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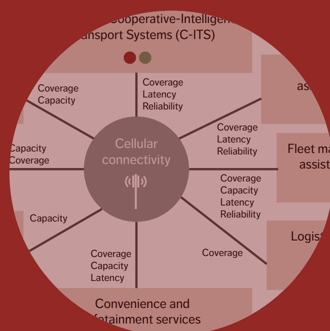
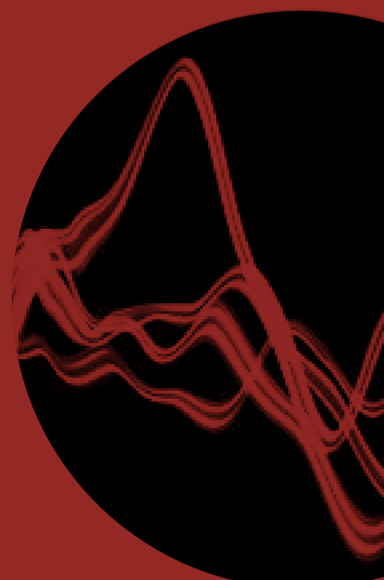
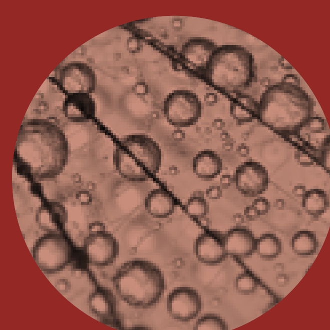




TRANSFORMING TRANSPORTATION WITH 5G



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Driving transformation

IN THE AUTOMOTIVE AND ROAD TRANSPORT ECOSYSTEM WITH 5G

Major mobile network operators around the world have started rolling out 5G cellular networks, with subscriber penetration expected to reach about 20 percent by 2024 [1]. One of the many benefits of these powerful, multipurpose networks is their ability to provide reliable, secure and fit-for-purpose cellular connectivity in automotive and transport applications.

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Once considered merely "nice to have," connectivity is rapidly becoming a critical part of road transportation systems. Ericsson predicts that the number of connected cars in operation will rise to more than 500 million in 2025 [9].

■ Already today, vehicle original equipment manufacturers (OEMs) are increasingly focusing on delivering services in addition to selling vehicles as products. Software is now a critical component of vehicles, and OEMs are investing heavily in automation, architecture simplification and new drivetrain technologies such as electrification.

At the same time, traffic and road authorities are seeking new technology solutions to reduce carbon emissions, traffic congestion and casualties – solutions that are often dependent on vehicle functionality and the ability to provide various types of support for drivers and vehicles. Meeting these diverse needs requires software-defined and network-aware vehicles, combined with advanced network connectivity.

While it is true that many of today's 2G-4G networks can provide sufficient connectivity for numerous Internet of Things (IoT) applications, the higher data rate, lower latency and improved capacity provided by 5G New Radio (NR) access make 5G systems the ideal choice to maximize the safety, efficiency and sustainability of road transportation.

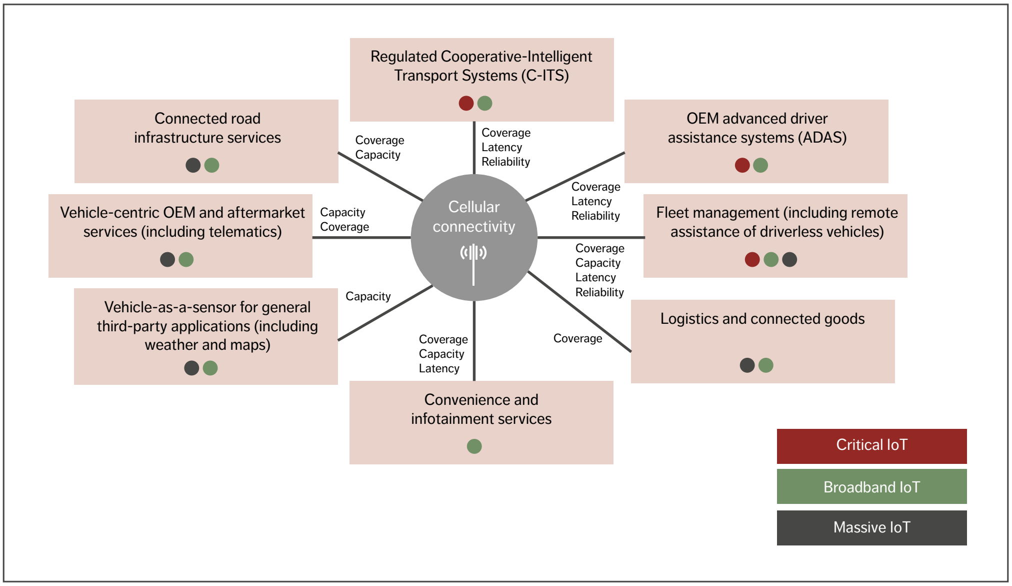

Figure 1 Overview of automotive and road transport services that require cellular connectivity

Overview of automotive and road transport services

A wide array of automotive and road transport services require cellular connectivity, with many already in commercial operation. To better understand the big picture, we have classified these services into eight groups, as shown in *Figure 1*.

Regulated Cooperative-Intelligent Transport Systems (C-ITS) focus on governmental regulated services for road safety and traffic efficiency. Traffic efficiency use cases have relaxed latency requirements, while safety-related data often requires reliable low-latency communication. A benefit of regulation is to encourage cross-OEM cooperation in standardized (regulated) information exchange. Regulated C-ITS services may also use dedicated ITS spectrum in certain regions; for example, for direct short-range communication using 3GPP PC5 or IEEE (Institute of Electrical and Electronics Engineers) 802.11p technologies.

The purpose of OEM advanced driver assistance systems (ADAS) is to increase road safety by focusing on the driver and driving behavior. They rely primarily on vehicle sensor information and are typically not collaborative across vehicle brands. ADAS services can also benefit from data provided by traffic authorities such as traffic light information. They are expected to evolve to support the driverless vehicles of the future.

Fleet management services are aimed at vehicle fleet owners such as logistics or car-sharing companies. The communication service is primarily used to monitor vehicle locations and the vehicle/driver status. When the fleet consists of driverless vehicles, the fleet management also includes communication support for operations monitoring and remote assistance, which can imply full remote driving.

The primary focus in the logistics and connected goods category is on the tracking of transported objects (commodities, merchandise goods, cargo and so on) during the production and transport cycle of the object.

Convenience and infotainment services deliver content such as traffic news and audio entertainment for drivers, and gaming and video entertainment for passengers.

In vehicle-as-a-sensor for general third-party use cases, the sensors installed in the vehicle to provide information to solutions aimed at achieving driving improvements (such as ADAS or automated driving) are reused to provide anonymized data to other parties to monitor city infrastructure and road status, maintain street maps or to give accurate and up-to-date weather information.

Vehicle-centric OEMs and aftermarket services focus on vehicle performance and usage. They make it possible for the OEM to collect vehicle diagnostics data that enables it to monitor/adjust the vehicle and give advice to the driver for improved driving efficiency. Other examples of services in this category include vehicle tracking and predictive maintenance.

Connected road infrastructure services are operated by cities and road authorities to monitor the state of the traffic and control its flow, such as physical traffic guidance systems, parking management and dynamic traffic signs.

Each service group contains multiple use cases, and requirements can be diverse within a group. The key connectivity requirements per segment are noted in Figure 1.

5G-enabled network for all services

Connected vehicles and road infrastructure are part of a broader IoT ecosystem that is continuously evolving. To ensure cost efficiency and future-proof support, mobile network operators (MNOs) aim to meet the connectivity demands of multiple industry verticals, including the automotive and transport industry, using common physical network infrastructure, network features and spectrum resources.

Ericsson divides cellular connectivity for the IoT into four distinct segments: massive IoT, broadband IoT, critical IoT and industrial automation IoT [2].

Examples of connected services trials

In addition to all the connected services already in commercial operation, there are many noteworthy advanced trials on 4G/5G cellular networks, including:

- **C-ITS in Australia:** *https://exchange.telstra.com.au/making-our-roads-safer-with-connected-vehicles/*
- **C-ITS in Europe:** *https://5gcar.eu*
- **Multi-party information exchange for C-ITS:** *https://www.nordicway.net/*
- **Connected traffic light information and driver advice for C-ITS:** *https://www.talking-traffic.com/en*
- **ADAS:** *https://www.ericsson.com/veoneer*
- **AD-aware traffic control:** *https://www.drivesweden.net/en/events/demo-ad-aware-traffic-control-0*
- **Tele-operated driving and HD mapping:** *https://5gcroco.eu/*
- **Self-driving, remote-assisted trucks:** *https://www.ericsson.com/en/press-releases/2018/11/ericsson-einride-and-telia-power-sustainable-self-driving-trucks-with-5g*
- **Service continuity at border crossings:** *https://www.ericsson.com/en/blog/2019/5/connected-vehicle-cross-border-service-coverage*
- **Connected logistics:** *https://clc.ericsson.net/#/use-cases*

The first three segments are relevant for automotive and transport services. The colored dots in Figure 1 indicate their relevance for each of the eight service groups, based on key connectivity performance indicators.

Massive IoT

Massive IoT connectivity targets low complexity narrow-bandwidth devices that infrequently send or receive small volumes of data. The devices can be in challenging radio conditions requiring coverage extension capabilities and may solely rely on battery power supply. Massive IoT is suitable for low-data-rate use cases that can be supported with narrow bandwidth modems. These use cases can be found in logistics, telematics, fleet management and connecting parts of road infrastructure, for example.

Broadband IoT

Broadband IoT connectivity enables large volumes of data transfer, extreme data rates and low latencies for devices with significantly larger bandwidths than massive IoT devices. Broadband IoT connectivity is also capable of enhancing signal coverage per base station and extending device battery life if requirements on data rate and latency are not stringent. Broadband IoT is vital for the majority of the automotive use cases that require high data rates and low latency, such as infotainment, telematics, fleet management, sensor sharing, basic safety and ADAS.

Critical IoT

Critical IoT connectivity enables ultra-reliable and/or ultra-low latency communication. It aims to deliver messages with strictly bounded low latencies even in heavily loaded cellular networks. Critical IoT can enable some very advanced services, such as remote driving of automated commercial vehicles on specific routes.

4G networks already support massive IoT (based on LTE Category M1 and Narrowband IoT access) and broadband IoT (based on LTE access). 5G networks will boost broadband IoT performance and enable critical IoT with the introduction of NR. With the evolution of cellular IoT in the 5G era, cellular networks would enable the full range of existing and emerging automotive applications. This horizontal approach of supporting all services through the cellular network is much faster and more cost-efficient than deploying dedicated systems for different services, such as a dedicated short-range communication system for regulated C-ITS [3].

Accelerating the adoption of 5G connectivity

When rolling out 5G networks, MNOs aim to balance investments, new revenues and competitiveness. Decisions about where and when to deploy 5G networks depend not only on commercial factors but also on spectrum availability in different regions. Accelerated adoption of 5G in the ecosystem, including the automotive and transport industry, requires:

- The ability of 5G NR deployments to deliver value from day one.
- The ability to efficiently share spectrum resources between 5G NR and 4G LTE.
- Operators' ability to reuse 4G LTE radio base station equipment for 5G NR deployments as much as possible.

One of the 5G fundamentals is tight interworking between 4G LTE and 5G NR radio access. This interworking allows 5G-capable devices to simultaneously access 4G LTE and 5G NR carriers. A 5G-capable modem can connect with NR (when in NR coverage) to experience a boost in performance and capacity while maintaining its 4G LTE connection. This approach ensures that 5G NR deployments can deliver value for automotive and transport services from day one.

Both wide-area 5G coverage and automotive sector requirements demand that 5G NR and 4G LTE are able to efficiently share spectrum resources. Lower carrier frequencies where 4G LTE is operational are ideal from a coverage perspective (due to better radio wave propagation characteristics) and very attractive for 5G NR deployments. However, 4G LTE will be required for many years to support legacy devices (such as vehicles with 4G

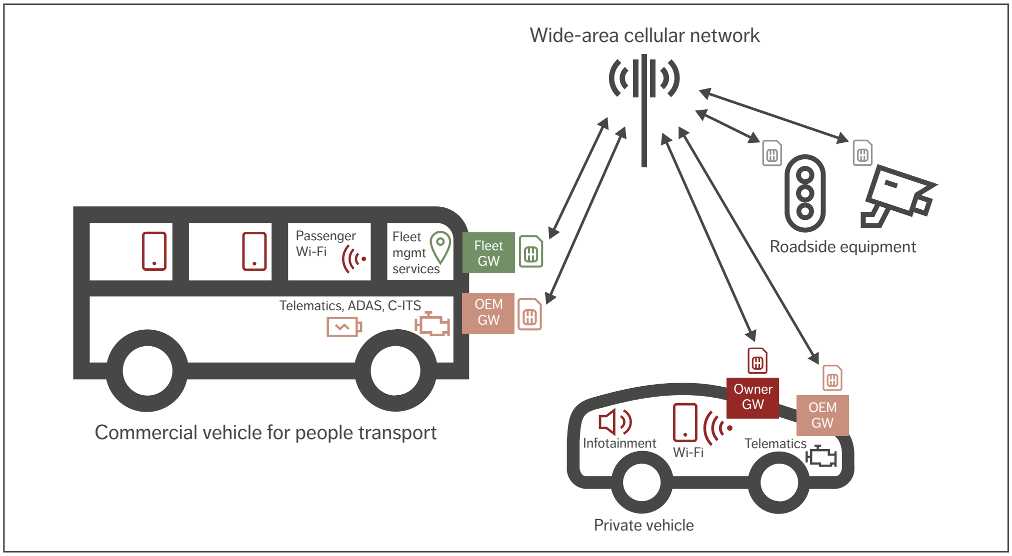

Figure 2 Cellular connectivity for vehicles and roadside equipment

modems). To address this, Ericsson has developed fully dynamic spectrum sharing between NR and LTE on a millisecond level for optimized utilization of spectrum [4].

With respect to operators' ability to reuse 4G LTE radio base station equipment for 5G NR deployments, the Ericsson Radio System can be fully reused on existing sites following a remote software upgrade, including baseband units, radios and antennas (when NR and LTE share a spectrum band) [4]. This important 5G functionality will facilitate market-driven deployments along most streets and roads. However, in some cases, public incentives can trigger faster road coverage deployment, for example by letting MNOs deploy networks using road authorities' site assets, or regulating road coverage requirements in spectrum license auctions [5].

The relation between in-vehicle and wide-area connectivity

Figure 2 illustrates how cellular connectivity works for vehicles and roadside equipment. It visualizes vehicles as multipurpose devices in which several connectivity-dependent use cases are executed simultaneously. At the same time, each vehicle also contains an internal network that interconnects in-vehicle sensors, actuators and other devices, including driver and passenger smartphones.

A gateway function (traditionally implemented in the Telematics Control Unit) connects the vehicle-internal network(s) to the external network. Among other things, this gateway function protects the vehicle-internal devices against external misuse. Additional security and traffic separation solutions restrict access to sensitive in-vehicle devices from inside the vehicle as well.

Connectivity to the external network is realized by one or more modems, containing one or more subscriptions (represented by SIM cards) when using cellular access. The number of modems and supported subscriptions (provided by the OEM, for example) has generally been a trade-off between cost constraints and simple service usage. More recently, capacity and redundancy gains have also been taken into consideration.

In some cases, the fleet operator provides connectivity to the transported objects (passengers in this case), as illustrated in Figure 2. Alternatively, the vehicle's OEM subscription can be used to provide passenger Wi-Fi.

Instead of using the vehicle-mounted connectivity support, infotainment and navigation are often provided by a smartphone with its own subscription that is carried into the vehicle. As future ITS and ADAS services evolve, they too will be available through smartphones, which will increase service penetration to older vehicles.

Achieving global consistency in automotive and transport connectivity

Vehicles all around the world need connectivity to communicate, and, like any other device, a vehicle needs an MNO subscription to access a cellular network. The stark contrast between the global nature of vehicles' connectivity requirements and the local nature of MNOs presents significant challenges to meet the automotive and transport ecosystem's connectivity needs, most notably in the areas of subscription provisioning, roaming, local breakout/distributed computing and cost separation/traffic prioritization.

Subscription provisioning

One of the challenges particular to the automotive and transport ecosystem is that the long life cycle of vehicles and their varying roaming needs over time may make it necessary for a vehicle owner and/or OEM to change the subscription multiple times. Since the physical SIM cards that contain the subscription credentials are not easily accessible in vehicles, it is problematic to have to change them.

Embedded SIM (eSIM) technology overcomes this challenge by enabling remote provisioning of MNO subscriptions. An eSIM unit can be soldered into the cellular device which stores the MNO-specific network access credentials (the subscription) as a SIM card profile. The subscriptions can then be changed remotely over-the-air without physically touching the vehicle. To simplify the usage of this technology, the GSMA has developed an eSIM profile specification [6].

Roaming

It is common today for a vehicle to be produced in one country, sold in another, owned in a third, and driven across borders to numerous additional countries or regions, with high requirements on data throughput and latency independent of location. In light of this, roaming is frequently the default operating model for a connected vehicle. Today's roaming solution, however, is single-human-user-centric – designed to support users traveling outside the coverage of their home mobile networks. It is not designed for connected vehicles on a global scale. As a result, it has a number of limitations in automotive and transport applications.

Terms and abbreviations

3GPP – 3rd Generation Partnership Project | **ADAS** – Advanced Driver Assistance Systems | **AMQP** – Advanced Message Queuing Protocol | **C-ITS** – Cooperative Intelligent Transportation Systems | **DSDA** – Dual Sim Dual Active | **eSIM** – Embedded SIM | **GW** – Gateway | **HTTP** – Hypertext Transfer Protocol | **IEEE** – Institute of Electrical and Electronics Engineers | **IoT** – Internet of Things | **MAC** – Media Access Control | **MNO** – Mobile Network Operator | **MQTT** – Message Queuing Telemetry Transport | **NR** – New Radio | **OEM** – Original Equipment Manufacturer | **PC5** – LTE-V2X short-range access interface | **PGW** – Packet Data Network Gateway | **PDCP** – Packet Data Convergence Protocol | **PHY** – Physical Layer | **RLC** – Radio Link Control | **SCEF** – Service Capability Exposure Function | **SLA** – Service Level Agreement | **TCP** – Transmission Control Protocol | **TLS** – Transport Layer Security | **Uu** – Utran-UE (interface in 3GPP)

Firstly, since roaming fees are only partially regulated, they depend to a large extent on bilateral agreements between two MNOs. As a result, the fees can vary, which can make it difficult to predict the cost for the used connectivity in certain cases.

Secondly, it has traditionally been the case that only basic connectivity and communication is enabled while roaming, which means that some more advanced service and capacity requirements may not be met when a vehicle connects outside its home network. Roaming agreements between MNOs typically put limitations on how the connectivity can be used, and the visited MNO can disconnect the device if it is not in line with the agreement.

Thirdly, the currently deployed roaming architecture is designed to route traffic to the home network first, which increases latency. This is problematic in automotive use cases that are latency-critical or produce high data throughput. In these cases, fast access to national/local data centers is required.

Fourthly, the fact that a mobile device loses connectivity for some time (up to about 120 seconds) when being handed over from one MNO to another is a serious issue for many use cases. The reason for the delay is that the mobile device needs to first scan for a suitable network provider and then register itself in the new mobile network. This applies at both international country borders and national coverage borders.

In Ericsson's view, there are two complementary paths to overcoming roaming challenges in the automotive and transport industry:

1. Enhancing the existing roaming solution through the creation of an alliance of MNOs.
2. Avoiding roaming altogether by using local subscriptions and eSIM technology for provisioning in each local network.

The enhancement of the existing roaming solution would ensure that operators treat roaming users the same way they treat local users – that is, there would be no additional costs and roaming users would have consistent capability and support for low-latency and high-volume services. This could be achieved through the creation of an alliance of MNOs that enables the 3GPP roaming architecture "Local breakout in the visited network," [7] which would provide direct, fast access to local data centers.

Alternatively, it is possible to avoid the roaming model altogether by using local subscriptions and eSIM technology for provisioning in each local network. This approach ensures access to all the functionality and capacity provided by the local network, including direct access to local data centers. Some form of coordination of service, subscription and cost models between the involved operators would be required to achieve consistency.

Both of these alternatives involve the use of different core networks, which means that there can be variances in service experience and SLA support between operators. This is due to the fact that the core network is the entity that controls most of the service-specific parameters and manages the technical SLAs. Full harmonization of services and SLA control requires an alignment of core network functions.

Regardless of which option is chosen, a fast inter-MNO mobility solution is also required to reduce the time for network swap. A combination of network features in a recent trial has been shown to provide fast inter-network service continuity [8].

Local breakout and distributed computing

Several emerging automotive services require vehicles to be connected to the cloud and networks to facilitate the transfer of a large amount of data between vehicles and the cloud. Some of the services may be more time-critical, while other services allow time phasing to a different time slot or another access network. The AECC (Automotive Edge Computing Consortium) addresses the technical realization of such use cases by designing a topology-aware distributed cloud solution on a global scale, to better accommodate the needs of the automotive industry [9, 10].

Cost separation and traffic prioritization

In the automotive and transport ecosystem there is a need to separate the costs for cellular connectivity for different services in the vehicle targeted at

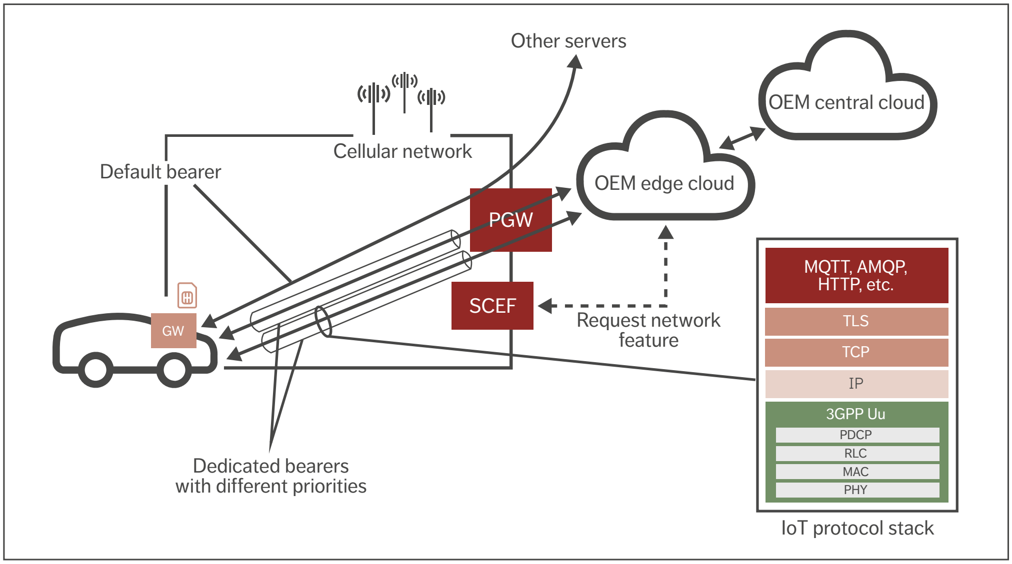

Figure 3 Usage of dedicated bearers for traffic separation within one vehicle OEM cellular subscription

different stakeholders – such as the owner of the vehicle or vehicle fleet, the driver/user of the vehicle, the vehicle OEM and traffic/road authorities. For example, one may want entertainment-related costs to be charged to the passengers, while the OEM covers the cost for vehicle-centric sensor data uploads. Support for data traffic prioritization is also essential, particularly at times of high network usage, such as when vehicles are stuck in a traffic jam.

There are two main alternatives for cost separation: multiple subscriptions or multiple connections using a single subscription (also known as dedicated bearers). A vehicle can have multiple subscriptions to connect with one or multiple mobile networks for multiple services. Multiple subscriptions can be active simultaneously when multiple services are needed concurrently. The vehicle can be either natively equipped to support multiple simultaneous active subscriptions through the use of a Dual-Sim Dual Active (DSDA) device, for example, or additional communication devices can be added to the vehicle later (each with its own subscription). These devices could be permanently mounted or they could be temporary devices such as the driver's smartphone.

A dedicated bearer framework allows separation of traffic flows for differentiated QoS handling and charging using a single subscription and single modem. 3GPP systems support traffic differentiation based on Policy and Charging Control rules. The term 'policy' refers to various traffic-handling policies, such as different QoS for different traffic flows.

In 4G networks, the separated data streams are handled as different bearers, which are known as dedicated bearers. The cellular network identifies the traffic flows based on traffic flow templates – typically a 5-tuple in the form of IP addresses, protocol and transport layer ports. The consumed data volumes can be accounted separately for each bearer. Within 5G networks, the separated data streams are handled as different QoS flows.

Figure 3 depicts an end-to-end architecture using dedicated bearers for traffic separation, considering distributed computing with edge clouds.

The edge cloud servers are shielding the central cloud servers by executing the heavy lifting workloads. The central servers coordinate the heavy workload functions and distribute the load across different edge cloud servers and sites.

The central cloud servers steer the vehicle's connection to an appropriate edge, which supports the service and has sufficient computational capacity. The policy rules for traffic separation can be provided either statically within the policy system of the network or dynamically using the Service Capability Exposure Function (SCEF), which is provided by the mobile network toward the OEM. The SCEF is evolving into the Network Exposure Function in 5G.

Figure 3 also illustrates an example protocol stack for different IoT connectivity protocols. Popular publish/subscribe IoT protocols like MQTT(S) or AMQP(S) can be used for event notification to one or more receivers. Vehicles can subscribe to channels (called topics) that provide information relevant to a certain geographical area.

HTTP(S) is typically used to fetch information or provide feedback. For use cases such as remote driving, additional protocols are used for sending uplink video and download vehicle control commands. When used with dedicated bearers, all the messages using the same transport connection (TCP, for example) will be treated according to the same policy rule (prioritization, for example).

In upcoming 5G networks, the network slicing concept [11] may be used for service and cost separation.

“5G PROVIDES A COST-EFFICIENT AND FEATURE-RICH FOUNDATION FOR A HORIZONTAL MULTISERVICE NETWORK”

Conclusion

The connectivity needs of the automotive and transport ecosystem are diverse and complex, requiring a common network solution rather than a single-segment silo approach. The ongoing rollout of 5G provides a cost-efficient and feature-rich foundation for a horizontal multiservice network. 5G networks (including 2G-4G accesses) offer excellent capabilities that make them the ideal choice to meet the wide variety of needs in the automotive and transport ecosystem. The time-to-market for 5G networks and services is faster than earlier generations, and the connectivity capabilities can be tailored to different services using mechanisms that enable both separated QoS treatment and separated charging. This functionality contributes to making 5G instrumental in helping to maximize the safety, efficiency and sustainability of road transportation.

Further reading

» **Learn more about evolving cellular IoT for industry digitalization at:** *https://www.ericsson.com/en/networks/offerings/cellular-iot*

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