use cases have been investigated for instance by 5GPPP[15] and 3GPP[16], as well as by vertical customers themselves [32] . Some typical use cases are briefly explained in the following.

Smart grid

Due to the urgent demands of smart grids, an efficient and reliable communication network solution is expected. The backbone network domain is a typical network in which terminals are in the high and extra high voltage area. The terminals of a backhaul network are in the medium voltage area. As for the access network, the end points are in the low voltage area. A large amount of growing demand happens in the medium-voltage and low-voltage domains, which are secondary substations and distributed energy resources, between primary substations and secondary substations. At this moment, there is a lack of energy measurement and communications system between substations. 5G Network Slicing could be an economical and efficient wireless solution compared with a traditional fibre-based communication system.

Micro-grids

Micro-grids consist of a set of micro-power, load, energy storage and control devices. It could operate in both grid-connected mode and island mode. Micro-grids will play a significant role in the future electricity smart grid architecture and the associated control network. All Micro-grid elements need extensive exchange of signalling between each other. 5G Network Slicing could provide an economical and efficient way to support the communication needs.

Smart meters and aggregator gateways

Future power terminals are expected to supply frequent measurements. This evolution leads to the requirement on future networks to carry short data packages from thousands of users. The data will enable near real-time optimisation of sections of the low and medium voltage infrastructures. This optimisation will be particularly beneficial for utilities to better serve customers (residential and business) in densely populated areas where 5G Network Slicing is expected to become available first.

Electricity traffic scheduling

Power supply and delivery play a more and more significant role in modern life, commercial and industrial operation. Power outages as a result cause significant economic damage both to the power company and consumers. At present fault location is performed by means of fibre and Wi-Fi, which results in high latency and low level of reliability. 5G Network Slicing could play an important part in fault location and fault isolation by transmitting critical monitored data, controlling signals among feeders, bar switches and automation control servers,. 5G URLLC Network Slicing has the low-latency and high-reliability characteristics needed to promptly and precisely respond to power outages. Furthermore, by building a precise map of power consumption it is possible to improve the traffic scheduling and production.

4.3.3 Summary of requirement

Here are some requirements for reference:

Bandwidth	1 kbps per residential user.
E2E Latency (upper bound)	<5ms between the primary substations and towards the control centre.
Packet-loss	< 10-9 (which is more demanding for high/extra high voltage than for medium voltage applications. This is the end to end packet loss including the device.).
Availability	>99,999% equal to about 5 minutes downtime per year.
Failure Convergence Time	Seamless failover required, i.e. no loss of information in case of a failure while keeping real-time delivery of the information (i.e. within a small number of milliseconds).
Handling of crisis situations	(Surviving long power downtimes on a large scale, assuring black start capability): mandatory.
Connection density	> 1000 km2

4.4 Healthcare

4.4.1 Overview

The health & wellness industry is about to change dramatically thanks to the availability and usage of electronic processes and communication technology. This change will be driven by demographical changes and the resulting growing costs as well as the growing demand for flexible and individual treatment.

4.4.2 Use cases

The health & wellness use cases are very diverse with many sub-use cases. The following list aims to briefly summarise the most important ones. More details to some of these use cases can be found in [17]:

Hospitals

Deals with processes in and around a hospital. The most prominent examples are medical device tracking, emergency communication, (real-time) data availability and exchange and data transfer.

Rehabs and care homes

Processes in and around rehabs and care homes. Here, the most important use case is assisted living.

Health and wellness monitoring

Tracking health-relevant indicators using various types of sensors. This data can be collected at a central office where it can be analysed by automated data analytics processes as well as human experts.

Remote healthcare

Live bidirectional video for more efficient consultation, diagnosis, treatment, monitoring as well as for assisted surgery.

Remote surgery

In this use case medical devices are controlled remotely allowing off site surgeons to operate on a patient. This is probably the use case with the most demanding requirements in terms of latency, reliability and guaranteed quality of service. It is unlikely that the early deployments of 5G networks will have sufficient capabilities to support the functionality required by remote surgery.

4.4.3 Summary of requirements

The requirements for the health & wellness industry need to be further analysed. With the exception of remote surgery, it seems reasonable to assume that the requirements on the network are not very stringent, therefore it should be possible to support most of the use cases when the 5G network is deployed.

Availability is most important requirement for these use cases, followed by latency and then throughput.

From a functional point of view, many of the mentioned use cases are likely to require precise positioning solutions that also work when the device is indoor, strong security and both cloud and edge computing capabilities.

4.5 Industry 4.0, Manufacturing

4.5.1 Overview

The “Fourth Industrial Revolution” or Industry 4.0 is set to fundamentally change the manufacturing industry. The main drivers are improvements in terms of flexibility, versatility, resource efficiency, cost efficiency, worker support, and quality of industrial production and logistics.

To achieve the required flexibility, wireless connectivity (as a substitute for the wire-bound connectivity available in today's factories) is essential. Generally speaking, Industry 4.0 use cases have very demanding requirements, e.g. in terms of latency, synchronicity and availability.

4.5.2 Use cases

In [18] the Industry 4.0 use cases have been grouped into five different application areas. These are: Factory automation, Process automation, Human-machine interfaces (HMIs) & production IT, Logistics and warehousing and Monitoring and maintenance.

These application areas are composed of a set of basic use cases. These use cases are briefly summarised below:

Augmented reality

Augmented reality optimally supports shop floor workers, for instance, in tasks like: monitoring of processes and production flows, step-by-step instructions for specific tasks (e.g. in manual assembly workplaces), ad-hoc support from a remote expert (e.g. maintenance or service tasks). It is expected that the AR devices have minimum capabilities and that complex functions are executed at the edge cloud.

Control-to-control (C2C)

Control-to-control (C2C) communication refers to the communication between different industrial controllers. For higher flexibility it is expected that this communication is wireless. Depending on the concrete scenarios, these C2C systems typically have very challenging requirements on the communication service.

Motion control

Motion control controls moving and/or rotating parts of machines. Wireless communication is well suited for the control of components, which move and/or rotate.

Mobile robots and mobile platforms

Mobile robots and mobile platforms perform activities like assistance in work steps and transport of goods, materials and other objects and can have a large mobility within the industrial environment.

Mobile Control Panels with Safety Functions

Mobile control panels with safety functions are devices for the interaction between people and production machinery as well as for the interaction with moving devices, e.g. for configuring, monitoring, debugging, controlling and maintaining machines, robots, cranes or complete production lines. Optionally these panels are equipped with an emergency stop button.

Closed-loop control

Closed-loop control in which several sensors are installed in a plant and each sensor performs continuous measurements. The measurement data is transported to a controller, which takes a decision to set actuators.

Process monitoring

Process monitoring in which several sensors are installed in the plant to give insight into process or environmental conditions or inventory of material. The data is transported to displays for observation and/or to databases for registration and trending.

Plant asset management

Plant asset management that is required to keep a plant running. It is essential that the assets, such as pumps, valves, heaters, instruments, etc., are maintained. Timely recognition of any degradation and continuous self-diagnosis of components are used to support and plan maintenance. Remote software updates enhance and adapt the components to changing conditions and advances in technology.

4.5.3 Summary of requirements

Regarding performance, the most demanding requirements of the Industry 4.0 use cases are latency, reliability, device synchronicity, data rates, seamless mobility and energy efficiency. The most important functional requirements are plug-and-play support, positioning and local edge cloud support. For Industry applications, safety and security requirements are very critical and different from the other industries. Malfunction of the communication and potential external attacks via hacking can cause significant damage of production process even employee health. Moreover, 5G industrial solutions also need to consider how to seamlessly integrate the legacy communication methods used in the industrial environment.

Campus networks are well suited to satisfy the local coverage requirements of the use cases. Due to the very stringent requirements of these use cases, especially in terms of availability and reliability, some of the factory owners believe that arrangements such as exclusive access to spectrum and a private network operated by the owner of the factory will be needed.

The high throughput needed for some use cases, for example to support AR, will require a large bandwidth that may only be available in the above 6GHz spectrum bands.

4.6 Internet of Things for Low Power Wide Area Applications

4.6.1 Overview

The Internet of Things (IoT) describes the coordination of multiple machines, devices and appliances connected to the Internet through multiple networks [19]. The IoT encompasses a huge variety of use cases including some of the ones already described above. This section will cover use cases relevant for Low Power Wide Area (LPWA) applications, where the goal is to improve power efficiency, coverage, total cost of ownership and sustainability. Areas like agriculture and environment, consumer, industrial, logistics, smart building, smart city and utilities [20] are addressed.

There are several use cases, some of them have been also included in the other vertical industries (i.e. road warnings, smart meters, etc.) since they apply to a huge variety of sectors. In the following, only the most important use cases not address by other vertical industries are briefly described.

4.6.2 Use cases

The following list summarises the most important use cases:

Asset Tracking and monitoring

Being able to track and monitor assets is a very attractive use case because it allows to optimise the operational aspects, which differs depending on the type of asset. There are available examples of assets tracking that range from suitcases to pallets or containers.

Waste management

To minimise both costs and the impact on the environment, city administrations are looking to make waste collection smarter. Sensing when residential bins require to be collected improves operational cost. In addition, there could be a variety of sensors installed in bins, like for detecting the emission of gasses or fire.

Smart parking

Sensors are used to collect data about the occupancy of each parking space are becoming a very prominent use case for IoT. This solution not only improves traffic congestion, but it can also improve revenue collection where parking is paid for and improve usage of parking spaces where drivers can be directed to a free space.

Smart manhole

Smart manhole can be used to detect leakage in the infrastructure, both for water and gas. Smart pipeline monitoring can be deployed by utilising a variety of sensors like pressure, water flow, gas detector and acoustic, which report constant measurements to the control room.

Water metering

Involves the use of a flow sensor that allows measuring the water consumption. Water meters tend to not have any access to mains power and with an average lifetime that exceeds 10 years and in some cases reaches up to 16 years.

Gas Metering

Gas metering is very similar to the water metering use case. Gas meters have stricter requirements on the power consumption in order to prevent explosions. Also for this use case, the expected lifetime for the meter is normally set by national regulations, for example in Europe it is generally for 15 years or above, while in China it is around 10 years.

4.6.3 Summary of requirements

The requirements for LPWA have been analysed in quite some detail already. From the above use cases, the following requirements can be highlighted:

- A small amount of information is generally exchanged per transmission, low throughput required.
- Latency tolerant, better latency performances are expected for use cases like asset tracking and parking, but still acceptable in the range of a couple of seconds.
- Coverage is particularly important, for some use cases coverage is more important indoor and for other it is outdoor, but it is a constant requirement for all the use cases.
- Power consumption, all use cases described above do not have access to mains power and therefore require mechanisms to reduce as much as possible the battery consumption of the devices.
- Mobility is only relevant for asset tracking and marginally for waste management.

IoT is a good example in which most of the use cases can be served with available technology, such as 2G, NB-IoT, etc. However, these are networks built and operated independently from each other. Serving the IoT use cases over 5G and Network Slicing technology has the potential to greatly reduce operational costs, increase efficiency and leverage additional capabilities an operator can offer.

4.7 Public Safety

4.7.1 Overview

Several countries are considering updating their existing PPDR networks to take advantage of the advancements in mobile technology and capabilities such as high speed data transfer that are underdeveloped in the current mainstream systems in use such as TETRA and P25. Adopting the new technology will also unlock economies of scale and the introduction of innovative solutions as they become available for commercial services.

Countries such as the United States, South Korea and the UK are spearheading the introduction of LTE-based PPDR networks and the trend seems to point to a deployment of such networks as an overlay of existing commercial networks. A public safety network is therefore conceptually consistent with a network slice and due to the performance, availability, isolation properties it is natural to expect that it will be in a future deployed in a network slice.

4.7.2 Use Cases

The following use cases have been identified for public safety enabled mobile networks:

Mission Critical Push-To-Talk

As for the legacy TETRA and P25 networks, users of public safety networks need to be able to communicate in groups characterised often by strict hierarchy and facilitated by powerful floor control mechanism. The enablement of MCPTT is underpinned by the following requirements:

- Very low end-to-end talk setup time; below 100ms

- Very high number of users in one cell; ca. 6000
- High quality voice, incl. noise cancellation
- Group call capabilities
- Broadcast call capabilities
- Pre-emption and prioritisation for specific services, like Emergency Call
- Symmetric utilisation
- End-to-End encryption; 256 bit or higher
- Interface to narrowband standards, (e.g. TETRA)

Mission Critical Data

Data communications to allow the exchange of text messages, files and images between public safety officers can greately enhance the efficiency of their operations when compared to using only voice media. The following requirements are expected to be met:

- Real-time capability with very low delay and jitter, due to automatic analysis and overlaying during simultaneous usage of different sources
- High bandwidth in one network cell; up to 5 Gbit/s
- Pre-emption and prioritisation for specific services
- Symmetric utilisation
- End-to-End encryption; 256 bit or higher
- Interface to narrowband standards, like TETRA

Mission Critical Video

Real-time capability with very low delay and jitter, due to automatic analysis and overlaying during simultaneous usage of different sources

- High bandwidth in one network cell; up to 5 Gbit/s for video signals with a minimum resolution of 1080p60
- Pre-emption and prioritisation for specific services
- Asymmetric utilisation; higher uplink capacity than downlink
- End-to-End encryption 256 bit or higher
- Interface to narrowband standards, like TETRA

Massive Mission Critical IoT

Access to the ever-growing number of IoT devices such as security cameras, drones, smoke detectors, health monitors will provide unvalued support to the operations of public safety agencies, it is therefore required that a network can support communication with these devices in a secure and reliable manner. The following requirements apply to IoT devices used for mission critical operations:

- Real-time capability with very low delay and jitter, due to automatic analysis and overlaying during simultaneous usage of different sources
- Pre-emption and prioritisation for specific services;
- Asymmetric utilisation
- End-to-End encryption; 256 bit or higher
- Interface to narrowband standards, like TETRA

4.7.3 Summary of Requirements

Many commonalities emerge from the analysis of the requirements of the public safety use cases. Some of the requirements, such as backwards compatibility towards legacy PPDR communication systems, can probably be realised at application level via some interworking function. Security, which stands out as a main requirement for public safety use cases, could be provided at application level (e.g. end to end encryption), however it seems a better choice to utilise the capability of implementing different security models as well as isolation properties that Network Slicing allows to fulfil the security requirement of the public safety use cases.

The network slice will also need to be designed to provide capabilities for pre-emption and prioritisation of mission critical traffic, radio bearers with high bandwidth for mission critical data or with low delay and jitter for MCPTT and Mission Critical Video.

4.8 Smart Cities

4.8.1 Overview

The concept of smart cities envisages the deployment, management, usage and maintenance of city's assets using ICT. The goal is to improve efficiency, sustainability and to address the requirements coming from changing demographics. Thereby, areas like public transport, infrastructure, utilities, public safety, etc. are addressed.

The smart cities use cases are very diverse and many of them have already been addressed within other vertical industries (e.g. waste management, smart parking, smart bike sharing, energy grid, etc.). The following section focuses on the most important use cases that are not already addressed in this paper as part of other by other vertical industries are briefly explained.

4.8.2 Use cases

Intelligent lighting

Intelligent lighting refers to lighting networks in which, for instance, lights can be turned on in a formation on-demand. In addition, maintenance gains can be improved through regular status reports. However, the gains are expected to be relatively low. Therefore, the bundling with other services is needed, e.g. for monitoring, reporting, and coordination tasks as well potential sites for small cells or roadside units (for V2X services).

Public safety

Public safety networks open new opportunities to detect and fight crime. Examples could be secure and reliable communication networks for security service and law enforcement as well as the real-time analysis of data coming from different sources like cameras, sensors, etc.

Emergency service management

Emergency service management is about efficient and target-oriented communication in disaster (natural as well as man-made) scenarios. Herby, warnings to the people as well as communication to non-human entities (e.g. shutting down elevators, etc.) is envisioned.

4.8.3 Summary of requirements

The requirements for the smart cities industry have not yet been analysed in detail. For most of the use cases and requirements no concrete values but indications are available. However, it turns out, that most of the use cases are not very demanding e.g. compared to other industries.

Regarding the performance requirements, a very high density of devices as well as the high availability/coverage and high data rate are the most important requirements.

From the functional requirements energy efficient operations, especially for sensors and security are most important.

5

Industry Recommendations and Reshaping the Network Slicing Concept

5. Industry recommendations and reshaping the Network Slicing concept

This chapter aims to conclude the findings from the service requirements analysis discussed in section 4. Rather than providing details about the collected service requirements, this chapter provides conclusions and recommendations derived thereof. Recommendations towards cross-standardisation collaboration are expressed and the concept of the generic networking slicing template is briefly introduced. In addition the concept of Network Slicing is reshaped for the purpose of clarifying some common misunderstandings.

5.1 Requirements analysis

5.1.1 Use case clustering

This section provides a descriptive comparison outlining similarities and differences in use case requirements. In the future this clustering can be extended allowing identification of required service slice types and their characteristics.

In the literature future use cases are normally clustered based on their performance requirements into:

- Enhanced mobile broadband (eMBB)
- Ultra-reliable low latency communications (URLLC)
- Massive machine type communications (mMTC)

eMBB in contrast to MBB provides improved data rates, capacity and coverage. URLLC refers to critical types of communication supporting very low latency, high reliability as well as small to medium data rates. mMTC supports the IoT use cases with scenarios in which a very large number of (millions to billions) of small devices have to be connected efficiently, e.g. in an energy efficient way.

The use cases discussed in this document can be also grouped into these three main groups. An overview for non-IoT use cases is provided in Figure 7 in which use cases are roughly categorised based on their throughput, latency and availability requirements[1]. However, based on the performance requirements at least two additional service types can be identified:

- eMBBLLC use cases have high requirements on latency and bandwidth at the same time. Availability requirements are in most of the cases a bit more relaxed compared with URLLC use cases. Examples are augmented reality and virtual reality use cases.

- mMTC/URLLC use cases comprise sensors sending data which needs to be delivered with a very low latency and a high reliability. One example is the motion control use case of Industry 4.0.

[1] It should be noted that the clustering should be seen as indicative. Where available concrete values have been considered in case ranges of values were available the worth case was assumed and where no values were available and educated guess was done.

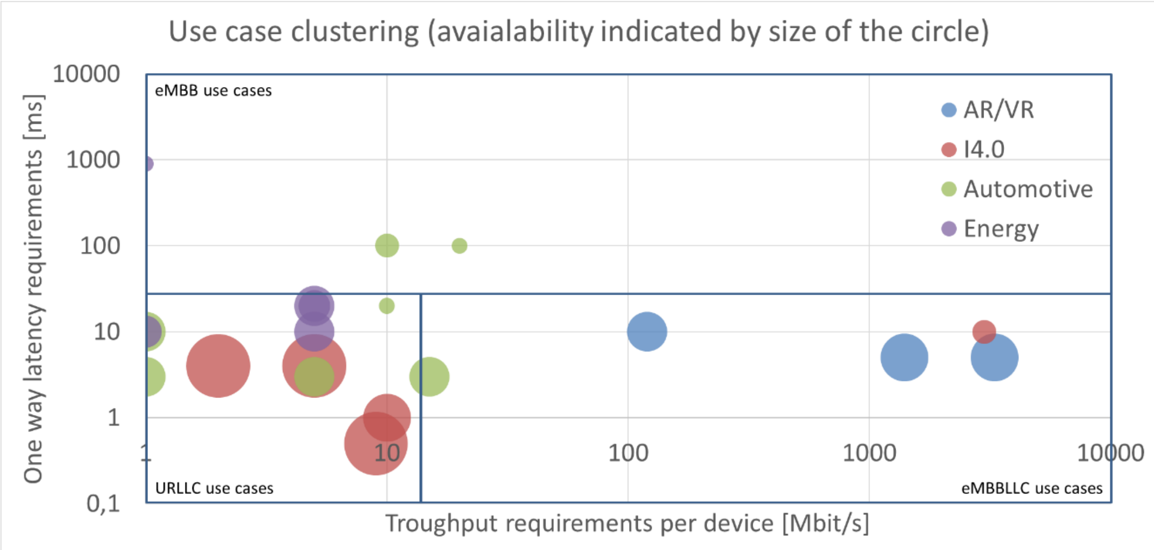

Figure 7: Use case clustering

Based on the previous findings one of the most important steps is to identify service slice types required to serve the different use cases. These service types could be selected based on performance, functional or operational requirements. How to do it exactly is subject to future discussions.

5.1.2 Performance requirements

This section highlights the most important performance requirements requested by the vertical industries. Requirements are explained and initial ideas are discussed on how to address these requirements.

5.1.2.1 Very tight synchronization

Some use cases have stringent requirements in terms of synchronicity of communication devices. Examples are cooperative driving use cases from the automotive industry or motion-control and control-to-control use cases from the Industry 4.0 vertical. For the latter ones, values of smaller than 1 microsecond are required.

Today these requirements are met by the deploying cable connections/networks as like industrial Ethernet systems or fieldbuses. These networks are normally closed solutions by a single vendor in which all the equipment is perfectly aligned. Based on standards like IEEE 802.1 AS [29] or IEEE 1588 [30] very high synchronicity can be achieved in the networks.

When thinking about 5G networks it is the expectation of the vertical industries that these very demanding synchronicity requirements can also be provided by wireless and cellular network. However, especially in wireless scenarios and for moving communication partners this is not an easy task and it requires more detailed investigations.

5.1.2.2 Cyclic traffic

Some applications rely on cyclic/deterministic traffic. Cyclic traffic is traffic with very regular traffic patterns, e.g. inter-packet delay (X) – see Figure 8.

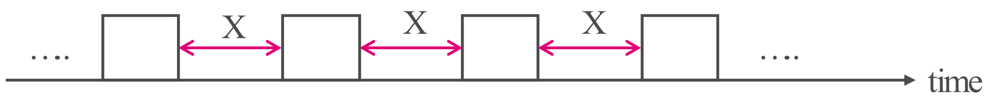

Figure 8: Cyclic traffic

Relevant use cases are, for instance, Voice over IP (e.g. 20ms inter packet delay), motion control (e.g. < 0.5ms inter packet delay), control-to-control (e.g. 4ms inter packet delay), etc.

The network slice must be able to deliver this type of cyclic traffic with minimum impact on the inter-packet delay. Especially in the RAN, this requires a special treatment. The pre-scheduler feature available in LTE since Release 8 might be a good candidate as it allows sending traffic in specific intervals by assigning resources in regular intervals. This reduces the delay and jitter as well as signaling overhead which improves the efficiency. However, more analysis is required.

5.1.3 Functional requirements

This section highlights the important functional requirements derived from the service requirements discussions. Some basic functions that operators could provide for industry customers include authentication, firewall, identity management, etc. Upon these fundamental requirements, a number of new functional requirements are also indicated by variant vertical industry use cases.

5.1.3.1 Security

Security is a general concern for all industries, because of the damage that security leaks may cause. However, the security requirements may be very different from industry to industry. For instance, the method to provide secure connectivity for millions of low-cost sensors could be very different to the mechanisms used to provide security for public safety services. Appropriate technical solutions should be defined to meet these requirements and comply with the requirements and solutions defined by 3GPP [28].

5.1.3.2 Isolation

Isolation refers to the degree of resource sharing that could be tolerated by the industry partner. Some customers may not mind to share network resource with other customers, but would require isolation for the computing resource. Sensitivity or criticality of the processes used by some customers may on the other hand lead to the requirement to only want to share the physical site like base stations, but use dedicated spectrum. Network Slicing should be able to be configured with different levels of isolation to satisfy the customers' needs.

More details about isolation are discussed in 5.5

Positioning

Many use cases have a strong demand for the capability of positioning (geo-localisation) devices. Different customers may have different requirements in terms of accuracy, energy efficiency, indoor/outdoor support, and cost, etc. For some of the use cases, positioning techniques will have to work reliably under challenging conditions, e.g. deep indoors.

Figure 9 graphically represents the positioning requirements in terms of accuracy and energy efficiency for a number of use cases.

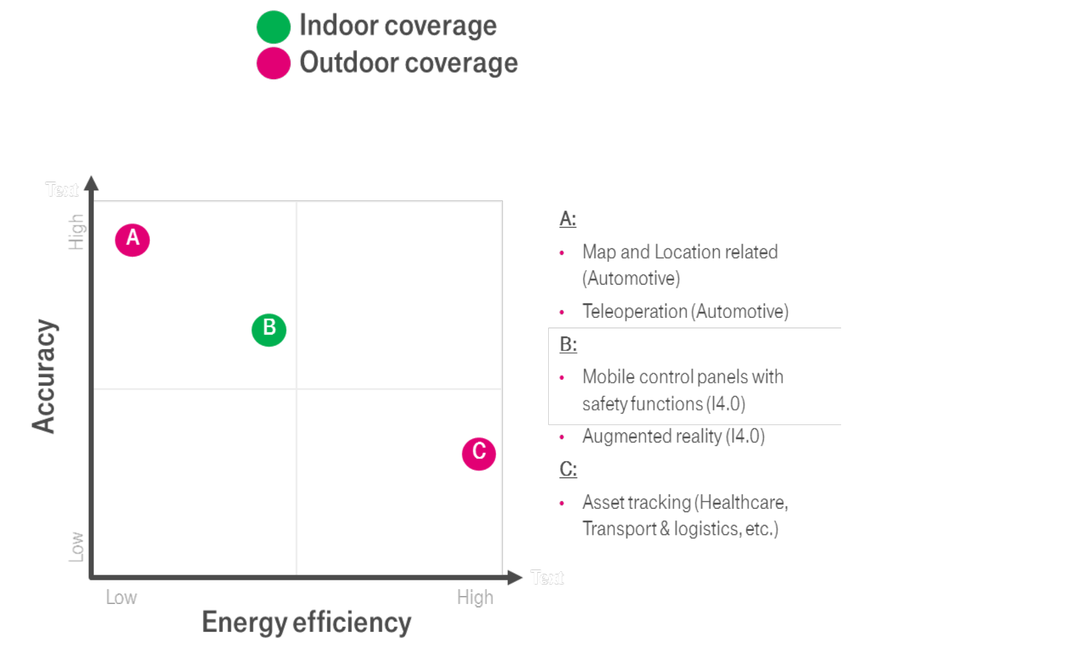

Figure 9: Positioning accuracy and energy efficiency indoor and outdoor

For automotive use cases (A), e.g. automated cooperative driving like short distance platooning, high precision positioning feature with an accuracy of a few centimetres is expected to be supported by the mobile network to ensure the vehicle-to-vehicle/network communication can be used even when GPS is not available, such as when moving through very dense urban scenarios or in bad weather condition.

For manufacturing use cases (B), high precision indoor positioning with an accuracy of <1m is required to support for instance mobile control panel with safety functions.

For asset tracking type of use cases (C), like.g. container tracking in Transport & logistics sector, it is often sufficient to provide a positioning solution that works outdoors and with relatively low accuracy. On the other hand, as mobile devices may be battery operated, the energy efficiency feature of the positioning solution plays an important role. In addition, in many of these use cases the positioning is expected to work globally across different networks and countries.

It should be noted that for some use cases, such as many IoT use cases, GPS or other Global Navigation Satellite Systems (GNSS) are not an option either because of the high energy efficiency consumption or because simple devices are not equipped with the suitable receiver.

For other use cases, e.g. automotive, GNSS is a suitable positioning solution for most of the times although there are a number of situations where this is not accessible e.g. tunnels, indoors, etc. Hence, it is beneficial to combine the advantages of these systems with the positioning capabilities of 5G to provide a solution that meets the customer scenarios.

5.1.3.3 Delay tolerance

To support certain vertical industry use cases, mobile system should be able to provide guaranteed SLA that is agreed with the customers. For instance, certain traffic flows should reach the end user within certain latency boundary. At the same time, there are use cases that are less sensitive to delay variations giving the mobile system some level of flexibility in scheduling traffic. For instance, in automotive industry, (non-critical) software/firmware update could be deprioritised and delivered when traffic is low such as during off-peak hours.

5.1.3.4 Predictive QoS

Predictive QoS is an important feature allowing operators to inform the service in advance about a quality drop. Predictive QoS can be applied to various KPIs, e.g. coverage, throughput, latency, etc.

For instance, when a vehicle is moving along a path under autonomous driving mode, the mobile system may foresee performance drop (e.g. due to channel condition or system congestion situation). In this case, the mobile system could as a precaution take corrective actions e.g. resource rescheduling (scaling up/out), or simply inform the vehicle about the potential performance drop. Such information could be evaluated by the vehicle itself in order to make decision to switch from autonomous driving mode to manual driving mode to avoid potential danger. The higher accuracy a system’s predictive QoS provisioning capability is, the higher possibility for the system to support industry use cases with critical system performance requirements.

To find out how predictive QoS works under realistic conditions and which accuracies can be achieved more analysis and field trials are required.

5.1.4 Operational requirements

In previous generation mobile systems, operator’s infrastructure as well as the provided network services have always be presented as a black box for the OTT or enterprise customers. Only few APIs are provided by the network to the service providers including making and receiving voice calls, sending SMS/MMS, the Service Capability Exposure Function (SCEF) that provides a means to securely expose the services and capabilities provided by 3GPP network interfaces, etc.

However, these APIs might not be enough for some of the future use cases or future customers. To better support vertical industries to deliver their services to their own end users via slicing method, under specific regulatory regimes it may be possible to open up certain operational capabilities of the mobile system towards the vertical industries. Operators could provide a set of APIs to expose such capabilities towards vertical customers. This does not only provide convenience for verticals to manage their own service, but also enrich the Network Slicing business model for telco industry.

According to the business incentive as well as service operation methods, vertical customers have very different perspectives in terms of required operational capabilities.

5.1.4.1 Monitoring capability

Monitoring capability is one of the fundamental operational requirements, for instance monitoring traffic characteristic and performance (e.g., data rate, packet drop, and latency), end user's geographical distribution, etc. Moreover, monitoring itself also contains many subcategory according to the add-on requirements, for instance, monitoring granularity (e.g. per second, per hour, etc.), per session/user/slice instance based monitoring, etc.

5.1.4.2 Limited control capability

Vertical customers could use APIs provided by the operators to control network service. For instance, instead of simply using the network service, vertical customers could decide where to locate the network functions. Moreover, verticals could also decide how to integrate their own applications with the other network functions to run together within the network slice instance provided for them.

5.1.4.3 Configuration capability

Configuration refers to the capability to allow vertical customers to adjust and modify the network functions as well as underlying resources within the network slice instance provided for them.

5.1.4.4 Full operation capability

Full operation is the highest operational capability that could be provided via slicing method. Within the provided network slice instance, vertical customers could have full control of the network service operation. Therefore, they are self-responsible for the network service assurance and maintenance within the limit set by the network operators. In particular network access should remain under the control of the operator. The impact and the application of the regulatory obligations will have to be studied in this approach.

This might be very helpful for the customer in case of networks problems or outages for instance by configuring backup paths.

5.1.5 Coverage requirements

Vertical requirements very much differentiate in the type of coverage they require. Three main groups have been identified: Local, nationwide and global coverage. More details are provided in the following.

5.1.5.1 Local coverage

Local coverage is requested mostly by Industry 4.0 and healthcare industries in which a very specific geographical area needs to be covered, e.g. an industry area or a hospital.

Local coverage requirements could be met by a network slice (as a kind of VPN based on an existing public network) restricted to a small number of base stations or by so called campus networks. A campus network is a dedicated physical network installed in the premises of the enterprise. This makes campus networks very flexible (i.e. build out independent of an already existing public network) as they are limited to a small number of devices, which allows the rollout of new hardware fast and efficiently.

Typically for local coverage a single administrative domain is sufficient to serve the customer or use case.

5.1.5.2 Nationwide coverage

Nationwide coverage requested by industries, which do not need coverage outside a specific country. Examples are utilities industries, government services and smart cities.

For this type of coverage, typically a single administrative domain (e.g. a single network operator) is sufficient. For very demanding use cases, national roaming could be envisioned in order to meet for instance the availability and coverage requirements. According to NGMN [26] this is the “business vertical” scenario.

5.1.5.3 Global coverage

Global coverage is required by companies and industries with worldwide points of presence or which are selling their products globally. The most obvious industry requiring global coverage is automotive. Other examples are transport & logistics use cases. Providing global coverage normally means that network services need to be provided across multiple administrative domains. According to NGMN [26] this is the “roaming” scenario.

For this type of coverage, the network slices used to serve customers need to be made available also when the device is outside its home network. Several solutions are discussed in literature on how to achieve this. Three of the most prominent approaches are briefly introduced: (1) the visited network could provide to the roaming user a network slice with equivalent functionality of the slice used in the home network, e.g. using standardised slices. (2) the home network may export the blueprint of a custom network slice used by a user so that it can be instantiated and administered by the visited mobile network operator. (3) the home network may extend the slice into the visited network, provided it has authorisation from the visited network to control the resources.

5.2 Generic Network Slicing template

As discussed in this section, a network slice has different characteristics or attributes which can be roughly grouped into three categories: performance, functional and operational.

These attributes need to be specified and quantified in some way, so that:

- the slice buyer knows what to expect and to be sure that the service requirements can be met
- the slice provider knows what to deliver
- there is a sound basis for a SLA/contractual agreement between the Slice provider and buyer
- UEs can roam onto another networks, but maintain access to the services that require particular network capabilities e.g. by allowing a home operator to buy a Slice in a visited domain

The general set of attributes that characterise a slice (in terms of performance, functionality and operation) should be the same for any slice implementation, regardless of the values associated to those attributes.

NOTE: some attributes may be void or not applicable to some slice implementations

It is highly beneficial to achieve a common method the industry can refer to in order to describe the characteristics of any slide – that is what we refer to as a “Generic Slice Template (GST)”. Every Slice can be fully described by allocating values (or ranges of values) to each relevant attribute in the GST.

One of the main areas the industry should focus is to agree a definition of a Generic Slice Template, with all the KPI names, units and granularity, but no actual values. This would allow to unlock all the benefits described above. For example, an operator may easily communicate the expected behaviour of a network slice provided to a customer when such customer moves to a visited network allowing the visited network to decide what mappings would be needed between slices in home and visited networks. This generic template would not be specific to a vertical, and so would be useable by any future 5G services. When deploying or offering a slice to a customer, the “contract” would specify the values that each parameter would take for a given slice instance. Some examples of parameters, or ranges for parameters may be given to communicate the intent.

The generic slice template serves as a baseline for the definition of service/slice types by specifying the values (or range of values) for each of those attributes. The GST also serves as baseline for slices only negotiated between the operators and its customer.

5.3 Cross-Standardisation Collaboration Recommendations

E2E Network Slicing contains different technical domains as discussed in Section 3 (e.g. AN, CN, TN, Cloud), and many SDOs are working in parallel to provide slicing solution under their area of competence. The technical content is as a result fragmented. In order to form an E2E solution, significant work is required in terms of cross-SDO cooperation and coordination, which will be explained in the following sections.

5.3.1 Coordination from System Architecture Perspective

The overall 5G system architecture is under the development of 3GPP SA2 Working Group, for whom Network Slicing is one of the fundamental design feature of the 5G system. To enable E2E connectivity of Network Slicing across multiple technical domains, potential coordination between 3GPP and other SDOs is desired. For instance, in an FMC (Fixed Mobile Convergence) scenario, part of the E2E slice may be provided using non-3GPP access such as WLAN or fixed access defined in BBF), therefore combined efforts between 3GPP SA2 and BBF may be required to guarantee the correct deployment.

When considering slices that should fulfil use cases with low latency requirements that can be provided using Multi-access Edge Computing (MEC) coordination between 3GPP SA2 and ETSI MEC [21] would be required. For instance, some information such as application instances locations, traffic rules, identification of traffic that needs to be offloaded to the edge needs to be exchanged between 3GPP network and ETSI MEC system for the purpose of selection and/or reselection of the User Plane Function (UPF) and potentially to relocate the application. There is an ongoing work item in ETSI ISG MEC named “MEC support for Network Slicing” [24], which focuses on identifying the necessary support provided by Multi-access Edge Computing for Network Slicing and, in addition, how the orchestration of resources and services from multiple administrative domains could facilitate that. This could be a potential candidate for cross-SDO coordination for MEC topic.

5.3.2 Coordination from Management Perspective

5.3.2.1 Transport Network Aspect

As shown in Figure 6 of Section 3, management aspect is considered separately in different SDOs based on the targeted technical domain. 3GPP SA5 Working Group is responsible for the life cycle management of slices (e.g. creation, run-time assurance, etc.) in the 3GPP realm that contains the RAN and CN parts of the slices. Transport network, which is one essential part in E2E Network Slicing solution, is not in 3GPP scope. TN slicing management architecture is instead defined by BBF. To enable E2E management of a slice, it is essential to align BBF and 3GPP SA5, in terms of terminology, architecture, interfaces, etc. Moreover, interoperation between 3GPP and BBF-defined slicing management entities needs to be in place. For instance, 3GPP SA5-defined slicing management system needs to send transmission link requirements to BBF-defined TN slicing management system. Vice versa, 3GPP slicing management system needs to retrieve TN information to establish the transmission link between 3GPP network function entities. The northbound interface that is used for such information exchange should be aligned between BBF and 3GPP, and IETF could be used to standardise the protocol of the northbound interface according to the requirements collected by BBF.

5.3.2.2 Virtualisation Aspect

Virtualisation and cloudification have been deployed in 4G cores already. This technologies will continue to be the major features in the 5G new core (5GC) design. 5GC network functions are modularised (so that they can be executed as software in a datacentre) and interconnected with each other using service based interfaces. Hence, to deploy and manage slices in a virtualised network environment, 3GPP SA5 should coordinate with ETSI ISG NFV.

5.3.3 Coordination from Security Perspective

Security is a built-in feature of the overall system architecture that supports Network Slicing in order to provide the fundamental guarantee of the telecom services as well as the specific requirements of the safety-critical applications and services. Way beyond the slice-internal and slice-specific security provisions and the access control to the slicing subsystem, slice security should be also systematically designed to empower secure and reliable E2E slice life cycle management.

E2E slicing security can be implemented at different levels and dimensions, e.g. from communication method (e.g. authentication) to isolation method (e.g. soft isolation based on virtualisation or hard isolation based on physical entity). Security related work is carried out in multiple SDOs in parallel as well. 3GPP SA3 works on the security/isolation method for Network Slicing, including the definition of overall implementation, strategies, standard interfaces and protocols etc., but as in the case of slice management, it does not cover transport as well as virtualisation aspects. Hence, the coordination between 3GPP SA3 and ETSI ISG NFV, BBF, and IETF are necessary for an overall E2E security.

5.3.4 Coordination between SDOs and Open Source

Other than the work from SDOs, open source is fast becoming more and more prominent in the scope of 5G. For example, Open Network Automation Platform (ONAP), an initiative from operators in cooperation with the Linux Foundation, is an open source software platform that delivers capabilities for the design, creation, orchestration, monitoring, and life cycle management of VNFs, carrier-scale Software Defined Networks (SDNs) as well as higher-level services [22]. Open Source MANO (OSM) is another operator initiative from ETSI community, which aims to deliver production-quality open source Management and Orchestration (MANO) stack aligned with ETSI NFV [23]. Currently, there is a lacks of clear understanding of the relationship between standardisation and open source especially at the management domain as well as competition between open source initiatives.

As mentioned previously, ETSI's Zero touch network and Service Management (ZSM)[24] aims to help in this area of coordination among SDOs and open source solutions. Part of its mandate is to analyse gaps and help align approaches from these different organisations. Currently, one of the work items in ZSM is to develop an end to end view of Network Slicing management looking across domains, for example, 3GPP network slice management and the ETSI NFV virtualisation platforms.

5.4 Other recommendations

Additional recommendations are:

- It turned out that for many KPIs, e.g. for latency, different interpretations and understanding throughout the industries exist. Therefore, it is recommended to specify/define relevant KPIs in order to get a common understanding.

- Requirements some industries pose on 5G and Network Slicing have been derived from today's use cases and processes. However, today these requirements are met using fixed line network technologies as like industrial Ethernet or optical fibres. These requirements very often are too demanding for cellular networks as 5G. Therefore, discussions between telecommunication and vertical industries are required to cooperatively find solutions for that.

- Some use cases and industries have very demanding availability and reliability requirements. However, it is not well understood how these requirements can be met, e.g. which mechanisms can be applied to improve availability and reliability beyond state of the art networks. It is recommended to have a deeper look into these aspects.

- It would be beneficial to standardise a small set of globally available network slices serving use cases that are of interest in many countries and common to different verticals and use cases.

5.5 Network Slicing Concept Evolution

Compared to 2015, when NGMN first introduced Network Slicing concept, the understanding of Network Slicing is much more mature now. The fundamental system architecture defined by 3GPP is capable to support a terminal to use multiple slices simultaneously. There are a number aspects that need particular attention.

Operational isolation vs. network level isolation

"Isolation" is considered as one of the key features that Network Slicing could provide. Isolation could be understood from two dimensions: (1) operational isolation, means that vertical customers could have independent monitoring, control, configuration, or even full operation capability of the network slice; (2) network level isolation, means that vertical customers do not share network function or resources with the other customers. Network level isolation also has different sub-categories, for instance, shared RAN but isolated core, or isolated RAN as well as core, etc.

Operators can provide operational isolation without or with very weak network isolation. For instance the system could use IDs to differentiate the users belonging to different tenants who share the infrastructure. One example is NB-IoT, which can be treated as a pre-configured network slice, with many different IoT tenants sharing the same NB-IoT network.

On overview of the different levels of network isolation is provided in Figure 10. It is obvious that the different levels of isolation will have different cost. Most expensive mode will be dedicated RAN (L0 or L1), which may only be relevant for very few use cases.

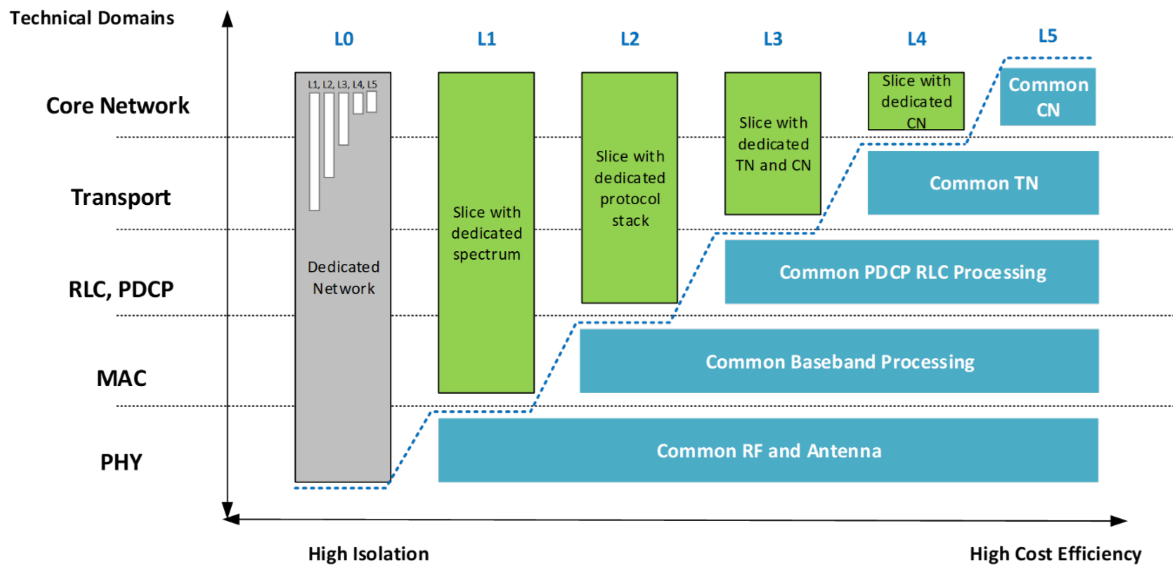

Figure 10: Different Levels of Network Isolation

It is essential to understand, how to let vertical customers comprehend this feature from business aspects and which kind of isolation do they prefer to have.

From an operator's perspective, isolation requirements could be identified in different ways. In some cases, it is the vertical customers' direct requirement, i.e. they directly ask for operational isolation or network level isolation. In other cases, customers do not express any isolation requirement, but the operator takes decisions on isolation based on other requirements. For instance, if a customer requests a service level which is quite demanding, the operator may assign dedicated resources in order to ensure it can meet the service level commitment, which in turn is implemented via Network slice isolation solution.

Based on a survey with vertical customers, the majority of those who have isolation requirements, have direct requirements on operational isolation instead of network level isolation. There are also some specific vertical industries that have clear network level isolation requirements, e.g. public safety, smart grid, for security and safety purpose. Hence, their network slice(s) may not share any network function and resource with the other network slices. Such customers are minority cases.

Not a network slice for each vertical customer

Based also on the clarification of slice isolation matter, it is not necessary to provide an independently deployed E2E network slice for each vertical customer, because this is not their fundamental requirement. One network slice could serve many vertical customers simultaneously.

Number of slices supported by the 5G system

This is one of the fundamental question about Network Slicing. Potentially, the amount of network slices could be very high under the assumption of full system automation and programmability. However, the amount of slices should be designed based on the capability of the underlying deployed infrastructure, as well as the performance, functional and operational requirements of business customers (especially at the initial phase of slice deployment). Moreover, it ought to be an individual operator choice. It is technically feasible to have roaming solutions where the HPLMN and VPLMN have taken different strategies in the number of deployed network slices to serve the same customers.

Network slice deployment

Network Slicing deployment will benefit from network automation. The automation in rolling out network slices will be subject to normal learning curve that new technologies are commonly experiencing. So it can be expected that the degree of automation of deployment of a network slice will evolve over time.

6

Regulatory Aspects

6. Regulatory aspects

Network Slicing will be a feature of 5G - this is based upon software defined network and network function virtualisation. In reviewing Network Slicing, regulation should be considered and views on key areas are provided below. However, from a regulator's perspective they will want to understand what, if anything changes from developments in technology, and how this impacts customers. These changes might impact and / or be constrained by the regulatory aspects listed below. Further analysis is required to understand the evolution of the regulatory aspects to align with these changes.

6.1 Net Neutrality

While there is no single definition of net neutrality, it is often used to refer to issues concerning the optimisation of traffic over networks.

Mobile network operators face unique operational and technical challenges in providing fast, reliable internet access to their customers, due to the shared use of network resources and the limited availability of spectrum. Network Slicing may provide options of how mobile operator networks can better meet customer needs.

As the net neutrality debate has evolved, policymakers have come to accept that network management plays an important role in service quality.

Industry position –

- To meet the varying needs of consumers, mobile network operators need the ability to actively manage network traffic and the flexibility to differentiate between different types of traffic.
- Regulation that affects network operators' handling of mobile traffic is not required. Any regulation that limits their flexibility to manage network, service quality and provide consumers with a satisfactory experience is inherently counterproductive.
- Consumers should have the ability to choose between competing service providers and a variety of offers / tariffs to best meet their individual needs.
- Mobile network operators compete along many dimensions, such as pricing of service packages and devices, different calling and data plans, innovative applications and features, and network quality and coverage. The high degree of competition in the mobile market provides ample incentives to ensure customers enjoy the benefits.
- Where there is flexibility, mobile network operators are able to offer a bespoke, managed service to providers of new connected products, such as autonomous cars, which could not exist without constant, high-integrity connectivity. Operators can also enter into commercial arrangements with content and application providers that want to attract users by offering free access, that is, zero-rating their content so mobile subscribers are not 'charged' for the data usage. These kinds of arrangements enable product and service innovation, deliver added value to consumers and generate new revenue for network operators, which face constant pressure to enhance, extend and upgrade their networks.

6.2 Quality of Service

The quality of a mobile data service is characterised by a number of important parameters, notably speed, packet loss, delay and jitter. It is affected by factors such as mobile signal strength, network load, and user device and application design.

Industry Position

- Competitive markets with minimal regulatory intervention are best able to deliver the quality of mobile service customers expect. Regulation that sets a minimum quality of service is disproportionate and unnecessary. The quality of service experienced by mobile consumers is affected by many factors, some of which are beyond the control of operators, such as the device type, application and propagation environment. Defining specific quality targets is neither proportionate nor practical.

- Mobile networks are technically different from fixed networks; they make use of shared resources to a greater extent and are more traffic-sensitive. Mobile network operators need to deal with continually changing traffic patterns and congestion, within the limits imposed by finite network capacity, where one user's traffic can have a significant effect on overall network performance.

- The commercial, operational and technological environment in which mobile services are offered is continuing to develop. Mobile network operators must have the freedom to manage and prioritise traffic on their networks. Regulation which rigidly defines a particular service quality level is unnecessary and is likely to impact the development of these services.

- Competitive markets with differentiated commercial offers and information that allows consumers to make an informed choice deliver the best outcomes. If regulatory authorities are concerned about quality of service, they should engage in dialogue with the industry to find solutions that strike the right balance on transparency of quality of service.

6.3 Cross-Border Data Transfers

The global digital economy depends on cross-border data transfers to deliver crucial social and economic benefits to individuals, businesses and governments.

When data is allowed to flow freely across national borders it enables organisations to operate, to innovate and to access solutions and support anywhere in the world. Enabling cross-border data transfers can help organisations adopt data-driven digital transformation strategies that ultimately benefit individuals and society. Policies that inhibit the free flow of data through unjustified restrictions or local data storage requirements can have an adverse impact on consumers, businesses and the economy in general.

Cross-border transfers of personal data are currently regulated by a number of international, regional and national instruments and laws intended to protect individuals' privacy, the local economy or national security. While many of these instruments and laws adopt common privacy principles, they do not create an interoperable regulatory framework that reflects the realities, challenges and potential of a globally connected world. Emerging frameworks such as the APEC Cross-Border Privacy Rules and the EU's Binding Corporate

Rules allow organisations to transfer personal data generally under certain conditions. These frameworks contain accountability mechanisms and are based on internationally accepted data protection principles.

However, their successful adoption is undermined by the implementation by governments of ‘data localisation’ (also known as ‘data sovereignty’) rules that impose local storage requirements or use of local technology. Such localisation requirements can be found in a variety of sector- and subject-specific rules including for financial service providers, the public sector or professional confidentiality reasons and are sometimes imposed by countries in the belief that supervisory authorities can more easily scrutinise data that is stored locally.

It is envisaged that network slices may be utilised to offer services outside of the home jurisdiction, potentially in a similar manner to international roaming. Any transfer of data across borders may need to consider regulatory requirements.

Industry Position

Cross-border transfers of data play an important role in innovation, competition and economic and social development. Governments can facilitate cross-border data flows in a way that is consistent with consumer privacy and local laws by supporting industry best practices and frameworks for the movement of data and by working to make these frameworks interoperable. Governments can also ensure that these frameworks have strong accountability mechanisms, and that the authorities can play a role in overseeing/monitoring their implementation. Governments should only impose measures that restrict cross-border data flows if they are absolutely necessary to achieve a legitimate public policy objective. The application of these measures should be proportionate and not arbitrary or discriminatory against foreign suppliers or services. mobile network operators welcome frameworks such as the APEC Cross-Border Privacy Rules or the EU’s Binding Corporate Rules, which allow accountable organisations to transfer data globally, provided they meet certain criteria. Such mechanisms are based on commonly recognised data privacy principles and require organisations to adopt a comprehensive approach towards data privacy. This encourages more effective protection for individuals than formalistic administrative requirements while helping to realise potential social and economic benefits. Such frameworks should be made interoperable across countries and regions to the greatest extent possible in order to seek convergence between different approaches to privacy while promoting appropriate standards of data protection and to allow accountable companies to build scalable and consistent data privacy programmes.

Requirements for companies to use local data storage or technology create unnecessary duplication and cost for companies and there is little evidence that such policies produce tangible benefits for local economies or improved privacy protections for individuals.

To the extent that governments need to scrutinise data for official purposes, mobile network operators would encourage them to achieve this through existing lawful means and appropriate intergovernmental mechanisms that do not restrict the flow of data.

6.4 Illegal Content

Today, mobile networks not only offer traditional voice and messaging services, but also provide access to virtually all forms of digital content via the internet. In this respect, mobile network operators offer the same service as any other internet service provider (ISP). This means mobile networks are inevitably used, by some, to access illegal content, ranging from pirated material that infringes intellectual property rights (IPR) to racist content or child sexual abuse material (child pornography).

Laws regarding illegal content vary considerably. Some content, such as child sexual abuse material, is considered illegal around the world, while other content, such as dialogue that calls for political reform, is illegal in some countries while being protected by ‘freedom of speech’ rights in others.

Communications service providers, including mobile network operators and ISPs, are not usually liable for illegal content on their networks and services, provided they are not aware of its presence and follow certain rules e.g., ‘notice and take-down’ processes to remove or disable access to the illegal content as soon as they are notified of its existence by the appropriate legal authority.

Mobile network operators are typically alerted to illegal content by national hotline organisations or law-enforcement agencies. When content is reported, operators follow procedures according to the relevant data protection, privacy and disclosure legislation. In the case of child sexual abuse content, mobile network operators use terms and conditions, notice and take-down processes and reporting mechanisms to keep their services free of this content.

The issues in relation to illegal content, liability, regulatory and self-regulatory obligations and commitments will need to be addressed with the introduction of Network Slicing. These may also vary depending on how slices are implemented.

Industry Position

The mobile industry is committed to working with law enforcement agencies and appropriate authorities, and to having robust processes in place that enable the swift removal or disabling of confirmed instances of illegal content hosted on their services. ISPs, including mobile network operators, are not qualified to decide what is and is not illegal content, the scope of which is wide and varies between countries. As such, they should not be expected to monitor and judge third-party material, whether it is hosted on, or accessed through, their own network.

National governments decide what constitutes illegal content in their country; they should be open and transparent about which content is illegal before handing enforcement responsibility to hotlines, law-enforcement agencies and industry.

The mobile industry condemns the misuse of its services for sharing child sexual abuse content. The GSMA’s Mobile Alliance Against Child Sexual Abuse Content provides leadership in this area and works proactively to combat the misuse of mobile networks and services by criminals seeking to access or share child sexual abuse content.

Regarding copyright infringement and piracy, the mobile industry recognises the importance of proper compensation for rights holders and prevention of unauthorised distribution.

6.5 Summary

At this stage there do not seem to be new regulatory challenges as a result of Network Slicing. However, the challenge(s) may be on how best to meet existing regulatory obligations as result of Network Slicing.

Implementation of Network Slicing may also need to consider a range of other regulatory issues from, but not limited to - access to emergency calls, support of law enforcement and government access to data and the related legislative frameworks that enables this, to consumer protection and competition policy.

7

Next Steps

7. Next steps

To date within GSMA we have looked at the Network Slicing topic as a new capability that will be delivered with the new 5G core network. We still have considerable work to do, including; definition of slice types and the parameter sets that may exist within different slices, validate 3GPP defined Slices, coordinate industry Slicing activities, explore Business Models, market sizes, market opportunities and value chains, etc. This will form basis for the deliverables in the next phase. We welcome input from Operators, Vendors and customers into this technical paper.

Also, many operators are not waiting for 5G Core (3GPP Release16) to explore the concept of delivering differentiated capabilities to different customer sets. Operators have different physical and increasingly virtual networks and network capabilities today, including; 2G, 3G, 4G, NB-IoT, Emergency Services LTE, etc. Virtualisation of network elements facilitates the automation of network orchestration, configuration and deployment. Current capabilities like Edge Cloud allow us to start to explore lower latency opportunities, and in the near future we will begin to add 5G New Radio to serve new and existing customers. We will also use 5G NR to deliver against MNO requirements like Fixed Wireless Access substitution. Operators are beginning to differentiate between Consumer focused networks and Business or Vertical focused networks.

While 5G core and the real slicing capability allow for significantly more efficient deployment of sliced capability, orchestration and configuration mechanisms, operators are willing to explore opportunities for service differentiation and optimisation offered by pre-5G solutions.

Consequently, another deliverable in the next phase will be a paper focusing on the emerging (or bottom up) trend of using Multiple Dedicated Core Networks (MDCN) to deliver differentiated services and solutions utilising existing EPS system capabilities. We anticipate this paper to be available at the end of Q318. We welcome input from Operators, Vendors and customers.

Finally, it is important to continue the interactions with the vertical industries in order to better understand their use cases and requirements.

Annex A Document Management

A.1 Document History

Version	Date	Brief Description of Change	Approval Authority	Editor / Company
1.0		New Future Network Programme document	Future Network Programme Network Slicing Taskforce	Future Network Programme Network Slicing Taskforce

A.2 Other Information

Type	Description
Document Owner	GSMA Future Networks Programme
Editor / Company	Michele Zarri / GSMA Kelvin Qin/ GSMA
Reviewed & Approved by	Future Network Programme Network Slicing Taskforce

It is our intention to provide a quality product for your use. If you find any errors or omissions, please contact us with your comments. You may notify us at 5GNetworks@gsma.com

Your comments or suggestions & questions are always welcome.