Accelerating the deployment of 5G with simple and flexible transport networks

Mobile Network Operators (MNOs) are struggling to meet the demands of connecting their existing 4G/LTE networks, building out transport for new 5G networks, and laying the groundwork for distributed compute. ADVA can help with a proven solution that meets the operational requirements and the demanding business case.

Challenges faced by MNOs in their 5G transport network planning

MNOs aiming to deploy 5G face a fundamental question of how to design their transport network. This is the network connecting cell towers and small cells to their core network. It is referred to as Mobile Backhaul, Fronthaul, Midhaul and X-Haul, depending on the technology used.

MNOs plan to make a strategic investment in fibre for mobile transport, with microwave and mm wave radio deployed only where needed[1]. Drivers for microwave include cases such as avoiding delays in fibre deployment and overcoming obstacles in geographic regions such as roads and railway infrastructure.

In addition to the physical medium for transport, MNOs face other questions in three broad areas:

- Support of existing 4G macro cells, and new 5G cells
- Architecture and technology selection
  - Architecture options such as the optimal location of edge compute
  - Technology options and protocol selection - such as use of small cells, massive MIMO, C-RAN, common radio public interface (CPRI), eCPRI, O-RAN, and backhaul
- Accommodating sharing of the transport network to bring cost per cell site down

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[1] https://www.gsma.com/spectrum/wp-content/uploads/2019/04/Mobile-Backhaul-Options.pdf

ADVA can help MNOs answer these questions using simple and proven technologies. In this paper we describe an example X-Haul network architecture for 5G transport. The solution is simple, cost-effective, and is deployed in volume in a live 5G network. In this paper we explain our solution and provide answers to the questions above.

Support of 4G legacy and new 5G Cells

MNOs are deploying both 4G and 5G cell sites in their networks. We expect a mix of distributed radio access network (RAN) and centralized RAN deployments, dual connectivity, and in order to mitigate against inter-cell interference in dense networks, we believe that coordinated multipoint transmission and reception (CoMP) will be needed. These requirements will drive new technologies such as Centralized RAN, split CU and DU functions, and eventually a mix of fronthaul and backhaul protocols over common infrastructure.

Baseband Unit Split Architecture

The BBU (Baseband Unit) is a complex part of the radio network. Responsible for converting packets from data sources such as the internet into radio symbols for transmission over the air interface, it sits at the boundary between the transport and the RAN network. However, in future the BBU is likely to be decomposed and the resulting functions placed across a number of network locations, obscuring the Transport and RAN boundary. Centralization of some BBU components is considered for reasons such as co-ordination between cells, accommodation of dual connectivity, and the deployment of smaller, lower cost radio units, as well as the benefits arising from BBU pools (cooling/power system sharing etc.).

With 5G, the centralization and virtualization of elements of the BBU is therefore considered by many operators and actively planned by some. The BBU is likely to be split into the DU and the CU functions, which we expand on in the following text. The CU and DU transmit and receive over the air interface using the RU.

The RU (radio unit) is placed at the edge of the network interfacing to the antenna is likely to host a small part of the BBU; elements from the low Phy associated with conversion between frequency domain to time domain signals and converting from digital to analogue signals in the direction towards the air interface.

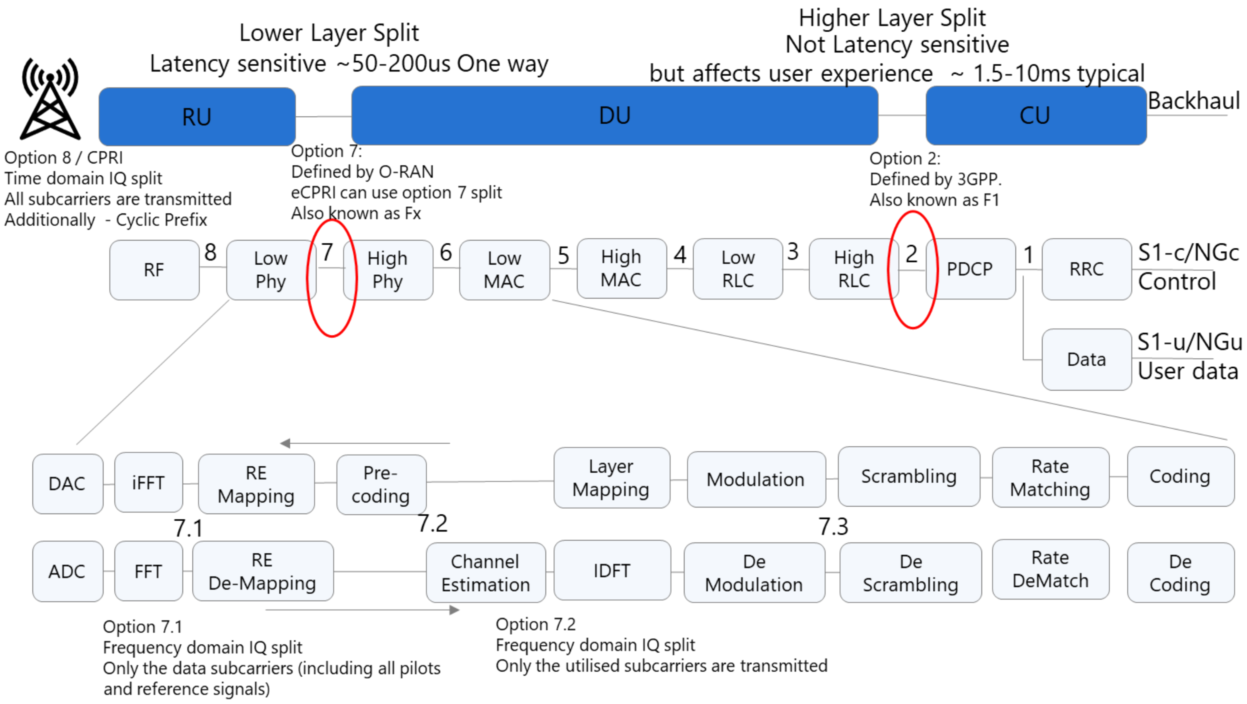

Figure 1: Baseband unit split into major components expected in 5G deployments

The DU (Distributed Unit) could be located with the RU. Alternatively, if co-ordination is required for example in a dense network, or if a service requires geographic/localization detection of the user, then it could be deployed in a more centralized location. The challenge being that deeper centralization of the DU consumes some of the latency budget of the Radio network, for functions such as HARQ, and therefore a limit of about 10km (typical values could be in region of 50/100/150us one way delay) is expected for the separation of the RU and DU. Protocols likely to be used here include eCPRI, O-RAN, and the use of flatter Layer 2 transport as opposed to Layer 3 is likely to be typical.

Finally, the CU (Centralized Unit) is expected to be deployed more centrally, although still relative to the access network. This means it will typically sit at the boundary of the access network and the service providers MPLS Core, at the first major POP/ Provider edge location. The location of the CU will define the latency experienced by a user, and therefore in order to serve a reasonable latency for eMBB, some operators might expect this to be one or two milliseconds one-way delay from the radio sites. This accounts for an 8ms radio latency, and then a 1-2 ms delay to the CU enabling an eMBB latency target of 10-15ms a reasonably safe target. Protocols used between DU and CU are still expected to be Layer 2 focused, although Layer 3 is not precluded. Between the CU and the Core network functions (whether distributed along with a User Plane function or centralized), a layer 3 network is expected to be typical. To accommodate network slicing and deterministic latency control, SR-MPLS is highly likely in this part of the network.

Our solution provides a transport network for Small Cell, Macrocell and Massive MIMO deployment for 4G and 5G. Our solution also supports synchronization and phase alignment for FDD and TDD.

Ethernet will be a preferred transport

At ADVA, we believe that optical transport network (OTN) adds complexity, latency and cost that is inappropriate for the mobile X-Haul market. We propose Carrier Ethernet instead, using products from our FSP 150 portfolio. These products are already deployed in 4G and 5G networks, as shown in the diagram below.

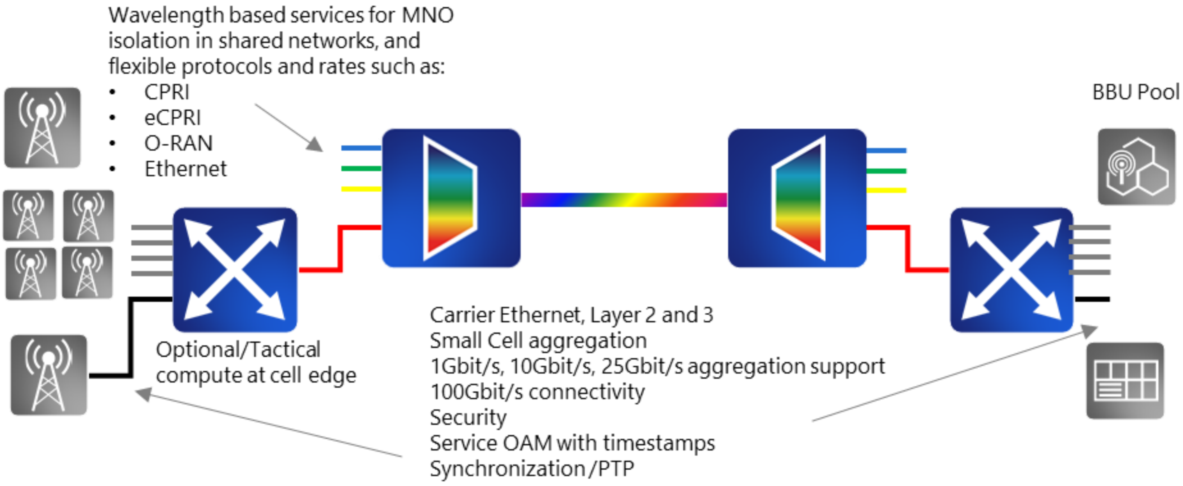

Figure 2: X-Haul Mobile Solution

The ADVA portfolio includes products with 1, 10, 25 and 100Gbit/s interfaces, aggregation, Service OAM, synchronization features, and security options. In addition, we provide flexibility and future-proofing with our use of FPGA technology. We can easily add new protocols such as time-sensitive networking (TSN). We enable rapid introduction of fronthaul by provisioning the Ethernet NIDs and the underlying Open Line System (OLS). When combined, our solution provides a cost-effective facility to enable the deployment of additional services without impacting latency.

Our products are carrier-class. They support full line rate services, industrial temperature ranges, tunable wavelengths, and fiber monitoring. Lower-cost enterprise-level switches and routers have limited features and throughput, and will not be able to deliver the required performance and features.

Architecture and technology selection

There is a clear trend within the industry to prepare for edge compute at various locations within the network. Edge compute will support use cases such as existing 4G Internet services and enhanced Mobile Broadband. Some traffic will be processed locally, while other traffic is sent to the operator's centralized core network.

To support these use cases, MNOs will deploy large racks of compute in POPs/COs, and they will need to move traffic intelligently between the transport and the edge compute domains. This will drive the need for data centre Ethernet interfaces at 10Gbit/s and 25Gbit/s.

Equipment deployed at the POP/CO is likely to include aggregation, switching and router-based functionality. MNOs can program this functionality using a Network Slicing model enabled by SDN and potential adoption of SR-MPLS.

MNOs need a robust transport network, supporting synchronization to the cell sites and a large amount of edge compute. We believe that the way to build this robust network is to separate the transport equipment from the compute infrastructure. In addition, we believe that edge compute will be deployed throughout the network. This will support applications such as DU hosting, and tactical deployment of small cells based on vRAN.

ADVA's Ensemble suite supports this edge compute model. Our Zero Touch Provisioning enables deployment on whitebox compute servers or on the ADVA mobile edge devices for DU hosting.

The 5G market is in flux, especially with respect to technologies like CPRI and CPRI over Ethernet, as well as how rapidly new technologies such as eCPRI and O-RAN will be adopted by vendors and MNOs. The ADVA solution provides a future-proof solution. We can meet today's demands, and we can also add new features using our field programmable gate array (FPGA)-based designs. FPGA technology brings flexibility and programmability. In contrast, products based on fixed-feature commercial chipsets and application specific integrated circuits (ASICs) cannot be upgraded once deployed.

In addition, our solution provides a passive optical solution based on wavelength technology. The MNO can use this for CPRI transport, or to guarantee low latency support for eCPRI/O-RAN at 25Gbit/s and 100Gbit/s, should those speeds be needed.

Our Ethernet and Layer 3 devices support 1G/10G/25 and 100Gbit/s options. These enable MNOs to use eCPRI and O-RAN on Ethernet platforms and save on the number of wavelengths consumed. Where relevant long term, the flexibility of our platform, based on programmable hardware, allows ADVA to turn on fronthaul mapping features in the packet layer as the business case arises. Co-location with an open line system allows rapid deployment of fronthaul technologies in the short term if they are needed prior to maturity of packet layer solutions by standards bodies.

Security cannot be neglected. Today, Mobile Backhaul is dominated by IPSec tunnels deployed from the BBU to the Mobile Core. We expect this to continue from the CU interface into the network (S1-c/NGc and S1/NGu) and likely over the F1 interface between the CU and DU. However, due to stringent latency requirements of Fx/Fronthaul interface, we believe MACSec may be an alternative that could be considered useful. Since eCPRI makes the use of IP optional, and use of layer two protocols is likely, then MACsec with lower latency and higher throughput at smaller packet sizes could be more efficient for fronthaul support.

ADVA FSP 150 devices targeted for Mobile X-Haul come with optional functions for MACsec and IPsec over the relevant locations in the network for which they are likely to be deployed.

Figure 3: FSP 150 Mobile X-Haul Portfolio

Sharing the transport network to bring down cost per cell site

5G is going to drive MNO investments. Operators will be exploring ways to introduce sharing agreements to spread their costs. Tower, network sharing and wholesale operator environments could lead to reduced total cost of ownership (TCO).

But MNOs using active Ethernet/Layer 3 devices such as cell site gateways as the first point of sharing will be in trouble. Why? Because other sharing operators may be depending on the equipment for wholesale services. This dependence may delay the other party from upgrading their transport domain equipment. In these cases, it may be better to achieve sharing via fibre assets with DWDM and dedicating separate wavelengths to each operator.

The ADVA solution uses a combination of packet solutions and optical filters. This enables fibre-sharing, with wavelength isolation, in addition to the flexible adoption of any fronthaul protocols utilizing either the FSP 150 portfolio if IP and or Carrier Ethernet based fronthaul is deployed, or the open line system if CPRI/OBSAI or indeed any other fronthaul technology is considered.

Carrier Ethernet and DWDM for simple mobile transport enables a 5G future

As mobile demand continues to grow, and new revenue streams are explored, 5G will begin to dominate the future network architecture. 5G demands a step change in the transport network in both speed and latency. Different implementation options for different cell site types and parts of the network will lead to different network architectures and the need to support different protocols at various phases of the 5G deployment. A solution utilizing Carrier Ethernet with synchronization, and DWDM filters with support for industrial temperature, and offered in a range of rack and outdoor enclosures brings simplicity, reliability and the flexibility needed to support 5G transport network deployment.

Reference Use Case

Foreword by Anthony Magee, Senior Director, Global Business Development - Mobile: ADVA's description above of a solution for Mobile X-Haul describes many facets of the transport network and the architectural requirement. We do not expect every MNO to need every part of the solution initially or concurrently. We expect MNOs and Wholesale operators to have transient requirements as their 5G network evolves and expect different aspects of the solution to resonate with different customers depending on where they are in the deployment of 4G and 5G. We believe the solution of targeted packet-based solutions and an Open Line system delivers that flexibility and avoids complex fronthaul mapping features in the packet layer which could lead to redundancy of features and sunk costs in the long term.

We invited Andy Sutton from BT in the UK to provide comment on the use of the ADVA X-Haul solution as outlined in this paper. The UK market as with other geographies has regulations which influence the design of connectivity services, Openreach provides active point to point services rather than dark fibre, hence the use of a CSGW and an active NTU prior to the optical filter.

Professor Andy Sutton,

BT Principal Network Architect.

A Multi-Radio Access Technology (multi-RAT) network:

BT launched the UK's first 5G network on the 30th May 2019, and this network is branded as EE. The investment in 5G enables EE to enhance the mobile broadband experience despite rising demand for mobile data. Initial 5G deployments operate in EN-DC (eUTRA & New Radio - Dual Connectivity) mode which means that 4G LTE is used for the control plane while 5G new radio is aggregated with 4G LTE carriers to provide high-speed user plane throughput. A 5G enabled site can therefore provide significant data throughput so a solution was required to migrate from the existing 1Gbps backhaul circuit to something which offered greater scalability, flexibility and was as future proof as possible.

Several solutions were considered. However the preferred solution is based on a fibre-first strategy in which an access DWDM solution is deployed, which consists of an active optical network termination unit (NTU), an ADVA FSP 150 XG210 and DWDM filter, the ADVA FSP 3000 16CSM. The combination of these two components forms an Openreach product known as OSA-FC (Optical Spectrum Access - Filter Connect). Due to the regulatory environment in the UK, the active NTU provides a lit 10Gbps service over channel 1 of the DWDM filter while the remaining 15 wavelengths are available for use as required; these may be utilised for additional 10 or 25Gbps backhaul circuits, for backhaul network sharing, or for mid-haul or fronthaul interfaces. This solution ensures we have the flexibility to scale to meet growing data traffic demand while keeping options open for evolving the RAN through functional decomposition.

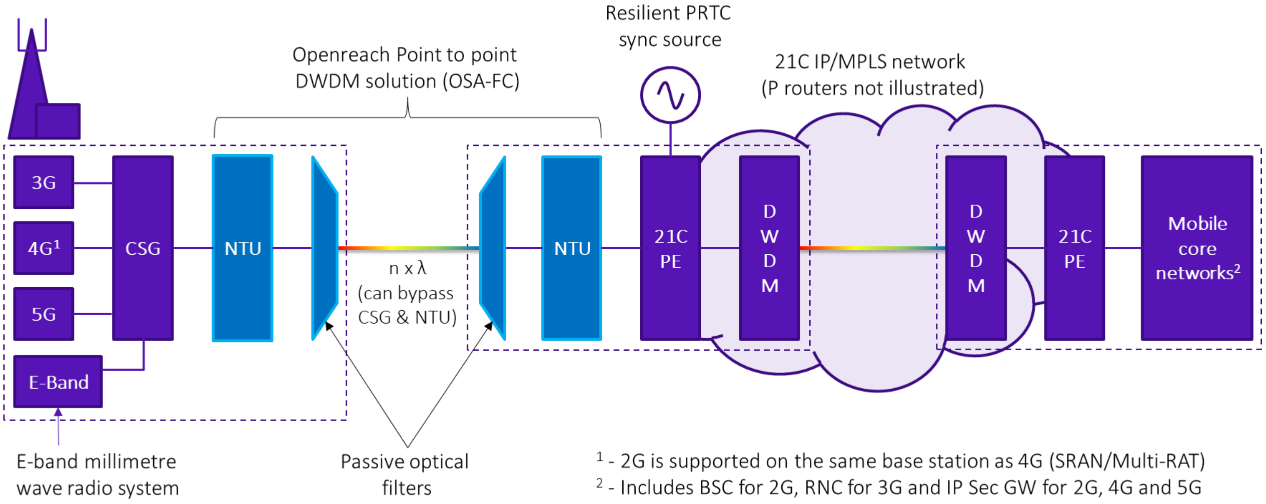

Figure 4: BT/EE Multi-RAT mobile backhaul architecture

Figure 4 illustrates EE's end to end mobile backhaul architecture. The local cell sites (2G, 3G, 4G & 5G) connect to the Cell Site Gateway (CSG) and on to the NTU and optical filter. The reference to E-band refers to an 80 GHz millimeter wave radio system which extends backhaul from the fibre based cell site to a sub-tended cell site, this increases the total traffic load on the OSA-FC solution.

Multiple cell sites connect back to an aggregation site via multiple OSA-FC circuits. The aggregation node is where BT has IP/MPLS PE routers which allow access to the national core network, at this point the mobile backhaul traffic is mapped to a number of IP VPNs to enable connectivity to the respective core network nodes (control and user plane) and OAM elements.

The aggregation node provides access to a resilient frequency and phase (time of day) synchronisation source which is accessed through a Primary Reference Timing Clock (PRTC), a number of PRTC units are deployed to provide geo-resilience and mitigate any of the likely outages which can be caused through reliance on local cell site based GNSS synchronisation sources. BT has selected the ADVA OSA5440 as the PRTC platform.

In summary, recent developments in optical access solutions mean that access DWDM products are now available and viable for deployment in volume for cell site connectivity. The flexibility of an access DWDM solution enables the optimal architecture for the RAN to play out over time, as initiatives such as O-RAN deliver new and innovative capabilities.