Building the Networked World

ABIresearch for visionaries | Dimitris Mavrakis
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1. INTRODUCTION

The world has experienced a massive technological evolution in the last 80 years with transistors, general-purpose computing, the Internet, broadband data access, and smartphones. These are tools that enable the rapid evolution of many different facets of life and business, including cloud computing, healthcare, education, reducing poverty, extending life expectancy, and much more. There are also great technologies to come that will change many aspects of our daily routines and business processes, including: artificial intelligence, commercial drones, driverless cars, 3D printing, renewable energy breakthroughs, and much more. It is truly a remarkable era of technological revolution.

These technology advances have been made possible due to the networked nature of human intelligence; in fact, humankind is the first to extend beyond physical boundaries. The Internet and information technology (IT) have created the foundation on which many advances have been developed and we are now experiencing the next evolution, with a truly networked world emerging.

1.1. WHAT IS THE NETWORKED WORLD?

The networked world has evolved alongside technology innovations and is the concept that networks are not about one-on-one interactions alone; rather, they represent more complex settings in which people create value and conduct their everyday lives. The long history of academic study in relation to humanity's interactions with systems, and networks in particular, is well documented.[1]

Despite currently being at an inflection point where 5G will newly enable increasingly complex networks, the use cases that create value for people have been explored for decades. Harvard University has done extensive work on the networked world, which was published in 2002 and aimed at developing markets. This scholarly work defined the networked world as adhering to the examples listed in Table 1.

Table 1: Definition of the Networked World, 2002

(Source: Harvard University)

An artisan in a rural village using her community center's computer to sell handicrafts on the World Wide Web.
Healthcare workers accessing online databases to research recent health advisories.
Students in different countries collaborating on a science project over the World Wide Web.
Programmers creating customized software for distant clients through the Internet.
Government procurement officers using the World Wide Web for purchases and contracts.
A farmer using a wireless handheld device to research market prices.

[1] *Additional Reading on the "networked society" includes: Manuel Castells, Sociologist, who has probably done the most formidable work on the topic of networks and network society from a socio-technical standpoint, Mark Granovetter who writes in the early 1970s about weak and strong ties, and Lee Rainie and Barry Wellman's 2012 book, Networked: The New Social Operating System.*

Since this research was published 16 years ago, many of these use cases have become a reality and are being deployed across the world, even in developing markets.

It is important to keep in mind that humans have always been a part of networks, which have always been reflective of our social and economic connections. The introduction of new technologies and computational power is having a profound impact on these human-centric networks. This all comes with the need to evaluate the implications of this new configuration:

- **Human Networks Transcend Boundaries of Physical and Digital Worlds:** For example, humans orchestrate collaborative economy transactions and utilize several applications or virtual private networks (VPNs) to work across many different fields.
- **Networks Involve Both Humans and Machines:** People utilize many connected devices for many purposes; the value and definition of these devices is shifting due to placement of computing power in the network. For example, with the advent of 5G, small sensors and other Internet of Things (IoT) devices will be able to perform heavy computational tasks, leveraging mobile edge computing for processing power. Human social and economic circumstances change the value of devices according to shifting requirements.
- **Technology-Driven Networks May Need to Emulate Human Values and Behaviors:** The forthcoming ubiquitous connectivity and the advent of intelligent networks may change, with individual developers and end users creating new value through network effects. Networks are dynamic where connectivity and artificial intelligence are key components.[2]

1.2. WHY DO WE NEED A NETWORKED WORLD?

There are several reasons that indicate the evolution of communication is moving to the next domain, in everyday life. A few of these examples include:

- **Generation Z Takes No Prisoners:** Those born around the year 2000 are the most demanding consumers for digital services. They make up a huge percentage of the telco's customer base and are also the most adoptive when it comes to new digital services, they seize the opportunity to stay up to date with the latest trends and technology that brace the market.

  Unlike previous generations, Generation Z has grown up with almost-ubiquitous connectivity: broadband and Wi-Fi at home and 3G or LTE outdoors. This is an environment that previous generations did not have and is profoundly changing the way new generations socialize and will, in the future, work and consume data. As a generation comfortable with technology at an early age, this group's skills with advanced communications technology will disrupt the way services and applications are provided moving forward. In other words, what has worked in the past does not predicate what business models will be successful in the future.

- **Webscale Companies Are Redefining Global Business:** As the global economy turns digital, the telco industry is being disrupted by the increasing number of third-party digital communication services as also known as over-the-top (OTT) services. Examples that illustrate the sheer strength and popularity of OTT services include Facebook Messenger and WhatsApp Messenger with 1 billion monthly active users and Skype with more than 300 million users. Despite the global reach of these applications and companies, there is a growing need for national expertise that will create new business opportunities. Moreover, Webscale companies are attempting to commoditize connectivity so that they are able to access more users, including Facebook's Aquila and Google's Project Loon. A recent ABI Research webinar indicates that mobile service providers are indeed prone to marginalization.[3]

[2] *January 2018 interview with Intel's Maria Bezaitis, Senior Principal Engineer*

[3] *ABI Research Webinar: Are Mobile Service Providers Doomed to Marginalization?*

- **Enterprise Verticals Are Digitizing Rapidly:** Many industry verticals, including utilities, energy, manufacturing, transport, logistics, healthcare, and retail, are rapidly digitizing their operations to take advantage of analytics, improved operations, and new technologies. Connectivity is at the heart of this transformation, often in markets where the latest technology is not necessarily deployed. For example, the mining sector still uses 20-year-old technology in underground mines for safety and security.[4]

These are elements of the networked world across the consumer and business domains, indicating that there will be an increasing need to couple connectivity, processing, and data in a much tighter way, perhaps opening the market for more companies. Mobile service providers will surely have a role to play in this value chain, but enterprises, Webscale companies, and new entrants may also attempt to capture some part of this value chain. Mobile service providers are discussing 5G, edge computing, network slicing, and new air interface as hot topics in the industry. This is taking place at the same time as Webscale companies are trying to address the very same verticals.

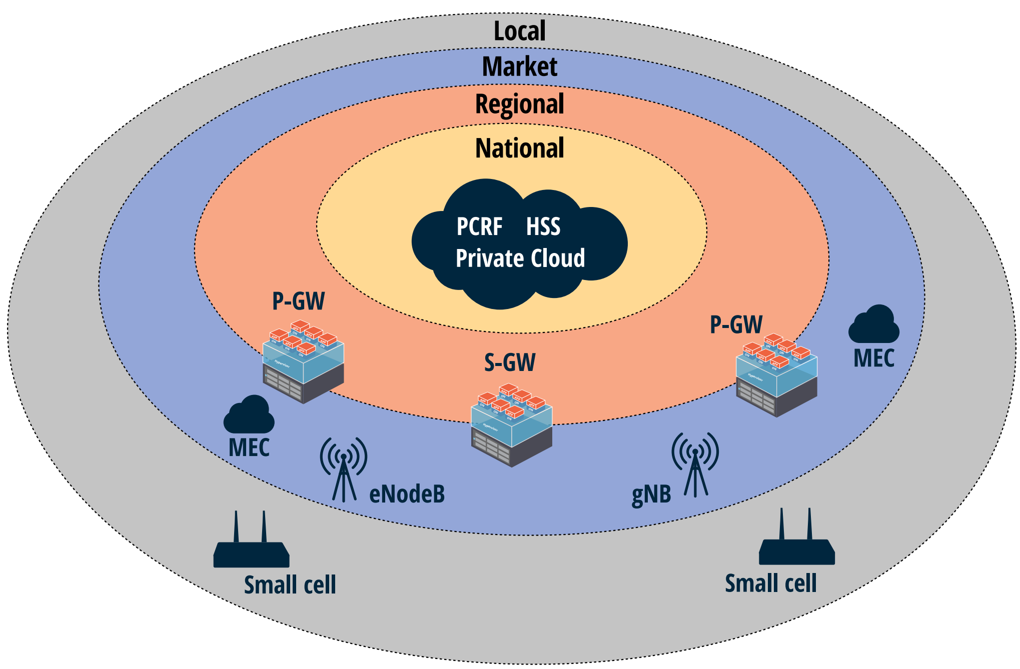
2. 5G AS A KEY COMPONENT OF THE NETWORKED WORLD

5G is being positioned as a radical upgrade to previous generations, which acted as access-driven technologies: 2G enabled mobile voice and SMS; 3G enabled mobile data; and 4G brought mobile broadband to the masses and created the foundation for the next step. 5G will enable new experiences for consumers and will appropriate cellular networks for enterprise verticals. There are several new components being introduced with 5G in the telco network that enable granular, application-specific use.

5G networks will be significantly different from today's implementations and will focus heavily on cloud computing, software, and virtualization:

Figure 1: Structural Elements of a Future 5G Network

(Source: ABI Research)



[4] *ABI Research report: Private Networks for the Mining Industry (AN-2773).*

There are many differences compared with today's networks:

- National or centralized network elements now run on a common cloud computing platform, which is centrally orchestrated.
- Regional points-of-presence (POPs) now house mini-data centers (*e.g.*, Mobile Central Office Re-architected as a Datacenter (M-CORD)) that host virtual network functions.
- The edge of the network now hosts computing resources (Multi-access Edge Computing (MEC)) and 5G basestations (eNodeBs).
- There is a much higher need for high-speed, low latency fronthaul and backhaul, so that advanced 5G use cases are enabled.
- Control and user plane are split and the former can be centralized, while the latter distributed.

Compared to previous generations of cellular networks, 5G now extends both centralized (virtualization of network components) and distributed (edge computing) processing capabilities for many new use cases. The following sections describe three components of a 5G system that enable the networked world.

2.1. 5G NEW RADIO

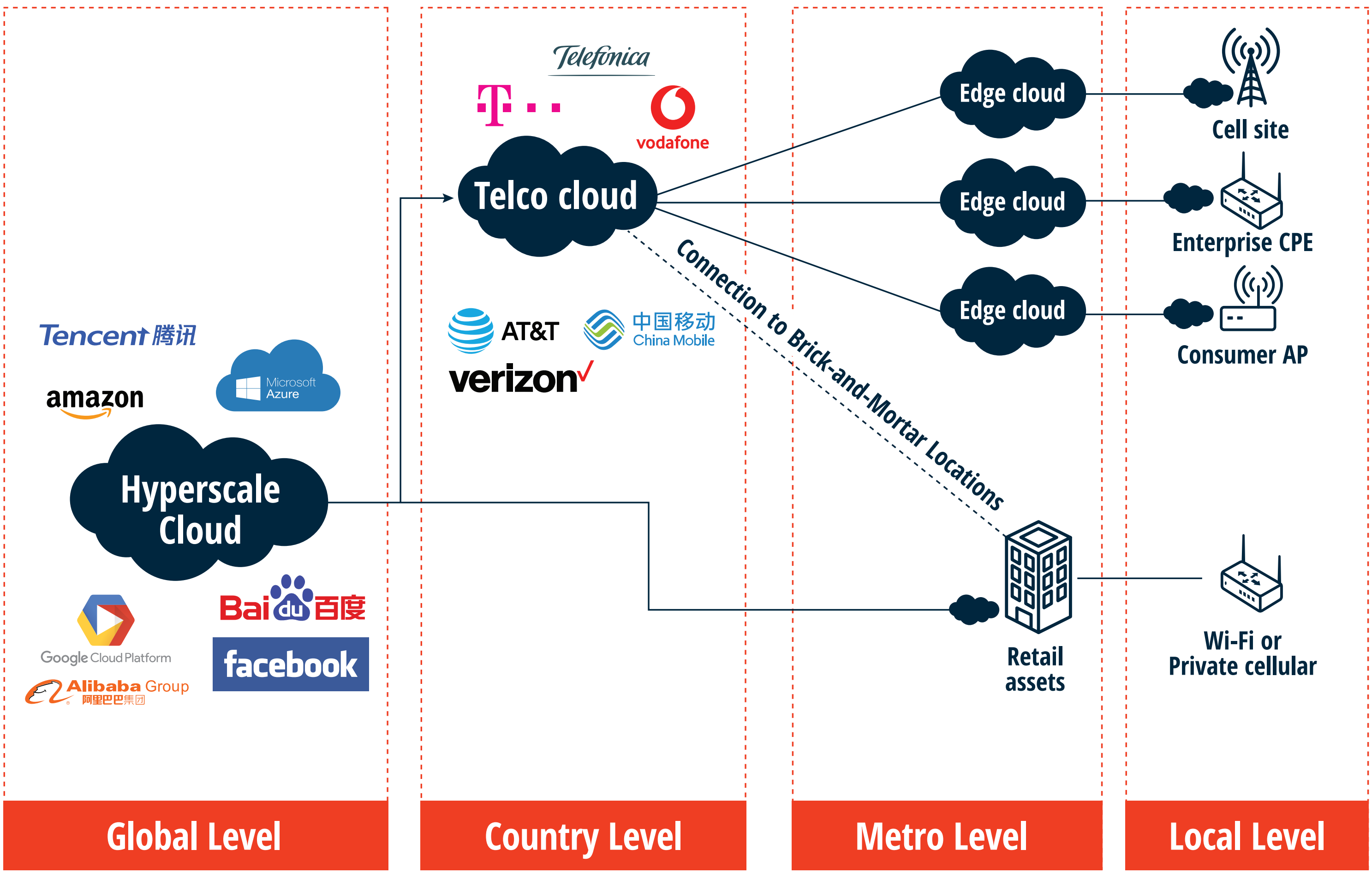
5G New Radio (NR) is designed to serve as a uniform connectivity layer that can span different spectrum types, use cases, and performance requirements. Unlike previous generation telcos, 5G is not expected to simply support higher bandwidth and speeds, but to support advanced use cases in various verticals as they are developed over the next 5 years. To support this kind of flexibility in applications and spectrum bands, 5G NR features need to support the three most important attributes of 5G networks: flexibility, scalability, and efficiency. For example, 5G is expected to offer scalable speeds from 2 Gbps to 20 Gbps. In LTE, the maximum spectrum bandwidth is 20 MHz, while in 5G, 100 MHz is being recommended as the minimum. Due to a lack of spectrum availability, 100 MHz is unlikely to be the case at lower frequencies, but wider contiguous bandwidths are available at higher frequencies.

Current plans for 5G NR deployments are focusing on increasing top speeds and enhancing the user experience, rather than introducing new use cases. The early drop for 5G NR in December 2017 provided an initial blueprint for vendors to create radio products in time for the full Release 15 in June 2018, but there is still a large amount of work to be done for the full specification of the NR standard. 3GPP standards development and the advancements in product development by the vendor ecosystem address one of the main challenges to launching 5G: making it cost-effective and seamless. Therefore, 5G standards leverage features that were first developed for LTE networks, and ABI Research expects that 5G NR deployments will be anchored in LTE for at least the next 2 to 3 years, and perhaps even longer after that. Advanced services, including network slicing, will be introduced with NG Core in Release 16, expected during December 2019. Nevertheless, several mobile service providers are starting to deploy edge computing, which will create the foundation for network slicing and the networked world.

2.2. EDGE COMPUTING

There was no shortage of edge computing activities during 2017, in both telco and Webscale domains. Several Tier One mobile service providers (MSPs), including AT&T, China Mobile, and Deutsche Telekom (DT), have announced that edge computing will be a key component of their future network strategies, and several new use cases are expected to be powered by edge servers. In the cloud domain, Amazon, Facebook, and Google are pushing further toward the edge of their own networks, creating more PoPs throughout the world. Amazon's acquisition of Whole Foods in the United States could also be interpreted as a first attempt to gain real estate across the U.S. market that can be used for Amazon's edge servers. In fact, all major Webscale companies—Amazon, Google, and Microsoft—have announced edge computing services that are driven by IoT use cases.[5]

Figure 2: Edge Computing in the Telco and Webscale Domain



Telcos own almost 100% of the last mile of consumer connectivity (with a few exceptions, such as Google Fiber) and a large share of enterprise connectivity, whether this is spectrum or a fixed connection. This provides a unique advantage compared to Webscale companies, especially in the context of edge computing. By deploying edge servers in their network, telcos can provide significant value to end users

[5] *ABI Research report: "Edge Computing in Mobile Networks: Market Developments and Future Visions" (PT-2102)*

and enterprises, well beyond their simple connectivity value proposition of today, and that is only the beginning. Edge computing will run on general-purpose hardware, allowing enterprises to use their own software and applications. Of course, as mentioned above, this depends on technical, economics, and use case challenges to be addressed, but the presence of processing capability at the edge of any network is an undisputed advantage.

Licensed spectrum is not the only opportunity for edge computing. Private cellular is creating new use cases in enterprise segments hungry for carrier-grade network capabilities. The energy, manufacturing, and utilities segments are a few examples where digitization is creating the need for better connectivity throughout a factory floor, a solar energy sub-station, or a power plant. Unlicensed spectrum throughout the world and the Citizens Broadband Radio Service (CBRS) in the United States are expected to create new opportunities and use cases for edge computing. Moreover, there are further possibilities for cellular spectrum, including purpose-designed spectrum for specific use cases; for example, ITS-specific spectrum for automotive applications. When 5G matures, flexible and purpose-designed spectrum may become the norm.

2.2.1. GETTING CLOSE TO THE END USER

It is no secret that the edge of the network—that precious location that lies closest to end users, devices, and enterprises—will be the next frontier for telcos and Webscale companies alike. Once the technology, economics, and deployment mechanisms of edge computing reach maturity, potential use cases and new applications introduce unique functionality that can create significant new service opportunities, particularly for telcos that own the last mile of network connectivity.

Enterprise digitization and the accelerating trend to merge operational technology (OT) with IT will likely create vast amounts of data that need to be exchanged between enterprise locations. The largest companies are likely to own their own dark fiber and build their own networks, but almost all small, medium, and even large enterprises will rely on telcos to connect them to their PoPs and the Internet. On top of transferring these vast amounts of data, enterprises will also require data processing and analytics capabilities, which will saturate the current centralized cloud computing model deployed throughout the world. Moving these capabilities to the edge of the network is the next wave of digitization, analytics, and IoT.

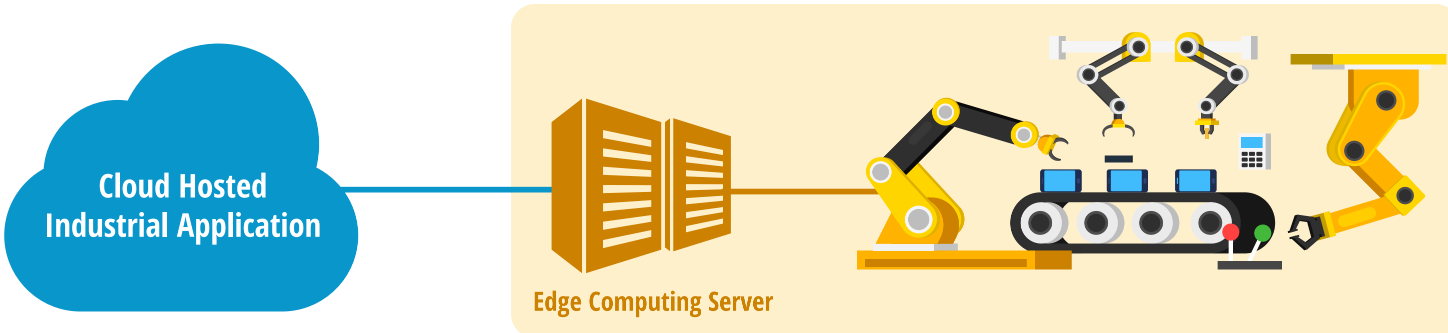
Getting closer to the end user brings more advantages, including:

- **A Path to 5G:** Edge computing will be a foundational technology for 5G and learning about the deployment and management of these nodes before 5G is fully deployed will provide a competitive advantage for early adopters.
- **Localization:** Creation of services that are specific for an environment, *e.g.*, for manufacturing or transport. These applications may also be portable between different locations.
- **Security:** Fewer steps before sensor data are processed can increase security for IoT use cases. Also, the edge of the network now becomes an intelligent environment that can be active in securing the network and end users.

Figure 3 illustrates how edge computing can create business opportunities in a connected factory, which is a previously unexplored environment for telcos. An edge computing server communicating with the factory control room or even an application hosted on the telco or private cloud can create new types of robotics use cases.

Figure 3: Concept of Edge Computing for Manufacturing

Source: ABI Research



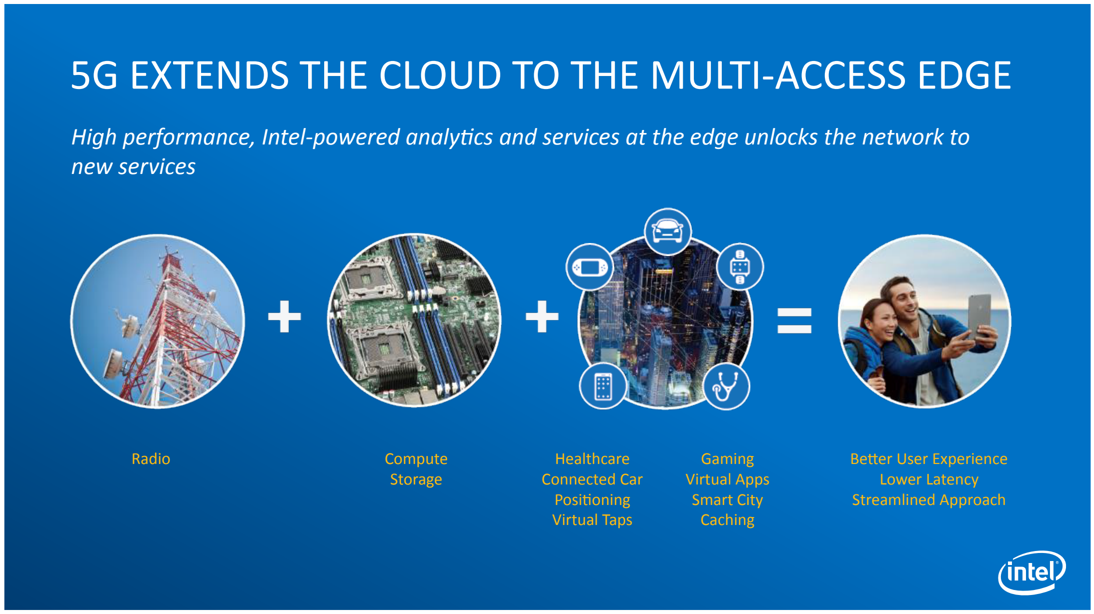
In the manufacturing market, collaborative robotics and digital twins are rapidly increasing efficiency. Robots are also becoming mobile, and thus need carrier-grade, low-latency connectivity. Edge computing will be used to control these digital platforms and ensure that the factory floor is a safe, connected, and efficient environment. Honeywell is working with Ericsson and Intel as part of the 5G Innovators Initiative to uncover the possibilities of digitizing and simplifying the manufacturing floor, such as replacing Wi-Fi as the last mile of connectivity with a 5G network slice, which allocates connectivity resources with high priority to the manufacturing use case.

2.2.2. EDGE COMPUTING REDEFINES APPS AND NETWORK DEPLOYMENT

The distribution of processing and storage capabilities will likely marry the cloud computing deployment model with the distributed nature of telcos, allowing new use cases. In this new environment, it is important to note that the need for new capabilities that do not necessarily align with previous expertise in telco networks; today's networks are largely centralized and depend on application processing in either the telco or Webscale cloud. On the other hand, tomorrow's networks are likely to be distributed and customized according to a specific use case, and the edge of the network becomes much more than a connectivity enabler, as illustrated in Figure 4 below.

Figure 4: 5G Extends the Cloud to the Multi-Access Edge

Source: Intel



The edge of the network is now augmented by processing and storage capabilities, and when coupled with applications that are tailored for end markets, it can create new types of value for consumers and enterprises. The applications or use cases that will be most successful are not clear to the industry today; this is similar to how it was not clear that the Apple App Store would create vast network effects and increase the value of the iOS ecosystem exponentially. The same concept applies to edge computing in that a common fabric of processing capability at the edge can enable a new development environment that developers can use to create location-based applications, end market-specific use cases, and much more. The possibilities that a common edge computing layer enables are endless:

1. **Edge Applications:** The edge of the network can enable different use cases and offer different levels of service that require different network capabilities. This may be essential to justify large-scale 5G deployments that use edge computing as a foundational element.

2. **Machine Learning for IoT Sensor Collection:** Edge computing can be used to deploy machine learning algorithms at the edge of the network to collect, process, and validate IoT sensor data, before forwarding to the cloud for further processing and storage. This is quickly becoming a key challenge as sensor data increase rapidly.

3. **Vertical Applications:** Telcos can use edge computing to provide end markets with specific functionality that no other party can enable. For example, a telco can deploy an edge computing server in a factory floor, coupled with a private network to offer real-time remote control for robots.

4. **Network Efficiency:** Local caching, traffic optimization, and control and user plane separation (CUPS) are a few examples where edge computing can significantly increase network efficiency. Edge computing also reduces congestion in the core network.

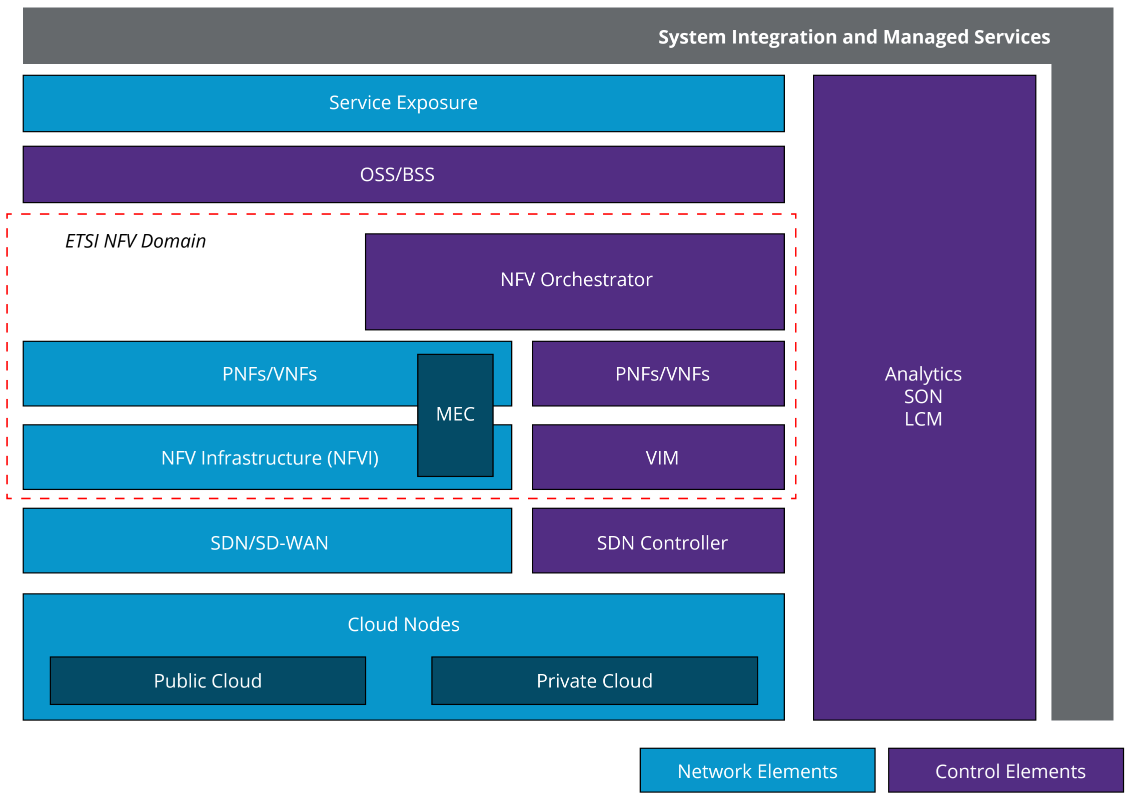
Edge computing presents a foundational and structural evolution of the telco network, and monetizes the most precious asset of the telco: the last mile. Although there are some challenges to deploying edge computing on a large scale, the distribution of processing capabilities will create new opportunities and will pave the way for service innovation in an environment that is ripe for it.

2.3. NETWORK SLICING

The current telco market is facing a major evolutionary step, where software, cloud, and automated technologies are set to redefine the way telcos plan, deploy, maintain, and monetize their networks. It is also clear that telcos can no longer continue selling connectivity alone, although this will remain profitable in the long term. Telcos have access to the last mile, whether this is spectrum or a fixed connection, and hold a vast amount of data for end users, which can be beneficial in predicting major incidents, improving user experiences, proactively expecting what a user will need, and much more. Connectivity is the foundation of these advanced services and telcos can evolve to become much more. Figure 5 illustrates a telco cloud framework that will allow many of these advanced services.

Figure 5: Telco Cloud Framework

Source: ABI Research



Network slicing is being positioned as the cornerstone of advanced services, where telcos can sell tailored slices of network functionality to different types of end users; for example, bandwidth-heavy video or signaling-heavy sensor IoT applications.

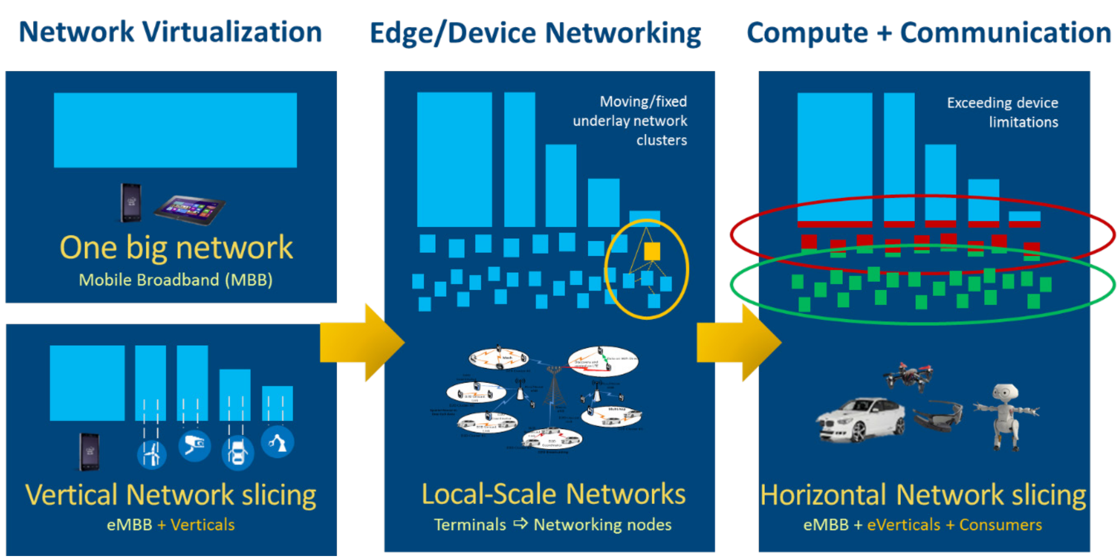
2.3.1. DEPLOYMENT STATUS OF NETWORK SLICING

The market is currently trialing early network slicing use cases, mostly enabled by tightly integrated network equipment, rather than competing-vendor network elements. Although the market is in deep discussion regarding network slicing, the application of the concept in the commercial domain is still in a research and development (R&D) and early standardization phase. One example is the European 5G-MoNArch project working toward the complete development of a network slicing framework, which started during 3Q 2017 and expected to last 2 years. In China, FuTURE Forum has been working on a white paper on end-to-end network slicing since early 2017. Both the RAN and SA working groups within the 3GPP are looking into different technical aspects of network slicing for standardization. This is in line with telcos' abilities to monetize such advanced functionality and, in a way, the technical and commercial evolution of the network slicing concepts need to keep up for successful mass market deployment. An early technical breakthrough could potentially find telcos unprepared to deploy these concepts commercially and for good reason: they have been accustomed to selling connectivity for decades and an immediate shift in business priorities would cause disruption.

In a few years, telcos will deploy the necessary infrastructure, OSS/BSS, 5G Next Generation Core, and supporting technologies to enable network slicing. At that point, the network will have already evolved to a distributed, carrier-grade telco cloud, where the core and the edge of the network will be running on common computing platforms, namely x86 servers. As with all new technologies, network slicing will evolve with time and expand its current applications. Today, telcos are slicing mobile broadband networks vertically, and with each slice, they are serving a specific industry from end-to-end. In the future, telcos will be presented with the opportunity to take network slicing a step further and introduce horizontal slicing, where a networking node, such as a MEC server, within a vertical slice can further slice its computing resources horizontally, and dedicate one of its slices for use by a mobile device connected through a high-data rate and low-latency radio link, such as 5G NR. This horizontal slicing will augment the computing capability of a mobile device beyond its physical limitations, creating a new generation of moving underlay network, as show in Figure 6.

Figure 6: The Evolution of Network Slicing from Vertical to Horizontal

Source: Intel



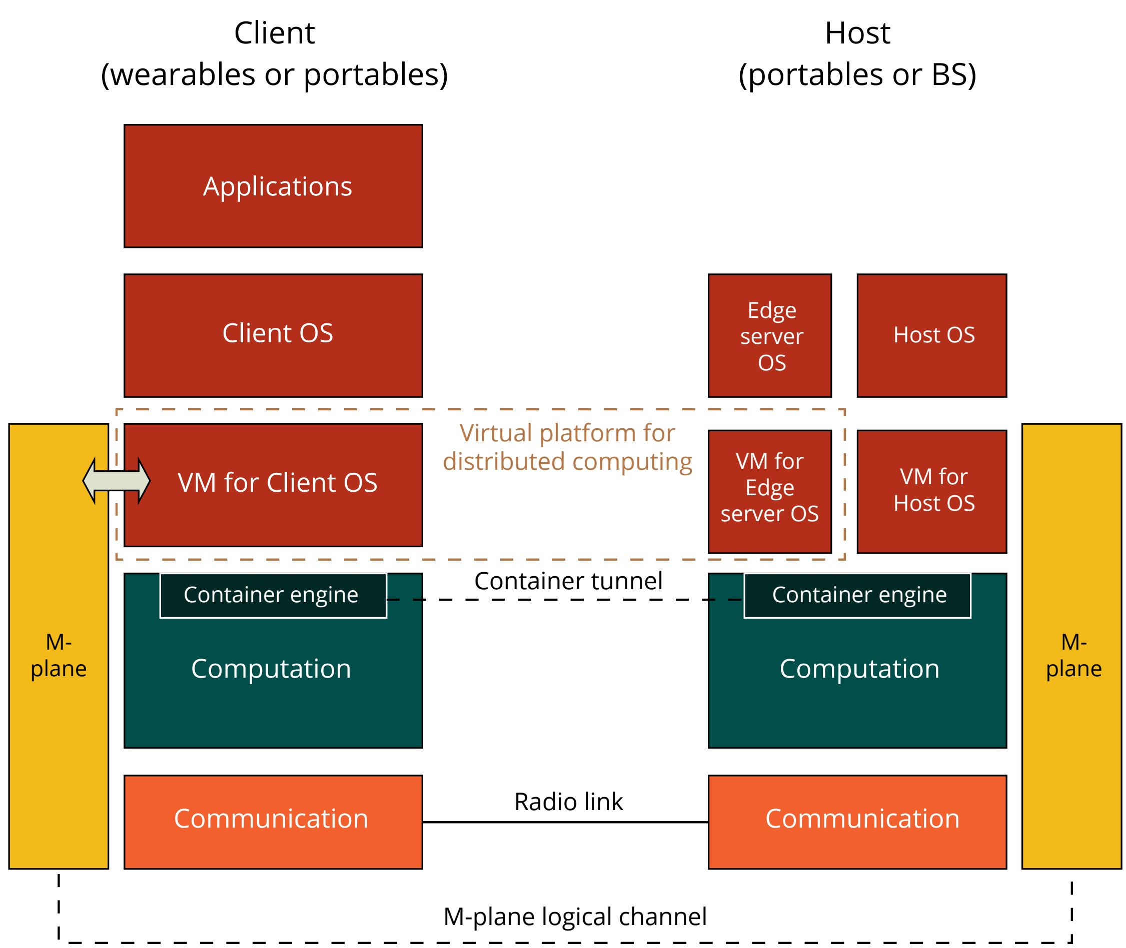
2.3.2. THE NEXT EVOLUTION OF NETWORK SLICING

In vertical network slicing, each network domain is partitioned in different slices according to the use case. These domain slices are then paired with slices from the rest of the network to create a complete network slice. It should be noted that matching slice ingredients is not always proportional, because different applications will use different parts of the network according to their user or control plane payload.

In horizontal slicing, functionality is decoupled from the physical boundaries of the device itself, where computational, storage, and network functionality can be shared, even between infrastructure nodes and devices, and between devices. For example, a smartphone used by a professional in the health industry may use a vertical slice for healthcare (*e.g.*, for a low latency, video tele-health application), a vertical slice for eMBB (for general Internet use), and at the same time, a horizontal slice for a wearable sensor, where the smartphone shares part of its processing capabilities with the lightweight wearable. Horizontal slicing achieves in the device what vertical slicing achieves in the network; it democratizes resources, and at the same time, wraps these resources in use case-specific slices. Figure 7 illustrates an example of horizontal slicing using a wearable and a smartphone.

Figure 7: Horizontal Slicing Example

Source: Intel



Horizontal slicing has many applications and brings several benefits to both consumer and enterprise communications. *For example, it lessens the energy footprint of wearables and consumer devices*, allowing the creation of smaller and more compact form factors. Moreover, it removes the need for in-device processing capabilities, which may, in turn, enable new form factors for many new types of applications. For example, augmented reality (AR) and virtual reality (VR) head-mounted displays (HMDs) are currently limited in terms of processing capabilities, and most require a tethered connection to a more powerful device. In the future, a 5G network that allows vertical and horizontal slicing will be a true enabler.

Facilitate a network slice that brings low latency and high bandwidth communications for AR and VR

1. Facilitate a network slice that brings low latency and high bandwidth communications for AR and VR
2. Horizontal slicing will allow the smartphone (or similar end-user terminal) to share processing and storage capabilities with the HMD, so the application is possible with an untethered connection

AR and VR are two examples where advanced network slicing can create new opportunities **in adjacent markets** that are not possible without telco involvement. Examples include automotive, healthcare, transport, logistics, and many more sectors. The ubiquity of processing capabilities is expected to create new opportunities in both telco and enterprise verticals.

Although the industry is currently involved in the first phase of network slicing, certain aspects of horizontal slicing will need to be introduced to the discussion, so that when the time comes, both types of slicing will be possible without redesigning parts of the first vertical slicing phase.

3. CONCLUSIONS

5G is the next evolution of cellular technology, but it is not a mere linear upgrade to existing networks. It presents a structural and fundamental evolution where monolithic use evolves to specific network appropriation for different verticals. The processing capabilities of these networks expands exponentially in both core and edge. Virtualization centralizes and pools core network capabilities and allows it to adapt faster to unplanned events. On the other hand, the introduction of edge computing creates a significant number of new opportunities, such as in the IoT, including sensor data processing at the edge of the network.

The networked world will provide an always connected experience for end users and enterprises where intelligence is hidden in the network or in applications hosted in the cloud, core, or edge of the network. The availability of processing capabilities across the network will likely create a new level of innovation, but also a new wave of challenges that will need new solutions. For example, the wider availability of processing capabilities will require new security measures and a new set of companies providing them. One thing is for certain: we cannot yet fully understand what opportunities and challenges the networked world and mature 5G networks will bring, in the same way we did not foresee how 4G would change the world.

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