Orchestration of Ultra-Dense 5G Networks

The Network Function Virtualization (NFV) transformation is gaining incredible momentum within mobile operators as one of the prominent solutions to improve the resource allocation and system scalability infuture fifth generation (5G) networks. The process of migrating proprietary hardware solutions to the NFV domain creates a complete new cycle of dynamic service management that can adapt in response to users' behavior and resource availability. Virtual hardware, denoted as virtual machines (VMs), are normally dependent on the underlying cloud hardware through thin software layer that abstracts virtual resources to NFV applications. In the current vision, 5G networks will adopt a distributed cloud architecture that supports local processing of users requests within mobile edge computing (MEC) data centers. In addition, the 5G core network (5GC) will be deployed as a virtual composition that can instantiate interfaces to various radio access network (RAN) technologies over the cloud. Small 5GC packages will also be deployed at local data centers to manage calls coordinated within a single network cluster. Software-defined networking (SDN) is another important cloud component that facilities traffic forwarding between virtual switches. To this end, the adoption of the NFV/SDN model implies a new innovative blueprint of network infrastructure leading towards a more automated, power efficient, and low cost mobile industry. In suchan environment, network adaptation events can include rerouting data, allocation of resources, instantiation of VMs, enforcing of certain policies, etc. These events are part of a business framework that defines use cases within software orchestrators that govern the life cycle managementfor all network state changes. Even in such native cloud models, the network performance remains dependent on two main factors: 1) achieving hyper automation of network end-to-end services and 2) efficient utilization of resources throughout network clouds. Considering automation, orchestrators should be able to manage all types of hypervisors within network clouds and communicate to other types of orchestrators at other operators clouds. From a resource perspective, scaling virtual resources with minimum dependency on hardware drivers enables advanced virtual operations such as elasticity, VM migration, and policy enforcement without being restricted by server operating systems. Therefore,orchestrators should be able to provisionvirtual layers and monitor physical hardware to ensure QoS guarantees and enable intelligent policy refinement considering key cloud platforms health indicators.

Massive network densification may lead to many orchestrated deployment scenarios that increase network complexity in heavilyloaded sliced network models. All these factors drive the radio and virtual computational resources to the edge of the network. Therefore, there is a strong need to articulate the integration of SDN/NFV in a hierarchical open architecture for networking and orchestration between different network clouds. Efficient orchestration facilitates chaining services to evolve network operations from operations driven to software driven administration with specific features that support 5G slices. This requires leveraging new automation models, interfaces, and open-source building blocks to achieve efficient adaptation, interoperability, and integration between different network segments. Orchestrating network operations in a programmable fashion laydown the roadmap for conceptual network in form of "Anything as a Service" (ANYaaS).

This feature topic on *Orchestration of Ultra-Dense 5G Networks* provides the research and industrial communities the opportunity to explore new research findings on ultra-dense networks employing NFV/SDN in their cloud-based architecture. The focus is on the use of virtual management and

orchestration features to drive the various network resources in response to the load changes at the RANand distributingtraffic between various cloud entities. This special issue has six articles that study various cloud challenges in5G ultra-dense networks and associatedvirtual components:

The first article “Slice Orchestration for Multi-Service Disaggregated Ultra Dense RANs” is written by Chia-Yu Chang, Navid Nikaein, Osama Arouk, Kostas Katsalis, Adlen Ksentini, Thierry Turletti, and Konstantinos Samdanis. The article studiespotential customization required forradio access network (RAN) deployments to support certain slice service considering user requirements. The goal is to support slice orchestration procedures when dedicated or shared between multiple slices over a common RAN. The features of orchestration and management and exposed to RAN modules through a number of new interfaces that set the logic for each slice. The authors investigate RAN runtimeto support slice-based multi-service chain creation and chain placement, with an auto-scalingmechanism to increase the performance.

The second article “5G-TRANSFORMER: Slicingand Orchestrating Transport Networks for Industry Verticals” is authored by Antonio de la Oliva, Xi Li, Xavier Costa-Perez, Carlos J. Bernardos, Philippe Bertin, Paola Iovanna, Thomas Deiss, Josep Mangues, Alain Mourad, Claudio Casetti, Jose Enrique Gonzalez, and Arturo Azcorra. The authors introduce a network slicing paradigm for next generation mobile transport networks to support vertical industries with a diverse rangeof networking and computing requirements. The proposed mechanisms allow provisioning and managing customized sliced networks considering vertical industries. The given solution combines three building blocks: vertical slicer, service orchestrator, and mobile transport and computing platform (MTP) to enable a federated, virtualized infrastructure throughout network segments.

The next article by Zhenyu Zhou, Junhao Feng, Chuntian Zhang, Zheng Chang, Yan Zhang, and Kazi Mohammed SaidulHuq, is titled “SAGECELL: Software-Defined Space-Air-Ground Integrated Moving Cells”. The article addresses the complexity and cost of deploying large number of small cells in ultra-dense networks. The authors introducethe softwaredefinedspace-air-ground integrated moving cells (SAGECELL) framework to integrate space, air, and ground resources for matching dynamic data traffic demands with network capacity. The proposed space-air-ground integrated resources appear as virtual small cells to different-tier SDN controllers. The virtualized space-air-ground resources are accessed by mobile virtual network operators (MVNPs) that provide services to their customers using all virtual small cells to improve resource utilization.

The fourth article is “Traffic Matching in 5G Ultra-dense Networks” by Yi Zhong, Xiaohu Ge, Howard H. Yang, Tao Han, and Qiang Li. The article provides a summary ofthe spatiotemporal arrivalproperties of different traffic in ultra-dense networks. The authors show the choice of technologies corresponding to different scenarios of spatiotemporal arrival properties. The article proposes a new approach by combining stochastic geometry and queueing theory to provide the conceptual groundwork for designing ultra-dense networks when traffic is spatiotemporally fluctuating. The model provided can be used to define polices that can be enforced by SDN in ultra-dense network deployments.

The next article is “On-demand Ultra-Dense Cloud Drone Networks: Opportunities, Challenges and Benefits” by Navuday Sharma, Maurizio Magarini, DushanthaNalin K. Jayakody, Vishal Sharma and Jun Li. The authors refer to the severe interference in ultra-dense networks and other complicated issues such as limited capacity due to the dense deployment of small cells, complexity of acquiring new locations for deploying new base stations, interworking with backhaul, energy consumption, etc. The article proposes

an ultra-dense cloud-drone network (UDCDN) architecture to provide “on-demand” quality and substantial flexibility of deployment. The authors highlighted the operational monitoring of the drone as a key component of UDCDN architectures. The mechanism invokes certain UDCDN features depending on slice functionality in an embedded virtual to physical network model.

In the last article, Ahmed AbdelazizAbdelltif, Ejaz Ahmed, Ang Tang Fong, Abdullah Gani, and Muhammad Imran, present “SDN-based Load Balancing Service for Cloud Servers”. The authors study the challenge of load balancing in cloud servers to meet the highly demanding requirements (e.g., data rates, latency, quality of service) of 5G network applications. The article presents SDN-based load balancing services (SBLB) for cloud servers to improvetraffic distribution and reducethe response time of various requests. The proposed scheme is anticipated to run as a plugin software module to the SDN controller. ThisSBLB module consists of many functionates service classification, dynamic load balancing and monitoring. During evaluations, the proposed SBLB reduced average response times up to 5% and reply times up to 3% compared to a contemporary scheme in using a homogeneous environment.

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