State of the Art Packet and
Optical Networking

Solving the 5G Network Connectivity Challenge

White Paper

Hello 5G

5G promises to change the way we live our lives. How? By providing unprecedented services and unparalleled user experience. But to make this happen, operators need to build an underlying connectivity infrastructure that's capable of delivering in areas like massive machine connectivity, ultra-low latency, and hyper-flexible bandwidth.

These days, the majority of 5G discussions center around the required changes in the radio network. However, 5G is not just another 'G' nor is it simply about the radio technology. Rather, 5G is set to change networking as we know it.

Cracking the connectivity challenge will herald the arrival of a new and exciting range of cutting-edge 5G mobile services. Services that will allow service providers to not only differentiate themselves as never before, but also take advantage of new technological advances and trends, including massive broadband, IoT and augmented reality.

Two phased development track for deploying 5G

There are two roll-out approaches for 5G:

1. **Non-standalone mode (non-SA mode)** – where the 5G radio is deployed on an LTE host network, using an LTE control plane for session management, along with an LTE core network. It's thought this will be faster and easier to deploy, 5G can be launched sooner.
2. **Stand-alone mode (SA mode)** – where 5G is deployed without any dependencies on 4G and includes a full system architecture, core network, and control plane. In many cases, it combines 4G and 5G networks, but a 4G network isn't required to deploy SA mode.

Mobile network operators (MNOs) have focused on non-SA mode for their initial; 5G deployments . As they move to mass rollout of enhanced Mobile Broadband services (eMBB) we will start to see them transition to standalone 5G networks. And they will need the performance guarantees that standalone mode mode brings to offer 5G advanced services which require low latency and guaranteed performance and reliability.

Of course, the MNOs business model and rollout plans will impact the speed of this evolution from non-standalone to standalone. This in turn will have a large impact the connectivity network, and how investment is phased.

Solving the 5G Connectivity Challenge

Connectivity Fabric	Radio Access Technology	Connectivity Fabric	Core Network	Applications & Services
• Ubiquitous connectivity	• Inter/Intra-RAT • Massive MIMO	• Network slicing • Mobile Edge computing	• Fully meshed • Highly dynamic	• Internetapplications • Cloud services

Today's LTE networks have been primarily focused on delivering mobile broadband to the end user. All services supported by LTE's mobile broadband are delivered on the same network architecture, albeit with a limited set of Quality of Service (QoS) parameters. This architecture uses mobile backhaul (MBH) to connect radio access technology (RAN) at the edge of the network, to a centralised EPC (Evolved Packet Core) located at the core of the network, in a logical hub and spoke arrangement. As the network is 'static', so is the MBH network, with connectivity and bandwidth essentially nailed down.

With 5G, Everything Changes

5G is about giving mobile network operators (MNOs) a universal service platform that supports superfast broadband, massive machine communications (IoT), and services requiring ultra-low latency and/or ultra-high reliability. Many services planned for 5G are 'business and mission critical', (meaning widespread disruption and potential risk to life if they fail). Think intelligent eHealth, intelligent transport systems, and private networks. The best effort mobile broadband approach provided by 4G is no longer good enough, so 5G must provide an architecture able to offer assured service delivery on a service-by-service basis. The headache for MNOs is that each service type has fundamentally different needs. For example, massive IoT has a huge number of connections but low bandwidth needs, while gaming requires a reliable network with ultra-low latency. In today's world, a separate network could be built to support each service type, but this would be prohibitively expensive. This assured any-to-any connectivity requires embedded and distributed intelligence across the mobile network, hence a truly dynamic, distributed architecture is needed. In effect, extending the Self-Organising Network concept from the RAN to the connectivity fabric. The connectivity fabric must have the dynamic intelligence to autonomously meet the need of each service, on a service-by-service basis. Network resources must be instantiated across physical and virtual network resources when and where they're required. In effect, creating an assured, virtual, private, dedicated network (referred to as a network slice) for each service.

Evolving to a 5G Connectivity Fabric

The traditional hub and spoke backhaul can't achieve this as the transport network needs to backhaul to multiple different points that will also vary over time across the network. This is no longer a hub and spoke architecture or indeed backhaul, but an intelligent high-capacity mesh network that provides a full connectivity fabric for 5G services.
As we've discussed, 5G focuses on assured services and this requires an extension beyond simple connectivity and capacity. The transport network becomes an essential part of this evolution providing a fully assured connectivity fabric for 5G services.

The 5G Connectivity Fabric

Evolving the traditional mobile backhaul network into a 5G connectivity fabric means focusing on seven key areas:

01 Network Slicing – this is a key architectural concept for 5G. A network slice is created for each service type, with each slice architected to meet the specific service needs of the service it carries.

02 Massive Capacity And Connectivity – 5G needs up to a thousand times more capacity than 4G.

03 Multi-Access Edge Computing (MEC) – allows allocation of compute and storage when and where it's required in the network. Edge processing is specifically useful for low latency services.

04 Xhaul – the combination of fronthaul, midhaul and backhaul.

05 Synchronisation – high accuracy synchronization is required for massive MIMO and for location-based services.

06 Security – business and mission critical services require enhanced network security, while dynamic networks with virtualized resources increase the security risks.

07 Assured service delivery – assuring the network and services being delivered over the network is essential as the network moves beyond 'best effort' mobile broadband.

Let's look at the key challenges in these seven areas and what we can do to overcome them.

Network Slicing

Network slicing is required to deliver the virtual private networks (VPNs) needed to support the massive diversity of services expected in 5G. A network slice, by definition will span from user equipment (UE) to application/service. As such, slice control must be from a central orchestration engine, with the connectivity fabric domain meeting slice definitions given to it from the central engine. Depending on the service definition, a network slice may have dedicated resources (VNFs and PNFs), or use shared resources (i.e. multiple slices passing through the same network function). The slice must support separation of the control plane (CP) and user planes (UP), with the ability to utilize MEC to locate these functions in different parts of the connectivity fabric.

The slice must be dynamic enough to allow extra capacity, processing and VNFs to be brought up and down as the requirements of the service change. It must also be possible to move the slice resources as the service is spun down, or when it is not in use.

Network slicing uses intelligent orchestration systems to compute and activate the optimal path across the network (PCE) for each service type. It identifies the transport layer required, which optimal transport resources and technologies to use (Segment Routing, FlexE, OTN), where compute resources are needed, where to instantiate VNFs, and where the CP and UP processing is required.

The service needs are continually monitored to ensure capacity and compute resources are added as required, and dynamically follow a service as it moves across the radio network.

New technologies required for network slicing in the 5G connectivity fabric

As already discussed, to use 5G as a universal service platform it must support services that require ultra-high capacity, ultra-high reliability and ultra-low latency. This requires evolving the transport technology that underpins the 5G connectivity fabric.

Segment Routing as a Slicing Enabler
Segment routing is a key enabler for network slicing. Segment routing uses source-based routing controlled by a centralized path computation element (PCE), allowing precise, deterministic paths to be created across the network. This allows network slices to be created that meet the specific service demands of the service type being transported. So for example, a slice created to deliver high bandwidth might follow a very different path to one with strict requirements on service reliability.

FlexE (Flexible Ethernet)
FlexE adds a TDM frame structure to Ethernet. This is important because it allows more efficient dynamic bandwidth capacity than the link aggregation used in traditional Ethernet transport – and without the latency associated with flow control.

IP and Optical Interworking
Seamless multilayer optimization of IP and Optical resources allows the right transport technology to be used at the right point in the network. This can range from using OTN and optical connectivity between devices to using a fully flexible photonic layer.

Massive Capacity and Connectivity

To become a universal service platform, 5G needs to provide superfast broadband connectivity, supporting speeds up to a thousand times faster than 4G. To achieve this, the 5G connectivity fabric must support:

- Cost-efficient 100GB connectivity to the cell site.
- Seamless IP and Optical interworking, allowing a flexible photonic layer to provide lowest cost per bit transport of bulk traffic.
- Dynamic bandwidth allocation enabled by SDN – to maximise network capacity use over time.

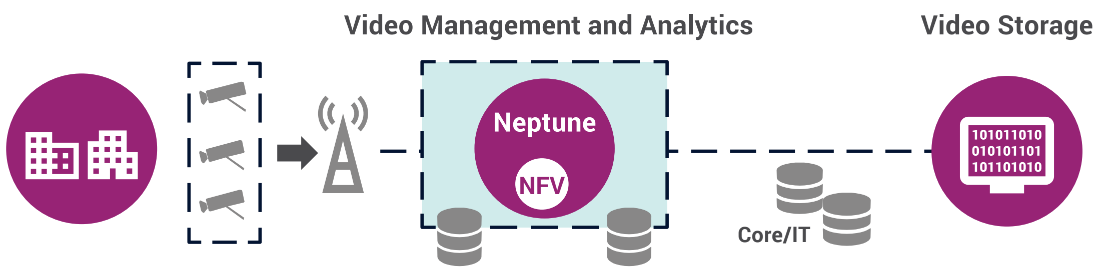
MEC – Multi-Access Edge Computing (MEC)

Multi-access edge computing enables compute, storage and networking to move around the network, enabling these resources to be used where and when they're required. MEC capabilities are particularly associated with moving resources closer to the end user when ultra-low latency or ultra-high capacity is required.

A typical example could be a sports event watched by many people on mobiles devices. It would take a lot of network capacity to stream the video individually from the core of the network to each individual watcher. However, as the event will be watched in real or near-time, it makes sense to download a virtual content delivery network (vCDN) as a VNF (Virtual Network Function) onto a MEC platform in each radio cluster. The video can be streamed to each vCDN which in turn streams to the end users. This greatly reduces the capacity required in the core of the network.

Another example below is the video analytics and video management of a fleet of cameras connected to the cell site with the 5G modem. We can run video management on the MEC platform and offload most of the traffic. Plus, provide ultra-low latency response decision-making, as traffic doesn't need to go to the core and back.

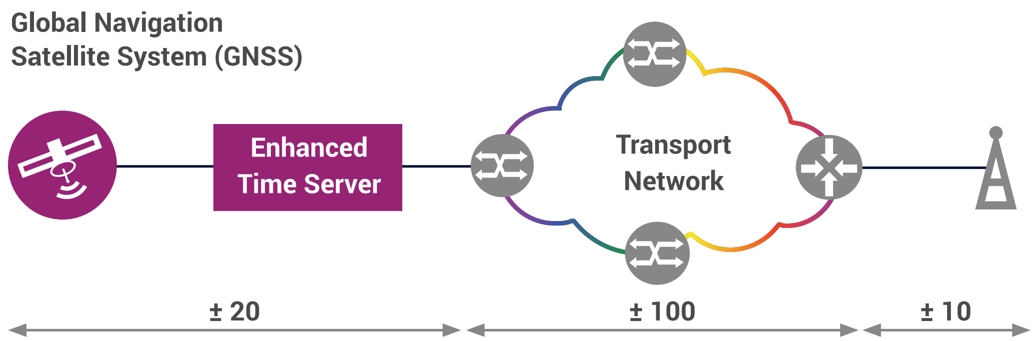
It is key to note that the transport needs to integrate into the MEC or, at least, be able to handover or steer traffic to the MEC platform. Whichever it is, you need to locate the MEC platform wherever it's needed to meet the 5G service requirements it's supporting.



Synchronization Solution for 5G

Synchronization and timing are crucial in allowing 5G mobile networks to support superfast broadband to UEs. End-to-end accuracy needs to be +/- 130ns as shown is the diagram below. This means each radio cluster must be accurate to +/-10ns. An added advantage of providing this timing accuracy in a radio cluster is that with 10ns accuracy, you can pin down UE location to a 3-metre cube, 80% of the time. This means MNOs will finally have the accuracy to offer location-based services based on the 5G network rather than having to rely on GPS.

Synchronization accuracy is based on a next-generation, end-to-end timing solution. For example, in the diagram below the GPS server is very close to, or even embedded in, the GNSS receiver inside the transport equipment. On the other side, you need a boundary clock (with new timing standards) that improves the accuracy to support the ±5ns each element can add to the total budget.



XHAUL

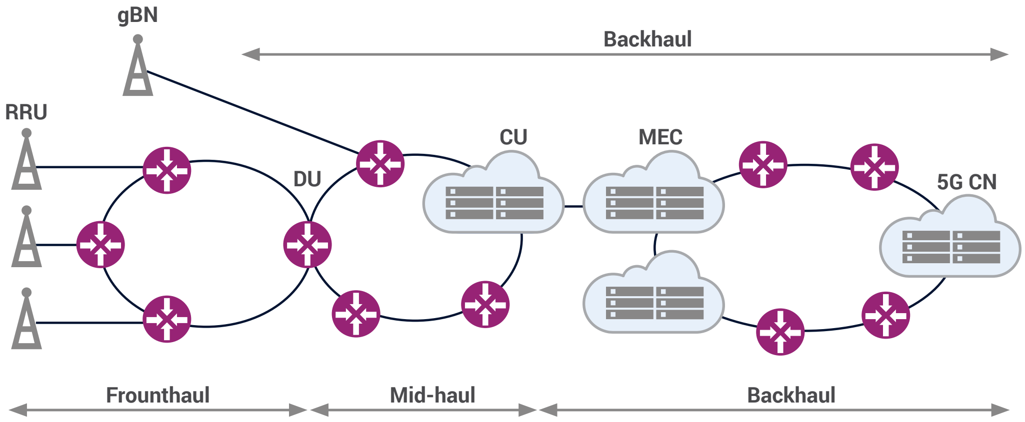
Xhaul is the combination of fronthaul, midhaul and backhaul.

Fronthaul was originally introduced with small cells in 4G networks, but for various reasons penetration was limited. However, with 5G the whole radio architecture has been revisited and it is likely fronthaul and midhaul will be commonly deployed. In 5G, the RAN is split into 3 logical blocks; the Radio Resource Unit (RU), the Distributed Unit (DU) and the Centralized Unit (CU):

1. Fronthaul RU to DU: point-to-point eCPRI interface, distance 1 to 10km with low latency requirements.
2. Mid-haul DU to the CU: similar requirements to today's backhaul networks typically point-to-multipoint. One CU controls 300-500 physical stations, latency under 1ms for signalling control, distance 40km-80km.
3. Backhaul CU-Core: typically multipoint-to-multipoint, distance under 200km, latency related to services and is under 10ms.

You can realize these functions by separate or combined physical elements. It's highly likely the same network will employ multiple functional splits based on the geography, services and capacity being served.

It's clear the midhaul and backhaul have similar requirements and it makes sense for them to share one network technology, especially considering that sometimes the DU and CU will be combined and other times split – plus the fact that core functionality will sometimes be moved towards the edge of the network. However, the fronthaul requirements are different and require the 5G connectivity fabric to provide additional technology like Time Sensitive Networking (TSN), optimized WDM and OTN, and millimetre wave microwave.



5G Security

Strategic and critical industries will be the main users of massive IoT capabilities offered by 5G, with 5G-enabled IoT accelerating adoption of trends such as smart buildings, smart cities, smart grid, and intelligent transport systems. This makes them an interesting target for cyber attackers, as we've seen in recent years. By definition, these mission critical services must be resilient to cyber-attacks, which would have widespread impact. In addition, the 5G network's mix of physical and virtual functions increases network vulnerability. The network will no longer be a walled garden with dedicated transport equipment.

Given this, it's essential to ensure the security of the network by design. So expect to see more integrated cyber security solutions to protect 5G infrastructure.

For example, in the network we'll see more encryption solutions on Layer 1 or Layer 2 using MACSec or IPSec to encrypt traffic in the data path. We'll see firewalls, deep packet inspection (DPI) and anomaly detection to protect the network at point of access. And we'll also see more complex holistic solutions using centralised algorithms to collect data from what's happening in the network and applying big data analytics to allow smart decision-making, either autonomously or by skilled security operators using a real-time, unified threat dashboard.

All in all, you'll need to handle every part of the transport network far more securely than today.

Assured Service Delivery

The domain management for the 5G connectivity fabric must provide network and service assurance. This is a pre-requisite as MNOs move from 'best effort' mobile broadband to becoming a Universal Service Provider.

The domain management must provide applications to assure and monitor slice. This assures the services running on the slices meet all service parameters. In addition, these applications must be able to look to the future to ensure service delivery continues to meet its parameters as service resources move across the network. This is particularly important for services like autonomous cars that require ultra-low latency. Or remote surgery, where not only must the traffic path always be within specification, but a back-up route must always be available which meets the same specifications.

The network assurance applications must provide automation, re-optimization and prediction of network degradation and potential outages. Plus, they should provide network applications that analyze the behavior of network resources, to ensure the network is kept at maximum utilization, 'defragging' isolated network resources where necessary, and predicting where network bottlenecks will occur. In other words, proactively ordering and installing new network resources before an actual bottleneck occurs.

To bring it all together, we've seen how the 5G connectivity fabric links together distributed intelligence across a distributed architecture, while providing an assured any-to-any connectivity for 5G services.

It's worth noting you can't view the 5G connectivity fabric in isolation from the rest of the 5G network. The domain manager for the 5G connectivity fabric must provide the instrumentation and APIs to plug seamlessly into the wider 5G radio and core service domains. It must also provide a clean evolution path from, and for, existing mobile generations.

An Exciting Future

What's truly exciting is that with 5G, the connectivity fabric has the potential to create differentiation for mobile network operators for the first time. Achieving this differentiation to its full potential will require advanced operational software. And this starts with SDN control, orchestration, path computation, and virtualised resource control – all extended by Machine Learning, network analytics, and seamless integration of best-of-breed tools.

By powerfully combining hardware and software in mobile networks for the first time, this transport layer, this so-called connectivity fabric, really can add value to MNOs keen to offer new and exciting next-generation services. For example, the ability to tightly control synchronization and monitor services right to the edge means mobile operators can finally make AR (augmented reality) with location-based services, a reality.

And finally...

The transport layer can achieve value differentiation for service providers through:

- Scalable transport – that provides the connectivity to glue together the highly dynamic distributed 5G architecture.
- Integrated MEC – to further optimise performance.
- Adaptive Network Slicing – provides a real opportunity for service differentiation, especially when it's allied to ensuring the 5G services travelling over these slices.
- Assured 5G connectivity – the connectivity fabric must be seamlessly integrated with the rest of the 5G infrastructure and provide a platform for best-of-breed, state-of-the-art instrumentation that evolves as the 5G network evolves.

Put simply, there's huge potential in this 5G network to really support a wide range of exciting services

Contact us for more information about how Ribbon can help you meet and overcome the 5G network connectivity challenge at rbbn.com

About Ribbon

Ribbon Communications (Nasdaq: RBBN), which recently merged with ECI Telecom Group, delivers global communications software and network solutions to service providers, enterprises and critical infrastructure sectors. We engage deeply with our customers, helping them modernize their networks for improved competitive positioning and business outcomes in today's smart, always-on and data-hungry world. Our innovative, end-to-end solutions portfolio delivers unparalleled scale, performance, and agility, including core to edge IP solutions, UCaaS/ CPaaS cloud offers, leading-edge software security and analytics tools, as well as packet and optical networking leveraging ECI's Elastic Network technology.