WHITE PAPER

Network Transformation
5G

5G End-to-End Network Slicing

Communications Service Providers are looking to 5G technology as an enabler for new revenues, with network slicing providing a cost-effective means of supporting multiple services on shared infrastructure. Different radio access technologies, network architectures, and core functions can be brought together under software control to deliver appropriate Quality of Service "slices," enabling new levels of service innovation, such as high bandwidth for video applications, low latency for automation, and mass connectivity for Smart Cities.

Table of Contents

The 5G Vision is About Service Customization

Communications Service Providers (CoSPs) can envision the business opportunities being presented by the use of 5G technology, based on the ITU's definition of the 2020 International Mobile Telecoms framework[1], which outlines the evolution of the mobile network in three main directions to handle new market needs as shown in Figure 1.

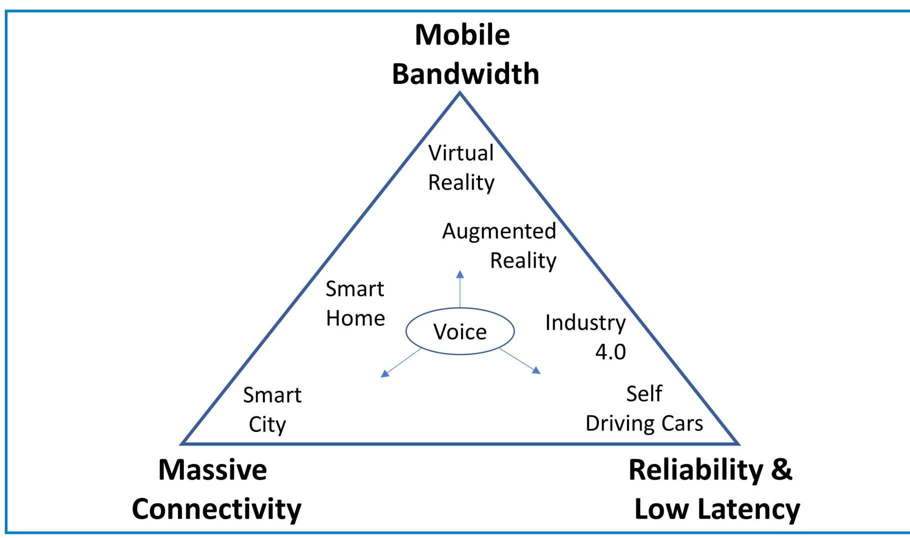

Figure 1. 5G Mobile Network Evolution

Each of the three directions introduces new challenges for the CoSP, as discussed in the 5G-PPP 5G vision document[2].

- First, a 10 Gbit/s peak terminal data rate will be needed for applications such as augmented reality. Much higher carrier frequencies than those used for traditional mobile communications will be required to deliver to this proposed bandwidth, giving rise to new millimeter wave radio system requirements. These frequencies need line of sight paths, resulting in very short range in built-up areas, driving up the number of cell sites required. However the short range also enables the use of unlicensed spectrum such as IEEE 802.10ad WiGig®. Applications will typically use edge processing or content caching to avoid the need for massive backhaul transport capacity.

- Second, the 1 millisecond latency needed for vehicle-to-vehicle communications (to support applications such as collision avoidance) drives a need for local switching near the base station to avoid core network delays. Local breakout to the internet also implies distribution of classic mobile core functions rather than use of centralized equipment.
- Finally, the need to support up to 1 million devices per square kilometer for Smart City applications introduces a need for mass connectivity, with specific radio technologies such as Narrowband IoT support within LTE systems and low power systems such as LoRaWAN supporting battery operated devices. These radio technologies can also be complemented by edge processing to minimize the amount of data that needs to be transferred to remote cloud processing locations.

However, another key concept of 5G is the flexibility to handle new market requirements, leading to the use of software-based services hosted on reusable network infrastructure platforms. In 2017, 23 leading CoSPs proposed in an ETSI white paper[3] that Network Function Virtualization (NFV) technical features should be adopted to accelerate progress and avoid duplication across the industry to deliver the 5G vision. The NFV experience also includes the ability for CoSPs to quickly create new "flavors" of services based on Virtual Network Functions (VNFs) for specific customers or market segments, and a recognition that automation is needed in the Operating Support Systems (OSS) and Business Support Systems (BSS) to handle the complexity and scale of niche services involved.

The industry challenge with 5G is how to bring together all the various components needed so that CoSPs can form end-to-end services, from allocation of appropriate radio bandwidth, transport network capacity, and hosting of network functions at the appropriate node sites.

Business Drivers for Network Slicing

Network slicing is expected to provide the most cost-effective means of supporting multiple services, through use of shared infrastructure. Historically, CoSPs developed networks on a siloed basis, where a separate technology set would be deployed for each major service. New services such as mobile wireless or broadband internet were established on separate platforms from fixed-line telephony. CoSPs could achieve an economy of scale at the lowest network levels by providing dedicated point-to-point circuit services from shared TDM transport networks to higher level services. With the advent of packet networking, Quality of Service (QoS) functions became available, allowing different traffic types to mingle in MPLS and All-IP architectures, consolidating the traffic and reducing overhead costs.

With 5G, it would be technically feasible to create entire national networks optimized to support individual major services, such as an IoT network separate from mobile broadband. However, the cost of establishing a complete platform for new unproven services is likely to be prohibitive. Similarly, network nodes could be created to handle the most demanding services at all points in the network. The complexity and scale of the equipment involved in this solution is unlikely to be cost-effective. Network slicing seeks to take a middle-ground approach between these two extremes, where the amount of equipment dedicated to a single service is minimized, with connectivity and processing infrastructure virtualized to accommodate multiple services on a shared platform with defined QoS in each logical partition, as shown in Figure 2.

Recent developments with Virtual RAN technologies mean that most of the "gNB" base station, the associated mobility management, and the mobile core functions can all be provided in software running on shared infrastructure processors. The only element needing dedicated hardware may be the radio frequency transceivers to suit the required

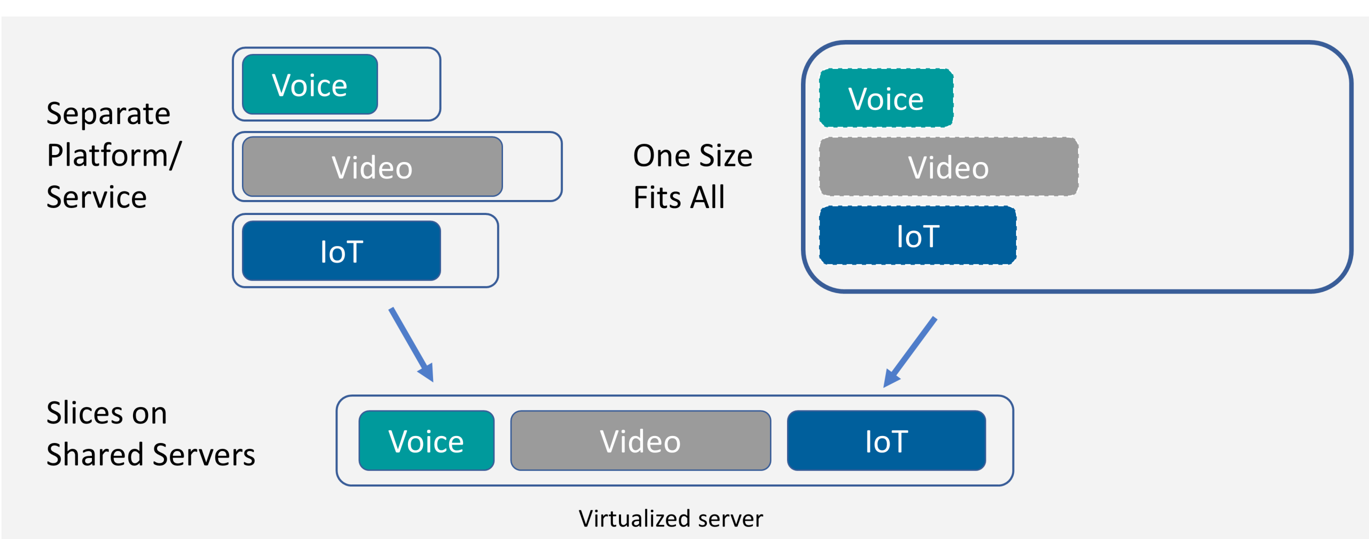

Figure 2. Network Slicing

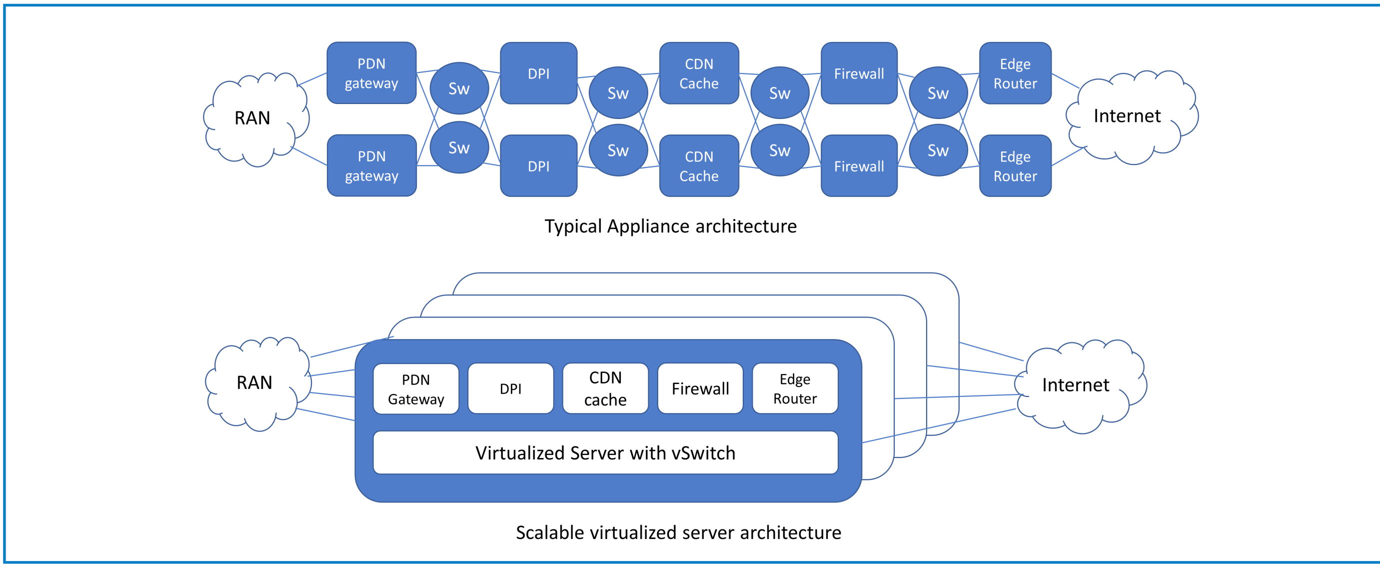

Figure 3. Mobile Core Cloudification

frequency bands. Similarly, the use of "non-ideal transport" is being studied in the Telecom Infra Project[4] to allow the use of existing CoSP access networks (such as ethernet-based PONs and DOCSIS cable networks) to support RANs.

Virtualization of the mobile core is a well-known NFV use case for Narrowband-IOT deployments. Massive operational simplification of the "Gi Services LAN" can be achieved by virtualization of all the components, including the switch and load balancing as shown in Figure 3.

Having all the network functions virtualized enables "cloudification," where the traffic handling capacity can be quickly changed by addition or removal of processing instances. Routine capacity upgrades can be achieved on short notice using Commercial Off-the-Shelf (COTS) servers, and the number of active instances can be changed dynamically, using IT cloud management tools to minimize power consumption during off-peak traffic periods.

Bringing these concepts together we can see that a 5G End-to-End network slice is expected to involve an aggregation of components, including radio bandwidth, relevant base station RF systems, fronthaul and backhaul connectivity, and a variety of base station and mobile core software functions deployed at appropriate network node locations. In the NGMN Alliance white paper[5], they suggested that different slices are expected for three typical scenarios. For example, a smartphone slice could benefit from redistribution of classic user and control plane functions around the network. An autonomous driving slice could specify security, reliability, and latency features. Finally, a massive IoT slice serving fixed sensor devices could have a very simple control plane without roaming facilities, and have contended access.

It may also be appropriate to devote instances of slices to specific vertical industry sectors or for a commercial "tenant" that seeks to mount their specific services on the CoSP's shared infrastructure platform.

With the levels of complexity, variety of options and overall scale involved, CoSPs will need to transform network management processes with automated systems to handle multiple slices effectively.

Network Transformation and Business Innovation

End-to-End slicing represents the third stage of software enabled network transformation, as shown in Figure 4.

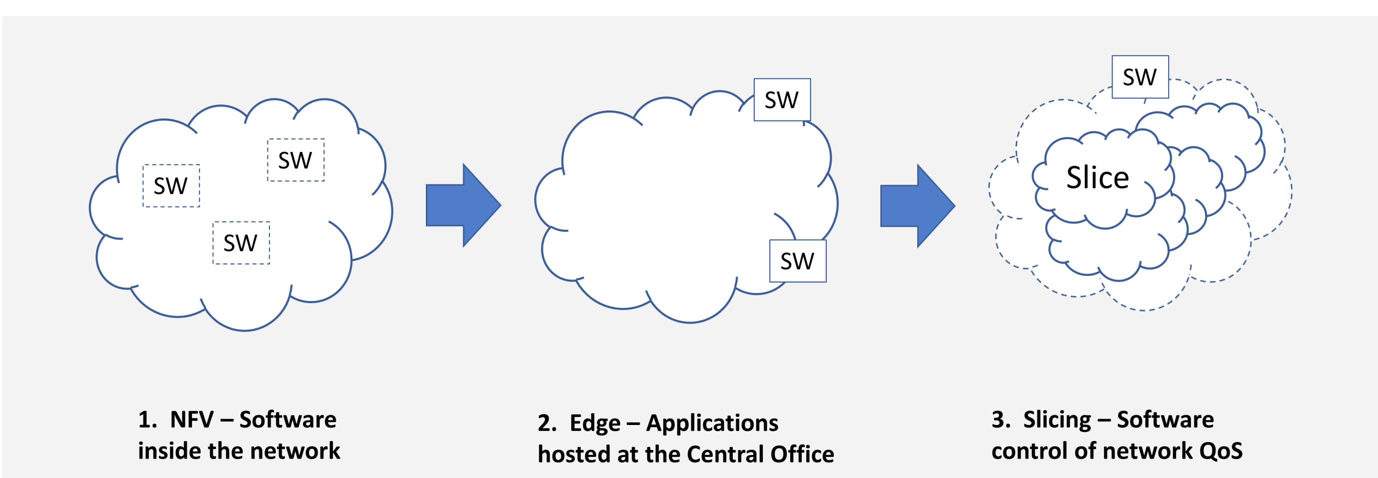

Figure 4. Network Transformation Stages

The first significant business innovation came from Network Function Virtualization (NFV), which essentially involved the use of software from many potential vendors inside the network, enabling new levels of business and service innovation.

The second wave, exemplified by Multi-access Edge Computing (MEC) and edge services, examines how the CoSP can provide processing capability at locations close to customers. The OpenCORD Initiative[6] shows literally how the Central Office (CO) can be "Re-architected as a Datacenter," with support from major CoSPs such as AT&T, China Unicom, Deutsche Telekom, and Telefonica. This allows the CoSP to provide a variety of local "cloud" services for enterprises seeking low latency, local data handling within geographic limits, or simply a cost-effective option complementary to the use of remote Cloud Service Provider (CSP) offerings. Content Delivery Network (CDN) operators have seen the value of cache hosting[7] within CoSP facilities for many years, and CSPs now appreciate the need for local edge processing[8,9].

The 5G end-to-end slicing wave introduces a framework for network evolution to handle application requirements. Classically, IT applications had to be developed within the restrictions of commodity network services provided by CoSPs. Slicing introduces two new levels of flexibility for customization to meet specific application needs. First, a slice can be quickly created to bring together virtual capacity from across the various network elements to suit the specific needs of the application. Second, the overall architecture is modular, enabling integration of new software functions in the user, control, and management planes. New hardware units can also be introduced into the network, such as specific radio access systems to suit application needs, or processing infrastructure upgrades to gain the performance benefits from "Moore's Law" silicon evolution already experienced in the data center.

Intel has several initiatives to support the use of software-based services. FlexRAN and Next Generation Central Office (NGCO) are notable developments to ensure that the underlying computing, networking and storage resources provide effective support for the 5G network slices. This includes isolation of the virtual resources per slice from the hardware pool to ensure Service Level Agreements, and giving scalability and flexibility of resource allocation.

FlexRAN is a 4G/5G reference implementation, which demonstates how Layer 1 to 3 functions of a Base Band Unit (BBU) in a 4G or 5G new radio base station can be implemented in software running on Intel processors at centralized or distributed network node sites. Intel is making the Layer 1 software available to the industry to further the development of products to suit the various 5G market segments. This is accompanied by network slicing manager software that ensures that Intel® Xeon® Scalable processor resources (such as processor cores, cache and DRAM memory, accelerators, and I/O device capacity) can be dynamically allocated to virtualized BBU network service slice instances, as shown in Figure 5.

Intel® Resource Director Technology[10] enables precise allocation of capacity to individual virtualized processes within a physical Intel® Xeon® Scalable processor core, enabling secure partitioning for latency sensitive workloads and optimized infrastructure utilization. FlexRAN is also designed to operate on a high availability hypervisor if required on major network nodes, such as the open source Wind River* Titanium Cloud* components of The Linux Foundation Akraino Edge Stack[11].

Multiple instances of the baseband function can be hosted on a single Intel® Xeon® processor, providing scalable capacity for large nodes, or support of multiple base stations from a single site. Dynamic load distribution to baseband processing pools can be undertaken using the traffic steering capability in attached Intel® Wireless Network Interface cards. The virtualization environment also allows the entire RAN network user and control plane functionality to be virtualized on standard Intel® Xeon® processors, with the option of hardware acceleration using Intel® Altera® FPGA enabled PCI-E plug in cards. The same systems can simultaneously support instances of virtualized mobile core elements if they need to be distributed to RAN sites.

Meanwhile, the NGCO initiative has created a reference architecture[12] for a Multi-Terabit processing rack suitable for classic CoSP aggregation and regional nodes in COs. This solution demonstrates how requirements for the Virtual BNG function for fixed broadband or Virtual EPC Edge for mobile

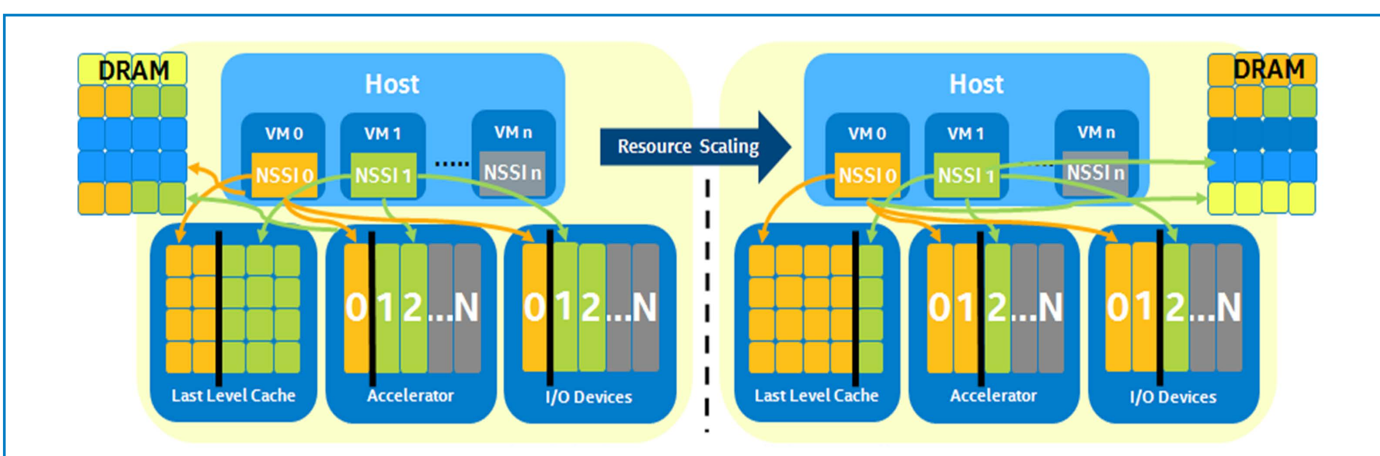

Figure 5. Intel Platform Resource Slicing and Scalability

wireless for a typical CoSP aggregation node can be handled on a single server, based on current and projected traffic volumes. NGCO is also expected to handle various workloads, including separated Control Plane and User Plane (CUPS) functions for mobile wireless with production deployments in 2020.

This NGCO Initiative reference architecture includes processing, storage and switching resources with resilient power supply modules, along with platform telemetry facilities for Intel® Service Assurance Manager and Intel® Cloud Integrity Technology (Intel® CIT) features for Security Integrity Assurance.

Enabling Network Transformation

Artificial Intelligence (AI) techniques are expected to optimize the use of network node infrastructure to minimize equipment costs and accelerate the cycle time for "Self-Organizing Network" reconfiguration from the classic 15-minute period to more real-time processing. This would address the expected rate of cell site introduction, and also potentially involve reallocation of the network capacity to handle priority user session requirements.

Strategically, using software in the network will enable some consolidation of CoSPs IT cloud and networking activities, from procurement to operational practices and management tools. This is being advanced by The Linux Foundation[11], through open source projects from data path acceleration to network data analytics.

Intel Enabling Network Transformation

In addition to developing the silicon components, Intel is actively supporting other industry initiatives to help CoSPs evolve to 5G sliced network solutions.

To simplify the use of standard servers in the network, Intel® Select Solution for NFVI[12] provides a performance benchmark for a standard COTS server that has been optimized for NFV workloads when combined with a virtualization software stack. Commercial products are then validated against that benchmark, so that CoSPs can procure hardware from the competitive market in the knowledge that it will perform to the required level without further evaluation.

Intel also contributes extensively to various Open Source Software initiatives to ensure that software is available to build systems that can fully utilize Intel® architecture. Intel is supporting the Linux Foundation Networking Fund program, which encompasses open source projects from low-level dataplane acceleration up to network analytics. One key initiative is the Open Platform for NFV (OPNFV), that brings together the various streams of open source activity to form a complete working system, providing patches and other feedback from interoperability events. OPNFV provides regular releases of the system, following cross industry Continuous Integration/Continuous Delivery (CI/CD), and provides standardized testing methodologies and tools that CoSPs can use to evaluate solutions.

Another key initiative is the Telecom Infra Project, where the OpenRAN effort[13], led by Intel and Vodafone, is developing a reference framework architecture for implementation of a gNB software stack on standard servers, which includes APIs to abstract application vendors from the underlying hardware platform capabilities. Reference implementation of the basic building blocks and algorithms are being developed as software libraries.

Practical experience is also gained from undertaking proof of concept (PoC) projects with leading CoSPs, such as testing FlexRAN with Telefonica in 2017[14]. More recently, Intel demonstrated[15] how FlexRAN fits into a wider 5G reference design as shown in Figure 6.

In addition to the Network Edge Virtualization SDK provided to help developers build 5G edge nodes, this system included partner contributions such as the Wind River* Titanium* hypervisor, Radisys* Mobility Engine* gNB components, and the Mavenir* vEPC all running in one server with management provided by Amdocs* NFV powered by ONAP* orchestration.

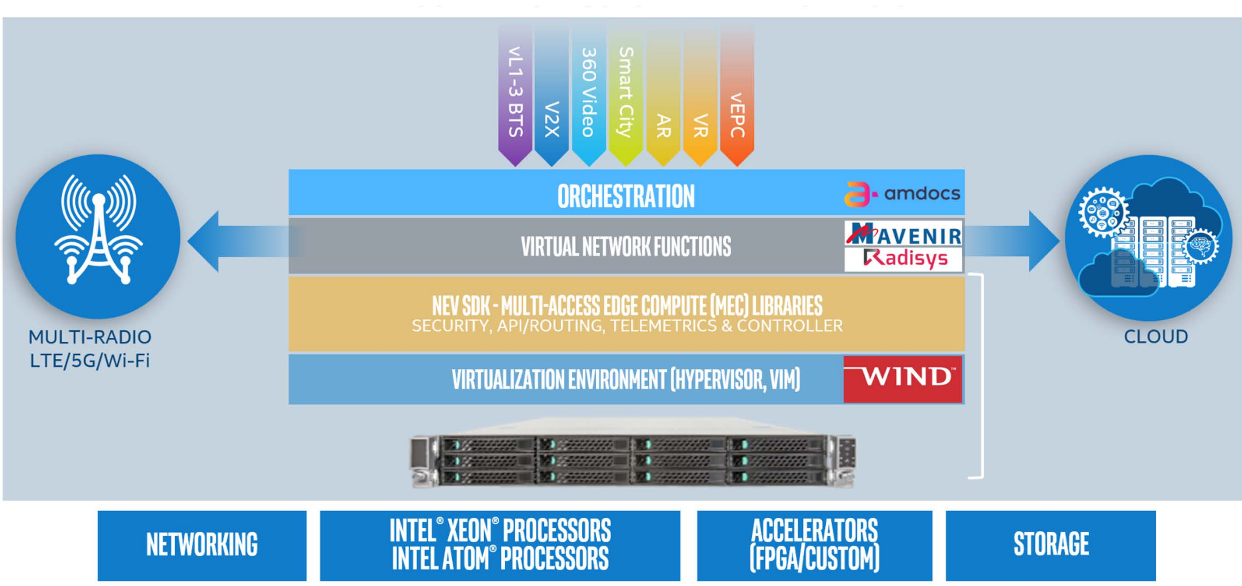

Figure 6. Intel 5G Infrastructure Reference Design

These companies are all members of the Intel® Network Builders ecosystem of over 300 companies involved in providing component parts of virtualized network solutions, including hardware, operating system, VNF software, management systems, testgear providers and systems integrators, with a specific sub-group looking at Edge applications. Their products are presented in an online Solutions Catalogue (at https://networkbuilders.intel.com) along with solutions briefs enabling CoSPs to learn about use of the products.

CoSP network operations skills and culture need to evolve to handle the rate of change typically experienced in IT organizations. Technical training is also available from the Intel® Network Builders University, which provides on-line courseware aimed at network and IT staff who need to understand the network virtualization technologies. The courses can also be integrated into CoSPs' own learning management systems to allow staff management to track employee usage and performance.

Solution Summary

5G network slicing is the target architecture enabling Communication Service Providers (CoSPs) to achieve optimal economies of scale from a shared network platform supporting an evolving portfolio of innovative services. Building on experience gained with NFV and MEC solutions for the mobile core and edge, Intel has a set of components available to build flexible 5G access networks with Intel® Network Builder partners. With a consistent Intel® architecture foundation, workloads can be sited in the small cell, the base station street cabinet, the Central Office and the data center to give maximum flexibility to service the evolving 5G market.

Intel® Technology Foundation

Intel Atom® processors and Intel® Xeon® processors form a key foundation for 5G systems at all network node sites, using technology proven for IT systems and cloud services.

Learn More

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Visit http://intel.com/network to learn about the path to 5G.

Visit http://networkbuilders.intel.com/ to get started now.

References

1. ITU Recommendation, "Recommendation ITU-R M.2083-0, IMT Vision – Framework and overall objectives of the future development of IMT for 2020 and beyond," September 2015
https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2083-0-201509-I%21%21PDF-E.pdf

2. 5G-PPP Brochure, "5G Vision," 2015
https://5g-ppp.eu/wp-content/uploads/2015/02/5G-Vision-Brochure-v1.pdf

3. ETSI White Paper, "Network Operator Perspectives on NFV priorities for 5G," February 2017
https://portal.etsi.org/NFV/NFV_White_Paper_5G.pdf

4. IP White Paper, "Creating an ecosystem for vRANs supporting non-ideal fronthaul," early 2018
https://telecominfraproject.com/wp-content/uploads/VRAN_WP_final.pdf

5. NGMN 5G White Paper, 2015
https://www.ngmn.org/fileadmin/ngmn/content/images/news/ngmn_news/NGMN_5G_White_Paper_V1_0.pdf

6. OpenCord membership,
https://opencord.org/members/

7. Akamai website, "Aura Managed CDN,"
https://www.akamai.com/uk/en/products/network-operator/managed-cdn-solutions.jsp

8. Amazon Web Services Cloudfront
https://aws.amazon.com/cloudfront/

9. Amazon Web Services Greengrass
https://aws.amazon.com/greengrass/

10. Intel Website "Resource Director Technology"
https://www.intel.co.uk/content/www/uk/en/architecture-and-technology/resource-director-technology.html

11. Linux Foundation Press Release, "Akraino Edge Stack," March 2018
https://www.akraino.org/press/2018/03/27/the-linux-foundation-announces-expanded-industry-commitment-to-akraino-edge-stack/

12. Intel Next Generation Central Office White paper,
https://builders.intel.com/docs/networkbuilders/creating-the-next-generation-central-office-with-intel-architecture-cpus.pdf

13. Linux Foundation presentation, "Open Source Networking and ONAP" TMForum ActionWeek, September 2017
https://actionweek.tmforum.org/wp-content/uploads/2017/09/TMF-Keynote-LF-Networking-ONAP-Sept-2017-vfinal.pdf

14. Intel website, "Intel Select Solutions for NFVI"
https://builders.intel.com/intelselectsolutions/intelselectsolutionsfornfvi

15. TIP Website, "OpenRAN project,"
http://telecominfraproject.com/project-groups-2/access-projects/openran/

16. Telefonica Press Release, "FlexRAN PoC project," February 2017
https://www.5tonic.org/news/telefonica-proud-announce-delivery-and-installation-intel-flexran-platform-5tonic-open-5g-lab

17. Intel Blog, "5G Use Cases and Intel Innovation on Display at 5G World in London," June 2018,
https://builders.intel.com/blog/5g-use-cases-intel-innovation-5g-world-london/