TECHNOLOGY

Mobile transport for 5G networks

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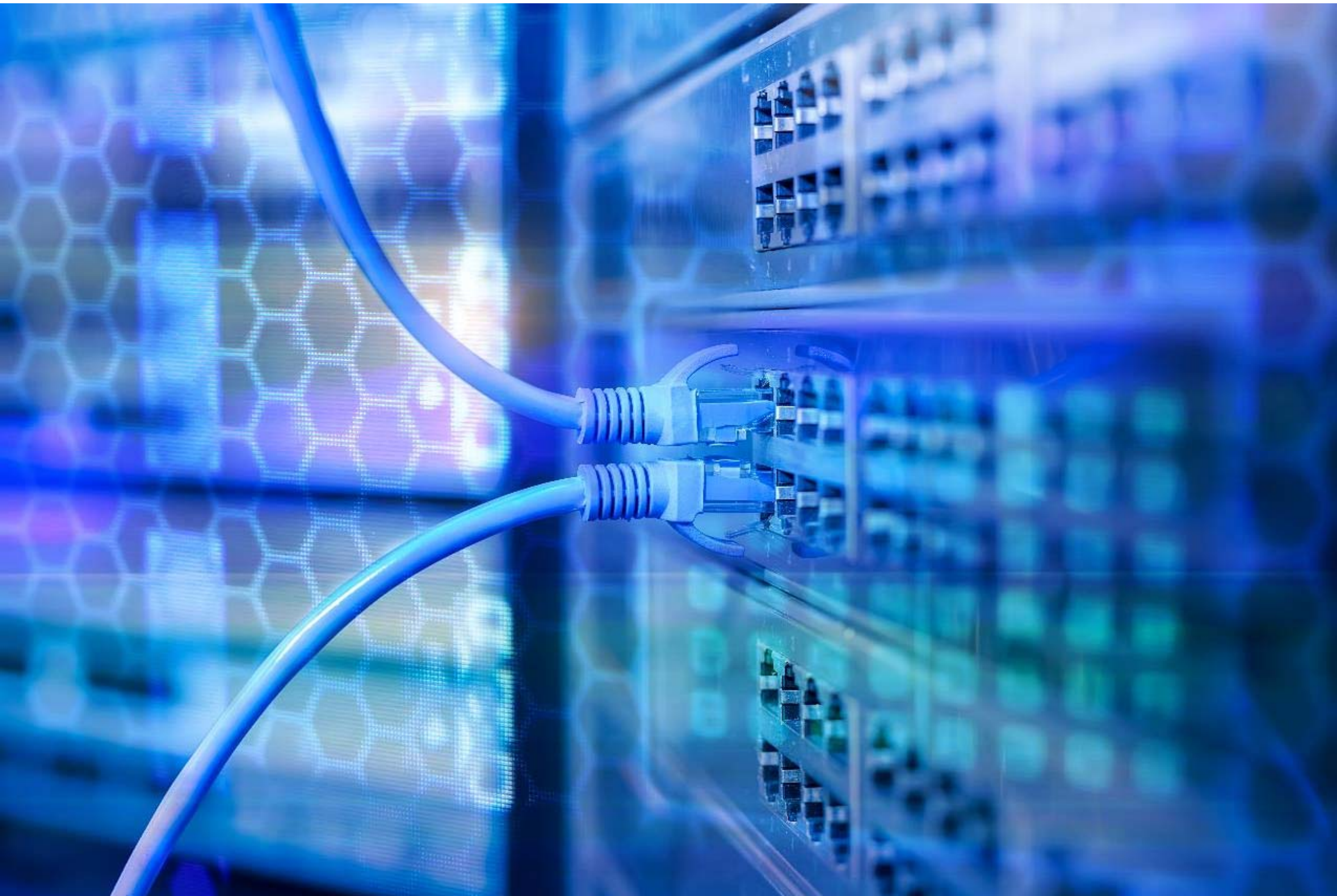

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Introduction

5G brings the promise of a range of new applications enabled by 10x higher wireless speeds, low latency, and ultra-reliable connectivity. To support these new applications in an efficient manner, the underlying mobile transport network infrastructure must evolve. In addition, new 5G radio technology and evolving radio network architectures will also drive new transport requirements. There are several emerging technologies and applications that are expected to play a key role in 5G mobile transport infrastructure.

The evolution of mobile transport

Mobile transport is the underlying infrastructure that interconnects mobile network elements, including radios and baseband processing units, to the mobile core where connections are managed and mobile services are delivered. Typically, mobile backhaul has dealt with supporting connectivity from the radios to the mobile core, while the mobile backbone has provided connectivity between mobile core elements in different physical locations.

Mobile transport and, in particular, mobile backhaul, has evolved over time with each successive generation of radio technology and services. 2G radios, which supported digital voice and SMS services, required 64 Kbps transport connections and were served by a TDM-based PDH backhaul network infrastructure. The introduction of 3G brought support for data in addition to voice services and supported peak rates of 2 Mbps. ATM networking technology was commonly deployed in 3G mobile backhaul networks for its ability to efficiently support both TDM voice and packet data with the appropriate quality of service required to guarantee voice traffic while concurrently transporting best effort data traffic. As 4G radios and services hit the market, the volume of data traffic began to exceed voice traffic and the transition towards pure packet-based backhaul began in earnest. ATM was replaced by IP over Ethernet-based backhaul, and IMS infrastructure was introduced to support voice over LTE services (VoLTE).

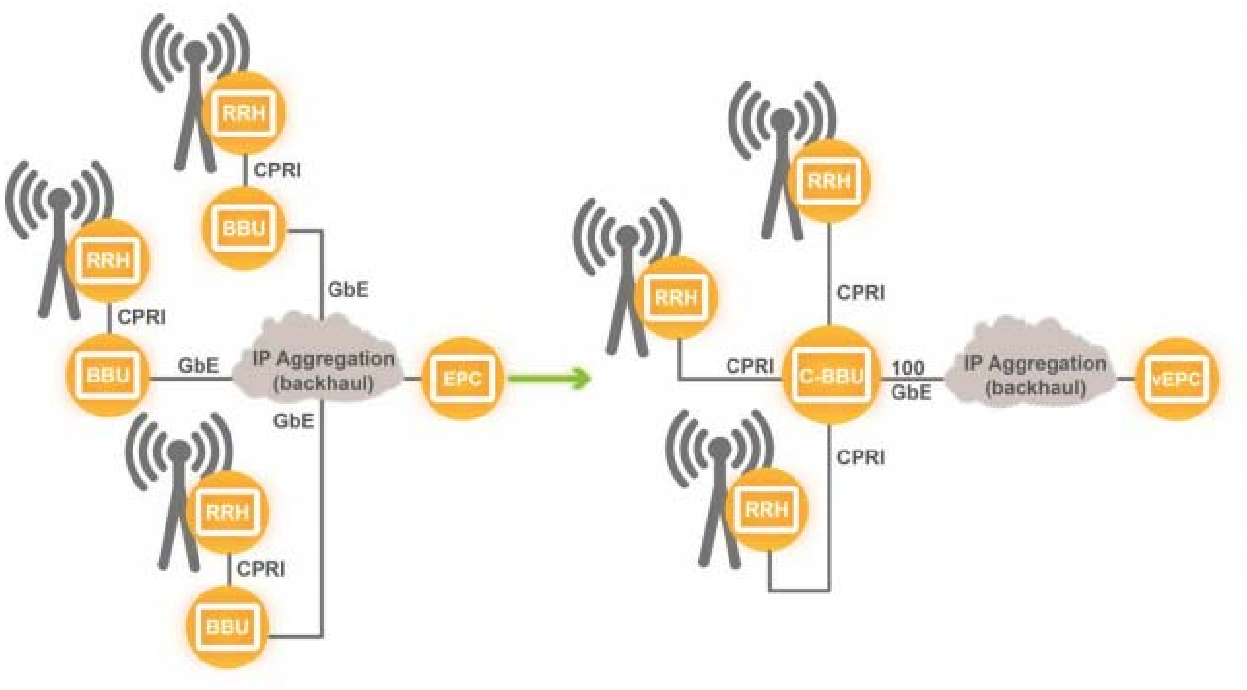
Exhibit 1: Summary of mobile transport evolution

Generation	Capabilities	Service characteristics	Peak speed	Transport
1G	Analog Voice	• 1st wireless voice service • 'Luggable phones'	2 Kbps	Analog
2G	Digital voice + SMS	• TDM voice, SMS • Smaller handsets	64 Kbps	PDH/TDM
3G	Mobile data	• Voice + SMS + email • Blackberry devices	2 Mbps	Hybrid TDM, ATM
4G	Mobile broadband	• Internet + video + voice • iPhone, smart phones	1 Gbps	All-IP, packet
5G	Extreme speed, connectivity, reliability	• eMBB • Fixed wireless • NB-IoT • Ultra-reliable, low latency services	10 Gbps	Cloud-based, more capacity, KPIs for latency, security

Source: IHS Markit, 2018

A new and fundamental shift in mobile network architectures began in later releases of the 4G specifications with the concept of the centralized RAN (CRAN). CRAN architectures separate the baseband processing units (BBU) from the radio heads (RH) and consolidate the BBUs at centralized locations remote from the radios. Mobile fronthaul was introduced as a term to describe the up to 20 km long analog connection between the remote radio heads (RRH) and the centralized BBU. Typically, CPRI or OBSAI protocols are used to support transmission of analog data between the RRH and BBU. Due to the high capacity and stringent latency requirements, dark fiber, CWDM, or DWDM transport is typically used for these connections.

Exhibit 2: C-RAN architecture - distributed RRH / centralized BBU



Source: IHS Markit "Mobile Fronthaul Equipment Market Report", July 30, 2018

The introduction of 5G wireless technology will bring yet further evolution to the mobile transport infrastructure. The service mix will evolve from high speed mobile broadband services to a mix of even higher speed enhanced mobile broadband (eMBB) services, end-connection intensive machine-type-communications (MTC), and ultra-reliable, low latency communication (URLCC) services. Each of these service types puts different requirements on the underlying network infrastructure and drives evolution in the capabilities and architectures of mobile transport networks.

Challenges on the road to 5G mobile transport

5G has the potential to set the stage for significant innovation in consumer services and to provide a platform for transformation across a wide range of vertical industries including healthcare, public safety, and transportation. Much in the way the Internet set the stage for a new economy based on e-commerce and social interactions, 5G also has the potential to open up a new economy and create new markets.

This breadth of scope in new potential 5G services will impact the evolution of the underlying transport infrastructure and drive transport network evolution in multiple ways:

- eMBB fixed and mobile services will drive backhaul connectivity speeds from the 300 Mbps to 1 Gbps speeds typical in 4G deployments to 10 Gbps and beyond for 5G deployments.
- Applications such as autonomous vehicles, remote surgery, and industrial automation will put new requirements on the transport network for latency, reliability, and security.
- Scale in the number of connected devices anticipated with IoT and massive machine-type communications will drive a mix of connection-oriented and connectionless services and the need to efficiently support at scale—a combination of best-effort services and mission critical services over a single network.

In addition to new applications, the evolution of the radio network itself will place new requirements on the transport network:

- Radio features such as coordinated multi-point (CoMP) and inter-cell interference coordination (ICIC) will require very low-latency connections and precision timing and synchronization to function optimally.
- Massive MIMO on radios offers improved performance but necessitates very high connectivity speeds on fronthaul connectivity.
- The combination of the desire to cost-effectively support higher speeds using packet-based technology while also supporting stringent timing/synchronization requirements introduces the need for new packet-based, time-sensitive transport technologies.
- The disaggregation of the mobile core plus radio network slicing to support different classes of services will drive the need for the transport network to also support KPIs for different network slices.
- Industry interest in “open RAN” technology may place further requirements on the network in terms of new protocols to be supported and new transport network APIs for orchestration and control.

It is also important to note that the transition from one generation of wireless technology to another always happens over an extended period of time. As a result, there will be a further requirement to concurrently support the needs of both 4G and 5G (and even 3G) transport for several years. With these challenges in mind, let’s now have a closer look at some of the emerging transport technologies and architectures emerging to support the demanding requirements of 5G transport.

5G-ready mobile transport

Fronthaul evolution

To date, CPRI has been the main fronthaul interface deployed in CRAN architectures. CPRI was designed as a simple synchronous protocol for carrying sampled radio signal and synchronization data between the radio and the baseband processor. However, it requires a large amount of bandwidth and very stringent delay and delay variation support. To meet the twin requirements of capacity and low delay, passive and active CWDM and DWDM solutions have been developed and deployed for CPRI fronthaul in 4G/LTE CRAN network architectures. Moving towards 5G, it is clear that CPRI was not designed for high bandwidth applications and must be evolved.

The notion of split processing providing different functional splits of what functions occur at the RRH and what functions occur at the BBU is at the core of new fronthaul solutions. Putting more functionality closer to the RRU reduces the bandwidth and latency requirements on the transport network, enabling the use of packet transport. The approach, however, also reduces or eliminates the advantages of centralized baseband including BBU pooling, resource sharing, and features such as CoMP. As a result, a range of splits optimized for different use cases has been proposed by the 3GPP. Different splits will be more suited to different types of applications. For example, fixed wireless applications do not rely on cell site coordination and have less stringent latency requirements. This is contrasted with autonomous vehicles where the round-trip delay budget will be tightly monitored and can be better addressed with a different functional split. We expect that a small number of solution-oriented splits will be identified and fronthaul solutions and networks will be designed accordingly.

Two main camps have emerged for the evolution of the CPRI interface and mobile fronthaul in general:

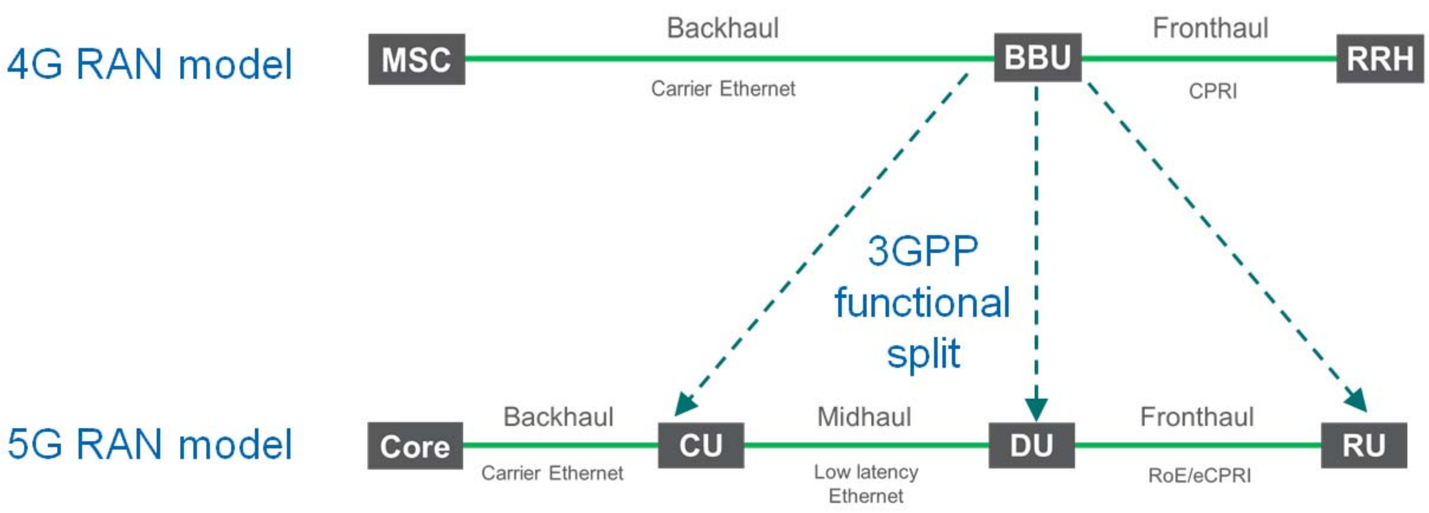
eCPRI is a packet-based fronthaul interface defined by the CPRI Forum and is focused on enabling transport over Ethernet/IP with synchronization and security relying on existing standards. eCPRI promises a 10x reduction in the amount of required bandwidth as compared to traditional CPRI. The specification outlines a functional split in the PHY layer that keeps most of the functionality in the BBU. This preserves the benefits of the CRAN architecture while also enabling the use of Ethernet for transport, SyncE and PTP for timing and synchronization, and a variety of protocols including IPsec and MACsec for security.

NGFI (next-gen fronthaul interface) is an alternate approach proposed by the IEEE addressing both the transport architecture for fronthaul and a new specification for encapsulating radio signals into Ethernet packets (RoE). Along with RoE, the IEEE has also recently published the 802.1 CM specification for time-sensitive networking (TSN) for fronthaul, providing a path for Ethernet to be used in fronthaul applications.

Midhaul emerges

With the introduction of BBU functional splits, fronthaul in the 4G RAN context evolves into two transport segment splits in the 5G RAN context. As seen in the following diagram, BBU functionality is in effect virtualized and split out across three different functional locations in the network: the radio unit (RU), distribution unit (DU), and central unit (CU). Fronthaul describes the connection between the RU and DU in this model, whereas a new term "midhaul" is used to describe the connection between the DU and CU.

Exhibit 3: Impact of BBU functional splits on midhaul transport



Source: Fujitsu Network Communications

From a transport technology perspective, the CPRI over WDM solutions deployed in the 4G RAN fronthaul model will evolve from WDM to packet-based solutions leveraging new specifications for time-sensitive Ethernet. Backhaul connections between the 4G BBU and mobile switching center (MSC) or the 5G CU to mobile core are anticipated to continue to leverage similar solutions albeit with increasing capacity demands as more 5G traffic is onboarded to the network.

Options for network slicing

The concept of network slicing in carrier networks has been around for a long time, delivered in the form of VPNs, VLANs, and IP/MPLS VPNs. Today, the mobile world has defined radio-layer network slices that will enable the efficient support of different wireless services with different requirements. For example, mobile broadband services are connection-oriented, require increasing bandwidth, and scale to serve millions of connections. M2M/IoT are primarily connection-less, may require very little bandwidth per connection, and could potentially scale to support billions of devices. Designing a single radio network architecture to meet multiple use cases in an efficient, cost-effective manner is very difficult if not impossible. However, the virtualization of mobile core functions means that it will now be easier than ever to dedicate a mobile core instance to a particular service or end customer. For the radio slice to work as required, a corresponding mobile transport network slice must also be enabled.

For the underlying mobile transport, network slicing capability has been available for years in different guises. L2 and L3 VPN services are network slices, Ethernet VLANs, OTN ODUs, and even wavelengths are mechanisms to provide separate and delineated networking capacity over a shared common infrastructure. Historically, mobile transport has been a “set and forget” kind of project—once backhaul was commissioned, it was pretty much left alone until the next round of capacity enhancements was implemented. Moving forward, fronthaul and backhaul will become much more dynamic. The underlying physical connection will still be set, but traffic flows and patterns will become much more dynamic and aligned with the ebbs and flows of the various services supported across the infrastructure.

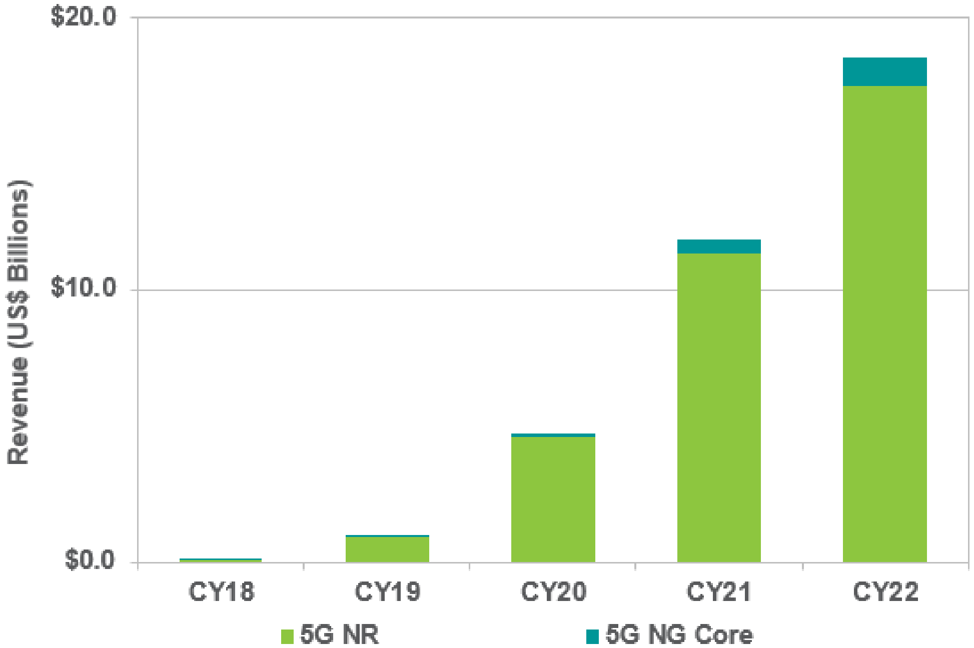
Bringing it all together will require a network slice servicing the entire connection from end user to end user. To make this happen, there must be close coordination between RAN and mobile transport and some common cross-layer network intelligence that can bring it all together. Vendors with both mobile and transport resources have the best shot at solving these challenges, but it is not a slam dunk. There is a lot of work ahead on the transport side to help the mobile team realize their vision for delivering both consumer and M2M services in a cost-efficient manner.

Timing for the introduction of 5G

The introduction of 5G will happen in stages, much as we saw in 4G LTE as we went from LTE, LTE-A and then to LTE-Pro. The first of the 5G standards, the 3GPP’s non-standalone (NSA) – new radio (NR) release 15 specification, was frozen in December 2017. The follow-on standalone (SA) specification was frozen in June 2018. The industry now has the initial standards and building blocks for initial 5G applications with more to come in 3GPP release 16.

With the standards becoming available, IHS Markit anticipates initial 5G radio deployments in 2018 and 2019. Deployments will ramp up in volume in 2020 and continue to grow through 2022. We expect North America will be the initial market for 5G, followed by China in a 2020 timeframe. The market forecast for 5G radio and mobile core solutions is forecast to grow to over $18B by 2022.

Exhibit 4: Total mobile 5G hardware infrastructure revenue



Source: IHS Markit “Mobile Infrastructure Market Tracker”, March 29, 2018

Bottom line

After many years of debate and discussion, 5G radio technology is becoming standardized, and early deployments are starting in 2018. The potential for a wide range of new 5G-enabled services holds great promise for the industry and for the evolution of communications in general. With the introduction of new 5G radio networks and services, the underlying mobile transport infrastructure must evolve. In addition to greater capacity, there is the need to introduce capabilities and architectures that can accommodate large numbers of low-latency, highly reliable connections. Virtualization of the mobile core and the introduction of network slices at the radio layer will require close coordination with mobile transport.

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