Final Report

Single and Multi-Domain Service Management

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ABOUT 5G-ENCODE

The 5G-ENCODE Project is a £9Million collaborative project aiming to develop clear business cases and value propositions for 5G applications in the manufacturing industry. The project is partially funded by the Department for Digital, Culture, Media, and Sport (DCMS), of the UK government as part of their 5G Testbeds and Trials programme. The project is one of the UK's biggest investments in using 5G to modernise manufacturing.

The key objective of the 5G-ENCODE project is to demonstrate the value of 5G as part of industrial use case delivery within the composites manufacturing industry. It is designed to validate the idea that using private 5G networks in conjunction with new business models can deliver better efficiency, productivity, and a range of new services and opportunities that would help the UK lead the development of advanced manufacturing applications.

The project will play a key role in ensuring that the UK industry exploits the 5G technology and remains a global leader in the development of robust digital engineering capabilities when implementing complex composites manufacturing processes.

The project will highlight how 5G features such as neutral hosting and network slicing can be applied to transform a private 5G network into a dynamically reconfigurable network able to support a wide range of applications (uRLLC/eMBB/mMTC) including industrial applications of Augmented Reality/Virtual Reality (AR/VR), asset tracking of time sensitive materials and automated industrial control though IoT monitoring and big data analytics. Such a dynamic network would enable new business models and creation of bespoke virtual networks tailored to specific applications or use cases.

A state-of-the-art test bed was deployed across three sites centred around the National Composites Centre in the southwest of England. In support of the West of England Combined Authority (WECA) industrial strategy, the NCC plans to keep the test bed as an open access facility for the experimentation and development of new products and services for the composites industry after the completion of the 5G-ENCODE project. The location and nature of NCC's business would ensure the creation of an industrial 5G ecosystem involving multiple industry sectors and SMEs.

The project consortium, led by Zeetta Networks, brings together leading industrial players (e.g., Siemens, Toshiba, Solvay), a Tier 1 operator (Telefonica), disruptive technology SMEs covering all aspects of network design, deployment, and applications (Zeetta Networks, MatiVision, Plataine), application performance as measured by probes (Accedian), world-leading 5G network research group (High Performance Networks Group in the University of Bristol) and the NCC representing the high value manufacturing industry.

EXECUTIVE SUMMARY

5G connectivity services are being explored not only by the incumbent global mobile network operators but also by enterprises looking to have more secure and flexible mobile connectivity solutions for their various connectivity requirements. In an already complex enterprise IT environment, 5G will yet add another level of complexity for those having to manage their networks.

Abstracting away the underlying complexity of provisioning and managing a multi-site and multi-technology enterprise network environment provides great value for enterprises. As Network engineering teams managing these enterprise networks might not have access to the expertise typically required to fully manage this ever-growing complexity, solutions to simplify daily operations are of critical importance.

Zeetta NetOS and Zeetta MDO provide this level of abstraction for the case of single site and multi-site enterprise networks respectively. These tools provide network administrators with a single dashboard for management of various network services - including 5G PCN services - allowing end to end services to be deployed seamlessly across various network infrastructure devices and application servers.

At 5G-ENCODE, Zeetta deployed a cloud based Multi-Domain Orchestrator and demonstrated the benefits of using this application by creating a multi-domain end-to-end connectivity slice that was automatically provisioned across different network domains, reducing the time required to enable service connectivity and avoiding manual intervention in the various network devices.

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ABBREVIATIONS

3GPP	Third Generation Partnership Project
API	Application Programming Interface
AWS	Amazon Web Services
eMBB	Enhanced Mobile Broadband
gNB	Next Generation NodeB (5G Radio Node)
IEEE	Institute of Electrical and Electronics Engineers
IP	Internet Protocol
LLDP	Link-Layer Discovery Protocol
MDO	Multi-Domain Orchestrator
mMTC	Massive Machine Type Communications
MPN	Mobile Private Network
NCC	National Composites Centre
OMS	Operations and Maintenance Solution
OPEX	Operational Expenditures
OSPF	Open Shortest Path First
OSS	Operation Support Systems
PCN	Private Cellular Network
PDN	Packet Data Network
PTP	Precision Timing Protocol
QCI	Quality of Service Class Identifier
QoS	Quality of Service
RAN	Radio Access Network
SA	Stand Alone
UE	User Equipment

uRLLC	Ultra-Reliable Low Latency Communications
VLAN	Virtual Local Area Network
VPN	Virtual Private Network

1 INTRODUCTION

1.1 Zeetta's solution to network complexity

The configuration of networks is complex, with the introduction of 5G this is getting even more complex, therefore ways to reduce the time, cost and errors is required. DevOps engineers will require simplified ways to manage these networks for 5G to be a feasible solution.

Zeetta's products simplify the deployment, monitoring and management of Private Cellular Networks as they enable a single-pane-of-glass control and management of network devices operating in licenced and unlicensed spectrum.

This project has required Zeetta to create a new product to orchestrate services across different network domains and assure end-to-end availability and compliance.

This report will show how Zeetta's products have simplified the configuration of Private Cellular Network services to ensure 5G can be adopted at the earliest opportunity.

1.2 Project Objectives

The main project objectives are:

1. **Support for 4G and 5G 3GPP networks**
    a. Zeetta Automate software: Topology aggregation and service orchestration across IEEE and 3GPP network technologies.
2. **Multi-Domain Orchestrator (MDO)**
    a. Zeetta Multi-Domain Orchestrator (MDO): Pre-production prototype of cloud-native service orchestrator provisioning end to end connectivity (aka. Network Slicing) across multiple administrative domains (via multiple Zeetta Automate instances).
    b. Zeetta Multi-Domain Orchestrator (MDO): Create a model that supports traffic management across aggregated IEEE and 3GPP network topologies.

1.3 Overview of Use Case

The main purpose for the **single domain service management** is to:

- Provide a single pane of glass management interface to control the various multi-vendor network devices/nodes that are part of the 4G/5G service on a single administrative network domain. This enables service orchestration via a single GUI for the provisioning of the end-to-end service, including specifying the Quality-of-Service parameters, as opposed to manually provisioning each device.
- Being able to visualise the topology of all the devices in the network and to see in Zeetta Automate when a device or link is down.
- Zeetta Automate will automatically compute the path between end points when provisioning a 4G/5G Private Cellular Network service.
- Zeetta Automate will apply the necessary configurations to the various network devices along the path.

The main purpose for the **multi-domain service management** is to:

- Enable network slice orchestration via a single cloud-based GUI for the provisioning of the end-to-end service across multiple and independent administrative network domains, including the IP Layer 3 connectivity between the respective domains.
- The Multi-Domain Service Management provides the user the ability to validate the feasibility of the network slices across the respective network domains by analysing the existing configuration at each domain against the design.
- The ability to visualise the topology of all the devices across multiple domains and to see in Zeetta Multi-Domain Orchestrator (MDO) when a device or link is down.

2 SINGLE DOMAIN NETWORK SERVICE MANAGEMENT AND ORCHESTRATION

2.1 Single Domain Service Management

Zeetta's solution to single domain network service management is NetOS. Within a single network domain, NetOS provides a single point of management and orchestration of network services. It allows network administrators to provision various end-to-end services within the network. Examples of such services include provisioning of Layer 2 connectivity between end points, setting up Wi-Fi services as well as 5G PCN services to provide connectivity for 5G enabled end devices.

Within the 5G Encode Project, NetOS was deployed at the National Composites Centre Headquarters (NCC Main Site) and at a second location we refer to as NCCi (as will be described in section 3.1.1).

2.1.1 Single Domain Service Management

At the main NCC site, Zeetta Networks Engineering team, together with NCC Engineers, designed and implemented a complete Open RAN 5G SA Private Cellular Network operating with an Ofcom Shared Spectrum Licence within the n78 frequency band (3.6GHz). The processing elements of this network, were physically installed at the NCC datacentre, including all the required Layer 2 and Layer 3 network equipment and the PTP timing HW required to provide the required timing synchronisation for the 5G gNB. This Network was integrated with an already existing 3GPP 4G PCN. The radio units were installed in locations within the NCC workshops themselves and connected to the NCC datacentre.

The Figure below shows a diagram of the 5G SA deployed at the main NCC site.

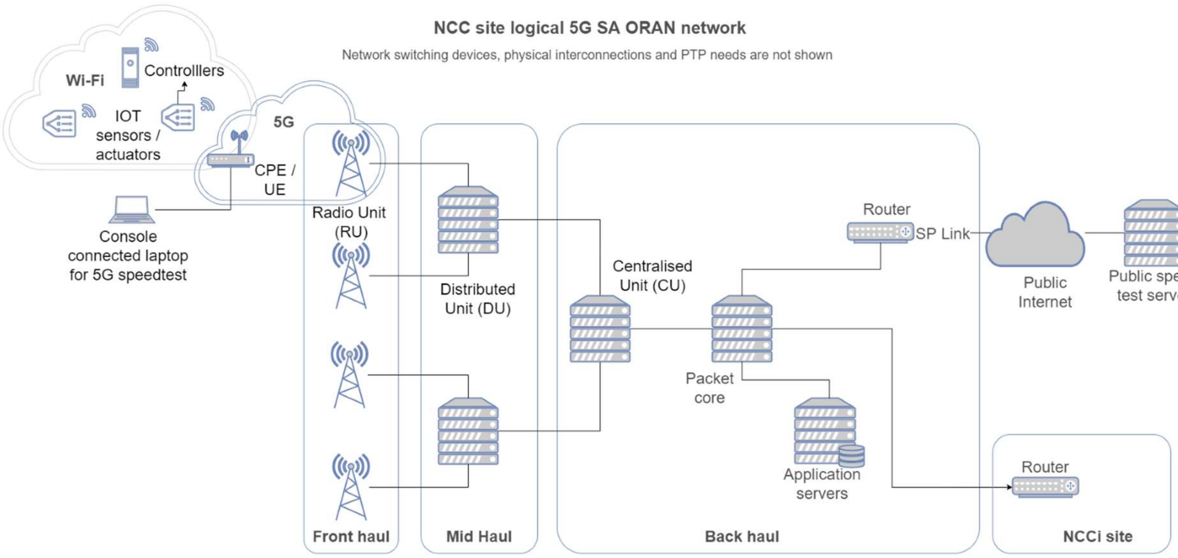

Figure 1 - NCC 5G Network Diagram

At the main NCC site, NetOS was configured to adopt all the network devices, which includes Juniper Router and Firewall, Edgecore Switches, ADVA switches and the 5G Core - supporting a multi-vendor network environment. A screenshot of NCC's NetOS dashboard is shown below.

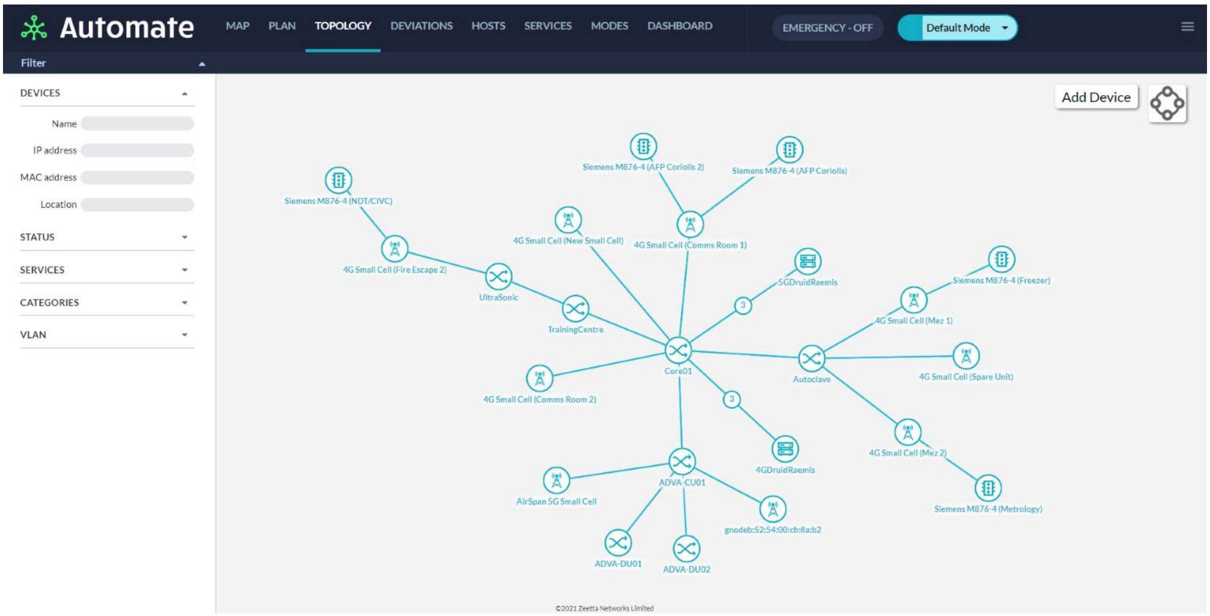

Figure 2 - NCC NetOS Topology View

The dashboard enables network administrators to visualise all the network from a single interface, to easily identify any disconnected devices, to automatically provision end-to-end services that may involve several devices depending on the device endpoints selected when defining the service.

The NetOS internal path calculation feature automatically selects the complete path between the respective end points and applies the required configuration to all the network devices and all the switch ports along the path (which can vary from just a single switch to various switches interconnected by Layer 2 trunk links).

NetOS uses APIs to interact with the various network elements to read and/or write configuration data. The network topology creation process is assisted with LLDP data that NetOS reads from the devices to establish all the existing physical connections. Logical connections are dealt with via the multi-domain service management functionality described later in this report.

The PLAN view available through the NetOS GUI is used to physically locate the various network devices, as shown below.

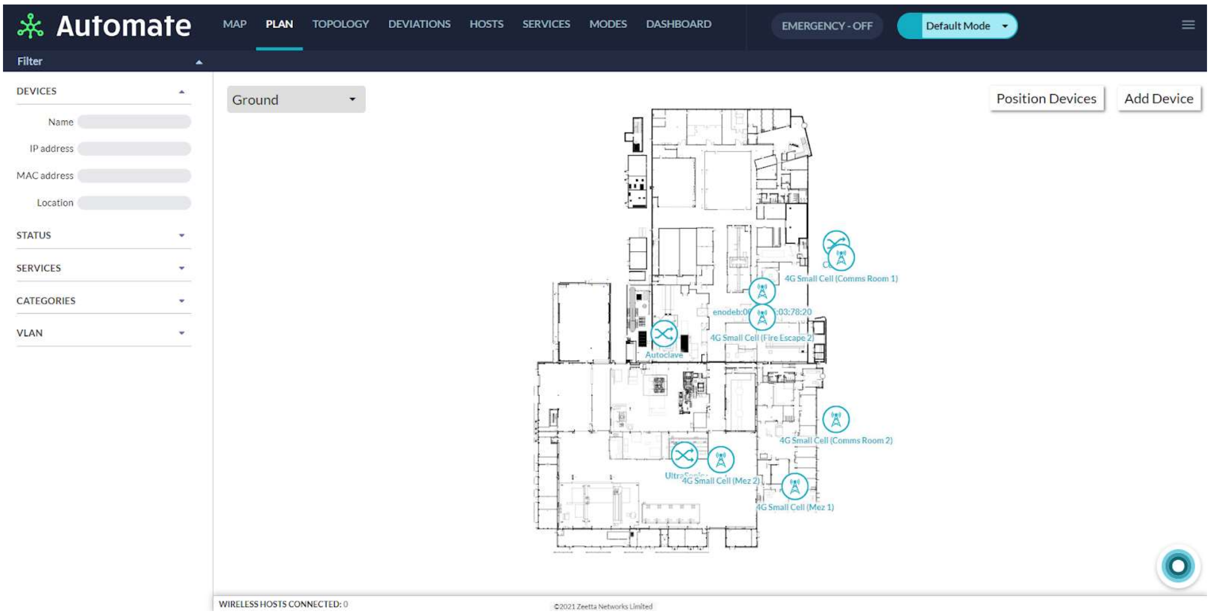

Figure 3 - NCC NetOS Plan View

2.1.2 Single Domain Service Provisioning – 5G PCN Service

Many types of service can be created through the Services tab. In this section we describe the creation of a 5G PCN service using NetOS.

This process starts with assigning a name and optional description to the Service.

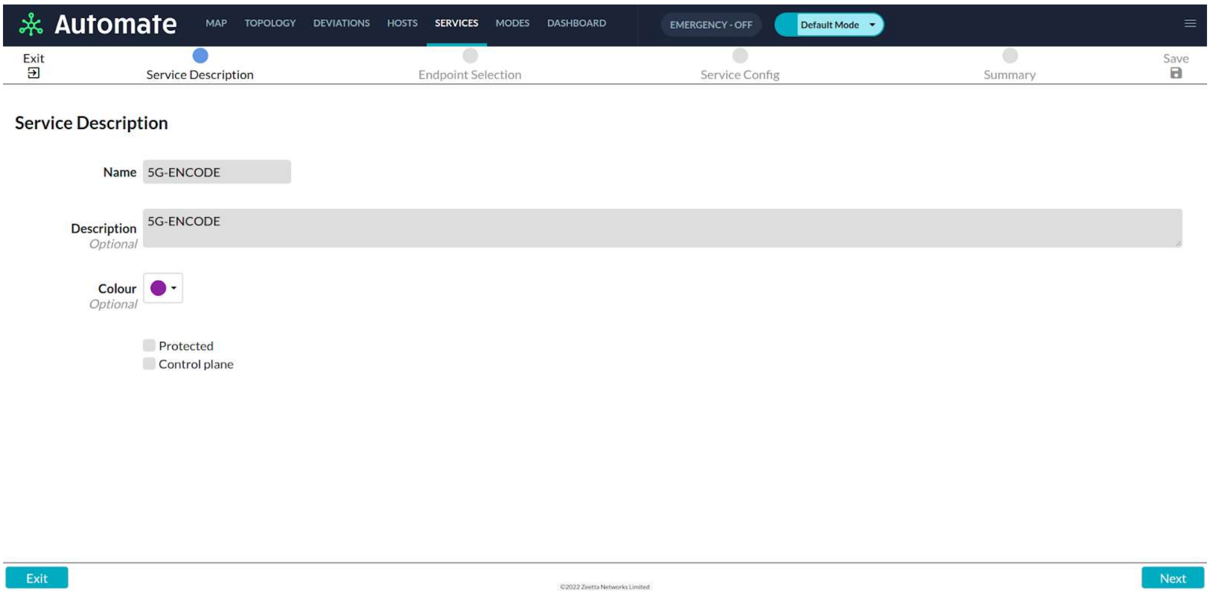

Figure 4 - NetOS defining the service description

The next step is the selection of the endpoints that should be part of the 5G service. This will include the respective 5G core interface and the UEs that should be part of this service, which is the 5G UEs that will be able to attach to the 5G service being created. NetOS automatically identifies the switch port where the required 5G core interface is connected to and will also add the specified VLAN to it.

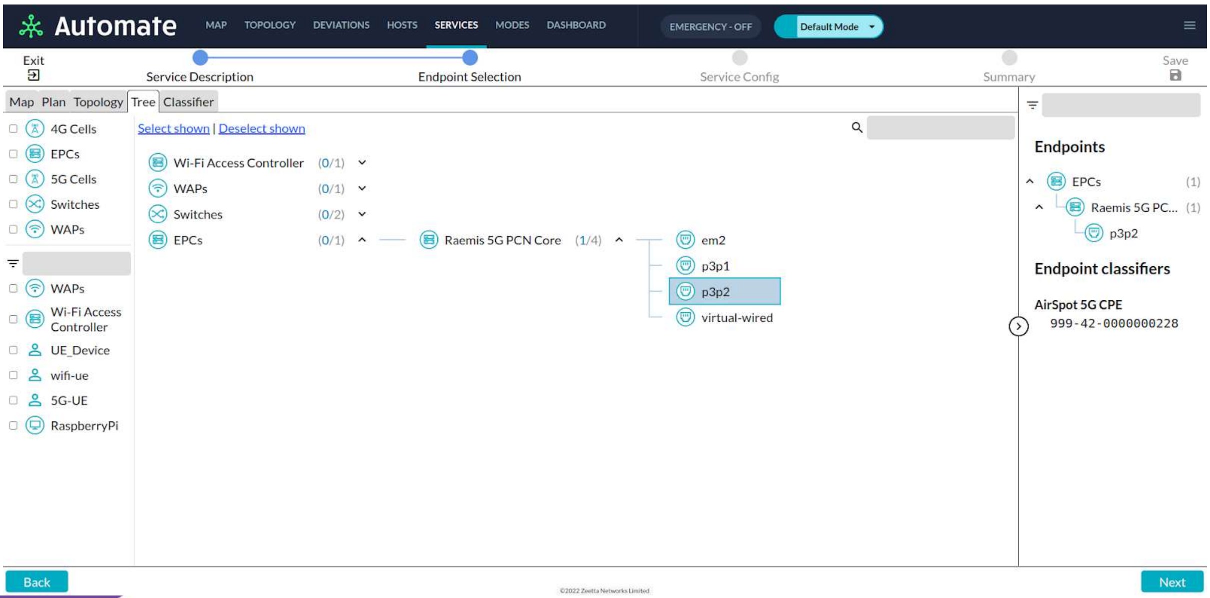

Figure 5 - NetOS defining the service end points

In the Service Config section, the user selects the VLAN this service will be using and specifies the packet data network (PDN) name for this 5G network. The quality-of-service (QoS) settings associated with the PDN being created are also specified in this section. These include QCI, the priority and AMBR 5G network parameters.

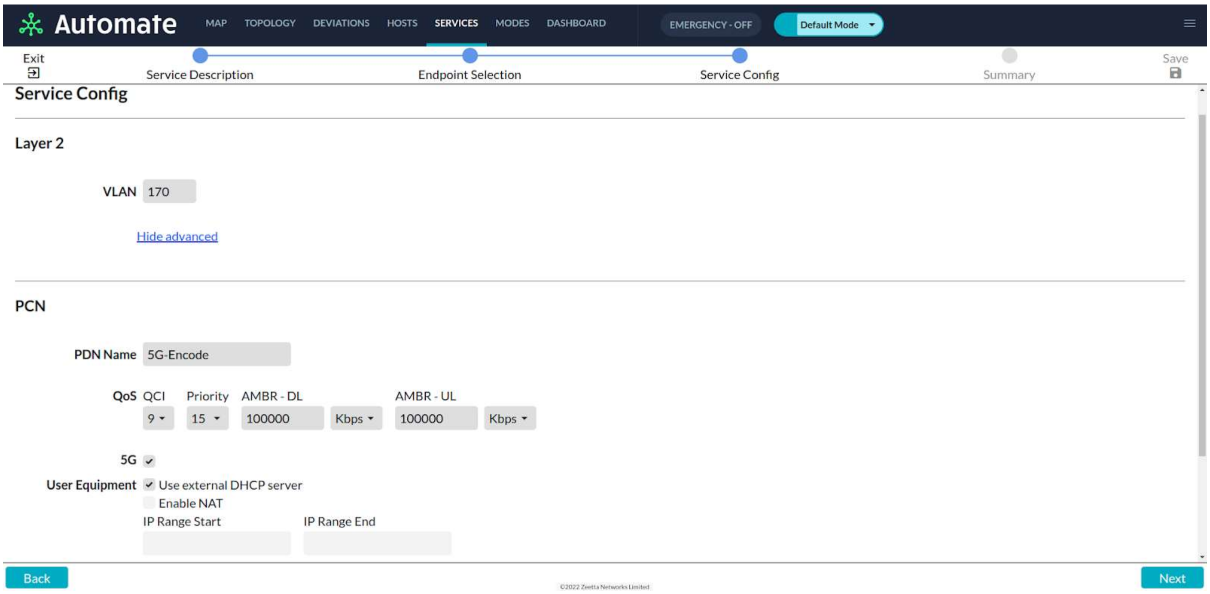

Figure 6 - NetOS defining the PCN parameters

From this point onwards the service creation process is complete, and the user will then be able to activate and deactivate the service as required. This step is only reached after NetOS validation of the data provided, thus avoiding any potential configuration conflicts before any data is sent to the various network devices to be changed when implementing the service.

When activating the service, all the PDN related parameters will be automatically provisioned on the 5G core application server, and the specified VLAN identifier will be configured on the switch port that is connected to the 5G core server.

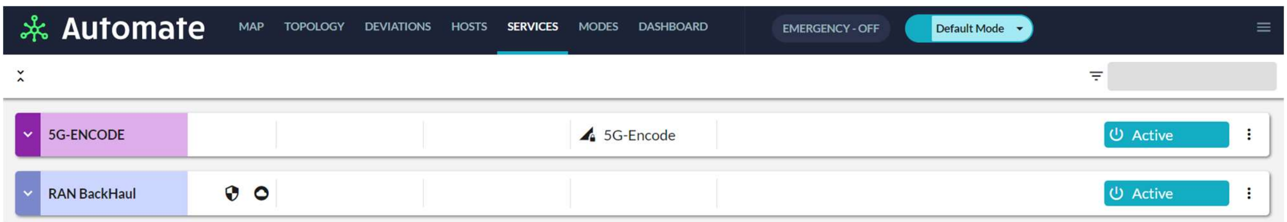

Figure 7 - NetOS overview of 5G related service

The figure above shows the activated 5G related services. The RAN Backhaul control service was created previously, to provide control plane connectivity between the 5G Core and the gNB. This control plane service applied the necessary Layer 2 VLAN configurations to the switch where the 5G Core and gNB were connected to.

After the PCN service has been activated, all UEs that were included as end points will then be able to attach to this 5G PDN and access any services available through it.

This 5G PCN service can be filtered in the topology to show the Layer 3 link from the UE device to the 5G Core with the connecting switch, as we can see in the figure below.

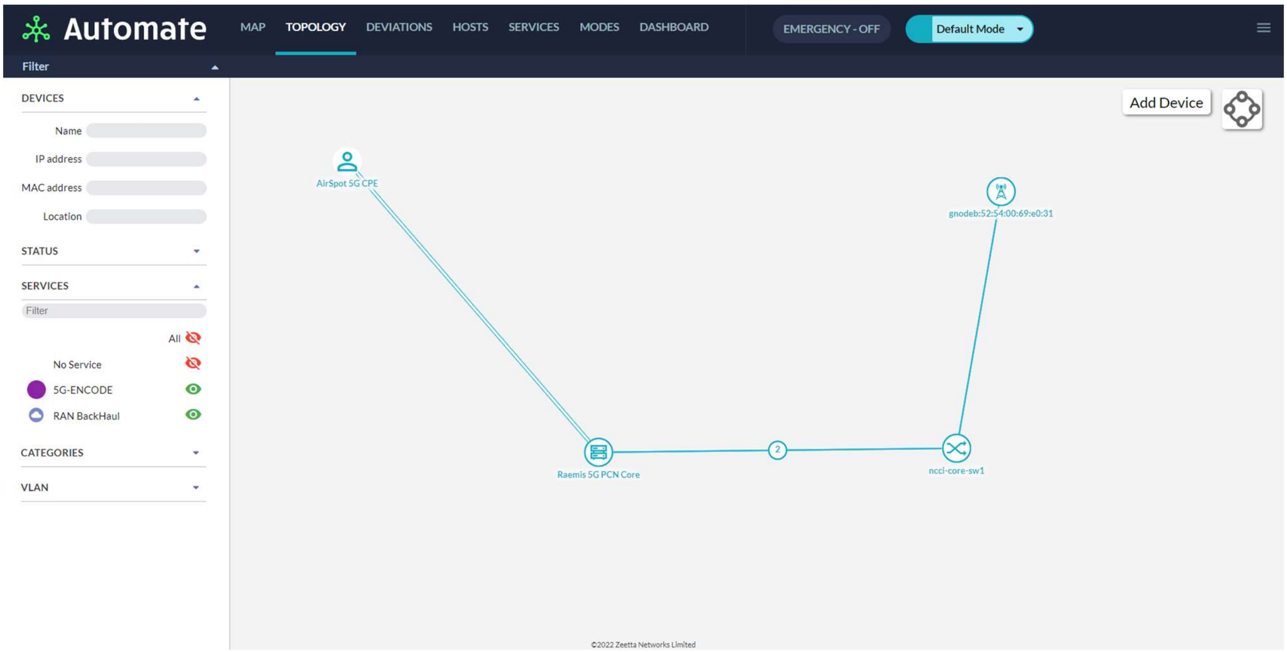

Figure 8 - 5G services filtered in the topology view

In this section we have demonstrated, from a single management interface the network administrator is able to provision the various network devices that are part of the services (e.g. in the case described above, these include the 5G Core server and the infrastructure switch) without having to separately and manually logging to each device.

3 MULTI DOMAIN NETWORK SERVICE MANAGEMENT AND ORCHESTRATION

3.1 Multi-Domain Service Management

MDO provides a single point of management and orchestration of network services across multiple network domains. It allows network administrators to provision various end to end layer 3 slices inter-connecting the different network domains (which are typically located at different physical locations).

Within the 5G Encode Project, MDO was deployed in an AWS cloud instance, with WireGuard VPN access provisioned to provide secure connectivity to the NCC and NCCi networks.

3.1.1 Deployment of Secondary Network Domain - NCCi

To support the multi-domain service management use case, Zeetta Networks designed and deployed an additional network - including a secondary 5G SA setup - that was installed in a different physical location also belonging to NCC, a site named NCCi. This network is connected to the main NCC site via an existing fibre link between the two buildings.

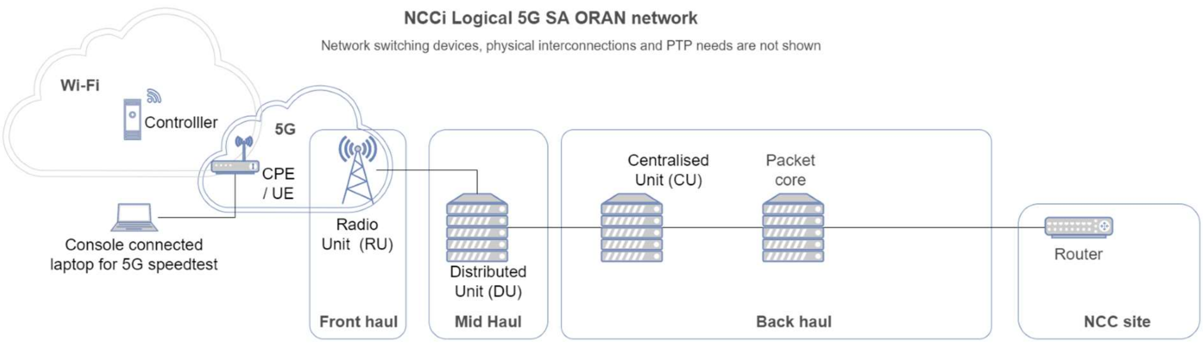

Figure 9 - NCCi Network Diagram

The above diagram illustrates the NCCi 5G SA network. The Open RAN 5G gNB was interconnected by a carrier grade PTP enabled aggregation switch and is connected to the 5G core server. An additional server was deployed to host the NetOS instance dedicated to this network. A Wi-Fi controller was also deployed in this network, along with a Wi-Fi Access Point, thereby providing a multi access technology environment.

Figure 10 - NCCi Rack

The NetOS instance at NCCi was configured to adopt all the network devices, as can be seen in the picture below. These include all the layer 2 and layer 3 devices, 5G Core and Wi-Fi devices.

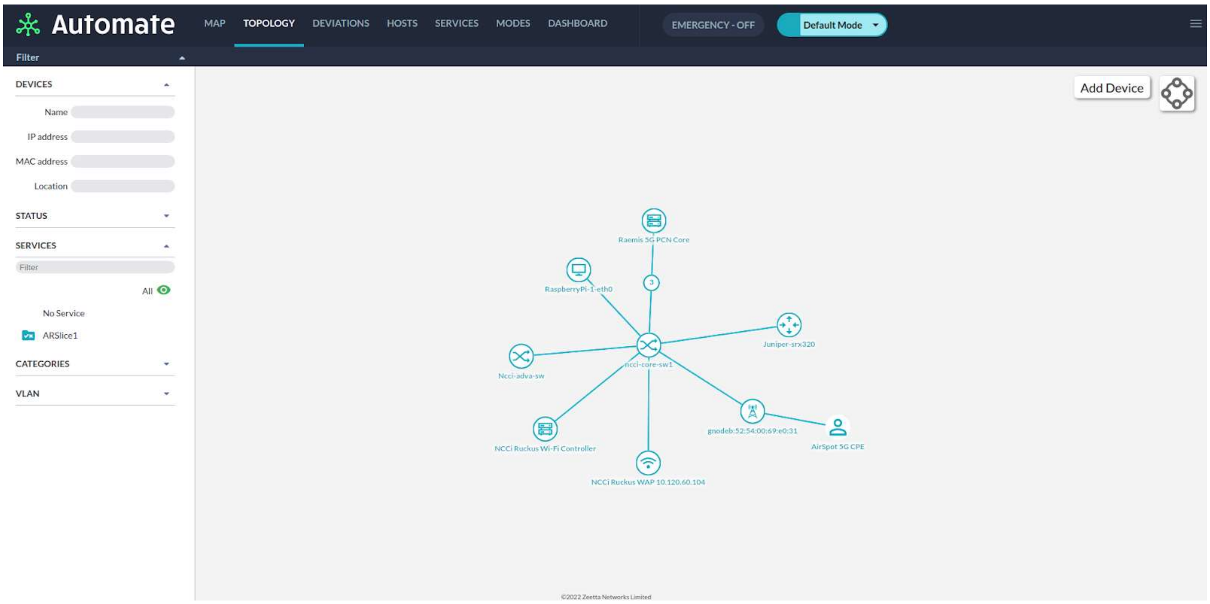

Figure 11 - NCCi Topology View

3.1.2 Multi Domain Slice Across Different Domains

For the multi domain service management use case, Zeetta MDO (Multi Domain Orchestrator) was deployed on the AWS cloud. Both the NCC NetOS and the NCCi NetOS instances are connected to MDO via a WireGuard VPN, for secure communication. This VPN interface allows MDO to collect network topology information from both network domains as well as to push configurations to be applied at each domain. These configurations are sent to each domain in the form of NetOS services.

The diagram below illustrates the MDO setup on AWS, showing that network administrators can interact directly with MDO to manage the multi-domain services. WireGuard needs installing in each location to connect.

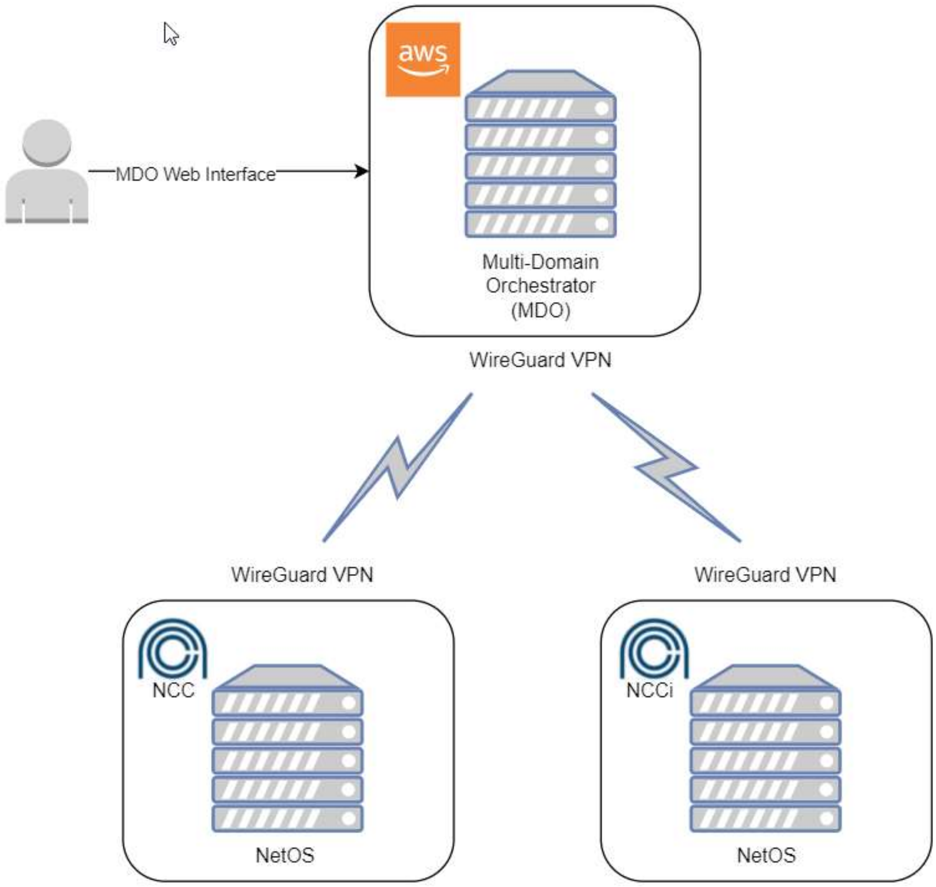

Figure 12 - Connectivity of MDO with NetOS instances

This diagram shows MDO hosted on AWS, interconnected to the two NetOS instances (NCC and NCCi) through a WireGuard VPN connection.

MDO solution allows the users to manage services across the various network domains, including the design and automatic provisioning of inter-domain Layer 3 slices, providing Layer 3 connectivity between end points from different domains.
Within the NCC-NCCi setup, an example of how this technology can be used is in the deployment of a 5G mediation slice between the two 5G core instances from each domain. This would allow 5G users that are configured in one of the 5G cores to use the other 5G core for network registration purposes, thereby allowing the 5G UE the possibility of roaming between the two 5G PCN networks.

MDO Layer 3 slices involve the use of various technologies and provide effective ‘slice isolation’ by deploying dedicated virtual routing instances at the point of entry for each network domain. This provides enhanced network security and effective Layer 3 routing isolation between multiple slices, as each slice will only have access to its own routing table, preventing

The Layer 3 slices are composed of a Layer 3 inter-domain link that is established between the gateway routers from each domain, along with any Layer 2 intra-domain links required to reach the respective endpoints. At each domain, NetOS’s path calculation feature determines the exact path to reach the endpoint and configures all the devices along this path. Inter-domain routing configuration is also automatically provisioned by configuring OSPF routing protocol to run between virtual routing instances at each network domain.

All these configurations are automatically provisioned to the respective devices at both network domains.

The diagram below illustrates an end-to-end Layer 3 slice that was deployed between the NCC and NCCi sites, including the inter-domain Layer 3 link and the intra-domain Layer 2 switch connections. This slice was specifically provisioned to provide Layer 3 connectivity between the two end devices that are at each end of the diagram - at the left-hand site there is a host physically located at the NCC main site and on the right-hand side there is a 5G connected host physically located at NCCi.

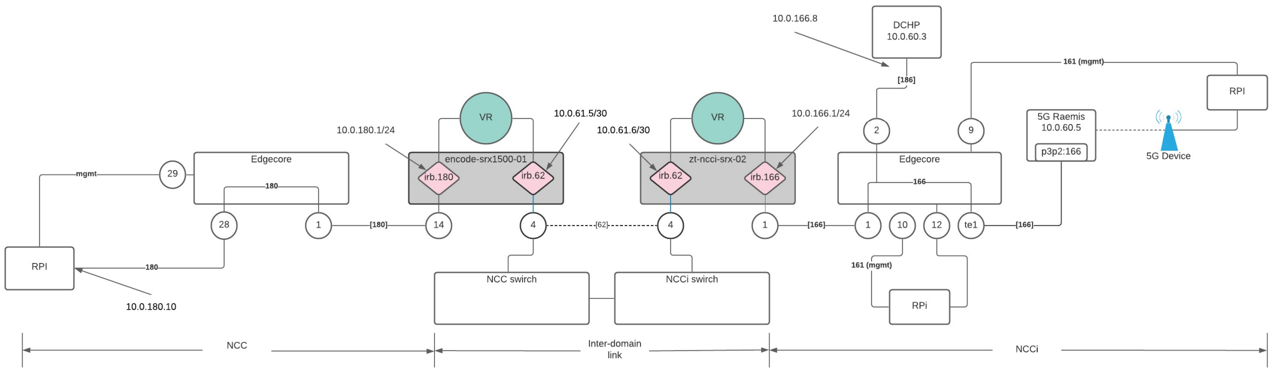

Figure 13 - Inter-domain Layer 3 slice

The process of Layer 3 inter-domain slice design and activation follows a similar structure to the single domain NetOS services described above in this report. The user first provides the VLAN identifiers and IP subnet network addresses to be used at each network domain, as well as the data required to implement the inter-domain link between the gateway routers.

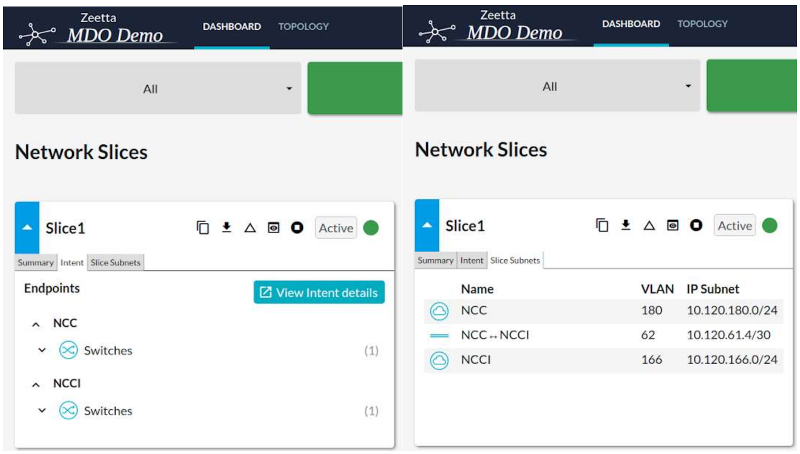

Figure 14 - MDO Slice provisioning

From the information provided, MDO builds the slice blueprint, detailing all the Layer 3 and Layer 2 network device configurations. The user can then review all the data before MDO applies the configuration to the network.

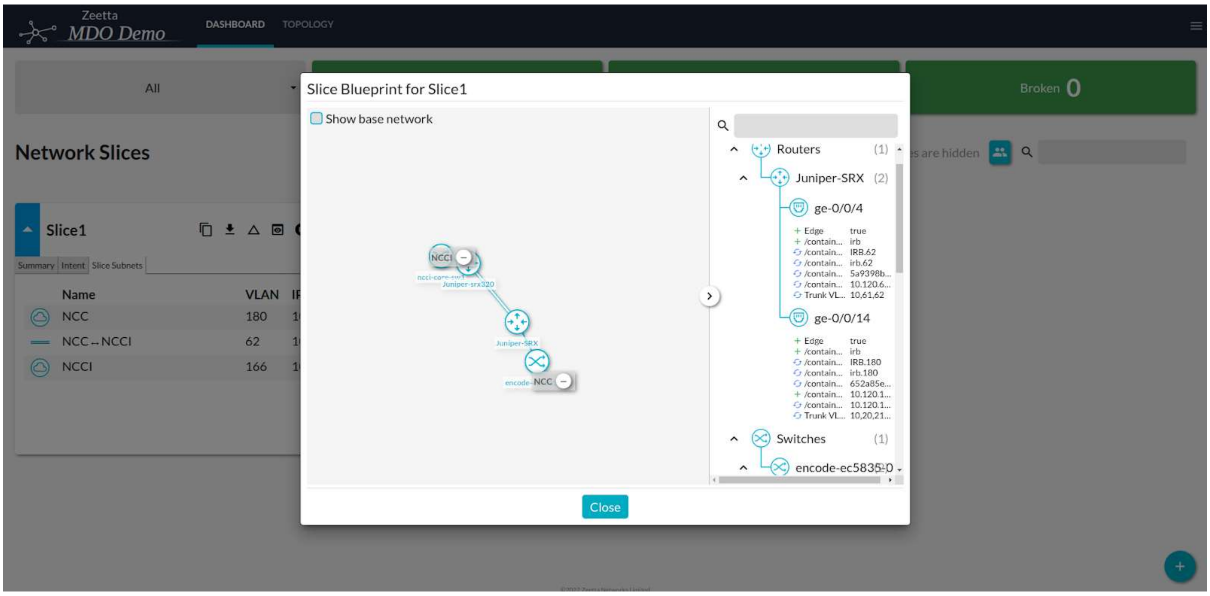

Figure 15 - Slice blueprint

After reviewing all the data, the user can then activate the slice, which will instruct MDO to create the required NetOS services. At each domain, NetOS will then automatically install the respective services and automatically activate them - the user can manage the multi domain service via a single interface. There is no need to login to each NetOS instance.

Following the slice activation, MDO topology view allows the user to have an overall view of the slice interconnecting the two domains

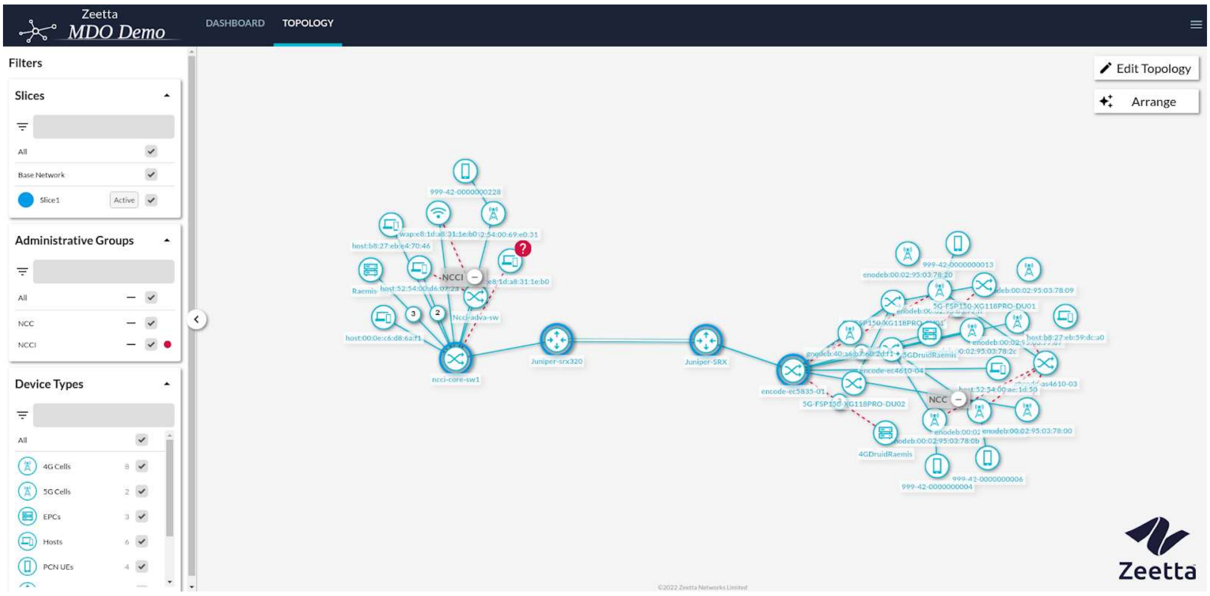

Figure 16 - MDO Inter domain Layer 3 slice topology view

From a single cloud-based GUI, MDO was able to deploy inter-site connectivity as well as provide detailed network topology visualisation, by leveraging data aggregation capabilities of each NetOS instance.

4 CONCLUSIONS

Enterprise IT networks are continually evolving. Significant evolutionary steps included moving from a fully cabled network to a cable and Wi-Fi network. The most recent evolution is the adoption of mobile private networks (MPN). Enterprise modernisation to include MPN is set to accelerate with the more flexible service features introduced in 5G.

With each evolutionary step Enterprise IT networks have become more complex to manage creating a need for easy-to-use solutions that simplify and reduce the user interaction needed to implement changes that affect multiple elements in a network such as configuring a service that includes a high number of network endpoints.

Benefits

Lowering operational cost - The need to schedule, manage and coordinate the activities of specialists for each device type has been removed. Device specialists may still be required in the Enterprise. These employees can be redeployed to focus on monitoring and supporting the network with a reduced need for specialist support to implement configuration requests. For example, using a traditional approach to plan, deploy and verify a Layer 3 slice service across various network domains would take several staff days. By using the innovative solutions developed for this project, much less effort to plan and execute change is needed with most of the activity being spent on planning. The need for the end user to be trained on a specific PCN solution is reduced. The user issues service updates from NetOS using the four-step wizard to set up the change to be made. NetOS provides an abstraction of the underlying 5G service parameters that simplifies the input needed from the end user.

Multi-Domain slice management simplifies network management – Traditionally, each enterprise location is treated as an IT domain and each domain administered locally. The IT operation for cross domain slicing (service management in each domain) is simplified and similar benefits to the previous paragraph are yielded.

Detecting change - For enterprise IT departments tasked with managing multi-domain and multi-technology networks, being able to visualise network topology deviations enables support agents to see changes as they occur and investigate if the change is planned or unplanned. Detecting issues in a complex network consisting of multiple device vendors in multiple network domains can be time consuming when the network cannot be visualised on a single topology view. In the 5G technology the topology can be configured to show changes on the 5G core, gNodeB and devices attached to the gNodeB.

Deployed hardware savings – Whilst the NetOS platform is typically deployed within the Enterprise domain to minimise security risks, the multi-domain slice manager (MDO) is deployed in the public cloud. Using a public cloud for applications with smaller compute needs is beneficial as the cost of ownership is usually cheaper than buying and owning equipment.

<u>**Challenges**</u>

Neutral Hosting – this feature in the product scope was not realised as the entitlement and billing system did not mature in time for the mobile network operator to fully engage on this topic during the 5G ENCODE program. This created an issue for MDO to demonstrate network 'splicing,' the ability to create a slice between mobile network operator and the enterprise. To address this challenge the MDO network design and slicing use case were modified such that the two domains were interconnected using a leased line.

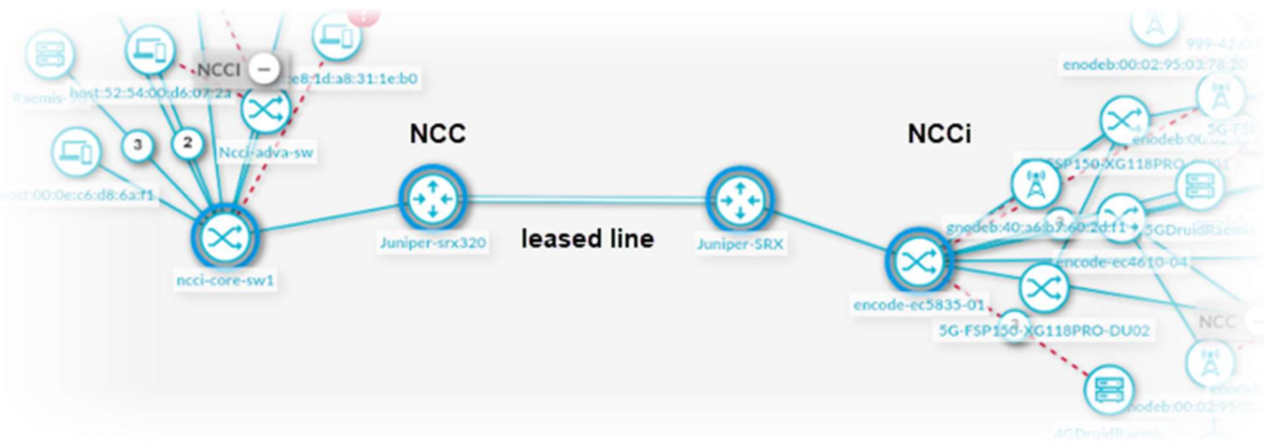

Figure 17: leased line replacing mobile network operator

ADVA FSP150-XG118PRO driver development – this device is classed as a carrier grade Ethernet Demarcation Device; this means it was more complex to adopt and manage than a simpler enterprise network switching device. This device was recommended for use in the network design as it supports the precision timing protocol (PTP) for synchronising the 5G RAN. The engineering and development effort required to understand and develop a solution for this device was greater than expected and needed careful management in the program schedule.

Connectivity issues and 5G maturity – the network deployed for the project was 5G SA ORAN based in SR15. Multiple suppliers involved in this project continued to rapidly develop their solutions during the deployment phase. These developments required updates to the NetOS solution to ensure connectivity to the network was preserved. This created additional unplanned work for the development team that needed careful management to ensure the program remained on schedule.

Conclusions

There is a need for solutions that simplify network visualisation and automate the management of ever changing and increasingly complex networks. Complexity arises when enterprises need to start managing services in multiples of:

- devices
- technologies
- domains

Simplifying and abstracting devices, technologies and domains from network designers reduces the effort required to implement changes.

The need for domain and technology knowledge is not completely removed as designers will still need some basic knowledge of the network design to enable them to translate configuration change requests into actionable changes.

In complex networks new challenges are introduced when determining if the services using that network are operating as expected. The network administrator needs a solution whereby any change and the impact of that change can be detected and identified quickly. For this, a 'single pane of glass' view on the network devices and domains in use is essential. Changes to identify are:

- device states that have changed
- connecting link states that have changed

This ‘single pane of glass’ view should not be confused with a similarly named feature documented in the network probing report where a dashboard is used to visualise probe results.
Creating an environment whereby change can be seen quickly is key to effective response planning in an operational network. Network status changes can be in the form of planned or unplanned. Planned status changes are known events in the network and can be acknowledged as expected changes. Unplanned status changes often indicate outages in the network and its services that will need further investigation. It should be noted that, a common topology view onto the complete network does not replace the vendor specific operations support systems needed to investigate and troubleshoot specific devices.

The MDO and NetOS solutions used and introduced in the 5G ENCODE project address the following network management issues:

1. device visualisation
2. service status change detection
3. configuration change simplification

To understand the benefit of these solutions, studies were conducted to understand:

- revenue unlocked
- cost saved
- cost avoided

Revenue unlocked – in this project future revenues were not measured. It is expected that with the cost savings introduced (next paragraph) the need for services and service updates in the network will grow as new solutions adopt 5G network slicing and cross domain services required to support slicing. This growth will create revenue in the applications consuming slices and services.

Cost saved – introducing the functionality to change multiple devices, using different technologies across various network domains introduces an estimated 66% saving in engineering compared to the effort needed to complete the same changes manually e.g. resources needed from three persons to one person to complete similar activities.

Cost avoided – The ability to visualise multiple domains with different technologies and numerous devices in a common topology view (‘single pane of glass’) reduces OPEX costs. Network administrators no longer need to use vendor specific OSS solutions when detecting network-wide issues during extended network outage events. The estimated costs avoided grow as network complexity increases (domains, devices, and technologies). In the figure below, the levels of investigation effort for each scenario were tuned using data captured from this project (Appendix A).

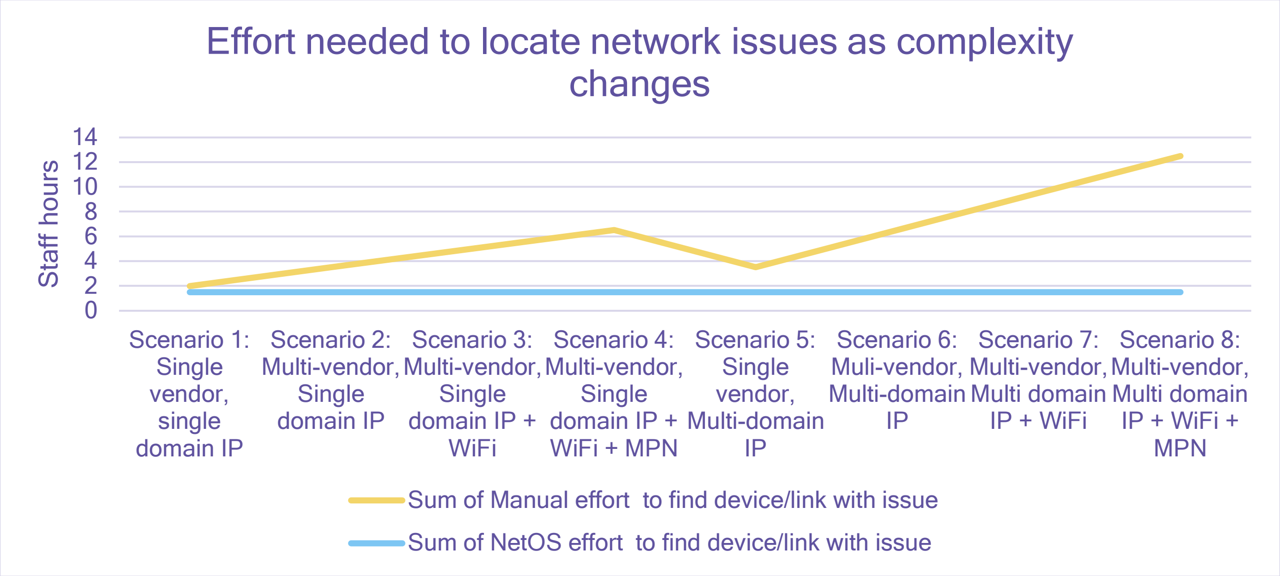

Figure 18: Effort to find network issues with and without NetOS or MDO

For each scenario identified in the figure above, there are assumptions for the number of technology vendors in the network. These assumptions are based on differing Enterprise network configurations. The assumptions are as follows:

- two IP vendors - switch vendor and router vendor
- one Wi-Fi vendor
- one MPN vendor

The effort in resolving problems increases with number of vendors and network complexity.

This project has demonstrated that there are clear benefits of having a consolidated network management tool to visualize and manage various connectivity services, including 5G, in an Enterprise.

5 APPENDIX A

					Without NetOS (Manual effort to investigate a network issue)						With NetOS			Cost Avoided (%)
Scenario	Technology	Device Vendors	Domains with equipment	Domains & Devices	Detect and start issue processsing	Per team start up time	Form working group and task investigating team	Per Vendor Search Time	Time spend searching without NetOS	Manual effort to find device/link with issue	Detect and start issue processsing	Open NetOS and locate issue	NetOS effort to find device/link with issue	% time saved
	IP	1	1	1		0.5	0.5	1	1					
Scenario 1: Single vendor, single domain IP	Sub-Total	1	1	1	0.5		0.5		1	2	0.5	1	1.5	25%
	IP	2	1	2		0.5	1	1	2					
Scenario 2: Multi-vendor, Single domain	Sub-Total	2	1	2	0.5		1		2	3.5	0.5	1	1.5	57%
	Wi-Fi	1	1	1		0.5	0.5	1	1					
	IP	2	1	2		0.5	1	1	2					
Scenario 3: Multi-vendor, Single domain IP + WiFi	Sub-Total	3	1	3	0.5		1.5		3	5	0.5	1	1.5	70%
	Cellular	1	1	1		0.5	0.5	1	1					
	Wi-Fi	1	1	1		0.5	0.5	1	1					
	IP	2	1	2		0.5	1	1	2					
Scenario 4: Multi-vendor, Single domain IP + WiFi + MPN	Sub-Total	4	1	4	0.5		2		4	6.5	0.5	1	1.5	77%
	IP	1	2	2		0.5	1	1	2					
Scenario 5: Single vendor, Multi-domain	Sub-Total	1	2	2	0.5		1		2	3.5	0.5	1	1.5	57%
	IP	2	2	4		0.5	2	1	4					
Scenario 6: Muli-vendor, Multi-domain IP	Sub-Total	2	2	4	0.5		2		4	6.5	0.5	1	1.5	77%
	Wi-Fi	1	2	2		0.5	1	1	2					
	IP	2	2	4		0.5	2	1	4					
Scenario 7: Multi-vendor, Multi domain IP + WiFi	Sub-Total	3	2	6	0.5		3		6	9.5	0.5	1	1.5	84%
	Cellular	1	2	2		0.5	1	1	2					
	Wi-Fi	1	2	2		0.5	1	1	2					
	IP	2	2	4		0.5	2	1	4					
Scenario 8: Multi-vendor, Multi domain IP + WiFi + MPN	Sub-Total	4	2	8	0.5		4		8	12.5	0.5	1	1.5	88%

Figure 19: Table showing effort needed to investigate issues increasing as network complexity increases