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Precision 5G Transport – The Foundation of Future Mobile Network

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1. Executive Summary

As 5G networks develop, it becomes obvious that the quantum leap in capabilities of radio network also brings significant shift in system-wide architectural requirements. In this context, transport network, connecting 5G radio to the core of the network, needs to evolve in several directions:

- Significantly higher capacity and scalability
- Support for varied deployment models
- Sophisticated slicing capabilities
- Precise, varied, and robust timing and synchronization
- Low and controllable latency characteristics, to the point of determinism

These requirements effectively define the new mobile transport network, one purpose-built to support mature 5G networks, capable of supporting major new revenue-generating use cases, such as IIoT, AR/VR streaming content and gaming, critical communications, and autonomous driving. In the context of system-wide performance, 5G transport network that effectively delivers capabilities in line with the above requirements represents a necessary element of operator's 5G network development strategy.

1.1. Key messages

5G transport network standards, technologies, and ecosystem are still evolving; nevertheless, the developments in the marketplace have shown that:

- Current 5G networks have not generated massive demand for new transport network capabilities – this will however dramatically change with standalone 5G deployments.
- The list of quantitative and qualitative differences between legacy and future-state 5G transport is relatively long, and the complexity of new networks will be, in most cases, significantly higher compared to legacy mobile transport.
- 5G mobile transport will need to set new standards in capacity, scalability, and precision of service delivery, satisfying stringent timing and synchronization requirements, and tight system-wide latency budget. Additionally, it will need to be very versatile in terms of protocol support, and likely utilize a wider set of connectivity solutions than was the case with previous generations of mobile technology.
- The new transport network will need to be built relatively quickly, to support massive increase of subscriptions and new use cases that will underpin digitalization of industry verticals and society functions.

2. Current Perspective of 5G Transport

2.1. 5G Transport Market State of Play

In planning, development and deployment of mobile networks, transport needs primarily stem from the capacity of deployed radio access. With that in mind, the current situation in 5G transport corresponds with the state of the 5G radio access deployments:

- Operators are at present mostly using 5G as the carrier of high-speed data, using the non-standalone (NSA) mode of operation, utilizing 5G radio access in mid-band spectrum, in conjunction with legacy (4G) transport and core networks.
- Additionally, these NSA deployments' geographic footprint usually corresponds with existing 4G network deployments.
- The above characteristics of NSA deployments usually mean that the transport needs of such networks scale mostly in capacity required per link.
- Consequently, mobile network operators therefore primarily choose to augment capacity of transport links in accordance with the pace of 5G deployment, using legacy technologies at their disposal.

However, the NSA deployments will likely be a relatively short and transitional phase of 5G networks development. A wide industry consensus is that great majority of networks will, over time, transform into standalone (SA) 5G networks. This is because only an end-to-end, SA 5G network will be able to satisfy the capacity, availability, latency, and determinism needs of advanced mobile connectivity use cases that are expected to be the primary revenue drivers for mobile operators in the future. With that in mind, operators and vendors are at present evaluating and developing several types of solutions designed to contribute to SA 5G architecture and provide transport fit for future advanced use cases.

2.2. Status of Standard Development

The complexity of the future 5G radio landscape translates into complexity for 5G transport as well. Several standards bodies, or trade organizations, like CPRI Consortium, 3GPP, ORAN Alliance, IEEE, or TIP have already defined, or are working on defining. elements of the 5G transport. Other organizations, like ITU for example, are contributing standards related to system-wide functions, like operations and management and network slicing.
Finally, 5G transport also can use standards not specifically developed for this specific purpose, but very useful for enabling some demanding 5G use cases, like FlexE (developed by OIF), and IETF-defined segment routing.

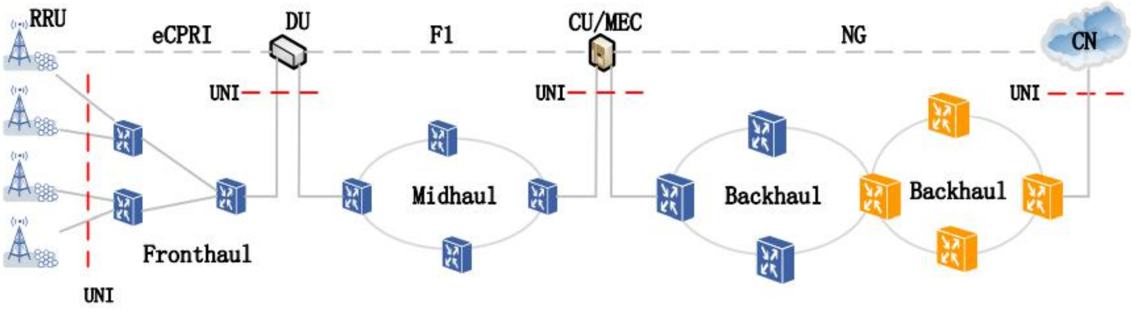
Most of these technologies are standardized already, with the notable exception of xRAN interface promoted by ORAN Alliance.

2.3. Technologies Used and Projected

As a rule of thumb, mobile transport network complexity grows with each new generation of mobile radio technology. 5G is no exception to the rule – quite the contrary, because the number of options for distributing physical and logical elements significantly increased in 5G, compared to previous mobile technology generations.

2.3.1. Fronthaul and Backhaul

5G Reference architecture divides transport domain into three subdomains, which may all be used within one network. Virtually all 5G networks will need backhaul; the use of fronthaul and midhaul depends on the chosen network architecture, namely on the level of network distribution used. As a rule of thumb, the more geographically distributed the radio network, the more complex transport network that serves it will become.



SOURCE: ITU-T, 2018

Figure 1: 5G Transport Reference Network

3GPP standardized F1 interface, deployed over IP/Ethernet links, seems to be the most probable candidate for the midhaul standard interface; while backhaul will most likely remain the domain of L3-capable, routed IP connectivity.

2.3.2. L0-L1 Choices

The complexity in architecture and protocol selection translates into increasing complexity in physical and connection layer technology choices. Most vendors today offer a blend of WDM and gray optical interfaces in their mobile transport portfolio; smaller number of operators offers PON (passive optical networking) based solutions in service of mobile transport; proprietary solutions, such as point-to-multipoint WDM have also been proposed. In parallel with wired solutions, several microwave options stay in play, although in mature 5G networks optical fiber will most likely be used as the preferred medium.

3. 5G Transport Key Challenges

3.1. Growing Capacity Demand

Transport bandwidth requirements vary with the radio channel bandwidth; for example, fronthaul will require single-digit Gbps links for 10-20 MHz channel bandwidth, to tens of Gbps for 200 MHz of spectrum used, with future fronthaul links of up to 200 Gbps conceivable for high-load scenarios with millimeter wave cells in dense urban areas.
Notwithstanding the much higher efficiency of 5G fronthaul interfaces compared to CPRI, these requirements will mean a quantum leap of capacity required throughout the network, all the way to the metro and in some cases long-haul transport. The impact will, however, not be linear, due to statistical multiplexing gains in parts of the network where L3 functionality exists.

3.2. Stringent Requirements for Latency, Timing, Synchronization, Determinism

5G use cases – especially the ones related to real-time IoT applications – require very low-latency performance from the transport network, both in 5G-specific transport domains (fronthaul, midhaul, backhaul) and the transport network overall. 5G also introduces very stringent time synchronization standards into the transport network. Network-wide synchronization precision of +-1.5 μs maximum time error has been adopted in ITU-T recommendations and 3GPP 5G standards. In addition to time synchronization, frequency and phase synchronization also need to be considered. Additionally, inter-band CA requires +/-130ns accuracy, while local area 5G high-precision positioning needs +/-10ns synchronization accuracy.

Table 1: 5G Transport Latency Requirements

At F1 interface	1.5~10 msec
At Fx interface	100, 125, 250 and 500 μsec (a few hundred μsec)
Fronthaul	<100 μsec
UE-CU (eMBB)	4ms
UE-CU (uRLLC)	0.5ms

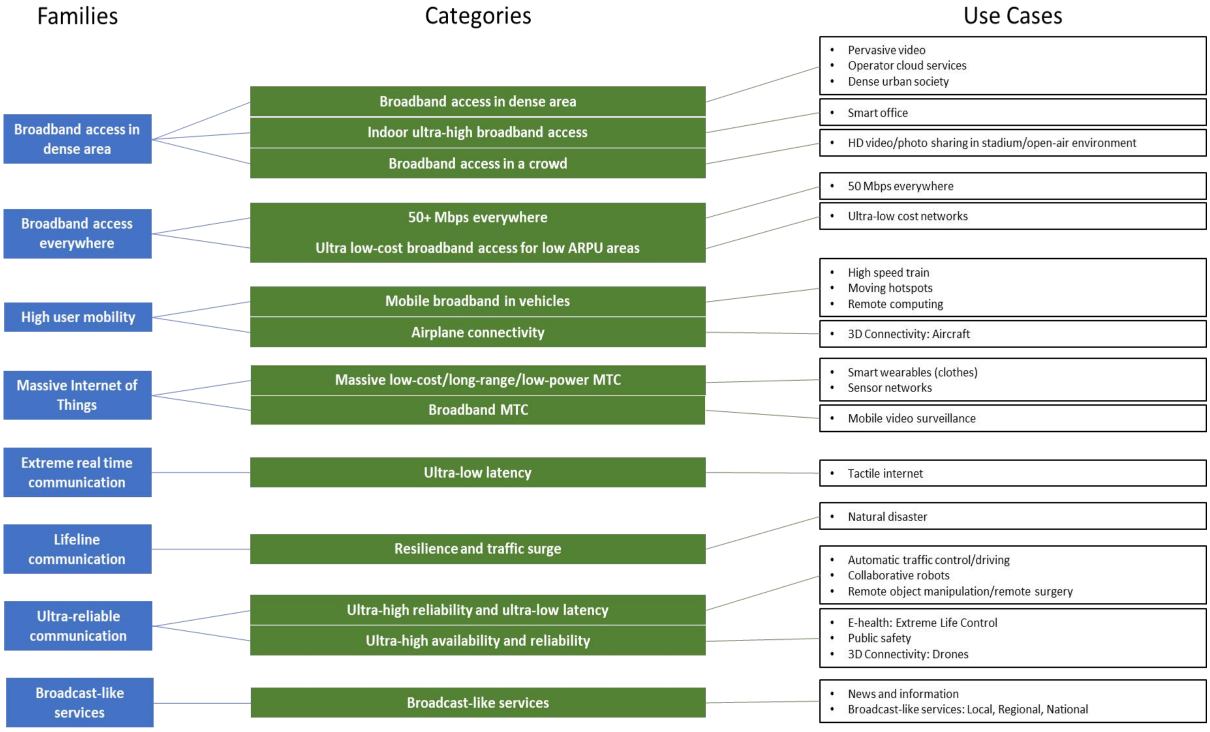
SOURCE: ITU-T, 2018

As is evident in the latency requirements, the importance of precision grows with more sophisticated use cases – the ones that are supposed to be the biggest new revenue generators for future 5G networks. This set of requirements is also one of the most important factors driving the redesign and innovation of mobile transport network elements, as legacy network elements cannot ensure adherence to these stringent quality requirements.

Additional to these requirements is the capability of networks to provide deterministic communications – meaning very little to no fluctuation in latency and synchronization (in addition to strictly guaranteed bandwidth and superior availability and resilience). This network characteristic may be vital for some existing and future use cases, most importantly in energy utility sector, and industrial M2M use cases.

3.3. Network Criticality Increasing

One of the most important differentiating characteristics of 5G networks is their role as a platform for vertical use cases, time-sensitive use cases, and critical communications. Whether these use cases belong to the category of ultra-reliable low latency communications (uRLLC) by their technological characteristics or not, the role of these communication services in vertical and society will inevitably be increasingly critical.



SOURCE: NGMN

Figure 2: 5G Use Cases Scenarios

Due to this increased criticality, operators deploying 5G transport need to focus on network QoS guarantees, QoS differentiation, traffic isolation, traffic management, service resilience and service reliability mechanisms much more than was the case with 4G.

3.4. Integration into the Current Networking Environment

Operators deploying 5G already understand the complexities of deploying 5G NSA networks in conjunction with their existing 4G infrastructures; 5G SA deployments, and associated new 5G transport will also need to be carefully integrated into the current network environments. This goes both for mobile network environments, but, due to network convergence trends and greater capillarity of 5G compared to previous network generations, increasingly for fixed access networks.

3.5. Automation and O&M

Transport network control and management will need to be tightly coupled with radio control and management, to be able to provide dynamic transport functionality required for support of network slicing, which is a foundation for more advanced 5G use cases. This requires implementation of SDN and automation into the transport network control and management domain and technologies such as segment routing across IP and optical network domains.

4. Key Features and Requirements of 5G Transport

4.1. High Capacity and Scalability

Connection capacity increase is one of the determinant factors for 5G mobile transport. Additionally, operators should count with inevitable increases in initial capacity requirements, as their 5G deployments mature and onboard increasing numbers of clients and cover additional territory. The same can be said for additional spectrum opened.

Due to the requirement for a high number of these connections (that will inevitably increase in highly centralized deployments) operators will need to pay special attention to reducing the costs per unit of capacity and connection of 5G transport networks. Operators should seek ways to rationalize their 5G transport by integrating it with other access domains, like fixed access, or subsuming legacy network transport into the newly built 5G transport. The use of technologies like IPoDWDM can serve to integrate L3-capable platforms with optical transport, thus simplifying the network somewhat, and reducing the cost per unit of traffic carried.

4.2. Easy and Automated Deployment, Sophisticated O&M

Building and deploying the 5G transport network will mean increased complexity, both in terms of the number of connections, number of network elements required, and their diversity. Furthermore, deployment of multiple use cases with differing requirements will mean that 5G transport network will have to be included in an end-to-end system featuring graduated QoS mechanism, and network-slicing based traffic isolation and security.
The 5G mobile transport capacity will also need to change over time – in response to changing traffic patterns, client requirements, and use case onboarding. All this defines the requirements for 5G transport O&M solutions:

- **High degree of automation:** SDN support and integration into rich automation solutions is a necessary feature of 5G transport network elements. This extends to all stages of connection service lifecycle, from setup and provisioning, through operation, to upgrade, repair, or decommissioning and replacement.
- **Northbound Integration:** 5G transport networks need to be service-aware, and feature open northbound APIs enabling integration with end-to-end service orchestration systems, hierarchical controllers, or both.
- **Openness and Extensibility:** 5G transport O&M solutions need to be open and extensible, to allow operators to integrate and streamline their multi-vendor network environments. Additionally, these solutions need to consider the changing nature of 5G services and allow for flexible changing of service parameters in accordance with operator priorities.

4.3. Network Slicing

Network slicing is constantly gaining prominence as one of the fundamental technological characteristics of 5G transport networks. This is a consequence of several distinct and parallel trends in 5G network development:

- **Use Case Differentiation:** 5G use cases feature diverse capacity and quality requirements, varying levels of criticality, and carry different monetization potential. This makes robust, automated, and manageable network slicing mechanisms a necessary characteristic of 5G transport.
- **Resilience and Security:** Operators need their networks to be able to provide heightened resilience and security for some use cases and for some customers; this requirement can be served through strict traffic isolation, achieved through hard slicing of 5G transport.
- **Network Multi-Tenancy:** Network slicing is also required for making supporting multiple clients and service types on the transport network – from subsuming legacy 4G mobile broadband onto the 5G transport, to enabling private mobile network users who carry traffic over operators' 5G network to monitor and co-manage their network slice.

Soft slicing, separating different network services' and/or tenants' traffic into logical slices, thus becomes a necessity for any 5G transport network. To enable soft slicing, 5G transport network elements must support segment routing (SR), coupled with MPLS and/or IPv6. However, use cases and clients with increased requirements for security and traffic isolation will require the use of hard slicing, where traffic in different slices is carried via physically separate interfaces. Hard slicing is technically more demanding, requiring network elements to support additional technologies, like FlexE.

4.4. Interface Support

5G transport networks will mostly be built supporting L2 and L3 networking protocols, such as Ethernet, MPLS, SR, and IPv6. However, in the fronthaul several specific protocols will be used, mostly deployed over basic Ethernet connectivity. CPRI (for legacy transport and short fronthaul connections) and eCPRI (for C-RAN) support is currently considered to be the norm. In the future, however, it is conceivable that open interfaces, such as xRAN promoted by ORAN Alliance, will gain prominence.

4.5. Timing and Synchronization

Stringent timing and synchronization requirements are a necessity for precision 5G transport. Moreover, due to increased complexity of 5G transport deployments compared to previous mobile technology generations, operators will need more robust and redundant timing sources going forward.

Most of today's network elements use GNSS (global navigation satellite system) clock information as a synchronization source; the use of these systems will continue, but will increasingly include multi-band capability, to improve accuracy and resiliency of these systems. Additionally, ITU-T has defined a new set of enhanced network clocks (enhanced primary reference clocks (ePRCs) and enhanced primary reference time clocks (ePRTCs)), designed to enable greater timing accuracy with PTP and SyncE services. Combination of GNSS receivers with network-based clocks will likely be necessary for most 5G transport networks, for resilience, accuracy, and support of indoor deployments.

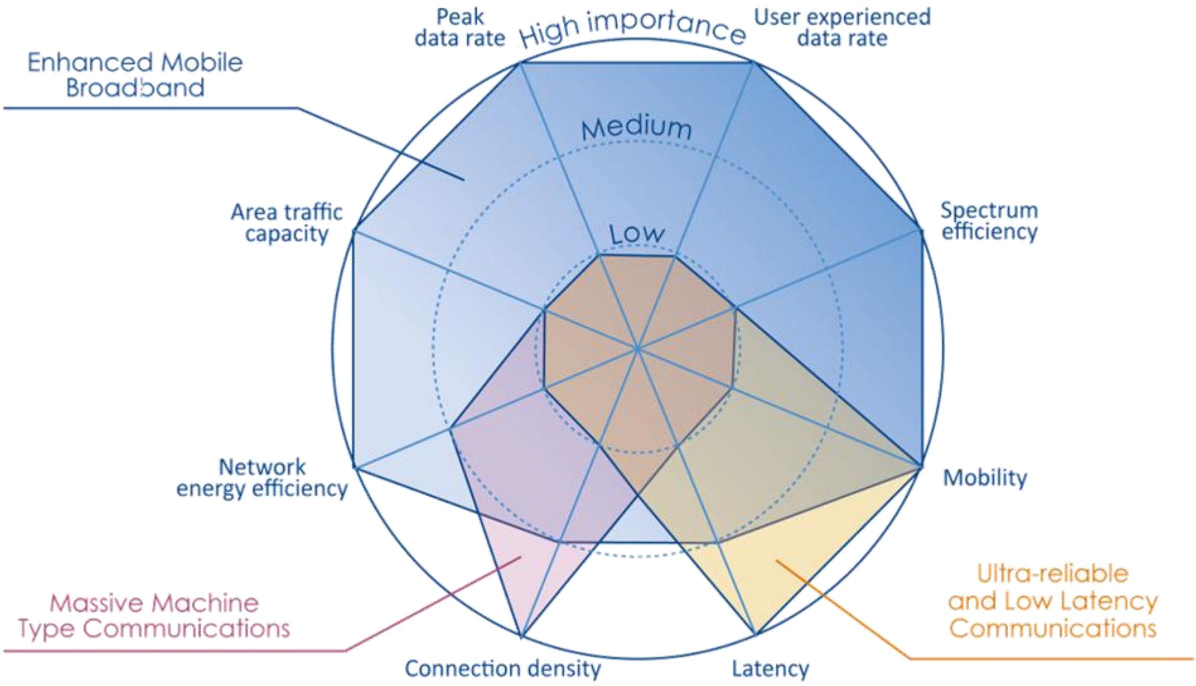
4.6. Platform and Technologies Choice

Operator choice of platforms and technologies will be the result of several factors:

- **Chosen radio network topology:** Operators mostly deploying macro base stations in D-RAN mid-band or low-band deployments will primarily need to invest into backhaul and put most emphasis on sophisticated backhaul routing platforms; those operating highly centralized, small cell networks operating in millimeter wave band will need to pay special attention to fronthaul and midhaul. However, these clearly delineated use cases will be exceedingly rare – most likely, the operators will need to operate heterogeneous, diverse

5G transport, consisting of several different platforms and transport technologies.

- **Use Case Support:** The most basic requirement for 5G mobile transport will be the step change in capacity required. This is already a requirement for industrialization and mass adoption of the first eMBB Operators aiming to support most sophisticated uRLLC and MMTC applications will need to invest into superior timing, synchronization, in addition to capacity.



SOURCE: ITU-T, 2018

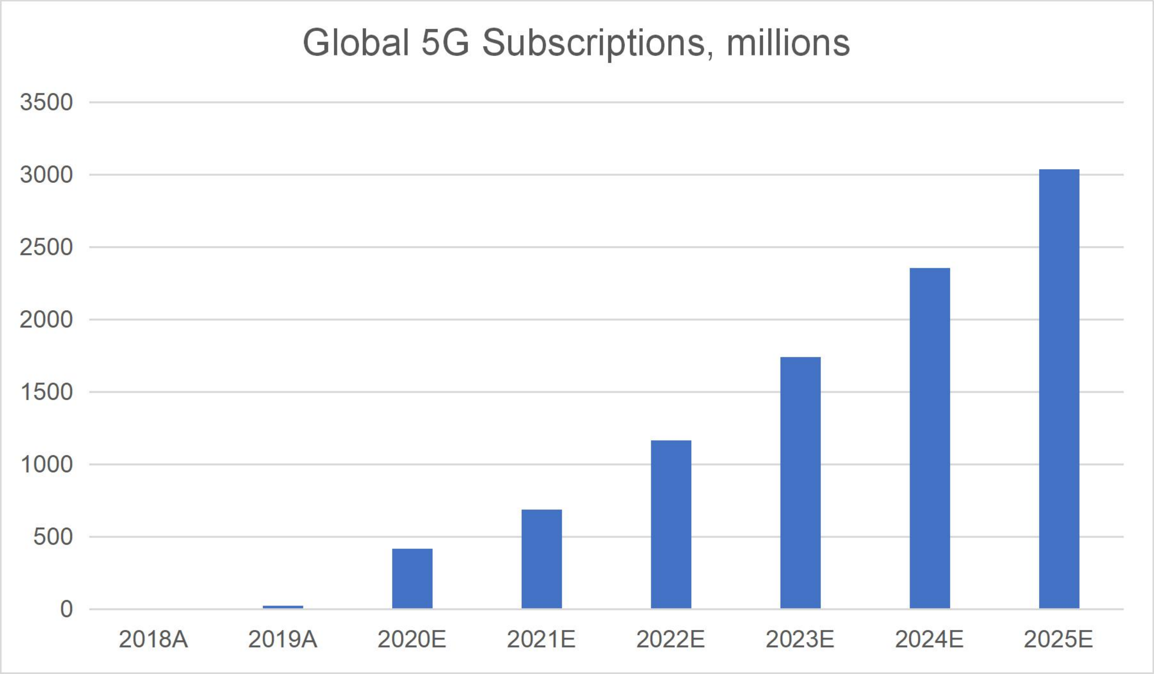
Figure 3: 5G Use Cases Requirements

- **Business Case:** Operators choice of platforms can and will depend on the business case they choose for their 5G deployments as well. For example, operators can choose whether to deploy L2 or L3 based mobile transport architectures, build standalone 5G transport or share transport resources between 4G, 5G, or fixed access services. Similar can be said of hard slicing, which will come into play for specific use cases and specific operator and client requirements.

5. Future Outlook

5.1. Projected 5G market development

GlobalData market forecasts project fast growth for 5G subscriptions globally, encompassing consumer and business users. This projected growth will require relatively quick scaling of 5G transport, in line with increasing 5G mobile data traffic as the dominant factor. The second driving feature will be the multiplication of 5G use cases requiring qualitatively higher network precision and performance.



SOURCE: GLOBALDATA GLOBAL MOBILE FORECAST, DECEMBER 2020

Figure 4: Global 5G Use Subscriptions

Growing customer base and familiarity with 5G services, coupled with newly designed use cases for 5G will open new business opportunities in several areas:

- **Vertical use cases:** With accelerated digital transformation of major industry verticals, operators will find increased revenue opportunities in supporting varied vertical applications and functions, that will in turn, require different combination of capacity and precision, along with variations in QoS and other use case-specific capabilities (network-managed device battery saving support, for example). Later in the 5G deployment cycle, massive new use cases like autonomous driving will appear.
- **Critical communications:** 5G networks can provide high capacity and availability in general; combined with hard slicing, they can also provide superior security and traffic isolation, enabling operators to create network slices reserved for critical communications with precisely defined network capabilities and QoS guarantees. 5G will thus effectively start to replace dedicated critical communications networks with essentially "network as a service" engagements between operators and critical communications users.
- **Private networks:** Enterprises operating large outdoor or indoor facilities will increasingly require private, dedicated mobile connectivity in those facilities, opening way for development of private 5G networks. Network slicing support can enable mobile operators to provide wholesale mobile transport to and between these isolated enterprise networks, opening new revenue opportunities.
- **Premium connectivity and digital entertainment:** The onset of streaming gaming platforms, combined with incessant growth in digital media consumption, will spell increased capacity and precision requirements in consumer sector as well. Once these requirements are recognized, operators will be able to monetize their superior network capabilities further, through differentiated QoS levels, or use higher QoS as a competitive differentiator.

5.2. Ecosystem Changes

In parallel with 5G ecosystem growth, network ecosystem will undergo several important changes:

- **Increased virtualization:** Practically all new network functions will be deployed as virtual, and mostly cloud-native, applications. Additionally, workloads will be deployed in different parts of the network, not only central data centers, and sometimes migrate between different locations, following customer requirements.
- **Edge cloud:** Compute and storage capacity will be intertwined with network capacity, creating different levels of regional, metro, local and edge data centers at virtually all network locations.

- **Openness and interoperability:** Most network functions will need to either be built using open-source components, or at least ensure seamless interoperability using open APIs.
- **Network convergence:** Operators will continue reducing the number of network domains they operate, under competitive pressures, and guided by principles promoted by webscale and ICP players.

5.3. Impact of these technology trends on 5G transport

The wider ecosystem trends described will have significant impact on 5G transport, both directly and indirectly. Virtualization and cloudification, along with edge cloud development, will make network traffic patterns less predictable and exacerbate the need for implementation of SDN-based OAM solutions, and likely increase capacity requirements as well. Openness and interoperability requirements will drive further standardization of 5G transport solutions and emphasize the need for these solutions to support open APIs and new open connectivity protocols as well. Finally, network convergence progress will require 5G transport planning and deployment to be more closely correlated with other parts of the network, including metro and long-haul transport on one side, and fixed residential and business access, on the other.

6. Key Recommendations

When planning the development of the 5G transport network, operators need to consider their projected requirements and define the target capabilities along several axes:

6.1. Capacity and Scalability

Current industry trends indicate that transport capacity will need to be increased approximately by an order of magnitude compared with 4G transport networks. This translates into fronthaul capacities of between 10 Gbps and 25 Gbps at present, with 100 Gbps fronthaul possible in the future. For midhaul and backhaul, 50 Gbps and 100 Gbps interfaces will soon become standard; consequently, 400 Gbps and faster interfaces will be needed in metro core. This capacity will need to be scalable as well, and ideally feature automated delivery, in line with traffic fluctuations and growth.

6.2. 5G Fronthaul/Backhaul Support

5G mobile transport will feature multiple deployment models and features, including concurrent and parallel deployments of fronthaul and backhaul. Operators need to consider their needs and choose their strategy in each of the subsegments, in accordance with their radio network deployment and service development plans, but also considering their wider company strategy and already deployed assets (such as passive optical plant, for example).

6.3. Timing and Synchronization

Advanced 5G use cases, that will likely bring the most important new revenue generators for operators in the future, bring stringent timing and synchronization requirements to transport networks. 5G transport platforms need to support varied timing and synchronization protocols, including IEEE-1588/1588v2 PTP and P802.1, with class C and D precision. GNSS clock support is already viewed as standard in the industry, while at least one other network timing solutions will be required for indoor deployments.

6.4. Network Slicing and Programmability

5G transport needs to support end-to-end network slicing, from radio access to the mobile core. Platforms need to support soft slicing as a minimum to support vertical use cases and varied QoS requirements of different services; hard slicing together with FlexE support opens way for critical communications support, along with superior availability and security that can additionally be monetized.

6.5. Portfolio Breadth

In choosing 5G transport vendor, operators should also examine their end-to-end capabilities. Offering multiple technologies for 5G transport, ability to provide radio access, IP and optical transport, and automation solutions will increase vendor’s 5G transport portfolio traction with operators’ preferring end-to-end approach in their network planning and deployment.

6.6. Physical Characteristics

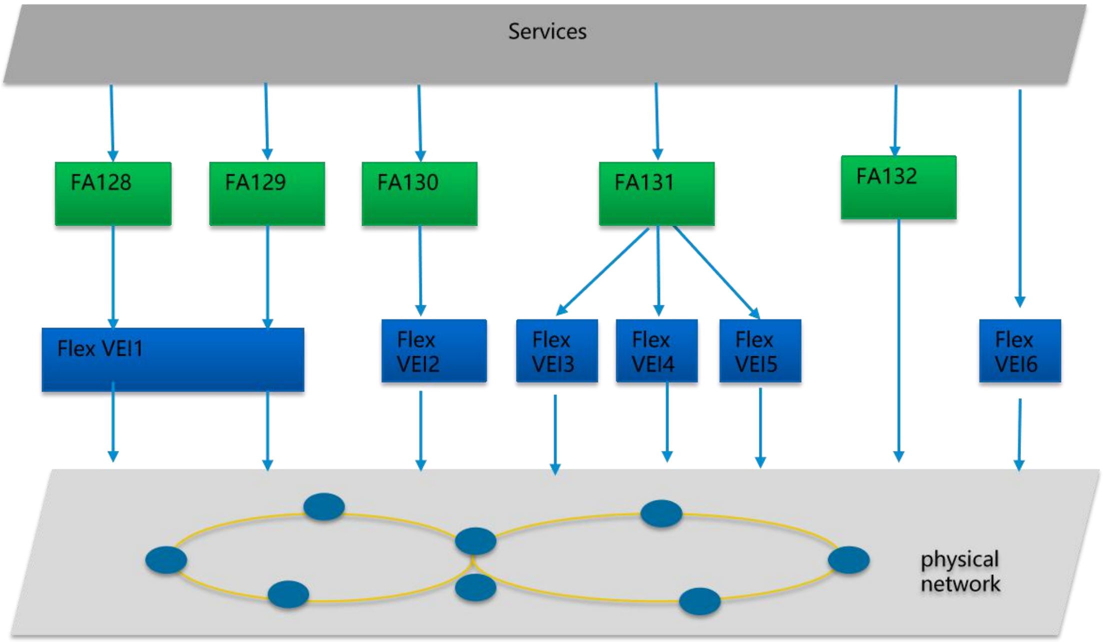
Some parts of 5G transport will likely be deployed in outdoor locations, or sparsely equipped facilities. In these deployments, but also in more traditional telco environments, operators should look for equipment featuring small footprint, low power consumption, multiple power supply options, extended temperature range, and IP environmental resistance ratings. These characteristics will be beneficial in all other scenarios for 5G transport deployment as well.

7. ZTE Precision 5G Transport Network Solution

7.1. Precision Slicing

The ZTE transport network slice solution provides physical port resources, 5G granule FlexE resources, and hard-isolation megabit granule resources based on the RFC7625 standard. The FlexE technology offers N×5Gbps sub-rate or channelized interfaces to flexibly match the bandwidth resources required by services, meeting the needs of large-bandwidth services or different types of service slices. The slices of less than 5Gbps granules can be divided into Mbps-level dedicated sub-pipes on the existing 5Gbps timeslots. By supporting small-granule resources, the transport network can accurately slice services to satisfy disparate demands while improving network resource utilization.

In actual applications, the services with high security and isolation requirements generally need hard-isolation slices, that is, the services exclusively occupy the underlying resources and support physical isolation. The ones with delay and jitter performance requirements usually need soft-isolation slices, that is, services can share the underlying network resources. In the ZTE slice solution, Flex-Algo is radically decoupled from the underlying resources, and allows flexible mapping with FlexE resources to isolate soft or hard slices from each other, as shown in the figure.

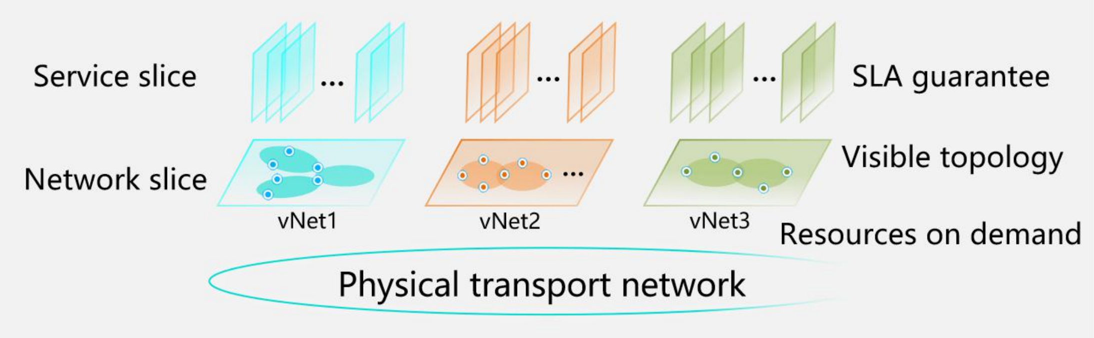


SOURCE: ZTE

Figure 5: Flexible Mapping Between FA and FlexE

7.2. Precision Deployment

The ZTE 5G transport solution supports hierarchical slice deployment. First, topologies and resources are re-architected on demand to form a vNet, called a network slice, which can be an independent private network tailored for a customer in a specific industry or for the same type of scenarios in various industries, and can be outsourced to a virtual operator. These network slices are physically isolated hard slices, each of which supports topology view presentation and service OAM on the management and control system. They can continue to be deployed with service slices according to specific service requirements to redistribute service resources by SLA. The smart grid network slice, for example, can be deployed with the ultra-low latency and ultra-high reliability slice of differential protection services, the large-bandwidth and low-latency slice of drone inspection services, and the low-performance ordinary slice of electric meter terminal data collection services, flexibly customizing multi-layer and multi-scenario slices.



SOURCE: ZTE

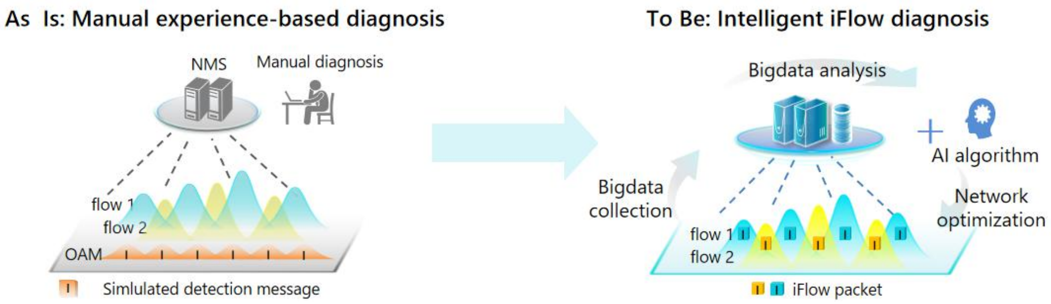
Figure 6: Hierarchical Deployment of Transport Network Slices

The entire slicing is automatically completed in minutes. After the slice is created, these virtual private networks can be visually monitored and managed on the slice view, making topology, operation, and status visible.

7.3. Precision Diagnosis

The ZTE iFlow intelligent O&M solution can be aware of service flow in the immersive way. Compared with the legacy one, the iFlow solution adopts Inband OAM technology to collect statistics on quality data such as service flow packet loss, latency and jitter, and change the “out-band detection” to “iFlow detection”. The link status detection is upgraded to immersive awareness of service flow to make the service path traceable. Telemetry is used to report measurement data in real time, and refines the original link status report into millisecond-level service flow performance report, leading to packet loss, latency and jitter measurements.

In addition, BigData platform performs data storage and correlation processing, with real-time analysis and evaluation by the awareness engine helping rapid fault location, dynamic path optimization, and increased resource utilization by 20%.



SOURCE: ZTE

Figure 7: Precision Diagnosis Enables Flow-based Perception & Optimization

7.4. Precision Synchronization

For a long run, satellite timing is an important means to solve high-precision synchronization. However, due to the coverage holes, susceptibility to interference, and high failure rate, relying solely on satellite timing will bring greater safety and reliability risks. It is necessary to study the use of high-precision synchronization technology for high-precision synchronization ground networking to enable mutual backup between the satellite and the ground node, effectively enhancing the high-precision synchronization service quality, safety and reliability. The ZTE intelligent time network solution employs the intelligent management and control system for automatic planning, deployment and O&M of the time network, which greatly improves the efficiency and availability, and makes possible the large-scale commercialization of the high-precision synchronization ground network.

SOURCE: ZTE

Figure 8: Precision Timing Enables Reliable Ground and Satellite Networks

The intelligent time network solution can automatically make synchronization planning and configuration to increase the activation efficiency from 75 NEs per person per day to 500 NEs, by about 7 times. With knowledge graph technology and customized policies, the failure analysis technology and the neural network technology shortens the fault locating time of the traditional time network from over 24 hours to under 15 minutes, the diagnosis efficiency improved by nearly 100 times. Moreover, ZTE drives the large-scale application of single-fiber bidirectional optical modules in the industry chain, and develops automatic time error correction technology on this basis, reducing the original fiber inter-node error from 30-100ns to 1-2ns.

This Whitepaper is sponsored by ZTE Corporation.