Enabling efficient resource allocation for applications in vehicular systems using Zero-touch management for Smart Mobility

Orin Claeys*, Raul Cuervo*†, Nina Slamnik-Kriještorac*† and Johann Marquez-Barja*†
*Faculty of Applied Engineering - Department of Electronics-ICT
University of Antwerp, Antwerp, Belgium
†IDLab imec
Antwerp, Belgium

***Abstract*—Future applications such as vehicular applications require higher Quality of Service (QoS) standards than current applications do as they require ultra-low latency function properly. For future mobile networks to support these applications and deal with the ever-growing number of connected devices, network operators will have to develop new Management and Orchestration (MANO) techniques to facilitate these QoS. Zero-Touch Service Management (ZSM) offers a solution for the new MANO techniques by stepping away from manual MANO towards fully automated MANO. In this paper, we discuss how vehicular applications such as collision avoidance can benefit from the deployment of ZSM. We also present the creation of Artificial Intelligence (AI) supported network intelligence for efficient resource allocation. In this way, network operators can offer the ultra-low latency requirements for collision avoidance to exist in the most cost-efficient way. To make the deployment of ZSM possible, real-life Proof of Concepts (PoCs) are necessary to illustrate the benefits of AI supported network intelligence. The data gathered from these PoCs can be used to further develop the Deep Reinforcement Learning (DRL) models used in the network intelligence.**

***Index Terms*—zero-touch service management, testbed, Smart Highway, orchestration**

I. Zero-touch management: State of the Art

New mobile networks such as Beyond 5G (B5G) or 6th Generation (6G) promise to increase the Quality of Service (QoS), offering new services such as neXt generation Ultra-Reliable Low-Latency Communication (XURLLC). Future applications such as extended reality or autonomous vehicles also require this quality of service to operate seamlessly. However, according to Coronado et all. current Management and Orchestration (MANO) solutions are already struggling to deal with the growing network complexity and service the ever-growing number of devices with high standard QoS. Therefore, Coronado et all. see industry stepping away from manual MANO solutions towards fully automated, zero-touch MANO. These new MANO solutions require network intelligence to be embedded into the automated system. Different methods are possible to implement them, such as policy-based automation or intent-based automation. However, using Artificial Intelligence (AI) techniques such as Machine Learning (ML) seems to be the most promising solution [1] [2].

The main goal of Zero-Touch Service Management (ZSM) is to create networks that are capable of self-healing, self-configuration, self-monitoring and self-optimization without human intervention. To help facilitate and organize the development of ZSM techniques, the European Telecommunications Standards Institute (ETSI) founded a new Industry Specification Group (ISG) in 2017. The group is aimed at defining the requirements and architecture of a network automation framework based on ZSM concepts. [1]

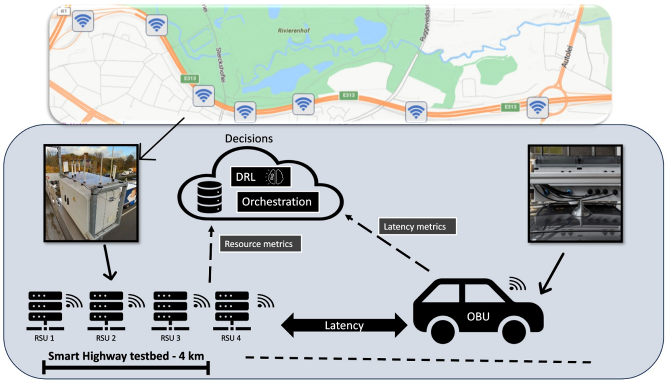

Fig. 1. Illustration of the Smart Highway [3].

The implementation of AI techniques into ZSM also has its challenges. One of these challenges is the lack of datasets for 5G and beyond networks. This is especially the case for networks used to support future applications such as vehicular applications. Techniques such as Deep Learning (DL) can resolve complex problems with great accuracy but require a long training time and a lot of computational resources. This can create problems for systems to provide fast real-time operations with low latency. [1] [2]

II. ZSM for vehicular applications

Modern vehicles consist of more and more sensors and computing capabilities. At the same time, the cost of these additional components has become cheaper. This opens the possibility for more advanced applications which also increase the demand for computing and network resources. These new applications include onboard infotainment or collision avoidance services and can become omnipresent in transportation.

They will depend on the performance of mobile networks such as B5G or 6G to support their existence. They require a QoS from the network that is higher than what current applications need. To make sure that future mobile networks can support these high requirements, ensuring the seamless operation of these applications, ZSM can play an important role.

In the context of Smart Traffic Management, critical services are enabled by efficient vehicular communication to support traffic coordination and provide important features such as collision avoidance. In this way, these services contribute to preventing accidents and eventually improve the safety of Vulnerable Road Users (VRU). One area where collision avoidance can help is by preventing a single collision from evolving into multiple collision scenarios. In the future, however, smart vehicles will be able to anticipate collisions happening in front of them to help avoid these multiple collision scenarios from unfolding. Efficient communication between vehicles is required for these novel collision avoidance strategies to work [4].

Therefore, the use case of collision avoidance requires Ultra-Reliable Low-Latency Communication (URLLC) to be maintained at all times for the application to be more effective than human interventions. If network operators cannot guarantee these latency requirements, the use of collision avoidance services can lead to dangerous situations where the smart vehicles respond too late.

It is therefore paramount that novel network management techniques are explored to ensure this level of QoS. Besides the URLLC requirement, networks supporting vehicular applications will also have to find a way to deal with the highly dynamic nature of its demand. To guarantee the low latency requirement, network operators will need to allocate resources most efficiently. To cope with the dynamicity of the environment where these networks operate, requires the management system to make predictions about its demand. This is where manual or other traditional management systems will struggle and ZSM can achieve superior performance.

ZSM techniques can be more successful because the network intelligence can be implemented using AI techniques such as deep reinforcement learning. In this way, the network management system can learn the dynamic demand patterns and use this to make predictions on how to allocate resources most efficiently. By continuously observing the network, it can learn new patterns in the demand and adjust its prediction accordingly.

The computational and network resources can be efficiently allocated based on ZSM services that constantly monitor the computational and network resources. The allocation is based on the availability and demand of these resources. The network orchestrator, based on ZSM services, achieves this by continuously monitoring the network. This guarantees the vehicular applications that use the network of the QoS they require. It can also allow network operators to offer these services in a cost-efficient way by preventing over-allocation of resources.

III. Proof of Concept: Smart Highway

To illustrate how the use of ZSM techniques can create the ultra-low latency QoS required by vehicular applications, such as collision avoidance, we present a Proof of Concept (PoC). This PoC will be deployed on the Smart Highway testbed [3] which provides a realistic environment that includes eight Roadside Units (RSUs) and one On Board Unit (OBU). For the PoC we will be using five RSUs and one OBU. In this scenario, four out of five RSUs will be used to run vehicular applications for the OBU. This represents the RSUs that could be hosting the collision avoidance service for smart vehicles on the highway. Meanwhile, the fifth RSU sends messages to the other RSUs, creating extra load for these units, and stressing their resources. While this is happening, the OBU, mounted on a vehicle, sends and receives messages to and from the four RSUs. It then measures the latency of these responses.

The latency that the OBU receives is then reported back to the network orchestrator which can use this data to decide to make changes to the network resources. In this way, ZSM can guarantee minimal latencies by making intelligent changes to the network. To create the network intelligence, needed to make the correct changes to the network, multiple methods

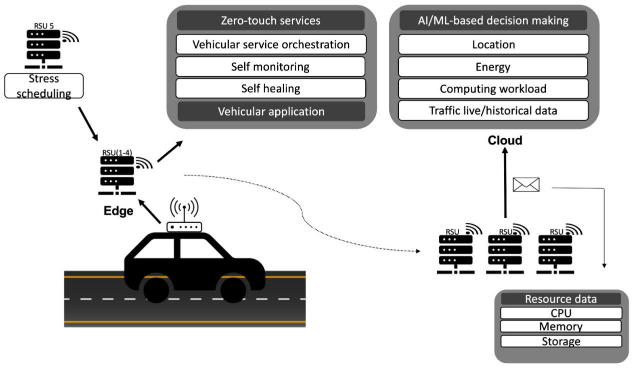

Fig. 2. Illustration of the PoC architecture.

would be possible. Although the AI/ML techniques may vary, Deep Reinforcement Learning (DRL) brings adaptability to a dynamic environment such as the one that can be found on the Smart Highway [3] testbed. For this PoC we used DRL to learn from the decisions made to allocate the computing and network resources and improve them. We do this by training and consuming a DRL-based component that can be hosted in the cloud, while the ZSM services are closer to the user in the Edge.

IV. Conclusion

This paper briefly discussed the current state of the art of ZSM techniques and their challenges. When then showcased how the use case of vehicular applications, more specifically collision avoidance, can benefit from ZSM. We discussed how ZSM can help the deployment of collision avoidance services by helping network operators ensure the ultra-low latency requirements needed to create safe collision avoidance applications. Afterwards, we discussed how we plan to create a real-life proof of concept, where we will illustrate how DRL techniques can be used to create network intelligence for resource allocation to attain minimal latency across the network.

Acknowledgement

This work has been performed within the European project: Horizon 2020 SNS project: TrialsNet (Grant Agreement No. 101095871).

References

[1] E. Coronado, R. Behravesh, T. Subramanya, A. Fernàndez-Fernàndez, M. S. Siddiqui, X. Costa-Pérez, and R. Riggio, "Zero touch management: A survey of network automation solutions for 5g and 6g networks," *IEEE Communications Surveys I& Tutorials*, vol. 24, no. 4, pp. 2535–2578, 2022, doi: http://dx.doi.org/10.1109/COMST.2022.3212586.

[2] M. Liyanage, Q.-V. Pham, K. Dev, S. Bhattacharya, P. K. R. Maddikunta, T. R. Gadekallu, and G. Yenduri, "A survey on zero touch network and service management (zsm) for 5g and beyond networks," *Journal of Network and Computer Applications*, vol. 203, p. 103362, 2022, doi: https://doi.org/10.1016/j.jnca.2022.103362.

[3] Marquez-Barja, J. and Lannoo, Bart and Naudts, Dries and Braem, B. and Donato, C. and Maglogiannis, Vasilis and Mercelis, S. and Berkvens, R. and Hellinckx, P. and Weyn, M. and Moerman, Ingrid and Latré, Steven, "Smart Highway : ITS-G5 and C2VX based testbed for vehicular communications in real environments enhanced by edge/cloud technologies," in *2019 European Conference on Networks and Communications (EuCNC), Abstracts*. IEEE, 2019, p. 2, [Online] Available: https://biblio.ugent.be/publication/8642435.

[4] A. J. M. Muzahid, S. F. Kamarulzaman, M. A. Rahman, and et all., "Multiple vehicle cooperation and collision avoidance in automated vehicles: survey and an ai-enabled conceptual framework." *Sci Rep*, vol. 603, 2023, doi: https://doi.org/10.1038/s41598-022-27026-9.