A Survey on 5G Standardization for Edge Computing and Internet of Things

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***Abstract*— The networking world is undergoing a radical change to support innovative use cases and new market verticals. International Telecommunication Union (ITU) has defined three categories of these use cases – Enhanced Mobile Broadband (eMBB), Ultra-Reliable and Low Latency Communications (UR-LLC) and Massive Machine Type Communication (mMTC). 5G is considered a harbinger for achieving high data rates, high connection density and ultra-low latency essential to realize these use cases. Emerging technologies, such as Software Defined Networking (SDN), Network Functions Virtualization (NFV) and Multi-Access Edge Computing (MEC), are needed to accomplish the desired performance, scalability and agility. Standardization bodies, like 3rd Generation Partnership Project (3GPP), the Internet Engineering Task Force (IETF), and the European Telecommunications Standards Institute (ETSI) are working in synergy towards defining standards around 5G and these supporting technologies. This survey article summarizes the key enablers added in 5G standards, to support the edge and Internet of Things (IoT) applications. The article also annotates standardization activities around the deployment of virtualization in all segments of the network. Finally, it explores standards around edge deployments and how they leverage these virtualized infrastructures to realize the services envisioned by future 5G Networks, for IoT applications.**

Keywords- Edge Computing; Standardization; 3GPP; Internet of Things.

I. INTRODUCTION

5G is proving to be the next major iteration in cellular technology. 5G promises to offer peak data rate of 20 Gbps in downlink and 10 Gbps in uplink, one way latency at the access side of about 1 millisecond, and connection density of the order of one million device per square km area to support the massive scale of IoT devices expected in the near future [40] [9].

Enterprises and service providers are offering a plethora of applications to end customers, e.g., IoT, Virtual Reality (VR), industrial control, ubiquitous on-demand coverage, as well as the opportunity to meet customized market needs. Each application differs in terms of expected data rates, latency, reliability and availability. Hence, they need different treatments by the underlying cellular networks.

This kind of network transformation involves changes at radio access, core and transport, how network softwarization at each layer helps, how emerging technologies, like Network Function Virtualization and Software defined Networking, help in network softwarization of the cellular network, how innovative ideas, like computing at the edge or network slicing can help improve application performance.

With the enormous number of IoT enabled devices, the amount of data they generate and the latency they expect, cloud computing is no more an option to deliver the promised Quality of Experience (QoE). Edge Computing brings the cloud resources (i.e., compute storage and networking) closer to the user. Compute intensive or latency sensitive applications can be hosted on these edge resources to realize the stringent 5G requirements. 5G networks need to serve a diverse set of applications. Network slicing allows creating multiple, logically isolated, virtual networks over the same physical infrastructure. Each network slice can be configured separately as per the requirements of the application it serves.

In May 2015, the International Telecommunication Union (ITU) conceptualized the International Mobile Communications (IMT)-2020 standard (IMT-2020) [9], to analyze how emerging 5G technologies will interact in future networks, as a preliminary study into the networking innovations required to support the development of 5G systems. The work involved defining requirements from the 5G network, the architecture reference models, the procedures and flows needed in the 5G system, adding network softwarization using NFV/SDN and augmentations, like Edge Computing to realize the desired efficiency.

This is where multiple standardization bodies have stepped in – each one trying to resolve one piece of this 5G puzzle. ITU, 3GPP, ETSI and IETF consortiums have been working cohesively for developing the specifications for IMT - 2020. This article surveys specifications released by these consortiums and how they address some of the practical challenges foreseen when trying to adapt to 5G cellular networks and using them for emerging applications. This article is structured as follows: Section II covers the contributions from ITU and 3GPP who are focusing on the 5G requirements, frameworks, reference architectures, procedural flows, management and control planes. Section III covers the ETSI focus on NFV specifications, NFV being projected as a key technology enabler for many use cases defined in IMT-2020. To cover the use cases from ultra-low latency services to massive Internet of Things, ETSI established MEC Industry Specification Group (ISG), contributing the edge reference architecture, its APIs and use cases. This is covered in Section

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IV. Section V discusses a few open source initiatives conceptualized around these specifications, which will work as building blocks for 5G cellular networks. The article finally concludes on the convergence of these activities towards developing standards in 5G for MEC and IoT.

II. 5G STANDARDIZATION UNDER ITU, ETSI AND 3GPP

ITU is responsible for coordinating the international standardization of 5G systems. In 2015, ITU shared a recommendation document ITU-R M.2083-0 [9] stating diverse usage scenarios and applications foreseen in next generation networks. It categorizes the usage scenarios broadly into three categories: Enhanced Mobile Broadband (eMBB), Ultra-Reliable and Low Latency Communications (UR-LLC) and Massive Machine Type Communication (mMTC). Different usage scenarios result in diverse requirements. This ITU recommendation further states the kind of capabilities required to handle these requirements under eight parameters – peak data rate, user experienced data rate, latency, mobility, connection density, energy efficient, spectrum efficiency and area traffic capacity.

ITU recommendation ITU-T Y.3101 [10] states the general principles expected from the 5G networks in terms of service diversity, QoS diversity, diversity of mobility levels, user data types and most crucially in terms of flexibility and programmability needed in such networks. The recommendation, then goes into the detailed requirements from service point of view (eMBB, UR-LLC and mMTC) and from networking point of view. The networking requirements state the need for programmability of network functions, separation of control and user plane, network slicing requirements, interworking among multiple heterogeneous access networks, support the exposure of network capabilities, etc.

3GPP started working on the requirements of IMT-2020/5G and came up with a document 3GPP TS 22.261 [11] summarizing the complete set of requirements that define a 5G system – these high level requirements served as guidance for the architectural study. The requirements focused on the need of network softwarization and a complete re-architecture of cellular networks – to support separation of control and user plane, to leverage SDN and NFV technologies to improve on operational efficiency and increase flexibility, to support network slicing allowing the operators to provide customized networks, to support network capability exposure to trusted 3rd party applications (for instance, MEC applications) in a Service Hosting Environment to improve user experience, to allow Interoperability with legacy 3GPP systems, etc.

The 3GPP specification on system architecture 3GPP TS 23.501 [1], covers the 5G architecture reference models, interworking between 5G system and EPS, architectural enablers for virtualized deployments, support for end to end network slicing and support for Edge Computing. Further, the specification 3GPP TS 23.502 [2] highlights the procedures and Network Function services for the 5G system in terms of end-to-end information flows and the NF service operations of these flows for the communication within the 5G core.

5G system supports a service based representation, where network functions, e.g., Access and Mobility Management Function (AMF), Session Management Function (SMF), User Plane Function (UPF), Network Exposure Function (NEF) and Policy Control Function (PCF), within the Control Plane enable other authorized network functions to access their services. The specification 3GPP TS 23.501 [1] emphasizes on separation of user plane and control plane to allow independent scalability and flexible deployments (e.g., centralized or distributed edge) locations of the network functions. This feature along with the concurrent access support to local/centralized services, enables the flexible deployment of UPF for MEC use cases.

To support virtualized deployments of 5G core, each instance of 5G core network functions need to be deployed as fully distributed, fully redundant, stateless, and fully scalable. The specification 3GPP TS 23.501 [1] explains the kind of interactions executed by the network functions to support the centralization of state information and statelessness of the network functions.

3GPP also highlights the network slicing concepts to serve a particular service category or customer. This is crucial for the MEC and IoT use cases which have different requirements with respect to bandwidth, guaranteed QoS, security level and latency. Specification 3GPP TS 23.501 [1] introduces a new network function “Network Slice Selection Function” which helps in selection of the set of Network Slice instances for a User Equipment (UE). For establishing global interoperability for slicing, this specification introduces Standardized Slice/Service Type (SST) values for eMBB, UR-LLC and mMTC (Massive IoT). The specification also explains the signalling interactions among the 5G core network functions to configure the availability of a Network Slice in a tracking area, on trigger from the operator. Another 3GPP specification 3GPP TR 28.801 [12] explains the management and orchestration of end-to-end network slice by demarcating the slice management at three levels - Communication Service Management Function (service instance layer), Network Slice Management Function (network slice instance layer), Network Slice Subnet Management Function (resource layer).

The specification 3GPP TS 23.501 [1] dedicates a separate section to the MEC enablers in 5G. This includes concurrent access to centralized and local servers using multiple PDU session anchors, Application Function (AF) to trigger UPF (re)selection and traffic routing, session and service continuity for UE and application mobility, support for local area data network and lastly the NEF to provide information or accept configuration from external 3rd party applications (MEC applications or functional entities). This NEF interface can be used by the edge applications to provide policies or trigger traffic routing via the 5G core. The specification 3GPP TS 23.502 [2] details out the procedural flows between AF and other 5G core network functions for handling the AF requests for these traffic routing scenarios. ETSI specification ETSI TS 129 522 [6] introduces the NEF northbound interface between 5G NEF and the AF. It specifies the RESTful APIs (e.g., TrafficInfluence API), leveraged by the AF to access the services and capabilities of the 3GPP network entities. It also defines the data models for each API.

MEC use cases require de-centralization of UPF functions and could lead to an exponential increase in number of UPF instances. In addition, handling massive number of devices could lead to a high demand which is not evenly distributed – thus address allocation in response to the UE demand may exhaust IP Address/Prefixes allocation in one function while low demand elsewhere in the network may leave unused IP Addresses/Prefixes in other functions. Thus, basic SMF allocation methods will not work in these complex cases. The 3GPP specification 3GPP TR 23.726 [13] highlights some of these key issues around the SMF and UPF interactions and suggests corresponding solutions for these issues. For instance, one such solution is the UPF allocating the IPv4 address/IPV6 prefix to be used by a PDU Session over N6 interface, instead of SMF.

III. NFV STANDARDIZATION UNDER ETSI, IETF AND 3GPP

ETSI released new use cases in context of NFV relating to the 5G features, like network slicing and IoT virtualization in its existing specification ETSI GR NFV 001 [16]. The "Network slicing" use case in this specification states how network slicing can leverage virtualization – network functions of the slice may be virtualized, or the network slicing management and orchestration entities may be virtualized. The use case also gives explains the possible realization and provisioning of network slices, explaining the life cycle of the network slice and entities participating in this life cycle. Another use case that the specification introduced is "Virtualization of Internet of Things" – IoT is a leading use case of 5G as per NGMN Alliance [40]. The specification explains how virtualization can help in augmenting efficiency and achieve desired agility for the IoT applications/services. It explains how the IoT service providers can leverage the NFV infrastructure to offer services for collection, storage, management and processing of the IoT data and how one can design more services based on these processed data. It introduces the various actors in this complete ecosystem.

To handle the scalability, resilience and performance requirement of IoT and edge applications, 3GPP specification 3GPP TS 23.501 [1] enlists some design principles for 5G core architecture – separation of control and user plane, modularity, minimal dependencies between AN and CN, stateless network functions, etc. These design principles push towards a cloud-native implementation for the 5G core, the 5G core network functions being implemented as Virtual Network Function (VNFs). ETSI standardized the classification of Cloud Native VNF implementations in ETSI GS NFV-EVE 011 [17]. It states the non-functional parameters for classification of cloud-native VNFs, e.g., resiliency, scaling, VNF design for location independence, use of containers, etc. With each parameter, it states the requirements of that parameter to be considered while designing the VNF as cloud-native. Taking an example, parameter "VNF design for location independence" states a requirement that the components of the cloud-native VNF shall be deployed independent of location if resource constraints (hardware acceleration capabilities) or placement constraints (affinity/anti-affinity rules) are met.

Massive deployment of virtualization technologies in the 5G networks signifies the need of service function chaining in mobile networks. IETF draft [39] discusses the kinds of service functions expected in 4G/5G networks. It also mentions the varied instantiation of 5G protocol stack – different instances can be physically located in different entities of the network based on requirements of the implemented service, the radio characteristics and the transport network capacity. For example, all the VNFs belonging to vehicular communications should be located close to the transmission point to ensure low latency. But the broadband access users can have their network functions in core network. This requires the concurrent execution of different instantiations of the 5G protocol stack on the same physical infrastructure. Service function chaining allows the deployment of different chains across such dynamic cloud infrastructure setups.

Acknowledging the importance of network slicing in 5G deployments handling the edge/IoT applications, ETSI dedicated a separate specification ETSI GR NFV-EVE 012 [18] identifying the changes needed in the NFV systems to support network slicing use cases. This specification mapped NFV and 3GPP network slicing concepts – 3GPP specification 3GPP TR 28.801 [12] states a network slice to be a concatenation of network slice subnets, each having one or more network functions. The ETSI specification ETSI GR NFV-EVE 012 [18] deciphers these network functions as VNFs or PNFs. Thus, NFV defined network service could be regarded as a resource-centric of a 3GPP network slice – each instance of a slice is basically a combination of one or more VNFs. The specification mentions the functional requirements for supporting Network Services over multi-site/multi Network Function Virtualization Infrastructure Point of Presence (NFVI-PoPs), to represent the network slice spanning multiple administrative domains. The specification also mentions the need for a functional interface between NFV Management and Orchestration (NFV-MANO) and Network Slice Management function (NSMF) to support resource orchestration of the network service supporting the network slice, in virtualized deployments. As per the IETF draft specification IETF draft-flinck-slicing-management-00 [19], NSMF is a part of Operational Support Systems / Business Support Systems (OSS/BSS) and sits above the NFV orchestrator (NFVO) of ETSI NFV framework architecture.

IV. MULTI-ACCESS EDGE COMPUTING (MEC) STANDARDIZATION UNDER ETSI

The core objective of Multi-access Edge Computing (MEC) is, to reap the IT cloud like benefits in telco environment, by providing cloud computing benefits within the radio access network. Close proximity to the user and receiving local radio-network contextual information aids in achieving extremely low latency, better QoE optimizations and efficient usage of the network bandwidth. ETSI has a dedicated ISG to develop standards around MEC, to create a standardized, open environment which will allow efficient and seamless integration of applications from vendors, service providers, and third-parties across multi-vendor MEC platforms.

The first relevant specification around this standard, ETSI GS MEC 002 [20] starts with some generic principles for MEC. It mentions the significance of aligning the MEC platforms with existing NFV platforms – MEC is expected to use a virtualization platform for running the user applications at the edge and NFV already provides such a virtualization platform. The specification also defines the MEC framework requirements (MEC system leveraging NFV and its interoperability with the 5G core network), requirements with respect to application lifecycle and its runtime environment, and service requirements in terms of platform services offered to the MEC applications.

A. MEC Service scenarios & Requirements

To support the new era of services in the operator's network, ETSI categorized the applications into three broad categories: consumer-oriented services, Operator and third party services, Network performance and QoE improvements. ETSI GS MEC 002 [20] enlists different use cases under each category and elaborates on the capabilities needed in the MEC system to support those use cases. Latest version of the specification has been augmented with interesting use cases, like 'Factories of the future', 'Flexible deployment with containers', 'Multi-RAT (Radio Access Technology) application computation offloading', etc. One new use case 'MEC System deployment in 5G environment', explores the requirements for interaction with the 5G core network, to support the applications running on a MEC system deployed in a 5G environment.

By providing service delivery at a closer proximity to the actual terminal devices MEC can significantly benefit the IoT applications. ETSI GS MEC-IEG 004 [21] introduces some service scenarios directly related to IoT. The scenario 'Assistance for intensive computation', mentions the use of MEC servers to perform high performance computations on behalf of remote devices – can improve the performance and battery life of low processing power devices/sensors in the IoT domain. The specification also mentions 'IoT gateway service scenario', where the MEC servers can be used to aggregate various IoT device messages connected through the mobile network close to the devices. This will provide an analytics processing capability closer to the devices and a low latency response time.

The use cases identified in ETSI GS MEC 002 [20] and service scenarios defined in ETSI GS MEC-IEG 004 [21] expect MEC to optimize the network and services, reduce latency, and support creating personalized and contextualized services. This requires the identification of metrics for these services/applications which can validate the optimization requirements promised by MEC. The specification ETSI GS MEC-IEG 006 [22] identifies several key performance indicators for these services and applications, based on the 5G service requirements defined by NGMN or 3GPP. Latency, energy efficiency, network throughput, system resource footprint and objective/subjective service dependent/independent quality metrics are the key metrics defined in this specification. It further elaborates on the measurement methodology of each metric – whether it should be computed in a standalone or an integrated environment, what measurement approaches can be taken, should it be done using a dedicated service monitoring tool or using common service monitoring, etc.

B. MEC Framework

Based on the framework requirements mentioned in ETSI GS MEC 002 [20], ETSI defined a framework and reference architecture in ETSI GS MEC 003 [3], which describes a MEC system that enables the MEC applications to run in a multi-access network. It starts with the MEC framework dividing the MEC system into different components - MEC system level management, MEC host level management and the MEC host (containing the MEC platform services, the virtualization infrastructure and the MEC applications running on it). The specification further identifies the different functional elements of each component and the reference points between them. It also mentions the platform services (radio network information, location, bandwidth management) provided by the MEC system. These services are essential to fulfil the use-cases driven requirements defined in ETSI GS MEC 002 [20]. The message flows and the data models for each service is defined in its respective specification - ETSI GS MEC 012 [24] for Radio Network Information service (RNIS), ETSI GS MEC 013 [25] for location service and ETSI GS MEC 015 [26] for Bandwidth Management service.

In continuation to ETSI GS MEC 002 [20] which highlights the need to align the MEC deployments with existing NFV infrastructures, the specifications ETSI GS MEC 003 [3] and ETSI GR MEC 017 [23] elaborate on the deployment of MEC in an NFV environment. This deployment instantiates the MEC applications and the existing/new NFV VNFs on the same virtualization infrastructure. MEC platform and the MEC applications are treated as VNFs and hence the existing ETSI NFV MANO components can be used for MEC management and orchestration. ETSI introduces a functional component, MEC Application Orchestrator (MEAO), responsible for management and orchestration of the MEC applications. MEAO uses a NFV orchestrator (NFVO) for orchestration of MEC application VNFs. Likewise, ETSI GS MEC 003 [3] and ETSI GR MEC 017 [23] define the new reference points for all such interactions between the MEC functional entities and existing NFV MANO components. ETSI GR MEC 017 [23] also identifies the key architectural issues in using a NFV environment for MEC deployments and suggests the normative work required to be performed in ETSI NFV ISG and ETSI MEC ISG to resolve these issues. For instance, using a network service to model Mobile Edge (ME) platform VNFs and ME app VNFs, the network service concept in NFV ISG might require re-work to support the association between each ME app VNF and associated ME platform VNF. This will require changes to the network service descriptor formats.

C. Lifecycle Management of MEC Applications

The specification ETSI GS MEC 010-2 [5] defines the complete lifecycle management of the MEC applications. It starts with the requirements on the reference points between the OSS, the Mobile edge orchestrator and the mobile edge platform manager. It then defines the message flows for application on-boarding, application instantiation and application termination. It defines the information model for application descriptors which includes the application requirement and rules. Based on these requirements and rules, the Mobile edge orchestrator can choose the optimal MEC host and then, the steering of traffic to this MEC host is triggered.

Though the mobile edge orchestrator can choose an optimal host based on the application descriptor, UE mobility in the underlying network might require a need to move the MEC application instance to a different ME host, to respect the optimality constraints. ETSI GR MEC 018 [8] signifies the need to support ME service continuity in such application mobility cases. The specification mentions the detailed message flow between the MEC functional entities for the application instance or application context re-location.

ETSI GR MEC 018 [8] also identifies some key issues in supporting ME mobility cases. For instance, MEC system needs to keep the connectivity between the UE App and the MEC application instance on the MEC host even after there is a change in the UE IP address since the UE is now served by a new UPF in the 5G network. To support this, ETSI GR MEC 018 [8] suggests passing the UE-ID and the UE IP address to the mobile edge platform during the application instantiation. Then, the mobile edge platform can use this UE ID to bind the application instance to the new IP context. Another issue that ETSI GR MEC 018 [8] highlights is the traffic steering to the target mobile edge host after application re-location. ETSI GR MEC 018 [8] indicates multiple options to trigger this traffic steering update. The source mobile edge platform might trigger this update towards the target edge platform based on radio network information it receives from the platform services or based on the trigger from mobile edge application orchestrator.

D. Upcoming initiatives

ETSI Work Programme portal [27] also mentions some in-progress specifications relevant to the MEC and IoT deployments. Work item 'DGR/MEC-0027ContainerStudy' explores the additional support needed in MEC for running applications in containers. Work item 'DGR/MEC-0024NWslicing' will work on support needed in MEC for network slicing. It will identify the new interfaces needed, the data models and changes needed in application descriptors, for the deployment of the MEC functions in combination with network slicing. Lastly, the work item 'DGS/MEC-0033IoTAPI' will define the APIs and the data models needed for device provisioning, configuration of the associated components and applications requiring connection to the IoT and MTC devices in a MEC environment.

V. OPEN INITIATIVES FOR 5G AND MEC AT 5G PPP

The 5G Infrastructure PPP (5G PPP) is a joint initiative between the European Commission and the European Information and Communication Technology (ICT) industry. Its initiatives are divided into three phases: research, deployment/optimization and large scale trials. It aims to deploy 5G around 2020. Phase 1 [28] included 19 projects targeting the research around technical challenges in the 5G deployments to cope up with future demands by year 2020. Some interesting projects of this phase were – 5GNORMA, SEASAME and SONATA.

5G NORMA (5G NOVEL RADIO MULTISERVICE ADAPTATIVE NETWORK ARCHITECTURE) [29] aims to develop a new mobile network architecture using SDN/NFV concepts, leading to flexible base stations, software-based centralized controllers and software-based RAN elements. The multi-service, multi-tenancy and context aware network functions developed by 5G NORMA will be resource efficient and enable dynamic sharing and distribution of network resources between operators.

SEASAME (Small Cell coordination for Multi-tenancy and Edge Services) [32] proposes the concept of Cloud-Enabled Small Cell (CESC), a new multi-operator enabled Small Cell - Light Data Center (Light DC) with low-power processors and hardware accelerators for time critical operations, used to build a highly manageable clustered Edge Computing infrastructure. It leverages logically isolated 'slices' to accommodate multiple operators under the same infrastructure, satisfying the profile and requirements of each operator separately.

Scope of SONATA (Service Programming and Orchestration for Virtualized Software Networks) [33] ranges from programmability of the networks to supporting service function chaining and orchestration. It aims to add a Software Development Kit (SDK) for service development, an orchestration framework and a DevOps model to integrate operators with external networks. Multi-access Edge Computing is one of the key cases focused in this project.

Phase 2 of 5G PPP [34] focused on the 5G architectures, pre-standardizations, applicability of SDN/NFV to Wired and Wireless Networks, including networking Clouds, IoT Services, etc. Some interesting projects of phase 2 are 5G ESSENCE, 5G-Transformer and MATILDA.

5G ESSENCE (Embedded Network Services for 5G Experiences) [35] is particularly focused on Edge Cloud computing and Small Cell-as-a-Service. It defines the interfaces for the provisioning of a cloud-integrated multi - tenant SC network and a programmable Radio Resources Management controller; development of the centralized SD-RAN (Software-Defined Radio Access Network) controller to program the radio resources usage in a unified way for all the CESCs (Cloud-Enabled Small Cells); development of orchestrator's enhancements for the distributed service management, etc.

5G-Transformer (5G Mobile Transport Platform for Verticals) [36] aims to transform the current mobile transport network into a SDN/NFV based Mobile Transport and Computing Platform (MTP). It particularly focuses on 'Network Slicing' paradigm in the mobile transport networks – it introduces a 'vertical slicer' for different verticals to request the creation of their respective transport slices. The project aims to demonstrate in verticals, like Automotive, eHealth and Media & Entertainment.

MATILDA [37] provides a framework for the design, development and orchestration of the 5G-ready applications and network services over sliced programmable infrastructure. It offers multi-site management of the Edge Computing and IoT resources using a multi -site virtualized infrastructure manager. It is particularly useful for Smart City Intelligent Lighting Systems, Remote Control and Monitoring of Automobile Electrical Systems, Industry 4.0 Smart Factory, etc.

Phase 3 of 5G PPP is focused towards Infrastructure projects, automotive projects and advanced 5G validation trials across multiple vertical industries. One interesting project in the phase 3 is 5G EVE (5G European Validation platform for Extensive trials) [38]. The 5G-EVE end-to-end facility, consisting of the interconnection of four 5G-site-facilities, will be used to conduct experiments with Mobile Edge Computing, backhaul, core/service technologies and means for site-interworking and multi-site/domain/technology slicing/orchestration.

VI. CONCLUSION

The 5G standardization process is complex due to its inter-dependence on other emerging technologies, such as Multi-access Edge Computing, Network Function Virtualization and Software Defined Networking. The diverse set of use-cases that the future networks will demand adds to the complexity due to the need for programmability of networks, network slicing and intelligent resource orchestration. Thus, there is a need for the various standardization bodies, as discussed in this paper, to work in close collaboration, to come up with exhaustive standards solving the challenges in future networks. While the scope of 3GPP Release 15 covers ‘standalone’ 5G, with a new radio system complemented by a next-generation core network, Release 16 would enhance the existing LTE and 5G RATs towards achieving the goals of IMT-2020.

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