NEW TECHNOLOGIES UNDERLYING DIGITAL TRANSFORMATION

Alexei Shalaginov
Shalaginov.com, Moscow, Russia,
ashalaginov@gmail.com

Victor Shalaginov
PAO Rostelecom, Moscow, Russia,
victor.shalagonov@gmail.com

Abstract

This article is a brief overview of the most prominent technologies underlying Digital Transformation. The most important Telecom and IT digital transformation trend is virtualization. The technologies presented in this article are not 'killer service' nor the key to success if taken alone. Only synergy of them is able to lead to Digital Transformation success. The 'Convergence' term frequently used recently, has got a new meaning due to below mentioned and other technologies impact.

Keywords

Digital Transformation; Iron Triangle; Convergence; SDN; NFV; 5G; Edge; Cloud; Fog

I. INTRODUCTION

The world is changing at staggering rate. What seemed like science fiction only 10-15 years ago, is becoming a reality today. We live in the developing Industry 4.0 supported by Digital Transformation of almost everything (except love, faith and other human values).

Access gradually become more important than Possession. Libraries with miles of bookshelves become obsolete for most of researches, who are turning to online information sources. The demand for the brand-new cars is dropping as people turn to car-sharing services. Desktop computers are being virtualized in Clouds, so people have a workplace everywhere with Internet access provided.

Some results of Digital Transformation seem antilogous. Facebook is the biggest content provider, but it doesn't have its own content. Alibaba is the greatest retailer, but it doesn't have its own warehouses. Airbnb is the global accommodation network but it doesn't have its own hotels. Uber is the most popular taxi service worldwide but it doesn't have its own cars. 3D-printing (or additive manufacturing) will soon drastically change the global logistic system as more and more goods will be produced locally and with much greater customization, rather than being manufactured in "global production shop" in Asia-Pacific countries.

Telecom carrier networks (and not only) is being virtualized. The bulky and expensive "Hardware Zoo" of traditional network elements is transforming to only three "species": servers, storages, and switches. Thus, telecom networks become more agile, flexible and economically efficient, oriented not only to connect people, but also things, and even more so.

These are only a few examples of emerging trends representing the Digital Transformation.

II. THE IRON TRIANGLE OF DIGITAL TRANSFORMATION

The most important technology groups for Digital Transformation may be represented as 'Iron Triangle'. Each group is accommodating underlying multiplicity of technologies in each 'angle' [1].

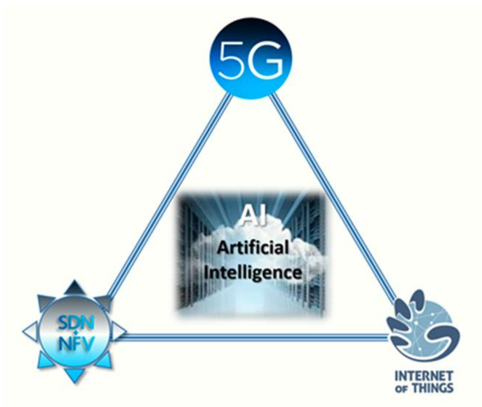

Fig. 1 'The Iron Triangle' of Digital Transformation *(source: Authors).*

The three basic technology groups are the 'corner stones' of Digital transformation, namely: Internet of things (IoT), virtualization technologies SDN/NFV (Software Defined Networks, Network Function Virtualization), and communication networks 5G (the 5^{th} Generation of mobile networks).

The derivative of the triangle synergy is the Artificial Intelligence (AI). The term was coined in 1956 by John McCarthy [2], but became feasible only when its technological prerequisites in Iron Triangle's corners have matured enough.

A. Internet of things

Connected 'Things', i.e. sensors, meters, actuators of IoT embedded in everyday utilities, like kettles, toasters, fridges etc., and in industrial equipment: machines, vehicles, cameras, etc. (Industrial IoT, IIoT) provide abundant scope of raw data for Big Data analysis systems to provide insights for Artificial Intelligence. IoT/IIoT are data sources for AI underlying technologies like Machine/Deep Learning, Computer Vision, Cloud, Fog and Edge Computing, etc. [3].

B. Communication networks (5G)

IoT-based AI and Big Data analytical systems are the applications working in Clouds of various types and levels. Telecommunication networks are necessary for interconnection of IoT data sources and data centres in Clouds. 5G mobile networks are oriented to IoT raw data sent uplink, as well as transmitting AI control signals downlink to IoT actuator devices. So, 5G is the universal medium between data sourcing and data processing levels in Cloud. It's not the only function of 5G communication network, but rather important function.

C. SDN/NFV

SDN/NFV are the most important aspect of Digital Transformation. As mentioned above, AI and Applications are software entities working in Clouds. Data-centers (DCs) of different types are Cloud physical medium, providing three main Cloud services: SaaS (Software as a Service), IaaS (Infrastructure as a Service) and PaaS (Platform as a Service).

From the other hand, one of the main principles of 5G is the replacement of hardware network appliances ("network function – physical appliance") by software entities. For example, in mobile networks 2/3/4G a network function was usually implemented in a hardware box. In contrast, in 5G a network function will be the software function working in DC server(s). So, DC computing infrastructure is a common environment for both 5G, AI, and SDN/NFV services.

In order to use DC computing power more effectively, it is necessary to be able to flexibly reconfigure the network connecting servers and storages inside a DC. The technology of programmatic, software defined network (SDN) is designed for that. SDN permits flexible network configuration, and 'slicing' the DC to multiple logically divided DCs, each and every logical DC for each and every application, or business.

Virtualization technology makes possible to represent the functions of telecom network elements as software entities (virtual appliances), working on standard servers. So, NFV makes possible to use only the three kinds of standard equipment for all possible network functions [4] (see. Fig. 2).

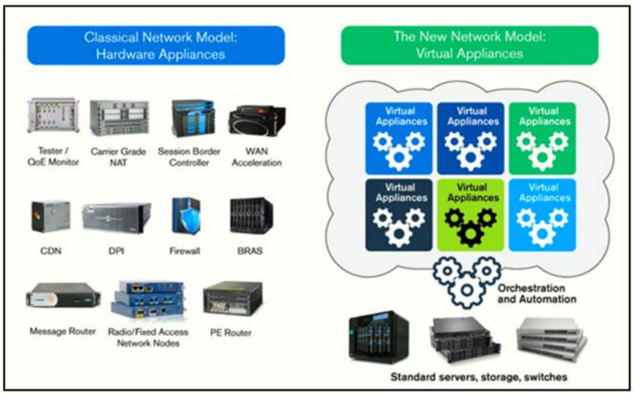

Fig. 2. Classical and new network paradigms *(source: Ciena Corp.).*

II. SDN/NFV UNDERLYING TECHNOLOGIES

A. MEC – Multi-Access Edge Computing

Carrier networks "go clouds" and became virtualized. AT&T have already virtualized about 75% of their core network in Domain 2.0 project since 2013 [5]. But moving all the network functions to the central cloud may cause some problems, like delays, core network throughput 'bottleneck' and overloading DC servers'.

The answer to these issues is moving network services and applications closer to the network edge. Network edge DCs became smaller, mobile and able to be deployed in a vicinity of user equipment (UE) generating data. It is especially important in IoT applications, which are the main focus of 5G [6].

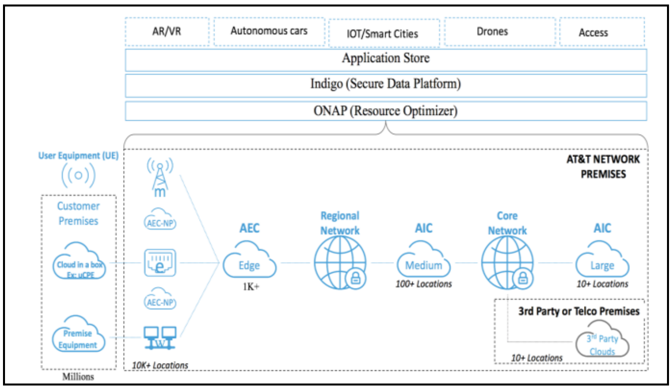

Fig. 3. UE traffic preliminary processing at Edge network *(source: AT&T Edge Cloud (AEC), White Paper. 2017).*

MEC originally meant Mobile Edge Computing, but now the term is redefined with the M for Multi-access. MEC is the concept of NFV computing co-located with cell-sites, local cell aggregation points, and fixed-network Central Offices (CO). MEC may be coupled tightly with NFV in Central Cloud, but also may work as independent edge virtualization platform.

Modular and mobile DCs are extremely important for MEC. These DCs may be deployed closer to network edge, quickly installed in indoor and/or outdoor sites. Cell-site Base Band Units (BBU) may reside in MEC DCs as virtualized applications chained from standard Virtual Network Functions (VNF).

Fig. 4. Edge Modular DC, that can be transported by regular truck *(source: mainlinecomputer.com).*

B. Virtualized C-RAN (Cloud RAN, Centralized RAN)

MEC is a way to implement C-RAN, which is a centralized cellular architecture that has the power to support current and future wireless communication standards. C-RAN architecture is able to efficiently centralize RAN processing [7]. C-RAN offers several benefits compared to the conventional RANs, such as flexibility and scalability.

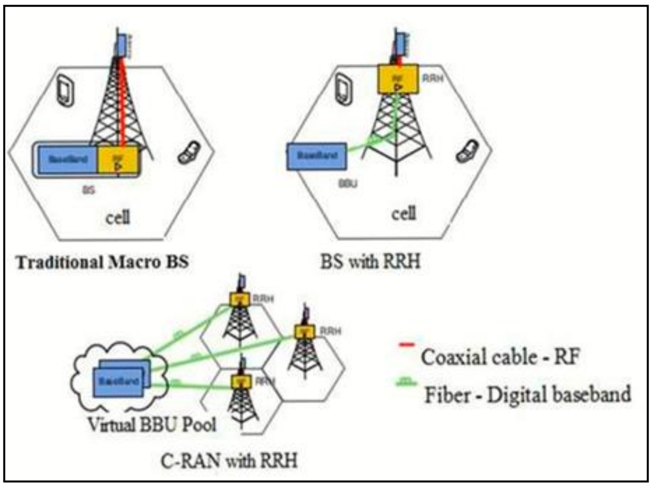

Fig. 5. The transition from traditional RAN to C-RAN *(source: International Journal on Informatics Visualization).*

C. CORD (Central Office Re-architected as a Datacenter)

The CORD platform leverages SDN, NFV and DC technologies to build agile datacenters for the Network Edge. Integrating multiple Open Source software projects and Commercial off the Shelf (COTS) standard devices, CORD delivers a cloud-native, open, programmable, agile platform for network operators to create innovative services [8].

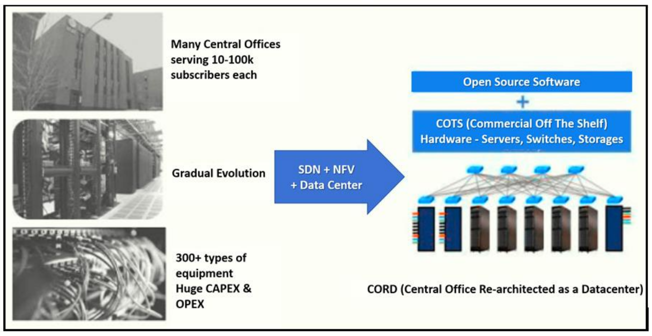

Fig. 6. CORD as CO virtualization in Data Center *(source: ONF).*

CORD provides a complete integrated platform, integrating everything needed to create a complete operational Edge datacenter with built-in service capabilities, all built on commodity hardware and software (COTS) using the latest cloud-native design principles.

III. IOT UNDERLYING TECHNOLOGIES

A. Fog Computing

Fog Computing extends the Cloud paradigm to the edge of the network. Fog and Cloud use the same resources (networking, computing, and storage) and share many of the same mechanisms and attributes: virtualization, multitenancy, etc. [9].

The Fog Computing was conceived to address applications and services that do not fit well the paradigm of the Cloud. For example, the applications requiring low latency may work not effectively using the central Cloud as the computing node. More than that, network bandwidth between the Edge and the Cloud should be too large. That leads to huge investments in network construction.

For example, in Fig. 7 a Smart Grid systems, before and after Fog deployment, are shown [10].

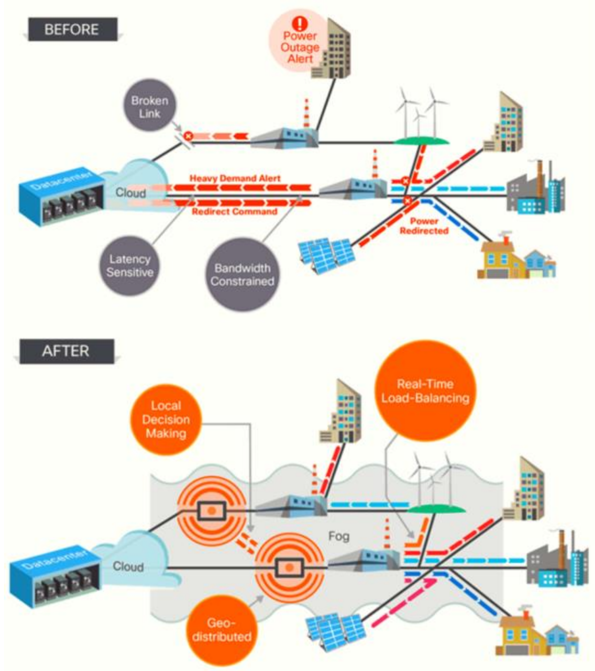

Fig. 7. Enhancement of Smart Grid system after Fog deployment *(source: blog.rankwatch.com).*

If the Smart Grid platform works only inside the Central Cloud, there should be substantial delays in response for power outage alert due to possible broken link, bandwidth demand alert due to bandwidth constraints, and latencies.

Smart Grid using Fog for local decision making enjoys real-time load-balancing, geo-distribution of traffic and energy consumers quality of service.

IV. 5G UNDERLYING TECHNOLOGIES

A. Network Slicing

A network slice is envisioned to support the communication services of particular connection type with 5G Radio Access Technologies (RAT) specific for these services. So, a "5G slice" could be composed of a collection of 5G Network Functions (NF) and specific RATs that are combined together for a specific use case or business model [11].

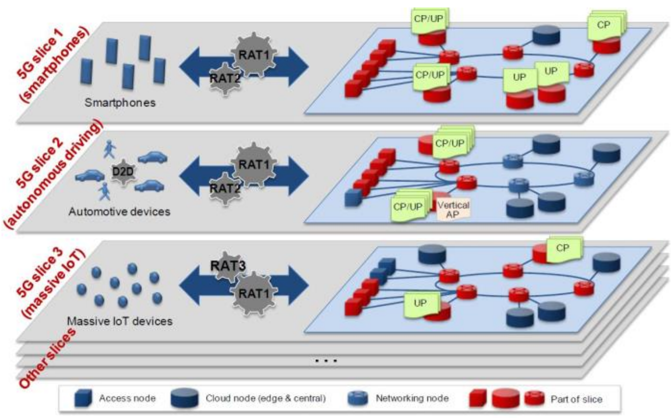

Fig. 8. 5G Network Slicing concept *(source: METIS-II Project).*

From an end customer perspective, a network slice is seen as an independent network. In former mobile networks it was necessary to deploy an independent network infrastructure for each application (smartphones, MBB, IoT, etc.). In 5G, an application will be deployed in its own logical slice of shared infrastructure (also referred to as "virtual network"). In this way, the infrastructure and assets utilization are likely to be much more cost and energy efficient. The slicing concept is envisioned to allow for a much faster set-up of new services and applications or modification of existing ones.

B. 5G New Radio

Mobile networks are facing a problem of rapid growth of data throughput. There are three main ways to increase data throughput: 1) to densify networks, 2) to increase spectrum usage efficiency, and 3) to gain access to more spectrum [12].

To address all these issues, 5G New Radio standard (5G NR) will natively support small cells, more antennas with massive MIMO (Multiple In, Multiple Out) technology, as well as many other enhancements. But a key aspect of 5G NR is the ability to mobilize higher spectrum bands that were previously not available for mobile applications. 5G NR is designed to natively support all spectrum types (licensed, unlicensed, shared) and spectrum bands (low, mid, high).

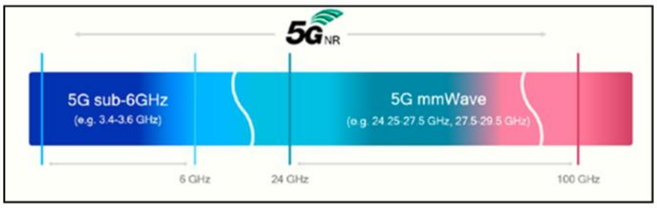

Fig. 9. Extended spectrum for 5G NR *(source: Nokia).*

5G NR provides higher energy and spectrum usage efficiency with the help of beamforming technology. The gNB (g Node B) matrix antenna is able to find a direction to UE and form a narrow beam directed to this particular device.

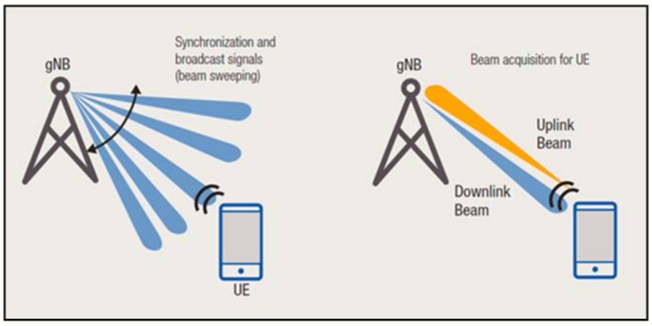

Fig. 10. 5G NR beamforming *(source: Nokia).*

V. CONVERGENCE

The term 'Convergence', frequently used recent time, has got more meaning due to above mentioned and other technologies influence. We may put forward the following considerations (see Fig 11).

1. Fixed networks and mobile networks are merging into unified structure of 5G virtualized network, which is able to provide network slicing for different platforms, applications, and services.
2. Time Division Multiplexing (TDM), Next Generation Networks (NGN), IMS (IP Multimedia Subsystem) and further NFV are steps in continuous process of software and hardware separation, functions and equipment boxes separation. Network elements (functions) as 'hardware boxes' in TDM/2G, NGN/3G, and in less extent in IMS/4G platforms, are becoming software functions in the SDN/NFV infrastructure of 5G.
3. 2G/TDM networks were oriented to voice and texting. 3G/NGN were oriented to fixed and mobile broadband (BB) access. 4G/IMS converged both voice and BB, and began to blur a border between fixed and mobile networks.
4. In 5G/SDN/NFV infrastructure, functions are moving to Data Centers, as for Core networks, as for Edge Networks. Network boxes are gradually transforming into software functions working in DCs.

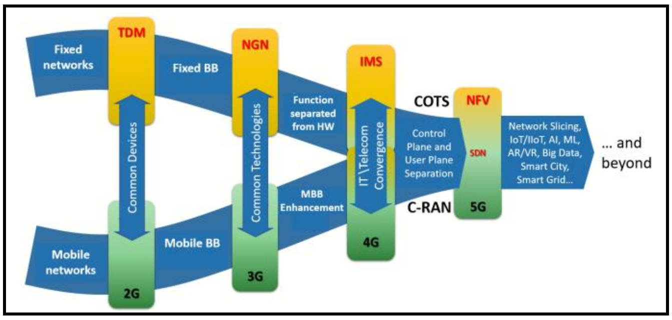

Fig. 11. IT and Telecom convergence and Digital Transformation *(source: Authors).*

These technologies (including but not limited to) are the examples of Digital Transformation trends in IT/Telecom Industry.

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