Demonstrating Situational Awareness of Remote Operators with Edge Computing and 5G Standalone

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***Abstract*—In this paper, we demonstrate and introduce a novel Situational Awareness with Event-driven Network Programming Edge Network Application (EdgeApp), designed to optimize network resource utilization during vessel teleoperation in congested port areas. The demonstration is conducted on an open real-life EdgeApp 5G Standalone (SA) and beyond testbed situated at the port of Antwerp-Bruges. Through this showcase, we demonstrate how 5G and beyond services, utilizing an open 5G SA testbed, can enhance vessel teleoperation. The proposed solution dynamically adjusts network configurations, allowing for lower-quality camera feeds during vessel autonomy and higher-quality feeds when in the teleoperation zone. The practical application and benefits are exemplified through visual representations within the testbed environment.**

***Index Terms*—EdgeApp, 5G SA, 5G SA Testbed, Teleoperation, Maritime vertical.**

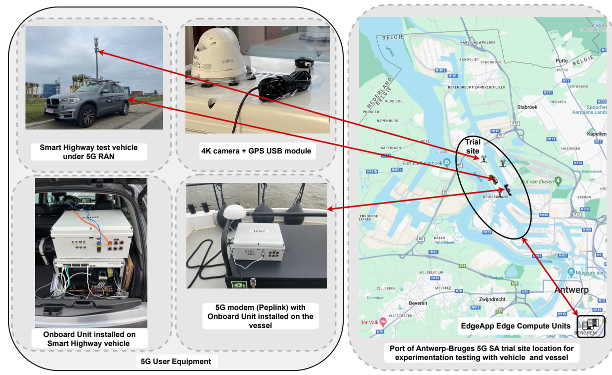

Fig. 1: Trial site with User Equipment.

I. Creating Enablers for New and Efficient Vertical Services

A. Situational awareness with event-driven network programming

In this paper, we demonstrate and introduce a novel Situational Awareness with Event-driven Network Programming Edge Edge Network Application (EdgeApp), designed to optimize network resource utilization during remote operation of User Equipment (UE). The specific use case we showcase in this demo is teleoperation of vessels in congested port areas. The demonstration of the Situational Awareness EdgeApp takes place on an open real-life EdgeApp 5G Standalone (SA) and beyond testbed located at the port of Antwerp-Bruges (Fig. 2). Through this demonstration, we showcase how 5G and beyond services, facilitated by an open 5G SA testbed [1,2], can enhance the teleoperation of vessels (Fig. 2).

When the vessel, as illustrated in Fig. 2, operates fully autonomously within the designated zone, there is no necessity to strain and drain all available network resources, given that the remote captain at the remote control centre is not actively teleoperating the vessel. Consequently, the real-life camera feeds received by the remote captain can be of lower quality, as depicted in Fig. 2, thereby alleviating the network stress and allowing the limited resources to be optimally utilized.

However, upon the vessel entering the teleoperation zone, the remote captain must assume control, necessitating a reliable and stable camera feed to comprehend the surroundings of the vessel. In such instances, the Situational Awareness EdgeApp dynamically configures the network to provide the remote captain with a higher-quality video feed from the teleoperated vessel. This distinction is evident in Fig. 2, where the picture quality significantly improves when the vessel transitions from the Fully Autonomous Zone to the Teleoperated Zone.

B. Experimentation setup

In this subsection, we provide the main technological enablers for the demonstration of the Situational Awareness EdgeApp.

1) On Board Unit (OBU) computing box: The OBU computing box (Fig. 1) serves as a purpose-built, portable computing platform, incorporating the following components: i) a Next Unit of Computing (NUC), ii) a switch, iii) a Power over Ethernet (PoE) module to supply power to the 5G SA Peplink modem, iv) Universal Serial Bus (USB) slots for interfacing with the portable Global Positioning System (GPS) USB module (Fig. 1), and v) the 4K camera designated for teleoperation (Fig. 1).

This configuration streamlines the process of testing with a vehicle or vessel, as the OBU computing box establishes a pivotal connection between the vessel or vehicle and the testbed, as depicted in Fig. 2 and 1.

2) The 4K camera for teleoperation: The 4K camera dedicated to teleoperation is linked to the computing box of OBU (Fig. 1). This connection facilitates the streaming of the captured video feed from the vehicle or vessel to the EdgeApps operating at the edge segment of the 5G SA and beyond network (Fig. 2).

3) The GPS USB module: The GPS USB module (Fig. 1) establishes a connection with the computing box of the OBU. This arrangement empowers the Situational Awareness EdgeApp to monitor the movements of the vehicle or vessel, thereby detecting its ingress or egress from a teleoperation zone and anticipating increased network demands during such occurrences.

4) The 5G SA Peplink modem: The 5G SA Peplink modem (Fig. 1) is intricately linked to the computing OBU computing box. This 5G modem functions as the gateway establishing the connection between the vehicle or vessel, and the edge segment of the 5G SA testbed where the Situational Awareness EdgeApp is operational (Fig. 2). Such a configuration facilitates the seamless transmission of the 4K camera feed for teleoperation, as well as the GPS positions sourced from the USB module.

5) The Antwerp 5G SA and beyond EdgeApp testbed: As depicted in Fig. 2, the comprehensive structure of the testbed is visible, spanning from the 5G UE layer to the 5G Edge, wherein the Situational Awareness EdgeApp is executed. This configuration enables the Situational Awareness EdgeApp to dynamically request diverse bandwidth slice profiles contingent upon the geographic location of the vessel within the network. The testbed is equipped with the requisite interface towards the 5G Core, exposing it for the EdgeApps to establish network awareness and programmability. Consequently, when the vessel operates within the Fully Autonomous Zone (Fig. 2), the Situational Awareness EdgeApp utilizes its interfaces to program a low bandwidth profile. This action results in a diminished quality of the streamed camera feed for the remote captain, as illustrated in Figure 2. Conversely, upon entering

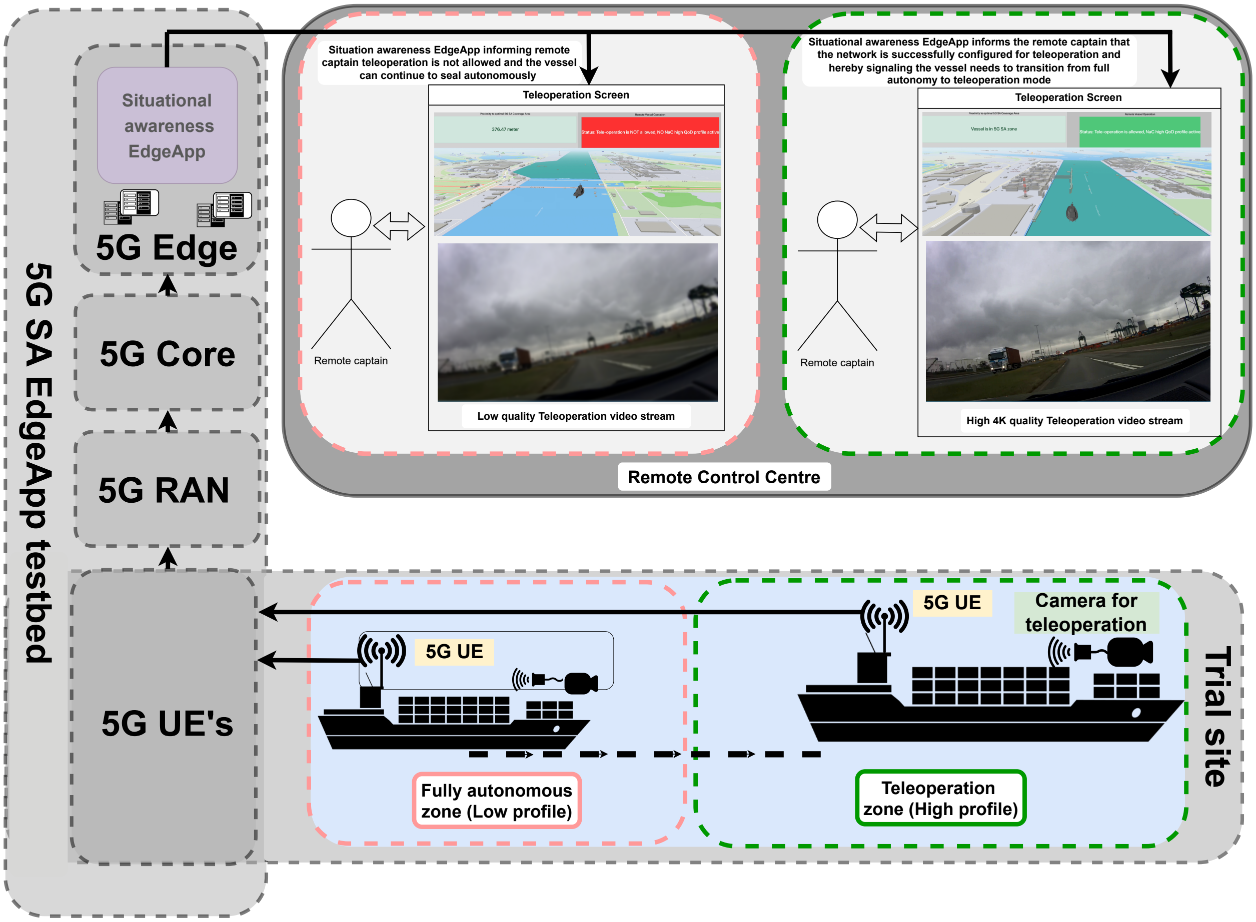

Fig. 2: Demonstration of the 5G EdgeApp enabled service for remote teleoperation of vessels.

the Teleoperation Zone (Fig. 2), the Situational Awareness EdgeApp once again utilizes its interfaces to program the network with a high bandwidth profile, ensuring the delivery of high-quality video streams to the remote captain.

II. Demo

Our demonstration unfolds through a multi-step process:

i) we exhibit the seamless onboarding of the EdgeApps onto the 5G SA Antwerp EdgeApp testbed, and by doing so demonstrate how exactly the Situational awareness EdgeApp is imported in the 5G SA and beyond ecosystem, ii) the activation of the Situational awareness EdgeApp is demonstrated through the testbed, initiating the EdgeApp-enabled 5G and beyond service, iii) following the activation of the Situational awareness EdgeApp, we provide a proof of concept. For this demonstration we will use the Smart Highway[1] vehicle as if it is a vessel entering specific geofenced locations in the port environment, the Situational-awareness EdgeApp, utilizing its interfaces towards the 5G and beyond network, triggers higher-quality bandwidth profiles. This ensures reliable streaming of teleoperation video streams to the remote captain this will be demonstrated with the camera footage obtained from the vehicle. This will be visually demonstrated by the real-life improvement of the camera feed as shown in Fig. 2, and iv) a detailed demonstration follows, illustrating how the testbed facilitates the entire logic outlined above.

III. Conclusion

In conclusion, this demonstration illustrates the potential enhancement in network utilization within 5G SA and beyond networks through the implementation of a 5G SA EdgeApp. The showcased scenario elucidates the capacity of an open 5G SA EdgeApp testbed to foster research and development endeavours directed towards the innovation and implementation of novel services in the realm of 5G and beyond. Furthermore, this demonstration also shows how the 5G SA testbed can facilitate new 5G and beyond services through EdgeApp-enabled services, enabling innovative solutions for vertical industries.

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