HEAVY READING

White Paper

5G: A Network Transformation Imperative

Prepared by

Teresa Mastrangelo
Senior Analyst, Heavy Reading
www.heavyreading.com

on behalf of

intel

www.intel.com

December 2015

Introduction

The explosive growth in mobile data traffic, combined with the proliferation of "smart" devices, is forcing communications service providers to transform their networks. Although much of this transformation to date has been tactical in its approach, future demands on the network will require new network architectures that support an increasingly diverse set of services, users, applications and resource requirements.

At the center of this network transformation is the broad-scale deployment of network functions virtualization (NFV) and software-defined networking (SDN) technologies. Although deployment of virtualization technologies is currently underway in many service provider networks, its role will be vastly expanded as it becomes foundationally critical to future networks – often referenced as 5G.

5G networks are anticipated to provide exponentially more capacity, lower latency, ubiquitous connectivity, as well as increased reliability and availability. Additionally, these highly-virtualized, software-driven networks will fully embrace an open ecosystem that will encourage innovation and value creation, delivered with a consistent experience and enabled by sustainable business models.

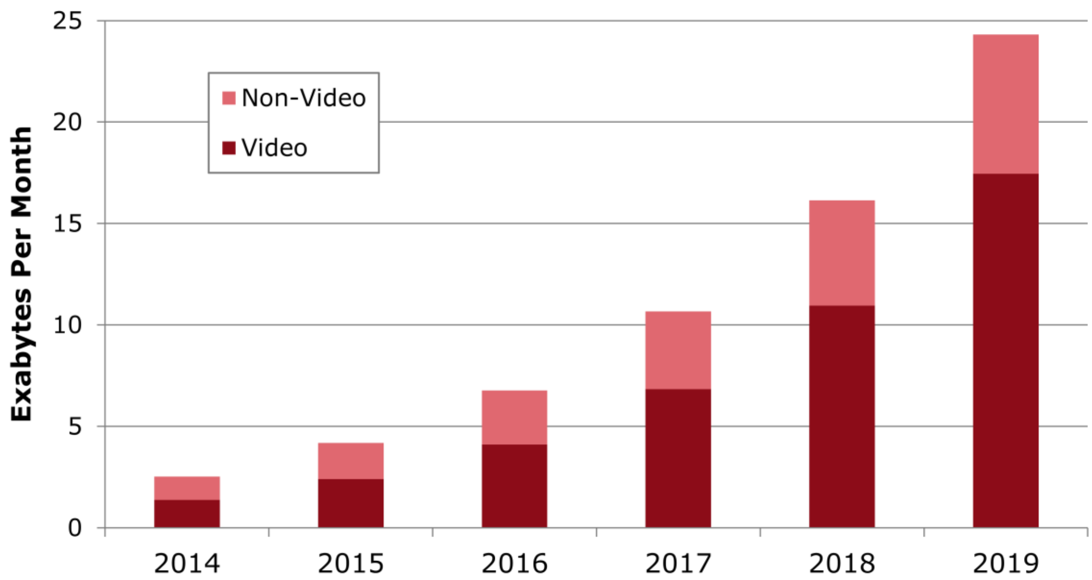
This white paper explores the necessity of network transformation in support of 5G networks and services, including its requirements, applications and challenges. In addition, it examines the enabling technologies and strategies that facilitate the 5G vision. It concludes by describing how Intel is well positioned to play a leading role in the future 5G network – from the device to the data center – demonstrating Intel's ecosystem and solution leadership to accelerate the adoption of NFV and SDN.

The New Connectivity Paradigm

In today's highly-connected society, communications service providers are facing unprecedented challenges as the proliferation and penetration of connected devices continue to surge and consumption models change. These challenges, combined with competition from non-traditional operators and over-the-top (OTT) providers, are forcing rapid and dynamic transformation in how service providers operate and deploy their networks.

A good example is the introduction of the smartphone, which has shifted the consumer appetite from voice to data, streaming video and media-intensive social networking. According to the latest Cisco Visual Networking Index, overall mobile data is expected to grow from 2.5 exabytes per month to more than 23.4 exabytes per month by 2019. Video will continue to consume the largest portion, growing from 55 percent of the total in 2014 to 72 percent by 2019, shown in **Figure 1**.

Figure 1: Global Mobile Traffic (2014-2019)



Source: Cisco VNI Report, February 2015

This growth in mobile data traffic is fueled by smarter device capabilities coupled with faster, more intelligent networks, such as those offered by 4G networks. This encourages the adoption and usage of high-bandwidth applications, thus generating more traffic. Additionally, the emerging Internet of Things (IoT) segment – a network of physical objects embedded with electronics, software, sensors and network connectivity, with the ability to collect and exchange data – will drive a significant increase in the number of connected devices across a range of vertical markets.

This new connectivity paradigm – where everything is connected, mobility is pervasive, and usage and connectivity patterns vary significantly – will require a network with capabilities that extend far beyond those of its current generation. As such, network operators, equipment vendors, regulators and standards organizations are aggressively working to define this network of the future – 5G.

5G: An Overview

5G is envisioned as an end-to-end ecosystem that enables a fully mobile and connected society. 5G will enable a "hyper-connected" world in which the network is highly heterogeneous, converging multiple types of access technologies (both fixed and wireless) across both licensed and unlicensed spectrum, offering unprecedented user experience continuity. Additionally, it will be modular in nature, allowing it to be deployed and scaled on demand to accommodate multiple types of devices, as well as multiple types of user interactions.

5G networks are anticipated to be more spectrally efficient than their predecessors, support substantially more users and higher device connection densities, offer higher data rates, and deliver services that are contextual, personalized, responsive and real-time. Additionally, wider network coverage, reduced latency and prolonged battery life of connected devices are also projected.

Figure 2 illustrates the key parameters of 5G networks:

Figure 2: 5G Key Parameters

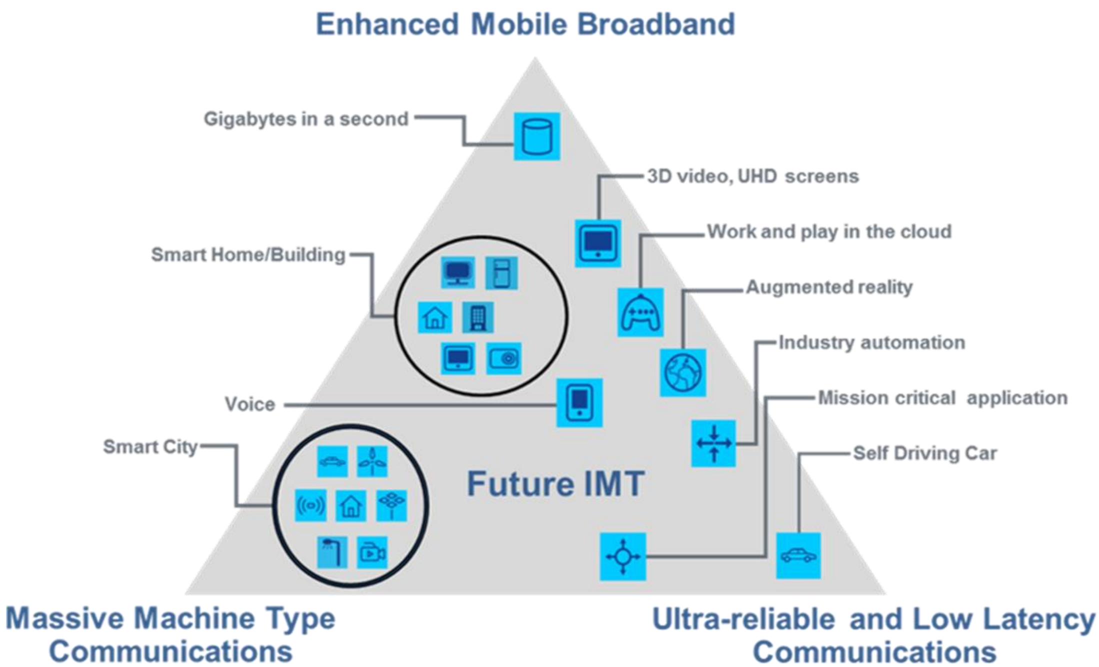
Source: Heavy Reading

Key Drivers & Use Cases for 5G

First- and second-generation wireless networks were focused on voice services, while the focus of 3G and 4G shifted toward data and mobile broadband. While the focus on mobile broadband will continue with 5G, support for a much wider set of diverse usage scenarios is expected.

The three major usage scenarios include: (1) enhanced mobile broadband; (2) ultra-reliable and low-latency communications; and (3) massive machine-type communications, as shown in **Figure 3**.

Figure 3: 5G Usage Scenarios



Source: ITU-R IMT-2020

The needs of each of these usage scenarios vary quite considerably across multiple dimensions, and it is unlikely that any single service or application will need the requirements of all three usage scenarios simultaneously. For instance, mission critical services, such as public protection and disaster relief (PPDR) services, require ultra-high reliability, ultra-low latency, high security and mobility. On the other hand, many IoT applications and services typically need relatively low data rates, low energy consumption and multi-year battery life.

In addition, contextual awareness will play a vital role in its ability to enable differentiated services and enhanced user experience. By understanding how the connectivity is being used, the network can provision network functions appropriately (for example, a stationary use case will not need mobility), allowing the network to run more efficiently and cost-effectively.

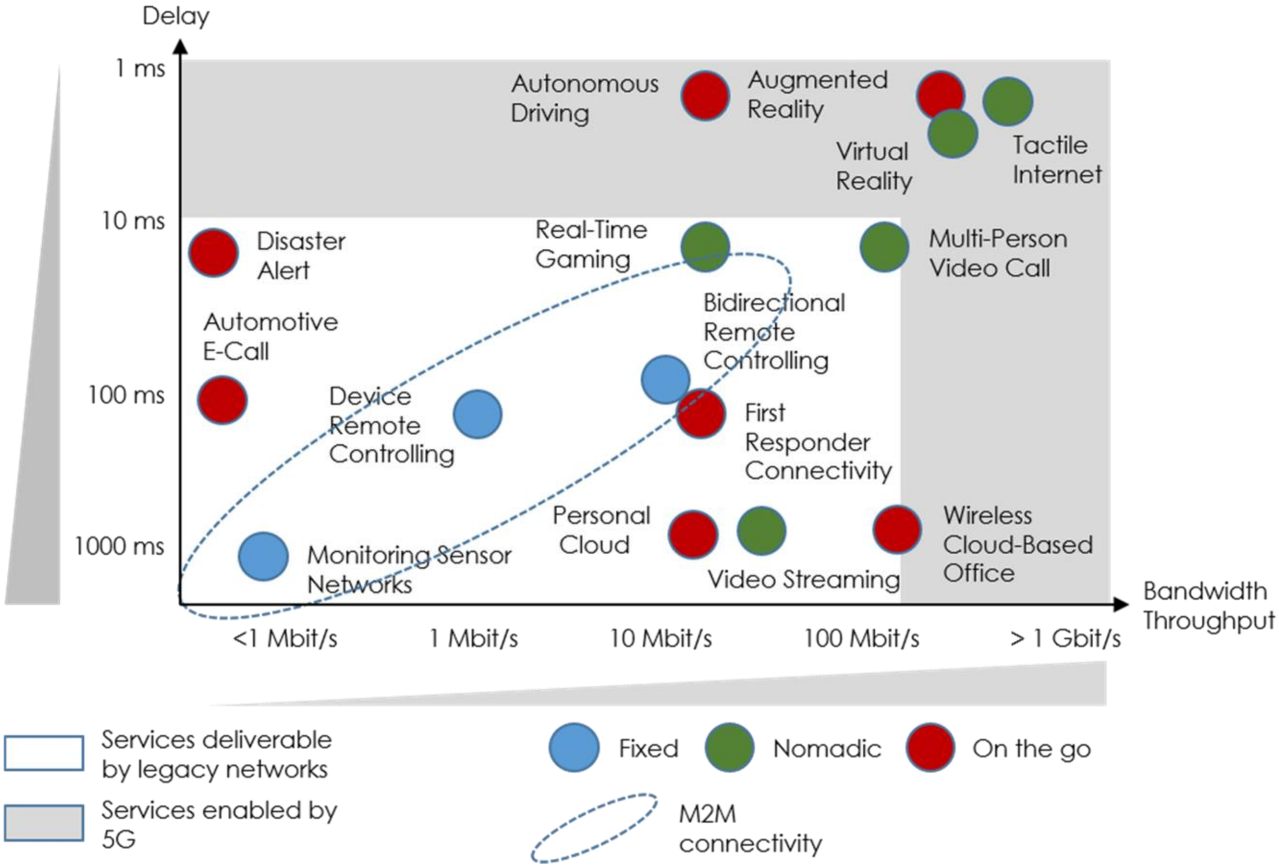
To support the wide variation of use cases and devices, 5G networks will have the ability to adapt network resources in both the user plane and the control plane to meet the performance levels of each service and device. These "network slices" – defined by a set of SDN network performance criteria, such as capacity, speed, latency, security, availability, coverage area, etc. – can be fully customized to match the delivery complexity required by a service using the slice.

5G Services

With key parameters of virtually no latency combined with broadband speeds ≥ 1 Gbit/s, the types of applications and services that can be offered from 5G networks are almost limitless. Over time, services are expected to move beyond simply audio and data toward visual, tactile and cognitive, creating an anything-as-a-service (XaaS) environment for service providers.

Figure 4 illustrates bandwidth and latency requirements for both existing services and some potential 5G use cases.

Figure 4: Bandwidth & Latency Requirements of Potential 5G Services



Source: GSMA, Heavy Reading

Although there are some challenges to supporting services that require both >1 Gbit/s downlink speeds and sub-1ms latency, 5G networks will not only leverage new network design principles based on SDN, but a range of emerging technologies, such as millimeter wave, massive multiple-input and multiple-output (MIMO), mobile edge computing, Anchor-Booster Cell and device-to-device communications (D2D). Additionally, a unified air interface that is scalable and adaptable for all spectrum, whether licensed or unlicensed, for both higher and lower spectrum bands using multiple domain types (time, frequency, orthogonal and non-orthogonal) is expected to enable these requirements.

5G: A Software-Driven Network

Most current networks are populated with a variety of proprietary, purpose-built hardware that does not offer agility or the ability to scale and is difficult and costly to maintain. Additionally, the lifecycle of this proprietary hardware continues to shorten as technology innovation accelerates, making it difficult to justify the investment. Furthermore, these networks can actually inhibit service providers' ability to offer new revenue-generating services or implement new business models.

To deliver the features proposed for 5G and beyond, it will be necessary to design and deploy a network architecture that moves away from these proprietary solutions and toward open platforms that offer significantly improved scalability, as well as increased efficiency, agility and flexibility. Additionally, these open platforms offer more programmability and automation capabilities to simplify infrastructure management and complexity. Although many service providers are discovering the benefits of implementing some aspects of NFV and SDN within their current networks, the role of these technologies will be vastly expanded beyond their current implementations and will become foundationally critical to 5G.

In NFV, a network is comprised of software-based applications called virtual network functions (VNF) that run in virtual machines or containers on standard commercial-off-the-shelf hardware (e.g., servers, storage and networking devices). NFV replaces the traditional purpose-built, hardware-based network elements and moves that functionality to the cloud, decoupling it from the underlying physical hardware. By separating hardware from software, NFV allows network functions to be programmed via software instead of by physical pieces of hardware. Additional network functions can be executed independently of location, allowing the placement of the function in different places in support of different requirements, such as latency.

SDN makes the network programmable by separating the control plane (telling the network what goes where) from the data plane (sending packets to specific destinations). It relies on switches that can be programmed through an SDN controller using an industry-standard control protocol, such as OpenFlow. The level of network programmability provided by SDN allows several network slices, customized and optimized for different service deployments, to be configured using the same physical and logical network infrastructure. Therefore, one physical network can support a wide range of services and deliver these services in an optimal way.

These technologies utilize an open source approach that leverages investments from a community of developers and solution providers, giving service providers a unified approach to implementation that offers economies of scale, interoperability, reliability and scalability, as well as shorter time to market. This software-driven approach will enable operators to better monetize their network assets and quickly and more easily roll out new services – often while reducing service creation time from months to weeks. According to a recent study, businesses that implement NFV/SDN-based networks can deploy new services 13 times faster than with traditional networks.

Capex savings will be realized from better utilization of network assets and the use of simpler, flatter networking infrastructure. According to findings in this same study, network utilization has historically ranged between 30-35 percent. By implementing a network infrastructure based on NFV and SDN, service providers can improve network utilization to 70 percent or even more since the network has the ability to be scaled up and down quickly, allowing service providers to build for the average and offer "on-demand" capacities when required. Finally, opex savings will be realized from auto-configuration and a simplified network operations infrastructure.

Accelerating Network Transformation With Intel

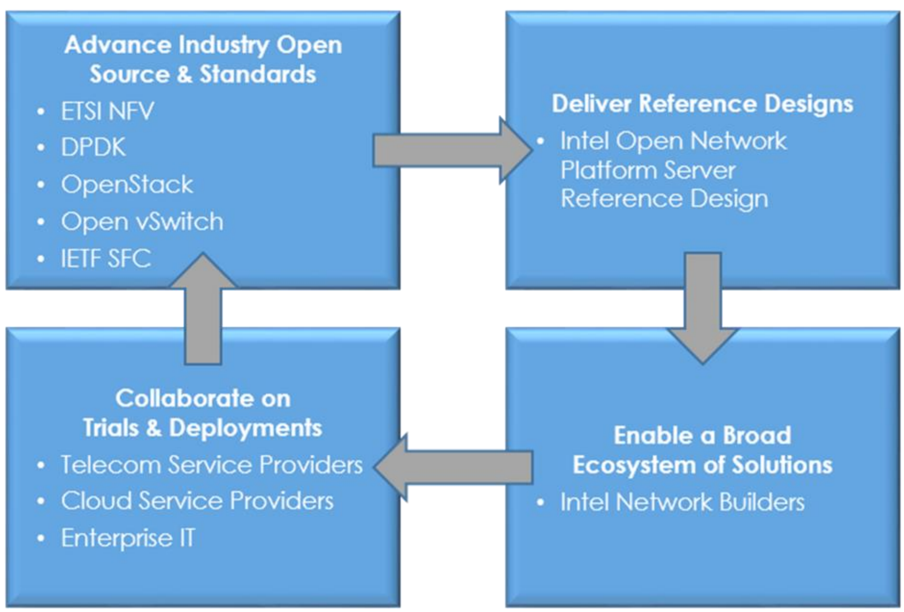
In order to support and deliver the services and features of 5G, the network must be transformed and reimagined with a new blueprint for the future. This future network will be elastic, programmable and dynamically manageable, with NFV and SDN at its foundation.

Intel offers the necessary building blocks needed for network transformation, starting with Intel Architecture (IA) processors, such as the Intel Xeon E5-based processor family with performance that is optimized for virtualized environments. Other key elements include Intel QuickAssist Acceleration Technology, which provides accelerator services (encryption, compression and algorithm offload) for up to 14 separate virtualized instantiations; Intel Virtualization Technology, which provides hardware assist to the virtualization software, reducing its size, cost and complexity; as well as 10/40/100 Gbit/s Intel Ethernet with Intel Flow Director and Network Overlays for maximum throughput in virtualized environments.

Open System Philosophy

Beyond its silicon and technology leadership, Intel is actively engaged in both open source and commercial software enablement, working extensively with standards organization and fostering expertise within the systems integration ecosystem. **Figure 5** illustrates Intel's open system philosophy and ecosystem enablement.

Figure 5: Intel's Open System Philosophy



Source: Intel

Intel has a particularly strong dedication to a few of the open source projects closely associated with SDN and NFV, including OpenStack, OpenDaylight, Open vSwitch, OpenFlow and the Data Plane Development Kit (DPDK). The DPDK is a set of data plane libraries and network interface card (NIC) drivers that provide a programming framework for fast, high-speed network packet processing on general purpose processors. The DPDK provides advanced data packet performance for virtualized networking applications, such as virtual routing, virtual firewalls and others.

Intel Open Network Platform (ONP)

Intel ONP is a reference architecture that combines leading open source software and Intel technologies into a platform that can be used by developers to create optimized commercial solutions for SDN and NFV workloads and use cases. The main goal of Intel ONP is to reduce the cost and effort required for service providers to adopt and deploy SDN and NFV architectures. The Intel ONP reference architecture was designed to provide an open source platform, comprised of hardware and software to ensure interoperability and faster time to market with commercial deployments.

Intel Network Builders

Intel Network Builders is a cross-industry initiative aimed at driving innovation, reducing development efforts, advancing open networking standards, increasing interoperability and reducing time to market. With participation from independent software vendors, operating system vendors, original equipment manufacturers, telecom equipment manufacturers, system integrators and carriers, the goal is to accelerate network transformation through the development and deployment of proven SDN and NFV solutions for telecom and data center networks.

Intel recently announced Intel Network Builders Fast Track, the next phase of working with the networking industry to accelerate innovation in the ecosystem. Through a combination of market development activities and Intel Capital investments into strategic and disruptive companies, the program is designed to drive the integration of solutions for deployment, ensure interoperability across stack layers and across networks and accelerate adoption of standards-based technologies using Intel Architecture with trials and deployments with industry leading service providers.

NFV Proof of Concept

Proof-of-concept (PoC) demonstrations build industry awareness and confidence in NFV as a viable technology. Additionally, PoCs help to develop a diverse, open, NFV ecosystem. Intel is currently involved in several ETSI-accepted NFV PoCs around the world, working with service providers such as Telefónica, Sprint, China Mobile, China Telecom, AT&T, Telecom Italia, BT, SK Telecom, Vodafone and Orange. Some PoC examples include:

- E2E vEPC orchestration in an multi-vendor open NFVI environment
- Virtualized mobile network with integrated deep packet inspection (DPI)
- C-RAN virtualization with dedicated hardware accelerator
- Long Term Evolution (LTE) virtualized radio access network (vRAN)
- Orchestrated assurance enabled by NFV

5G Collaborations & Trials

Intel is collaborating with equipment and device manufacturers, network operators, service providers, academic institutions and others to accelerate 5G standards development and solve key technical challenges. Through these collaborations, Intel is applying its unique combination of computing, networking and wireless communications expertise to develop 5G solutions that integrate intelligence across the entire end-to-end network. This systems-level approach will enable more functional devices, more cost-effective and efficient networks and user experiences that are more intuitive, enriching and immediate than ever before.

Additionally, Intel is a member of seven research projects as part of the 5G Public Private Partnership (5G-PPP) under the Horizon2020 Program. Intel is the project coordinator of the Flex5GWare project, a Horizon2020 project that includes 17 industry and academia partners to execute research on 5G key components to enable flexible, reconfigurable communications platforms for 5G mobile services and applications.

Some notable 5G collaborations include:

- Intel is working with **NTT Docomo** to conduct experimental trials of 5G handset chipsets. The two companies will also work together on 5G interface concepts, design and laboratory and field trials.
- Intel is working with **SK Telecom** to develop and verify 5G technologies. Together, they will build a modem that supports 5G, existing LTE and 3G networks and ensure seamless interworking among multiple radio access technologies. The two companies will also continue to develop Anchor-Booster Cell, one of the core 5G technologies that enables seamless transmission of massive amounts of data via a combination of an LTE network and next-generation wireless local area network (LAN).
- Intel announced its membership in the **Verizon 5G Technology Forum**, contributing to 5G requirements, testing and standards. In addition, Intel is developing 5G technology at its 5G test bed in Oregon, which will be used to contribute to Verizon's 5G sandbox test environments. Lastly, Intel is collaborating with Verizon on network transformation through Verizon's SDN Network Evolution initiative, which will lay the foundation for next-generation networks, including Verizon's 5G access network.

Conclusion

Network transformation is an imperative for 5G, as current network architectures will be unable to support the key performance parameters required in support of future services. Beyond simply voice and data, 5G networks will enable and integrate visual, tactile and cognitive capabilities to support a wide diversity of use cases – all with unique connectivity and device requirements. This requires a network that will automatically and dynamically adapt to meet the needs of different services, traffic variations and network topologies. As such, the capabilities of NFV and SDN will be foundationally critical to this future network.

Intel offers the necessary building blocks to enable network transformation from the device to the data center – illustrated in their investments in processor, network, storage and software. Additionally, Intel has and will continue to play an instrumental role in leading the industry in forming common standards to building an open ecosystem. By embracing an open system philosophy, Intel is helping to accelerate market adoption of NFV and SDN through reference architectures, PoC demonstration and trials, ecosystem partnerships and deep customer engagements.