ERICSSON

Time-Critical Communication

Leading the next wave of 5G innovation

5G roll-outs have been much faster than the earlier generations of mobile networks. In less than two years, more than 1 billion of the world's population is within 5G coverage [1]. Now, having established the initial 5G roll-out, we see that many emerging use cases are time-critical in nature and demand the highly reliable and consistent low-latency connectivity that 5G can provide. Time-Critical Communication will play a major role in the next wave of 5G-driven innovations for consumers, enterprises, governments, and public institutions [2].

Time-Critical Communication is designed to enable high reliability and consistent low-latency (commonly known as bounded latency), connectivity on a large scale – in wide and local coverage areas leveraging any 5G frequency band.

Time-Critical Communication

Emerging 5G applications are often time-critical in nature. Figure 1 shows some of the major applications – along with their key drivers and benefits – that can be enabled or enhanced by Time-Critical Communication.

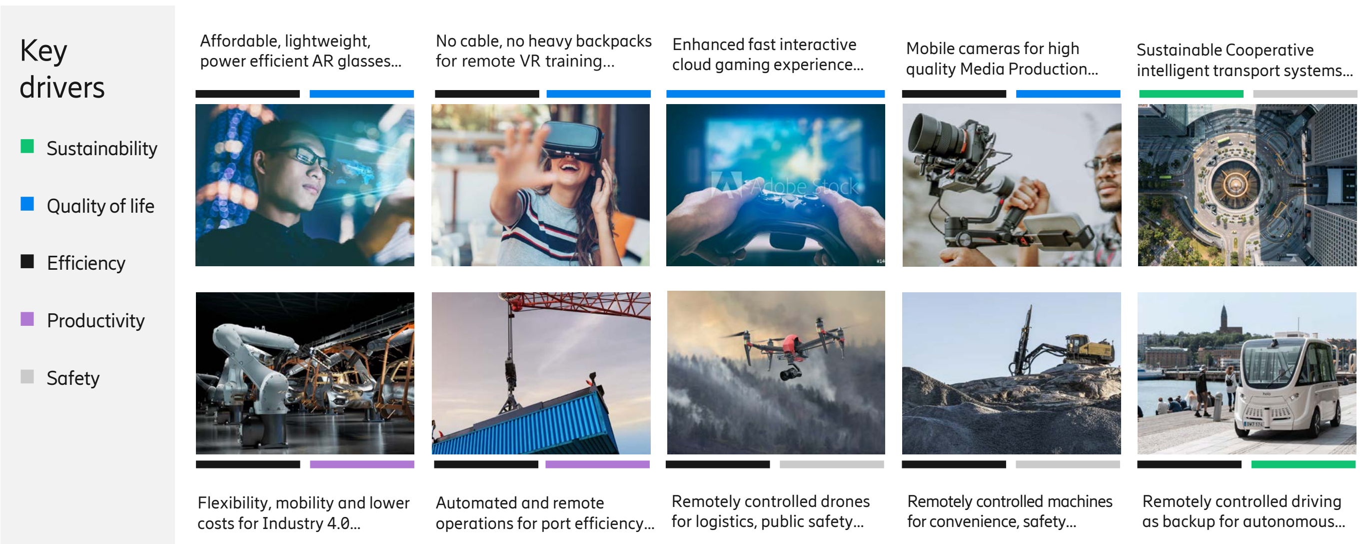


Figure 1: Key drivers for major time-critical applications

Definition of Time-Critical Communication

Time-Critical Communication is a software toolbox combining the 3GPP-sepecified ultra-reliable, low latency communication (URLLC) standard with Ericsson innovations to deliver a wide range of consistent low-latency and high reliability for diverse time-critical use cases.

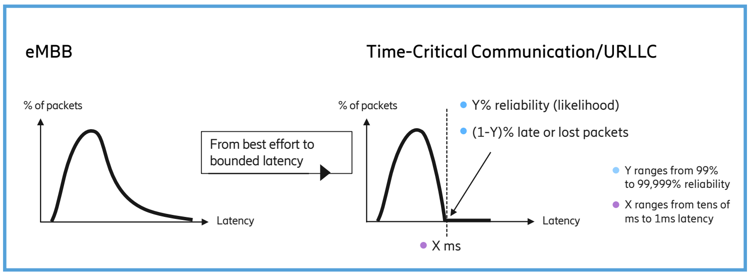


Figure 2: eMBB vs Time-Critical Communication/URLLC

Time-Critical Communication deliver data within the specific time window required by the application. A system designed for eMBB maximizes data rates without any guarantee regarding latency. In contrast, Time-Critical Communication is designed to secure data delivery within specific latency bounds (X ms) with the desired reliability (Y percent). Depending on user requirements, X ranges from tens of milliseconds to 1 millisecond latency and Y ranges from 99 percent to 99.999 percent reliability.

Use case categories

Each category includes use cases with a broad range of requirements – from consistent (that, is bounded) latency of tens of milliseconds down to single-digit milliseconds.

Real-time media:

Applications where media is produced and consumed in real time. For example, interactive cloud gaming, cloud-based augmented reality (AR), and virtual reality (VR) for various enterprises and consumers, including remote learning. Time-Critical Communication enables the offloading of processing and rendering to the mobile network edge, thus enabling the use of lightweight and cost-efficient devices such as head-mounted displays. AR and VR possess significant potential in terms of improving productivity, convenience, and safety for consumers, enterprises, and public institutions [3].

Industrial control:

A broad set of use cases for industrial automation systems requires real time control. These include process monitoring and control, controller-to-controller communications, smart grid control, machine vision for robotics, and motion control. Time-Critical Communication supports reliable exchanges of real time information between sensors, controllers, and actuators, which are a fundamental requirement of these applications [5]. Compared to wired communication, which is the norm for industrial automation today, 5G connectivity offers significant benefits in terms of mobility, flexibility, cost-cutting, and digitalization.

Remote control:

Applications of teleoperated machines, equipment, and vehicles. Time-Critical Communication enables real time sensor information to be exchanged between the tele-operated machine or vehicle and the remote operator. Remote controlling can improve working environments by removing humans from inconvenient or hazardous situations and give access to a broader workforce in off-site locations. Remote controlling is an important functionality for autonomous vehicles - especially for taking temporary control in case of mechanical failure or when in need of assistance [4].

Mobility automation:

The automation of control loops for vehicles and mobile robots. Time-Critical Communication support highly reliable real time information exchanges between moving vehicles and/or robots and the environment for control and coordination. Major applications in this category include automated guided vehicles, autonomous mobile robots, cooperative maneuvering of vehicles, critical communications for trains, and advanced intersection safety.

Reliability is defined as the success rate of data delivery within the time constraint required by the targeted service, according to 3GPP [3GPP TS 22.261].

Which markets can be addressed with Time-Critical Communication?

Time-Critical Communication represents the biggest differentiation between 5G and other technologies such as Cable, WiFi, Land Mobile Radio (LMR) and GSM-R. Cellular connectivity is the only viable option for many time-critical wide-area coverage use cases. For time-critical use cases with short-range connectivity needs, 5G outperforms wired connectivity both in terms of flexibility and cost-efficiency – and outperforms other short-range wireless technologies in terms of reliability, flexibility, and security.

Communication Service Providers (CSPs) can seize market opportunities presented by Time-Critical Communication through two complementary network deployment approaches depending on use case requirements in terms of consistent (that is, bounded) low latency, service availability , and coverage area:

- **General public infrastructures:**
  CSPs can provide software upgrades for Time-Critical services with moderate bounded latency and service availability requirements - reusing the existing network infrastructure to enable Time-Critical Communications. This will enable CSPs to monetize public networks beyond eMBB services by generating revenue from high-value, Time-Critical services to consumers and enterprises. Examples include AR, remote control, cloud gaming, and automotive use cases.
- **Dedicated infrastructures:**
  In contrast to general public networks, CSPs can deploy dedicated 5G infrastructure for an enterprise or a government (public) agency for use cases with extremely high requirements for service availability and/or bounded latency – either as an isolated network or as an extension to the existing public network. The dedicated infrastructure can be deployed either in a local area such as a factory, a port, or a mine, or in a confined wide area along a rail track, highway, or a city center, depending on the radio coverage needs of the user(s).

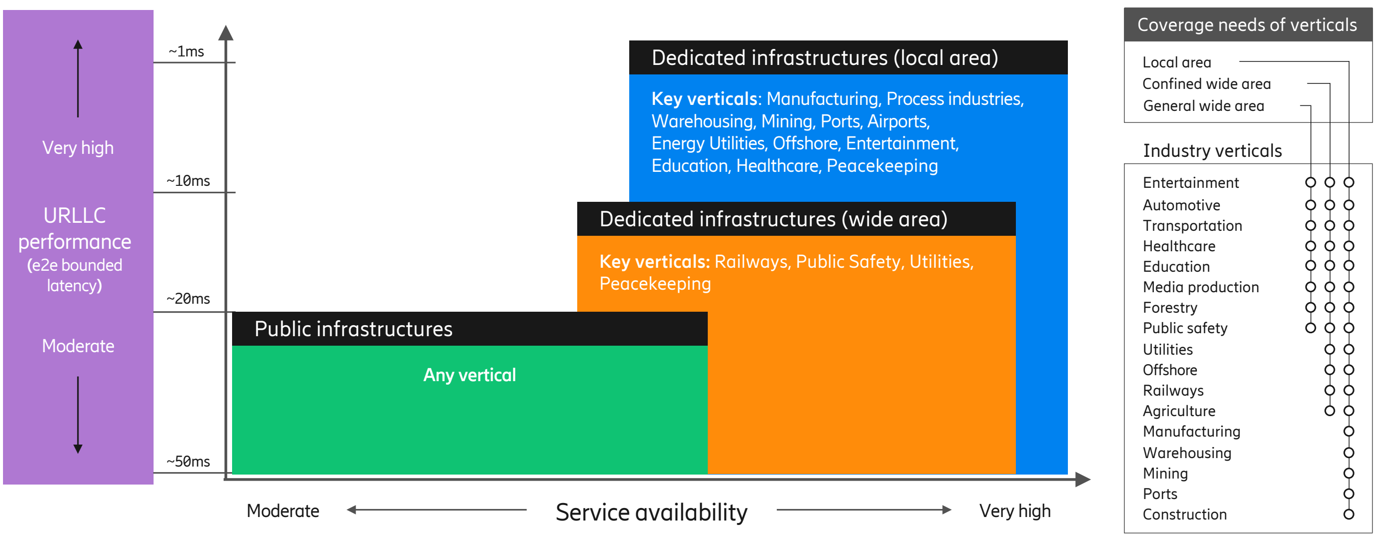
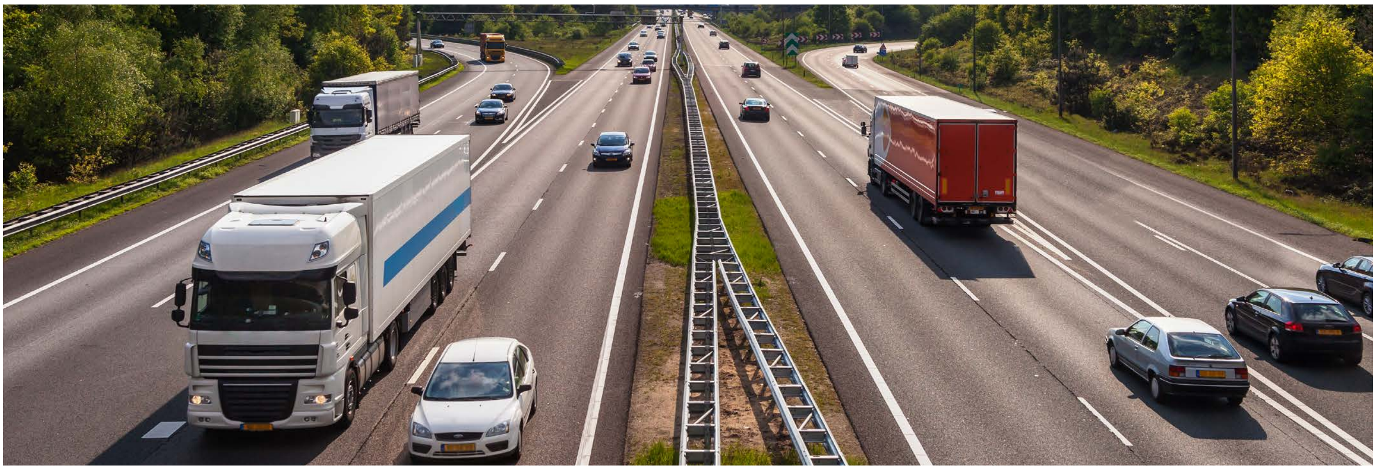


Figure 3: Market opportunities for addressing the time-critical use case requirements of verticals with 5G public and/or dedicated network infrastructure.

Service availability is defined as the success rate of delivering service according to an agreed Quality-of-Service (QoS) in a specific area, according to 3GPP [3GPP 22.104].

Spectrum considerations



Ericsson has the products, solutions, expertise, and vision to enable CSPs to take full advantage of all available spectrum assets. Time-Critical Communication can be supported on any 5G frequency band.

Frequency Division Duplex (FDD) bands are fundamental to coverage availability as they can transmit uplink and downlink at different spectrum frequencies at the same time. In contrast, Time Division Duplex (TDD) bands transmit in both uplink and downlink in using the same spectrum frequencies but at different times. For TDD bands, there are trade-offs to consider between uplink and downlink capacities, latency, and coverage, depending on the choice of the TDD transmission pattern. In addition, an important aspect of TDD bands is synchronized TDD patterns for networks on the same or adjacent spectrum. High Bands offer better isolation than Mid Bands due to radio wave propagation characteristics and, consequently, have relatively relaxed TDD co-existence constraints.

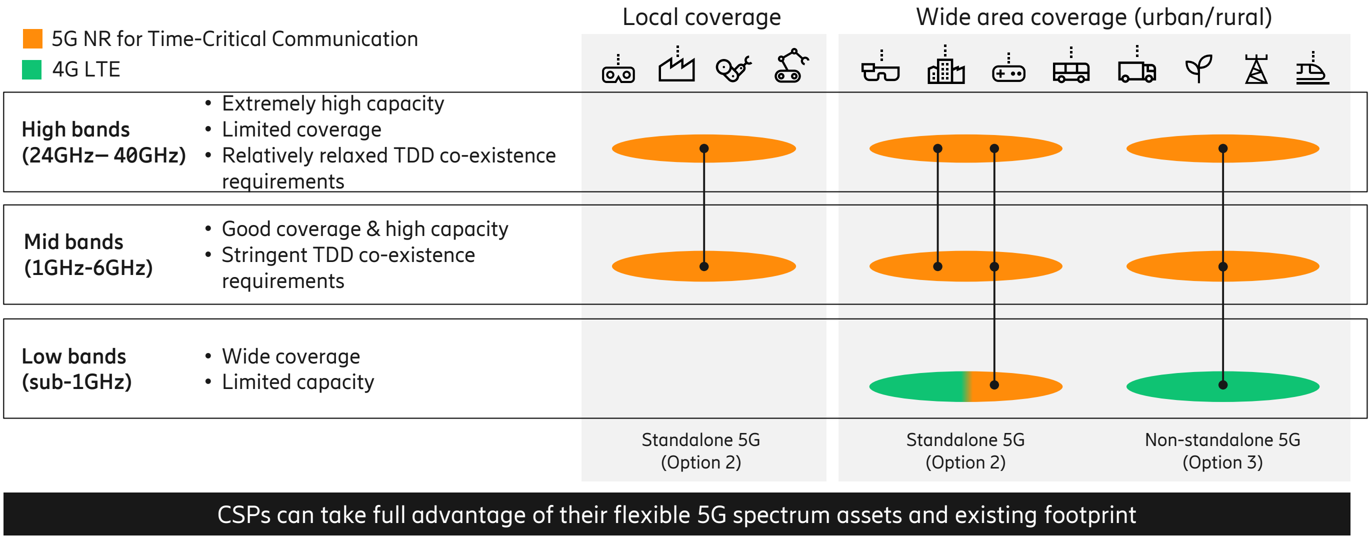


Figure 4: 5G spectrum for Time-Critical Communication

Dedicated spectrum has been allocated to some industry sectors in certain regions [6]. In wide-area scenarios such as public safety and railways, the allocated bandwidths are typically small (10MHz or below) and unable to meet the capacity demands of emerging use cases – especially those with time-critical requirements. In some regions, a significant amount of TDD spectrum has been allocated to enterprises for local use (in the order of 100MHz) in the Mid and High Band frequency ranges. For both confined wide-area and local-area scenarios, the reuse of existing infrastructure and their flexible spectrum assets with dedicated spectrum (if available) represents a source of major value and opportunities for CSPs. This approach makes it possible to exploit the full potential of various band combinations and support seamless mobility and interaction between public and dedicated communications infrastructure for enterprises.

How can service providers realize Time-Critical Communication?

Realizing Time-Critical Communication involves an end-to-end approach across the domain functionalities to give the desired end output. Ericsson's end-to-end solution for Time-Critical Communication encompasses the following domains: Radio Access Network (RAN), the transport layer, the cloud-native 5G Core (5GC) network, and the Operations and Business Support (OSS/BSS) domain.

While the 5G New Radio (NR) offers highly reliable and low latency access links between the User Equipment (UE) and the 5GC components of the network, the 5GC on the other hand establishes reliable, secure connectivity to the network for subscribers and provides access to its services. In addition to that, the core domain handles a wide variety of essential functions in the mobile network that is essential to Time-Critical Communication like QoS management, reliable communication, network exposure among others.

Ericsson has identified six major causes of latency and interruption in mobile networks [3]:

- Congestion
- Radio environment
- Mobility
- Standards and protocols
- Power saving
- Network topology

Ericsson approaches Time-Critical Communications by addressing these sources of latency and interruptions in efficient coexistence with eMBB. Relevant tools for addressing each source of latency are described in Figure 5.

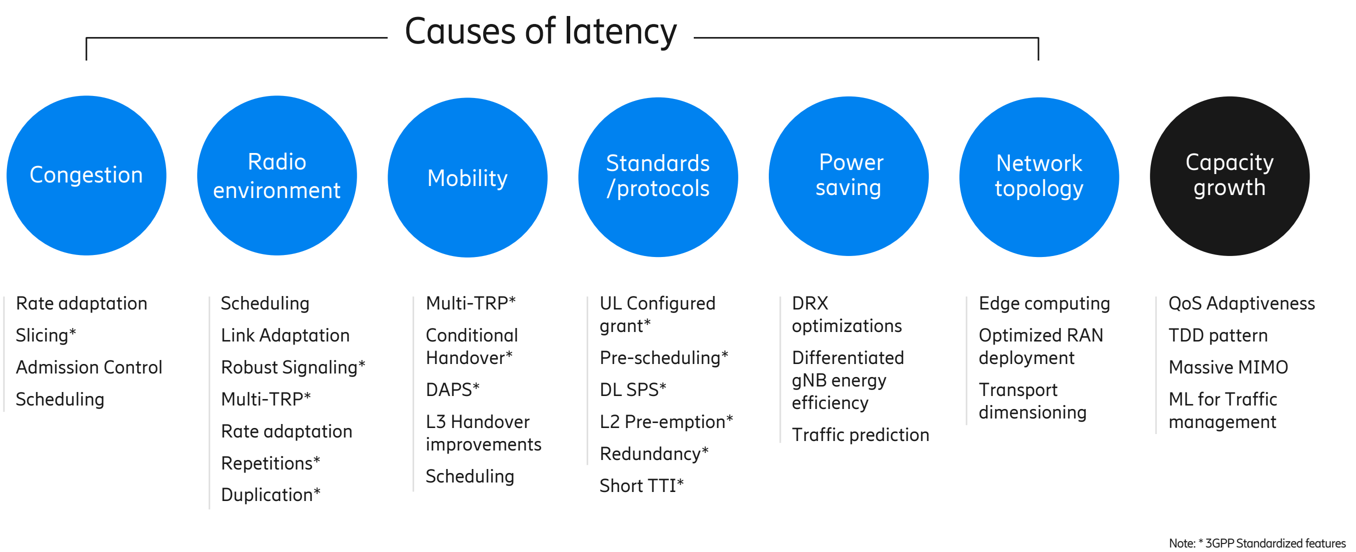
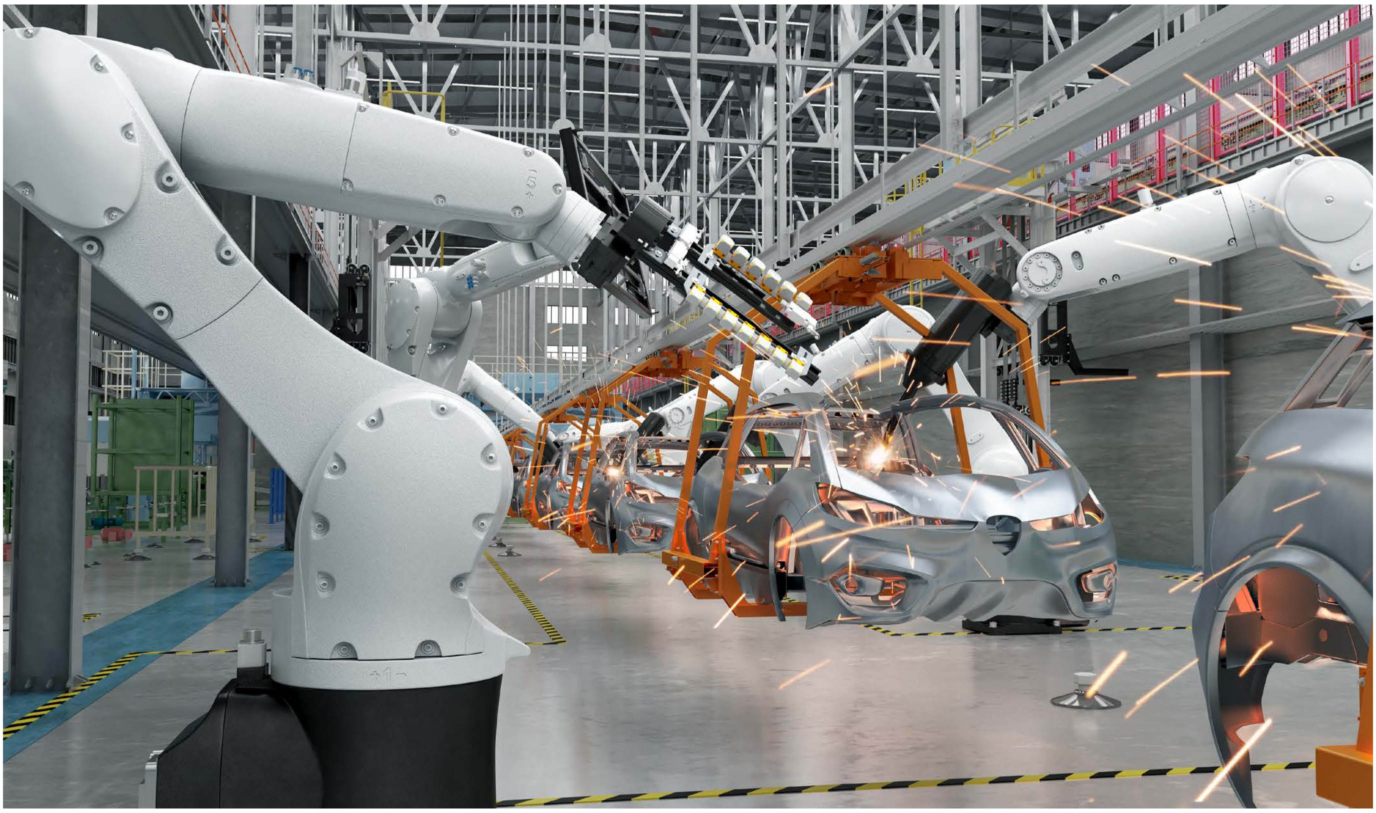


Figure 5: Time-Critical Communication overcome major sources of latency and interruption in mobile networks – an efficient coexistence with eMBB.

Time-Critical applications can work well over 5G networks provided CSPs differentiate the time-critical traffic from best-effort eMBB traffic using the end-to-end 5G Quality of Service (QoS) framework illustrated in Figure 6 below. This framework is designed to support the optimized treatment of time-critical traffic throughout the mobile network and mitigate different sources of delay by employing the relevant Time-Critical Communication tools.



Ericsson recommends two complementary 5G QoS approaches for time-critical applications [3]:

- Service-optimized QoS flows: These can be established for specific services with known service requirements in terms of packet delay budgets, packet error rates, and minimum guaranteed bit rates, among others.
- Generic latency-optimized QoS flow: This can be established when specific service requirements are unknown. The 5G system can have latency-optimized treatment of all packets following the generic latency-optimized flow. This can be an important tool to enable a large ecosystem of high rate, rate-adaptive, time-critical applications – without relying on tight coupling between applications and network.

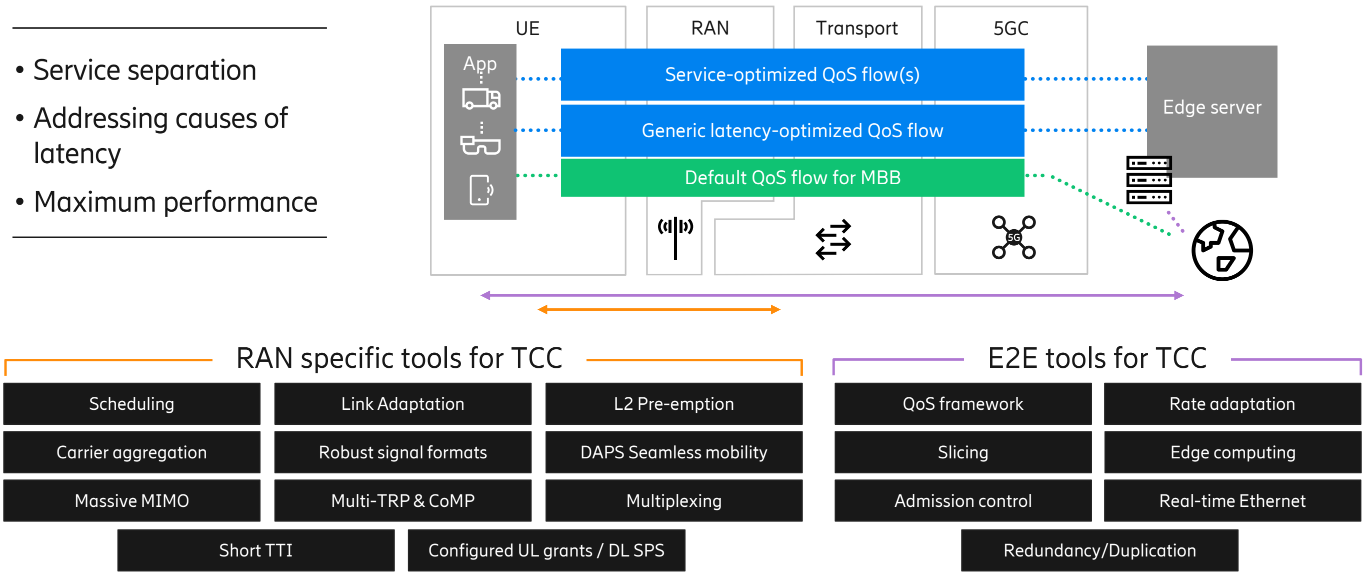


Figure 6: End-to-end solution for enabling time-critical services with 5G networks.

How to get started with Time-Critical Communication?

Ericsson puts forward a systematic approach for the introduction of Time-Critical Communication in 5G networks – building on its best-in-class offerings for 5G standalone systems, Massive MIMO (massive multiple-input multiple-output), edge computing, and network slicing. The approach illustrated in Figure 7 consists of preparing networks in terms of baseline enablers and introducing Time-Critical Communication capabilities step by step.

Some CSPs have started to deploy standalone 5G networks with Massive MIMO, QoS differentiation, edge computing, and network slicing. While not a mandatory prerequisite for Time-Critical Communication, these functionalities can provide a solid foundation for delivering time-critical services in efficient coexistence with eMBB. For some industrial deployments, integration of 5G with real-time Ethernet is also a fundamental requirement.

Ericsson recommends four overlapping steps, as shown in Figure 7.

1. The first step involves overcoming the most common sources of delay: Congestion, radio environment, and protocol-related delays.
2. The second step aims to minimize mobility-related interruptions such as handover latency optimization.
3. The third step strives for efficiency by optimizing for fundamental trade-offs between resource efficiency, energy efficiency, latency, and reliability.
4. The fourth step aims to achive ultra low latencies for selected deployments.

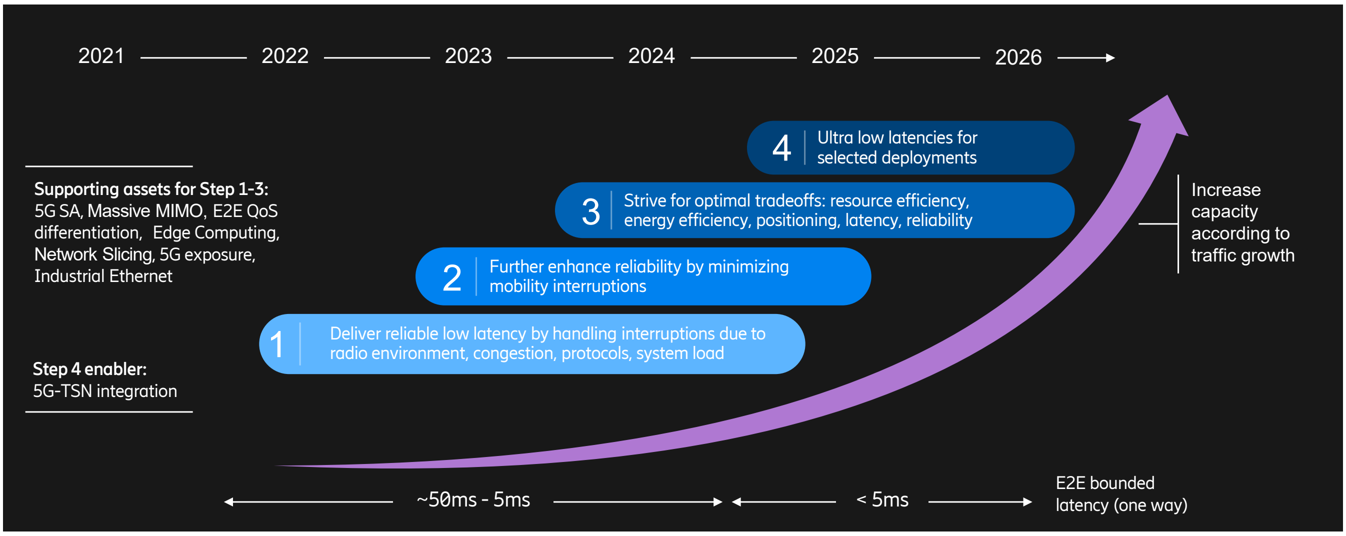


Figure 7: Phased introduction of Time-Critical Communication capabilities in 5G networks.

The first three steps are crucial for both wide area and local area network deployments and are more broadly applicable than the last step. The last step also targets extremely low bounded latency (below 5ms with ultra-reliability) for Local Area Networks, for example, to address the most demanding use cases in industrial automation.

Emerging use cases for Time-Critical Communication may bring additional requirements. These include precise device positioning for mobility automation, high uplink capacity for applications such as AR, remote control or media production, extreme service availability for public safety, and integration with wired industrial networks in smart factories. These requirements differ significantly from eMBB usage scenarios. Ericsson addresses these needs in conjunction with support for Time-Critical Communication to realize the full value of 5G.

Support services for Time-Critical Communication

As technology is evolving towards Time-Critical Communication, automation and collaborative services are becoming more important to help meet the demands on network performance and achieve an always-on network vision.

Ericsson support services powered by artificial intelligence and machine learning to deliver predictive automation and actionable preemptive insights capable of locating and fixing network anomalies automatically. This helps avoid impacting overall network performance – assuring high degrees of reliability and consistently low latency. Ericsson cocreates solutions and services adapted to the unique needs of each CSP to enable new use cases and deliver service continuity throughout the technology evolution journey.

Ecosystem evolution is happening

Figure 8 shows the evolution for time-critical applications with 5G public and private networks. Ericsson has demonstrated both the feasibility and value of various time-critical applications in collaboration with global ecosystem partners. The 5G ecosystem is moving towards the commercial introduction of time-critical applications in 2022, beginning with Real-time Media, followed by Remote Control and Industrial Control. Use cases employing Mobility Automation are expected later. Many time-critical use cases, such as AR and remote control, are common across various verticals.

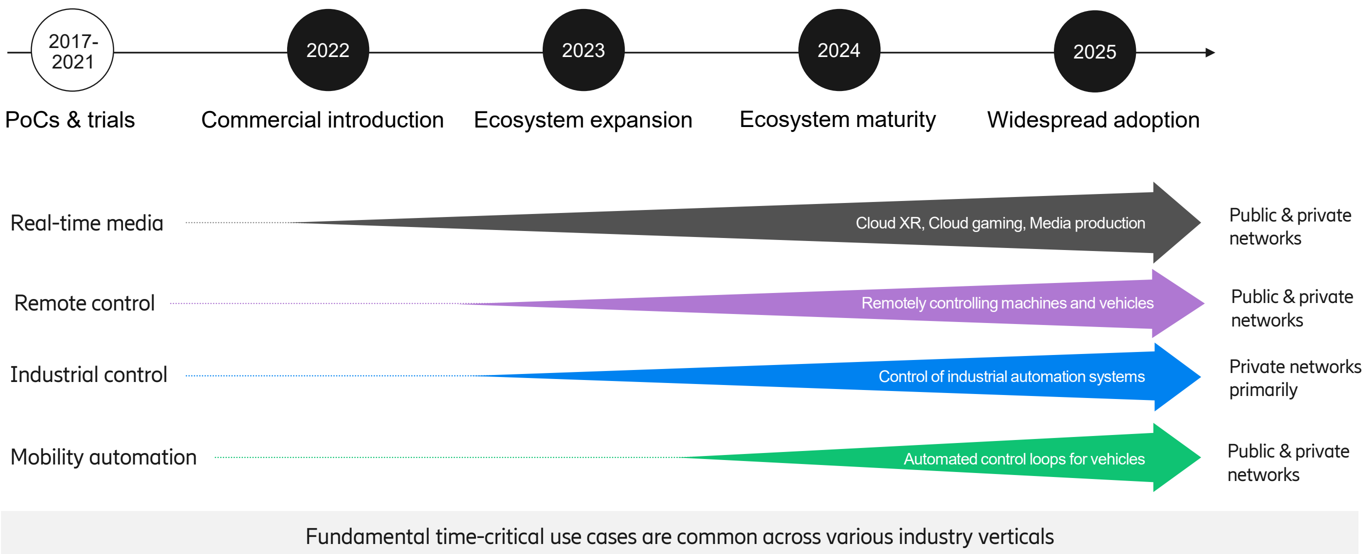


Figure 8: Expected evolution of time-critical services with public and private 5G networks.

Summary

Time-Critical Communication is designed to empower 5G networks and enable innovative services for consumers, enterprises, governments, and public institutions with requirements for consistent low-latency and high reliability. They enable CSPs to monetize existing 5G public network assets by delivering new services beyond eMBB. They can also enter the high-growth private networks market by substituting cables, Wi-Fi, and legacy LMR systems cost effectively with 5G across various industry verticals.

Ericsson's end-to-end solution for Time-Critical Communication is unique in its holistic approach for addressing the entire range of time-critical applications with 5G public and private networks. The solution focuses on flexibility and scalability. It can be deployed as a software solution on top of the existing 5G network infrastructure, levering all available 5G bands. It contains tools for efficiently overcoming the major causes of latency and interruption in mobile networks, in coexistence with eMBB. The tools help CSPs optimize networks for best trade-offs, considering the mix and volume of services being supported in each deployment, building upon Ericsson's best-in-class 5G standalone architecture, Massive MIMO, network slicing, and edge computing technologies.

Trials

Ericsson has been piloting 5G for time-critical use cases with customers and industry partners since 2017, visit this page for more reading.

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