Zero-touch Service Management for 6G verticals: Smart Traffic Management Case Study

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***Abstract*—The diversity of Beyond 5G (B5G)/Sixth-Generation (6G) technologies and the increasing density of Internet-of-Things (IoT) clients, are pushing the traditional MANagement and Orchestration (MANO) into more complex scenarios. The European Telecommunications Standards Institute (ETSI) Industry Specification Group (ISG) Zero-touch Network and Service Management (ZSM) has published several documents that presents ZSM as a visionary concept, which promises to deliver benefits for B5G and 6G networks, such as increased efficiency in MANO and for tackling the challenges and limitations endured in the transition from human-intervention assisted network management to a fully autonomous network management. This work-in-progress paper provides insights into the recent trends in defining and developing ZSM, the efforts towards standardization of its guidelines, coverage of existing solutions that applies the ZSM principles, a discussion about the imperative of its adoption in the domains of the evolving mobile generations and a proposal for its application in a vehicular use case of Smart Traffic Management (STM), where B5G/6G applications are enhanced by a robust ZSM capability of edge resources, to improve the effectiveness of intelligent traffic management.**

***Index Terms*—zero-touch service management, smart traffic management, 6G verticals, orchestration, smart cities**

I. Introduction

The increasing heterogeneity and density of Beyond 5G (B5G)/Sixth-Generation (6G) network technologies and Internet-of-Things (IoT) devices are continuously adding complexity to network and service management. It is a challenging task for MANagement and Orchestration (MANO) operations to match the speed of the constant evolution of vertical applications and their requirements [1]. The demand for new business-oriented services in the B5G networks is growing along with the need for more agile use and configuration of Network Slicing (NS), Network Function Virtualization (NFV) and Multi-Access Edge Computing (MEC). These technologies enable the creation of customized network slices for different vertical industries (automotive, ehealth, transport & logistics) that require high performance, reliability and security like smart city management and other innovative applications that demand low latency, high bandwidth and dynamic resource allocation.

Zero-touch Network and Service Management (ZSM) aims to automate the management of 6G network services based on service-level policies and rules to improve service performance [2]. By applying ZSM, network operators can efficiently control network resources and enhance network performance. ZSM also enables an autonomous network system that can self-monitor, self-heal, and self-optimize its operations. These capabilities provide great benefits to the B5G and 6G paradigms with minimal latency during real-time operations, improve performance, high reliability, seamless connection and mobility support. They rely on the following technologies that enable network programmability: Software Defined Networking (SDN), NFV, MEC, NS, with the aim to fulfill the need of efficient End-to-End (E2E) automated network systems.

An important aspect in smart cities is traffic management, taking into account that these cities are usually identified by their high density of road users and vehicles. A common issue in many large cities with high population density and insufficient infrastructure is traffic congestion [3]. This problem has multiple causes and impacts on the road as it stems from low-quality public transportation and the lack of effective traffic management.

In this work-in-progress paper we describe how ZSM contributes to the B5G technologies, specifically Smart Traffic Management as part of the 6G vertical services, in a use case for Smart Traffic Management from the TrialsNet project. To navigate through these topics, we present the ZSM principles provided by the European Telecommunications Standards Institute (ETSI) ZSM Group and how they are represented in a reference architecture for network management. Following that, a review about the existing practical works that implement ZSM techniques and the feasibility of their application in the TrialsNet project, taking the potential advantages of ZSM for the benefit of the B5G and 6G technologies. Then, a description of the Smart Traffic Management Use Case and how the ZSM techniques are going to be adopted in a proposed Vertical Application Layer (VAL) framework based on a Service Enabler Architecture Layer for Verticals (SEAL) architecture for the network services and management. Finally, a discussion of the challenges and limitations that the design and implementation of ZSM techniques have to face.

II. Zero-touch Management architecture reference

One of the key goals of ZSM is to enable automated network management across different vendors and domains. To achieve this, a common interface is needed for data analytics and closed-loop control components. This interface facilitates the creation, execution, and governance of single or multiple closed-loops within end-to-end networks and supports the adoption of ZSM by the Mobile Network Operators (MNOs).

The ETSI introduced the ZSM Industry Specification Group (ISG) in 2017. This group is dedicated to the design of a framework for network automation based on Zero-touch Management (ZTM) principles, such as the specification of solutions for the orchestration and automation of network resources allocation [4].

The design of the ZSM architecture reference shown in Fig. 1 supports open interfaces, model-driven services and resource abstraction to provide modularity, flexibility, scalability and extensibility. In this figure we illustrate the general structure proposed in the principles of ZSM [5], where the domains are defined and managed by an E2E Service Management Domain. This figure displays the composition of one single

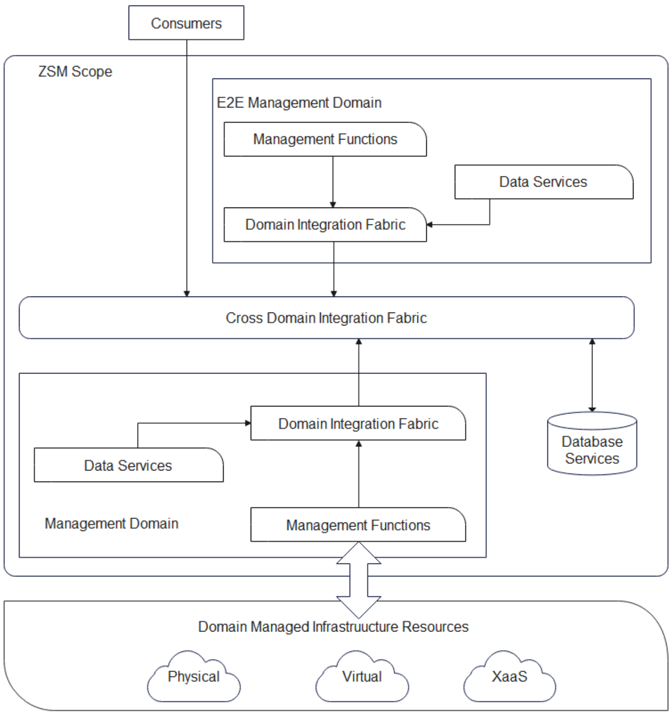

Fig. 1: ZSM architecture high-level overview reference

Management Domain as a templated pattern to be followed in each Management Domain withing the architecture of ZSM.

One of the core ideas from the ZSM principles is the separation of concerns. This means that each management domain should be defined by clear boundaries around administrative, geographical, or technological factors [1]. Each of these management domains are structured into the following blocks as seen in Fig. 1:

- *Management Functions:* to provide capabilities through the exposition/consumption of endpoints,
- *Data Services:* to enable the integration of authorized data management across domains for persistence and sharing data,
- *Domain Integration Fabric:* to expose and control the management services beyond their domain boundaries.

Furthermore, a Cross-domain Integration Fabric is another component of the ZSM framework that plays the roles of both service consumer and service producer. Its function is to facilitate the communication between management functions within and across management domains [4]. One of the features of the ETSI ZSM framework is that it enables various data analytics services for different management domains, both single and end-to-end.

III. ZSM & Smart Traffic Management (STM) Use Case

A. *TrialsNet: Use Case of Smart Traffic Management*

The main challenges for urban traffic management are to ensure the smooth and safe flow of traffic, especially with the growing number of vehicles and new modes of transportation such as self-driving and micro-mobility vehicles. To achieve this, B5G technology can provide faster and more reliable data transmission at higher rates, which is essential for real-time traffic surveillance for safety functions. This can be achieved by using specific sensors such as Light Detection and Ranging (LiDAR) to observe, detect and classify the traffic participants and understand traffic situations via Artificial Intelligence and Machine Learning (AI/ML) techniques.

The TrialsNet project[1] designs and performs large-scale trials to implement a heterogenous and comprehensive set of innovative Fifth-Generation (5G)/6G applications. These applications are also facing the challenges of i) high data volume that increases their computing demand, but also ii) time sensitivity in terms of the overall communication and data processing, which require Ultra-Reliable Low-Latency Communication (URLLC). To cope with this limitation, the AI/ML algorithms are executed on the MEC for applications that need fast response times, and on the cloud for services that do not have strict latency constraints.

The trials cover the relevant domain of the urban ecosystems in Europe identified by Infrastructure, Transportation, Security & Safety. The following use case explores the usage and applications of B5G (towards 6G) networks to optimize traffic flow and prevent accidents in a busy intersection in Iasi, Romania. It also shows how to leverage B5G capabilities for environmental sensing and emergency response.

The STM use case aims to optimize the usage of available network and computing resources to improve the safety of Vulnerable Road User (VRU) and ensure city resilience. To accomplish this, the use case involves the design and deployment of tools that enable a tight interaction between humans and the surrounding environments such as IoT sensors, Computer Vision and Cameras deployed through the city. These devices communicate over reliable B5G and Wi-Fi networks, providing relevant data for intelligence on Traffic Monitoring. They are integrated and managed by the Edge resources capabilities that are supported by the B5G/6G applications in large-scale environments.

A fundamental goal of the use case is to predict hazardous traffic situations based on techniques such as predictive models and sugestions of intersection rules. Due to the time sensitivity of the functions that will process the data and generate the predictions, they will be placed closer to the end users through Edge Network Applications (EdgeApps). These applications are programmable, modular and configurable, and they provide abstractions from the complex infrastructure of 5G and Wi-Fi, to address specific services requirements such as collecting data from distributed sensors or sending prioritized notifications to VRUs.

B. *Existing Solutions for ZSM approaches*

Despite the short life of the ETSI ZSM group, an increasing number of works have been carried out based on the principles described in the published technical reports. These works have focused on both theoretical and practical contributions, with solutions developed by innovative projects that have been able to demonstrate the application and feasibility of ZSM in comparison with traditional MANOs.

The efforts dedicated to materializing the references provided by the ETSI for ZSM can be grouped into the categories described in Table I [2].

Relevant works were selected as practical solutions that have provided tangible results for the implementation of ZSM:

- **Proposal of an AI-based framework for allocating network resources [6]:** This work is focused on the

[1]TrialsNet: https://trialsnet.eu/deliverables/

TABLE I: Reviewed works based on ZSM principles

Category	Contributions
General review on ZSM for B5G networks	6
Automation and Autonomy on network management	6
Practical accomplishment of cross-domain E2E services	6
Security measures and possible threats on ZSM	9
Standardization development projects	6

allocation of network resources. Its proposals are based on Artificial Intelligence (AI) techniques that aim to achieve the ZSM principles of self-healing, self-optimization and self-configuration. This work demonstrates that the AI-based resource allocation achieves better scaling and resource efficiency than conventional methods.

- **Zero-touch coordination framework [7]:** This is practical work that applies optimization techniques based on AI/ML algorithms to improve the coordination among self-organized network functions. The paper demonstrates that the proposed method outperforms manual provisioning methods for a realistic IoT environment.
- **Parallelization/distributed computing component in ZSM architecture [8]:** To address the challenges of processing large amounts of data in real time in ZSM implementations, the Fiaidhi and Mohammed [8] propose a technical solution that leverages graphical processing units Graphic Processing Units (GPUs) for deep learning applications. GPUs can accelerate the training and inference of deep neural networks. This approach aims to reduce the computational complexity of the deep learning models.
- **Toward ZSM and Orchestration of Massive Deployment of Network Slices in 6G [9]:** This work complies both ZSM and Experiential Networking Intelligence (ENI) to reach their goals within the same architecture. It provides a decentralized management framework that copes with the massive number of dynamic slices in 5G/6G scenarios. It improves the scalability and reaction times of self-management and self-configuration of network slices by applying ZSM in a hierarchical closed-control loop.
- **A case of automated Cloud-Radio Access Network (RAN) deployments towards 6G zero touch networks [10]:** This is a proposed Zero-touch Commissioning (ZTC) model that performs resource discovery while looking for both antennas and computing capacity as near as possible to the targeted coverage zone. It can automatically instantiate a Cloud-RAN chain and start the network service on Kubernetes-based infrastructures without human intervention.

In the field of AI-driven approaches for ZSM architecture, other practical approaches can be seen in existing implementations from real life use cases in these projects [2]: Projects in the field of ZSM (5G phase I & II)

- **SELFNET[2]:** Focuses on 5G network management, with the main objective of developing an efficient self-organizing network management framework for 5G through the combination of a virtualized and software defined network infrastructure with artificial intelligence technologies
- **CogNet[3]:** Focuses on applying Machine Learning (ML) research to these domains to enable the level of Network Management technology required to fulfil the 5G vision. We believe that Autonomic Network Management based on ML will be a key technology enabling an (almost) self administering and self managing network.
- **SLICENET[4]:** Implements on a Smart City use case to define a 5G network slicing architecture for Smart Lighting application, such as metering solution (gas, energy, water), real-time traffic information and control, city or building lights management and public safety alerts for improved emergency response times.
- **DESIRE6G[5]:** Aims to design and develop a novel zero-touch control, management, and orchestration platform, with native integration of AI, to support eXtreme URLLC application requirements over a performant, measurable and programable data plane. This is a recent project that promises to demonstrate a new wireless communication system that will provide near real-time autonomic networking.

C. ZSM application in the Smart Traffic Management Use Case

This use case covers the design, development and deployment of tools that implement the guidelines for STM by the support of the 6G-applications in large-scale environment. This approach involves the use of IoT Sensors, Computer Vision, LiDAR Enhanced Vision, On-Demand Intelligent and Autonomous Drones Surveillance and Cameras, deployed above the ZSM capability of EDGE resources within B5G networks. These efforts are headed to the enhancement the interaction between humans and the surrounding environments.

The data collected from the network in real-time are used in the MANO for performing continuous analysis of the network for troubleshooting, network planning and optimization. The measurement of network infrastructure provides the detection of anomalies, in order to improve the performance of the MANO operations. ZSM complements the management of NFV performed by MANO during the automation of the management of network services.

The evolution of the AI/ML techniques have reached a mature point to provide solutions for tackling the limitations of traditional MANO operations of managing complex and heterogeneous networks, thanks to their capacity for dealing with optimization and decision-making processes. That is the reason why they are integrated into a closed-loop framework for the realization of a fully autonomous NFV MANO. Nevertheless, multiple ML models have to be applied for each MANO operation because of the dense and diverse presence of the services that are provided to vertical industries in B5G systems.

AI/ML techniques in automating MANO operations, are selected depending on their suitability for supporting Zero-touch Service (ZTS) in specific tasks such as resource allocation and mobility pattern recognition. This integration contributes to NFV in the selection of MANO procedures.

The Closed-loop framework for NFV MANO in B5G systems defines the following phases [11]:

- **Data collection and pre-processing:** data is collected from various sources, and then pre-processed and shared with the Zero-touch that apply corresponding AI/ML techniques.

[2]SELFNET: https://5g-ppp.eu/selfnet/
[3]CogNet: https://5g-ppp.eu/cognet/
[4]SLICENET: https://5g-ppp.eu/slicenet/
[5]DESIRE6G: https://desire6g.eu/

- **Zero-touch services:** relevant data is selected and predictions and/or decisions are made to improve the operations of the orchestrators such as optimizing network resource allocation.
- **Decision-making for MANO operations:** instantiation/scaling/migration/termination is performed based on the decisions provided by a group of Zero-touch services. For service scaling, the decision relies on the outputs from learning resource utilization pattern and the infrastructure resource analysis, then the decision is adjusted to a specific service class that was previously identified by the Zero-touch service in charge the MEC vertical services classification.
- **Executing AI-enhanced MANO operations:** decisions made by orchestrators and re-configure service deployments are applied. The ZSM implementation in the TrialsNet project will include several 6G ZTSs, in order to provide the closed-loop framework for the enhancement of the STM services operations at the network edge.

The Use Case presents how a robust ZSM approach for edge services can boost the effectiveness of STM, while designing the applications following the lines proposed in the framework. The application of ZSM methods is easier due to their simplicity and tight coupling with the 3rd Generation Partnership Project (3GPP) systems.

IV. Challenges and Limitations

Despite the development of NFV, SDN, MEC and NS, these technologies alone are not enough to achieve the desired level of automation, as they still require manual processes for configuration, orchestration and monitoring [12].

The challenges for the standardization regarding ZSM lie in the complexity of reaching consensus in a heterogeneous and competitive environment of suppliers and technologies [13]. Additionally, it is also challenging to keep up with the demand of the exponentially increasing number of new IoT devices.

Most of the reviewed papers are primarily focused in the use of AI, i.e. for resource allocation, its limitations and risks. However, these works do not delve into important aspects of ZSM. The integration of topics related to network management with ZSM still presents limitations when it comes to broadly covering ZSM applications in the field of wireless network management.

As ZSM relies on AI and Big Data Analytics to provide secure and resilient network operations and services in B5G networks, these technologies may also introduce new security threats or vulnerabilities, such as data breaches, model tampering, or spoofing attacks. Privacy concerns are commonly associated with the inherent presence of AI in the 6G network architecture [1].

To face the challenge of processing large volumes of data for a network that is designed to be autonomous, learning transfer techniques have proven to suit better these conditions [2]. This approach allows ZSM-based network management systems to balance the processing demand by reusing the previously processed information. This is also a progressive way of acquiring knowledge and leveling the capacity of to deal with the demand at the same time, as the implemented solutions progressively gain autonomy and robustness over time, eliminating the human intervention eventually.

V. Conclusion

In this work-in-progress paper, we have presented the main principles and the reference architecture of ZSM, as well as its potential applications such as various domains. We have focused on the STM case study of the TrialsNet project, which aims to demonstrate the effectiveness and benefits of ZSM for 6G-enabled systems for STM. Finally, a resume is exposed about the main challenges and limitations faced by ZSM to achieve its vision of full automation of network and service management and operation.

VI. Acknowledgement

This work has been performed within the European Union's Horizon 2022 project: TrialsNet (Grant Agreement No. 101095871).

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