Remote Control of a Robot Rover Combining 5G, AI, and GPU Image Processing at the Edge

F. Civerchia(1), F. Giannone(1), K. Kondepu(1), P. Castoldi (1,2), L. Valcarenghi(1), A. Bragagnini(3), F. Gatti(3), A. Napolitano(3), Justine Cris Borromeo(1)
(1) Scuola Superiore Sant'Anna, Pisa, Italy, l.valcarenghi@santannapisa.it;
(2) Department of Excellence in Robotics & A.I., Scuola Superiore Sant'Anna, Pisa, Italy
(3) TIM, Italy.

Abstract: The demo shows the effectiveness of a low latency remote control based on 5G and image processing at the edge exploiting artificial intelligence and GPUs to make a robot rover slalom between posts.
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1. Overview

The combination of 5G Ultra Reliable Low Latency Communications (URLLC), supported by a low latency optical fronthaul and backhaul, and of intelligence at the edge, supported by accelerated micro data-centers, is paving the way to the remote control of moving machineries (e.g., robots, robot rovers, cars). Such remote control would allow lowering the cost of moving machineries by offloading most of their intelligence to the network. Standard Development Organisations (SDOs) are conducting several initiatives in this direction. One of the important working items of Release 16, expected to be released in ASN.1 in the second quarter of 2020, is the Enhancement of URLLC support in the 5G Core network [1]. In parallel, to decrease the end-to-end latency further, Multi-Access Edge computing (MEC) [2] or, more in general, edge technologies [3] are being developed. Edge technologies can also benefit from the development of edge micro data-centers [4] in which the traditional elaboration based on Central Processing Units (CPU) is complemented with elaboration offloaded to Graphical Processing Unit (GPU) or programmable hardware, such as Field programmable gate array (FPGA). Artificial Intelligence (AI) and Machine Learning (ML) algorithm can benefits from these accelerated data-centers for implementing part of the machinery remote control [5].

The proposed demonstration is organized as follows. A four-wheel drive robot rover is connected to an edge micro data-center where the rover remote control is deployed. A 5G network provides the connectivity between the rover and the data center. The rover remote control is based on an algorithm recognizing traffic signs. The algorithm resides in an edge node attached to the 5G Core Network (CN). The algorithm recognizing the signs is based on Artificial Intelligence. The algorithm is run on GPUs forming the edge micro data center. The rover sends the live scene acquired through a camera to the AI algorithm that recognizes the traffic signs. The recognized sign (e.g., left turn or right turn) is sent to the rover remote control that send the correspondent commnd (e.g., left turn or right turn) to the rover through the 5G network (i.e., optical backhaul, fronthaul and wireless channel).

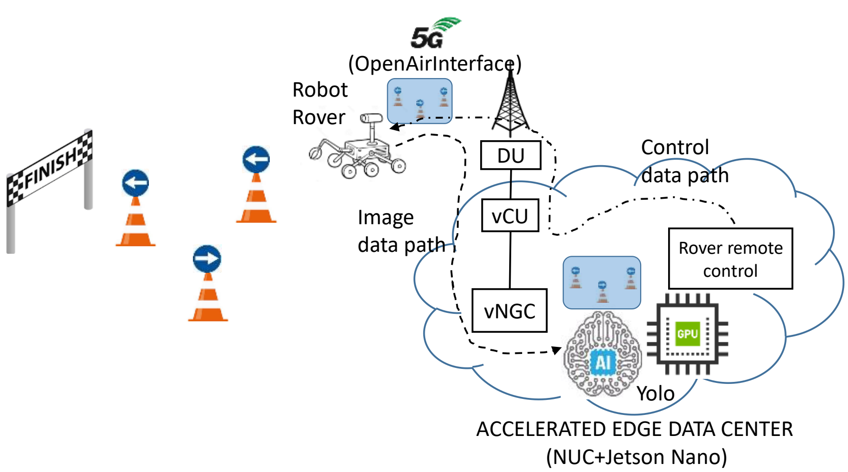


Fig. 1 Demo setup and architecture

Visitors to the demo will experience the capability of the 5G network, AI, and GPU based edge image recognition to identify the different traffic signs attached to the posts and to send command to the four wheel-drive robot rover to turn in the right direction. Visitors could challenge the rover performance by piloting the rover through a joystick.

2. Innovation

The innovation introduced by this demo is multifold. The demo combines very recent solutions in the service and communication fields.

First of all the considered service (i.e., the remote control of a moving machinery) is being considered as a first step toward assisted/autonomous driving. Moreover, it is currently a matter of investigation in the robotic research (i.e., the so called cloud robotics) to reduce robot cost by moving most of the intelligence at the edge.

The second innovation consists in the utilization of the 5G technology, including optical fronthaul and backhaul, to reduce the end-to-end latency. Indeed, when an application is extremely latency sensitive (i.e., when the time occurring between sensing a phenomenon and applying the control must be short) it is important that the mobile network, including bot the air interface and the fixed infrastructure, guarantees URLLC.

Last but not least, another important novelty is represented by the utilization of an edge micro-data center next to the 5G Next Generation Core (NGC). The deployment of intelligence at the edge allows the latency of the communication between the controlled machinery and the remote control to be minimized. To further reduce the latency, an accelerated edge data-center equipped with GPU is exploited.

Thus, the demo will show how the latency introduced by all the components of the whole service chain (including network (including virtualization), elaboration, and actuation latencies) for the remote control of robot rover will impact the service performance.

3. OFC relevance

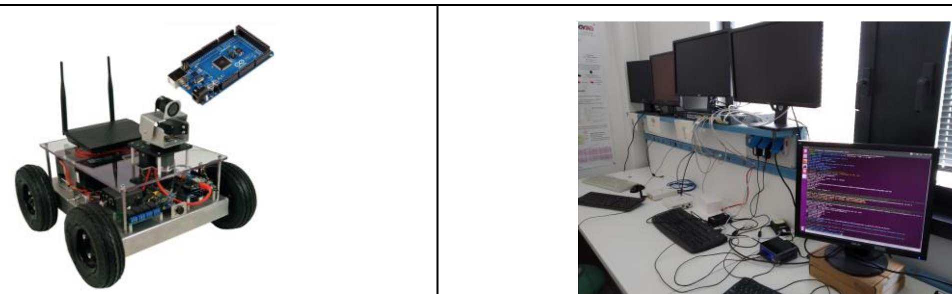
The demo presents a multifold relevance to OFC 2020. The demo shows advances in network and service deployment in a laboratory environment toward field trials.

In particular, it shows the capability of 5G, including air interface, fronthaul and backhaul, of providing a low latency communication between robot rover and remote control.

The demo deals also with edge computing for low latency remote control. In particular, it shows how, by deploying the intelligence at the edge in micro data-center equipped with GPUs, low latency, at the application level, is achievable.

Finally, it shows the potentials of utilizing AI/ML in combination with GPU acceleration for data analytics. In particular, the AI-based image recognition algorithm combined with GPU acceleration, allows to sensibly reducing the latency of the task with respect to a CPU based approach. Thus, the potentials of accelerated edge data center in reducing the end-to-end application-level latency are also shown.

4. Implemented software components and Demo description



(a) (b)

Fig. 2 (a) Robot rover; (b) 5G mobile access

For implementing the demo, the following components are utilized. A programmable WiFi Mobile 4WD Robot Development Platform IG32 DM by SuperDroid Robots is the utilized robot rover. The robot rover is equipped with a WiFi ASUS 3-in-1 wireless router that allows the robot rover to be controlled wirelessly. The robot can also be controlled through a joystick connected to a PC connected, in turn, to the robot rover WiFi router. The robot rover is equipped with an Arduino Mega 2560 R3 and a Pan & Tilt camera with a Wide View Color Infra-Red Camera with 10 IR LEDs. The robot rover video server is an Etrovision EV3151A with 2 way audio. The rover will be connected to the 5G network by implementing a bridge WiFi-5G inside a mini-PC (e.g., Intel NUC). On one side the mini-PC will be connected to the robot rover WiFi router and on the other side to an Universal Software Radio Peripherals (USRPs) Ettus X310. The remaining part of the 5G mobile network consists one additional USRP and mini-PC. The mini-PC hosts the Distributed Unit (DU), the virtualized CU (vCU), and the virtualized Next Generation Core (NGC). Moreover, an NVIDIA Jetson NANO is connected to the mini-PC through the Ethernet interface. The NVIDIA Jetson NANO is a system-on-chip featuring a 128-core NVIDIA Maxwell, a CPU Quad-core ARM A57 @ 1.43 GHz, and a Memory 4 GB 64-bit LPDDR4 25.6 GB/s. The open source OAI platform [6] is utilized as mobile network software. The OAI Radio Access Network (OAI-RAN) implements 4G LTE and 5G Radio Access Network. OAI Core Network (OAI-CN) implements 4G LTE Evolved Packet Core (EPC) and 5G Core Network. Moreover, OAI provides an implementation of few NG-RAN functional splits where the evolved Next Generation eNodeB (gNB) functions are decoupled into two new network entities such as the Central Unit (CU), where the base-band processing is centralized, and the Distributed Unit (DU), where the RF processing is performed. In the demonstration, Option 2 (i.e., PDCP/RLC or F1 interface) functional split will be utilized. OAI-CN is utilized for implementing the Next Generation Core (NGC) functions. In the demonstration, a virtualised version of the NGC will be utilized. The chosen virtualization technology is based on Docker containers. An image recognition application is utilized for recognizing the traffic signs installed on the top of the cones. The image recognition application is based on the You Only Look Once (YOLO) software. YOLO is a Unified, Real-Time Object Detection software based on a single neural network applied to the full image. This network divides the image into regions and predicts bounding boxes and probabilities for each region. YOLO is based on the Darknet framework [7]. An application implementing the remote robot rover control will run in a container and interact with the image recognition application.

The tentative deployment of the demo is the following. The robot rover sends the acquired images to the image recognition application through the 5G network. The result of the image recognition application are sent to the remote control app that will send back the command to the robot rover through the 5G network data plane. Two deployments of the image recognition will be considered. One in which the image recognition application is running on the mini-PC CPU and one in which the image recognition application is running in the Jetson Nano GPU. The qualitative performance evaluation parameter will be the capability of the rover of completing the slalom and passing the finish line without hitting any cone. Such performance will depend on the two-way latency of the overall control chain: image acquisition, image transmission through the virtualized 5G network, image processing by the image processing application, control decision, and control activation in the robot rover. Quantitative measurements of all the component of the service chain two-way delay will be also performed, such as the round trip time from the rover to the NGC N6 interface by means of user space probes such as ping.

The visitors to the demo will also be involved. They will be asked to pilot the robot rover through the joystick and race against the clock with the remotely controlled rover.

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