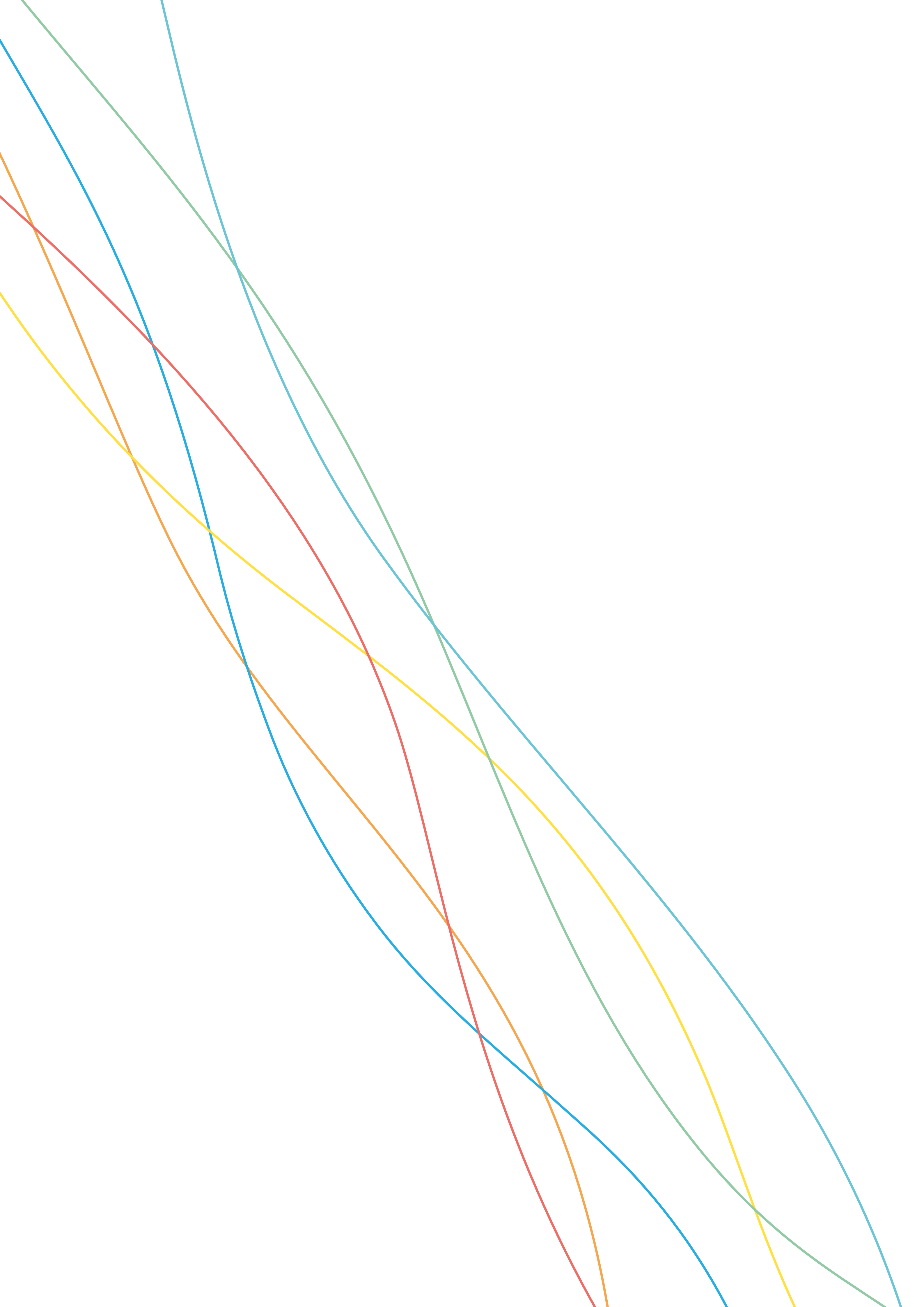
5G Network Slicing for Cross Industry Digitization:

Position Paper



Companies contributing to this paper

中国移动 China Mobile

T · ·

Fraunhofer FOKUS

HUAWEI

国家电网 STATE GRID
中国电力科学研究院有限公司
CHINA ELECTRIC POWER RESEARCH INSTITUTE

TIM

VOLKSWAGEN
AKTIENGESELLSCHAFT

DIGITAL DOMAIN 数字王国

Tencent 腾讯

Table of Contents

Executive Summary

Industry worldwide has been undergoing a tremendous digital transformation featuring the convergence of information/communications technology and operation technology in various segments. This ushers in an era of fully connected machines, controllers, platforms and storage systems running in nearby factories or remote data centers, and the sharing of open data among them. The digitized information fused with analytics is expected to shed new light on industrial planning, operations and maintenance processes, while changing business in a fundamental way, not only through streamlined process and optimized production, but also by enabling new business models.

In a nutshell, industry digitization involves the connection of massive numbers of machines and people, with open data sharing and a generic ICT infrastructure to support them. In this Paper the authors promote the concept of 5G Network Slicing to implement the connectivity of innumerable industrial nodes with various needs, unleashing the potential benefits of digitization. Use cases are presented to illustrate how a network slice can be utilized to redefine information sharing in a wide variety of industrial scenarios, ranging from ultra-reliable low-latency machine communications to the small-packet bursty transmission of operations data.

This Paper shares a cross industry understanding of how Network Slicing can enable and accelerate digital transformation in industry verticals[1]. It can also serve as the basis to inspire future efforts to investigate business rationale, derive technical requirements and unveil the financial values of Network Slicing.

[1]The term industry vertical refers to non-telecom industries such as automotive, transport, health, manufacturing etc.

Industry Digitization Overview

The convergence of information technology and operation technology platforms is expected to usher in a new world of machine-to-machine communication. But, until now, the internet has been dominated by a variety of consumer-based business models that deliver increasingly complex content to users in near real-time. The rise of new business models that take advantage of the ubiquitous appetite for streaming video and audio files has created over 2 trillion USD of market capitalization among top consumer internet companies like Amazon, Apple, Facebook and Google. The success of this wave of mobile internet is based on the pervasive connectivity now available to billions of people via mobile phones and the internet, by changing our way of living and doing business around the world.

But we might ask: what is needed now to bring tens of billions of machines and Internet of Things objects into a similar mesh of real-time data exchange and value-added transactions?

The authors of this paper believe wireless communications, and 5G slicing technology in particular, will help make pervasive networks of intelligent objects, machines, and people a reality.

Many machines are controlled by sophisticated management systems that generate and process enormous amounts of data at the edge of networks or as solitary entities. The default system design for most machine control devices relies on proprietary data bus technology and embedded real-time controllers. The life or death consequences of machine failure or interruption have made many traditional industries slow to embrace networked systems and open standards for data sharing across devices and platforms. However, there is a growing number of opportunities for new business models bringing artificial intelligence, robotics and autonomous control to networks of industrial machines, devices and systems. This is re-defining the need for a new type of secure, robust and customer managed communication.

The Industrial Internet is a concept that has taken hold over the past few years as the need to manage complex machines and systems becomes a goal for all industries. Globalization has extended the supply chain, logistic networks and manufacturing to the far corners of the world, powered by networks of machine learning, automation and real-time data access. But just as people do not always share a common language, the parlance of machines comes in many variations and dialects. Therefore it is critical to design a next generation communication network that facilitates communication among devices of different language context for informative decision-making.

Today we are looking at enabling Communication Technology for the next Industrial Revolution. We anticipate this will cause an even larger set of revolutionary technologies to be unleashed, when a ubiquitous 5G slicing connection fabric is created with the security, robustness and control elements necessary to satisfy the needs of industry, government and consumers alike. The 5G slicing network, with attributes discussed in following chapters, is expected to help connect, move and process information at speeds, security levels and costs that have proved elusive until now.

5G Network Slice Introduction

With the introduction of 5G, industries in digital transformation will move beyond traditional people-centered service, on an unprecedented scale. It is worth noting that this is not only a new value for the innovation of the telecommunications industry, but also a new engine for economic growth and social development.

Industry digitization will rely on the robust connectivity of trillions of devices and the open sharing of data that will subsequently be generated. Enabling technologies are desperately needed to do this. Traditional industrial networking technologies, such as industrial field busses coupled with closed fiber optic network, are silo solutions and cost prohibitive for large-scale deployments. In addition, these technologies are usually based on closed proprietary systems precluding lower cost hardware development, open information exchange and fast innovation due to small specialized markets.

To facilitate information sharing among sensors, controllers and analytics, we have begun to migrate to an industrial communication system with standardized interfaces, enormous economies of scale and a proven track record of operational excellence, like 3GPP networks. In particular, technologies under investigation should take into account the following factors as desired by future industries.

Firstly, industry-specific services have drastically different requirements for network characteristics and performance, which are impossible to meet with monolithic network architecture. We believe that industry digitization will be fueled by customized communication solutions that are dynamic and open. Secondly, future industry will be characterized by rapidly evolving service requirements and innovations. Correspondingly, the sustaining network technology should also be flexible and scalable to adapt to ever-changing business/service needs.

In addition, the next generation communication fabric should provide effective mechanisms to allow dynamic provision of communication services for different tenants (industry users) with proper independence and security protection.

In light of this, a new concept "Network Slicing" has been introduced by the telecoms ecosystem and it's starting to get the attention of vertical industries in the context of digital transformation. Network Slicing is one of the most important 5G technologies in terms of delivering customized, dedicated and logically isolated network services based on the differentiated requirements of various vertical industries. Network functions, performance, isolation level, security level, latencies, coverage of service, resource requirement, and operation and maintenance all vary depending on the needs of the industrial and customer segments and not on the arbitrary settings of a consensus infrastructure. Network Slicing is expected to be a basic 5G service to serve the customized and unique needs of industry verticals.

Network Slices and Industry Use Cases

How should we create a communication fabric capable of preserving the rich features of each data flow while allowing data interchange and connectivity across machine networks whenever required? To address this question, we have investigated some of the classes and approximate numbers of machines that we envision will inhabit this coming generation of hyper-networked communications.

Virtual Reality and Augmented Reality

Virtual-Reality (VR)

The initial popularity of VR headsets may have been fueled by their function as a consumer gaming device, but the technology is capable of doing much more. VR is now increasingly exerting its enormous potential to change the course of numerous fields, including medicine, business, education and manufacturing.

But VR is a voracious beast with an insatiable appetite for compute, power and data. VR's high compute load presents multiple challenges including fast battery drain for mobile devices, the need for expensive computers, and a tethered requirement for higher-end VR experiences. 3D live rendered VR experiences require significant downloads due to the size of the very high resolution assets required. Alternative 360° video experiences can address the power drain (video playback is far cheaper than computed 3D render) but require at least 25Mbit/s for streaming.

Users want untethered, highly interactive and real-time content-driven VR experiences. To address the challenges of these demands, the computing functions of VR can be partially or completely offloaded, and content needs to be rendered in or deployed from the cloud. This will require ultra-low latency and high downstream bandwidth configurations.

Network Slicing can integrate intelligent traffic management solutions, compression algorithms and very low-latency, high-throughput capabilities to handle the demands of VR content. Gigabit-bandwidth last mile connectivity and data centers will play a central role in supporting the network for delivering the seamless, high-quality connectivity that these immersive experiences will demand.

Augmented Reality (AR)

People's lives are dominated by their smart phones. In order to look at their phone, users need to disengage from the real world and stare down at the device. Their hands are full, impairing their ability to perform other tasks and their attention is consumed, compromising focus, putting them in harm's way, and creating social disconnection from the people and world actually around them.

AR, with its glasses and related wearable technology, will allow users to take the best of their smart phone experience and fuse it with natural human interfaces and new services merged with their environment, all while keeping their hands free and their attention engaged in their surroundings.

But to do this, AR will require significant new technology in several areas – real-time video transmission, computer vision, machine learning, speech recognition, point cloud databases and more. All of which will put significant performance and infrastructure requirements on the network - high availability and high reliability data at unprecedented bandwidths. And because services are performed in sync with real world experience, low latency will be required.

5G, and in particular 5G Network Slicing, will enable network operators to address these challenges and provision AR services.

AR will leverage the very high throughput from the configurable 5G air interface. And the ultra-reliable and low latency communication (uRLLC) service category will make network-aided position tracking possible, alongside low latency compute offload.

By empowering AR via the 5G network, the mobile operator not only frees the user from the clutches of the smart phone, but enables lightweight, battery efficient AR glasses and significantly enriched user experiences.

Automotive

It is currently estimated that there are over 1 billion[2] automobiles and light, medium and heavy duty trucks on the road across the world. Global trends in autonomous driving control, knowledge based services and fleet management demand a rethink of data use and connectivity.

Billions of cars with dozens of processors demand highly secure and robust connectivity.

Autonomous driving requires connectivity as a key enabler, and there are a number of other use cases requiring this too:

- Infotainment services, which today is provided mainly by LTE, will significantly increase as drivers don't need to spend all of their time steering a car/truck.
- Back-end connectivity may rely on 5G ubiquitous coverage to download maps or upload relevant sensor information to data centers where it can be processed, generating additional information for road traffic management, in cases such as black ice warning, traffic congestion etc.
- Time critical safety messages (e.g. hazard warnings) as defined by ETSI ITS need to be exchanged with ultra-low latency, so that device-to-device radio technologies

[2]Navigant Consulting

will be used. Hybrid communication with ITS-G5 and 5G will increase safety to a new level and enable more use cases relying on higher bandwidth.

- Communication with other peers in traffic through traffic lights, electronic street signs, but also with vulnerable road users (VRU) who may not be connected to the network, such as bicycles or pedestrians. Connectivity for VRU could be achieved with infrastructure sensors and advanced 5G localization technologies.

- Sensor connectivity used to supervise parking lots or wake-up cars in a parking situation need to be extremely energy efficient. For this reason, Narrow Band IoT or LTE-M will be used.

- Local traffic management, used to replace traffic lights by communication solutions, will require lots of local data processing so that Mobile Edge Computing may play a role here.

- Precise position information is required to steer vehicles with an accuracy of a few centimeters and at high speeds. Mobile networks will play a role in this, providing GPS correction information alongside live high definition maps with a layer of localized information augmented by object verification from other vehicles.

- Remote steering and control of autonomous vehicles, also known as teleoperated driving, is one of the key use cases for automotive slicing since it requires both reliability and Quality-of-Service (QoS) in an unprecedented way. If there is not enough connectivity to control a vehicle safely, it will trigger a safe mode, which could be a complete stop or movement at low speed. To avoid this, an automotive slice needs to predict the communication for the next several seconds and send this prediction to the vehicle, so that the onboard controller can decide if it wants to sail on with its own sensors until the communication becomes good again, or if it has to fall back to safe mode of operation.

All of these technologies may become part of automotive slices, even though infotainment may be regarded as part of a mobile broadband slice: It may have a different business relationship, as it is related to the vehicle user(s), rather than being related to the car itself as in the other cases.

A key enabler for all these use cases is the Agile Quality-of-Service Adaptation (AQoSA) principle. The basic idea of AQoSA is three-fold:

- The application informs the network about its communication requirements and updates these requirements whenever they change.

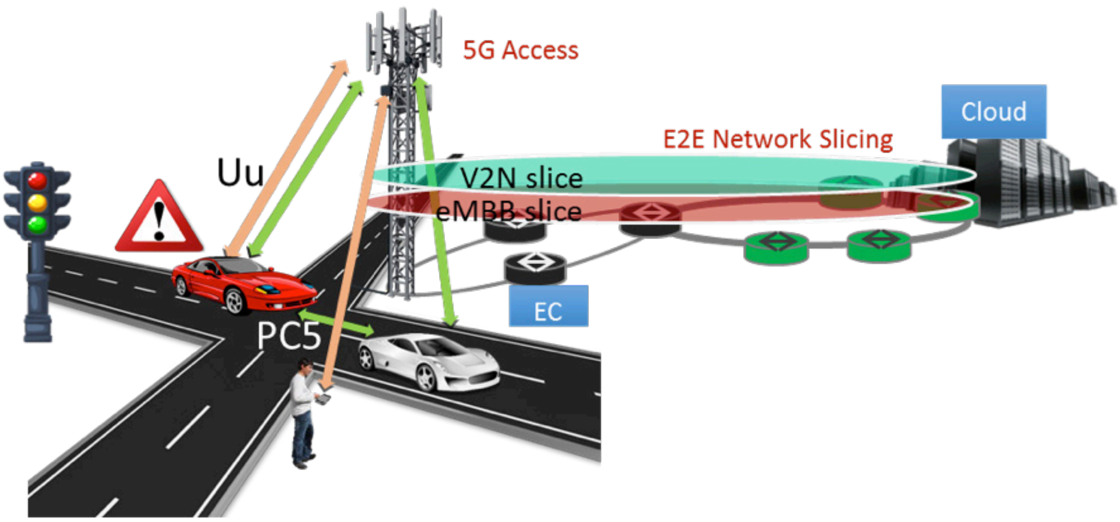
- The network predicts its capabilities to fulfill the requirements and informs the application whenever the prediction changes.

- The application reacts to these changes by adapting its own settings and its operation mode.

Though the AQoSA principle is not bound to Network Slicing, the latter furnishes a convenient means for applications to signal requirements to the network. This implies that Network Slicing is agile enough to accept AQoSA signals not only on a one-time basis but multiple times, i.e. whenever the application sees a need to inform the network about an update.

Key concerns for the automotive industry for a respective slice is ubiquitous coverage, both in terms of dense national coverage (everywhere, including remote areas), as well as in terms of global availability. However, connectivity should also be reliable and predictable. To this end, network status information for a given route may help here, as well as QoS mechanisms in the network.

2016 saw the introduction of the 5G Automotive Association (5GAA), a body that includes car manufacturers and their suppliers as well as telecom operators and vendors. Recognizing the importance of Network Slicing, the 5GAA is also embarking on an automotive slice study and is expected to issue its results soon.



Aviation

Tens of thousands of commercial aircraft haul ever-increasing amounts of cargo and passengers. The expectations of customers demand that the rate of unexpected downtime and unscheduled repairs should be as close to zero as possible. Real-time tracking expectations have already been set in the consumer space for package delivery. Industrial supply chains, repair and refurbishment operations and manufacturing operations are demanding more and more near real-time information to ensure the smooth execution of business objectives.

The advent of the smart factory requires connected machines that speak to each other but also need to respond to engineering updates, supplier delays and even customer demands.

Air travel relentlessly rises, and fly-by-wire systems coupled with GPS and on-the-ground diagnostics and maintenance process almost unimaginable data flows.

These scenarios show an increasing demand for connecting numerous supply chains, factory plants, maintenance centers and aircrafts in service, to flow data between them and managed networks. Variety in the nature of data transmitted to and from different nodes then demands a flexible, robust and customized slicing network in place.

Healthcare

Millions of medical devices, from at-home clinical diagnostic equipment to hospital-based multimillion dollar imaging systems, increasingly demand connectivity as a key value-added feature. Terabytes of detailed data produced by an ever-increasing array of machines is used to diagnose, treat and prevent more and more diseases. Communications from in-hospital attendants and from emergency responders and their equipment can be expected to be transferred to remote medical specialists in a more routine fashion. Remote robotic surgery promises to bring specialist care to millions of people in remote areas if the communication fabric is available.

Healthcare globally is going through a transformation caused by an aging population and economic drivers. In tandem, healthcare is going through a transformation enabled by technology developments. It is expected that as soon as 5G networks are rolled out, an estimated number of 50 billion devices and over 200 billion sensors will be connected. There will be fast intelligent networks that will handle the traffic flow and there will be cloud-based services that will allow applications to process content quickly and more effectively. This will enable many new approaches in healthcare in terms of imaging, (remote) diagnosis and data analytics. For example, hospitals could arrange remote robotic surgeries, as if the surgeon is right next to the patient, using virtual reality via a customized 5G network (slice). Autonomous vehicles and drones could be used in the distribution of medical aid during large-scale emergencies or in the collection of patient samples for testing. Personalized insights from sensors monitoring patients could be sent to a 3D printer to produce customized drugs.

These factors are bringing about a change in how healthcare is delivered. For example, in terms of care delivery, hospitals and clinics surrounded by General Practitioners are changing in a rapid and progressive manner.

More and more people receive treatment in day clinics, day surgery units, doctors' surgeries, at home – or over the Internet. Therefore the delivery of care in the future will be distributed and patient centered rather than hospital based and practitioner focused. There is a significant shift towards virtualization and individualization of care.

The trend that mobile technologies will be used to enable patients to conduct routine medical tasks themselves (which otherwise would have to be conducted by professionals) will only grow. Pharmaceutical companies are conducting research into smart pharmaceuticals aiming to collect real-time information from patients in order to massively enhance the effectiveness and the efficiency of their products. Manufacturers of medical devices such as infusion pumps, monitors, ventilators and hospital beds are looking for strategies to hyper-connect these machines to integrate patients and professionals.

Power Grid

Tens of thousands of traditional power plants, hydroelectric systems, wind turbines and solar farms contribute to our energy grids. Much of the developed world depends on and expects reliable and affordable power. While our lives depend on power, power systems themselves depend more and more on lots of timely data. Some machine controllers sample information at the millisecond level, while other systems detect patterns that may develop over longer periods of time measured in minutes or even days. Communication between these different types of control and intelligence platforms is crucial to ensure reliable, secure and affordable power. New technology has begun to take advantage of these distributed production and generation architectures, and novel business models are being created that require access to real-time data that is accurate and highly secured. The following few examples present Network Slicing application to different power grid scenarios.

Use Case 1: Distribution Automation Slice

Modern residential life, commercial and industrial operation and institutional business are highly reliant on reliable and economical power supply and delivery – and this trend will continue to grow in digital age. It is estimated that in 2001 the cost of power outages in the US ranged from $104 billion to $164 billion, representing 0.98-1.54% of national GDP for the year[3].

It's interesting to note that even though people and media are often impressed by the catastrophe caused by large-scale power outages over long hours, substantial loss has already been incurred by very brief power disruption.

As a result, national grid operators are setting their eyes on distribution automation to reduce power downtime to a minimum. In particular, great attention is paid to minimizing the temporary outage to avoid the substantial cost incurred as well as nip large-scale blackouts in the bud.

To this end, power distribution automation needs to be in place to autonomously monitor and control electricity distribution systems, including: distribution SCADA; feeder automation; troubleshooting; grid analysis; and the application and interconnection of these applications. 5G Network Slicing could play a pivotal role in transmitting critical monitored data and controlling signals among feeders, distribution boxes and automation control servers. Highly reliable communications and ultra-low latency are typical KPIs of distribution automation slice, where end-to-end latency between automation controllers and distribution boxes needs to be restricted to within a few seconds or less.

To bring distribution automation slice into practice, regulations also need to be resolved to ensure network slice SLA is compliant with grid service providers' requirements. In particular, the network slice may operate on a dedicated spectrum for electricity grids.

Use Case 2: Net Metering Slice:

The power grid is a complex system serving vast amounts of electrical terminals, including smart meters, electrical appliances, charging piles etc. In a typical Chinese grid service provider network, the management of billions of diversified terminals poses a significant challenge in daily operation.

A key enabler of electricity terminal management is real-time usage data collection, processing, and monitoring via net metering slice. In this case, power usage analysis and management, abnormal measurement monitoring, and power quality monitoring can be implemented automatically. Requirements yet to be fulfilled for net metering slicing include massive connectivity of up to tens of millions of devices in a populated mega-city and enhanced coverage to provide reliable links in non-line-of-sight (NLOS) or indoor environments. Additional transmission of things such as ambient data, image and videos may increase demands for much higher bandwidth.

[3]"The Cost of Power Disturbances to Industrial & Digital Economy Companies," EPRI 2001).

With net metering slice, power usage information can be made available in real-time to facilitate analytics for varying usage demands. This allows power grid providers to design automated energy trading that closely matches available power with regard to time-varying demands for power usage in millions of households, as well as in enterprise premises. It promises to bring a new level of efficiency, flexibility and control to our energy networks.

Use Case 3: Renewable Power Supply Slice

Future power supply consists of conventional power plants as well as renewable power sources such as solar and wind. More often than not, renewable power sources are decentralized in contrast to centralized deployment of the conventional electricity grid. This makes operation more complicated. New mechanisms are needed to smoothly incorporate and store energy from unsteady sources of power into the grid while maintaining stable operations.

In this scenario, service providers may consider running grids with a sophisticated monitoring system for decentralized power supply, including data acquisition and processing, regulation of active power, voltage reactive power control, islanding detection, scheduling and coordinative control. Such a monitoring system is composed of monitor master stations, substations and distributed power-monitoring terminals, connected by specifically-designed network slices.

Such network slices have the massive connectivity, support of both cellular and mesh topology, latency in the order of seconds and high network availability and reliability.

Use scenarios	Latency	Reliability	BW	# of Connectivity	Occurrence	Isolation
Distribution automation	ms - s	High	Low	10^5 - 10^6	Medium - High	High
Net metering	s - min	Medium	Low	10^7 - 10^8	Low - High	Low
Renewable power supply monitoring	s	High	Low	Massive connectivity	Medium	Low

Table summarizing the three power grid slicing scenarios, with specific KPIs.

Logistics

The logistics market is expected to face constant growth in freight volumes in the coming years.
Both cost pressure and customer requirements are driving the need to increase process efficiency along the logistics chain. Both consumers and businesses expect faster and failure-free delivery at low cost. Automation will be a key success factor in this context.

On the demand side, there has been an increasing expectation on customized services from business customers, and strong need for IoT solutions that enable mobile data collection on a large scale and use long-lasting battery-powered sensors.

5G, and especially Network Slicing, will help to overcome some limitations that exist with current technologies and provide substantial value in, for example, the fields of tracking and tracing (containers, goods, etc.), autonomous driving, and process automation. With networks of nationwide coverage and support of power-constrained devices/sensors, operators have the potential to provide end-to-end solutions – but they need to understand the specific needs of the logistics value chain in order to succeed.

Drones

In the near future, drones or other unmanned vehicles (UAVs) will have a more significant impact on our daily life. They will be used for delivery, air taxis, automated site inspection or provide support services in emergencies, like catastrophic events or search and rescue operations. With one million drones expected to be airborne in Germany alone by 2020, the need for solutions to manage the increase in air traffic will be substantial. The most dominant topics which need to be addressed include: beyond visual line of sight (BVLOS) operations; the tracking of drones; and real-time data transmissions. These topics have the potential to be connected to each other. BVLOS will be necessary for the use cases mentioned above, as well as many more. The need for tracking and monitoring of drones will increase with the amount of drones expected to be flying in the lower airspace by 2020. Real-time data transmission will also play a significant role. The analysis of images and video feeds of catastrophic events will be of great value to first responders and emergency services.

All of this poses the question of how these demands can be met in a reliable and secure way.

The 4G network already provides excellent coverage on the ground and to some extent in the lower airspace. Drones will be connected to the operator, the (local) UAV Traffic Management System (UTM) or cloud storage through the mobile network.

With a UTM, the local airspace authorities need to track and monitor all currently active drones, assign fly/no-fly zones, give out warnings to drone operators or contact them in case of an emergency. This could go even further so that the UTM can detect and introduce countermeasures against malicious or wayward flying drones. First generation tracking systems are currently being tested with the 4G network, and will be improved upon greatly with the enhanced features and capabilities of 5G. There are also more challenges that need to be tackled, such as the coverage in the lower airspace and the anticipated interference issues. Network Slicing, MIMO and Beamforming currently developed in the context of 5G will undoubtedly enable better performance, safety and quality assurance to be realized for the new business activities of the future.

5G Slicing Association: Mission & Objectives

In the preceding sections, a plethora of slicing use cases have been presented, together with the potential value creation opportunities enabled by Network Slicing across industry, business and product operations. Yet more research is needed to further understand, develop and address the business and technical needs of specific industries. The benefits of 5G slices can be seen as limited only by our imagination and resolve.

The 5G Slicing Association (5GSA) is an industry initiative that aims to transform business and society with 5G Network Slicing. Its mission is to define network slices that can provide value to various industries and society as a whole, while at the same time making 5G Network Slicing available to improve industrial business operations and enable new services.

Objectives of 5GSA:

- To serve as an open communication and information sharing platform on 5G Network Slicing among leading telecom operators, vendors and industry players in energy, automotive, manufacturing, media and entertainment, etc.
- To develop an industry-wide common understanding on 5G Network Slicing.
- To study use cases for diverse industries, derive requirement pertinent to Network Slicing and define network slices that meet industry requirements.
- To explore new business relationships between telecom operators, vendors, slicing service providers and industry users.
- To bridge the gap in end-to-end slicing technology and standardization through cooperation with other SDOs.
- To foster business-driven slicing proof of concept (PoC) and trials based on key use case and requirements.
- To promote awareness of the slicing ecosystem and value chain via marketing and promotional activities.

Concluding Remarks

Digitization represents a global trend that will profoundly impact the way the industrial world is planned, operated and managed. To make it possible, trillions of industrial devices, controllers and platforms undertaking operational and business activities need to be connected to allow open sharing of operational and business data. In this paper, the authors present 5G Network Slicing as a unified network framework to provision cost-effective, reliable, service-guaranteed and secure network services to various industries.

A number of use cases are investigated in which 5G Network Slicing is envisioned to enable robust connectivity, from autonomous driving to smart grids, unmanned vehicle management and healthcare – revealing the unlimited potential of slicing applications to various industry scenarios.

From these early-stage use scenarios, we hope to draw more attention to the challenges that Network Slicing needs to tackle and the merits it is expected to deliver. Joint efforts are needed across industry between the telecoms sector, industry verticals, standards bodies and government administrations where Network Slicing will be developed, adopted, specified and regulated. Realizing that many vertical business segments and the existing telecom industry may have different business models and ecosystems, we believe it is essential to get industry, operators and equipment manufacturers together to bridge the gap via the cooperative definition of use cases, requirements, technology solutions and commercialization for 5G Network Slicing.