MEF White Paper

Slicing for Shared 5G Fronthaul and Backhaul

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1 Abstract

This White Paper introduces the concept of 5G mobile access network sharing and use cases for providing multiple mobile access network services over a common underlying fronthaul and backhaul infrastructure. The use cases are described in the context of current MEF Services and the MEF Lifecycle Service Orchestration (LSO) reference architecture. The target audience for this White Paper includes fixed access line (fiber/copper) Service Providers and Mobile Network Operators (MNOs).

2 Introduction

Mobile Network Operators (MNOs) around the globe have started transitioning from 4G to 5G infrastructure. However, rollout of 5G access infrastructure requires very large investments by MNOs, for example: spectrum licensing, right-of-way for cell tower placement, cell towers and associated equipment. Substantial investment is also required to build out or use networks suitable for connecting the 5G radio access network (RAN) functional elements. This White Paper refers to these networks as mobile transport networks; fronthaul and backhaul are special terms for connectivity between specific parts of the 3GPP 5G network. To enable faster 5G network build-out, MNOs are developing new business models based on mobile network sharing and network slicing.

With revenue from services providing full or partial 5G mobile network sharing and slicing, MNOs can accelerate their return on investment for existing infrastructure and speed up the build-out of new infrastructure for areas where they do not have coverage.

Network slicing can enable the sharing of 5G RAN functional elements and the transport network. When referring to the combination of 5G network functional elements and the transport network, this White Paper uses the term “mobile transport”.

This White Paper provides Communications Service Providers (CSPs), MNOs and eventually private 5G mobile network operators (verticals) with an overview of the current status of the mobile access standards (including 4G and 5G) relating to data transport for fronthaul and backhaul as well as use cases with MEF standards and studies that support 5G mobile transport.

The main focus of this White Paper is sharing mobile transport for both fronthaul and backhaul.

3 Market Trends and Business Drivers

5G is, in many cases, being deployed in parallel with 4G – which is still growing. In some cases, sites will be purely 5G through, for example, the addition of small cells for increased capacity. Typically, in a 3G or 4G service environment, MNOs own the infrastructure for their mobile networks. In cases where MNOs do not have their own footprint, network sharing agreements between MNOs are used to cover the respective mobile network area. In cases where MNOs do not have their own mobile transport facilities, they use transport network services from local transport Service Providers.

Therefore, with the advent of 5G and the densification of sites to meet capacity and coverage, the interest in network sharing is growing. Network sharing agreements refer to the sharing of passive and/or active components of networks owned by different operators. These components include infrastructure such as towers and ducts, 5G RAN functional elements, transport networks, spectra and core networks.

In addition to MNOs, companies in vertical industries can operate 5G spectrum and offer services. These business entities may also use network sharing to complete the coverage areas for their services.

To enable 5G services such as enhanced Mobile BroadBand (eMBB), massive Machine Type Communications (mMTC) and Ultra-Reliable and Low Latency Communications (URLLC), 5G RANs have been designed with a far larger number of base stations when compared to 4G service footprints (cell site densifications). A 5G base station uses higher spectral bands with less favorable propagation than a 4G base station, though with much higher capacity. A 5G base station also has a much smaller range than a 4G base station, consequently more 5G cells are needed to cover the same service area. Higher cell density means relatively higher deployment costs for the 5G MNO building its own access infrastructure.

McKinsey & Company’s research shows that this is driving an important market for 5G access services where the 5G access infrastructure is shared. Sharing is enabling a faster return on investment for the owner of the 5G access infrastructure, much faster rollout of 5G services and larger footprints for the MNOs [13].

Figure 1 is from the report from GSMA [10] on network sharing. It shows that network sharing has become common since 2010. Like previous generations of network sharing, 5G network sharing can be further adapted to support competing or different needs. Examples of such adaptations are variations in the depth of sharing (small cell versus 5G Internet of Things macro layer) and using different network sharing models for competitive urban markets and rural areas. Customizing networks to specific situations allows MNOs with different needs to achieve new savings.

Figure 2 is from a McKinsey & Company report [13]. It shows that for a 5G RAN standalone deployment, the Total Cost of Ownership (TCO) increases by 86% compared to current (4G) deployments. It also shows that if MNOs use network sharing, the TCO of the 5G RAN deployment could be only a 57% increase over the current spending practice, significantly less than the 86% increase without network sharing.

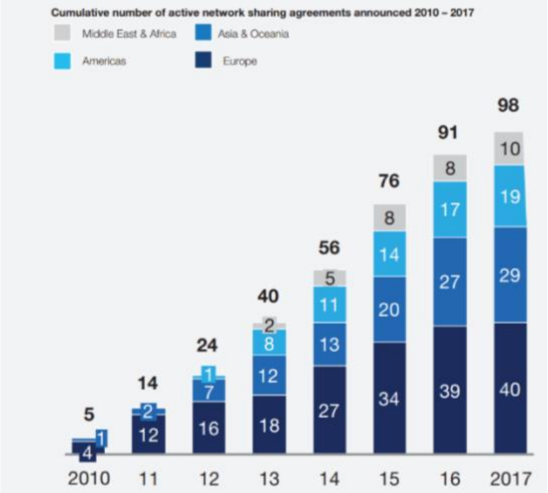

Figure 1 Network sharing agreements announced between 2010 and 2017

(Sources: GSMA Intelligence https://www.gsma.com/futurenetworks/ McKinsey analysis https://www.mckinsey.com/)

Figure 2 Network sharing cost reduction estimates

(Source: McKinsey analysis https://www.mckinsey.com/)

4 Mobile Networks and MEF LSO

This section starts with an introduction of current mobile network architecture, with the focus on 5G RAN functional elements and the mobile transport network. Subsections follow explaining 5G network sharing with an introduction to network slicing and its benefits and an introduction of the MEF Lifecycle Service Orchestration (LSO) reference architecture.

4.1 5G Mobile Network Architecture

Figure 3 shows examples of 4G and 5G mobile network architectures. The 4G mobile network in this example consists of Evolved Packet Core (EPC), Baseband Unit (BBU) and Remote Radio Head (RRH). The common public radio interface (CPRI) is used on the links comprising the transport network connecting the BBU and RRH; MEF refers to this transport network as 'mobile fronthaul' (MFH). The interface between the EPC and BBU is termed S1. The supporting transport network implementation is frequently referred to as 'mobile backhaul' (MBH).

In the evolution from 4G to 5G shown in Figure 3, the main change in the RAN is that the original BBU function in 4G/LTE is split into three units: a centralized unit (CU), a distributed unit (DU) and additional functionality at the radio unit (RU). The interface between the RU and the DU is commonly referred to as eCPRI. The interface between the DU and the CU is called F1. MEF terms the transport network implementing these two interfaces as the MFH. The new design allows RAN virtualization, with flexible assignment of computing resources across three functional network entities to better meet the latency demands of new 5G services.

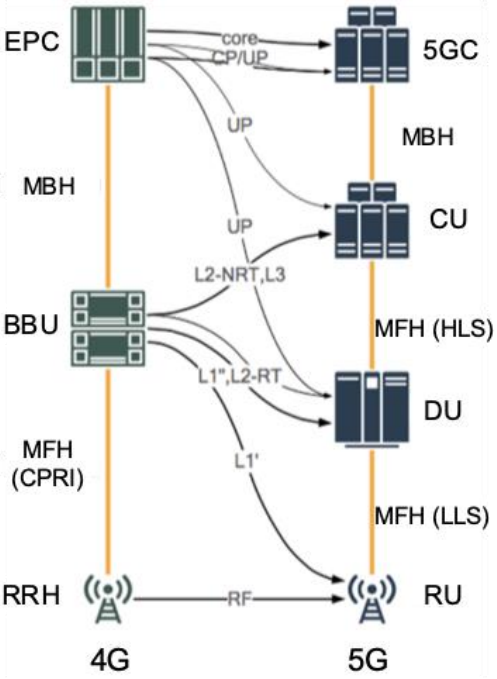

Figure 3 Example mobile network architecture evolution from 4G to 5G

A 3GPP study concluded that functional split Option 2 would be used for F1, which is called High Layer Split (HLS) [6], as shown in Figure 4. Low Layer Split (LLS) Options 7 and 8 correspond to the use of eCPRI and CPRI, respectively.

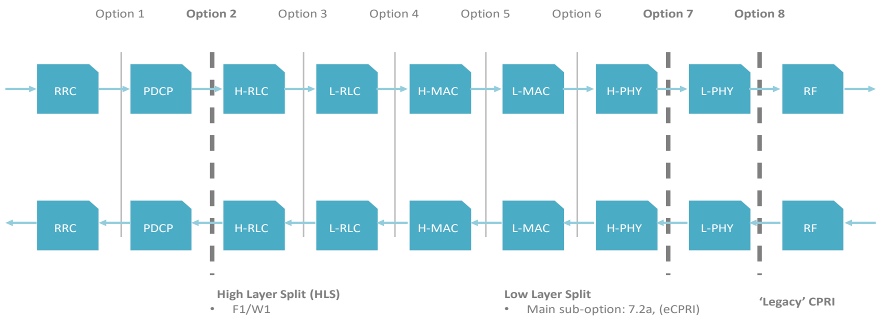

Figure 4 5G RAN base station functional blocks and split options

The interfaces for HLS and LLS differ in several aspects, such as bandwidth requirements, latency tolerance, functionality and complexity of RU, as discussed in the study by 3GPP and O-RAN [21]. HLS (Option 2) requires less bandwidth and tolerates higher latency than LLS (Option 7 or Option 8). LLS benefits from simpler and cost-efficient RUs and offers better possibilities for centralized aggregation and capacity integration.

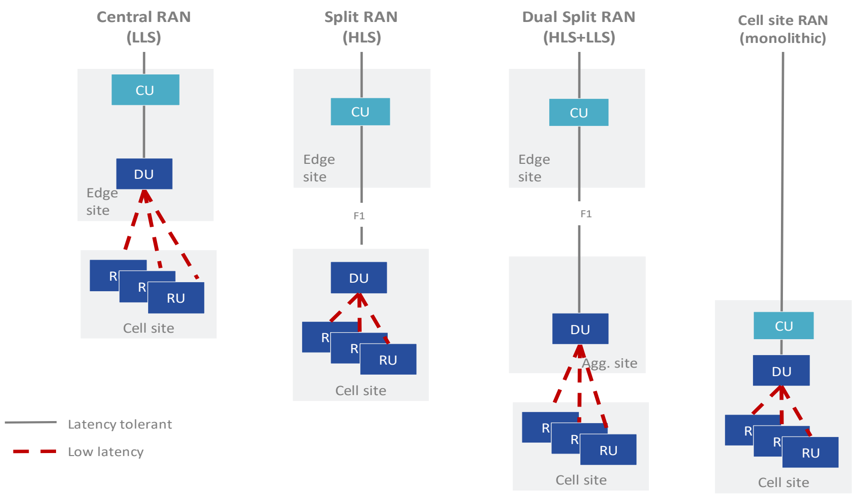

Figure 5 Some options for the gNB functional separation

Disaggregation of the 5G base station (gNB) functional entities and the corresponding MFH interfaces give operators new opportunities to place the functions in separate physical locations according to their priorities. Figure 5 presents several options for placement of these functions at a cell site, at an aggregation site that is traditionally used for transport aggregation, or at an edge site. The choice of option depends on several factors such as transport network topology, availability of sites, latency and capacity limitations, as well as the availability of compute resources.

A MEF MFH service can provide transport connectivity at the Option 2 (F1), Option 7 (eCPRI), or Option 8 (legacy CPRI) split points. In addition, MEF defined the MEF MBH service for the connectivity between a BBU and EPC and between a CU and 5G core (5GC) [15][16].

4.2 Network Sharing for 5G

Network sharing in mobile networks has been common since the introductions of 3G and 4G. The reasons to share mobile networks include reduction in the cost of coverage per operator and customer satisfaction. Network sharing is a rational approach that can help reduce costs, maximize efficiency and enhance customer satisfaction.

Figure 6 shows a range of mobile network sharing models. 3GPP standards fully support network sharing between operators in different scenarios such as Multi Operator Radio Access Network (MORAN) and Multi Operator Core Network (MOCN) [1]. In these models, generally called RAN sharing, base stations, RUs, DUs, CUs and the associated transport networks are shared among MNOs (such as MNOs A and B in Figure 6). Mobile transport sharing is a model in which MNOs lease transport network connectivity from transport Service Providers for their MBH/MFH. Another model is where an MNO's whole network is shared, including the mobile core and RAN, with Mobile Virtual Network Operators (MVNOs).

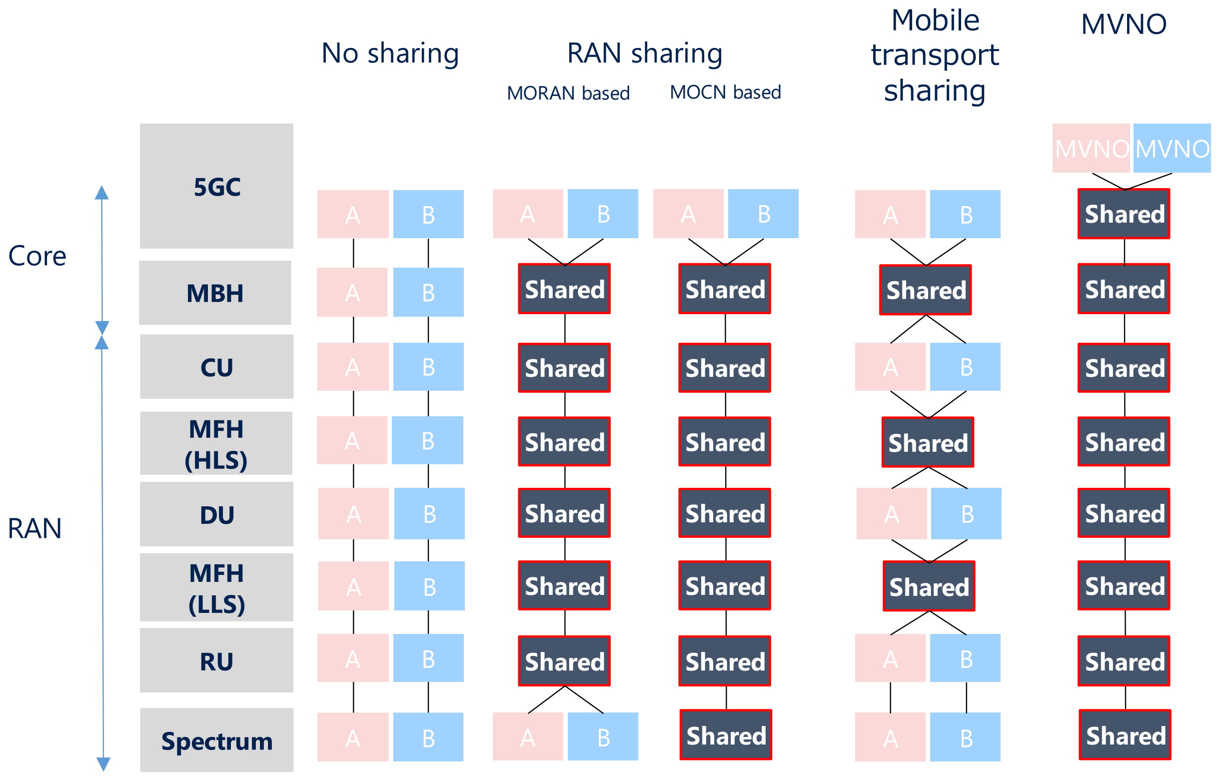

Figure 6 Mobile network sharing models

The mobile transport network is a key component for implementing mobile network sharing, as it is necessary for all models of sharing. MBH sharing has been common in many countries using 4G and will continue to be so in the era of 5G. On the other hand, legacy MFH LLS networks cannot be shared because they are implemented either with direct fibers or with wavelength division multiplexing (WDM) equipment for CPRI/OBSAI. In these networks the traffic occupies a dark fiber or a single wavelength of a WDM system. In 5G, MFH LLS networks will be sharable because eCPRI requires less bandwidth and is more latency tolerant than legacy CPRI. Furthermore, MFH HLS networks (Option 2) require less bandwidth and tolerate higher latency than LLS. This enables Service Providers to offer MFH services over shared networks as is currently the practice for MBH services.

MEF has developed implementation guidelines for mobile transport services which can be offered over shared mobile transport networks [14]. A MEF Service Provider may provide transport network services for MBH and/or MFH to multiple customers, i.e., MNOs. MEF standards play a significant role in network sharing for 5G mobile transport. Specifically, MEF standards can be useful in the following mobile transport network sharing scenarios:

1. Service Provider providing MBH and MFH services for multiple MNOs
2. MNO sharing its transport network with other MNOs

4.3 Network Slicing for 5G

Network slicing is a means for a Service Provider (or any network operator) to create independent, isolated logical networks within its common or shared network infrastructure. These network slices can be offered externally to customers or used internally by the Service Provider. A Service Provider can use network slicing to structure and organize the elements of its infrastructure, i.e., the capabilities and functionality exposed and their management, providing self-contained units (network slices) of varying sizes and complexity.

5G network slicing first emerged in the MNO domain and received additional attention when the NGMN 5G Vision White Paper was published in 2015 [19]. Many standards organizations — 3GPP being a prominent one — began work on the topic. Examples of other standards organizations with related activities are BBF, ETSI ISG NFV, GSMA, IEEE, IETF, and ITU-T. In addition to standards organizations, some open source communities, such as ONAP and OSM, are addressing the issue of implementing network slicing.

A 5G network slice, as defined by the 3GPP, is inherently an end-to-end concept used to connect the mobile user's equipment to tenant-specific applications (which may reside in public or private clouds). Within end-to-end 5G network slices, transport slices are created as independent logical networks that enable multiple tenants on each single physical infrastructure supporting the connectivity path. From a customer perspective, transport slices offer improvement in service flexibility/customization and deterministic service level specifications (SLSs) that can be strictly enforced (for example, to meet traffic engineering requirements for bandwidth, low latency, high availability).

Besides the focus on mobile networks — especially mobile transport in this White Paper — the 5G and network slicing concept has wider applicability. However, the terms 'network slicing' or 'network slice' are not always used in those broader contexts (for example, an alternative is 'virtual network'). The common concept is logical customized networks over a common infrastructure used to provide flexible solutions for different market scenarios. The scenarios have diverse network requirements with respect to functionality, performance and resource allocation.

4.4 Network Slicing vs Network Sharing for 5G Mobile Transport

This section presents the additional benefits of network slicing over and above those of network sharing.

Figure 7 shows the traditional network sharing model without network slicing. In this model, MNO_A and MNO_B share a physical mobile transport network, which is owned by a third party transport Service Provider or either one of the two MNOs. MNO_A and MNO_B directly control and manage each node and link for configuration and monitoring. Configuration and management actions of both MNOs must be carried out in a tightly coordinated manner because an operation by one MNO can affect the other MNO's services as a result of their sharing the same physical infrastructure. To avoid possible service quality degradation, a contract or agreement between MNO_A and MNO_B and strict compliance are necessary.

As shown in Figure 8, network sharing with slicing enables sharing of the physical mobile transport network via the provisioning of dedicated virtual networks for MNO_A and MNO_B.

These virtual networks are independent and isolated from each other even though they share the same physical mobile transport network, owned either by MNO_A, MNO_B or a third party transport Service Provider. Each MNO arranges a contract with the owner of the physical transport network for dedicated virtual networks as slices. Therefore, a sharing contract or agreement between MNO_A and MNO_B is no longer necessary since they each have independent control and management of their respective virtual networks. In other words, network slicing enables network sharing with independent operation and management by the MNOs.

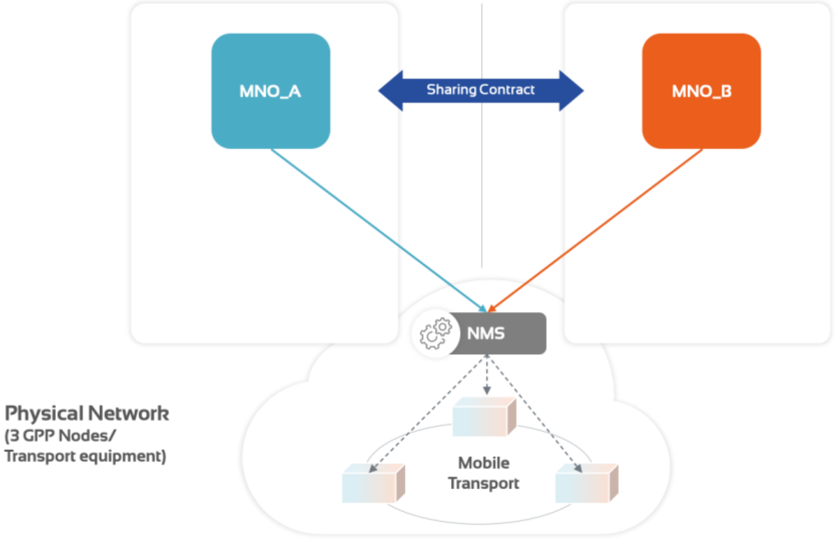

Figure 7 Network sharing without slicing

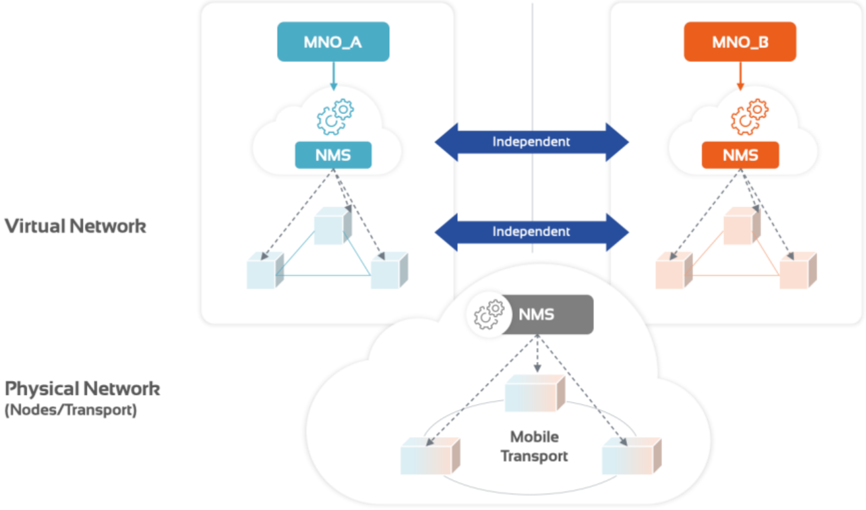

Figure 8 Network sharing with slicing

4.5 MEF LSO

Network automation with MEF LSO helps reduce management complexity so that operators can achieve the speed and efficiency they need to make 5G network slicing economical. According to Bell Labs, automated networks will see a 30% decrease in operational costs versus the present mode of operations used in traditional WANs [7].

MEF LSO provides APIs to automate the entire lifecycle of services orchestrated across multiple provider networks and multiple technology domains within a provider network [17]. The LSO reference architecture, shown in Figure 9, characterizes the management and control domains (e.g., SP and Partner) and functional management entities (e.g., Business Applications) that enable inter-provider orchestration. The architecture also identifies the management interface reference points (e.g., LSO Sonata) which are the logical points of interaction between specific functional management entities. These management interface reference points are further defined by interface profiles and implemented as APIs. Note that this is a functional architecture and does not describe how the functional management entities are implemented (e.g., single vs. multiple instances), but rather identifies functional management entities that provide logical functionality as well as the points of interaction among them.

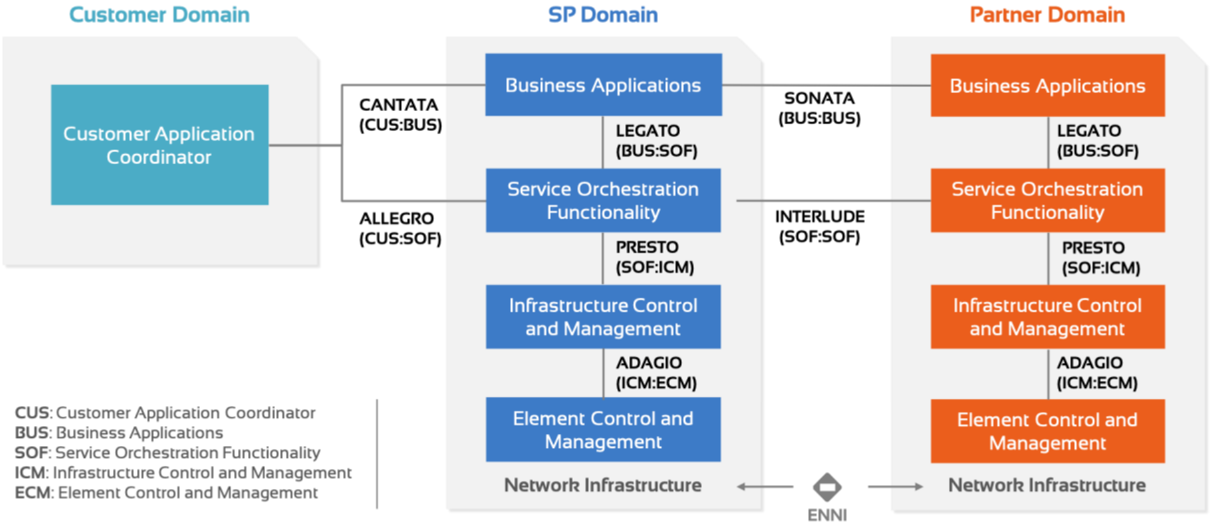

Figure 9 MEF LSO Reference Architecture

In LSO, services are orchestrated by a Service Provider across all internal and external network domains from one or more network operators. These network domains may be operated by, among others, CSPs, data center operators, enterprises, wireless network operators, virtual network operators, and content providers. LSO spans in a federated approach all those network domains that require coordinated management and control to deliver end-to-end services.

The LSO Cantata interface is used for business-related interactions such as ordering and billing between the Customer and the Service Provider, and LSO Sonata is used for similar business-related interactions between Service Providers.

The LSO Allegro interface is used for configuration and control-related management interactions that are allowed by the respective service agreement such as operational state queries, request updates to service parameters, or requests to instantiate other services.

The LSO Presto interface is used for orchestrating within the Service Provider domain at the network level and the LSO Adagio interface correspondingly orchestrates at the resource level. According to MEF 55, both these interfaces allow for APIs that are used for the purpose of orchestrating compute resources in parallel to other resources.

5 Network Sharing and Slicing for 5G Use Cases based on MEF 3.0 standards

In this section, network sharing and slicing for 5G use cases show how standardized MEF 3.0 Services apply. MEF Services supporting 3GPP 5G networks help MNOs implement their RAN by providing mobile transport and potentially the RAN itself as a virtual network.

The first mobile transport use cases focus on network sharing and slicing in a 5G RAN, i.e., MEF Services supporting 3GPP 5G networks. They show how MEF 22.3 [15] and MEF 22.3.1 [16] provide the MFH or MBH connectivity services to implement a RAN and the importance of LSO in the orchestration, control and management of mobile transport networks.

Figure 10 illustrates the business relationship where MNOs are the Customers who order mobile transport services from the transport network provider. The transport network provider implements LSO interfaces for service ordering and intra-provider service orchestration (not shown), then creates MFH (LLS), MFH (HLS), or MBH connectivity according to the MNOs' orders. In parallel, MNOs configure mobile network functions such as RUs, DUs, CUs, and 5G cores using their internal interfaces. By connecting these mobile network functions to mobile transport services, MNOs can build their mobile networks using a shared transport network.

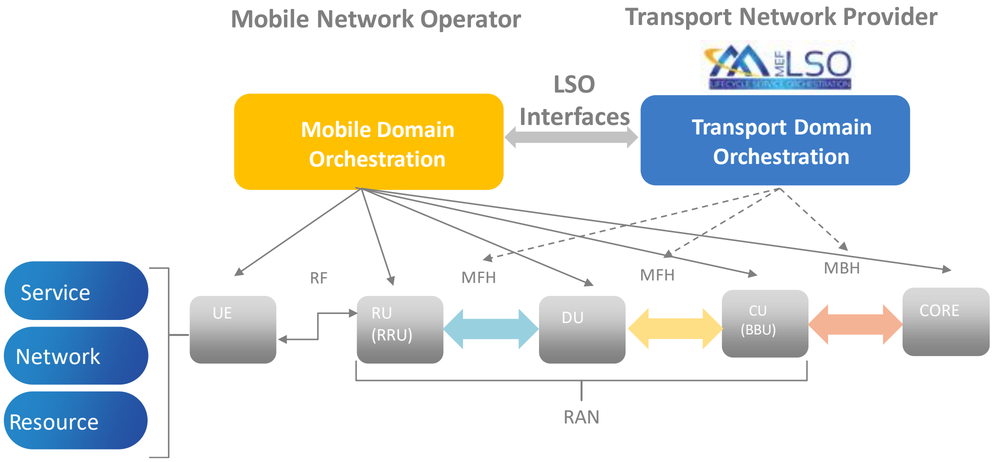

Figure 10 MEF services supporting 5G network

Other use cases introduce network slices for RAN sharing. These are based on different business models in which MNOs (Customers) buy either an entire mobile transport or RAN components provided as dedicated virtual networks (network slices) from a Service Provider. As MNOs will require orchestration, configuration and management capabilities for their virtual networks, these may be provided through LSO interfaces.

5.1 Network Sharing Use Cases for 5G Mobile Transport

The transport network is one of the largest investments for an MNO as it typically requires wireline connectivity between communication sites. For that reason, MBH sharing is already an established practice for previous generations of mobile service. Similarly for 5G, the key to making more investment savings in mobile transport for 5G is the sharing of MFH in addition to MBH while meeting the different requirements of MNOs with different types of connectivity and SLSs.

An MNO can use MEF Services to provide connectivity for its 3GPP RAN and core network (CN). MEF 22.3 [14] specifies the requirements for Carrier Ethernet Services and external interfaces (such as Ethernet UNI and ENNI) for MBH connections and MEF 22.3.1 [16] specifies the requirements for MFH (both HLS and LLS) connections.

Therefore, by using MEF 22.3 and MEF 22.3.1, mobile transport for MFH and MBH can be implemented with an industry-standard service. These standards are beneficial for both Service Providers and their Customers (MNOs). On the one hand Service Providers are afforded new revenue-generating opportunities to provide MFH services to MNOs in addition to MBH services. On the other hand, Customers (MNOs) can reduce their capital investment in MFH.

In this section, use cases based on MEF 22.3, MEF 22.3.1 and relevant standards for mobile transport services are presented. The mobile transport Service Provider can use network slicing of its infrastructure to create one transport network slice per MNO.

As summarized in a previous study [6], performance requirements for MFH (LLS and HLS) and MBH are different in terms of latency, bandwidth and synchronization. In general, MFH (LLS) has stringent quality requirements to support the eCPRI interface. MFH (HLS) is less strict for latency and bandwidth compared with MFH (LLS). MBH also has different characteristics and requirements. Service Providers need to take into account these differences in providing mobile transport services to their Customers.

5.1.1 Mobile Transport with Point-to-Point Connectivity Services

Figure 11 shows a simple use case of a mobile transport service. MNOs as Customers can choose from three types of connectivity services based on MEF standards, and are able to create, modify, and monitor the respective types of connectivity through LSO APIs.

The Customer (MNO_A) shown in blue requests MFH (HLS) from a Service Provider for the point-to-point connectivity between an RU and DU; the Customer (MNO_B) shown in green requests MFH (LLS); and the Customer (MNO_C) shown in orange requests MBH.

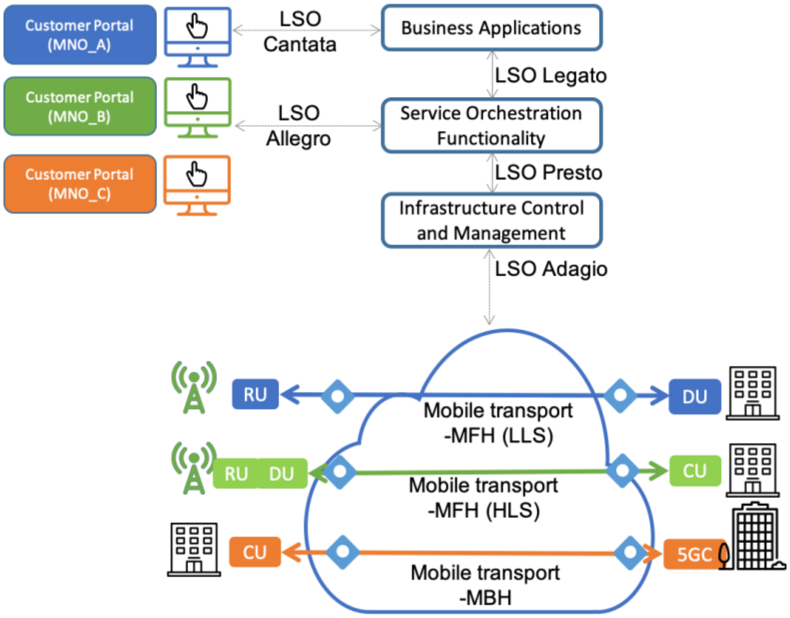

Figure 11 Point-to-point mobile transport use case

This point-to-point connectivity can be implemented with an Ethernet Private Line (EPL) Service (MEF 6.2 [14]) — the connectivity service between two UNIs.

5.1.2 Mobile Transport with Multipoint-to-Multipoint Connectivity Services

Figure 12 presents another use case of a mobile transport service. Multipoint-to-multipoint service is used where each MNO needs separated connections between multiple pieces of equipment at a radio site and multiple entities at a local/aggregation site.

As shown in figure 12, the Customer (MNO_A) shown in blue has multiple RUs at a cell site and corresponding DUs at a local site. Every connectivity between RUs and DUs is independent and should not be aggregated to ensure the MFH (LLS) latency and bandwidth requirements are met. The Customer (MNO_B) shown in green has dedicated MFH (HLS) connectivity services for all combinations between DUs and corresponding CUs. The Customer (MNO_C) shown in orange has MBH connectivity services for all combinations between CUs and corresponding 5GCs.

Multipoint-to-multipoint mobile transport service enables MNOs to connect multiple entities between two sites with dedicated connectivity. It can also be implemented using EPLs for mesh connectivity.

5.1.3 Mobile Transport with Multipoint-to-Point Connectivity Services

Figure 13 presents a general use case for MNOs. The traffic from a cell site or local site often aggregates at another site. The connectivity between multiple local sites and aggregation sites can also be implemented with a MEF Service.

In this figure, the Customer (MNO_A) in blue has MFH (LLS) connectivity between multiple RUs at different sites and a single DU at a local site. The Customer (MNO_B) in green has MFH (HLS) connectivity between multiple DUs at different sites and a single CU at an aggregation site. The

Customer (MNO_C) in orange has MBH connectivity between multiple CUs in different sites and a single 5GC.

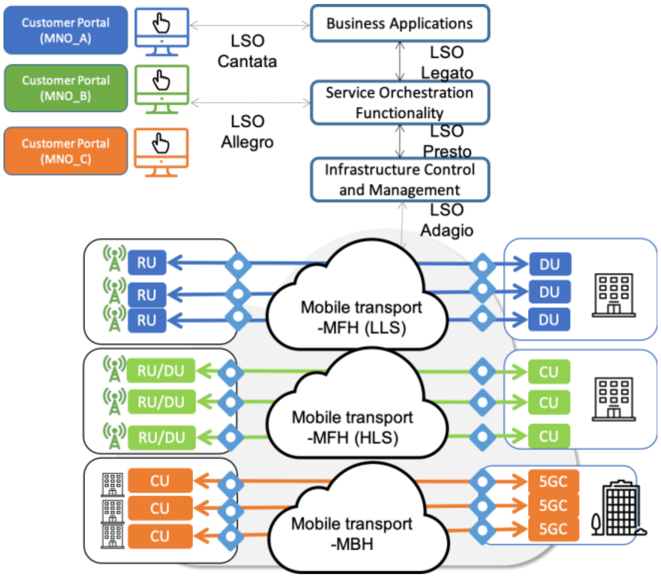

Figure 12 Multipoint-to-multipoint mobile transport use case

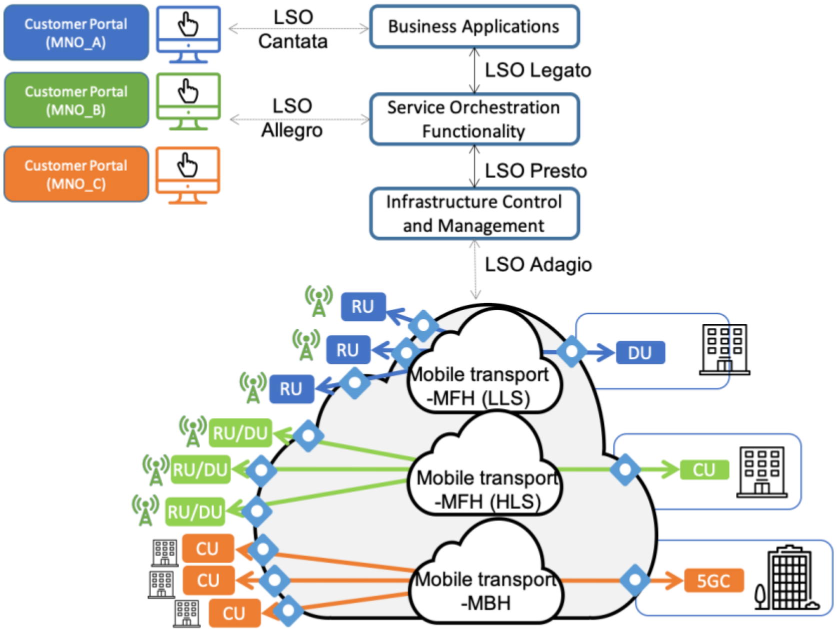

Figure 13 Multipoint-to-point mobile transport service

The connectivity described above can be implemented with an EVPL Service. MNOs can benefit from MEF standardized services and interface attributes for mobile transport services and the LSO automation benefits of on-demand creation and management of mobile transport services.

5.1.4 Mobile Transport with Multi-Layer Connectivity Service

As described in Section 4.1, mobile transport networks differ in their level of requirements for connectivity quality, such as latency, bandwidth and availability. To satisfy these requirements, MNOs can choose to create connectivity at the optimal transport layer.

Figure 14 presents the use case for multi-layer mobile transport services. The Customer (MNO_A) shown in blue requests optical transport connectivity for MFH (LLS) to connect a RU with a DU. The Customer (MNO_B) shown in green requests Carrier Ethernet connectivity for MFH (HLS) to connect a DU and CU. The Customer (MNO_C) shown in orange requests an IP service for the MBH to connect the CU and 5GC.

MEF standards have been defined for these multi-layer connectivity services and can be applied to mobile transport connectivity to satisfy SLS requirements. LSO APIs are also available to orchestrate these multi-layer connectivity services.

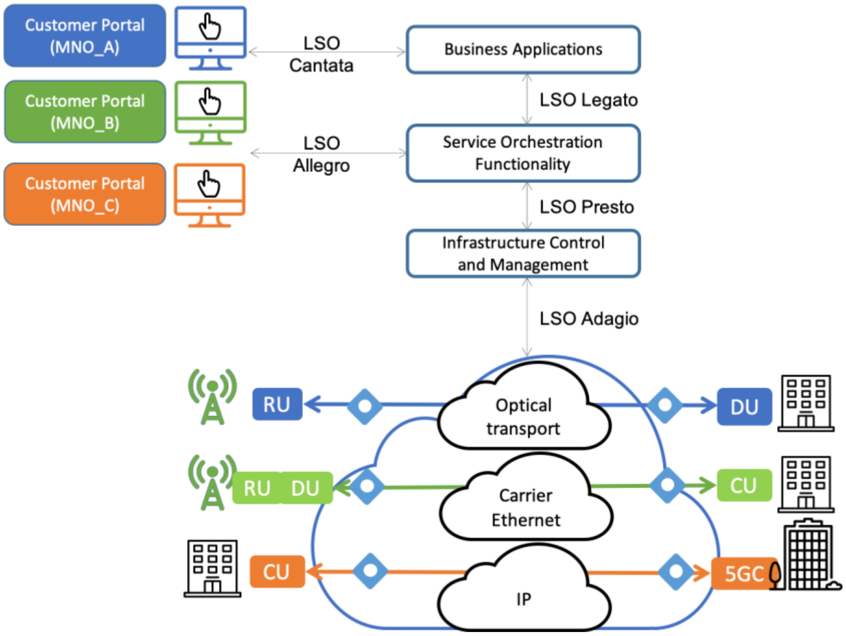

Figure 14 Multi-layer mobile transport service

5.2 Network Slicing Use Cases for 5G Mobile Transport

This section presents network slicing use cases for mobile transport. In these use cases, three MNOs use services from the same Service Provider of mobile transport connectivity connecting each MNO’s respective RUs/DUs/CUs to their corresponding DUs/CUs/5GCs. The Service Provider applies network slicing to its shared mobile transport network creating three network slices that include compute resources for deploying CU/DU functions — one slice per MNO: blue, green, orange. These three network slices are constructed on common infrastructure, with mobile transport network management enforcing their isolation.

The Service Provider provides each of its customers with network service and visibility into the network slice serving that customer’s connections. The customers are able to perform certain configuration and management activities, which are described in subsections 5.2.1 and 5.2.2 in different scenarios. Figures in these subsections show MNO_A and the corresponding Service Provider network slice MNO_A slice shown in blue; MNO_B and the corresponding Service Provider network slice MNO_B slice shown in green; MNO_C and the corresponding Service Provider network slice MNO_C slice shown in orange.

5.2.1 Mobile Transport Network Slice Configuration Scenarios

To obtain a network connecting their radio locations to the co-location site, MNOs use a network service from a Service Provider. The network service exposes a network for creating connections and computes resources for deploying functions.

5.2.1.1 VNF Deployment

In **Scenario 1** in Figure 15, the Customer (MNO_A) shown in blue uses its network service for deploying DUs/CUs and connections between them. MNO_A requests network functions such as DUs and CUs to be deployed to a specific compute node in the exposed network. It can request the instantiation of MFH (LLS) connections between RUs and DUs, MFH (HLS) connections between DUs and CUs, and MBH connections between CUs and 5GC. Although CUs and DUs are used as examples for network functions for simplicity in this scenario, other network functions are also possible, such as security and QoS control functions.

5.2.1.2 Topology and Redundancy Configuration

Many MNOs want to configure the primary and secondary path themselves for low latency or high availability. **Scenario 2** in Figure 15 illustrates a topology and redundancy configuration scenario of MNO_B slice for mobile transport. In this scenario, the Customer (MNO_B) shown in green is provided another network service by the Service Provider and it configures redundant paths as a combination of Ethernet Virtual Connections (EVC) for mobile transport connections. In this scenario, MNO_B requests connections to a DU from an RU through a specific link or node to minimize latency or implement redundancy for connectivity. For the connections between a DU and CU or between a CU and 5GC, MNO_B requests specific routes for latency or redundancy requirements.

5.2.1.3 Multi-Service

MNOs themselves need to ensure sufficient performance quality for mobile transport and cost reductions by network sharing, while guaranteeing SLS. Therefore, multi-layer connectivity configuration and control are essential. **Scenario 3** in Figure 15 illustrates configuring multi-layer connectivity in a network slice for mobile transport. In this scenario, the Customer (MNO_C) shown in orange requests L1 connectivity service for MFH (LLS), Ethernet L2 connectivity service for MFH (HLS) and L3 connectivity service for MBH.

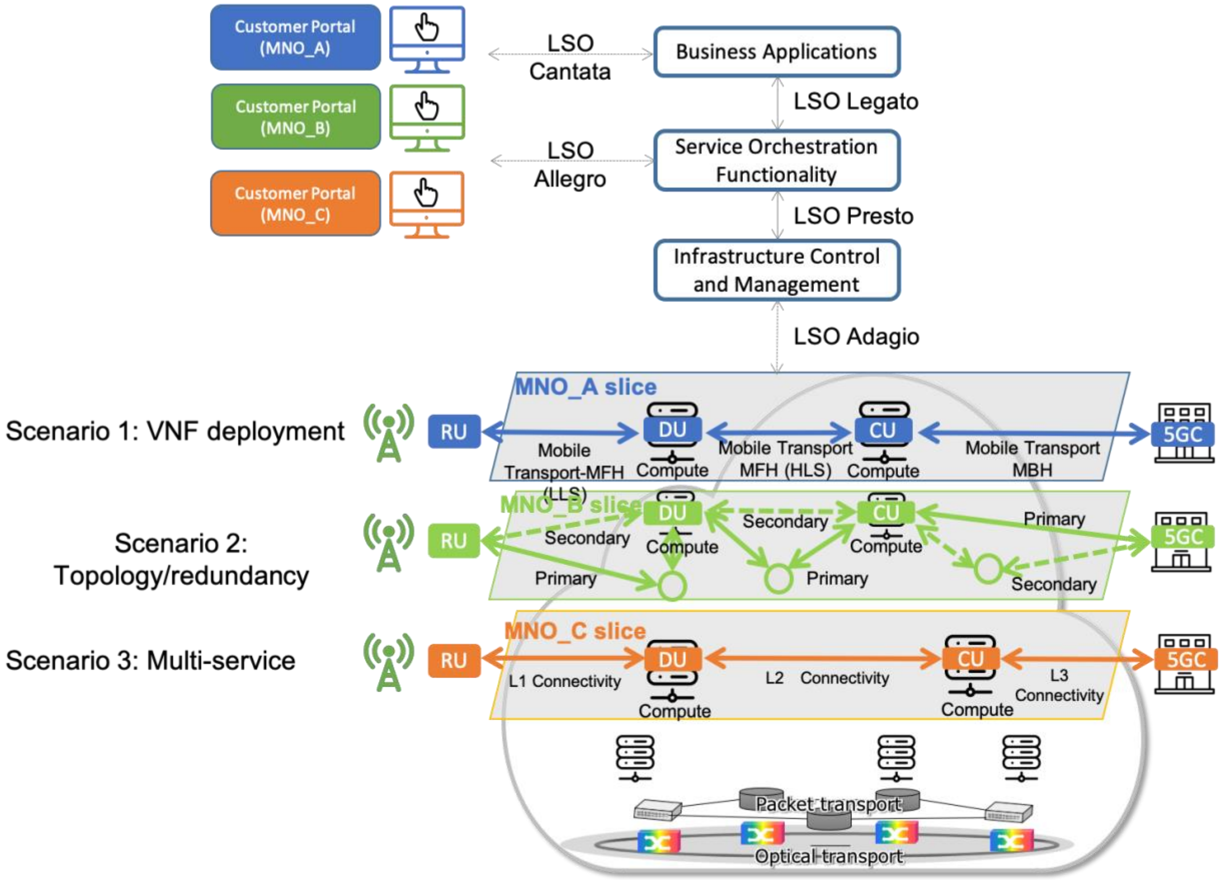

Figure 15 Mobile transport network slice configuration scenarios

5.2.2 Mobile Transport Slice Management

In addition to configuration, management is also important for mobile transport slices because mobile transport needs to satisfy strict SLSs regarding latency, jitter and bandwidth. In this section, three scenarios regarding mobile transport slice management are presented.

5.2.2.1 Performance Monitoring

Scenario 1 in Figure 16 illustrates the performance monitoring of a mobile transport slice. Through LSO APIs, the Customer (MNO_A) shown in blue configures a mobile transport network using a dedicated service provided by a Service Provider. Performance data, such as latency, for each connection/link is reported for the service to MNO_A. MNO_A monitors service performance and confirms that it satisfies the SLS requirements.

5.2.2.2 Resource Monitoring

Scenario 2 in Figure 16 illustrates resource monitoring of a mobile transport slice. The Customer (MNO_B) shown in green monitors network or compute resource usage, such as traffic volumes per link for transport resources and CPU/memory usage for compute resources. Resource monitoring is necessary for MNOs to keep mobile transport quality stable and optimize network/compute resources.

5.2.2.3 *Fault Monitoring*

Scenario 3 in Figure 16 illustrates fault monitoring of a mobile transport slice. In this scenario, the Customer (MNO_C) shown in orange uses a network service as a mobile transport slice. MNO_C monitors the states of links and nodes in MNO_C slice to obtain information about fault location, recovery and history enabling it to locate any causes of failure and to take remedial action.

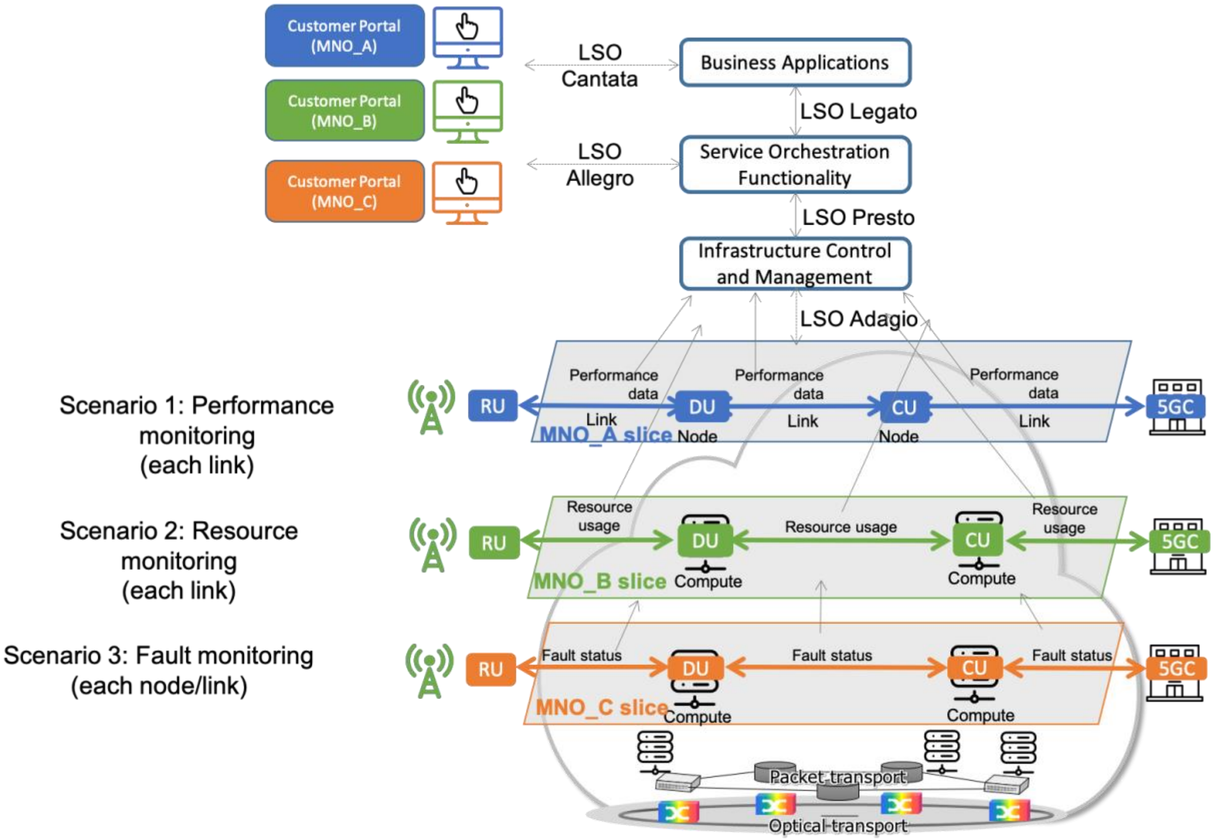

Figure 16 Mobile transport network slice management scenarios

5.3 LSO Orchestration of Transport Slices

LSO orchestration of transport slices is an important factor to consider in the context of supporting 3GPP 5G network slices.

Although the primary focus of this White Paper is network sharing and slicing for MFH and MBH, it is worth considering how LSO-based orchestration can be applied beyond MFH and MBH. This serves the aim of Service Providers to automate the service lifecycles and maximize the coordination of 5G services orchestration, management and control across all 5G mobile network domains (RAN, transport and core).

3GPP specifies standards for 5G mobile networks and mobile network slicing. In the following use cases, MEF LSO functions are correlated to 3GPP network slice and subnetwork slice management functions as follows:

- The MEF end-to-end Service Orchestration Function (SOF) is referenced by 3GPP as the E2E Network Slice Management Function (NSMF)
- MEF network domain controllers for RAN, transport and core network domains which provide Infrastructure Control and Management functions (ICM) are referenced by 3GPP as the Network Slice Subnet Management Function (NSSMF)

3GPP has defined the interfaces for the NSMF to communicate with both the RAN NSSMF and core NSSMF. However, 3GPP has not, as yet, defined the same interface for the transport domain. In this use case the MEF LSO Presto interface reference point (SOF:ICM) is applicable for the NSMF to communicate with the transport NSSMF.

In support of services on 3GPP-defined 5G E2E network slices, transport slices provide the corresponding mobile transport networks. These enable consistent operational practices and automation on less complex networks, thus accelerating service delivery.

Transport slices also enable different endpoints with specific SLSs to be connected using a multitude of types of shared or dedicated network resources with differing levels of isolation. There is a need for flexibility in implementing transport slices to support the delivery of 5G services across mobile transport networks consisting of products from multiple vendors, multiple domains and using various transport network technologies, tunnel types (e.g., ODU/OCh, Ethernet, IP, MPLS, segment routing) and MEF Service types (e.g., Optical transport, Carrier Ethernet, IP VPN). This implementation flexibility enables support for a wide range of E2E 5G deployment scenarios and use cases, including for 4G/5G hybrid networks.

For example, in Figure 17, a single Service Provider is both the MNO and the transport network provider. The E2E 5G network deploys an E2E network slice composed of a RAN subnetwork slice, three transport slices and a core subnetwork slice. The transport slices enable the transport connectivity between network elements in the RAN and core subnetwork slices across low latency MFH (LLS) (slice 1 with blue connections), high latency MFH (HLS) (slice 2 with yellow connections) and MBH (slice 3 with red and green connections). Transport slicing may also be applied from the 5G core to public networks or clouds.

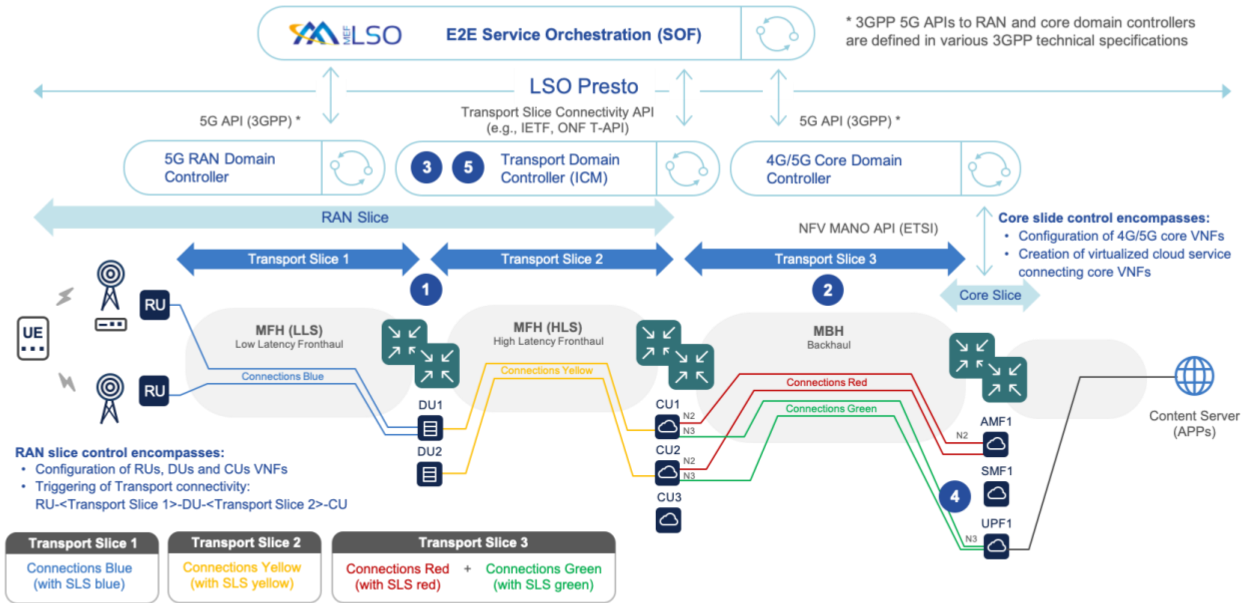

Figure 17 E2E 5G services support using 3GPP and MEF LSO for mobile transport domain use cases

The E2E network slice is orchestrated by the E2E Service Orchestration (SOF) using the RAN, core and transport domain controllers (ICMs) via APIs at the MEF LSO Presto interface reference point. The domain controllers can expose APIs at LSO Presto that can be implemented compatibly with relevant standards (e.g., 3GPP, ETSI-NFV, IETF, ONF T-API [20], MEF NRM [18]).

Figure 17 shows possible MEF LSO-related use cases for the 5G transport domain described in the following sub-sections.

5.3.1 Creation of MFH Transport Slices

In this use case (blue circle #1 in Figure 17), LSO Presto APIs are used to create two transport slices connecting the fronthaul RUs to DU1 (Transport slice 1) and DUs to CUs (Transport slice 2).

The 3GPP 5G API supports the creation of the RAN slice where the 5G RAN domain controller (ICM) configures the RUs, as well as the DU and CU VNFs, which then triggers the creation of the RAN transport connectivity (i.e., RU – Transport slice 1 – DU – Transport slice 2 – CU) by the transport domain controller (ICM).

5.3.2 Creation of MBH Transport Slices

In this use case (blue circle #2 in Figure 17), LSO Presto APIs are used to create a transport slice connecting the RAN to the core (Transport slice 3).

The 3GPP 5G API and ETSI NFV MANO API [9] support the creation of the core slice where the 5G core domain controller (ICM) configures the 4G/5G core VNFs, which then triggers the creation of the virtualized cloud services connectivity which connects the 4G/5G core VNFs. In this case, once the core slice has been created, the E2E Service Orchestration (SOF) triggers the transport domain controller to connect the RAN slice to the core slice.

5.3.3 Visualization and SLS Monitoring of Transport Slices

In this use case (blue circle #3 in Figure 17), visualization and SLS monitoring of transport slices 1, 2 and 3 are achieved through exposure to the E2E service orchestrator via LSO Presto APIs.

Once transport slices 1, 2, 3 have been created, the transport domain controller (ICM) is then able to streamline and automate the visualization and SLS monitoring of transport slices by exposing its transport slice connectivity data model to the E2E Service Orchestration (SOF).

5.3.4 Creation of New or Additional MBH Connectivity Triggered by New Core VNF

In this use case (blue circle #4 in Figure 17) that builds on the use case depicted as blue circle #2, the creation of a VNF instance in the core triggers via inter-domain (east-west) operational functionalities the creation in the transport domain of additional backhaul connectivity (Transport slice 3) to the RAN slice, after which the E2E service orchestrator is notified via LSO Presto APIs.

5.3.5 Creation of New or Additional MBH Connectivity Triggered by Core Optimization

In this use case (blue circle #5 in Figure 17) that builds on the use case depicted as blue circle #4, a core VNF being moved due to core slice optimization (i.e., after a core slice SLS violation) automatically triggers the required additional connectivity.

This same use case could be used within a RAN if, for example, the CU VNF is moved due to a RAN slice optimization (i.e., after a RAN slice SLS violation), where the moved CU VNF now requires fronthaul connectivity to a DU.

5.3.6 Cloud interconnect automation creating transport connectivity for 5G network slices

A key use case for 5G mobile network slicing is that of cloud interconnect automation, where the deployment of VNF instances can dynamically establish transport connectivity (using appropriate transport slices) to connect the core and RAN slices. In this use case, where a virtual 5G RAN or 5G core is within an edge cloud or central cloud, the data center gateway (see an example visualized in Figure 18) is a delineation point between the transport domain and the virtual network. The use of signaling protocols, supported by the data center gateway, is one method of implementing cloud interconnect automation to dynamically trigger the creation of transport connectivity for specific VNFs (that will be a part of a core or RAN slice). This type of cloud interconnection automation enables a transport domain controller (ICM) to coordinate across domains to achieve deterministic SLSs across E2E virtual and physical network resources.

The mapping of a transport slice SLS policy to specific transport network policy colors is one approach for cloud interconnect automation to implement closed-loop adherence for pre-determined SLSs (which for 5G transport slicing can be designed by the operator to support a specific type of slice). For example, in Figure 18, cloud interconnection automation can be used for a BGP EVPN virtualized overlay service over Segment Routed Traffic Engineered (SR-TE) inter-domain transport services. In this example, the transport slice SLS policy gets mapped to SR-TE policies between access and edge clouds, as well as edge cloud and core cloud.

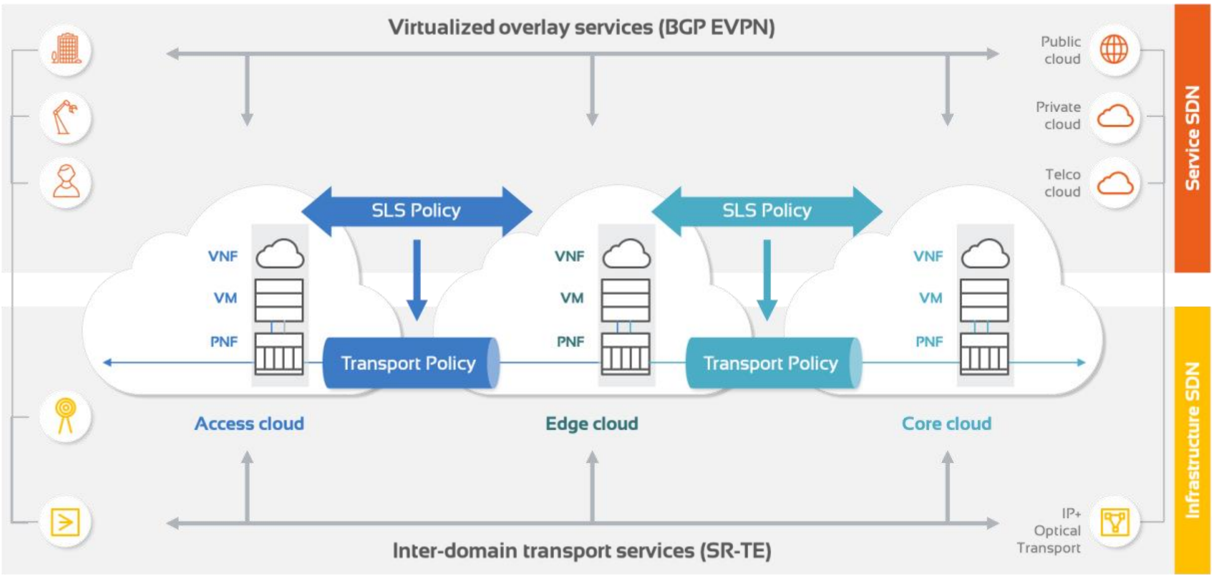

Figure 18 Example of SLS adherence using cloud interconnect automation

6 Ongoing MEF Developments for Network Sharing and Slicing for 5G

There are many possible use cases of network sharing and slicing for 5G. In addition to the use cases presented in this White Paper, MNOs can also apply MEF LSO principles to provide their customers (enterprises) with MEF Services deployed using the infrastructure provided by a 3GPP 5G network. Examples of such services are a VPN (utilizing MEF Carrier Ethernet or IP Services) or an SD-WAN, accessed via the MNO's mobile network, including overlay connectivity to applications hosted in public or private clouds. This includes use cases of network slicing of the entire 5G mobile network for third party Service Providers (e.g. verticals, application service providers and enterprise customers).

The publication of MEF 22.3.1 has created the basis for a wide range of new work in MEF to support the rapidly evolving needs of the network sharing and slicing services market. The following activities provide opportunities for industry players to participate in that MEF work.

- **Transport Services for Mobile Networks:** This project develops mobile transport service implementation agreements, including for 5G, such as MBH and MFH (LLS/HLS).

- **Network Slicing:** This project is defining Network Slicing in the context of MEF LSO and MEF Services.

7 Summary

Using MEF 22.3 and MEF 22.3.1, Service Providers can offer new mobile transport services such as MFH (LLS/HLS) and MBH, for 5G mobile network sharing in addition to the current 4G MBH. MNOs also benefit from the efficiency of sharing mobile transport with other MNOs and can focus on, and invest more in, expanding their 5G coverage.

Network slicing brings a new model of mobile transport sharing as virtual dedicated networks for MNOs. MNOs can configure and manage their dedicated mobile transport without the need for sharing agreements between them. This accelerates 5G mobile network deployment because there is no need for strict coordination between MNOs that are sharing transport networks.

This White Paper presents important use cases as the industry experiences dramatic new demand for network slicing as a result of the introduction of 5G.

MEF’s LSO framework enables the integration of MEF 22.3/22.3.1 mobile transport services in a federation of Service Providers supporting multi-operator, on-demand 5G connectivity services.

8 About MEF

An industry association of 200+ member companies, MEF has introduced the MEF 3.0 transformational global services framework for defining, delivering, and certifying assured services orchestrated across a global ecosystem of automated networks. MEF 3.0 Services are designed to provide an on-demand, cloud-centric experience with user- and application-directed control over network resources and service capabilities. MEF 3.0 Services are delivered over automated, virtualized, and interconnected networks powered by LSO, SDN, and NFV. MEF produces service specifications, LSO frameworks, open LSO APIs, software-driven reference implementations, and certification programs. MEF 3.0 work will enable automated delivery of standardized Carrier Ethernet, Optical Transport, IP, SD-WAN, Security-as-a-Service, and other Layer 4-7 services across multiple provider networks. For more information, visit https://www.mef.net and follow us on LinkedIn and Twitter @MEF_Forum.

9 Terminology

Term	Definition	Reference
BBU	Base Band Unit	3GPP TS 38.300 [5]
5GC	5G core	3GPP TS 23.501 [3]
CU	Centralized Unit	3GPP TS 38.300 [5]
Customer	An organization purchasing, managing, and/or using Services from a Service Provider. This may be an end user business organization, mobile operator, or a partner network operator.	MEF 55 [17]
CSP	Communications Service Provider	MEF 22.3 [15]
DU	Distributed Unit	3GPP TS 38.300 [5]
EPC	Evolved Packet Core	3GPP TS 23.401 [1]
EVPL	Ethernet Virtual Private Line	MEF 6.3 [10]
HLS	High Layer Split	3GPP TS 38.300 [5]
ICM	Infrastructure Control and the Management	MEF 55 [17]
LSO	Lifecycle Service Orchestration	MEF 55 [17]
LLS	Low Layer Split	3GPP TS 38.300 [5]
MBH	Mobile Backhaul	MEF 22.3.1 [16]
MFH	Mobile Fronthaul	MEF 22.3.1 [16]
MNO	Mobile Network Operator	This document
RAN	Radio Access Network	MEF 22.3 [15]
RRH	Remote Radio Head	3GPP TS 38.300 [5]
Mobile transport	Mobile transport is transport connectivity including from 5GC to CU, from CU to DU and from DU to RU. This term represents all of MFH (HLS), MFH (LLS) and MBH.	This document
PDN	Packet Data Network	3GPP TS 23.401 [2]
RU	Radio Unit	3GPP TS 38.300 [5]

Term	Definition	Reference
Service Level Specification	The technical section in a service provider's Service Level Agreement (SLA) is often referred to as a Service Level Specification (SLS) The SLS often includes, not exclusively, the following topics: • Service performance • Service objectives • Metrics definitions • Measurement of metrics • Method of classification • Bandwidth profile details • Tagging at interfaces	MEF Reference Wiki [22]
SLS	Service Level Specification	MEF Reference Wiki [22]
Service Provider	An organization providing Services to Customers in exchange for payment.	MEF 55 [17]
SOF	Service Orchestration Function	MEF 55 [17]

Table 1 Terminology

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