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Network Applications Software for Vertical IoT Industry

Network Applications is defined as a set of services that provide certain functionalities to the verticals and their associated use cases. In practice, this software piece consumes the exposed Application Programmable Interfaces (APIs) from the network, e.g., northbound APIs of 5G core network and RAN Intelligent Controller (RIC), and edge computing APIs. Considering the levels of interaction and trust, Network Applications can either be integrated with (a part of) vertical application or exposes its APIs (e.g., service APIs) to be further consumed by vertical applications. In short, Network Applications could be viewed as a separate middleware layer, which is contributed by both network operators and third parties, to simplify the vertical system deployments on a large scale and extend to vertical IoT industries.

Moreover, thanks to Network Applications, effort to migrate verticals' software-based systems is greatly reduced. This allows them to focus on value-added services and deepen their business into the IoT industry. Nevertheless, as we move forward to 5G-Advanced and 6G eras, the communication fabric and the way network services are consumed are re-architected by leveraging essential technologies such as cloud-native, software-led, low-touch operations, and ultimate automation (both the network and the services it delivers). Therefore, to provide network services suitable for vertical needs, the high flexibility in B5G/6G should be included when introducing Network Applications in the vertical IoT industry.

In addition, Network Applications is key to enabling data-driven decision making for vertical applications, especially for scaled IoT deployment. Specifically, it affects both the collected data characteristics and the decision enforcement limitations. Therefore, on top of Network Applications, adequate Artificial Intelligence (AI) algorithms and Machine Learning (ML) models are selected, based on the trade-offs among the control timescale, algorithm optimality, and solution robustness. To validate Network Applications capability for practical vertical tasks, new experimentation facilities are required to offer integrated, programmable, and fully featured networking platforms. To this end, another key to rollout Network Applications in different verticals is to utilize an experimental facility to represent a redesigned networking environment focused on operational innovation and secure/trusted service provisioning for verticals.

To harmonize the vision brought by Network Applications and new service architecture framework, several industry forums (e.g., 5G-ACIA [1], 5GAA [2], 5G America [3], 5G-IA [4]) and standardization bodies (e.g., 3GPP [5]) have consolidated the requirements to flexibly deploy services across network domains by interacting with the deployed Network Applications. Also, a white paper published by the 5G-PPP Software Network working group [6] investigates different API types and different levels of trust between the verticals and the platform owners, indicating Network Application implementations in several verticals.

Take one Network Applications called FIre DEtection and Ground Assistance using Drones (FIDEGAD)[1] as an example, it is onboarded to an aerial drone together with the services on the edge computing platform to ensure low latency for emergency response teams to conduct the first assessment. Telemetry, along with information from infrared sensors, speakers,

conventional video, and thermal vision, are transmitted to the 5G system using particular network slice, and from there to the teams on the ground. This Network Applications consumes the exposed APIs in edge computing, 5G core network, and end devices, not only for handling live streaming and processing, but also for adjusting the height of the flyover according to the flame height. Therefore, Network Applications can enrich new vertical applications, and ultimately, we expect that it can penetrate existing verticals and fertilize vertical IoT solutions.

This Special Issue (SI) focuses on cutting-edge research and innovation in Network Application, and six articles are specifically selected. They cover the conducted Network Application implementations for Industry 4.0 and automotive verticals, the recent advancement in the standardization bodies on Network Application, the orchestration system for an automated programmable factory floor, and the Network Application experimental facilities for wireless Time-Sensitive Networking (TSN) and 5G networks.

In "Edge Computational Offloading for Corrosion Inspection in Industry 4.0," Mohamed *et al.* present an edge computational offloading system to meet the requirements for corrosion inspection. The presented Network Application using AI-based solution provides high performance in inspecting corrosion for critical infrastructures. A prototype over an Unmanned Aerial Vehicle (UAV) connected to a 5G network testbed is verified with the significant benefits of computational offloading capability as well as the corrosion identification processing time. These results validate the performance benefits of Network Application and identify a cost-efficient and scalable solution for the vertical IoT industry.

In "Enabling Far-Edge Intelligent Services with Network Applications: the Automotive Case," Konstantinos *et al.* introduces the 5G-IANA Network Application platform supporting AI and ML-enabled automotive services. In particular, it offers service providers the ability to wrap all data manipulation within Network Applications for further reuse, the exposed Network Application Package construct to allow them to describe their services, and the capability of interfacing far-edge nodes (i.e., road-side and on-board units) for distributed ML. Specifically, the remote driving use case is described using three Network Applications: Training, Inference, and Remote driving. This article presents the benefits of flexibility and forward compatibility for Network Applications.

In "NetApps Enabling Application-Layer Analytics for Vertical IoT industry," Emmanouil *et al.* review the service enablement framework specified by 3GPP and others, and discuss different categories of Network Applications. Moreover, the recent 3GPP standardization status of the Application Data Analytics Enablement Service (ADAES) and its functional model are elaborated, which provide application-layer analytics service tailored to vertical needs. In addition, a prototype design based on the ADAES through two Network Applications (i.e., ADAES and data collector) is presented, which enables vertical clients to select the best server instance, using the predefined ML models for performance predictions. Based on this work, new potentials of Network Applications, like cross-domain AI-enabled analytic, are foreseen.

In "SLA-Driven Software Orchestration in Industry 4.0," Marco *et al.* focus on one challenge for an automated programmable factory floor considering the potential Service Level Agreement (SLA) violations in the orchestration system. This is the key to ensuring that Network Applications framework can fulfill vertical needs for flexible manufacturing, whereas current systems cannot guarantee programmable industrial SLA. In this regard, an orchestration approach is provided considering different SLA criticality levels and the SLA-aware adaptive mitigation strategies are defined as reactions to the detected and predicted SLA violations. This article provides design principles for Network Applications when facing SLA violations.

In "The Quality-Aware and Vertical-Tailored Management of Wireless Time-Sensitive Networks," Gilson *et al.* introduce a TSN controller Network Application to satisfy diverse vertical application needs by offering the requested Quality of Service (QoS). It is built on top of the controller-agent architecture and provides an interface for verticals to request resources. Such a Network Application is demonstrated by exploring the openwifi TSN extensions to perform traffic management for wireless clients and its scalability is shown even being operated with more than hundreds of network nodes. Based on this, the Network Applications can be further deployed in a scaled vertical IoT environment.

In "A 5G Facility for Trialing and Testing Vertical Services and Applications," Sagar *et al.* present the EURECOM 5G facility, in particular to verify the capability of Network Applications to support vertical requirements. Relying mainly on open-source components, it is designed to run vertical use cases by abstracting and simplifying the trial deployment and Key Performance Indicators (KPIs) collection, and provides a web portal for better usability. The authors demonstrate its performance from the vertical point of view to deploy different configurations of network services: at the edge cloud, at the far edge, and a mission critical service application on the facility. The introduced facility can serve vertical-centric trials in 5G to accelerate the adaptation of Network Applications.

In summary, this SI contains six peer-reviewed articles on several aspects of Network Applications, including network architecture, standardization activities, experimental facilities, and prototype implementations. Through these articles, we expect to lay a solid groundwork for research and innovation in Network Applications to offer network services with high flexibility tailored to the vertical needs.

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Biographies

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FOOTNOTES

[1] R. Sušnik *et al.*, "D4.3 Initial Design of NetApps in the Automotive and PPDR Verticals," *Zenodo*, Dec. 2022. DOI: 10.5281/zenodo.7418118.