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# Interfacing 5G Orchestrators With Data Analytics Functions

During the past few years, research and standardization communities have worked collaboratively to develop a composable 5G network for a digitized, connected world of humans and machines. This has been evident in every segment of the new communication system, including the powerful and reachable air interface supported by New Radio, multiaccess edge computing (MEC), a new transport network featuring dense wavelength-division multiplexing, the service-based architecture of the 5G core network, end-to-end (E2E) network slicing, network function virtualization (NFV) and service automation, and so on. Using predefined policies, this software-driven network is tactical, restructures domains, and mobilizes resources in response to traffic changes. Therefore, the internal network interfaces, resources, functionality, and task assignment are dynamically adapted through main network orchestrators that govern all components either directly or through specific elements.

**_THIS TRANSFORMATION TOWARD A SELF-OPTIMIZED NETWORK MUST IMPLEMENT THE TOOLS REQUIRED FOR CAPTURING THE NETWORK STATUS._**

This transformation toward a self-optimized network must implement the tools required for capturing the network status and analyzing the necessary subsequent actions. Remarkably, 5G already implements those technical enablers through the management data analytics service (MDAS), which provides analytics counters of different network components by monitoring load levels and resource status. The acquired parameters are representative performance data for objects, network functions, network slices, and domains. Those key performance indicators (KPIs) are incorporated into the policy control function of that slice or service type to determine compliance with predefined rules. This analytical system facilitates balancing service and preventing any interruptions resulting from unexpected incoming loads or lack of sufficient processing resources.

The MDAS has all the necessary functions that can be deployed across network sites for real-time evaluation of the system status. However, the current analytics service is still limited to policy enforcement functionalities and will need to be interfaced with the NFV management and orchestration framework. This will enable orchestrators to access the telemetry services of both logic and physical systems to create a fully automated network that can devise its own resource management policies.

The performance promises of 5G motivated many of the technical advances that have been made during the past several years. However, there is still a long way ahead before operators evolve their infrastructure with various automation and self-evaluation capabilities across the network E2E. Therefore, operators will need to deploy testing tools that operate in a live network to verify the functionality and tolerance of system components. This process will need to be implemented for every individual software and hardware component to define resilience factors and refinement aspects. Moreover, embedding analytics will help engineering teams to specify the necessary solutions to resolve any 5G defects and define the initiatives for beyond-5G networks.

Included in this issue of *IEEE Vehicular Technology Magazine* is the sixth installment of the "IEEE Future Networks" series. The series focuses on different technical areas that help research and industrial communities gain a better understanding of the state-of-the-art and performance assessments of 5G communications. This special issue features eight articles that

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address various network segments and technologies.

The first is “Advanced Wireless for Unmanned Aerial Systems: 5G Standardization, Research Challenges, and the AERPAW Architecture” by Vuk Marojevic et al. It provides an interesting survey of standardization projects that address the integration of unmanned aerial systems (UASs) into 5G and the requirements for an aerial wireless testbed. The authors share their experience with an aerial experimentation and research platform for an advanced wireless architecture to support UAS communications investigation and standards development. The article contains various use cases and technical features of UAS platforms, including experimental trials that show the radio frequency signals captured from UASs under realistic flight conditions.

The second article, by Ming Zeng et al., is “Massive MIMO-Assisted Mobile Edge Computing: Exciting Possibilities for Computation Offloading.” The authors propose bringing massive multiple-input, multiple-output (MIMO) and mobile EC (MEC) closer to reduce the operational delay acquired when exchanging signals between distant components. They also show that employing more antennas at the access point will reduce delays and energy consumption for connected users. The article concludes that joint wireless and computational resource allocations are the key pillars to enhance massive MIMO-assisted MEC systems.

In the next article, “CubeSat-Based 5G Cloud Radio Access Networks: A Novel Paradigm for On-Demand Anytime/Anywhere Connectivity,” Riccardo Bassoli et al. address a cloud radio access network (RAN) system that splits virtualized baseband processing units between mobile base stations and CubeSats (low-cost satellites). The authors show a provisioning of such a complex system that consists of three main layers:

**THE PERFORMANCE PROMISES OF 5G MOTIVATED MANY OF THE TECHNICAL ADVANCES THAT HAVE BEEN MADE DURING THE PAST SEVERAL YEARS.**

1) the terrestrial layer that includes all end users
2) the aerial layer that hosts mobile base stations
3) a satellite-based layer where small satellites or drones provide computing resources to enable the virtualization of RAN functions.

The fourth article, “Realizing the Network Service Federation Vision: Enabling Automated Multidomain Orchestration of Network Services” by Jorge Baranda Hortigüela et al., explores an NFV/software-defined network architecture, in which the authors use the 5G-Transformer service orchestrator to manage E2E deployment of composite NFV network services. The article shows the orchestrator workflows employed to create functions across multiple administrative domains (referred to as *network service federation*). The article details the architectural designs of the studied orchestrator and includes a performance analysis of the time consumed for various service deployments.

In the next article, “5G Wireless Security and Privacy: Architecture and Flexible Mechanisms,” Dongfeng Fang and Yi Qian provide a new security architecture for 5G that consists of multiple tiers of security for network access, the network domain, the user domain, and the application domain. Each of the security domains is associated with a network segment for flexible security and privacy mechanism support. The article also discusses a flexible security mechanism dedicated to Internet of Things applications, and the authors provide performance analyses that demonstrate the superiority of the given frameworks compared with baseline solutions.

The sixth article, “Energy Efficiency of Multiple-Input, Multiple-Output Architectures: Future 60-GHz Applications” by Steve Blandino et al., studies the energy efficiency of three different system architectures using power consumption measurements from a 60-GHz CMOS transceiver. The authors evaluate system throughput performance through hardware nonidealities, including power amplifier saturation, quantization, and phase noise variances. The obtained analysis enables the authors to provide certain recommendations for a millimeter-wave system architecture that achieves the highest energy efficiency.

The next article is “Predictive Voice-Over-Internet Protocol Fallback Over Vehicular Channels: Employing Artificial Intelligence at the Edge of 5G Networks” by Marco Centenaro et al. Here, the authors propose a mechanism that couples the 5G network exposure function (NEF) and MEC capabilities to predict the performance deprivation of voice-over-IP calls. The authors show that the user context is associated with the serving cell. This means that cell-specific user context can be obtained from control plane information exposed by the NEF. This information is then used to reconstruct the topology of the serving cell to provide a better experience to the user. The authors also provide an interesting analysis to demonstrate the performance of their proposed scheme.

The last article, “Effective Indoor Coverage via Radio-Over-Cable Fronthauls: Analog Fronthauls Come of Age” by Syed Hassan Raza Naqvi et al., investigates a radio-over-cable (RoC)-based analog link on a local area network cable (e.g., category 5) to connect the fronthaul with an indoor access point. The article

***MDAS PROVIDES ANALYTICS COUNTERS FOR DIFFERENT NETWORK COMPONENTS BY MONITORING LOAD LEVELS AND RESOURCE STATUS.***

provides a systematic view of the state of the art for RoC and its deployment challenges. The authors further propose a nonconfigurable distributed antenna unit with a related resource mapping scheme and nonconfigurable air-to-cable to achieve higher throughput and low power consumption for large-scale deployments. The simulation results demonstrate that the proposed RoC meets the 5G KPIs of peak data rate, peak spectrum efficiency, and latency.


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# Communication Support for Unmanned Air Transportation

During the past few years, unmanned air transportation has come to the forefront of aviation research. Aviation authorities around the world have been making progress toward integrating drones or unmanned aerial vehicles (UAVs) or unmanned aircraft systems (UAS) into their national airspaces. In parallel, private industry has been developing innovative applications such as transportation of people and goods, medicine delivery, pipeline monitoring systems, and disaster-area aerial surveys. Projects such as UAS traffic management (UTM) and urban air mobility demonstrate the industry's great enthusiasm for unmanned air transportation. Before unmanned air transportation becomes a reality, there is a need to improve the reliability and security of UAV communications, as they impact human safety.

Communication support for unmanned air transportation comes from three levels:

1) satellites operating at the geostationary and low-Earth-orbit levels
2) dedicated ground stations or 4G/5G cellular networks operating on the ground
3) ad hoc aerial networks operating in midair.

Today, with the support of a constellation of communication satellites, minute-by-minute global tracking of


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