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REMOTE OPERATION OF VEHICLES WITH 5G

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REMOTE OPERATION OF VEHICLES WITH 5G

In the near future it will be a common occurrence to see driverless buses on city streets. A key step towards introducing autonomously driven buses into the public transport system is the development of remote monitoring and control capabilities, which will help to ensure safety

While autonomous vehicles could revolutionize mass transportation as we know it, their safety has been widely debated. To address this concern, remote operation brings a safety mechanism that allows public buses to be monitored and controlled by a remote operator from a distance, if needed. The vision of operators scanning screens and on-hand to intervene if necessary, should contribute to public acceptance of autonomous vehicles.

Network requirements for remote operation include broad coverage, high data throughput and low latency to enable continuous video streaming and to send commands between a remote operations center and a vehicle. 5G will bring a number of benefits to remote control systems, including core network slicing that will enable priority service provisioning, and radio access to bring ultra-low latency and beamforming for high throughput and capacity.

At its headquarters in Södertälje, Sweden, Scania has a 5G proof-of-concept test network devoted to controlling a bus remotely from a vehicle operations center. Work at the site is focused on two important areas: total system response time for remote monitoring and control, and the automated tools required to provision prioritized network services.[1]

The tests involve a remote operator driving a bus around the test track, as well as to and from the parking facilities. Sensor data from the bus, including a high-resolution video feed, is streamed to the remote operations center over LTE radio access with an evolved 5G core network. The testbed features automated service ordering and provisioning, allowing the set-up and take-down of prioritized network resources needed for the remote monitoring and operation.

The 5G proof-of-concept network is not the biggest source of latency in the complete remote operation system. Additional factors that cause delays include servo-driven mechanics, as well as video encoding and decoding

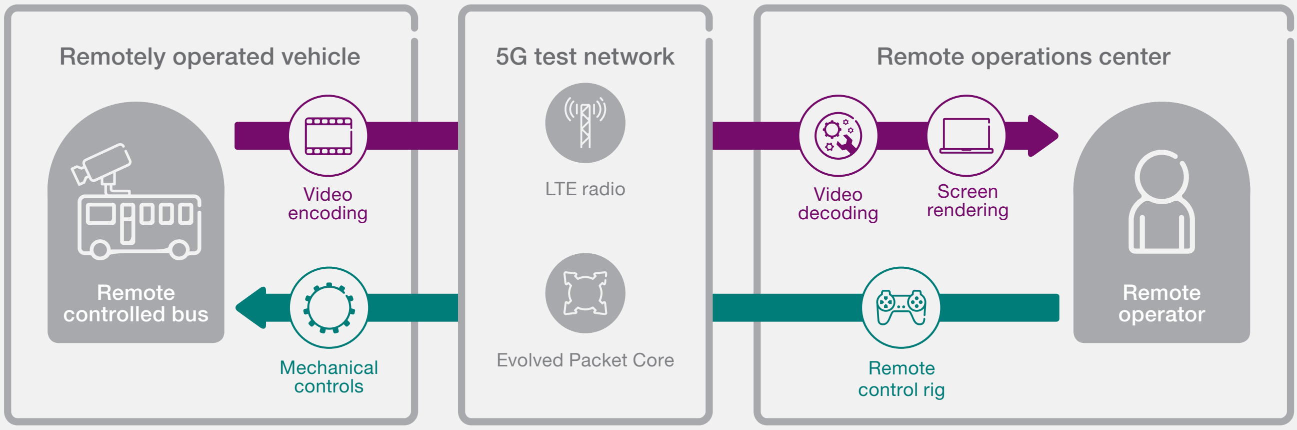
Isolating and measuring contributors to system response time

A key objective is to isolate and measure the different contributors to the remote control system response time, including network latency. Response time is measured in milliseconds (ms) – for example, from when an operator sees an obstacle on the road and reacts by using the remote controls to apply the brakes, to the point when the result (the bus slowing) is visible in the video presented to the operator. During the tests, total system response times of around 185 ms were achieved. The most significant contributors to the response time and its variation were mechanical delays (physical actuators controlling the bus), followed by the video processing delay and, finally, the network delay (round trip time (RTT)).

Network RTT mostly stayed under 50 ms during the study, although some areas with obstacles along the test route increased the latency beyond this value. Uplink throughput, which is critical for remote operation, was also measured. In good coverage areas, the uplink throughput was between 10–20 Mbps.

[1] Ericsson Research, "5G teleoperated vehicles for future public transport" (2017), Rafia Inam, Keven (Qi) Wang, Nicolas Schrammar, Athanasios Karapantelakis, Leonid Mokrushin, Aneta Vulgarakis Feljan, Viktor Berggren and Elena Fersman: www.ericsson.com/research-blog/5g/5g-teleoperated-vehicles-future-public-transport

Illustration of system response time and its components



5G radio access lowers round trip time to under 4 ms

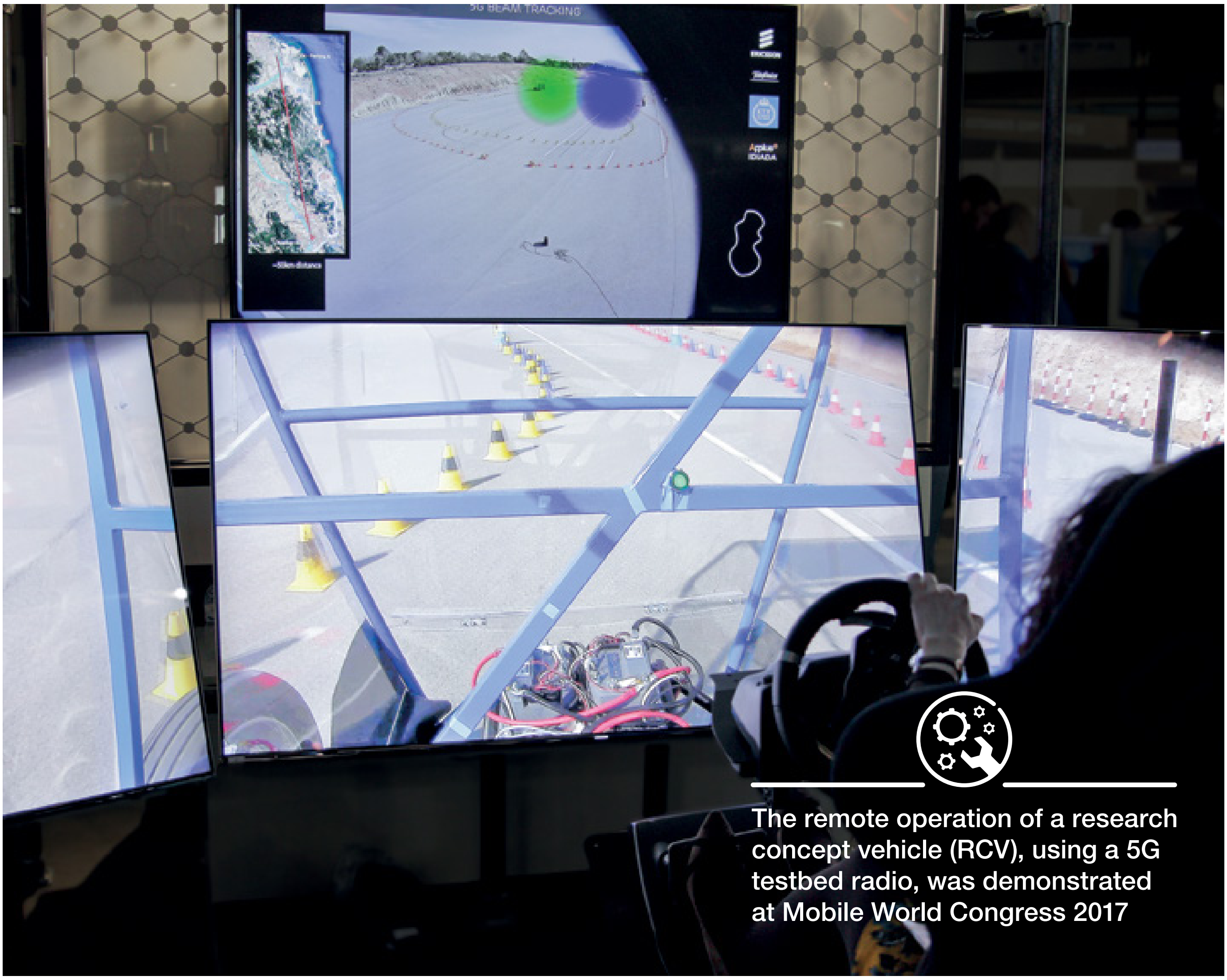
Reducing system response time

Improvements are being made in all areas affecting system response time. Network latency improves significantly with 5G radio access, lowering network RTT to under 4 ms. Video encoding and decoding are on a track to continuously improve, with advances in both codecs and adaptive streaming mechanisms. Mechanical delays will decline as the buses themselves are specially designed for autonomy and remote operation is deployed – rather than being converted from today's driver-controlled buses.

Automated network resource prioritization

A critical requirement for a remote vehicle control center is the ability to prioritize network services if remote operation is required, through a service ordering API to a mobile telecom operator. In the testbed, an interface based on the Open Mobile Alliance candidate standard is used for network resource prioritization.

Technology is being developed to enable a self-service portal, allowing network customers, such as public transport companies, to specify quality of service (QoS) requirements on their own terms; for example, to prioritize 4K video traffic for 40 buses. The software will then translate this specification into instructions for network resource prioritization.



Research concept vehicle

Parallel to the Scania activities, the remote operation of a research concept vehicle (RCV) – developed and custom-built by the Integrated Transport Research Lab at KTH Royal Institute of Technology – was demonstrated at Mobile World Congress 2017. A 5G testbed radio, using a 15 GHz carrier frequency, provided sufficient bandwidth for remotely operating multiple vehicles in the same cell. Delivering the throughput on 15 GHz is accomplished using beamforming; that is, tracking the moving vehicle and focusing the radio power for maximum effect. Due to the low latency of the 5G radio access, RTT was under 4 ms.

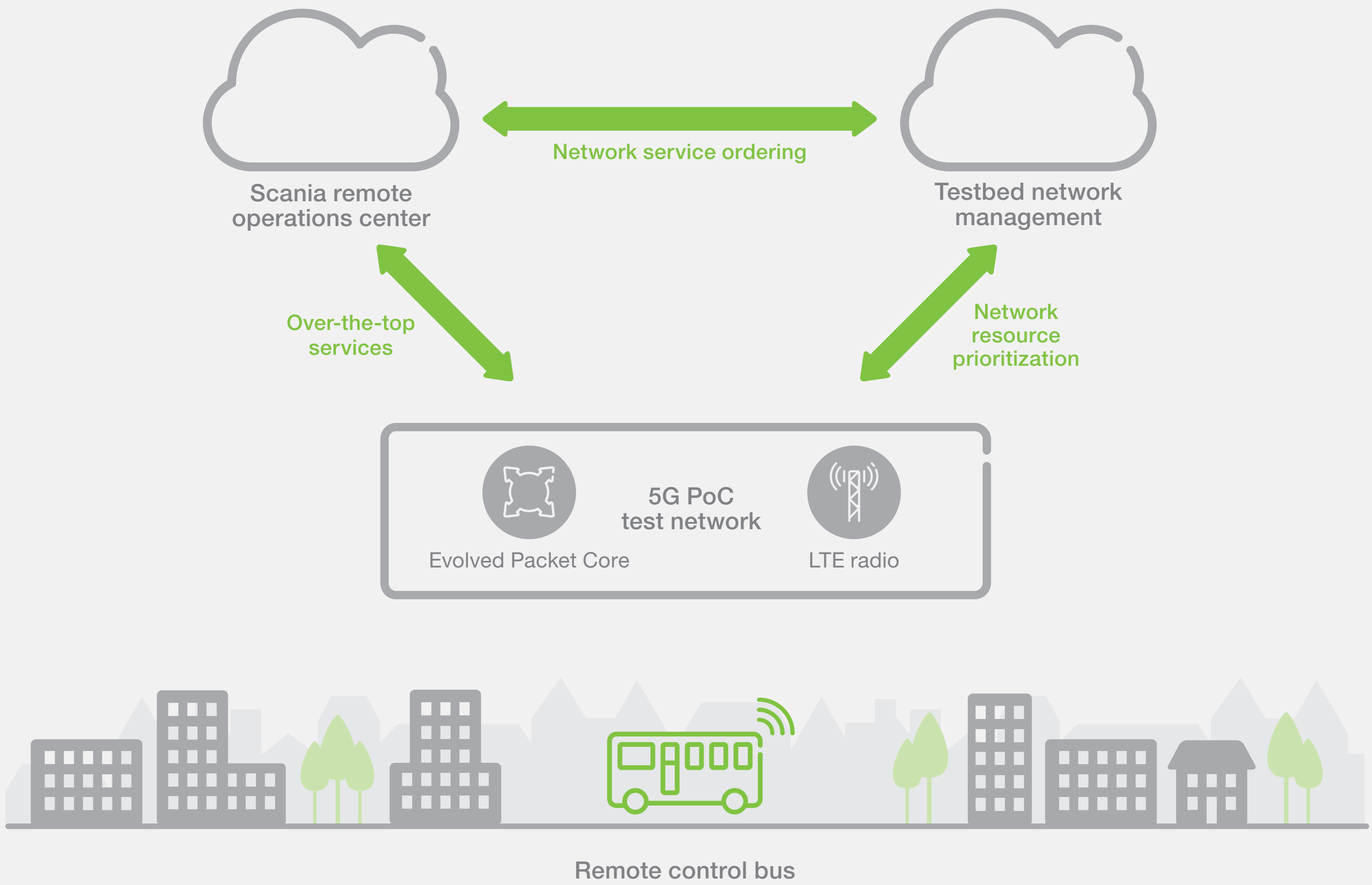
Attributes of 5G – including network slicing and low latency – will make safe public transport using autonomous vehicles a reality

The work on remotely controlled buses and the RCV are making safe, autonomous vehicles a reality. Additionally, the insights from these activities can be applied to other industrial use cases that require high uplink throughput, low network latency and automated service provisioning.

Integrated Transport Research Lab

The Integrated Transport Research Lab (ITRL), a collaboration between the Swedish Royal Institute of Technology (KTH), Scania and Ericsson, is actively exploring intelligent transport systems. Recent studies illustrate the use of emerging 5G cellular technologies in testbed environments.

Illustration of the remote control system



Testbed and methodology

Testbed network

The Scania testbed network uses LTE radio access on band 40 (2.3 GHz TDD) to provide data connectivity to the bus. Throughput and RTT were measured between the remotely operated bus and the network provisioning system. RTT was measured from the remote operations center to the vehicle and back, along with covered radio and network transport (both uplink and downlink). RTT measurements were collected at a rate of one per second, resulting in hundreds of measurements collected from different areas of the test track.

Video link

A single camera at the front of the bus requires an uplink throughput of 8 Mbps to stream a 1080p 60-frames-per-second video from the bus to the operations center. An industrialized solution will include cameras to capture video from the front, back and sides of the bus, requiring about 24 Mbps bandwidth using current codecs. The video latency was measured using two GPS-synchronized clocks. Each clock displayed time in binary format as a line of LEDs, allowing sub-millisecond resolution. One clock was placed on the bus in view of the camera, while the second clock was attached to the video display at the control center. Photos showing both clocks were taken at one-second intervals. The difference between the clocks indicated the video latency, measured to a high degree of accuracy.

In 5G radio, uplink/downlink allocation will be more flexible and able to meet the demands of uplink critical use-cases

Mechanical controls

The latency of the remote control rig can be reduced to under 1 ms by using optimized equipment. On the other hand, the vehicle latency, including mechanical controls, has a wide variation.

Automated network service prioritization

A cloud-hosted application function (AF) dynamically sets up virtual connections between vehicles and the 5G Evolved Packet Core (EPC) network, with specific QoS attributes such as designated latency levels and guaranteed throughput. This application functionality can be securely opened to third parties through an API. In the use case described here, the testbed uses this API to set up priority virtual connections for vehicles in need of remote operator assistance.

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