Network and Communication Technologies; Vol. 6, No. 1; 2021
ISSN 1927-064X E-ISSN 1927-0658
Published by Canadian Center of Science and Education

Toward an AI-Enabled O-RAN-based and SDN/NFV-driven 5G & IoT Network Era

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Received: May 6, 2021 Accepted: June 7, 2021 Online Published: June 15, 2021

doi:10.5539/nct.v6n1p6 URL: https://doi.org/10.5539/nct.v6n1p6

Abstract

Artificial Intelligent Technology has impacted tremendously in the areas of high performance computing, and network and communicatons industries. The advantages of a system applying AI includes performance improvent, optimization, and intelligent or smart AnFor intelligent fesure of 5G, network slicing, provided by Network equipment vendor by applying AI, softwarization and virtualization technologies to the network. For many other industries and applications such as healthcare, agriculture, finance, have benefited from AI technology in particular machine learning and deep learning within AL.With the integration of AI, 5G, and Inernet of Thngs, the industrial applications, smart farms, precision medicine.,smart city. This article focuses on the System architecture and design of open networking solution of the future of 5G, beyond-5G (B5G) or 6G. Among the challenges of an ON system solution, the propriety of radio access network (RAN) is one of essential challenges. The Open-RAN Alliance is formed through the integration of C-RAN Alliance and X-RAN Forum. The O-RAN Alliance mission's is converting the radio access network industry to become an open networking intelligent, virtualized, and fully interoperable RAN. To realize B5G or 6G by applying O-RAN architecture and ecosystem is called O-RAN based B5G/6G The Integration of O-RAN based 5G RAN part and the SDN/NFV-based softwarization and virtualization of Core Network, Transport Network and Management functions, we can derive a stage of fully Open Networking architecture for the software (AI/M/DL) developers to work.

Keywords: Artificial Intelligence (AI), Machine Learning (ML), Deep Learning (DL), the Fifth Generation Mobile System (5G), Internet of Things (IoT), Software Defined Network (SDN), Network Function Virtualization (NFV), Radio Access (RAN), Open-RAN (O-RAN)

1. Introduction

This paper addresses the fusion of AI, 5G, and IoT and how it impacts the Open Networking (ON) ecosystem to the network & communications industry. The softwarization and virtualization are the goals of SDN and NFV respectively. Indeed SDN/NFV hav00e been applied to solve Telco central office re-architected as a datacenter (CORD) (Peterson et al., 2016; Al-Shabibi et al., n.d.) and flexible optical networks (KingA, D., FarrelA, N., Georgalas N., 2015) since 2015 or earlier. But the radio access network (RAN) part do not play an important role until the integration of C-RAN Alliance and X-RAN Forum to become Open-RAN Alliance (O-RAN).

The remaining of this paper is organized as following; Section 2 describes the concepts of open networking, the open standard-based 5G (O-RAN based 5G and SDN/NFV-based 5G. and Internet of Things (IoT). Section 3 addresses the advances of AI, ML, DL and shows the differences between AI-enabled network and AI in network. Before the conclusion, Section 4 describes the new era of ON development for 5G/B5G/6G. Before the conclusion we give an example of AI-enabled network feature by network slicing through virtual elements of virtual network.

2. Open Networking and AI

2.1 Open Networking Trends and 5G

It has been a paradigm shift in the network industry, from a proprietary networking with vendor-dependent soft-ware/hardware to vendor-independent open source and white box switches as illustrated in Figure 1. The white box is the commodity hardware that is available from network equipment ODM vendors. On the other

hand, the open source software executed on the commodity hardware in the control plane (with controller) of SDN can be very complex. Currently, there are three (3) well-developed SDN controller operating systems (OS) open source available including, ONOS, ODL, and RYU developed by various open source foundations.

The development direction from proprietary networking to open source based networking called Open Networking (ON). The first ON solution for 5G (in Japan) was proposed by Rakuten Mobile (CNBC, 2019; Telecomscom, 2019) in September, 2019 and granted an operator license. Right now Rakuten is busy in the deployment of base stations and expect to provide the full coverage on for mobile services in 2021.

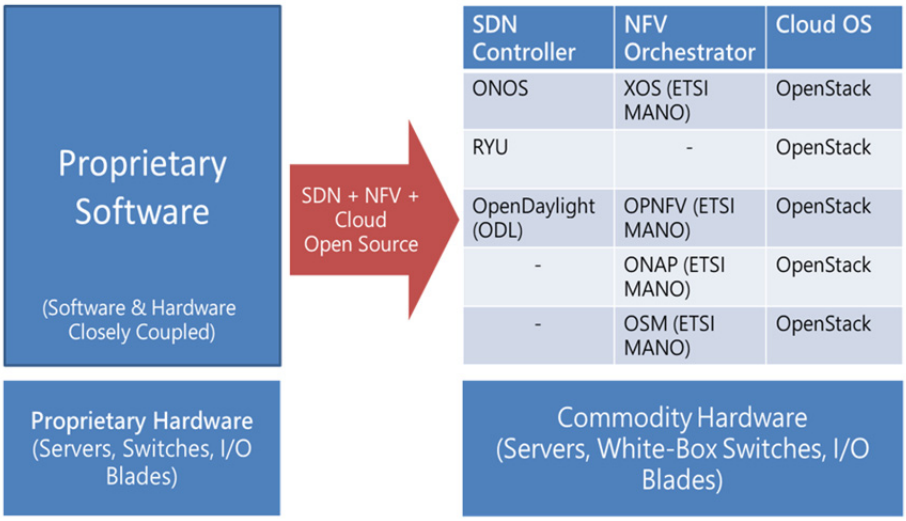

Figure 1. Open Networking (ON) Trend

2.2 The Open RAN –based 5G RAN

The mobile communications network consists of radio access network (RAN), transport network, and core network.The O-RAN Alliance mission's is converting the radio access network industry to become an open networking intelligent, virtualized, and fully interoperable RAN.The Open-RAN (O-RAN) Standards is proposed by O-RAN Alliance (O-RAN Alliance, 2020). O-RAN standard enable a more competitive and vibrant RAN supplier ecosystem with faster innovation.

The Alliance currently has nine Workgroups and several Focus Groups and have produced important outputs (1) O-RAN architecture and specification, (2) Open and intelligent software for the RAN, and (3) Testing Frameworparticulark Specification (O-RAN Alliance, 2020)

The O-RAN Software Community is a collaboration between the O-RAN Alliance and Linux Foundation (particular Open Networking Foundation, ONF). The O-RAN based mobile networks such as 5G, beyond-5G, and 6G empowered by principles of intelligence and openness, the O-RAN architecture shown in Figure 2 is the foundation for building the virtualized RAN open hardware and cloud with embedded AI, powered radio work control.

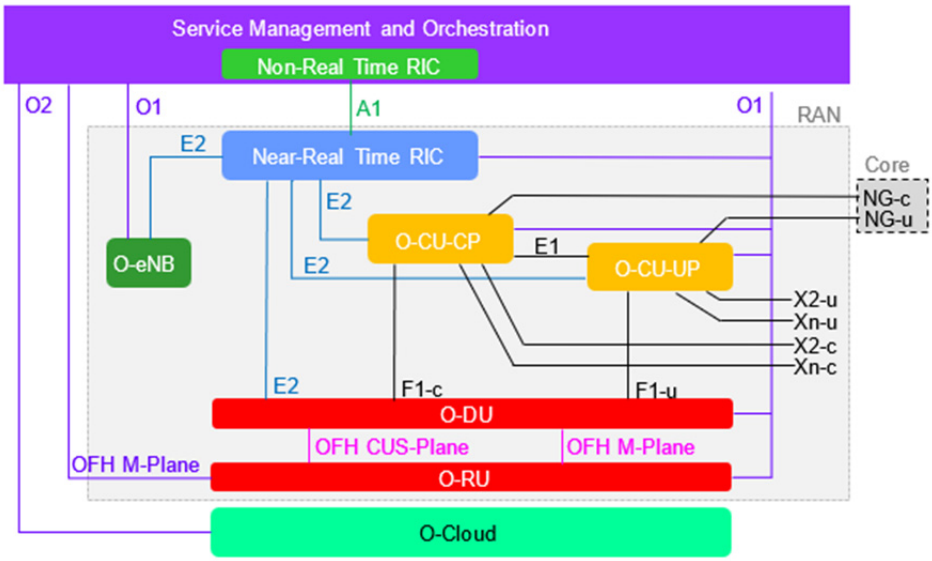

Figure 2. O-RAN Architecture (O-RAN Alliance, 2020)

2.3 SDN/NFV-Based 5G

In this article SDN-Based 5G means 5G network is constructed and deployed by using open source code related to SDN/NFV to do the softwarization & virtualization of 5G (Lin, B. S. P., 2020). The open networking architecture of 5G consists of O-RAN and virtual EPC (core network). O-RAN is an open source radio access network subsystem which separates RRH/RRU (remote radio head/remote radio unit) from BBU (baseband unit) and its core network is an available open source EPC. Figure 3 illustrates the open networking architecture of 5G. This open 5G network architecture creates the opportunity to be multi-vender to avoid lock-into one vender with proprietary solution. Also the separation of ORAN and EPC may create the new eco system of 5G industry.

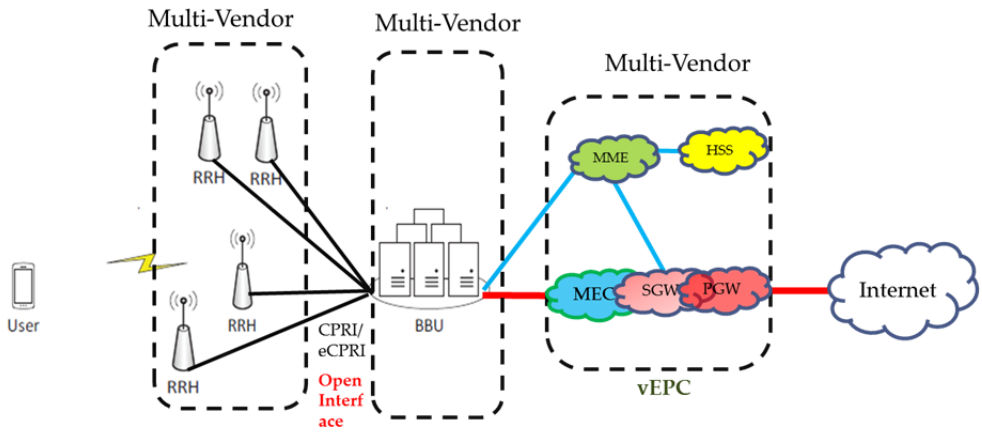

Figure 3. Multi-Vendor Solution for Mobile Communications Network

2.4 Interne of Things (IoT)

Figure 4 shows the definition of Internet of Things (IoT) and some examples.Currently, majority of Internet of Things (IoT) of the system applications snd services depend on 5G or 4G/LTE or even 3G as the gateway to send data to the destination for computing and applications generation and execution. Figure 5 illustrates example of wireless sensor network (WSN) which collects data and/or signals from devices and use 4G/LTE and 5G as the gateway to network and services platform for further application creation. Its equivalent 4 Layer Model of IoT is shown in Figure 4(Akyildiz, 2017). The 4 layer model consisits of layer 1: sensing and identification, layer 2:

network construction, layer 3: information processing and layer 4: integrated application.

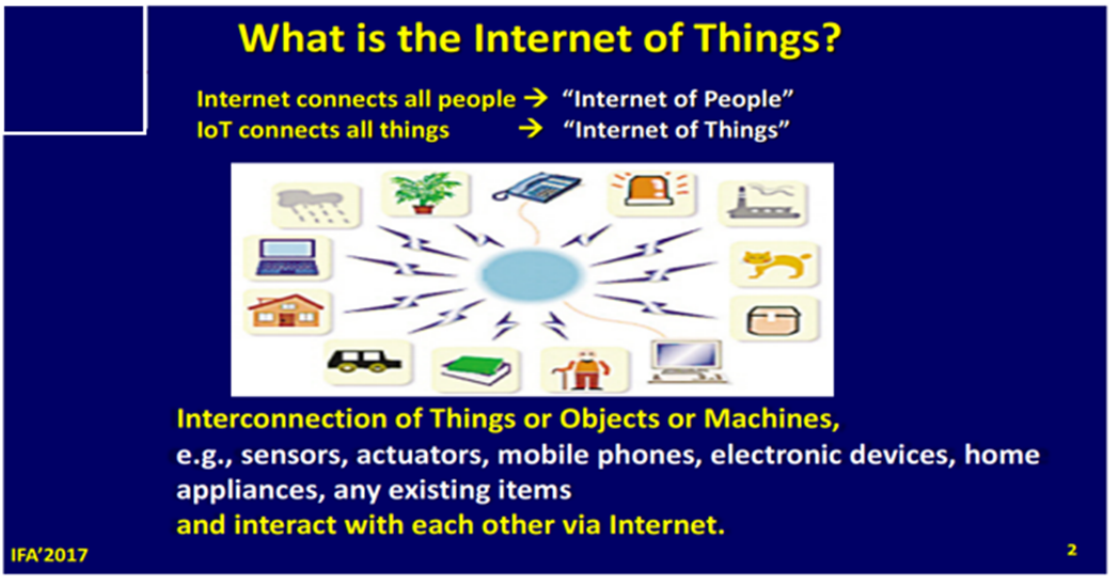

Figure 4. Internet vs. Internet of Things (Akyildiz, 2017)

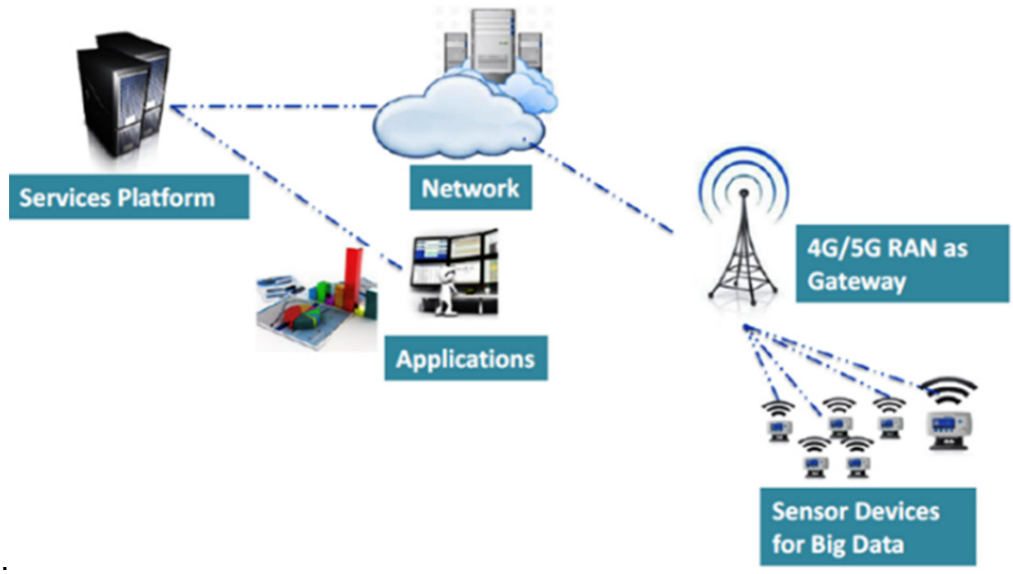

Figure 5. IoT Conceptual and Reference Architecture

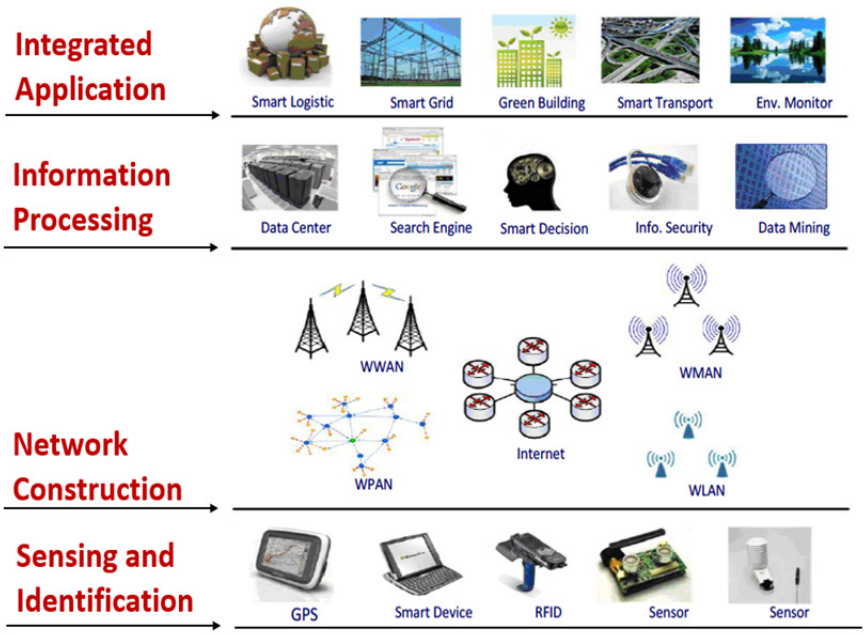

Figure 6. 4-layer model of IoT (Akyildiz, 2017)

3. The Advances of AI and AI-Enabled Network

3.1 The advances of AI, ML, and DL Technology

Artificial intelligent (AI) is a great technology and applications for which existing solutions require better automation or optimization and there is no good solution by using traditional approaches. So, when people say AI in Network really means using AI techniques to assist network operations, configuration, and management or to play a supporting role. On the other hand, Network with machine learning (ML), deep learning (DL) and other AI techniques used to manage network to be predictive and proactive, then AI/ML/DL becomes the driving force of network operations and management or the enabler of network operations. We call this kind of network is an AI-enabled Network (ATIS, 2018; 5G Americas whitepaper, 2019). AI is also an interdisciplinary science with multiple approaches but the advancements in ML and DL are creating a paradigm shift virtually every sector of the technology industry.

This section discusses the definitions of AI, ML, DL and their relationships and differences. AI is algorithms, programs, coding can make machine, objects and things more intelligence through learning and/or training. ML is a subset of AI while DL is a subset of AI and ML.

3.2 AI in Network vs AI-Enabled Network

There are two ways to migrate AI software to the existed system. One way is try to use AI algorithms or techniques to assist the system to become more automation, more optimization, and better service. So, AI in network means what AI can assist network to complete network functions. The other way is using AI/ML/DL techniques to complete the network migration. So, AI-enabled Network means AI driven network operation and management. The characteristics of 3 approach to architect and design the network include: Traditional Networking without AI, AI in Network, AI-enabled Network are (Lin, 2019; Lin et al., 2019; B. S. P. Lin, F. J.Lin.& Tung. 2016; Latah, M. & Toker, L. 2018; Wilson, 2019; Wu et al., n.d. 2019); in the following:

1) Traditional Networking with0out AI/ML/DL: reactive, no intelligence, no optimization, error prone, inefficient
2) AI in Network is: semi-active, partial intelligent, local optimization, semi-automated
3) AI-enabled Network is: proactive, intelligent, global optimization, automated, scalable

Table 1 (ATIS, 2018) shows the comparison of 3 approaches.

Table 1. Comparison of Traditional Networking, AI in Network, and Network AI

With AI Characteristics	Traditional Networking	AI in Network	Network AI
Approach	without AI/ML/DL	With AI/ML/DL	With AI/ML/DL
Active	Reactive	semi-full active	proactive
Intelligent	no intelligent	semi-full intelligent	intelligent
Optimization	no optimization	local optimization	global optimization
Automated	no automated	semi-automated	automated
Others	error prone inefficient	no-specific	scalable

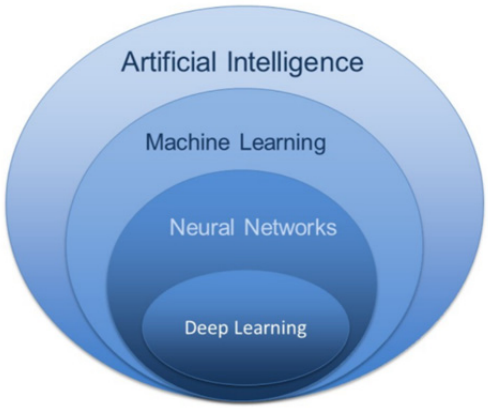

Figure 7. Domain coverage relationships among AI, ML, and DL

4. The New Era of ON Development for 5G/B5G/6G

The Figure 8 (Ericsson, 2020) illustrates the mobile communication network architecture consists of access network (radio access network/unit and baseband unit), core network, transport network and management system.

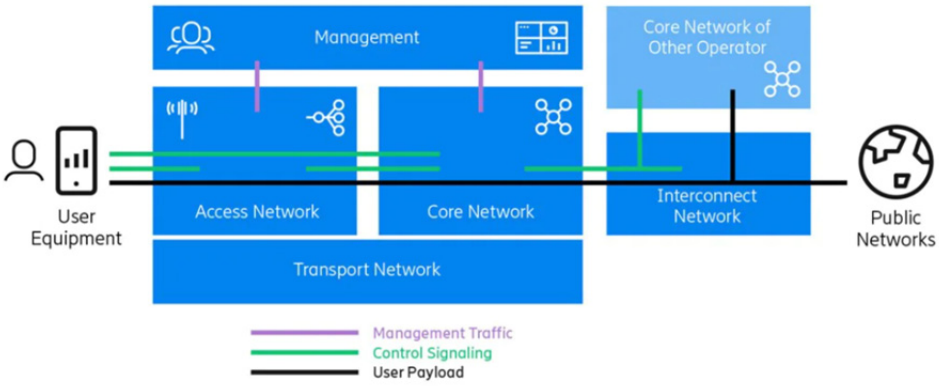

Figure 8. Mobile (5G) Communication Networks (Ericsson, 2020)

Figure 9 shows the way to create virtual O-RAN by applying Open-RAN Alliance architecture/Specs and Standards to 5G RAN. The virtual Core Network, TN (King, FarrelA, & Georgalas, 2015), and Management

System by applying SDN/NFV (mainly NFV) to each of them. Figure 10 draws the diagram with relationships among network components.

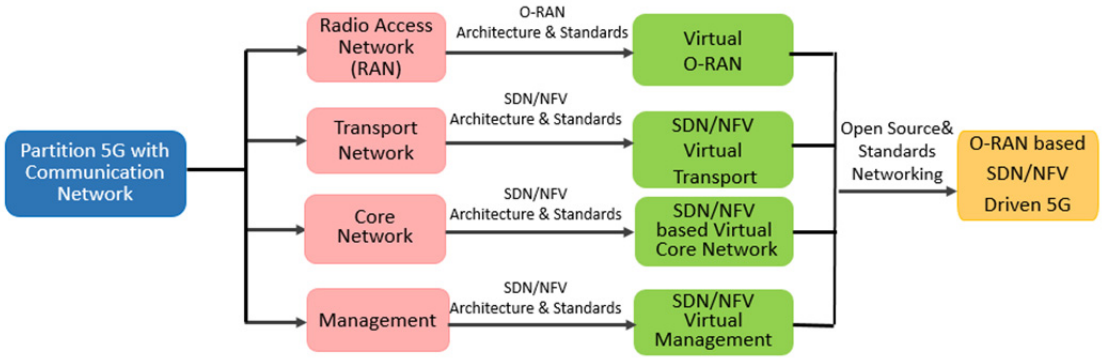

Figure 9. Creation of Virtual O-RAN and Virtual TAN CN and Management

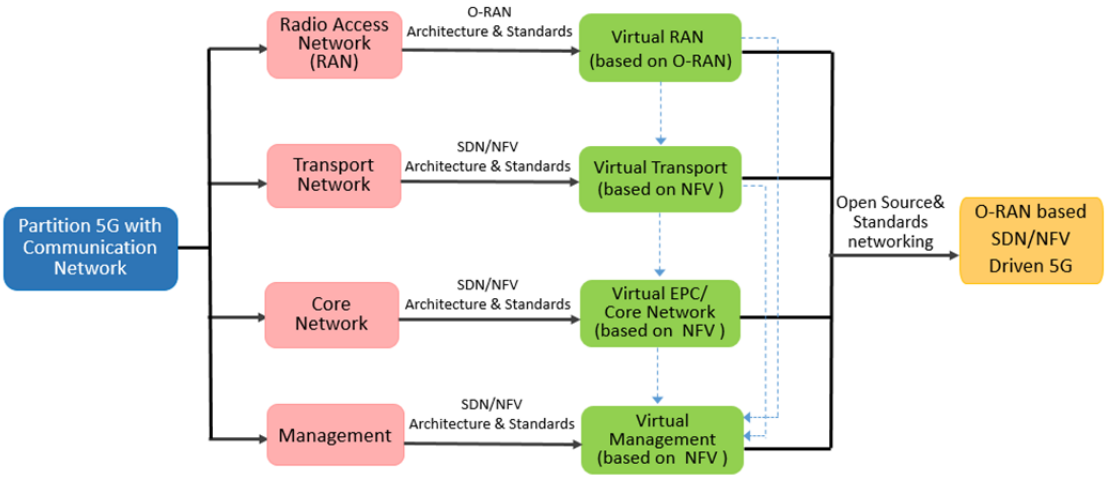

Figure 10. Provide relation among 5G O-RAN Virtual TAN CN and Management

Here we like to show an example with the fusion AI, 5G, and IoT. We have selected Open-RAN Alliance architecture, specs, and standards to convert 5G RAN to become Virtual O-RAN. We also choose SDN/NFV to re-architect the three mobile network components as Virtual Core Network, Virtual TN, and Virtual Management. AIoT (AI IoT or Advanced IoT) is created by embedding IoT with AI features according to the 4-layer IoT model. The gateway of AIoT and the transport of AIoT, this become Intelligent Connectivity. The open source version is called Open Intelligent Connectivity. The open source software foundation such as Open-RAN Alliance and Linux foundation are working on. Figure 11 shows the process of new era of open networking system architecture and open source software development.

·Virtual O-RAN (5G-RAN, architecture/spec, standards)

·Virtual Core Network (NFV (4G/5G) Core Network)

·Virtual TN (Traffic flow between RAN and core network or EPC)

·Virtual Management (5G-RAN, TN)

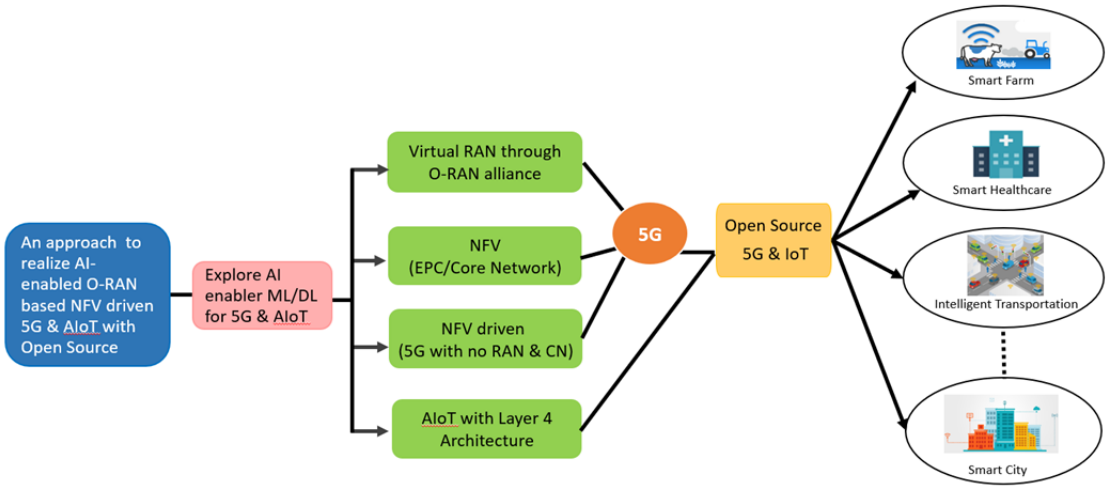

Figure 11. The process to convert 5G network into O-RAN based SDN/NFV Driven 5G. And fusion 5G AI and AIoT to apply industrial and complex applications

5. An Example of AI-enabled Network – Network Slicing

AI is playing an important role h how 5G or future networks become sliced, supporting uses including IoT and private 5G networks (Nelson, 2020). Network slicing is a form of virtual network architecture. Using the same principles behind SDN and NFV in fixed network. To deliver greater network flexibility by allowing traditional network architecture to be partitioned into virtual elements. Network slicing allows multiple virtual networks. This allows a network operator to support the numerous and varied services envisaged in 5G. The NGMN Standard has proposed a three categories of network slicing including smartphones, autonomous driving, and massive IoT (and other slices) shown in Figure 12 (Lin, 2019; B. S. P. Lin, F. J. Lin, & Tung, 2016). Applying SDN/NFV to IoT services to realize dynamic deployment of IoT services illustrated in Figure 13 (Lin, 2019; B. S. P. Lin, F. J. Lin, & Tung, 2016).

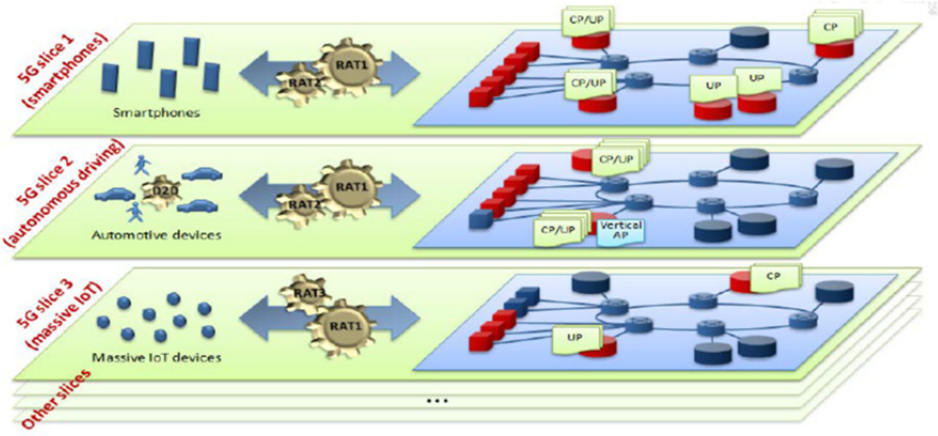

Figure 12. NGMN proposes three categories of network slicing

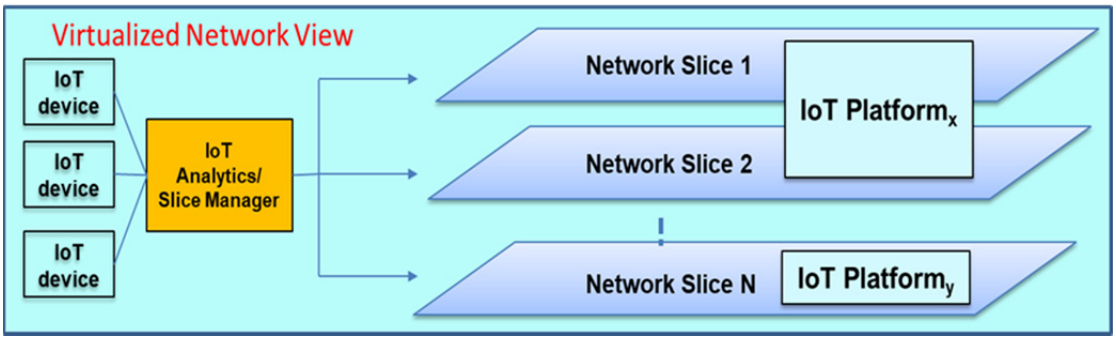

Figure 13. SDN/NFV based IoT Services to support dynamic deployment of IoT Services

6. Conclusion

Through the virtualization and softwarization of 5G RAN, TN, CN, and management of configuration, the multi-vendor solution for Open Networking community is becoming possible. AI-enabled network will take proactive, intelligent, and optimal way to manage or take good care of the network.

The remaining research works to be done include: the interfaces, protocol, and others APIs among virtual O-RAN, virtual (NFV) CN, and virtual (SDN/NFV) Management.

Acknowledgments

This work was supported by the Ministry of Science and Technology (MOST) of Taiwan and National Yang Ming Chiao Tung University (NYCU) under grants: MOST 109-2221-E-009-081- , 108-2221-E-009-043-.

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