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SKYNET

CATALYST 2019 – DIGITAL TRANSFORMATION WORLD 2019

Skynet Catalyst

Borderless Remote Health Care: A Reality with 5G

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Skynet team will like to also acknowledge offline consultation from Dr Sanjay Mehrotra, Renowned Cardiologist in India and Fio Corporation on the remote health care business scenario.

1.2 Document History

Version	Date	Author	Change Summary
1.0	May, 08, 2019	Skynet Catalyst Team	Initial Version

Version	Date	Author	Change Summary
1.1	May 11, 2019	Skynet Catalyst Team	Fixed table with Champions list (page 62)
1.2	May 11,2019	Skynet Catalyst Team	Added missing names in the contributors table (page 4)
1.3	May 11,2019	Skynet Catalyst Team	More names in the contributors table (page 4)

1.3 About the Document

This document captures the work done as part of Skynet catalyst, contributions of various participants, learnings from the catalyst implementation. This document also provides feedback to various industry forums for further evolution of business model, architecture and standards to facilitate adoption and automation of various industry vertical services on top of 5G network and promote seamless collaboration across diverse partners in this digital ecosystem.

2 Introduction

Last year we successfully showcased Blade Runner, Catalyst which demonstrated makes use of industry standards, including Open APIs and modelling languages (TOSCA), to allow shared service catalogs and faster deployment of cloud services, and to provide end-to-end, multi-operator closed loop assurance and wholesale enterprise billing/charging operations.

This year Skynet Catalyst builds on the foundation laid by Blade runner and demonstrates how remote health care services could become reality with 5G adoption.
Skynet further explores the business models, architectures and standards required for seamless collaboration across a diverse partner ecosystem, supporting 5G enabled digital services for industry verticals like health care, automotive, or smart city, and spanning different geographies.

Borderless collaboration across health care sector for regular medical requirements and epidemic management has been taken as a reference for this catalyst. The catalyst demonstrates how remote health care services including (but not limited to) drone based inspection, image analytics, remote diagnostics and potentially robotic surgery can come together for better management and control of epidemics or natural disasters. Remote health care services are one of the important service segments which could become reality with 5G roll outs. The business scenario aims to better control epidemics like the Ebola outbreak in Africa in recent years.

Remote health care services will involve a diverse partner ecosystem and therefore it's important to deliberate on various business models, the role of each partner, shared yet end to end traceability and accountability and address the potential challenges.
Our Catalyst makes use of industry standards, including TMF Open APIs / MEF LSO APIs and modelling standards (TMF SID, TOSCA, GSMA NEST), to allow different operators to provide end to end connectivity and to support end-to-end, multi-operator closed loop assurance and wholesale enterprise billing/charging operations via blockchain based implementation. The Catalyst uses the TM Forum Open Digital Architecture (ODA) at its core to demonstrate the need for abstract orchestration layers, properly integrated through TM Forum Open APIs. It demonstrates how a modelling language can enable a shared definition of complex 5G service chains that can be deployed by different operators. In addition, standard models provide a set of common policies/rules to serve the needs of closed loop assurance, even across different enablers.
Leading telecom service providers and their partners have come together to demystify “Remote Health Care" Offerings via a demonstrable end to end proof of concept.

Figure 1 Champions

Figure 2 Technology Partners

2.1 Business Scenario

Skynet catalyst has taken a very specific business scenario with respect to epidemic management for the purpose of exploring the complexities and associated solution options for remote health care services enabled via 5G. This solution is relevant for regular medical situations as well. Sophisticated medical equipment are available in bigger cities and hospitals. The availability of appropriate network slice like eMBB, uRLLC could allow some medical services to be provided remotely.

Reliable and low-latency communication option between the patient and the hospital may be required in crisis. There is also a need of transferring patient critical information reliably to the medical provider near real-time for doctors to facilitate doctors to collaborate nationally or internationally.
This service has a lot of social benefits apart from business benefits. But for the service provider, the ability to provide this kind of communication opens doors to other use cases as well (Transportation, Insurance and Manufacturing Industries). In case of emergencies, ability to send instant images to the Insurance company, sending information, images of the site will be of business value to the Insurance company and the respective industry.
This project explores various business models as options in accordance with the difference in business values among participants based on the knowledge from experts in the medical industry e.g. certain operator provides only connectivity, while others could provide the platform capability or vertical application.
Skynet Catalyst team has identified the stakeholders (including WHO, Health Ministry) for remote health care and defined business ecosystem based on the needs and requirements in real life, which is exemplified by the collaboration among operators and partners along with cash flow as E2E service at CurateFx.

Business scenario " epidemic medical management" driven from WHO report 2014 in West Africa illustrates the business ecosystem of the multiple actors where knowledge, expertise and field experience/feedback must be leveraged in quarantine areas where people need a lot of specialized medical services at the same time for better management of epidemic. Regular medical care could also benefit from such a working ecosystem. This ecosystem will need guaranteed network communication at specific throughput, minimal latency and very high reliability.

5G network will be able to facilitate a strong coordination between actors and devices (regional level, international level) which is a key in order to control epidemic and to curate the ill persons.

Scenario Context:
Several persons have reported sick in UK hospital immediately after a voyage to Ivory Coast. World Health Organization (WHO) is involved to ensure the disease is contained. UK Hospital needs to collect some samples from Ivory Coast and then consult doctors in France and Japan to quickly identify root cause of the problem and control the spread of disease.

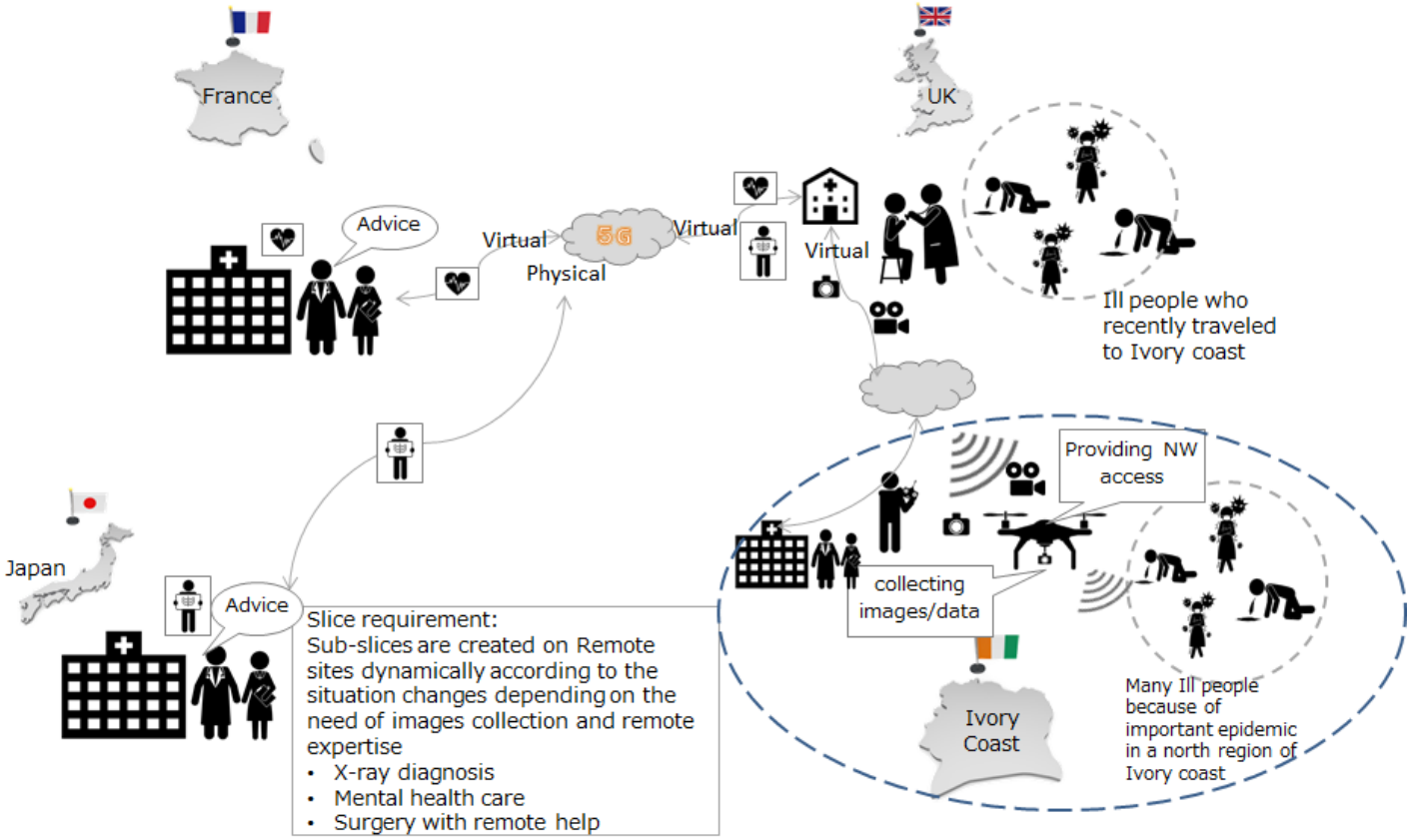


Figure 3 Remote Health Care Business Scenario

In this business scenario, it's important that all partners (WHO, Health Ministries, Hospitals, telecom Service Providers) are aligned on the end objective and work coherently towards the same objective. It's critical to manage the expertise available with different partners (even across geographies in certain situations) and react quickly to situations. See WHO report 2014 west Africa.
This scenario is applicable to the circumstances in the time of disaster. The remote site can be the devastated area where remote mental or medical care is needed. The experts will be expected to provide the knowledge and experiences remotely to support non-experts or non-professionals who have to be in charge of the circumstance locally.
To enable the business model of remote health care in emergency time, it is recommended to make the best use of the platform capability including medical application in ordinary time. Otherwise, it is very difficult to cover the costs for on-demand functions in addition to network connectivity through the revenue from Remote health care in emergency time.

2.2 Business Ecosystem

Remote health care facilitated via 5G Network Slices will be a complex B2B2X ecosystem with lots of partners providing specific capabilities. A high level view of the purpose of interaction across different actors Skynet specific business scenarios has been provided in this section. There are various business models possible. These business models have been detailed out and compared in subsequent sections.

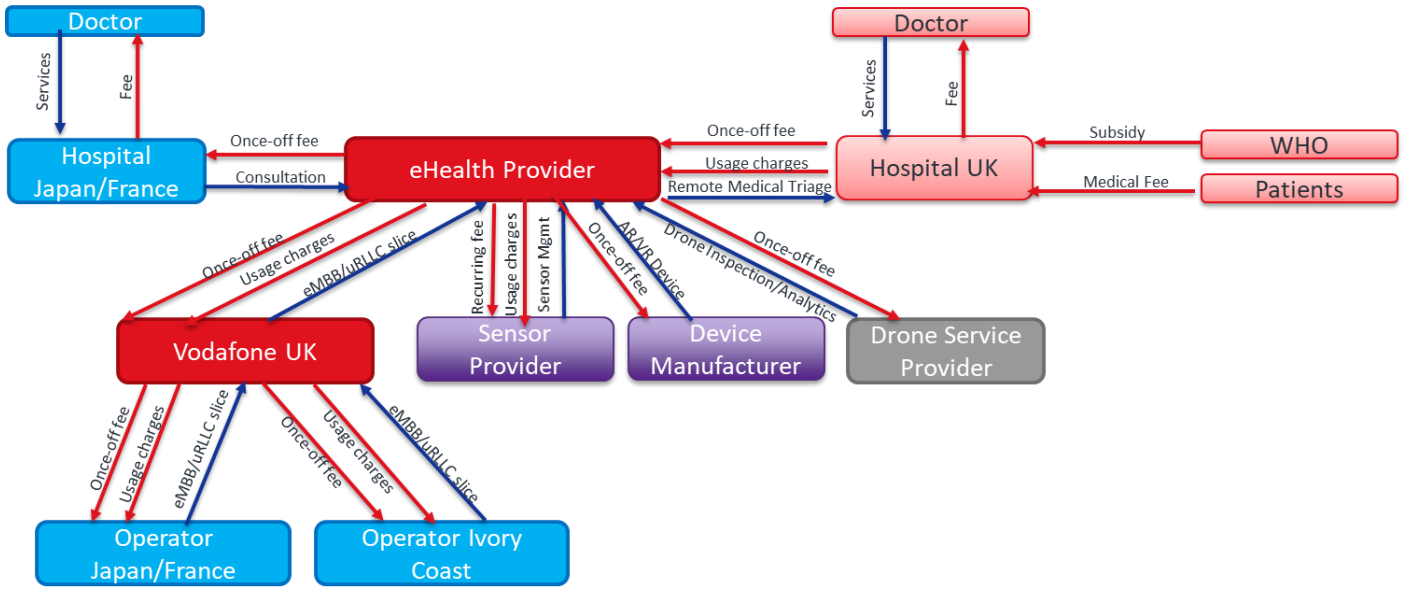


Figure 4 Remote Medical Care Business Model

Each partner (actor) in the ecosystem will have an integral role to play as highlighted below in the problem statement description. WHO and Health Ministries will be involved in case of epidemic management and therefore they have been marked as optional actors while other actors are marked as mandatory.

Telecom Operator (M)	Hospital (M)	WHO (O)	Health Ministries (O)	Medical Equipment Providers (M)	Doctor (M)	Patient (M)
As a Telecom Operator, I need to provide end to end network connectivity so that I can guarantee specific QoS required for different remote medical services like remote diagnostics, remote surgery etc. To do this I need to collaborate with different players like hospitals, health care organizations, medical equipment manufacturers to provide on demand services riding on "on demand slices" to facilitate remote medical care I know that I am successful when I am able to provide on demand services at agreed SLA and	As a Hospital, I need to collaborate with different other hospitals and health care organizations so that I can provide quick medical care at reasonable cost and regulatory compliance To do this I need to leverage ehealth care offerings from a telecom operator I know that I am successful when I have established right frame agreements with Telecom Operators and I am able to request for on demand services and slices at desired QoS which are provided in time with end to end accountability	As World Health Organization, I need to engage with hospitals quickly so that I can leverage technology advancement for the benefit of public health/better epidemic control and management To do this I need to have hospitals leveraging eHealth Care offerings from Telecom Operators I know that I am successful when Hospitals can leverage the digital ecosystem to react to a public health	As a health ministry, I need to quickly address a public health situation so that I can promote health care with quick support and affordable cost To do this I need to be part of an eHealth Care ecosystem with complete accountability and governance I know that I am successful when hospitals in my region are able to effectively leverage extended medical facilities (doctors, knowledge, sophisticated equipment) available remotely	As a medical equipment provider, I need to be part of a collaborative digital ecosystem so that I can get extended reach with good utilization of equipment To do this I need to collaborate with hospitals and telecom operators who could provide E2E connectivity with desired SLA I know that I am successful when I can improve the utilization of my	As a doctor, I need to be able to extend my services for remote health care and leverage facilities available remotely so that I can manage medical situations in time and with efficiency To do this I need to be able to collaborate effectively with remote doctors and facilities I know that I am successful when I am able to treat patients	As a patient, I need to get timely and best medical care so that I can recover quickly from illness or accidents To do this I need to be able to get seamless remote health care if situation demands I know that I am successful when remote health care comes with accountability, privacy and affordable cost

Telecom Operator (M)	Hospital (M)	WHO (O)	Health Ministries (O)	Medical Equipment Providers (M)	Doctor (M)	Patient (M)
monetize these value added services		situation at speed and at affordable cost		equipment for remote health care	effectively, with necessary privacy even when leveraging remote expertise	

Health Care Collaboration Model

Following figure highlights a collaboration view for the specific business scenario considered in this Catalyst. Field hospital shown below is the hospital which is under quarantine. Strong governance model would be key to ensure compliance to country specific privacy and medical regulations are complied with.

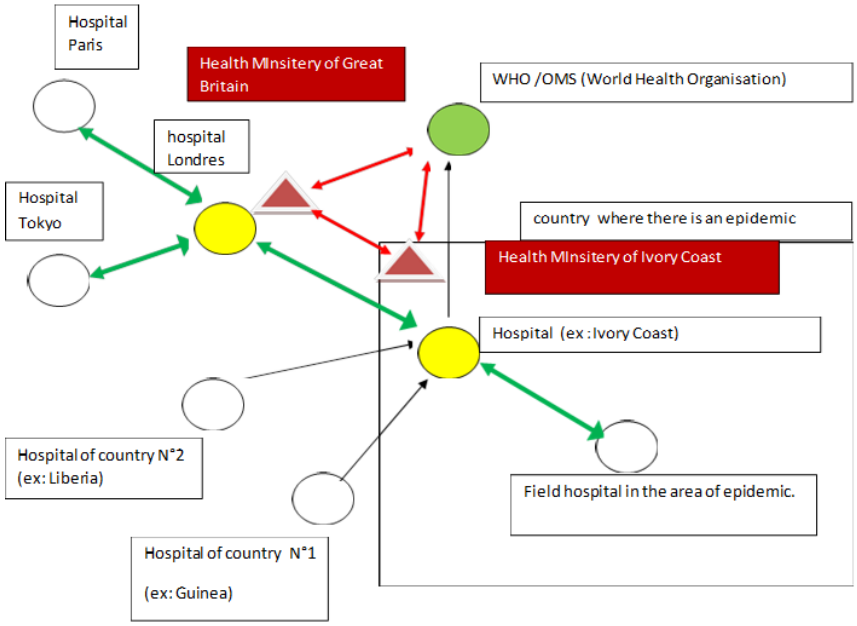


Figure 5 Health Care Collaboration Model

2.3 Business Impact

5G is not just technical roll out by telecom service providers. 5G will be the key enabler for digital lifestyle and digital ways of working. This is going to have equally high impact on other industry verticals. Automotive, Health Care, Entertainment and many other verticals will need to revisit their service offerings.

5G will bring positive disruption to health care industry

- Real-time monitoring and processing of patient data from various sensors for vital parameters could significantly improve effectiveness of treatment. This could allow analysis at scale, edge analysis close to patient and machine learning to facilitate personalized, data driven and intelligent health care
- Wider reach and usage of sophisticated equipment and specialized knowledge Technologies like AR / VR, 5G Network Slices and Standards based automation for on demand capabilities could promote adoption of remote diagnostics and remote surgery. This essentially means that knowledge and equipment in developed areas could be leveraged efficiently for remote areas. Apart from regular medical care, this could help in effective management and control of epidemics and disasters.
- New business models - Traditionally, health care services are offered based on one-time service charges and consultation charges. However, with remote health care approach, business models could be based on duration of medical procedure, outcome of treatment and time to cure a disease.

Telecom Service Providers need to look at what role they would like to play in enabling vertical industry services. Would they like to continue to be providers of telecom infrastructure and additionally offer 5G Network Slices, or would they like to be enabling the industry specific services. Monetization would be key for 5G.
If we consider remote health care services especially, then there are different aspects to be considered:

- What role each of the partner (operator, hospital, WHO, Health Care Equipment Provider et al.) will play in service offering?
- What is the business model of each partner?
- How cash flow will happen across different partners?
- How end to end service will be delivered and managed?

2.4 Social Impact

Health Care services are very personal and sensitive in nature. There are psychological and emotional aspects involved in addition to the actual medical care.
In certain geographies, regulations do not permit remote procedures on patients, however remote inspection and diagnostics might be still allowed. While the remote professional might bring in very niche expertise, it's important to have complete buy in into the process from local professional as well. If a local professional requests for remote assistance, he/she will be more receptive to support the same.
If remote health care services are provided with seamless collaboration between hospitals, medical equipment vendors and telecom service providers and if public and health care sectors are more receptive to remote services, this could significantly improve the time to answer to epidemic breaks out or natural disasters. In certain scenarios, this could bring down the cost of treatment. This could also fast track medical research.

2.5 Problem Statement

2.5.1 Business Challenges

Telecom Operators:

- Achieve the right business model to encourage smooth adoption, better monetization.
- Consider industry specific, geography specific nuances including social considerations and regulatory requirements.
- Every Industry will require a different partner ecosystem.
- Evolving business models like marketplace or traditional interconnect model.
- Ensure right accountability and trust in complex ecosystem to avoid any disruption in end to end service quality.
- Establish data privacy, end to end governance and accountability.

- **Hospitals**

- Revenue models for sustainable collaboration as the cost of equipment could be prohibitive in certain scenarios.
- Culture shift within medical practitioners for more active collaboration.
- Right business models with other hospitals, equipment providers for on demand collaboration.
- Ensure patient privacy is not compromised.
- Trust and traceability for remote health care services.
- Establishing data privacy, end to end governance and accountability.

2.5.2 Technical Challenges

A diverse ecosystem for "Remote Health Care" could pose certain technical challenges. Industries, Standards Organization, Technology Providers needs to come together to address these challenges quickly

- Common Vocabulary for Diverse Ecosystem - There is a need for common vocabulary across complex partner ecosystems. SID could be used as a foundation and additional business entities like patients, hospitals, equipment could be derived from SID.
- Open Interfaces for Seamless Collaboration- Dynamic collaboration is feasible only if the partner ecosystem is integrated via industry standard interfaces like Open APIs / MEF APIs.

- Trust and Traceability - There has to be complete trust and traceability in transactions which are happening across this complex ecosystem. Blockchain concept could be used for critical use cases like revenue settlement, E2E SLA Management, Identity Management.
- Speed of end to end network slice deployment on demand would be the key once frame agreements are available between different ecosystem partners (hospitals and telecom operators).
- End to End Service Monitoring, Correlation Based Impact Analysis and Closed Loop Automation could get very complex if the collaboration is required across different operator domains in different geographies. There is a need to further define the concept of automated or orchestrated test & monitoring – especially when dealing in a multi-carrier, multi-vendor environment where network slices and critical services are being established and maintained autonomously. Open APIs to allow trouble shooting across domains, standardization of models for 'beyond day 1 operations', and impact of service assurance on billing are a few of the open areas to be considered.
- Privacy and Data Security - To handle medical data, there is ongoing discussion about IT requirements - like "Encryption in Communication", "Terminal Without Storage", "Information Security at ASP/ SaaS". Concerning privacy protection, there must be different requirements and appropriate date depending on the ordinary or emergency time. The data should be limited but accessed by broader stakeholders in emergency situation with taking into account both convenience and security.

2.6 Overview of 5G Network Slices Concepts Across Standards Organizations

Before we have a closer look at Skynet's architecture let's have a quick glance at relevant concepts by various Standardization- and Industry Organizations.

2.6.1 TM Forum

TM Forum's "ODA Production: 5G Network Slicing User Guide" [TMF-1] emphasizes the decoupling of intent-based 5G slicing services as seen in the Core Commerce Domain and their implementation details in the Production domain of the Open Digital Architecture:

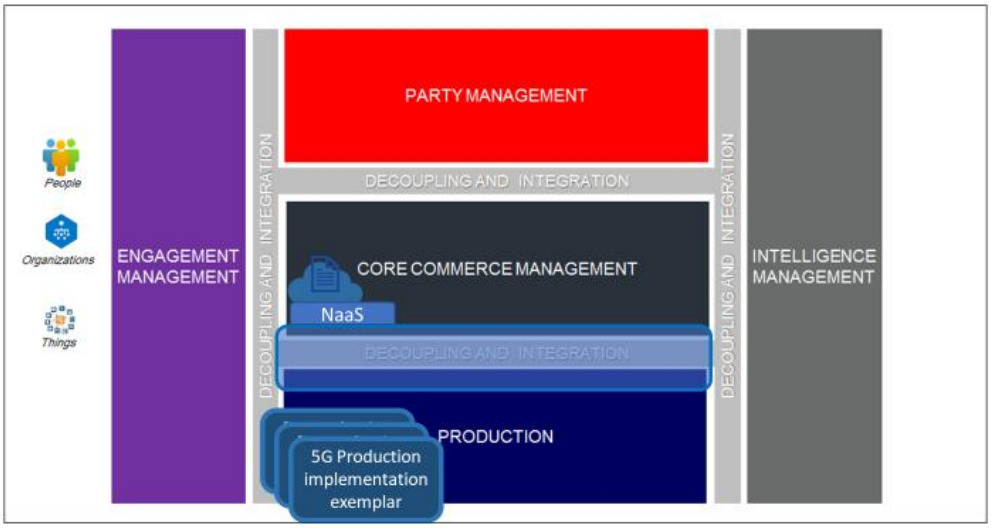


Figure 6 Relevance with TMF ODA

Skynet adopts that view and combines it with GSMA-NEST concepts for the NaaS description.

2.6.2 GSMA NEST

The GSMA has initiated the Network Slicing Taskforce (NEST) project within its Future Networks Program to guide Network Slicing standards, harmonies slicing definition, identify standardized slice types with distinct characteristics and consolidate parameters and functionality requirements.

They introduced the so-called Generic Slice Template (GST) to serve as a common language to uniquely describe the characteristics of network slices. The GST is a collection of attributes which was developed in dialogue with various industry verticals and potential network slice customers. It is supposed to enable the slice customer to uniquely describe service requirements and provide all relevant information to the slice provider to deliver that service. The GST is currently in a draft status and under review. For Skynet we used the draft version of December 2018 as provided to TMF with a liaison statement *[GSMA-2].*
A Network slice type (NEST) is a GST with filled attribute values for a (set of) specific use cases, e.g. eMBB or uRLLC.
GSMA intends to provide a set of industry-accepted standardized NESTs, so called S-NESTs, to support inter-carrier roaming agreements. Besides that, operators are free to define specific private NESTs (P-NEST) to serve individual customers or use cases [GSMA-1].

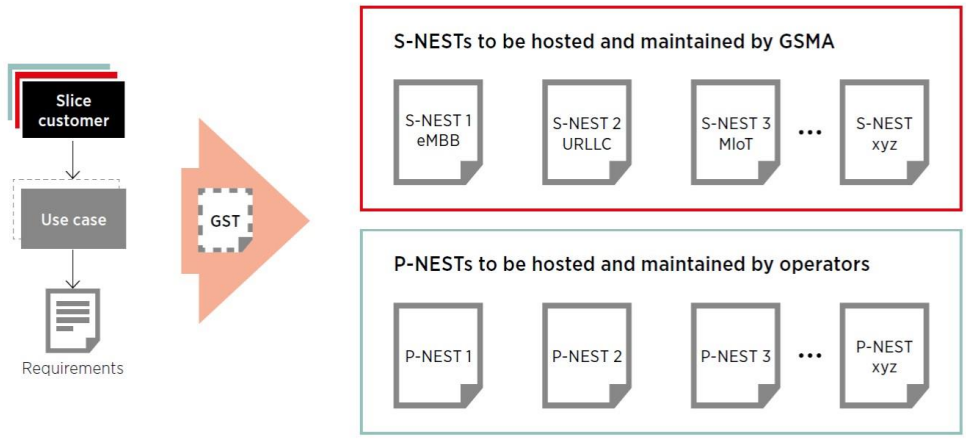


Figure 7 S-NEST and P-NEST Guidance from GSMA

Skynet requires network slice descriptions to support remote health care use cases over a global footprint where new countries can be on boarded easily. Therefore, standardized, operator-agnostic slice descriptions were called for. Since it is GSMA-NEST's ambition to exactly provide a common language for such slice descriptions, it was decided to apply a GST-based approach in Skynet.
In a perfect world we would have used predefined S-NESTs for remote health-care services. However, the S-NEST were still under construction, so we had to gain experience with the available draft GST-version of December 2018 and define our project specific health-care NESTs. Please refer to Section on "Product Modelling" and "Slice Definitions and their Mappings to the Skynet Architecture "in this document

2.6.3 ETSI

ETSI provides the base architecture, used as reference by many Service Providers, for the NFV management functions. ETSI matches very well the IETF E2E network service concept with a set of application functions required in real implementations.
We should start from the definition of E2E Network Service from IETF, being network slicing one. Its implementation is comprised of various logical layers to be considered.

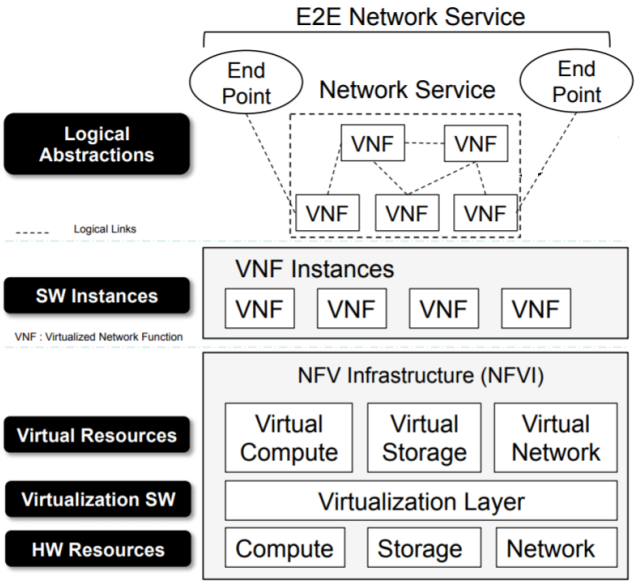


Figure 8 ETSI Reference Architecture (*Source: IETF)*

ETSI is providing a matching definition for Network Service: "A network service is constructed by chaining VNFs and/or Physical Network Functions (PNFs). ." (from the https://portal.etsi.org/Portals/0/TBpages/NFV/Docs/NFV_White_Paper3.pdf).
Therefore, in line with the ETSI MANO architecture, we can map what we called Domain Orchestrator to the ETSI NFV-MANO, in terms of functionalities and capabilities.

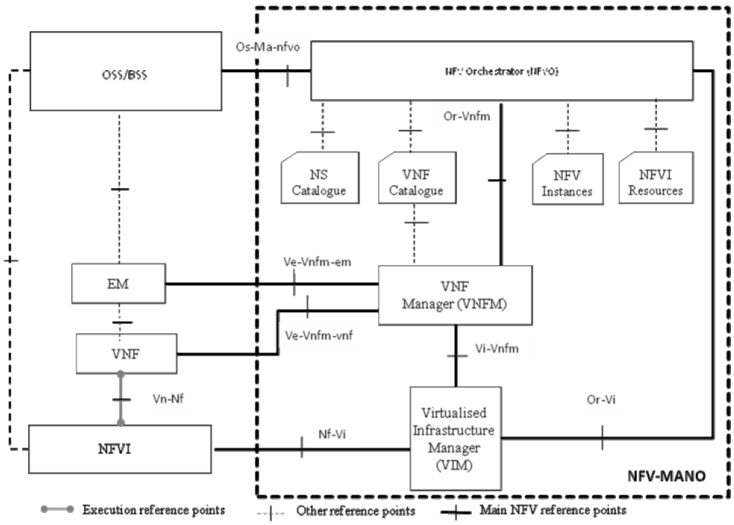


Figure 9 ETSI MANO Architecture

Source ETSI (https://www.etsi.org/deliver/etsi_gs/NFV-MAN/001_099/001/01.01.01_60/gs_nfv-man001v010101p.pdf)
The (Network) Service Orchestrator Module of the architecture will provide the missing piece giving the capability to do Network Service Design and apply Network Service templates, ultimately representing Network slices.
It is important to note that the Network Service as defined above by ETSI and IETF is NOT matching the TMF Service definition, but it's rather mapped to a composite Resource Function, using TMF SID terms.
The NFV MANO, can then be seen as an enriched Resource Order Management and Network Service Orchestrator is playing the role of Service Capability Orchestrator and Resource Capability Orchestrator, using TAM terms.
Ultimately we would like to mention, maybe as a possible contribution, that we consider the alignment between the terminology and definition of Service in ETSI and TMF as a key improvement to bring clarity in real life deployment were multiple standards are used. It is important to take this position to ensure the replicability of our solution in multiple operators, where we cannot assume homogenous industry standards adoption.
In the following chapters multiple mention of ETSI are made, and we made a strong effort to realize an architecture that is taking it into account alignment of these standards as much as possible, in order to build a reusable solution for the market.

2.6.4 3GPP

3GPP's work on slice management and related definitions, e.g. the concept of Network-Slices-as-a-Service (characterized by properties like end-to-end latency, bandwidth etc.) are central pieces taken up by Skynet.
3GPP 5G SA2 working group defines 5G Core System Architecture and they are defining the 5G Network Slicing as one of the main features of 5G Core. TS 23.501 highlights major functions of Network slicing and defines the 5G Network slicing types (SST). 3GPP SA5 working group specified 5G Slicing Management and Orchestrations in TR 28.801. TR 28.801 defines the following 3 major management functions for slicing:

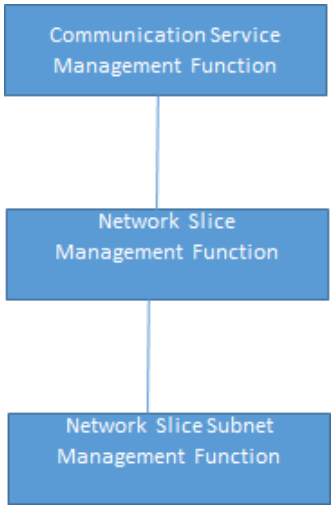


Figure 10 Slice Management (3gpp Reference)

3GPP TS 29.520, 5G System Network Data Analytics Function (NWDAF) is published in Release 15 (Stage 3); NWDAF function can be considered as an important component for Service assurance.

3 Architecture

3.1 Business Architecture

There was lot of deliberation done on how the service providers could offer remote health care services primarily on three dimensions

- Remote health care services could be offered under the existing brand or these could be launched under a new brand.
- Health care business will be a separate legal entity or operate under existing legal entity.
- Operator could launch remote health care portal or partner with third party health care platform provider.
- There could be multiple operators in the same geography enabling health care services or all operators could be permitted to offer health care services.

These options have been highlighted below. Option C was arbitrarily taken as reference for PoC implementation. In our blueprint all the business models proposed can coexist in order to push adoption of the collaborative approach, and give to the service providers the freedom to shape their own business strategy for the eHealth vertical.

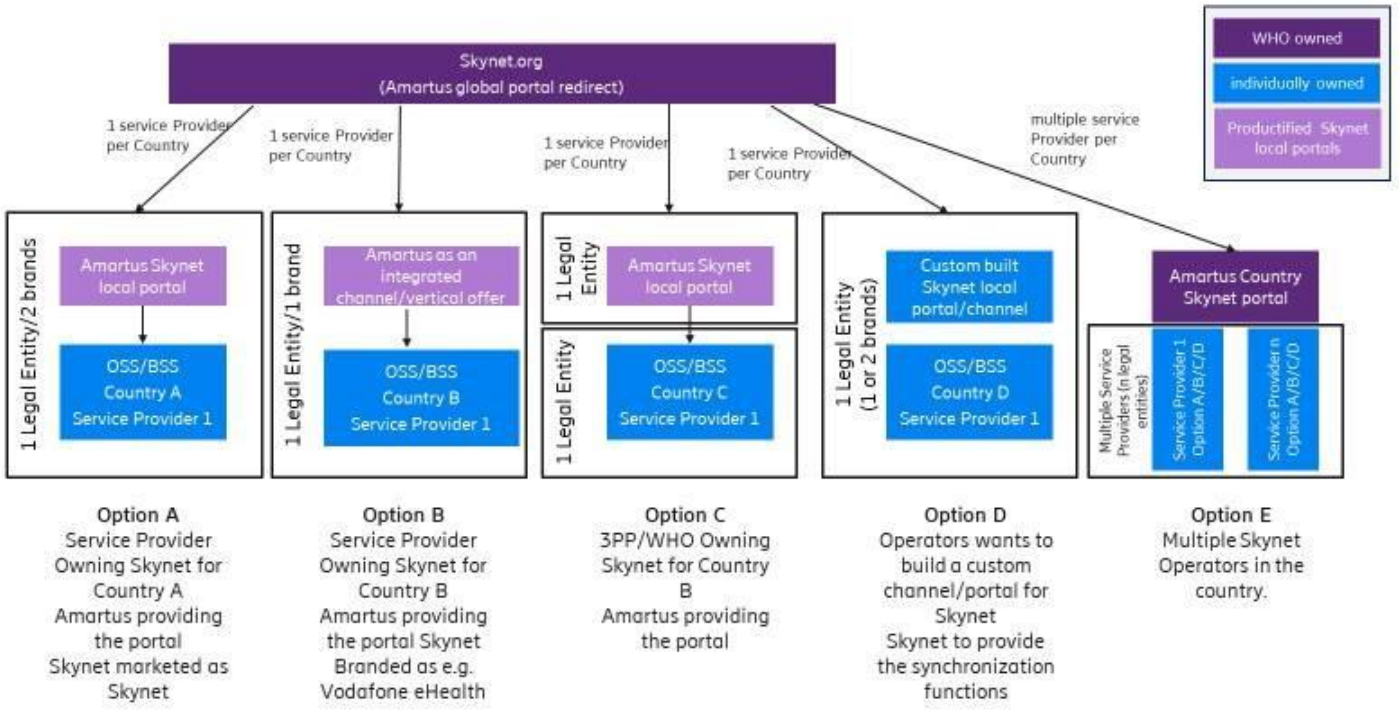


Figure 11 B2B2X Business Model

3.2 High Level Solution Architecture

Various Options were deliberated for Remote Health Care Offerings. These have been detailed out in this section

3.2.1 Hierarchical Marketplace

In this approach, Marketplace plays the anchor role for providing health care services.

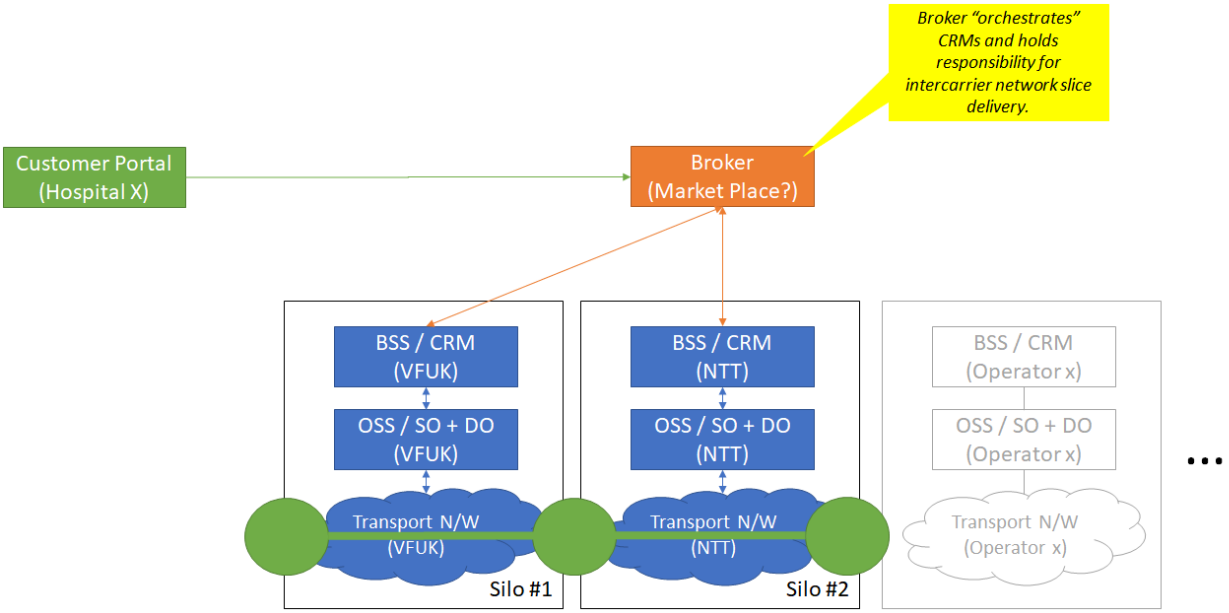


Figure 12 Hierarchical Marketplace

3.2.2 Federated (CRM to CRM) Approach for Marketplace

This approach is more aligned to MEF architecture and provides more realistic cash flow scenario. Introducing the "inter carrier aspect" will make the UC closer to possible real life scenarios, and allow to make the best use of Blockchain technology

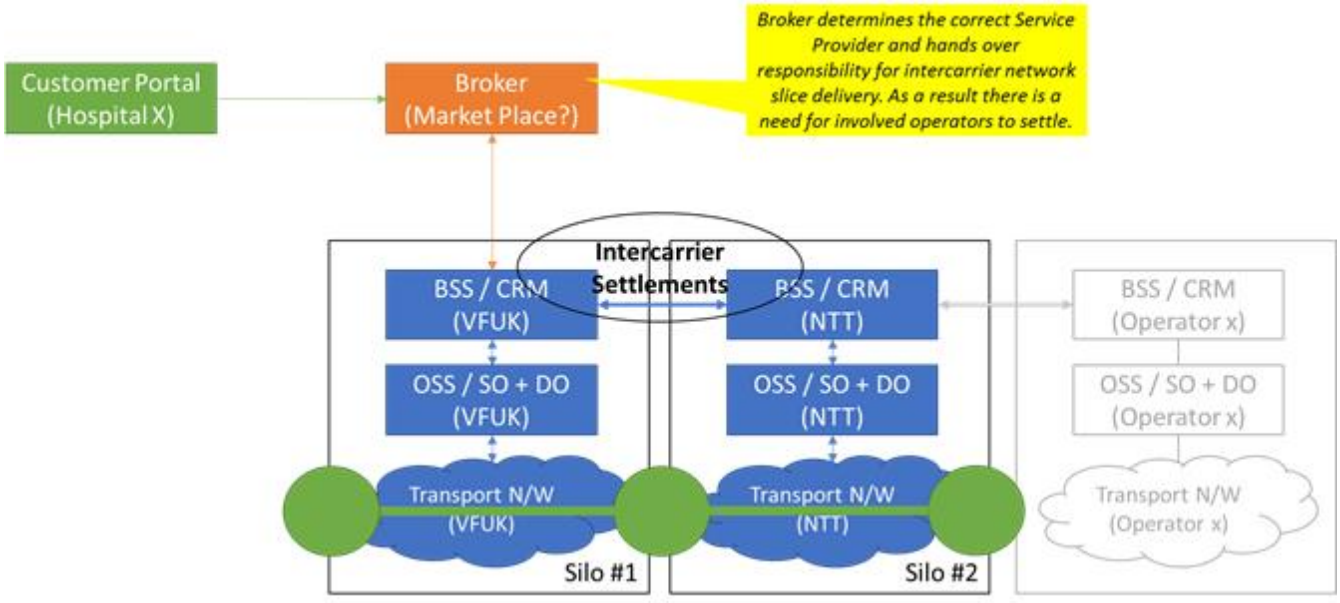


Figure 13 Federated (CRM to CRM) Approach

3.2.3 CRM Driven Federated Architecture

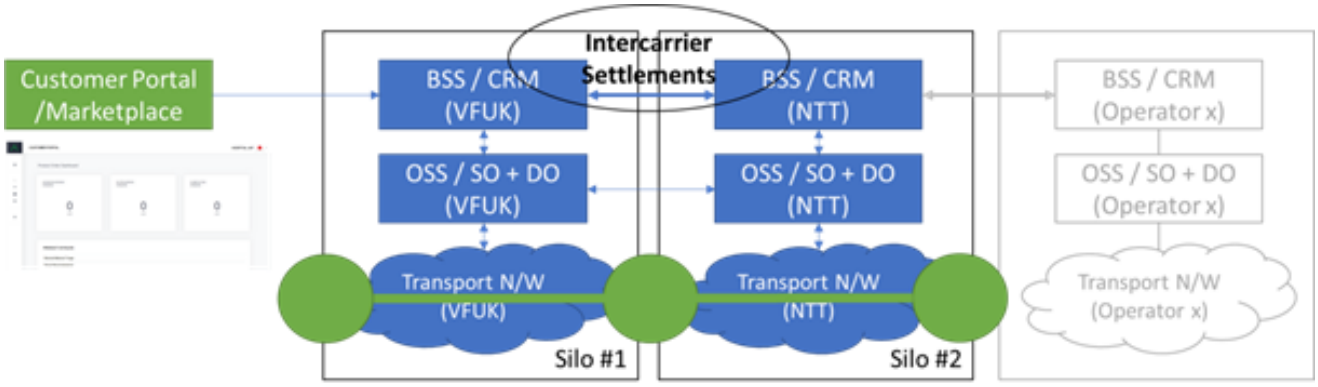


Figure 14 CRM Driven Federated Architecture

Comparison Dimension/ Model	Hierarchical Marketplace	CRM to CRM Federated Marketplace	CRM driven Federated Architecture
Partner Management	All Connectivity Partners, their offerings and contracts must be on boarded onto Marketplace.	Lead Operator contracts and offers must be on boarded onto Marketplace. Connectivity Partners, their offerings and contracts must be on boarded onto lead CRM	Connectivity Partners, their offerings and contracts must be on boarded onto lead CRM
Product Management	Marketplace has connectivity offers from different partners. Marketplace has "Remote Medical Health Care" Offer as well. Depending on the location selected by the customer for collaboration, the orchestration plan and price is determined.	Marketplace has Remote Health Medical Health Care offer configured from lead operator. Lead operator has connectivity product offers from other partners.	Lead Operators CRM has Remote Health Medical Health Care offer configured from lead operator. Lead operator has connectivity product offers from other partners.
Intercarrier Settlement	No direct settlement between operators. Marketplace drives settlement with all operators.	Marketplace has no visibility of various operators involved. Lead operators drives settlement with other operators like in case of wholesale / interconnect business models.	Lead operators drives settlement with other operators like in case of wholesale / interconnect business models.
End to End Service Orchestration	Marketplace should support federated orchestration to different CRMs.	Lead CRM owns the federated orchestration.	Lead CRM owns the federated orchestration.
End to End Service Management	This could get complex with Marketplace getting aggregated Service KPIs and managing the E2E Service SLAs	Lead Operator will own the	
Regulatory Compliance	Might be easier for operators to create Industry Vertical Specific Marketplace as these could be separate business units.		
Expected Adoption	Could take longer to set up Marketplace and onboard partners.	This could be optimal from TTM and complexity perspective.	Could be faster and complex to onboard industry specific services on existing stacks

CRM driven federated architecture has been selected for the PoC implementation.

3.3 PoC Architecture aligned to TMF ODA

Skynet Catalyst has taken ODA as reference architecture for the project. Following figure highlights the capabilities relevant to the focus areas of Skynet Catalyst.

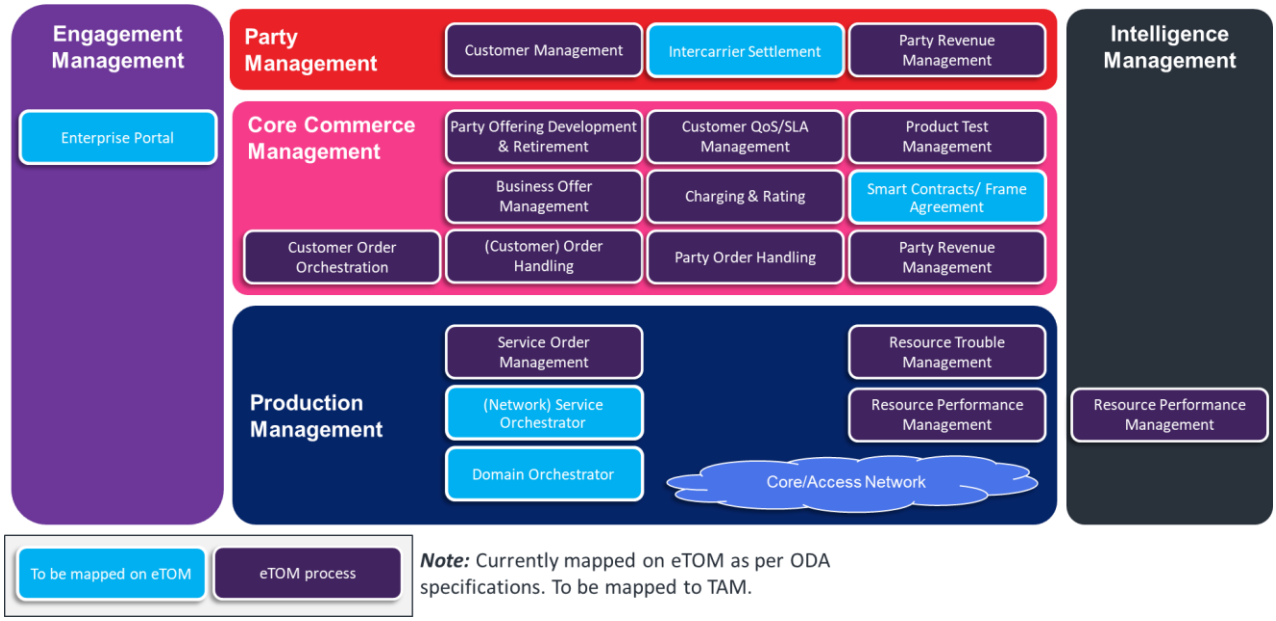


Figure 15 Skynet Functional Architecture

Following figure represents the high level E2E solution architecture for this catalyst. This highlights the key capabilities and technology components considered for different operators to participate in Remote Health Care Ecosystem. Service and Domain orchestrators include respective inventories and topologies. Explicit mention is avoided for the sake of simplicity

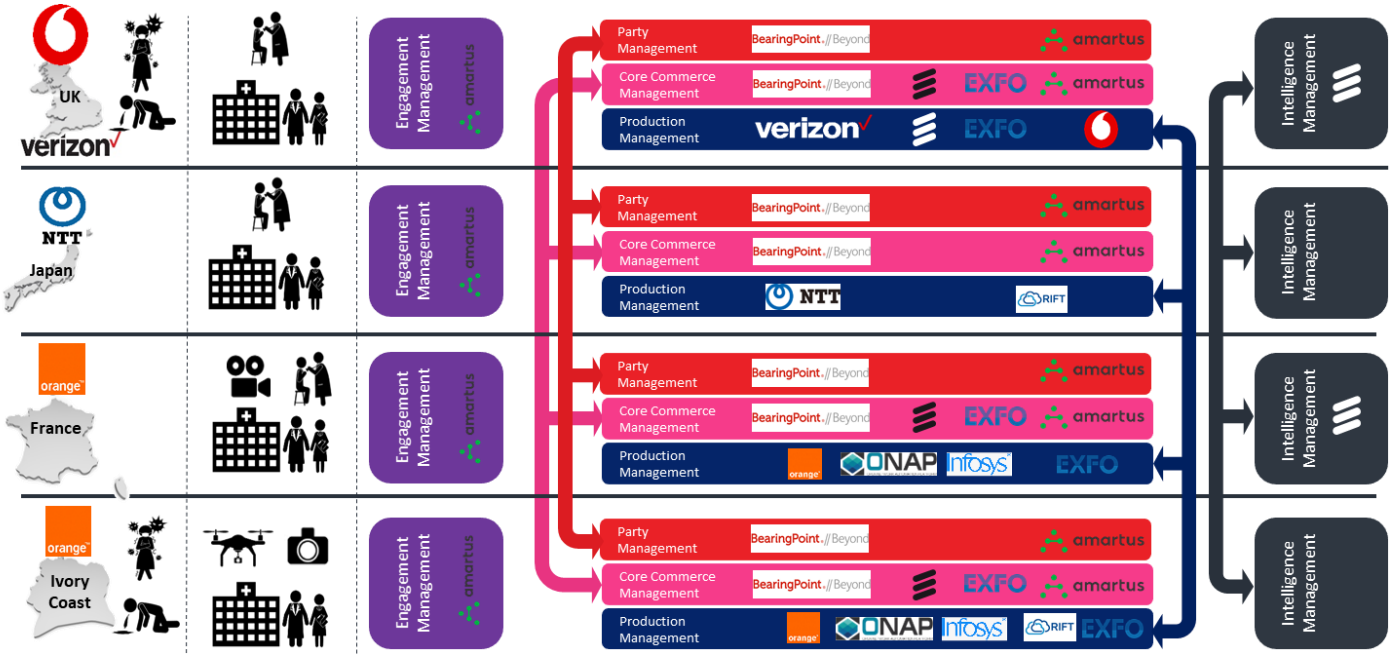


Figure 16 Skynet Architecture

Following figures depict the component architecture for different countries. Catalyst team has leveraged different components in different stacks to demonstrate that that the solution is suitable for heterogeneous environments as well. This is also the case across most of the collaborating telecom operators.

This is UK stack representing Vodafone collaborating with Verizon which provides RAN.

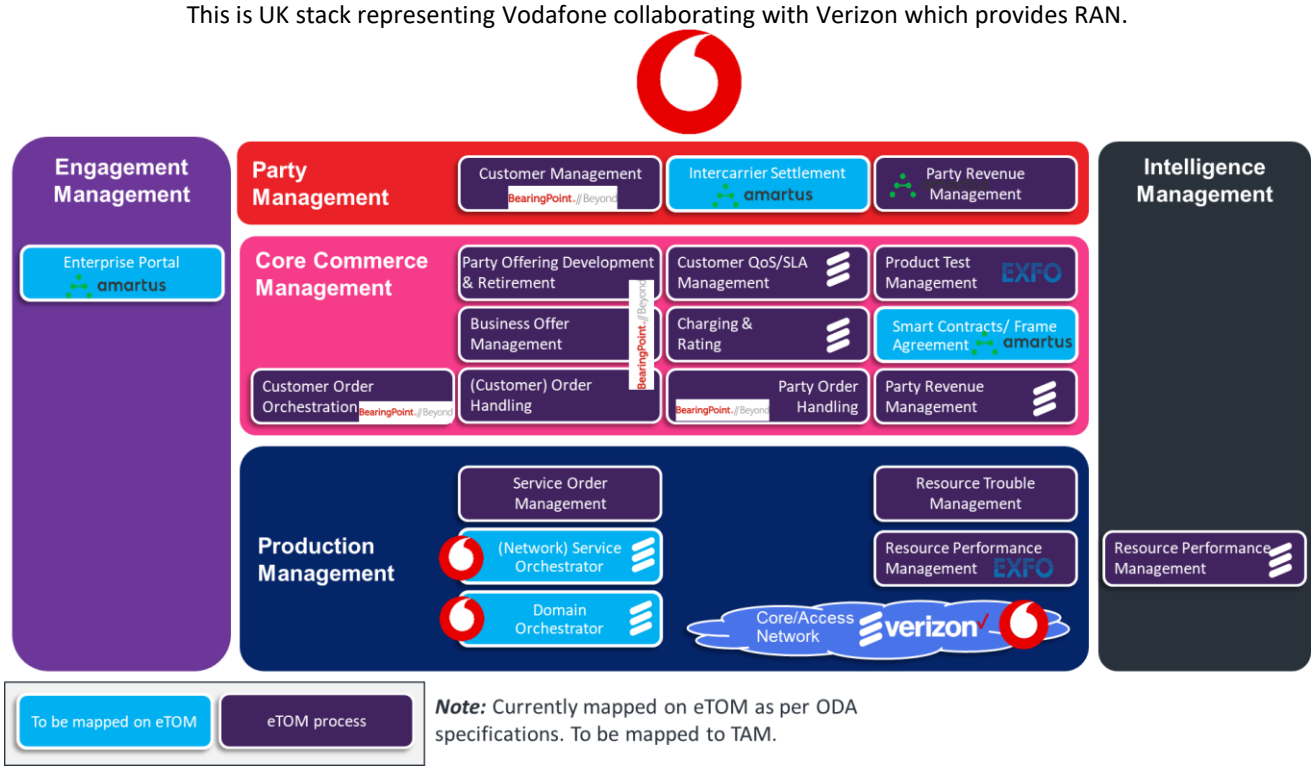


Figure 17 UK Stack Architecture

This is Japan Stack represented by NTT

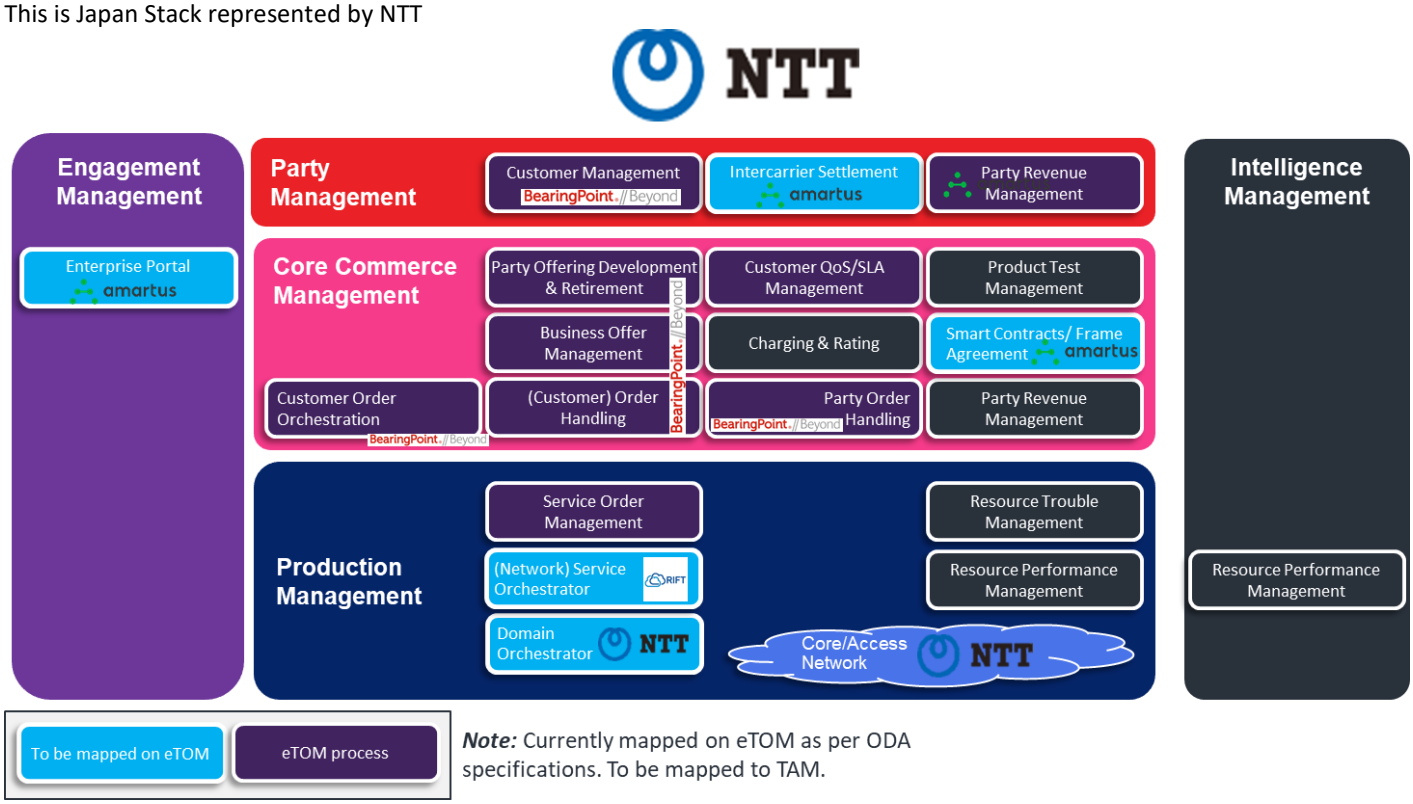
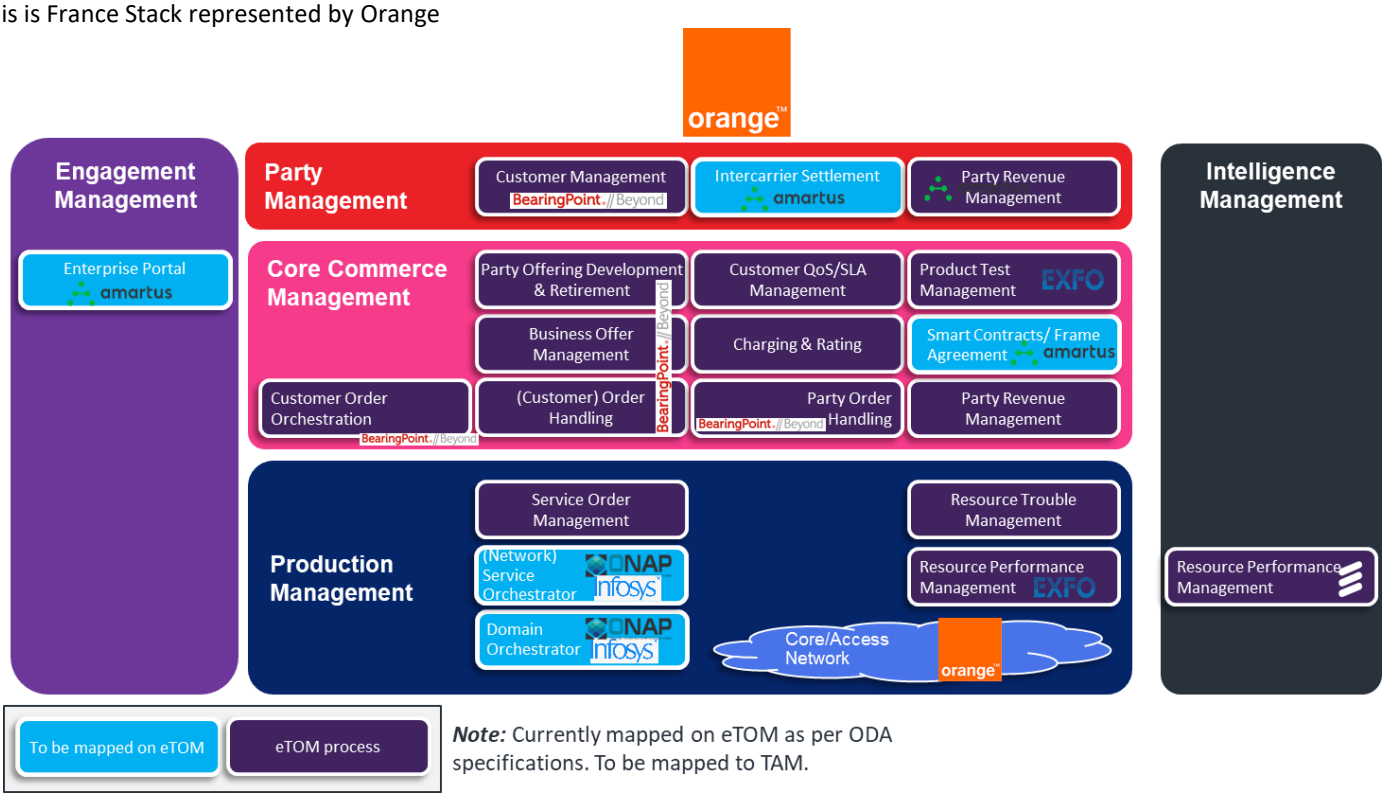


Figure 18 Japan Stack Architecture

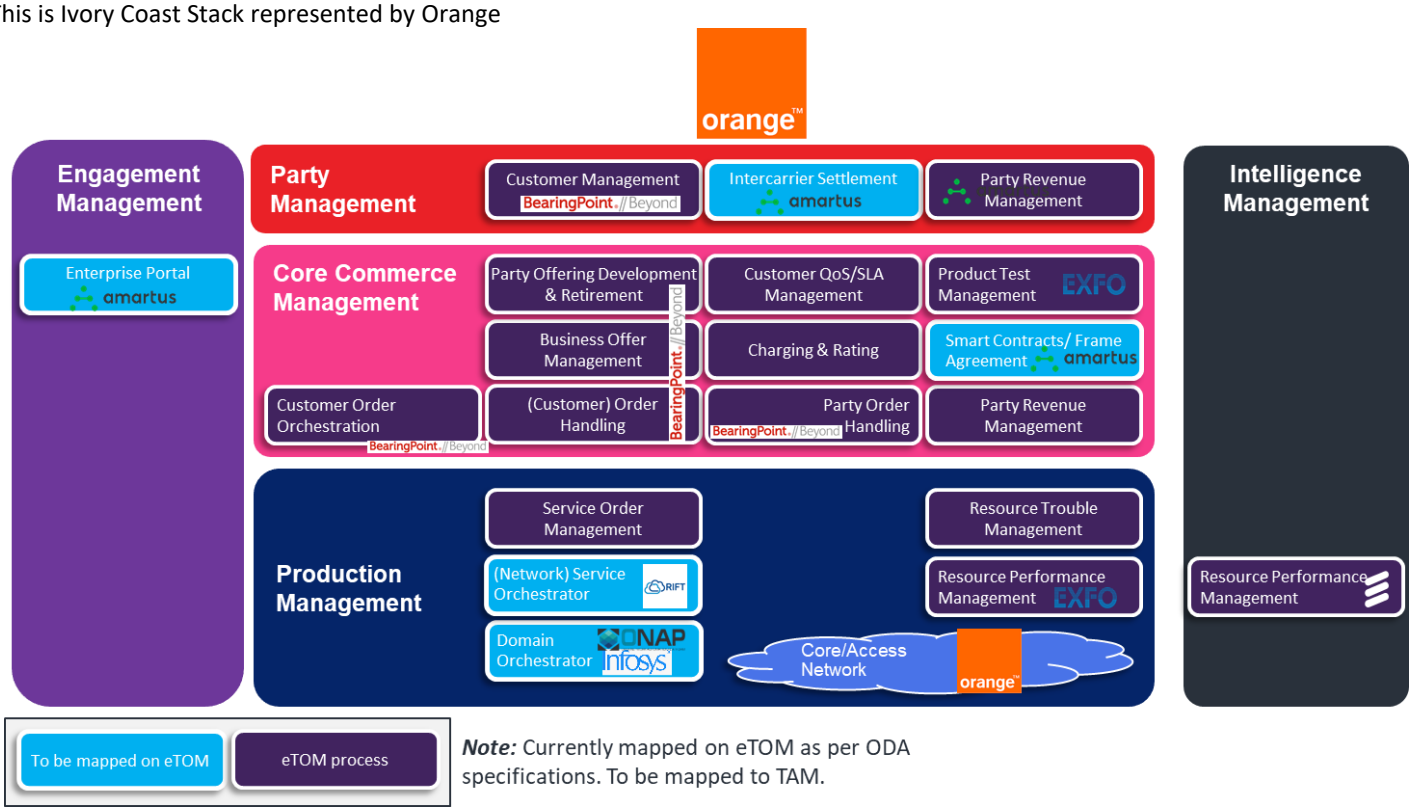
This is France Stack represented by Orange



Note: Currently mapped on eTOM as per ODA specifications. To be mapped to TAM.

Figure 19 France Stack Architecture

This is Ivory Coast Stack represented by Orange



Note: Currently mapped on eTOM as per ODA specifications. To be mapped to TAM.

Figure 20 Ivory Coast Stack Architecture

3.3.1 Slice Definitions and their Mappings to the Skynet Architecture

The illustration below depicts how slicing terms were mapped to the ODA-based Skynet architecture:

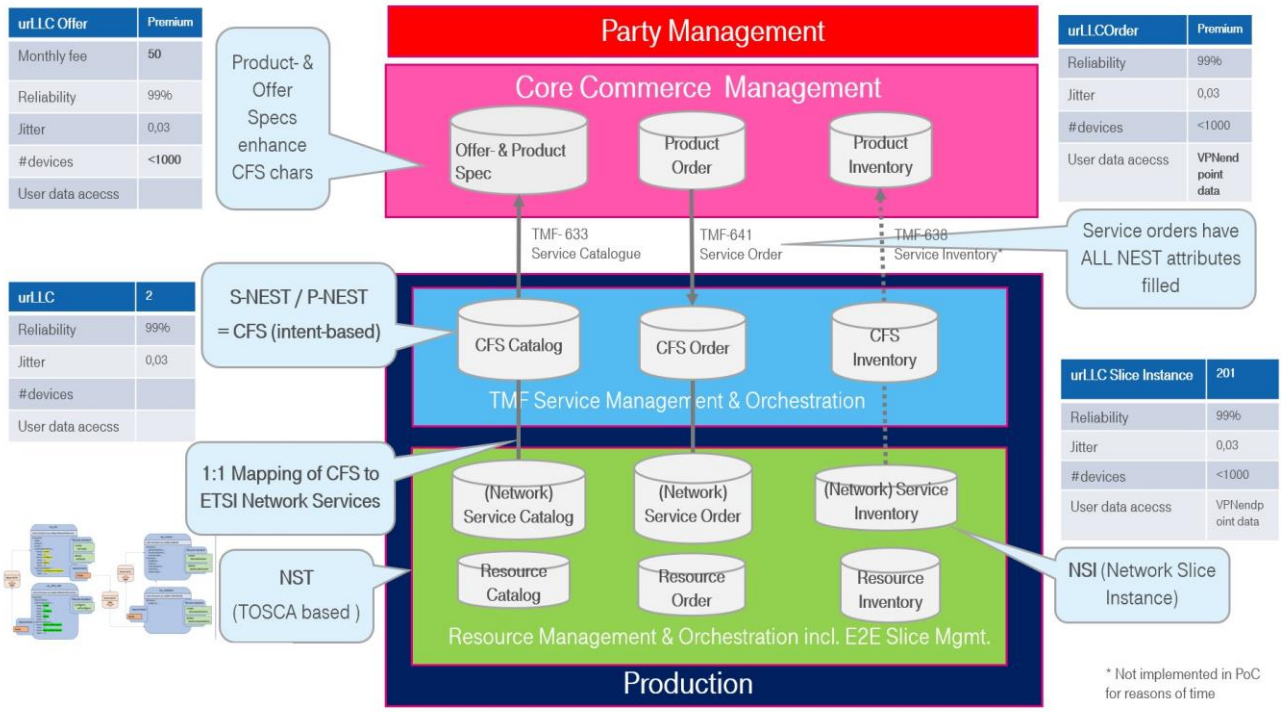


Figure 21 Slice Definition Mapping to Skynet Architecture

The Production Domain exposes network slices as customer-facing services to the Core Commerce Domain with the service characteristics corresponding to GST attributes via the TMF-633 Service Catalogue API. In GSMA terms network slice types (S-NEST or P-NEST) are exposed. For Skynet all operators use the same slice type specification, to ensure that the service is provided in a comparable quality over the global footprint. In fact, it is some kind of S-NEST, but not yet approved by GSMA. Therefore, it seems more appropriate to speak of Skynet P-NESTs.

There is a 1:1 mapping of the NEST based CFS Specification to an ETSI (Network) Service of the resource Management & Orchestration Layer. This is a simplification of then target architecture for pure PoC purposes only. We do recommend to implement a genuine cross-domain Service Orchestration (i.e. including OTT Service Domains). The ETSI (Network) Service is related to a NST (Network Slice Template) which describes the underlying model for service instantiation and could be for example TOSCA based.

The Core Commerce Domain would then define product- and offer specifications based on the customer-facing service descriptions exposed by the Production Domain, enriching them with commercial characteristics. Also if non-fixed characteristics of the CFS Spec could be specified here (e.g. number of devices). Here also a bundling with remote health-care services is applied.

Product orders of such slice offerings would be decomposed in the Core Commerce Order management and respective service orders (TMF-641 Service order) are placed at the Production Domain. These service orders would correspond to a NEST with all relevant attributes filled, i.e. also attributes which are to be specified by the customer (e.g. application endpoint descriptions) and are not filled in the slice type description.

As a result of the service order a network slice instance (NSI) is created, corresponding to a service instance in TMF terms. The reference to the NSI is provided to the Commerce Domain with the service order response. Detailed NSI information could be exposed by the Production domain via TMF-638 Service Inventory API which was not implemented in the PoC for reasons of time.

4 Use Cases

Remote health care will require various offerings like

Remote Health Care Offerings	Corresponding Network Capability
Diagnostic with Automatic Translation	traditional voice telephony service
Virtual Diagnostic	AR/VR based/HoloLens /eMBB Network Slice
Robotic Operation	uRLLC Network Slice
Drone Inspection and Analysis	eSIM, Edge Compute and Analytics
Supportive services for diagnostic/IoT sensors/ drones	mIoT Network Slice

Telecom operators will need to implement following use cases to design, deliver, assure and monetize these offerings

4.1 Network Service Design and Propagation; Remote Health Care Offer Creation

Following figure represents the sequence of steps to be followed for on boarding IMS VNFs, composing IMS Service for Voice/Data and propagating this definition to various run time environments (ONAP or External Components). Charging system will also receive the service specifications, however the rates will be manually configured in charging system. CRM for operators will hold details on telecom services. The network product details must be propagated to Blockchain platform as well. Blockchain platform will use these product details from various partners for inter carrier settlement. In UK CRM, remote health care offers should be created. Process flow will be similar for all operator stacks apart from slight variations due to different technical components used for catalog and orchestrator and billing. Similar process will be followed in all operator stacks for design and propagation of respective network services.

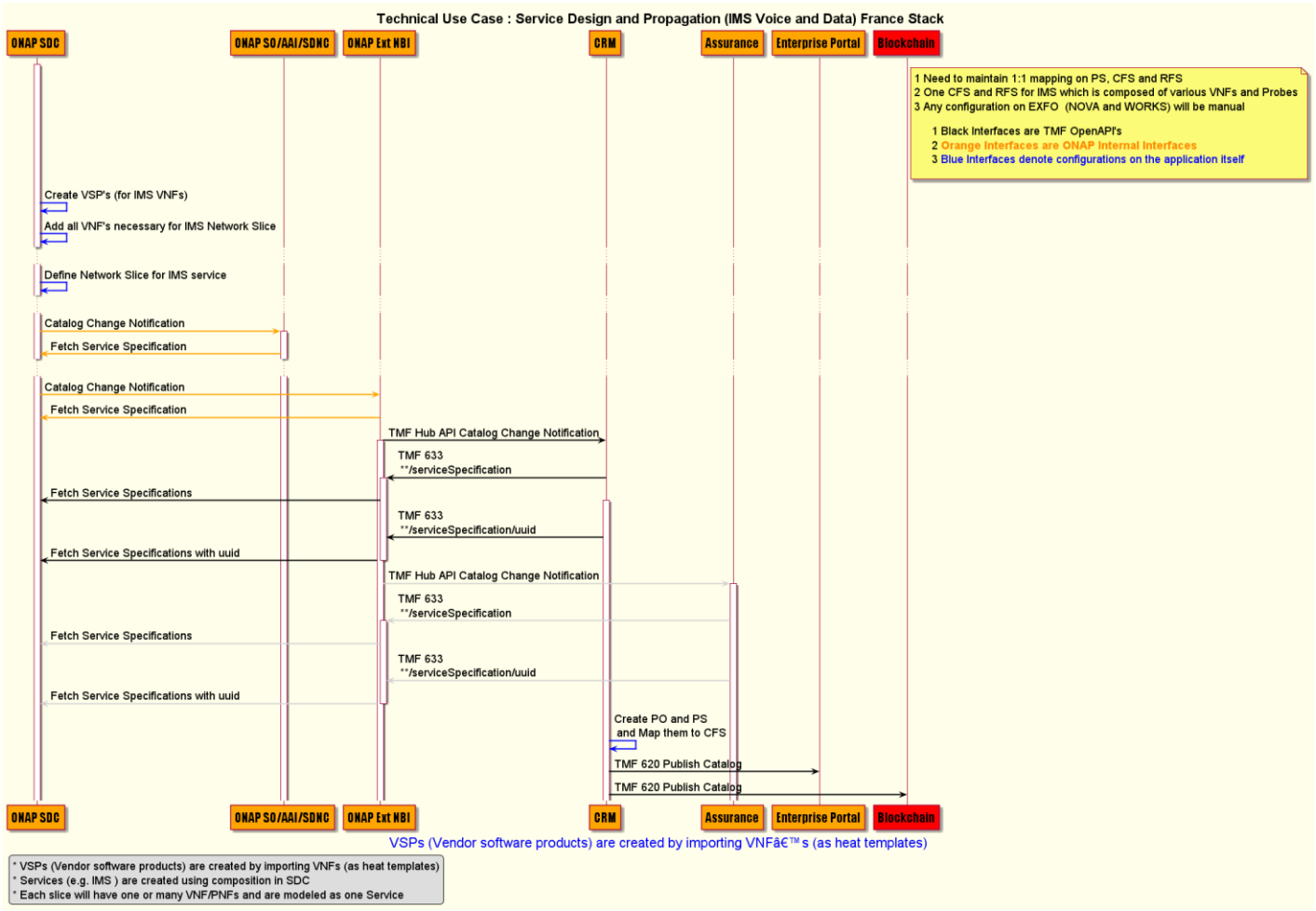


Figure 22 Network Service Design and Propagation

4.2 Remote Health Care Order Capture and E2E Orchestration

Following figure highlights end to end orchestration flow across UK and France

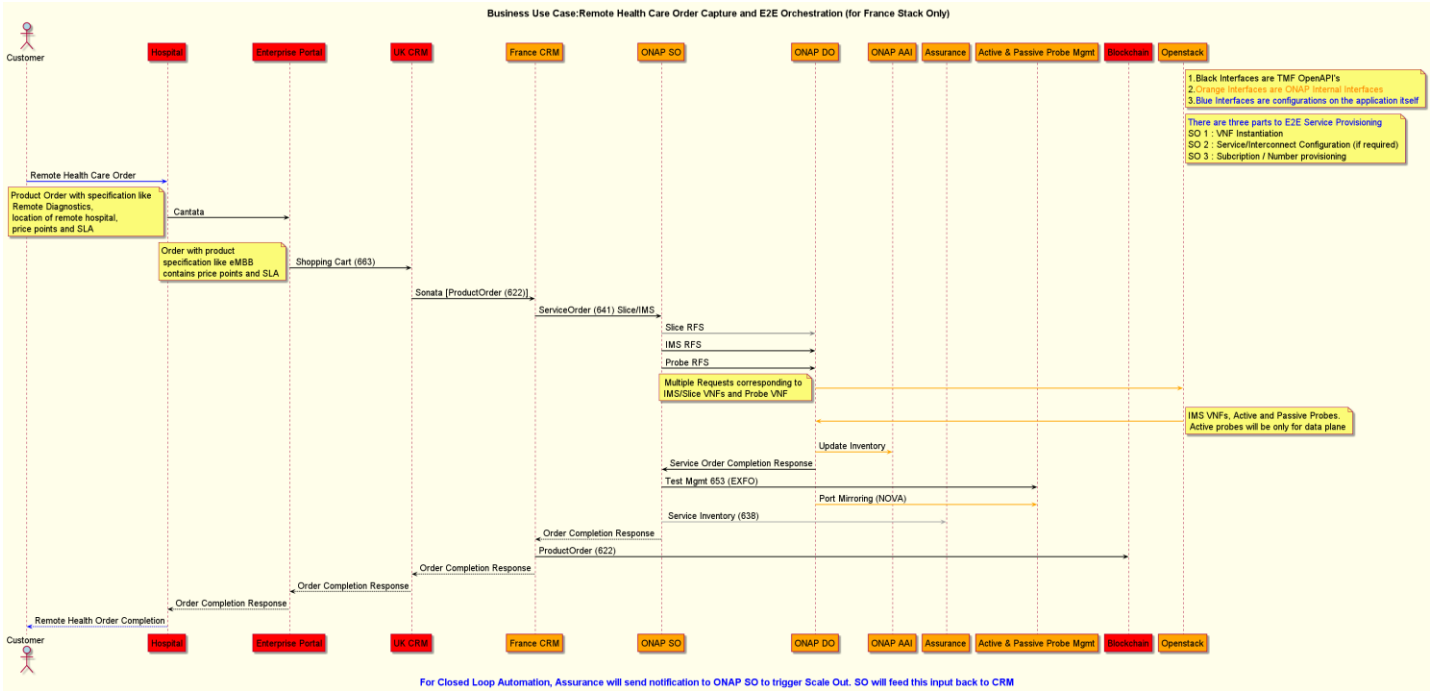


Figure 23 E2E Order Orchestration

Similar process flow will be followed for other stacks as well.

4.3 Service Monitoring

Service Assurance and SLA Maintenance Goals: In 3GPP Architecture, Network Data Analytics Function (NWDAF) plays a key role in Service Assurance. NWDAF function provides data analytics from multiple sources that affects the service performance such as VNF throughput, liveliness, latency of data services, RAN, Core and Edge component KPI that contribute to the slice SLA maintenance. Thus Skynet project architecture and demonstration correlates both VNF performance in the 5G Core functions and RAN performance KPI to maintain the intra-operator slice performance. In the inter-operator slice SLA maintenance, the 2nd operator provides services in region where the first operator does not have slice service and the 2nd operator is informed about the slice SLA requirements during the initial slice ordering process. Current practice is that each Operator maintains its side SLA and the two slices are joined by a PNF at the operators' boundary of services; there is no standard or benchmark for 5G Network Slice KPI sharing among the two operators. Based on the experience from Skynet demo, in future Verizon would like to collaborate with other operators to come up with a select KPI definitions for sharing.

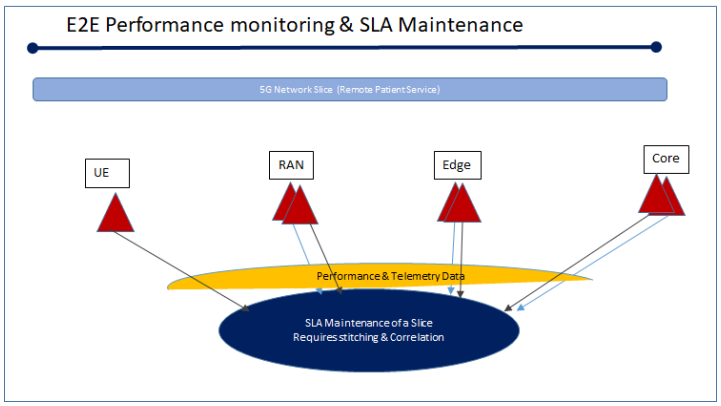


Figure 24 E2E Performance Monitoring

The ODA compliant architecture shows a full stack slice operator providing both Orchestration and Service Assurance for Slice network services. Since slice KPI is derived from various components of the Slice network (RAN, Edge, Core), and the operators often use multi-vendor solutions for its network services, it is important to define a set of Standard KPI for RAN slice measurements and identify the KPI for VNF functions serving Edge or Core functions for slice service. 3GPP describes use cases for 'Slice as a service'; the slice service can be offered to an Enterprise or to another operator. In both cases, understanding 5G Slice KPI as a common standard requirement is useful for conducting the business. Another challenges in Operators' world is to work with multi-vendor EMS API and Data models for collecting the counters and KPI for the services. In this particular example, collecting the telemetry and performance data can be simplified if there is a common API and Data-model for vendors to connect to the Operators' OSS systems. ONAP, TMF, 3GPP are the target standard bodies to approach with the 5G Slice KPI definition and reporting related APIs

As mentioned above in the 'Service Assurance & SLA Maintenance Goals' section, that a Network Slice is made up of sub-slices based on domains of the Network. An operator may own each domain (RAN, Edge and Core) or it may use another provider's service for a specific domain. In the Skynet demo, Verizon is acting a 5G RAN provider for the Vodafone Slice. Thus, for measuring and monitoring an operator slice, slice performance information for each domain is required and then stitching and mapping of the monitored KPI with that of other domains are absolutely the essential part of Slice monitoring and SLA determination end-to-end. For example, two providers may agree on a certain KPI for each domain of slice services they are providing and then each provider is responsible for maintaining the KPI of their respective domains. The KPI can be associated with both virtual and physical network elements. A slice, most likely is composed of multiple Virtual and Physical Network Functions.

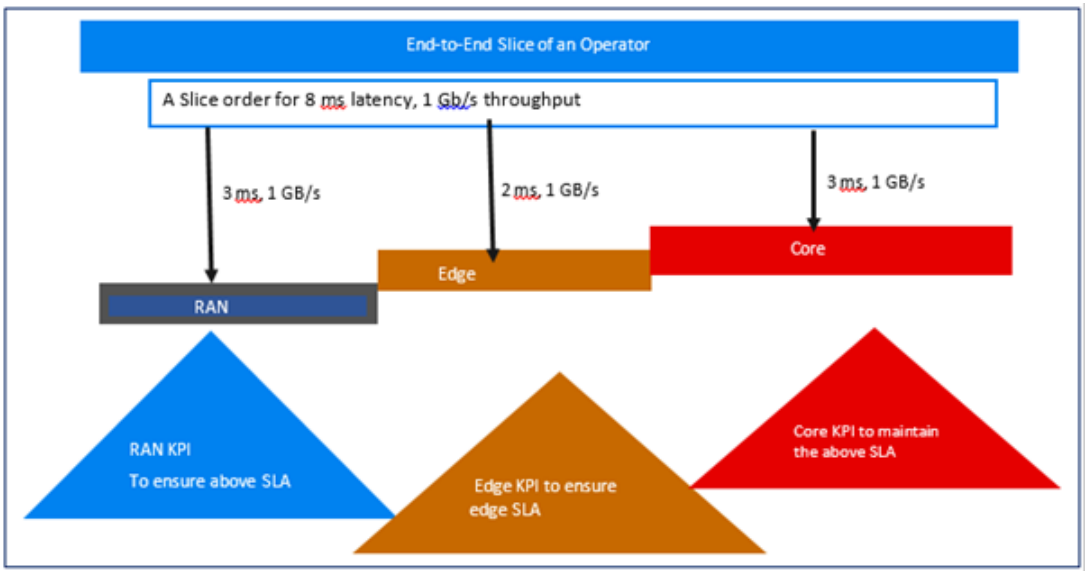


Figure 25 E2E Slice SLA Measurement

Each Sub-slice KPI are measured and correlated to calculate overall end-to-end slice SLA

- E2E monitoring: End-to-end monitoring is being used for 2 distinct functions. First, it is used to provide activation testing of both a network slice and the services being carried within those slices. In this way, the orchestration systems can be assured that the network and services are capable of supporting the required SLAs, prior to being turned over to the end-user. For remote medical applications, having this guarantee is critical to ensuring the safety of patients. After successful completion of the activation testing, end-to-end monitoring is used to assure the continued conformance to the stated SLA requirements, and when service level performance thresholds are crossed, the end-to-end monitoring solution alerts the service assurance policy orchestrator, as part of the close-loop automation system, to trigger appropriate remedial action. End-to-end monitoring is performed using virtual active probes and test management system.
- RAN monitoring: Usually the KPI value may be generated from the data collected on a large number of gNB within a RAN. While 5G NR deployment is very new and true 5G Slice services have not been deployed in the Industry yet, the project has started with a few experimental KPI values for the RAN bound to a specific slice. In the demonstration, Verizon OSS software generated a few KPI based on the above logic. Then the OSS component passes the simulated KPI toward Ericsson/CENX Service Assurance platform for correlation and corresponding action for service configuration modification via the Service Orchestrator. The KPI values are derived from the counters of 5G gNB management software. The Key Performance Indicators (KPI) may vary depending on the type of services.

- IMS/application monitoring: IMS/ application monitoring is used to provide in depth visibility into the performance of each individual service by collecting, correlating and analyzing the call data records (CDRs) associated with each service. By passively monitoring the entire set of CDRs, a complete history of the state of each service can be created and monitored for ensure performance is optimized and signaling issues identified and alerted immediately. Additionally, these records can be leveraged to determine root cause issues or understand more clearly how the customers are using a service and where the opportunities for improvement or upsell might be.

  IMS/ application monitoring is performed using virtual passive probes and analytics solutions.

4.4 Closed Loop Automation

Closed Loop automation is required for 5G Network Slicing SLA maintenance and it is a major Service Assurance function. Since the slice has multiple sub-slices for each domain, the performance data and metrics are collected for network connectivity, physical and virtual network function performance characteristics at different domains and the information are finally fed into a common analytics and assurance systems for end-to-end slice SLA mapping. If the SLA threshold values are not met, the intelligent service assurance system can send alarm or notification to the CRM or Service handling orchestrator for corrective action. At this point, based on the type of issue, the corrective action is taken by the SO and DO to adjust the resources in a specific domain where the problem might be originated from. The continuous monitoring and closed loop automation can maintain the SLA of an end-to-end slice.

4.5 B2B Charging and Billing

This chapter contains the end-to-end flows concerning product order, usage charging & rating and product deactivation. Each flow depicts the interactions between the different systems around Charging as well as Charging itself when used as BSS for Vodafone and NTT. Present is also interaction with blockchain to which Charging and Mediation is sending data records for the applicable events. The picture below depicts the product ordering flow of the medical product.

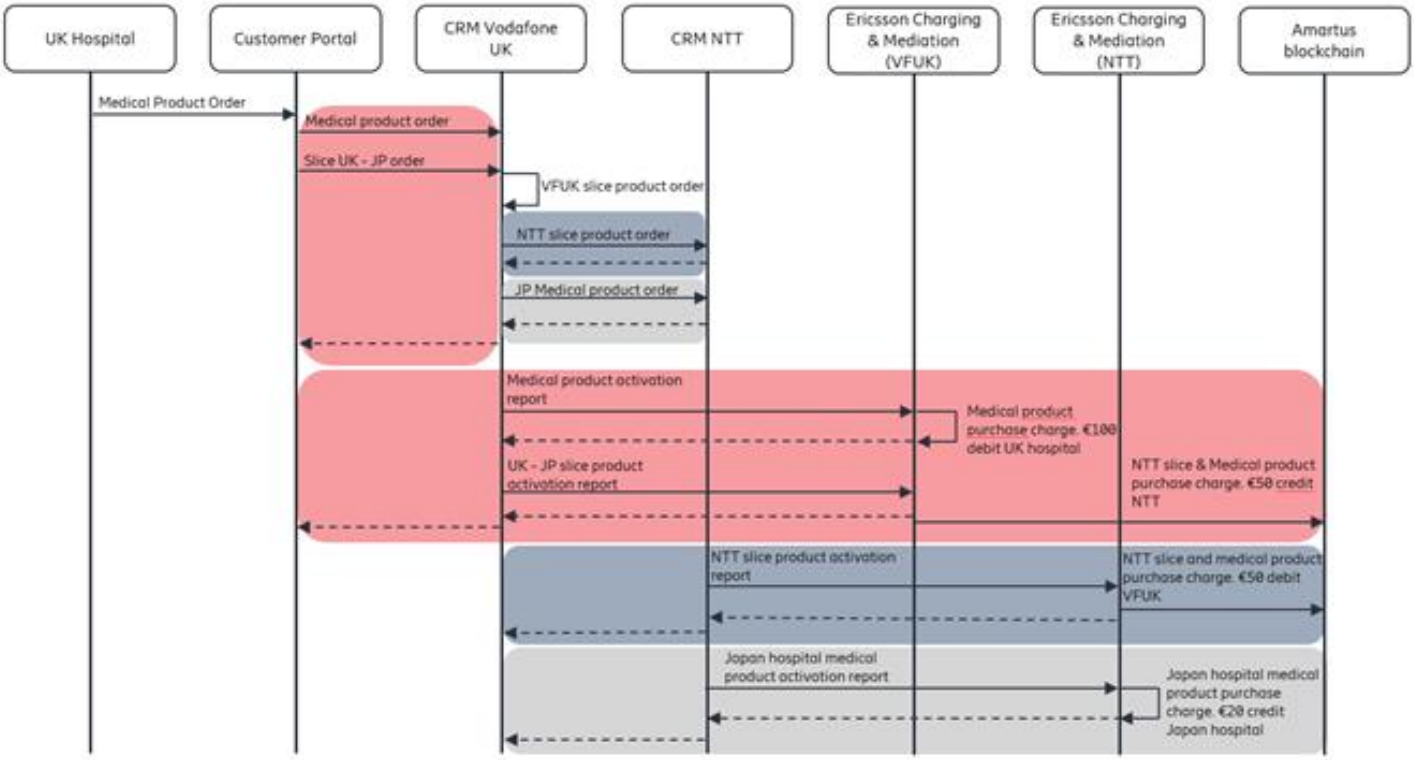


Figure 26 Product Ordering flow

The picture below depicts the applicable flow for usage charging and rating of the medical product.

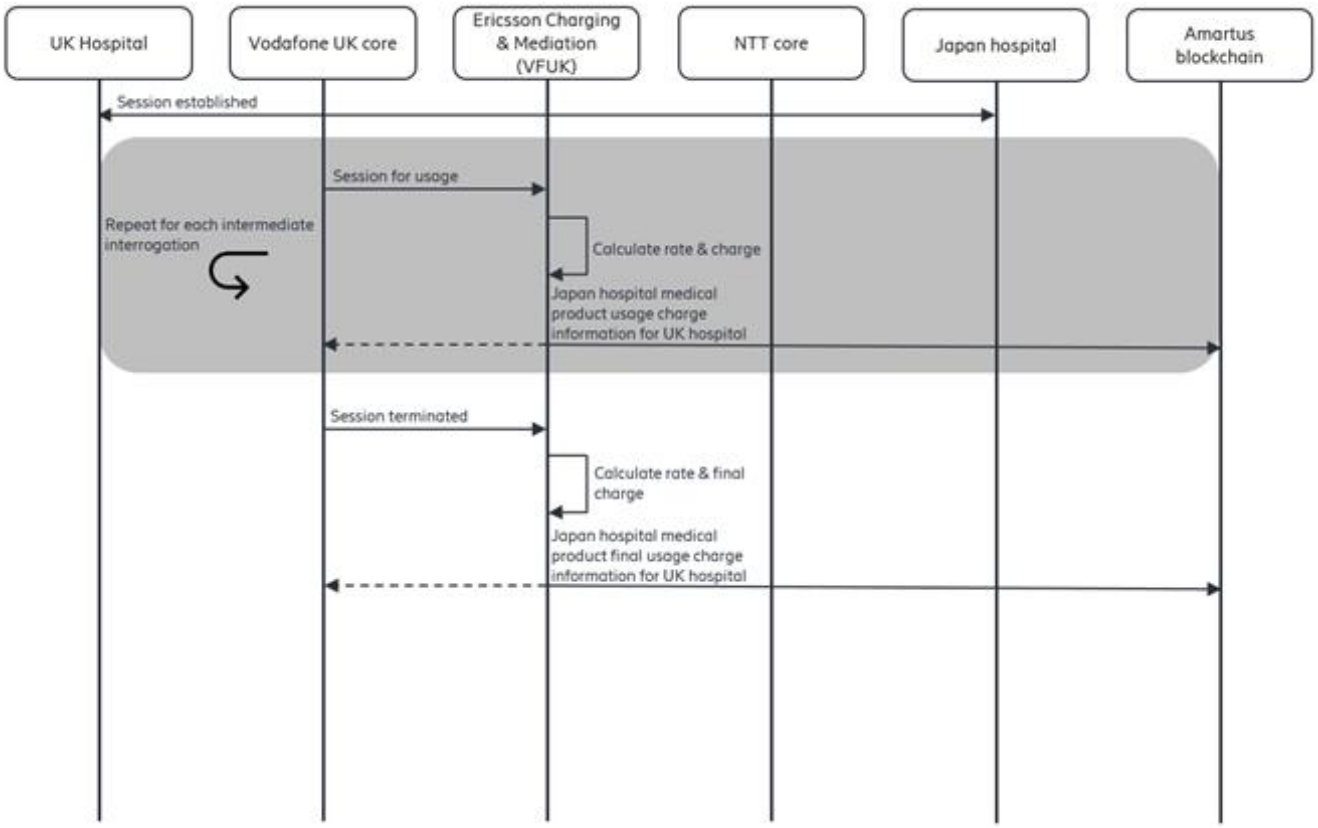


Figure 27 Usage Charging & Rating Flow

The picture below depicts the product deactivation flow of the medical product.

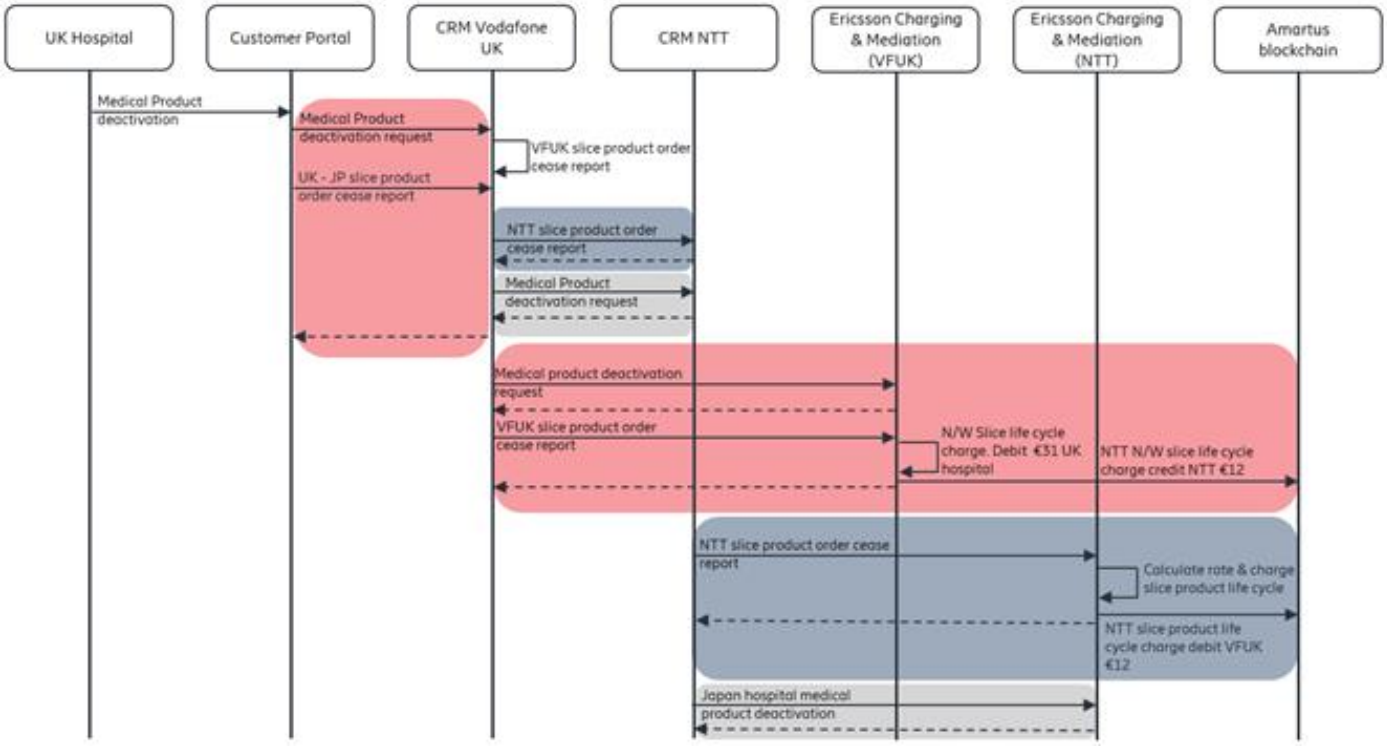


Figure 28 Product Deactivation Flow

4.6 PoC Demonstrations

While Skynet Catalyst team has debated on above use cases from holistic perspective, following specific scenarios are implemented for demonstration.

1. Order submission and Intercarrier slice activation (BSS) UK-JP
2. Operator slice activation flavors:
    a. Operator slice activation (OSS, **S**ervice **O**rchestrator - **D**omain **O**rchestrator): UK stack (TMF and ETSI)
    b. Operator slice activation (OSS, SO - DO): JP stack (TMF)
    c. Operator slice activation (OSS, SO - DO): FR stack (TMF and ONAP)
    d. Operator slice activation (OSS, SO - DO): IC stack (TMF, ETSI and ONAP)
3. Assurance
    a. Intra-Domain Service Assurance and Closed loop (UK-JP)
    b. E2E Inter-Carrier Service Assurance (UK-JP)
4. Charging and Intercarrier Settlement (UK-JP)

Skynet Catalyst team can be contacted for access to these demonstrations.

5 Technical Component Details

5.1.1 BearingPoint //Beyond Infonova

BearingPoint//Beyond's Infonova Digital Business Platform is a cloud native, multi-tenant platform with full BSS capabilities supporting multiple business partners on a single platform. The platform offers a full set of Open APIs enable interoperability and extensibility of the platform based on an event-driven, microservice based architecture. The multi-tenant capabilities were used to set up separate tenants for each operator representing the respective CRMs.

PRODUCT CATALOGUE

- Define products and bundles of services with flexible pricing options – including usage data pricing.
- Sell own and partners' services to customers with offers that are feature- and pricing-tailored to their needs.

CUSTOMER MANAGEMENT

- Consolidate all charges for all services on one single bill, with discounts applied, revenue shares and account transfers taken into account.
- Multi-currency, multi-language invoicing, automated financial transactions processing, collections and dunning.
- A complete inventory of customer products and services

ORDER MANAGEMENT

- Flexible, catalog- and business rule-driven order management spans the end-to-end capture to fulfillment of offer and service requests.
- Seamless service provisioning with automated order fulfillment processes spanning multiple services and service providers.

PARTNERS

- Define the settlement agreements for the reselling of services via other tenants, and manage relationships with business partners in the ecosystem
- Seamless orchestration and service provisioning of partner services
- Consolidated partner settlement billing and invoicing, independent of end customer invoicing and settlement

5.1.2 ONAP (Open Network Automation Platform)

ONAP will be used for network automation in France stack for both Service and Domain Orchestration. ONAP will be used for Domain Orchestration only in Ivory Coast Stack.
Orange stack is located in Orange's ONAP OpenLab with ONAP Casablanca release and Openstack. The VNFs are instantiated by ONAP on the Openstack VIM. It is key for Orange to enlarge the scope of ONAP because Orange is closely involved in this open source project and foresees ONAP as its future network automation platform.
ONAP Casablanca release has been leveraged for this catalyst. SDC, SO, AAI, SDNC, and ExtNBI are the key components in scope.
Support of TMF Open API is available in Casablanca: TMF 633 (Service Catalog), TMF 641 (Service Order) and TMF 638 (Service Inventory).
Interoperability between ONAP and other orchestrators in this catalyst (Ericsson and RIFT) is key to enable Intercarrier settlement and closed loop.

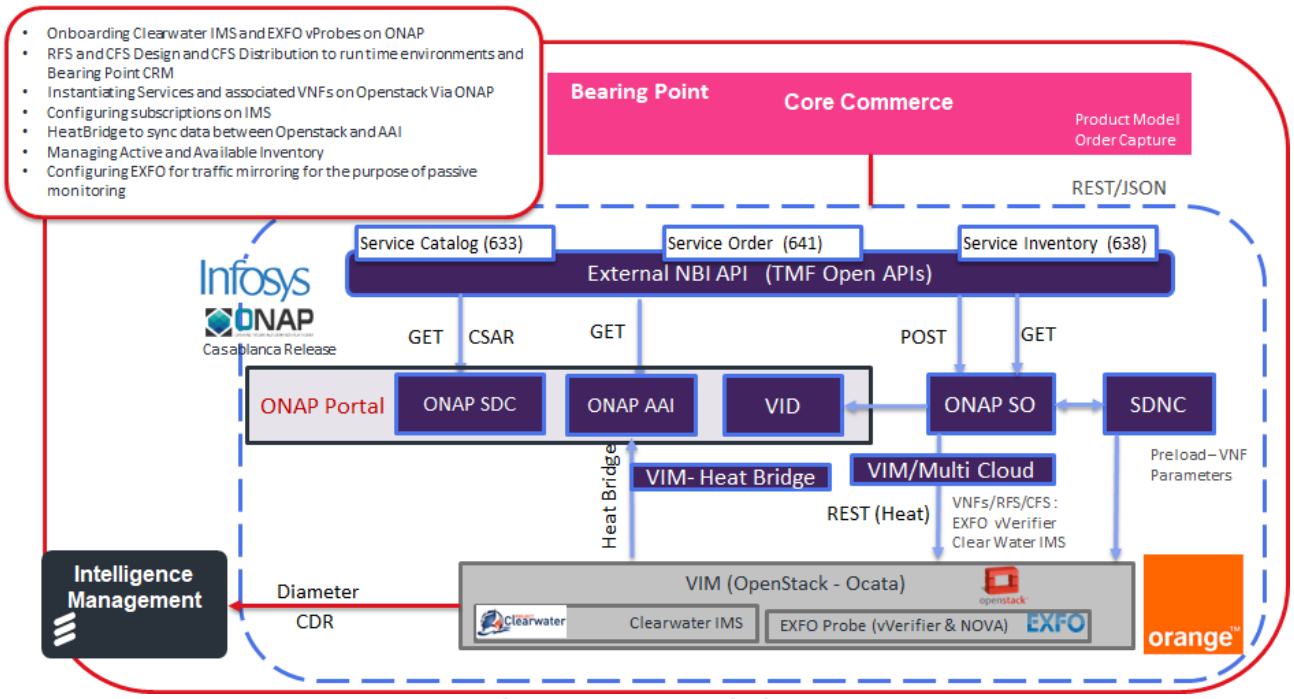


Figure 29 ONAP Solution

5.1.3 NTT DO

As the key of NTT Domain Orchestrator, we have been researching network resource management architecture that can provide flexible support for diverse types of networks.

This architecture incorporates configuration-management functions based on generic management targets (entities) as a mechanism for constructing the database necessary for network management. It also features an external mechanism for prescribing individual equipment and communications-protocol characteristics as a “specification” separate from the OSS program. This information can be prescribed together with inter-layer relationships in the vertical direction to enable integrated management in both the vertical and horizontal directions. In this way, a mechanism is achieved for changing the operation of the OSS program based on injected specifications and the relationships between those specifications.

This architecture makes it possible to build a network management database independent of any particular network. It also possesses extendibility enabling individual network characteristics to be appropriately expressed.

This technology enables a correspondence to be defined between SID logical resources used in this architecture as entities and individual pieces of network equipment used as network elements. The information expressed here as SID-logical-resource entities complies with Recommendation ITU-T G.800 (a compilation of uniform constructs (such as definitions and signals) for expressing the information transfer capability of a communications network), which means that transfer and coding functions for frame and packets in equipment for each type of communications protocol are treated as concepts that can be converted into data. Furthermore, to achieve a protocol stack based on the OSI Reference Model, SID logical resources are prescribed in such a way that the concept of information transfer capability can be defined in a recursive manner. This makes it possible to express inter-layer relationships in the vertical direction.

Among SID logical resources, the following three entities are typical of those adopted by this architecture: Termination Point Encapsulation (TPE: a termination point on a communications protocol layer), Network Forwarding Domain (NFD: the domain expressing the connection relationship between TPEs and enabling information transfer on each layer), and Forwarding Relationship Encapsulation (FRE: information-transfer path generated on NFD).

The management information necessary for managing multilayer communications protocols can be expressed by combining these generic entities in the following figure:

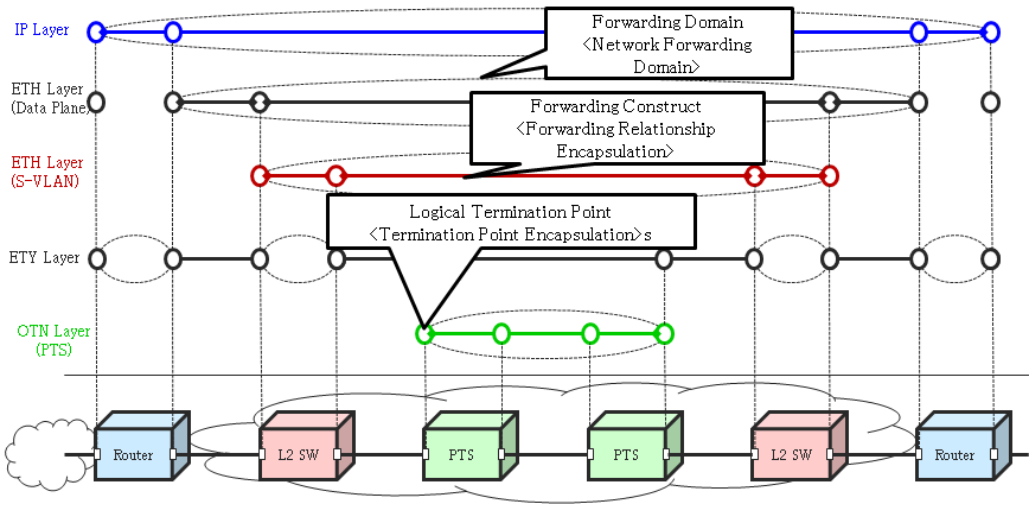


Figure 30 Multi-Layer Communication

This architecture includes a mechanism for adding characteristics of each communications protocol to the above generic entities and for storing protocol-specific information. The SID defines a Specification class that prescribes an entity specification and a SpecCharacteristic class that prescribes the attributes of that specification. It also defines a CharacteristicValue class with respect to a SID entity that prescribes attribute values expressing characteristics related to each protocol. In this architecture, using these Specification, SpecCharacteristic, and CharacteristicValue classes makes it possible to give common, generic entities characteristics that differ for each protocol in the following figure:

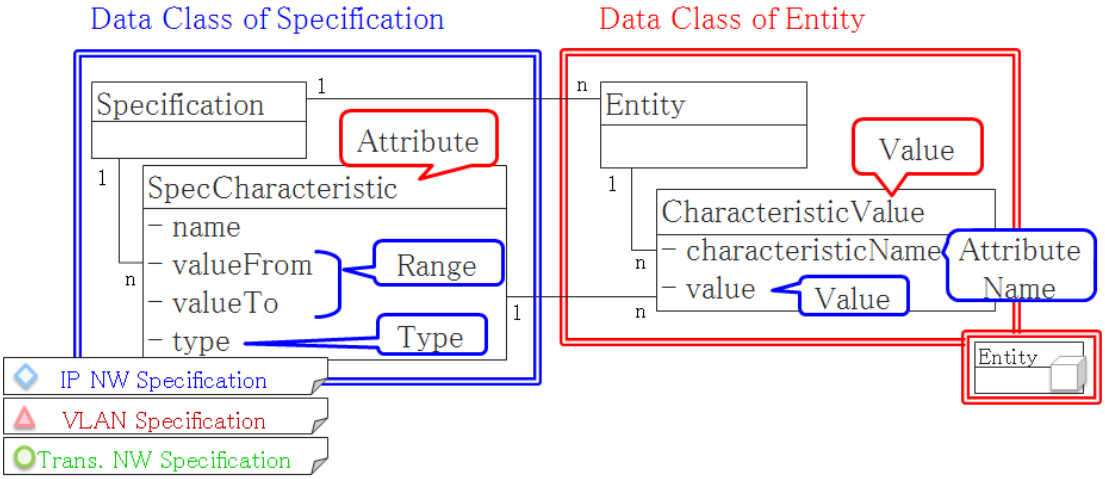


Figure 31 Specification Entity View

5.1.4 RIFT Service Orchestration

RIFT, Inc. supplies a next generation NFV Orchestration and Automation platform that delivers management, orchestration, and automation of virtual network services, applications, and functions with scale. RIFT's RIFT. Ware solution delivers management and orchestration (MANO) and automated operation of multi-vendor virtual network functions and services. RIFT.ware is a model-driven, multi-standard compliant NFV MANO solution that simplifies deployment of VNFs and the composition and management of complex network services.

RIFT.ware is fully compliant with and ETSI NFV Management and Orchestration specifications and uniquely supports all major orchestration standardization and open source efforts, including TM Forum, ONAP, ETSI NFV ISG, and ETSI Open Source MANO. RIFT.ware's unique capabilities include:

- **Model-driven** – RIFT.ware is a standards-based, model driven framework that supports multiple model formats such as ETSI NFV SOL001 TOSCA, ETSI Open Source MANO, and HEAT. RIFT.ware's unique translator layer allows suppliers and service providers to choose their preferred modeling language and migrate to the latest standards seamlessly
- **Designed for Networking** – Service provider workloads inherently rely on advanced networking services such as WAN connectivity, load balancing services, and VPN tunnels. RIFT.ware's network modeling capabilities are designed to simplify

deployment of complex networked services such as IMS, Network Slices, and other carrier services which rely on guaranteed connectivity and complex topologies

- **Open APIs and Modular Architecture** – Multi-language plugin architecture with well-defined industry standard interfaces offers integration with any 3rd party orchestration platform, analytics tool, Cloud Management Software, SDN platform, and Network Function. RIFT.ware provides a fully-automated, true, end-to-end multi-vendor environment for any application that can be ready for production in days, not weeks or months.
- **End-to-End Automation** – Enables zero touch Day 0, Day 1, and Day 2 operations from allocation of virtual infrastructure to closed control loop triggers to support full Life Cycle Management of network services from instantiate to scale, heal, and terminate, including configuration
- **Multi-cloud** – Validates and deploy VNFs and network service chains on any cloud management system and leverage the unique capabilities of the cloud environment.
- Intelligent Workload Placement with Enhanced Platform Awareness – Automatically and intelligently take advantage of unique network and cloud infrastructure capabilities to optimize utilization, cost, and performance.
- **Model-driven Visualization and Automation Tools** – The Visualization and Automation tools provide a simple and intuitive way to interact with the RIFT.ware platform. Composing a network service from selected VNFs and instantiating network services from the dashboard is as easy as browsing the catalog in an online app store, customizing its parameters for personalized service, and launching the service. Visualization and Automation also provides real time statistics for VNFs, network services, and a detailed view of compute and network topologies.

Through its technology RIFT simplifies deployment of VNFs and the composition and management of complex value-added Network Services.

5.1.5 Ericsson Orchestrator

Ericsson Orchestrator - In the context of ETSI NFV-Management and Orchestration (MANO), Ericsson Orchestrator plays the role of NFV Orchestration (NFVO) and End to End Network Service Orchestration (SO) in the Catalyst VF UK stack
End-to-End Orchestration - SO: To automate the instantiation and configuration of network slices in UK, including all intra-DC and inter-DC network services, across multiple domains and multi-vendor scenarios
NFVO - cloud manager: To handle the resource allocation in the VIM of the UPF, AMF and SMF network Functions.
Also, we have used the Element Management - E-VNFM component to provide VNF specific lifecycle management such as scaling and healing based on application specific knowledge for the network functions.
The Deployment starts from CRM (Bearing Point) and goes to SO, asks for deploying a network Slice, a 5G eMBB slice, the slice template is found in the SO catalog. The SO goes to inventory and tries to figure out what is already in the network. Based on that information, it creates a deployment scheme to the domain orchestrator component which then goes and deploy the individual VNFs (UPF, AMF, SMF) in a distributed environment, through SDN connects them to each other, establishes Virtual Links between Data Centers and connects them also to the surrounding environment.
As a next step, SO pushes down the configuration. Automating Day0 or Day 1 configuration, so it will go down to the element management system. If it is a simple VNF, it goes directly to the VNFs through YANG.

5.1.6 Ericsson Assurance (CENX)

With the continuous network virtualization, introduction of 5G including network slicing, automated management and end-to-end operations automation become even more imperative. CENX is Ericsson's service assurance product providing end-to-end service, network slice and network visualization and cross-domain, cross layer surveillance, performance monitoring and SLA assurance in virtualized and hybrid networks.

CENX provides topology visualization across multi-domain, multi-vendor, and inter-carrier networks and associated services. Alarms and performance indicators received from the various network functions both virtual and physical, cloud infrastructure and any other sources are mapped to the topology, correlated, root cause is determined and visualized in context of the topology. Closed loop action to correct the issue is triggered for appropriate alarms, performance degradations or SLA violations and notifications and or tickets can be also generated.

In this Catalyst, CENX builds a visualization of an eHealth Video Consultation service between a hospital in London and a hospital in France, which spans the Vodafone and Orange slices. As the service provider that owns the contract with the customer, Vodafone has the full end to end service assurance view. The detailed slice topology for Vodafone is ingested from the Ericsson Orchestrator and NFVO, while an abstracted representation of the Orange slice is received from the CRM and modelled. KPI's are ingested from

the network including VNF's, NFVI, and RAN (Verizon) and active and passive probes (EXFO) and mapped to the model across the various domains and down the layers. KPI's are monitored to determine if an SLA violation is about to be breached, triggering automated open loop actions such as ticketing towards Orange, or a closed loop action within Vodafone's slice

5.1.7 Ericsson Charging

Ericsson Charging provides customer, product management, and revenue management functionality for service providers to run a converged digital business. The scope and flexibility of Ericsson Charging help reduce the integration and maintenance effort needed in comparison to using different systems for different areas of the business. In the scope of TMF Skynet the Ericsson Charging presents a unified charging solution for each of the operators, meaning Vodafone UK and NTT Japan, separately
The following sub-chapters describe the main components of Ericsson Charging as seen in the architecture picture below:

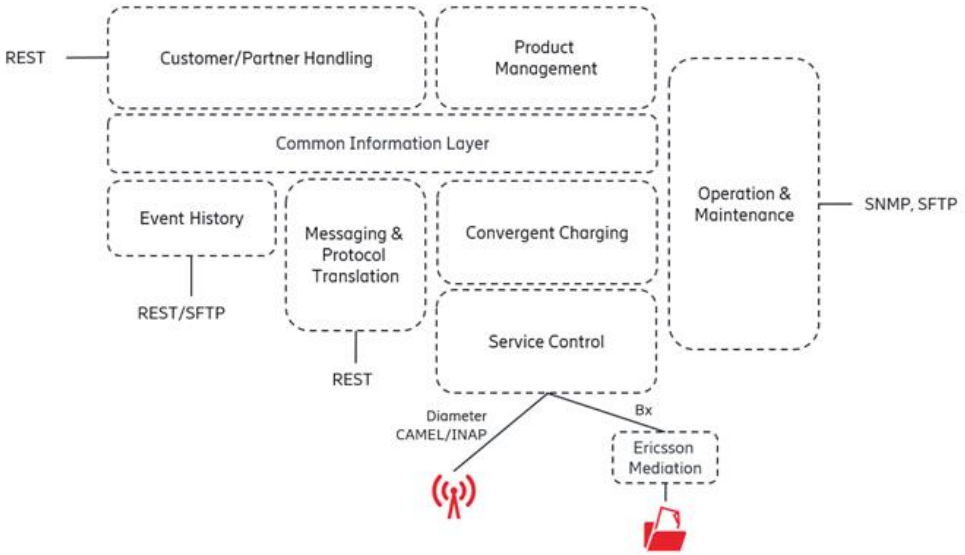


Figure 32 Ericsson Charging

Customer/Partner Handling
Customer/Partner Handling manages customer data for applications and provides information associated with customers. This component is responsible for storing the customer data and all the products that customer have purchased and the lifecycle of those products. It is Customer/Partner Handling that is storing the customers UK Hospital and Japan Hospital respectively.
Common Information Layer
Common Information Layer provides storage for both internal data of components and for common data, which is shared between components. This means that the data, such as the UK Hospital and Japan Hospital customers, is stored in the Common Information Layer. Common Information Layer is also used for long-term storage of any event generated in Ericsson Charging including the events generated by UK Hospital and Japan Hospital.
Product Management
Product Management provides the possibility to define and maintain entities, including resources, services, and products, and specify the behavior of rating in Ericsson Charging from a technical perspective. Product Management and the Product Catalog contained therein can also be synchronized with external catalogs. It is in Product Management that the products that the UK Hospital is utilizing are created. It is also this area that owns the products while, as described earlier, they are stored in the Common Information Layer.
Event History
Event History facilitates the management of customer-related events that are generated in Ericsson Charging. Event History collects and processes events from different components and expose events through multiple interfaces. It is Event History that is providing the generated events by UK Hospital and Japan Hospital to Ericsson Mediation for further processing in the Ericsson Charging TMF Skynet solution.
Service Control and Convergent Charging
The two areas Service Control and Convergent Charging executes business rules to determine charges and updates account balances accordingly. To be able to rate and charge different scenarios Convergent Charging executes rating rules and applies prices defined in the product offering. It is Service Control and Convergent Charging that is responsible for charging and rating the products used by UK Hospital in the TMF Skynet implementation.

5.1.8 Ericsson Mediation

Ericsson Mediation is used for the collection, processing and distribution of data records in the TMF Skynet implementation. Data records are received from Ericsson Charging then processed before being distributed to Amartus blockchain for further analysis of the data. Ericsson Mediation provides several tools to operators to define their own configuration as per their specific needs. These tools can be broadly divided into four broad categories, Collection, Processing, Distribution and Operations & Maintenance, as depicted in the picture below

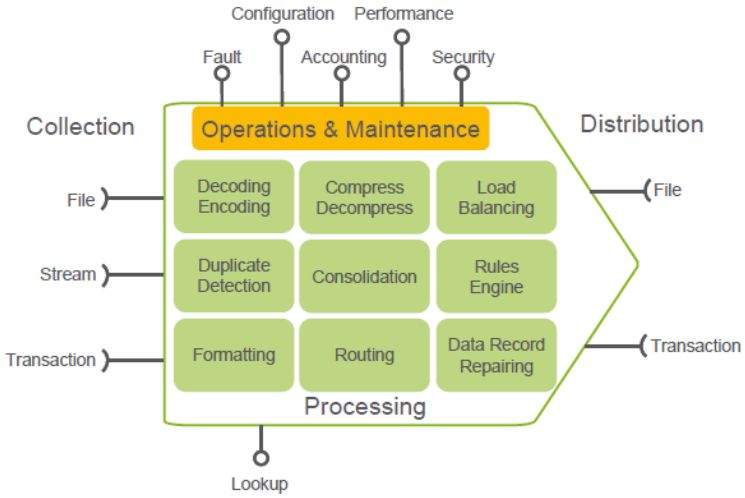


Figure 33 Ericsson Mediation

Collection

This category defines the Ericsson Mediation's capability to collect data from the network. Ericsson Mediation provides the support for multiple interfaces for data collection. The Collection interfaces can be further subdivided into three categories, File, Stream and Transaction.

Processing

This category describes the Ericsson Mediation's capabilities to process the collected data. Ericsson Mediation provides the support to decode/encode the collected data, to check the duplicate, to format the data as required, to compress/decompress the data, to consolidate the data, to route the data to the desired system, to integrate with rules engine, to repair the erroneous data, to balance load on the system and to perform external lookup for data enrichment. An operator can use these capabilities while creating a configuration and in turn can enrich, filter or translate the collected data.

Distribution

This category describes the Ericsson Mediation's capabilities to distribute the processed data to BSS and/or OSS domain. Toolbox supports file and transaction-based interfaces for distribution of the processed data.

Operation & Maintenance

This category describes the Operation and Maintenance of Ericsson Mediation. The O&M of Ericsson Mediation is divided into five parts, Fault Management, Configuration Management, Accounting Management, Performance Management and Security Management.

5.1.9 Amartus Blockchain

The current Intercarrier settlement and billing processes are isolated. Although high degree of automation is achieved in the own domains of the operators, the Intercarrier automation and settlement is to large extent manual. The fact that it is executed in isolation, limits the trust to the produced results when shared with partners. We can say that currently it is a labor-intensive process taking place in limited trust environment. That makes it expensive, error prone and slow.

We are in the new era of globalization and deep digitization and hyper-automation. It is a radical shift in how society will produce and consume goods and services. This very much applies to telecommunication wholesale sector which is expected to grow and which must meet the evolving customers' requirements.

Communications service providers who wish to remain competitive, stay relevant to their customers, and come first to market with innovation, should prioritize Autonomous Operation, minimize need for human, through applying logic operating by itself. Decentralized Ledger Technologies can in that sense improve their offering.

Amartus Intercarrier Settlement Platform aims for automating all the possible aspects on Intercarrier interactions: billing, reconciliation, dispute resolution and settlement.

Amartus is well aware of the operators' requirement for avoiding blockchain technology vendor lock in, and applied the selected IEEE standardization concepts both for the solution architecture as well as developed standardized Blockchain Project approach elaborated later in this document. The key principles of this approach are listed below:

- **open standards** – technical and business ways to solve some problems from certain domain, that are developed by standardization committees, associated companies or group of technology influencers and are publicly available, plus may contain process descriptions with various properties of how it was designed. Open standards expose also multiple intellectual property rights models which can be associated with them by any kind of individual as well as enterprise from micro through, small, medium and large corporations. Good example here is W3C (World Wide Web Consortium) which is ensuring that their specifications can be implemented on a royalty-free basis.
- **security** – key aspect in every application or platform spread across all layers.
- **technology agnostic** – ideally the solution which is going to be candidate for standardization should be easily switchable in case of technical frameworks, libraries and potentially platforms on which it was primarily built. In case of blockchain the full technology agnostic solution is almost impossible as we need to make decision at the initial step what kind of DLT Platform we're going to use and then we're tied by its services.
- **future proof** – in general, the term "future-proof" refers to the ability of something to continue to be of value into the distant future—that the item does not become obsolete. In case of telco domain, it can be easily explained as building systems which are flexible, scalable, adaptable and programmable to be able to react smoothly for communication technologies expansion.
- **interoperability** – in broadly speaking our standardized blockchain system interfaces should be completely understood, to work with other products or systems, at present or in the future, in either implementation or access, without any restrictions.
- **scalability** – solution should be easily adaptable to the increasing/decreasing number of users in order to ensure smooth and correct service within reasonable time outlined in its SLA.
- **modularity** – solution should be composed of loosely coupled, high cohesion modules where each of them is delivering some functionality and enabling access to it via service APIs – see microservice or OSGI.
- **manageability** – solution should be managed, controlled and monitored by specified engineering stuff and expose tools, APIs and GUIs to ensure this goal in an ergonomic way.
- **reliability** – solution should work in a reliable way for both aspects (customer handling and data processing) and in case of problems should be able to detect and identify faults that occur in the given system and basis on this make decision whether system is still able to work properly (without affected module) or require halt and instant service.
- **inclusivity** – when building the solution priority-setting strategy should be applied across partners in order to determine which of many items on an agenda should be undertaken first or how much of an available budget should be spent. In a shortcut it means – try to extract as much precise use cases solving your problems as possible and have an eye on the budget. Core customer functionalities should be pushed at the first stage, then during next iterations (depending on the budget spent) you can assess another functionality, its cost and effort to the system – not all at once, just tiny step-by-step but constantly grooving and … with success

Amartus solution is implemented according to layered architecture by IEEE which is illustrated below:

Figure 34 Amartus Blockchain Platform

A great example of Intercarrier Settlement Platform is the medical consultancy use case that is a part of Skynet. In order to provide a guaranteed quality of service, a 5G network slice needs to be ordered, provisioned and reconciled. Using Amartus Intercarrier Settlement Platform those processes could be automated to a level impossible before.

5.1.10 EXFO Active and Passive Probes

EXFO provides the active and passive monitoring solutions that underpin the performance of the Skynet solutions by providing real-time performance indications and SLA violation alerts to the service and domain orchestration systems.
The fully virtualized, active monitoring solutions provide end-to-end visibility into the performance of the network and the services carried within. End-to-end monitoring is implemented using both industry standard testing and monitoring solutions, such as RFC-5357 Two-way Active Monitoring and Test (TWAMP), ITU-T Y.1564 Ethernet service activation test methodology, as well as application layer testing, such as DNS response and Diameter testing. In all, the EXFO active monitoring solution support more than 150 test spanning layers 2-7. Active testing is provided using the EXFO virtual verifier (vVerifier), an ETSI compliant VNF, along with the EXFO WorX test management system. This solution has been on boarded into ONAP implementations as well as other vendor specific orchestration and management solutions.
EXFO's passive monitoring solution is also fully compliant with ETSI VNF standards. The solution collects and correlates call data records (CDRs) in the network and identifies erroneous signaling which would indicate call performance issues. By leveraging passive probing at key points in the network, the solution is able to construct a complete end-to-end view of the call signaling and report service and application level degradation northbound to the various other orchestration solutions involved in the end-to-end service. Passive monitoring is provided using the EXFO virtual probe (vProbe), the EXFO vHub and EXFO NOVA test management system. This solution is having also been on boarded into both ONAP as well as vendor specific orchestration and management solutions.

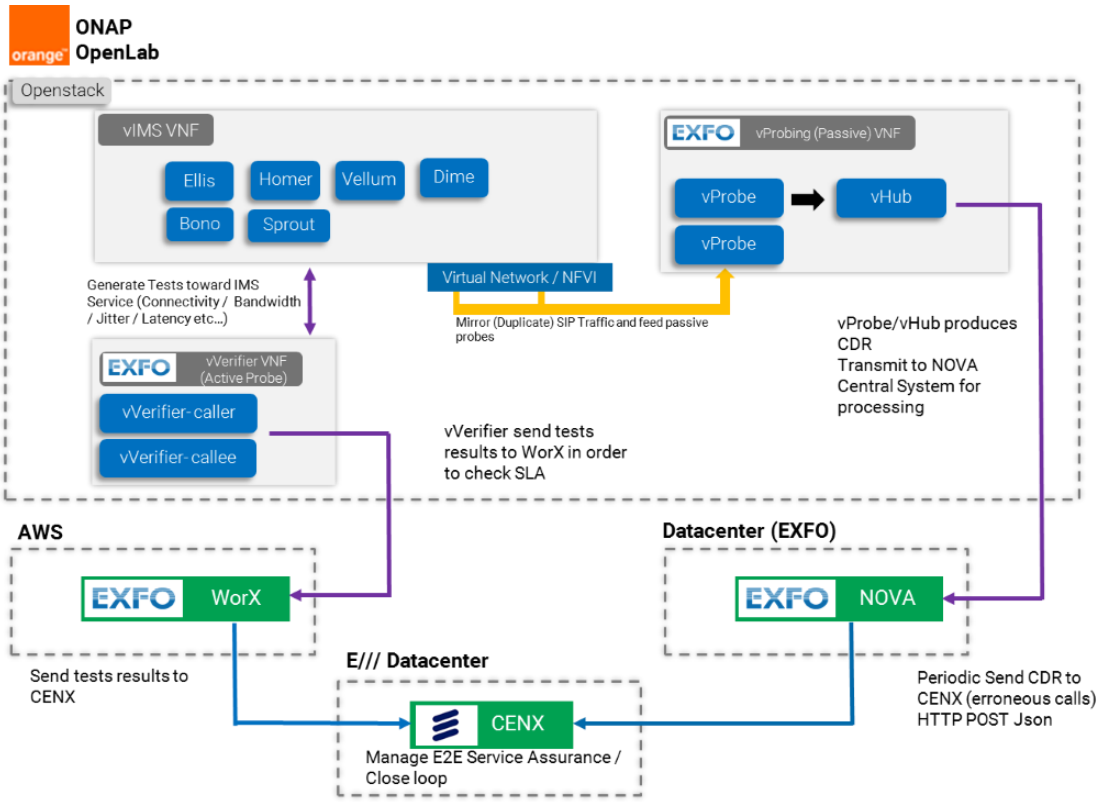


Figure 35 EXFO Powered Monitoring Solution

6 Information Model

6.1 Product Model

Even though 5G is a key component for providing the technical capabilities to solve the data and connectivity requirements for next-gen 5G-enabled use-cases, it does not solve the use-case alone. Only once you combine 5G connectivity technology and network slicing together with partner services and applications specific to the vertical solution, will the use-case be fully enabled. Therefore, CSPs will have to decide on their respective winning strategy such as building their own vertical or partnering with OTTs.
For the sake of the Skynet catalyst the product model has been designed under the assumption that the CSPs have built their own eHealth offerings by partnering with eHealth, medical and equipment providers. Therefore, to enable the provision of Remote Medical services via Skynet worldwide the involved CSPs have negotiated agreements to provide local connectivity and regional partner services under favorable conditions. TM Forum Information Framework aka SID is the fundamental paradigm for the product model enabling consistent modelling of products and offers across all involved operators and partners.
End customers that consume services via Skynet such as hospitals do so under an agreement between a countries' health ministry and the local Skynet partner CSP. The Product model is based on the assumption that all involved CSPs model CFS based on GSMA GST and expose the product specifications based on GSMA S-NEST or if required negotiated P-NEST to each other. Based on the use of GST assurance is not modelled as separate product offering but incorporated in the corresponding S-NEST or P-NEST and the RFS for network probes are linked to the slice CFS.
The premise of Skynet is a) that required slices are instantiated ad-hoc and terminated after completion of the medical procedure and b) offered as part of a bundle with the medical services that are enabled by the slice. Therefore, a) SIM subscriber slice access is always ordered with the slice and not modelled as a separate product offering and b) an end customer does not order a slice but a bundled product such as AR/VR based Virtual Diagnostics or Robotic Operation. Remote Medical Consultation is modelled as a separate Product Offering as it could by ordered standalone.

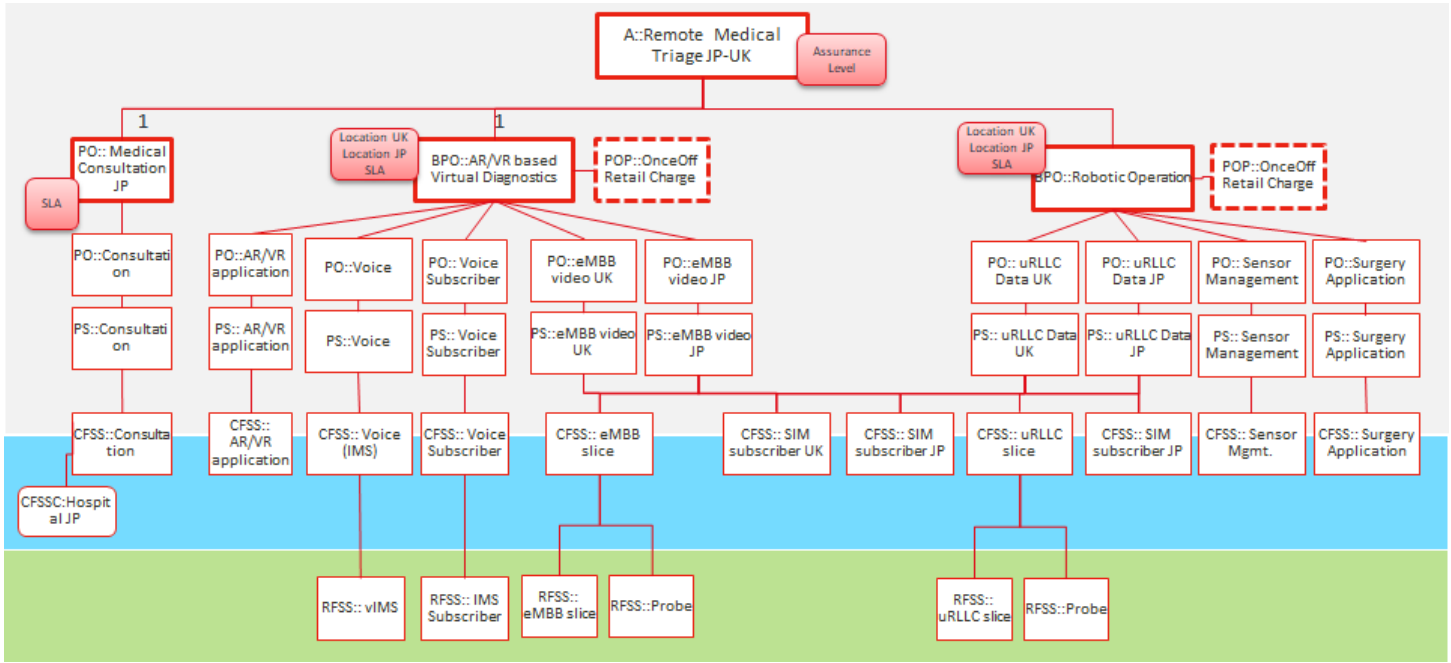


Figure 36 Health Care B2B Product Model

The same principles are applied to the Drone reconnaissance offering.

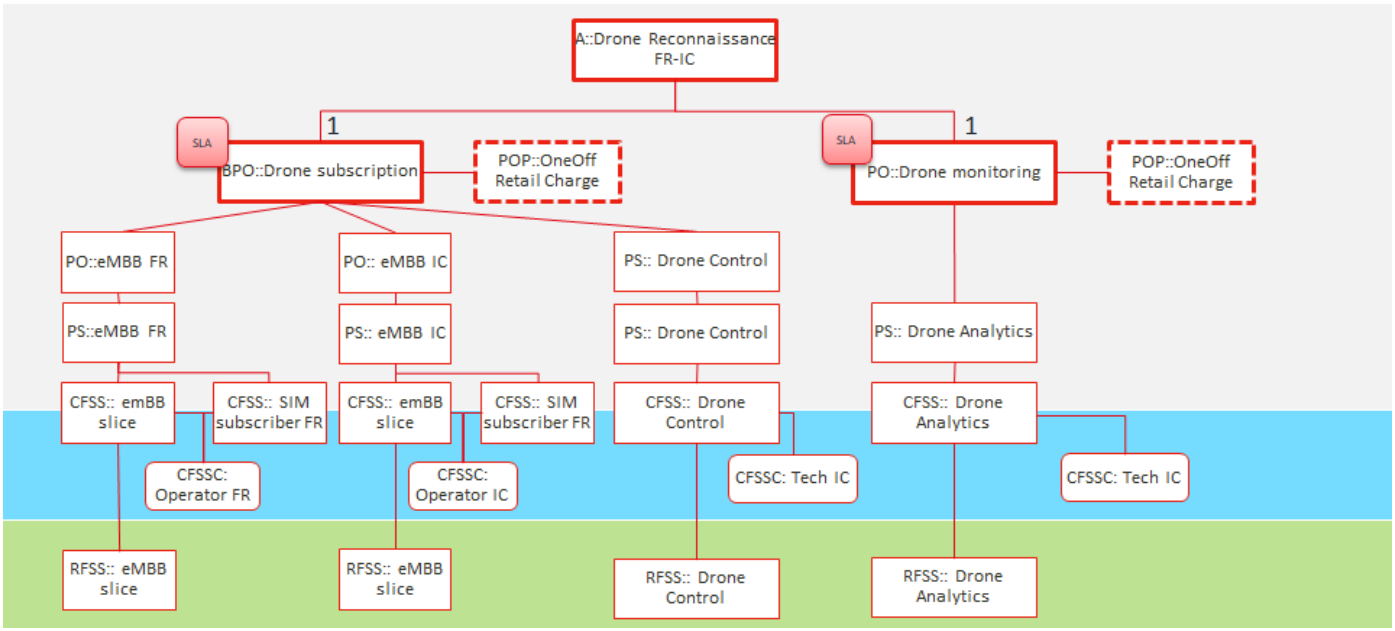


Figure 37 Drone Reconnaissance Offer

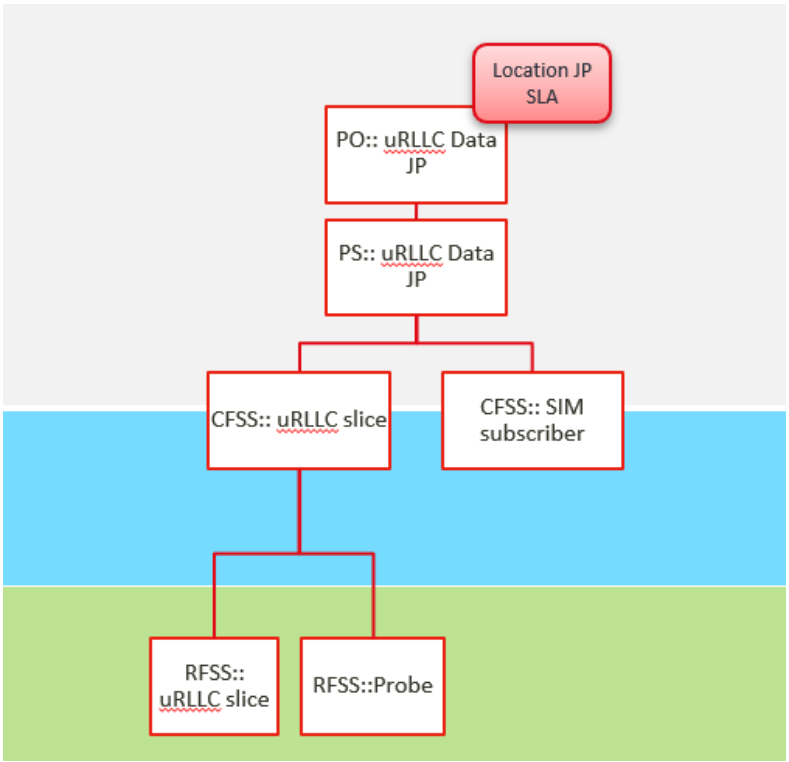


Figure 38 Wholesale Product Model

6.2 Charging Perspective of Product Model

Picture below depicts the Product Model implemented in Ericsson Charging for Vodafone UK BSS. Note that this picture also presents how the products are instantiated on the Customer.

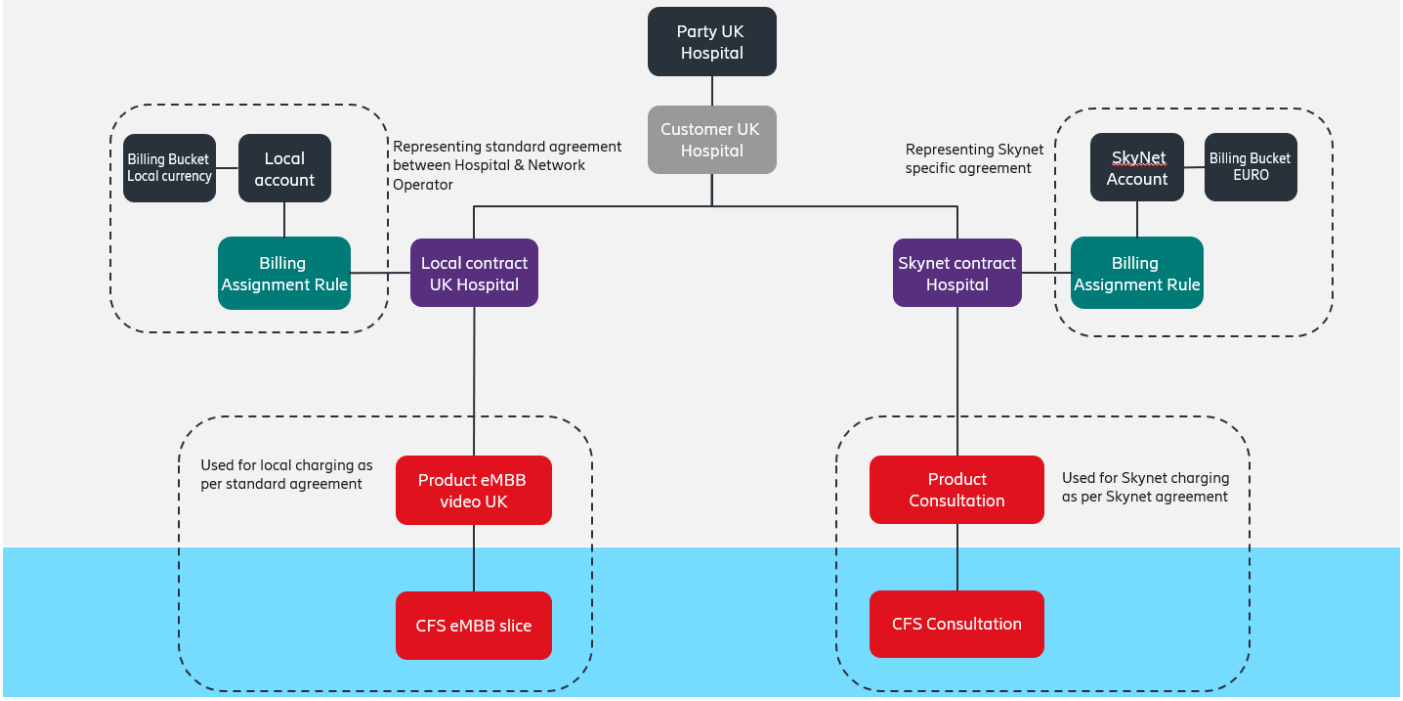


Figure 39 Product Model from Charging Perspective (UK)

Picture below depicts the product implementation in Ericsson Charging for NTT Japan BSS. This picture also includes the product instantiation on the Customer.

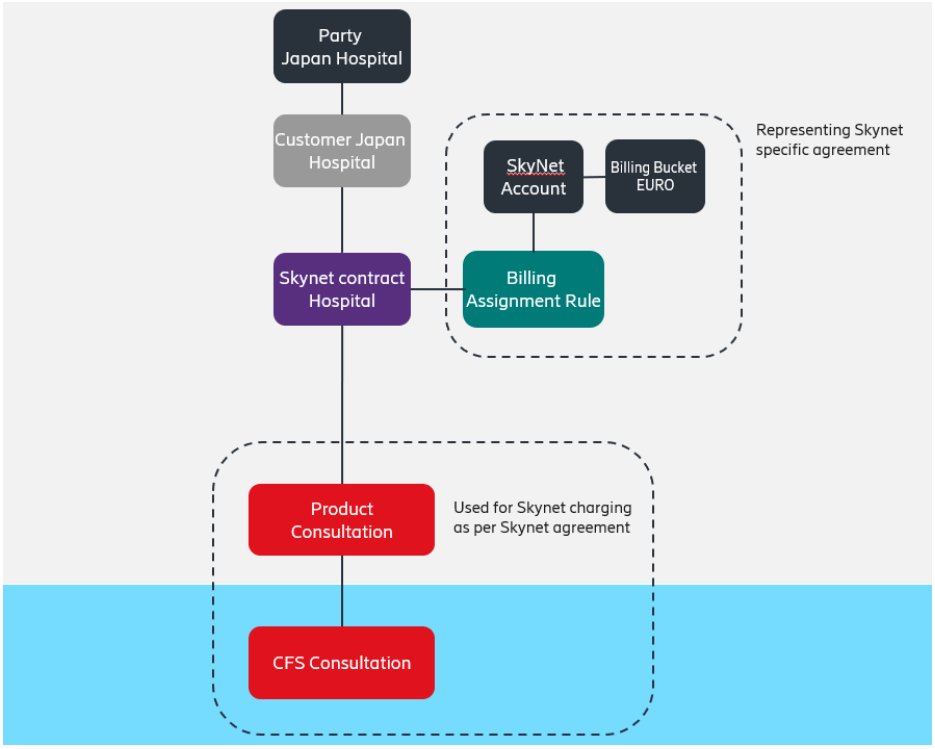


Figure 40 Product Model from Charging Perspective (Japan)

6.3 Service Model

We would like to express the way to describe NW Slice to realize the multi-service provider's connection in the aspect of Service/Resource. TOSCA provides the service/resource forms as the data model (not information model)
Different Product Specifications like "Robotic Surgery" or "Remote Diagnostics" could map to different CFSs. Learning from "5G Patisserie" catalyst- there could be a Generic Slice Template in CRM. This template could be used to create the definition of Service / NEST. This GST could have attributes like Latency, Upload Speed, Download Speed etc. These attributes could take different values for different types of network service (CFSs). These CFSs correspond to equivalent RFSs. These RFSs will correspond to the appropriate Service and VNF configurations.
For hybrid network Slice management, we should describe the network connectivity for network slice as shown in "GB999 ODA Production: User Guide for Network Slice Management"

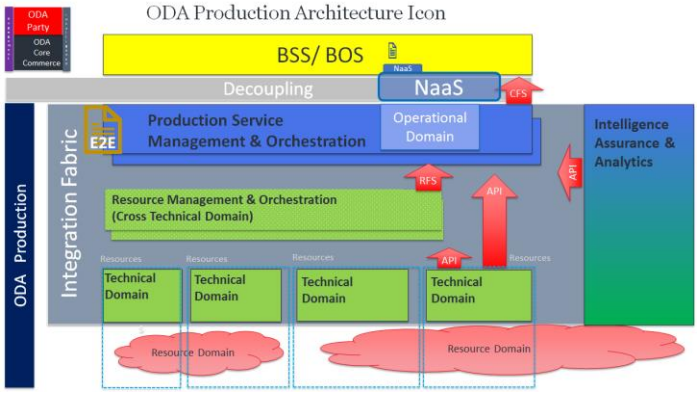


Figure 41 Federation Model

We propose the model federation in the service facing resource layer which is including ETSI NFV domain, SDN defined by ONF and Legacy network domain managed by traditional management systems. We can realize the life-cycle management for network slice using this federated model, especially point, link and domain entities as following figure:

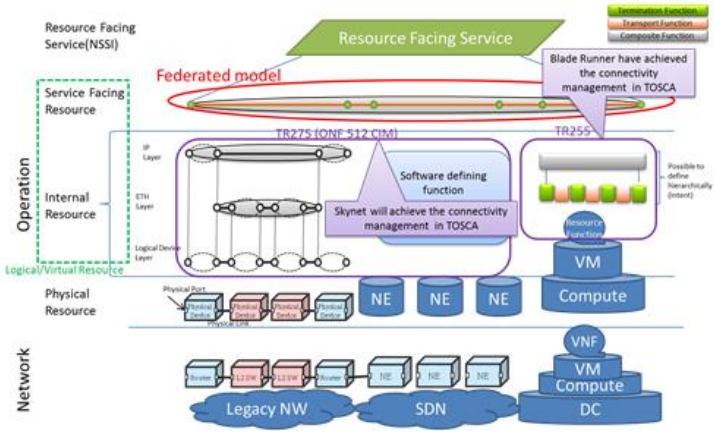


Figure 42 RFS View

RFS attributes should also align with what GSMA NEST defines. From the aspect of slice management, Infrastructure providers should manage the connectivity on the NW slice as described in GB999
In the context of the PoC, we have gone with "One to One mapping planned for PS:CFS:RFS". Each RFS could correspond to multiple Resources (VNFs)
Network Slice Concept for IMS Network
In case of IMS network for France Stack, DNS and Ellis nodes will be common across multiple slices. 3GPP TR 23.794 describes various possible options for how IMS network could be deployed for 5G Core. These options are still in discussion. For the purpose of this catalyst, we will have same onboarding configuration for different slices on IMS network.
TOSCA modeling
In Blade Runner Catalyst we described virtualized network service using TOSCA. In Skynet Catalyst, we have expanded TOSCA to enable non-virtual network description in order to realize hybrid network slice management. Multi-level TOSCA decryption is verified in this catalyst. High-level TOSCA could be decomposed into low-level TOSCA. For example, in JP stack, a 2 levels of TOSCA, CFS level TOSCA to specify slice properties and RFS level TOSCA to specify the resources that compose the slice. Then, this expression will be reflected to IG1176 TOSCA Guide for Model-Driven Automation in Open Digital Architecture Project.

7 Integration Architecture

Enterprise Portal is considered a channel towards customers and therefore, for the purpose of Skynet Catalyst we have adopted CANTATA /TMF 663 for Integration with CRM. Enterprise Portal is only a system of engagement and does not hold the catalog or COM capability.

Here is the integration interfaces view across UK and France

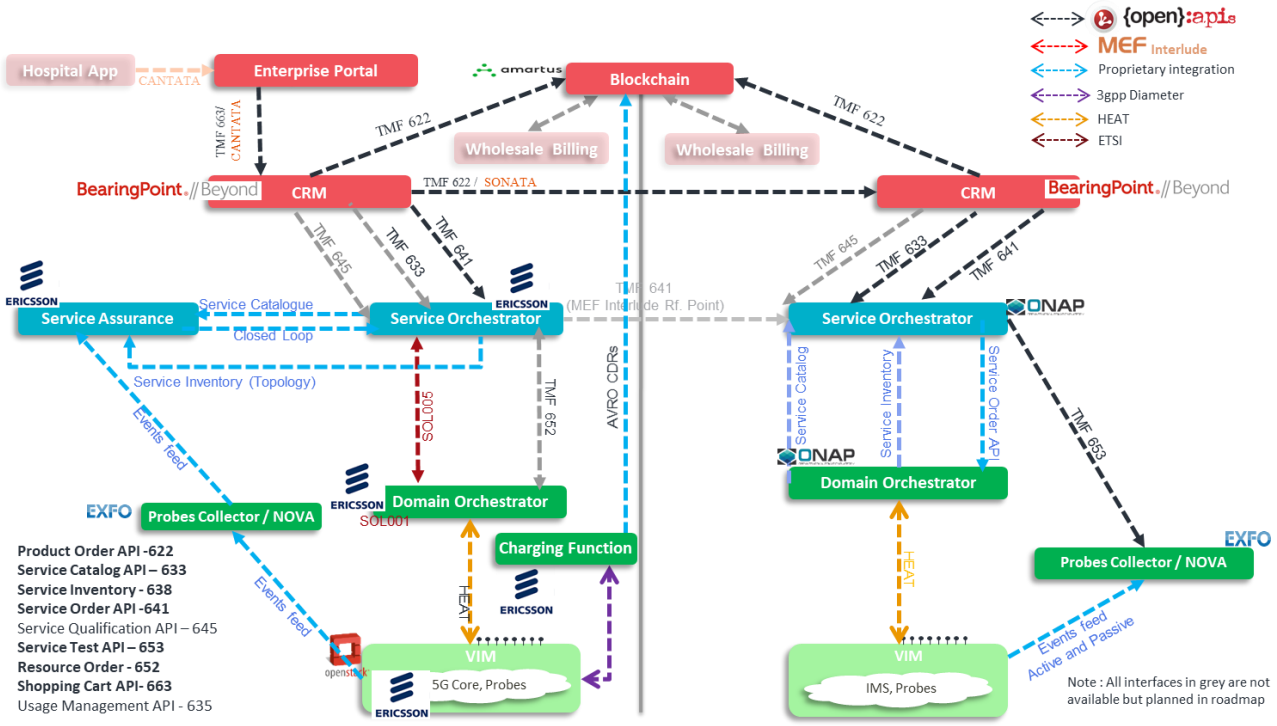


Figure 43 Integration Architecture (UK and France)

Here is the integration view across UK and Japan

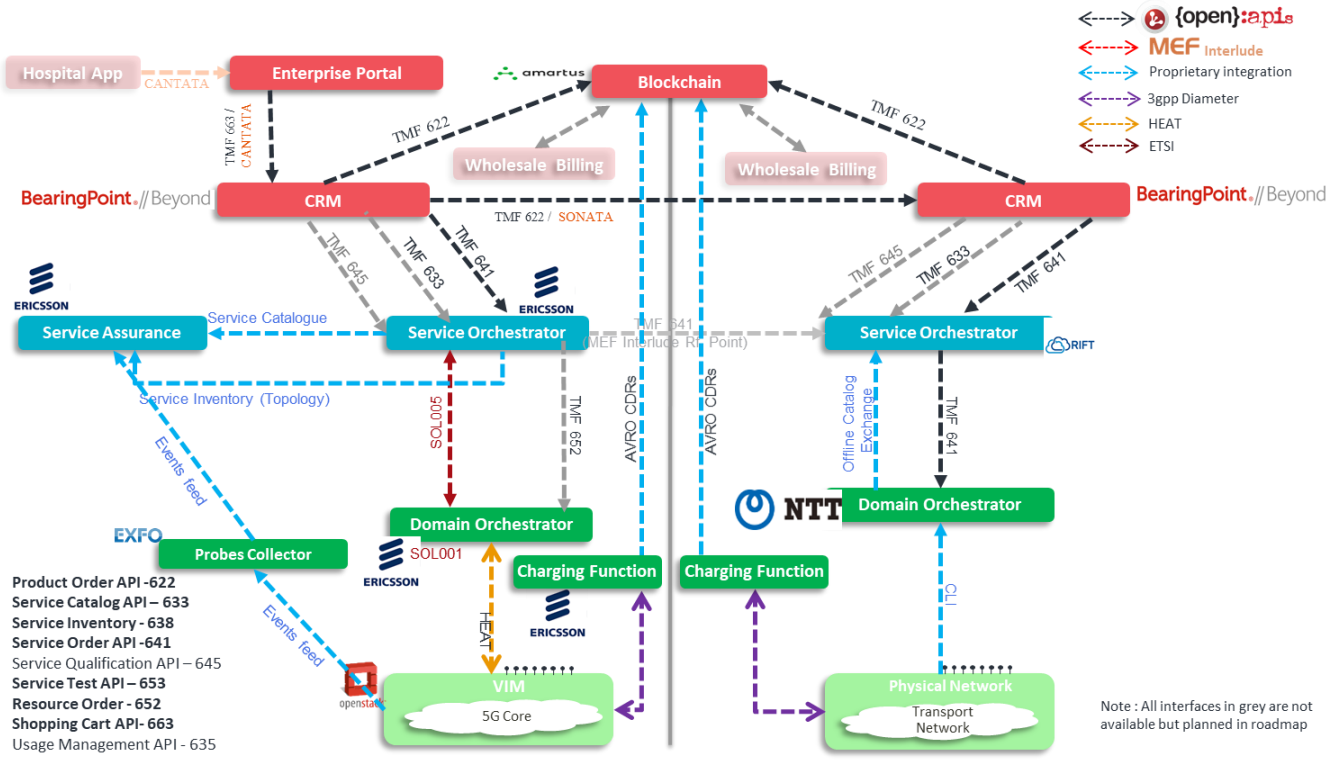


Figure 44 Integration Architecture (UK and Japan)

8 Network Slice Lifecycle

As described in 3GPP TR 28.801: “Study on management and orchestration of network slicing for next generation network”, the following phases describe the network slice lifecycle:

- Preparation phase
- Instantiation, Configuration and Activation phase
- Run-time phase
- Decommissioning phase

This is illustrated below:

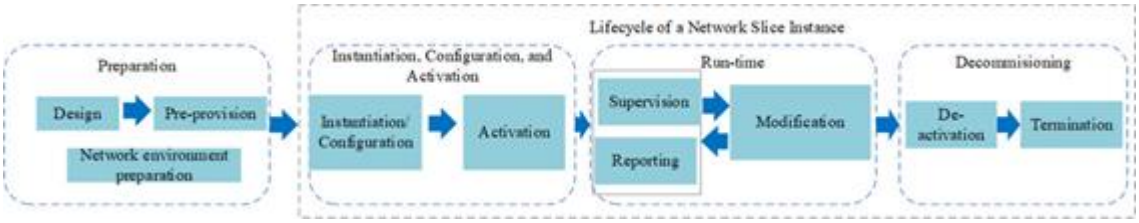


Figure 45 Network Slice Life Cycle

The meaning of network slice has two aspects: Service for BSS and network resource for OSS as described in IG1152.
In Skynet, Slice Design, Instantiation, Configuration, Supervision, Reporting, Modification have been implemented.

9 Network Service and Domain Orchestration

Since a 5G Network Slice can be composed of both Virtual Network Functions(VNF) and Physical Network Functions(PNF), orchestrating a slice requires selection of a set of VNFs and PNFs for a particular slice. The Service Provider may decide to pre-design a pool of slices for different service types, and allocate a slice to a service-request on demand and then recycle back to the pool. However dynamic slice creation when a slice service is ordered/requested may be performed as well. Thus in both cases, the set of VNFs and PNFs are bound to the network slice ID of the slice being created and goal of the orchestration software and onboarding of the VNFs would be to make it as efficient as possible and maintain the chain of network function information in the repository for subsequent retrieval of slice information.

Standardize the VNF vendor provided artifacts (VNF packages, VNF and NS descriptors)

Some of the key artifacts provided by Vendors during VNF software delivery are VNF Packages, VNF and NS descriptors (VNF deployment and configuration templates). In today's world, Vendor might provide the VNF packages in different formats with VNF artifacts in different structures and no standard way. ETSI is working on standardization of various NFV architecture components and ETSI have delivered the specification called SOL 004 for VNF package structure, file formats, etc. The recommendation is that service providers can ask the VNF vendors to be compliant with SOL 004 on their VNF software packages. So that Service provider NFV ecosystem can have validation engine to validate the VNF package standard compliance and accept / reject if VNF vendor package is not compliant to standard and this will avoid the automation failure on downstream orchestration tools.

Also VNF vendor will be delivering the VNF design, deployment templates as part of their delivery. Today, many of the VNF vendor might provide the design, deployments templates as heat scripts or proprietary scripts. For VNF and NS design & deployment templates (VNF and NS descriptors), ETSI have delivered the specification called SOL 001 (TOSCA based) and working on specification SOL 006 (YANG based). The recommendation is that service providers can ask the VNF vendors to be compliant with SOL 001 on their VNF and NS descriptors. So that Service provider NFV ecosystem can have validation engine to validate the descriptor compliance and accept / reject if VNF vendor provided descriptors is not compliant to standard and this will avoid the automation failure on downstream orchestration tools like SO and DO.

Majority of the VNF vendors provide the Specific VNFM tool to support LCM functions for their VNFs. For lifecycle management of those VNFs that come with a specific VNF manager (sVNFm), the integration is based on the SOL003 API.

Additionally, the service provider is recommended to a have a Generic VNFM tools conforming to ETSI SOL 003 specifications and ask VNF Vendor to meet the Generic VNFM capability based on ETSI SOL 003 specifications.

Use standard compliant Orchestration tools

As stated above, service provider's VNF onboarding & orchestration environment might have different Orchestration tools (SOs, NFVOs and VNFMs) and these may be from different vendor or different open source tools and they might not be interoperable with other orchestration tools in the ecosystem. So service provider is recommended to use standard compliant (TMF, ETSI, ONAP, MEF LSO) orchestration applications and these tools needs to be compliant to a subset of the following API, providing the required functionality:

- TMF Open API 641 for Service Ordering
- TMF Open API 633 for Service Catalog Management
- TMF Open API 638 for Service Inventory
- TMF Open API 645 for Service Qualification Management
- TMF Open API 652 for Resource Ordering
- TMF Open API 653 for Service Test Management
- ETSI SOL 005 for virtual Network Service Life cycle operations
- SOL 004 and SOL 001 for VNF package and descriptors
- SOL 003 for VNF Lifecycle Management

When required by the deployment environment different combination of them, based on the application capabilities can be used (e.g. northbound TMF and southbound ETSI).

9.1 Inter Carrier Network Slice Models

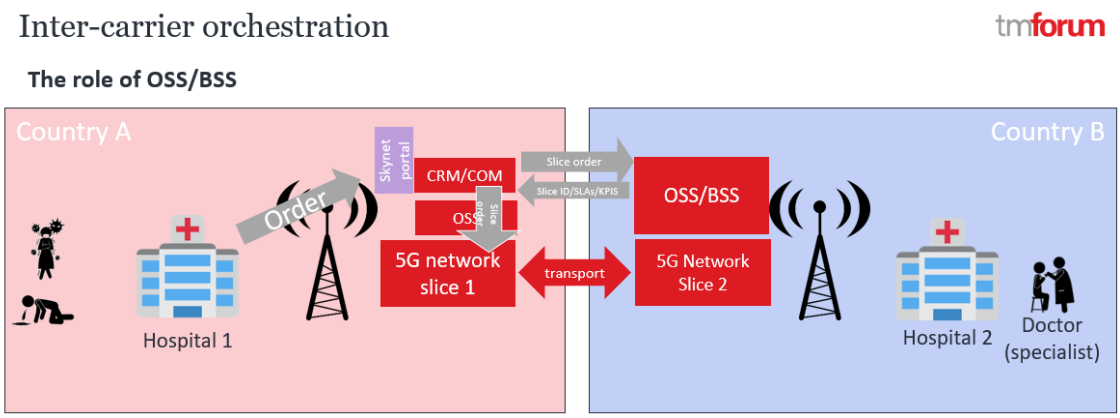


Figure 46 High Level Network Slice Model

Skynet portal in country A will execute the order capture and send the order to CRM (Cantata).
The CRM/COM elements will split the order in local and external components to orchestrate the on-demand e2E network slice creation.
The local order will be sent to the OSS as a Service Order (TMF641) (with reference to the proper S-NEST template parameters, identifying the need, low latency, high throughput, etc.)
The external component request will be sent to the partner operator as a Product Order (Sonata).
There can be other external orders enabling OTTs and Transport.
The local Service Provider as the accountable owner of the contract with the requesting hospital 1 will maintain full visibility on status and performances (as per shared SLA/KPIs and charging/settlement aspects) of the end to end network slice from hospital 1 to hospital 2.
Below picture describes the Network Slice in one of the countries

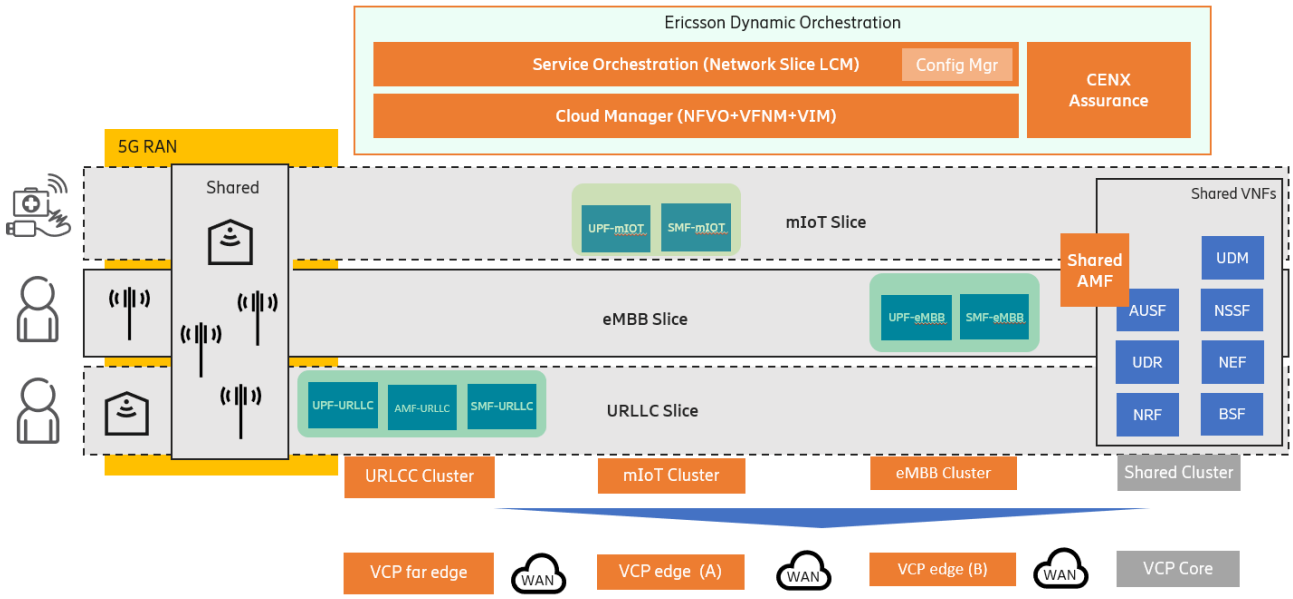


Figure 47 Network Slice Construct for Different Slice Types

In the case of the demo, the eMBB slice was instantiated with UPF and SMF as dedicated VNFs and AMF as Shared.
In addition to that, there was a network function (EXFO vVerifier) instantiated for the purpose of assurance, but that is not shown in the above picture.
When Network Service slice is created, it is a first time tested and after that E2E monitoring activated as described in the "**Remote Health Care Order Capture and E2E Orchestration**" and "**Assurance**" sections.

10 Inter-Carrier and Intra-Domain Network Slice Service Assurance

Service assurance of a network slice and especially an inter-carrier network slice is essential to ensure that the services riding over the slice can provide the SLA contracted with the end customer. A service assurance platform such as Ericsson's CENX Service Assurance will provide a function that collects and transforms relevant data including service and slice topology, performance and alarm data. The data is analyzed and correlated to detect when the slice is no longer performing as intended and can then trigger a policy manager (Apex) to initiate either open loop actions (automated ticketing), or closed loop actions to scale or heal the slice. The figure below depicts assurance within a slice (intra-domain).

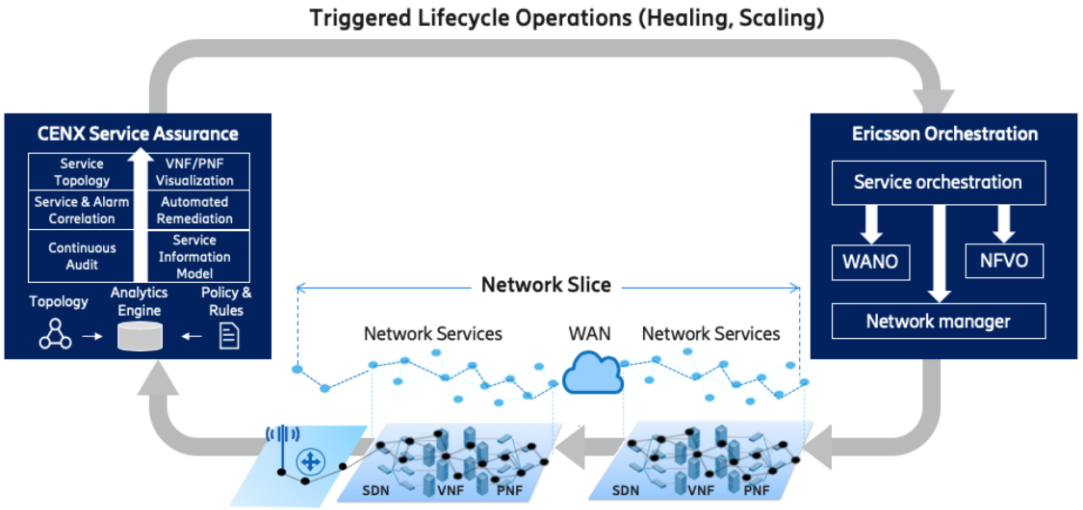


Figure 48 Intra Domain Closed Loop

When a service spans across multiple operators as demonstrated in this Catalyst, additional integrations are created to allow operators to pass SLA parameters and performance KPI's amongst each other as depicted below.

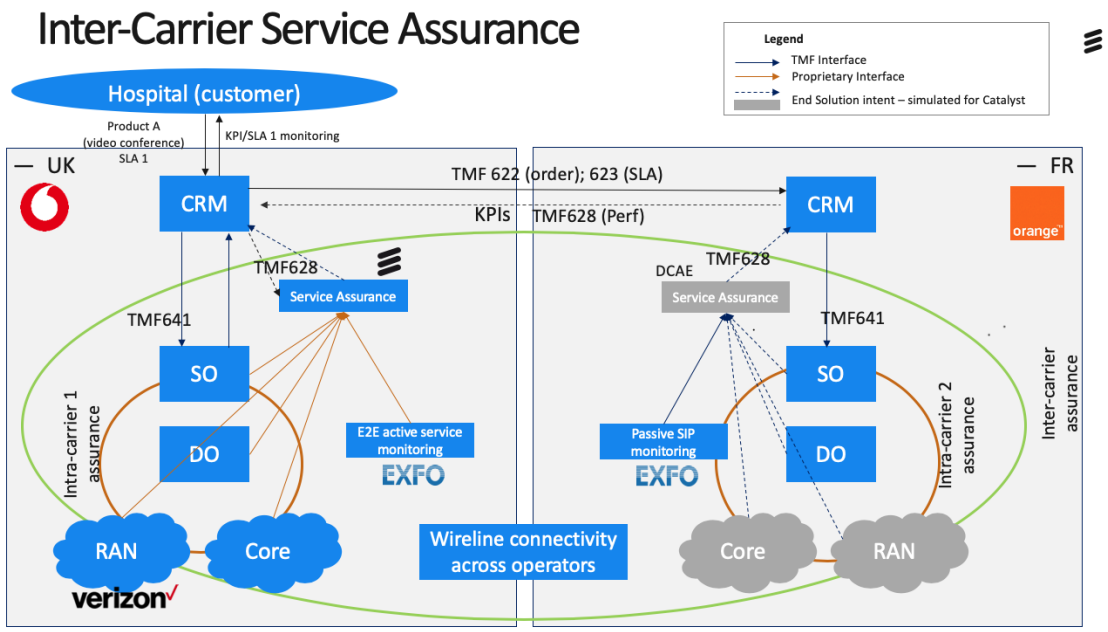


Figure 49 Inter Carrier Service Assurance

The key service assurance concepts demonstrated in this Catalyst include:

- building a topology model inside the service assurance platform that represents the network slices and services riding over those slices. This model is multi-domain (across multiple operators) and multi-layer (service, slice, RAN, VNF, and NFVI)
- instrumenting the network slice and service with active and passive probes (EXFO) to provide Key Performance Indicators (KPIs) to monitor the health of the slices and e2e service

- collection of other relevant KPI data in the network from VNF's and NFVi's (per VNF, VM's, hosts), slice (Vodafone and Orange), and sub-slice domains - RAN (Verizon), backhaul, and transport
- correlation of the collected data to the model - the collection process includes a transformation step that will allow the data to be correlated to the entities in the model
- analysis and thresholding - KPI's are analyzed over time to detect threshold crossings and other non-performant behaviors - in the future this will include machine learning and AI to detect anomalies and predict issues before they happen; generating alerts within the service assurance platform when non-conformance is detected
- classification of the issue by domain, layer, and entity; determination of impact -
- alert augmentation and forwarding to trigger open and closed loop actions - alerts can be augmented with topology information (affected entity, affected slice(s) and service count, etc.) - the augmented alert provides greater insight for a policy engine to make informed decisions on the best corrective action

Model Creation within the Service Assurance Platform

Topology data from the Service Orchestrator and Domain Orchestrator allows the service assurance platform to build a comprehensive model of the entities that are used to create a network service and slice. Additional information from the CRM system can add customer service level information, enriching the model. The model forms the basis for performing correlation of events and allows the service assurance platform to relate a singular fault to its impact beyond the directly alarmed entity. The model can also be explored visually, allowing network operators to understand what VNF's/VMs/hosts/slices/services exist in the network and how they are related.

The service from the viewpoint of the end customer - the ehealth service purchased here is an Extended Medical Consulting Video service:

Figure 50 Model Creation

This customer service is implemented as an inter-carrier slice between two operators.

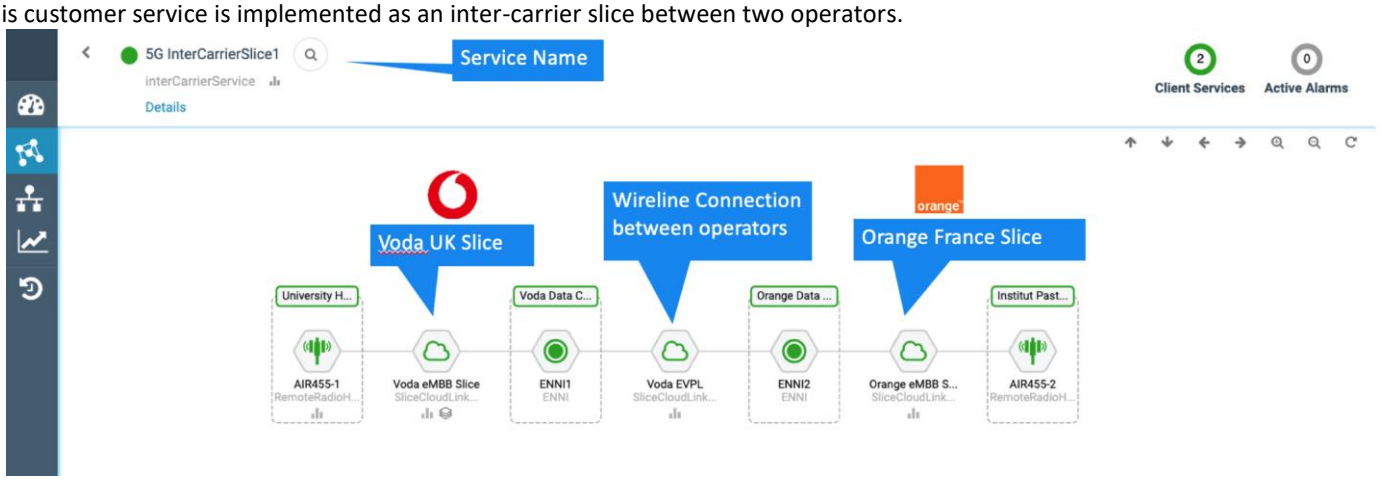


Figure 51 Slice Representation in Assurance Platform

This ability to visualize the model extends across domains and down through the layers. From the above visualization, Vodafone can drill into their own network slice and see that the slice consists of RAN, backhaul, and core VNF's.

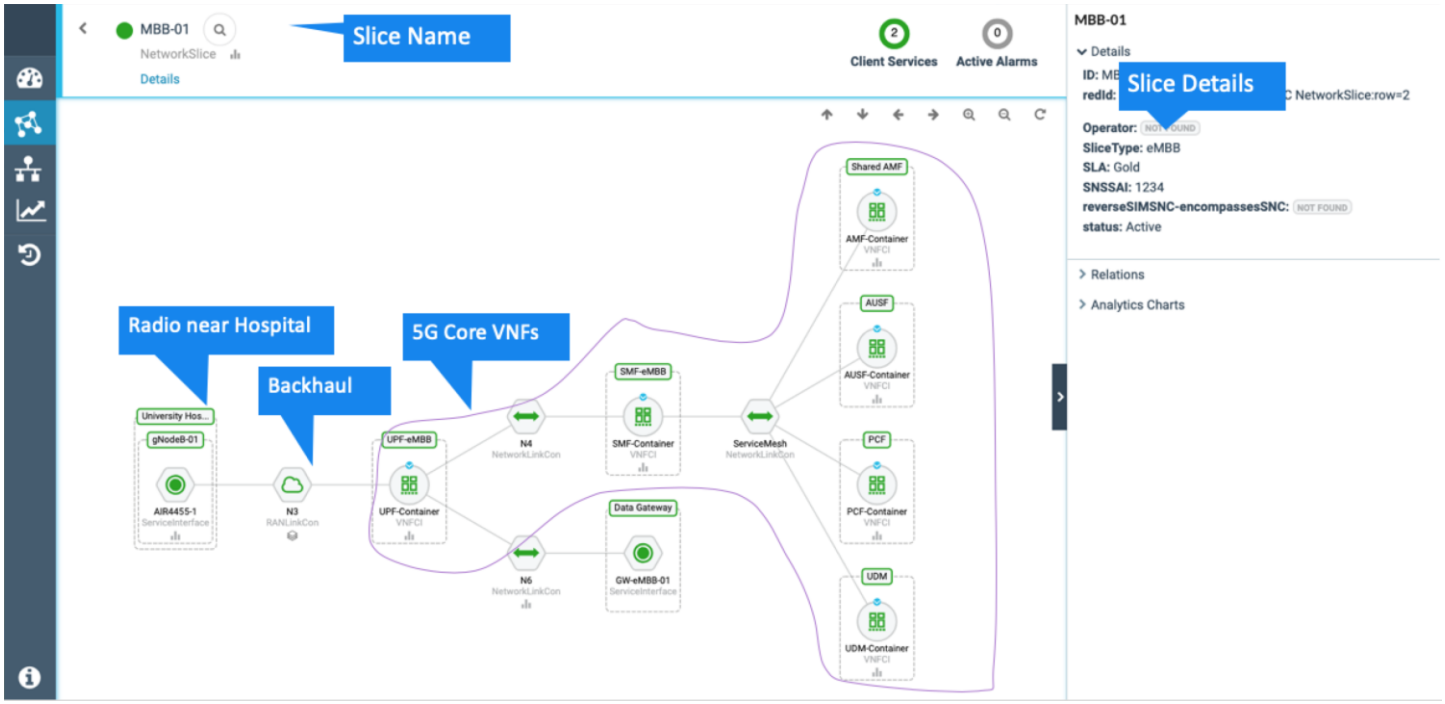


Figure 52 Slice Details from Assurance Platform

Continuing to drill down, each VNF is made up of one or more micro-services running on containers that in turn are running on virtual machines.

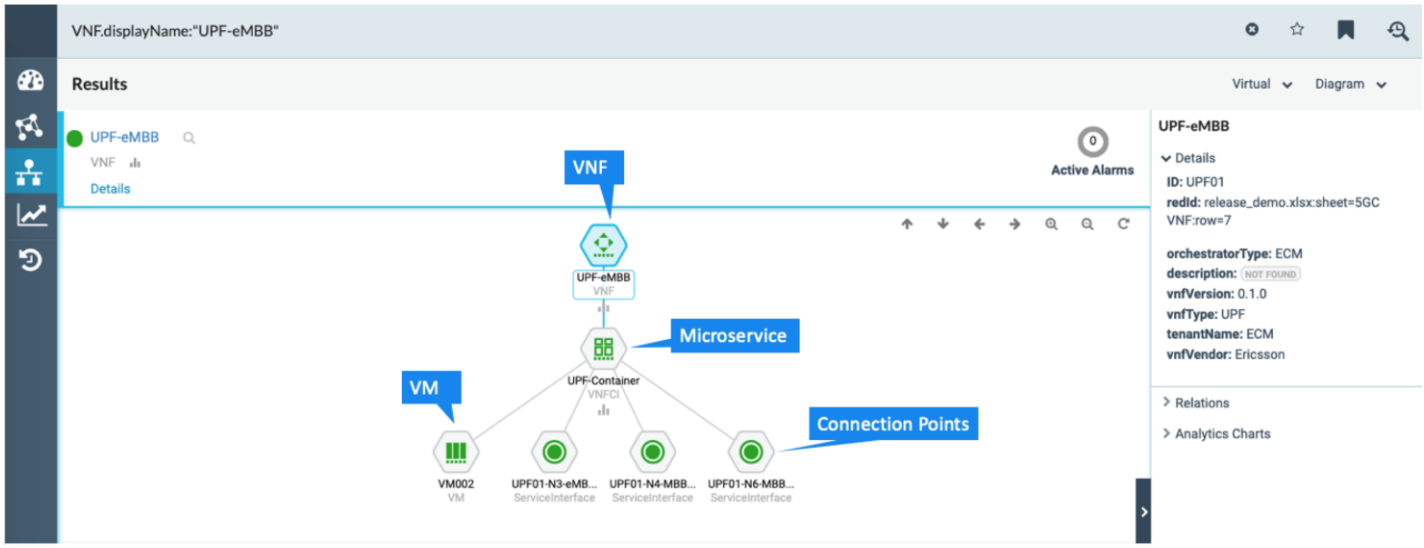


Figure 53 Drill Down View of VNF Constituents

Data Collection and Correlation to the Model

Data from virtually instantiated probes (both passive and active) and data generated by the network functions and NFVi elements are collected and stored in a repository within the service assurance platform. Various methods can be used to collect the data either in batch mode or streamed via a bus (Kafka, DMAAP). Once the data has been stored it is visible in the service visualization and will also be used by the analytics engine to detect issues. Having granular metrics per domain greatly enhances the ability for the service assurance platform to identify issues in specific domains of the service.

Figure 54 Per Domain (Slice) KPIs

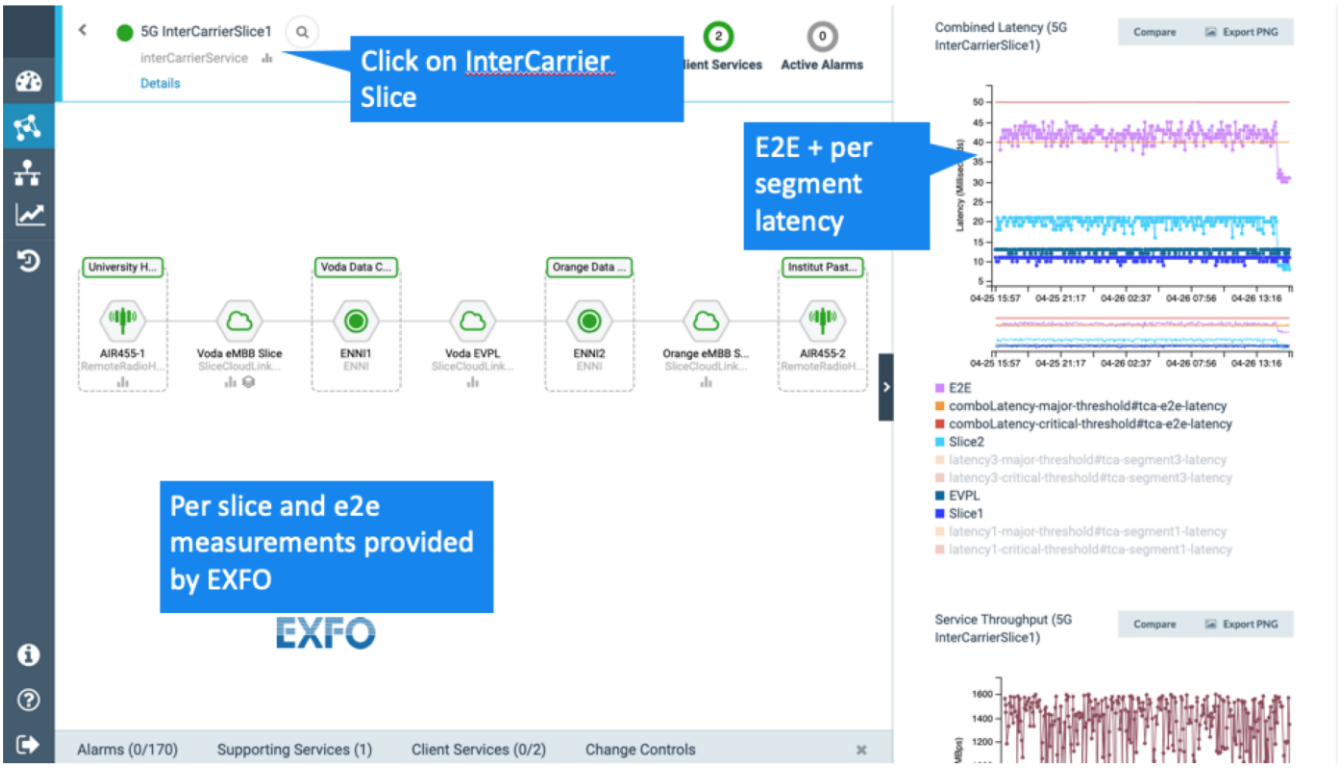


Figure 55 End to End Service KPIs

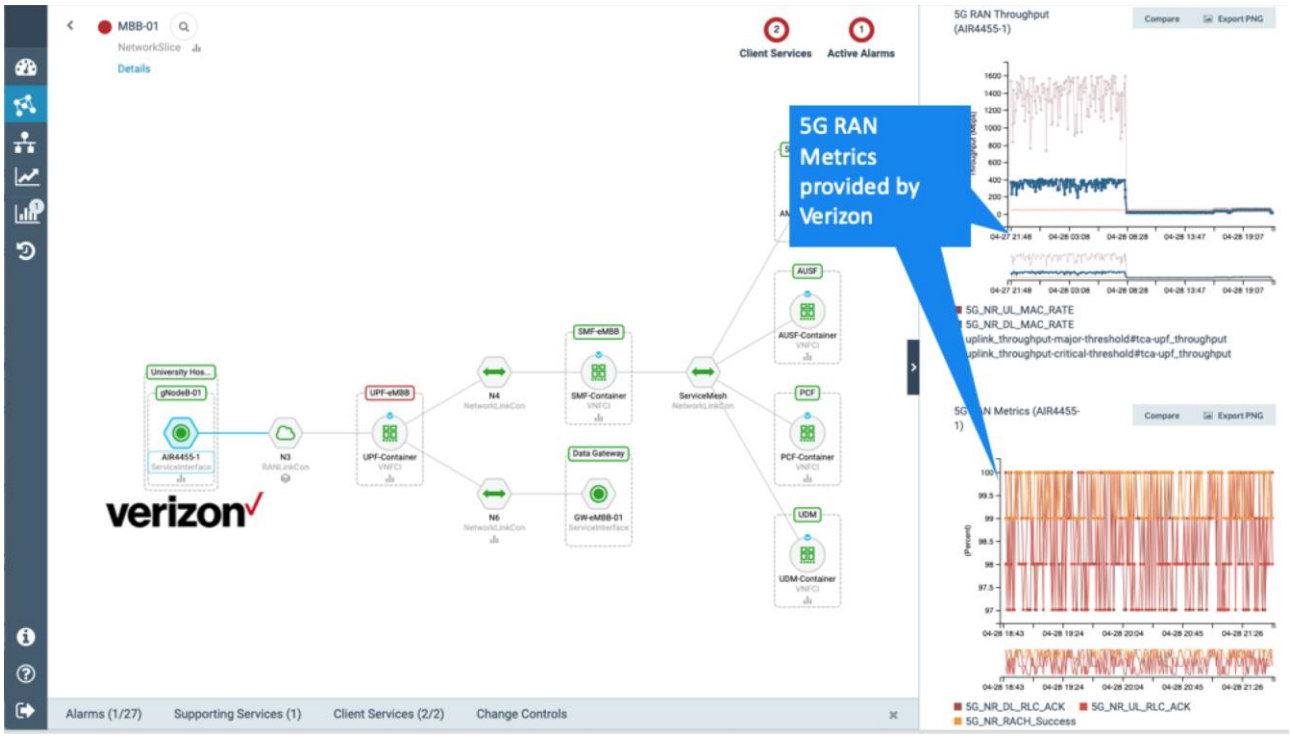


Figure 56 RAN KPI's provided by Verizon within the Vodafone Slice

Data Analysis and Alerting

Data in the repository is analyzed and correlated using a big data analytics engine such as spark. The analytics engine will detect anomalies and trigger alerts northbound. The alerts are augmented with topology information from the model, so that in addition to information about the directly alarmed entity such as a VNF, the alerts also contain information about the number of slices that the VNF participates in, and the number and types of service running on the slice. This impact correlation is only possible with topology awareness through an information model. The topology correlation also allows the service provider to quickly isolate the domain of the service that is having the problem. In an inter-carrier slice example, it is especially important to ascertain whether the issue is happening on-net within the service provider's own domain, or in a partner operator's domain. This can save many hours of troubleshooting effort by the service provider. In the case where a partner operator's domain is attributable, automated ticketing can initiate a request for corrective action and be used to track charging implications. Conversely, service assurance within Orange's slice could have already detected this threshold crossing. Since a closed loop action might be disruptive to the customers' service and Orange does not own the contract with the customer, they may elect to pro-actively notify Vodafone of the issue and request authorization to take corrective action.

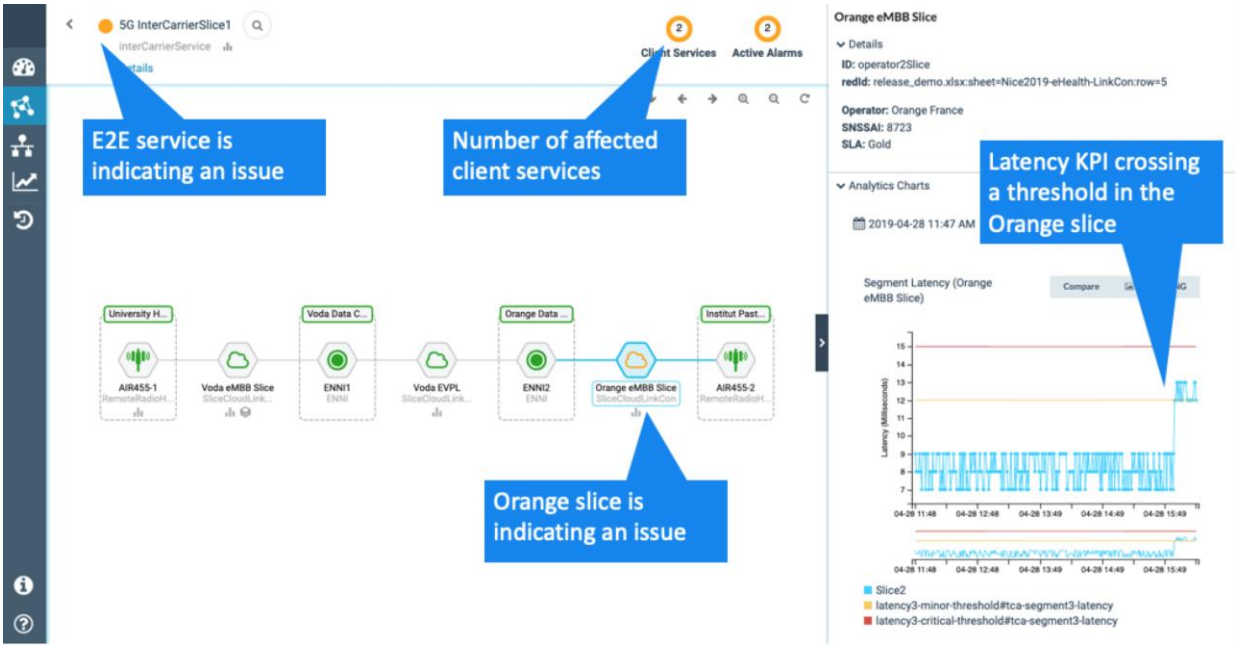


Figure 57 Monitoring Alerts

Closed Loop Actions

The events detected by the service assurance platform can trigger closed loop actions such as healing (restarting a VNF) or scaling (instantiating additional VNF's for capacity). In the figure below, both RAN throughput and UPF (5G data place function) KPIs have jumped up. A large number of new ehealth video conferences have been turned up, driving the RAN utilization and putting a load on the UPF. A threshold on UPF capacity is crossed. An alert is triggered by service assurance.

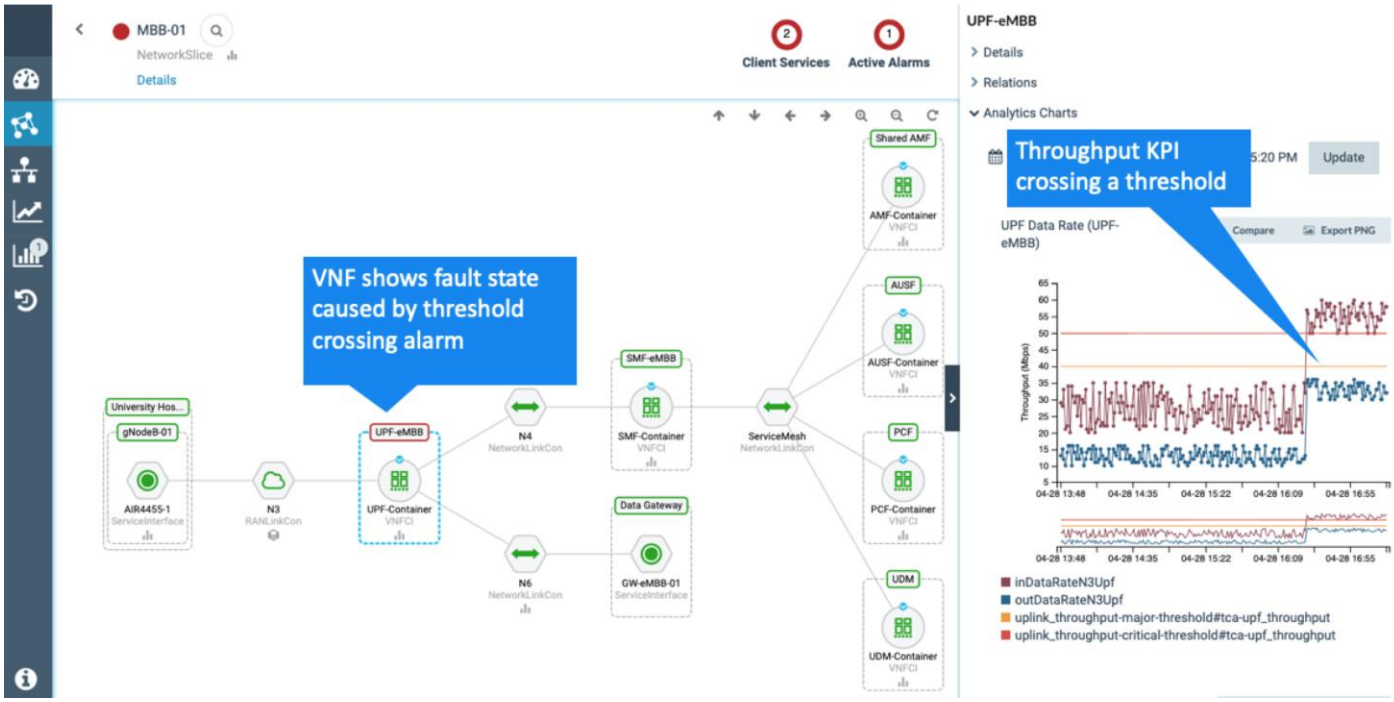


Figure 58 Threshold Violations

The augmented alert message is passed up to a policy manager (Apex), where additional inputs may be used to make a business policy based decision to take a closed loop action. A message is sent to the DO to instantiate a second UPF instance in the slice. Updated topology information is sent to the service assurance platform which updates the model to reflect the new state. After the new UPF is created, traffic is balanced across the two instances, increasing the capacity of the overall slice.

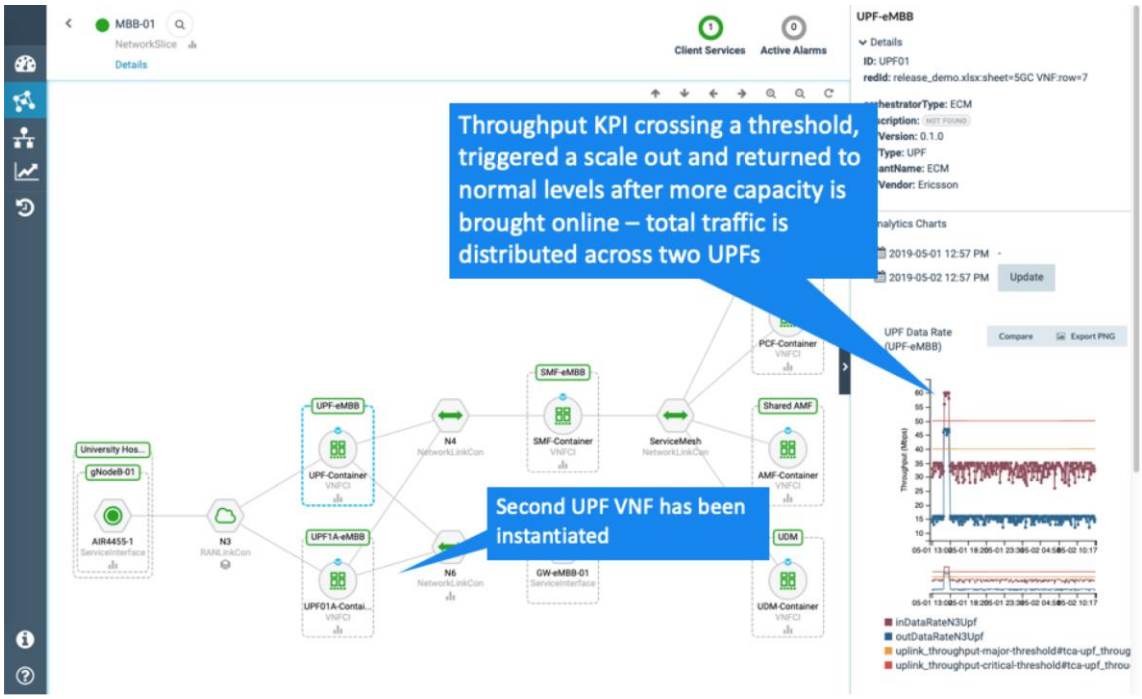


Figure 59 UPF Scale Out (Closed Loop Automation)

11 Charging and Intercarrier Settlement

In the Skynet Catalyst the Intercarrier Settlement Platform is used in the context of 5G network slicing as defined by ETSI. A great example of usage is the medical consultancy use case that is a part of Skynet. It calls for a 5G-enabled remote medical service provided between remote hospitals. In order to provide a guaranteed quality of service, a 5G network slice needs to be ordered, provisioned and reconciled. The objective is to enable multiple operators from different geographies to seamlessly provide a set of end-to-end hybrid services. In order to provision the Intercarrier 5G network slice, the BSS/OSS stacks of involved carriers utilize a federated orchestration approach.

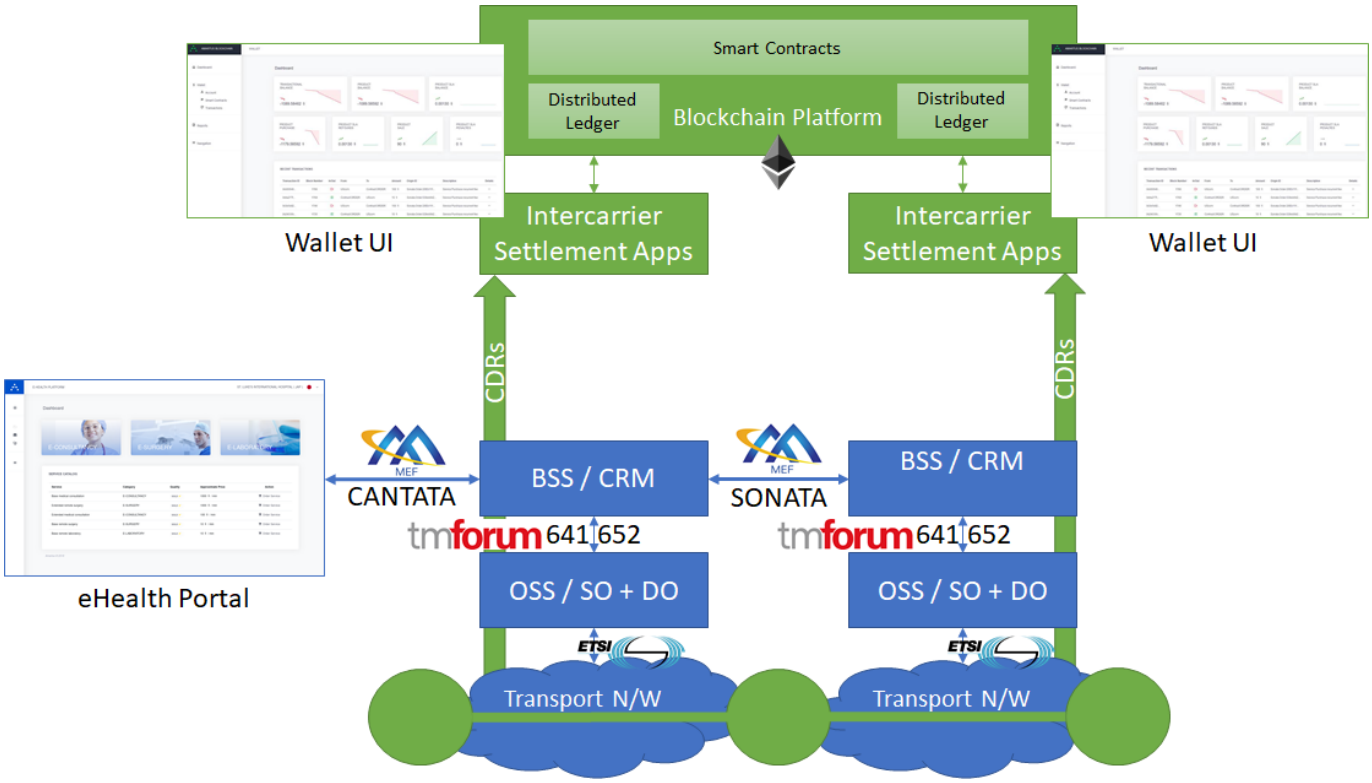


Figure 60 Blockchain Based Intercarrier Settlement

Amartus Intercarrier Settlement consumes data generated by 5G network slices in the partner's networks, and processes them. The rules under which such a service is provided are digitalized and take the form of a Blockchain smart contract. Smart Contracts contain agreements between partners with regards to i.e.: acceptable billing data discrepancy (dispute thresholds), charging fees, billing accounts in the Blockchain platform, and an accordant logic.
This allows for automation of the billing and settlement process by enforcing mutually agreed upon rules. Once data is obtained from the network, Amartus Intercarrier Settlement platform uploads it to the distributed ledger and triggers execution of the Smart Contracts. As a result of its execution a Intercarrier transaction balance is updated. Process is executed in a continuous manner and its results are presented in a near real-time fashion.

Please refer to following figure for Intercarrier settlement process flow

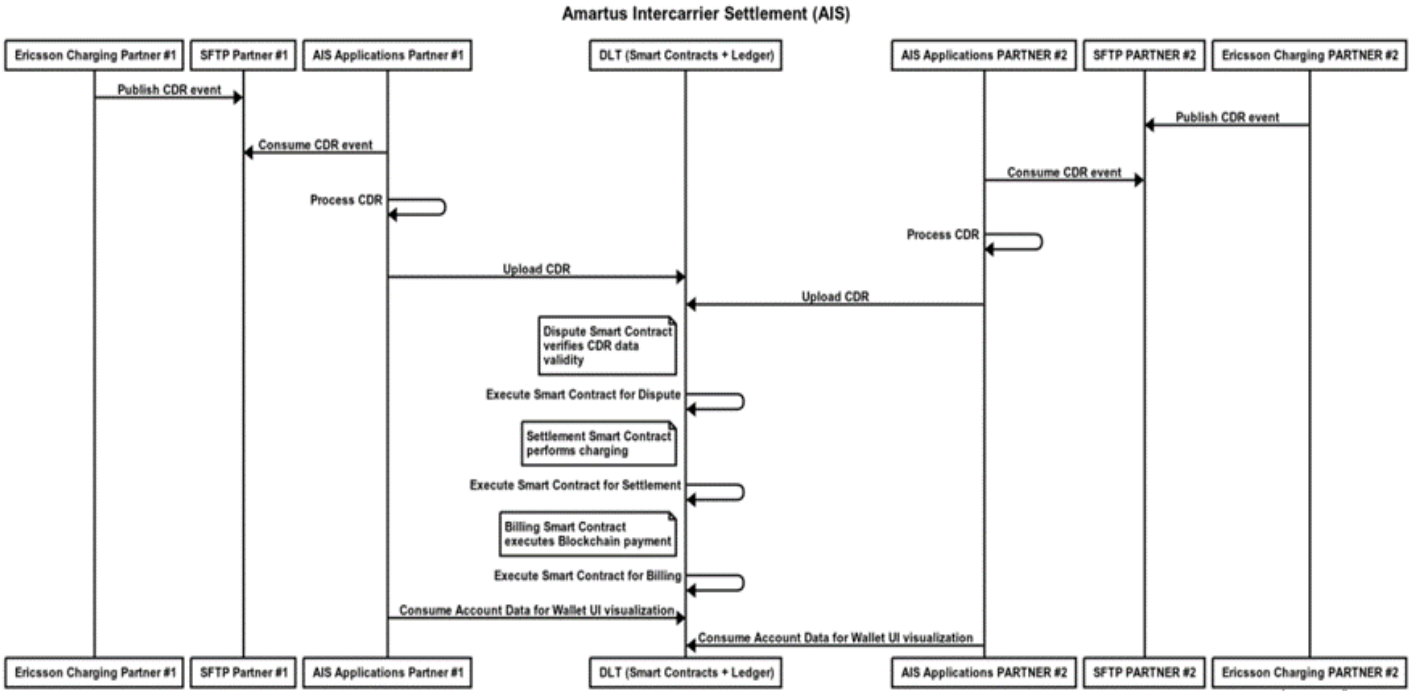


Figure 61 Intercarrier Settlement Process

11.1 Dispute Handling

An important functionality of the catalyst is dispute handling. Disputes can appear when CDR data describing the same billing event differs between operators. The solution demonstrated in the catalyst allows for automated identification of conflicting CDR data and noting of a disputed case and forwarding the information to a specialist for manual processing. The catalyst solution provides tools that allow partners to agree on the correct values and reinforce them for further processing. In this way, the labor-intense and long-lasting process of handling disputes is streamlined and radically improved.

11.2 SLA Violation

Another Intercarrier settlement process is the automation of penalty fees execution due to service SLA violations. Currently, executing these penalty fees is a manual process and is subject to dispute. Often times, the time and cost involved in investigating the violation can cost more than the service provider will recover in the SLA penalty fee. Manual resolution of SLA violations is a source of financial inefficiencies and not compliant with the concept of autonomous networks. The Skynet solution integrates the SLA violation events into the service assurance system so they can be spotted and processed by the Blockchain smart contract. As a result, a penalty fee gets calculated according to the respective contact records and automatically executed.

12 Skynet Catalyst Contributions

12.1 Contribution to TMF (including Open APIs, ODA)

- The SO-DO interface is implemented based on TMF641 to express a slice request. Slice Models in 3GPP and GSMA is referred to give TMF 641 the capability to create network slice (useful for NSSI creation API)
- SO requests the connectivity function in a hybrid slice. The connectivity is expressed based on the standard TR255(composite function, forwarding function and termination function) in TOSCA.
- DO decompose the connectivity requests into resources of multiple technical domain including IP, VLAN, optical, physical domains. The resources expression is based on the standard TR275 in extended TOSCA for hybrid network.
- In order to realize the on-demand network slice activation, we should manage the resource pool based on resource configuration. In Resource Pool Management API, the relationship between an order and a network slice is as the following figure. It is necessary to identify the state of network slice based on Logical termination point, Forwarding construct and Forwarding domain described in TR275.

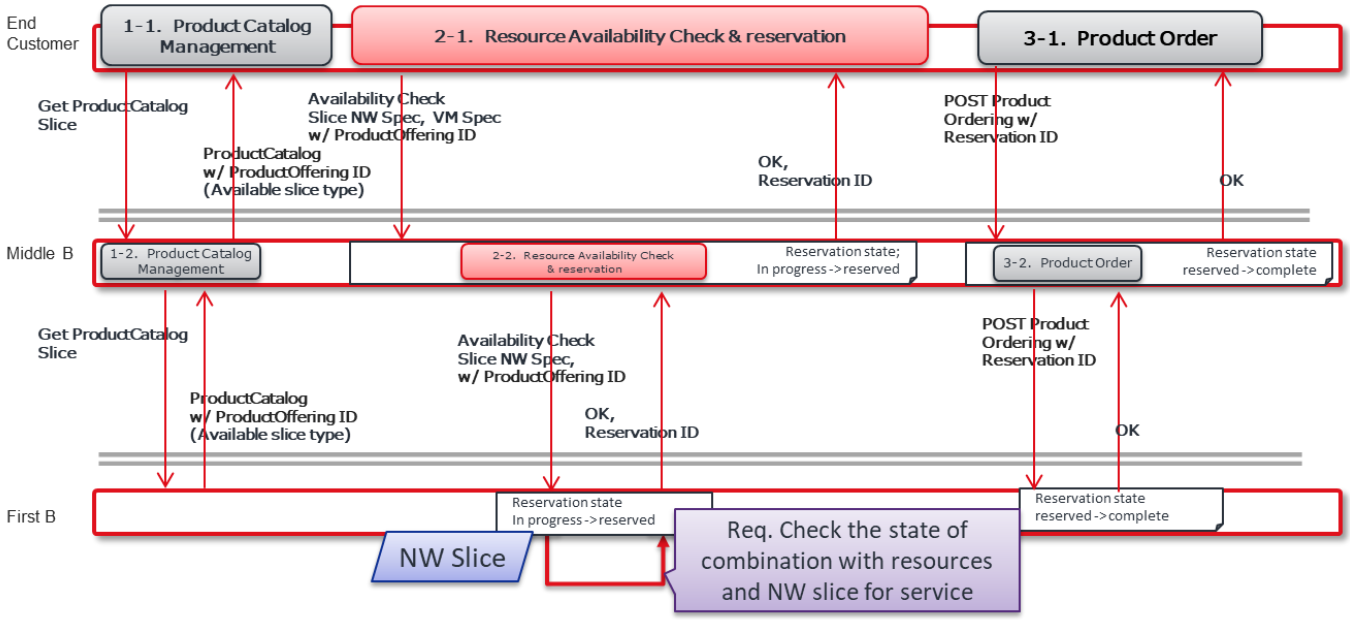


Figure 62 Resource Pool Management

12.2 Contribution to ONAP

We faced some constraints and limitations in ONAP (Casablanca Release) from Skynet implementation perspective. These should be considered for El Alto release in case these are not addressed in Dublin Release

1. **AAI Update** (Heat Bridge integration) VNF information such as the IP address, Management IP once instantiated on the target environment is not available in AAI. Heat Bridge enables this data to be propagated, however its currently a manual step and needs to be chained to the VNF instantiation and activation flow. (https://wiki.onap.org/pages/viewpage.action?pageId=58228881)
2. Heat bridge is specific to Openstack and should also expand to other cloud providers and make should be generic.
3. **ONAP - Preload VNF Module and Onboarding automation**: VNF instantiation steps needs manual interventions for as Preload data etc. This can be enhanced to retrieve information from the enhanced service order so that the NBI TMF 641 Service Order API completes the E2E orchestration of VNF's.

4. **NBI TMF 641 Chaining:** The current invocation of Service Order invokes the service order and responds to called party with an ACK and then a Completed status. However, the completion is only till the point of the Service Instance creation and not the complete VNF instantiation in target cloud environment.
5. **Number Provisioning:** Number management services use case for Clearwater IMS kind of services. In this scenario, the service on ONAP should provide not only onboarding of IMS Services but a service to provision number so that even ONAP runtime is aware of numbers provisioned and take Closed Loop service assurance.

12.3 Contribution to MEF

Skynet used MEF LSO 3.0 as a reference architecture framework. Among all APIs defined by it CANTATA and SONATA were selected to facilitate the activation and assurance of services across multiple service provider domains.

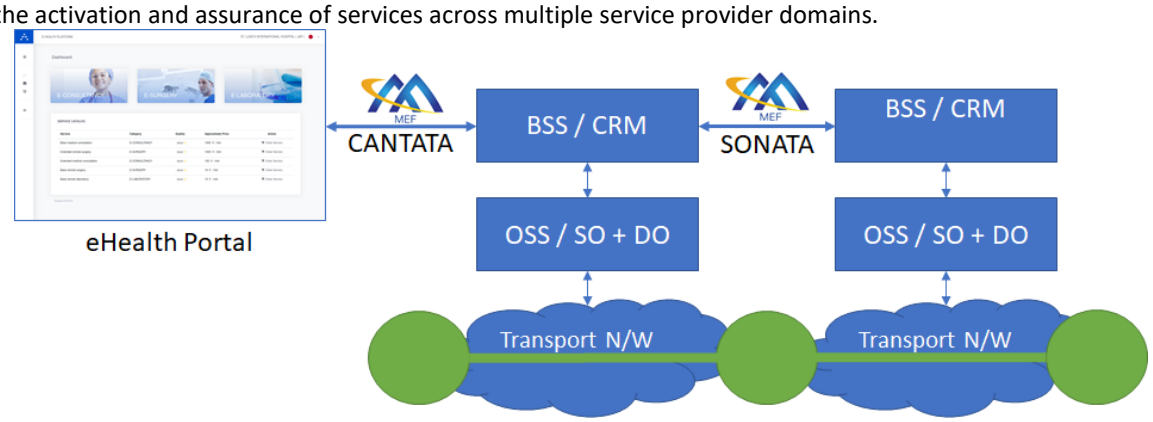


Figure 63 MEF Aligned Implementation for Health Care Offerings

MEF CANTATA was used as an API between a portal visualizing all available services that a hospital can order from the remote partner. As a result, on customer's service order submission the portal over CANTATA was directing an order towards responsible service provider. CANTATA API call was using a pre-defined catalog exposed by the service provider's business system.

In order to successfully activate required Intercarrier network slice BSS systems in each provider's domain were communicating using MEF SONATA. This was covering the following:

- serviceability (verification if a requested network slice can be delivered by the partner)
- ordering (placing and order for a desired and previously validated network slice at the partner)

That was the application of SONATA sequence described in the below picture:

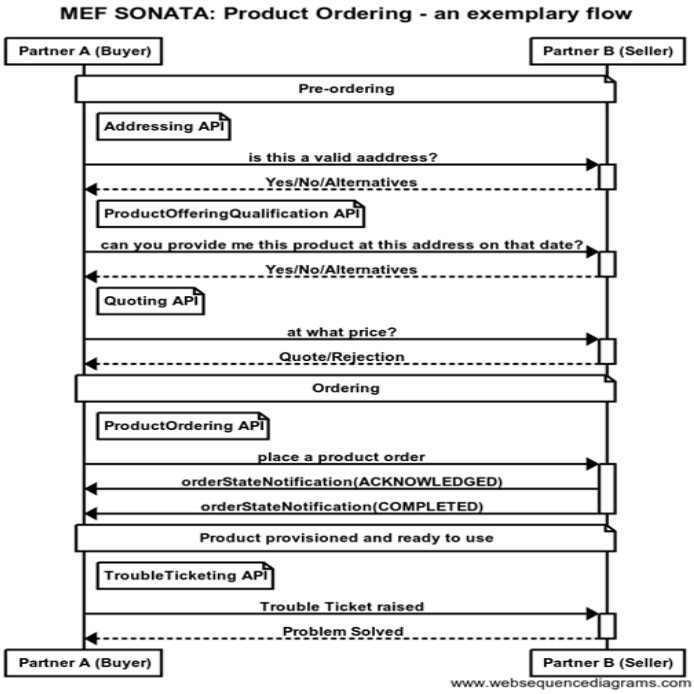


Figure 64 MEF SONATA Reference

In Skynet we managed to use data models outside of the original domain of application of MEF APIs which is Carrier Ethernet services, and engage SONATA for 5G Intercarrier network slicing orchestration.

12.4 Contribution to GSMA

Skynet used a GSMA-NEST approach to describe the network slice types required for its remote health-care services (see section on Skynet standards mapping and Service Modeling). We applied the Generic Slice Templates (GST) draft version as provided to TMF with the liaison statement of December 2018. The final version is still forthcoming and might consider provided by this catalyst. Please note that the value ranges for the different use cases are based on web research mainly. For the PoC a subset of the 10 most relevant GST attributes was implemented as a CFS characteristics.

Attribute	eMBB video	uRLLC telesurgery	uRLLC Drone
Downlink throughput per network slice	>= 137Mbps	>= 256 Kbps	>= 137Mbps
Uplink throughput per network slice	>= 137Mbps	>= 256 Kbps	>= 137Mbps
Packet Delay Budget	10 – 30*103 seconds	3ms	3ms
Packet Error Rate	10-2	10-4	10-4
Jitter	0,03	0,02	0,02
Maximum Packet Loss	0,10%	10-3	10-3
Maximum supported packet size	1500 (or 9000 if jumbo packets are supported)	20-50bytes	1500 (or 9000 if jumbo packets are supported)
MMTel support	yes	no	yes
Performance monitoring	THROUGHPUT / min	LATENCY / sec	LATENCY / sec
Performance prediction	THROUGHPUT / min	LATENCY / sec	LATENCY / sec
Synchronicity		0,0000001 seconds between BS and UE & UE and UE	0,0000001 seconds between BS and UE & UE and UE
Coverage	Local (indoor)	Local (indoor)	Local (indoor)
Delay tolerance	no	no	no
Deterministic communication	no	no	no
Isolation level	operational	operational	operational
Group communication support	no	no	no
Location based message delivery	no	no	no
Session and Service Continuity support	1	1	1
Resource Type	Delay critical	Delay critical	Delay critical
Support for non-IP traffic	no	no	no
User management openness	0	0	0
User data access	direct internet access	direct internet access	direct internet access

On the one hand experience regarding the application of GST in the Skynet health care context with an inter-carrier set-up was gained. On the other hand, NESTs were applied and evaluated in a highly-automated end-to-end approach for slice design, instantiation and monitoring including interplay with network service management and service orchestration.
GSMA NEST concepts and terms were mapped to Skynet's ODA-based architecture, with GST attributes corresponding to service characteristics and S-NEST / P-NEST slice type descriptions to TMF CFS. Service orders for Slices would include a completely filled NEST and Network Slice instances (NSI) correspond to TMF product/service instances (see section on GSMA standard mapping).

The Skynet use case context underlined that there is a strong need for an industry-accepted slice description standard and the support for international Intercarrier footprint. The catalyst showed that in general the GSMA-NEST approach can fill that gap and fits well to the TMF customer-facing service level. Its intent-based, use-case driven approach improves the end-to-end applicability of slicing as a service especially for verticals, tenants or individual business customers.
The attributes available in the GST were appropriate to describe the slice requirements for the different remote health care use cases. However, the slice type characteristic values were all fixed, i.e. the slice template did not support any parametrization besides IP addresses for the endpoints. That means the attributes are only for information or offer selection in the commerce layer. Attributes which are customer related like the number of devices, local coverage information (e.g. for campus networks) or VPN access information was not covered in the PoC for reasons of time.
The GST as just one big flat list of attributes, corresponding to one CFS, seems to have some disadvantages from the service order orchestration and pricing aspect. For example, it would make sense to represent "Positioning Support" or "User Data Access" (could include VPN) as separate services which could be booked and priced optionally on top of a basic slice service. A structuring of GST attributes according to orderable CFS services would help. Also the slice access endpoints could be represented as dedicated CFS, e.g. for mobile access, application access (here we have a set of services for VPN, MEC or public internet access) or further access types (e.g. Fixed Net or Wi-Fi Access). That would foster flexible service changes and charging for Campus networks with many access points.
Also, there are redundancies between some of the GST attributes, e.g. "mission critical service support", "reliability", "slice priority" and "slice quality service parameters/5QI". A redundancy-free description with clear dependency statements is needed for a formal, automated catalogue representation.
The attribute value range of "user management openness" might need some enhancements to properly support CFS specs for SIM-Subscriber slice access and related charging. A proposal will be prepared and provided to GSMA.
GSMA-NEST is currently assessing the impact of network slicing on contractual representation and management of SLA definitions. It could be subject of subsequent catalyst cycles to assess how that is supported by TMF's SLA framework.
Also, for the capturing of customer's slice orders it is to be evaluated how different types of customers can be supported in a user-friendly but catalogue-driven way:

- standard use case customers without technical background)
- big industrial players with detailed individual requirements versus, e.g. for Campus networks. Here the GST can help for a structured capturing of the customer requirements. However, there will always be the need for manual feasibility check by network designers and related slice template and service design.

Skynet's feedback to GSMA-NEST will be provided in alignment with the official TMF – GSMA cooperation stream.

12.5 Contribution to OASIS TOSCA -Modeling for Hybrid Network Slice

In Skynet Catalyst, TOSCA has been used to describe a hybrid network slice that is composed of virtual network and non-virtual network. Especially, NTT has explored about the needed node types and relation types for the non-virtual part of the hybrid slice. The hybrid network TOSCA generation and orchestration based on TOSCA are mainly implemented in UK-JP connectivity service.
High-level node types to describe non-virtual part of hybrid slice
2 types of high-level node types are used: Forwarding Function(FF) node and Termination Point (TP) node. Forwarding Function node is used to describe the "link" or "forwarding" function in a hybrid slice, e.g. a physical link, a logical link, an optical path. Termination Point is used to describe the endpoint or interconnection point function in a hybrid slice, e.g. a physical port, a logical port. FF type and FF properties are used to specify the particular communication protocol /mechanism for the FF. TP type and TP properties are similar.

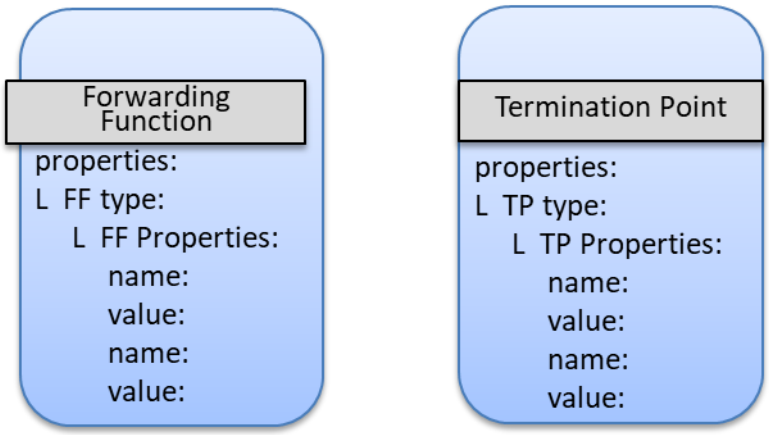


Figure 65 Forwarding Function and Termination Point

In a non-virtual connectivity, FF needs to be terminated by TP. TP needs to be connected by FF. The relationship Type needs reflect this kind of restriction.

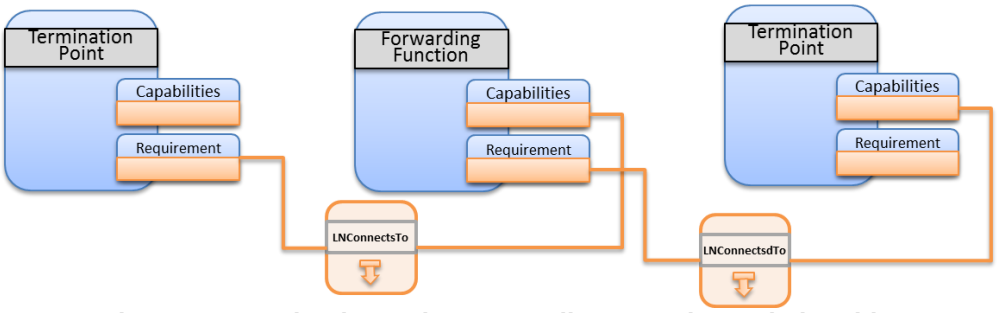


Figure 66 Termination Point Forwarding Function Relationship

Relationship Type to describe the horizontal relationship between non-virtual node types

In a non-virtual connectivity, the communication capability of a high-layer FF/TP could be provided by one or more low-layer FF as shown below.

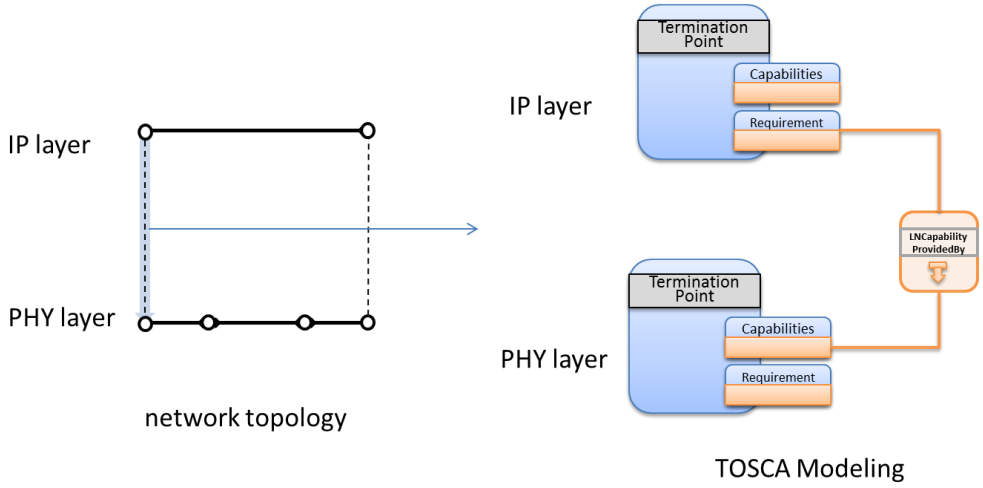


Figure 67 Termination Point Hierarchy

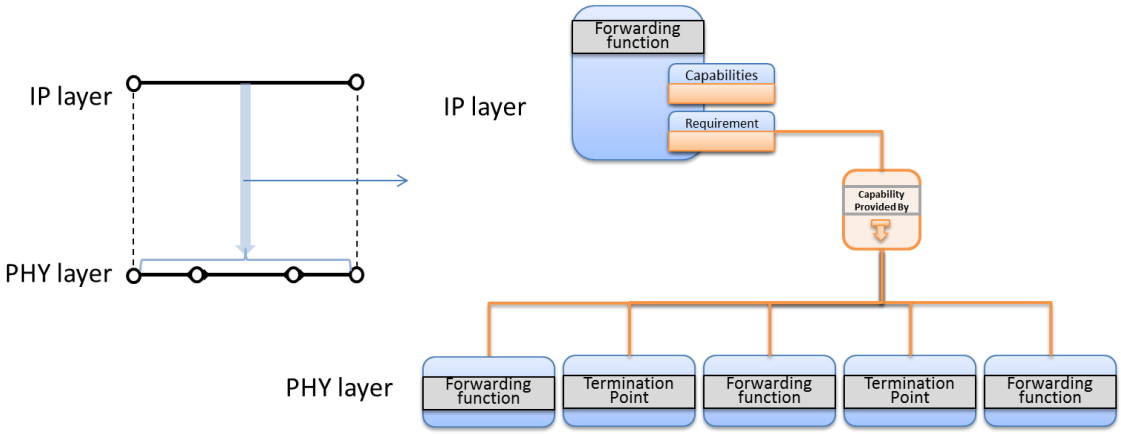


Figure 68 Forwarding Function Hierarchy

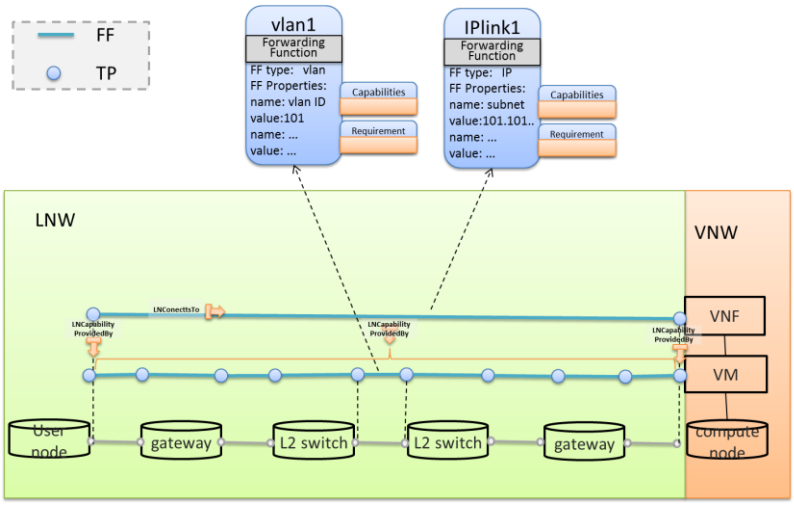


Figure 69 TOSCA modeling of Hybrid Network Slice

TOSCA Service templates are used to specify the topology and orchestration of services that are provisioned by Service Orchestration (SO). For example, UK stack SO supports a number of service template topologies to orchestrate new services. Below is a logical view of a service in UK SO, the SO service template complies with the tosca_simple_yaml_1_1 specification,

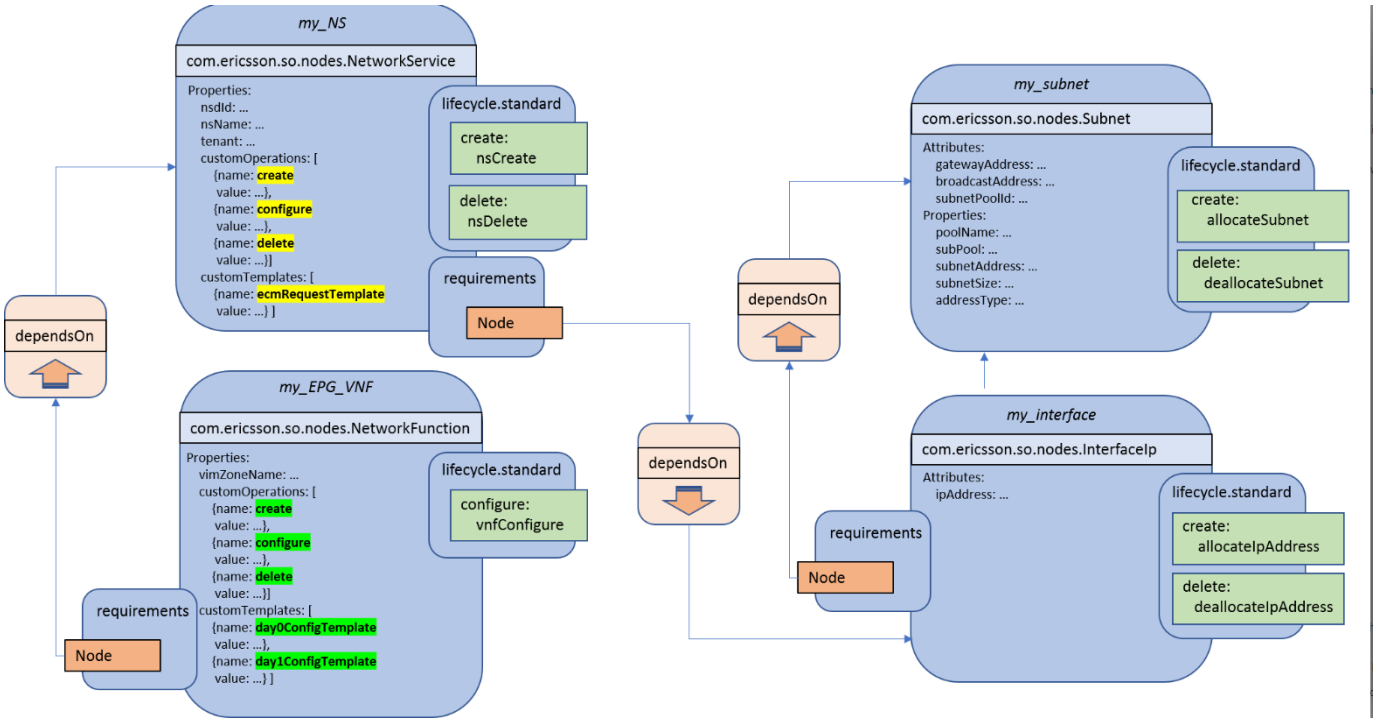


Figure 70 TOSCA to specify the Topology and Orchestration of Services

13 Skynet Catalyst Participants

Here is the snapshot of participants

Participants	Champions
Amartus	BT
BearingPoint	Chunghwa Telecom
Ericsson	Deutsche Telekom
EXFO	Du
Infosys	NTT
RIFT	Orange
	TIM
	Telenet
	Telus
	Verizon
	Vodafone

13.1 Champions

13.1.1 BT

BT is one of the world's leading communications services companies, serving the needs of customers in the UK and across the world, where we provide fixed-line services, broadband, mobile and TV products and services as well as networked IT services.

In the UK we are a leading communications services provider, selling products and services to consumers, small and medium sized enterprises and the public sector. We also sell wholesale products and services to communications providers in the UK and around the world. Globally, we supply managed networked IT services to multinational corporations, domestic businesses and national and local government organizations.

13.1.2 Chunghwa Telecom

Chunghwa Telecom (CHT) is the largest digital service provider in Taiwan. CHT provides a variety of ICT services, including fixed-line, mobile, broadband, internet, cloud, and IoT services, to the enterprises and consumers. In 2018, CHT co-founded the "Taiwan 5G Alliance – CHT Pilot Team" to accelerate the development of the 5G industry and related services in Taiwan. Linking together more than 40 corporations and organizations from the government, academia, and research sectors, the Taiwan 5G Alliance - CHT Pilot Team aims to launch pre-commercial 5G networks in 2020 with the vision of building a world-class 5G industry chain in Taiwan that is at the forefront of global development and commercial deployment.

By working with the leading telecom equipment suppliers, CHT has built a 5G trial network at the Chunghwa Telecom Laboratories to verify 5G key technologies and applications services as well as interoperability between 4G and 5G networks. Also, CHT works with the Taipei city government to build up a 5G trial field at the Taipei Pop Music Center and successfully demonstrate CHT's MEC (Multi-access Edge Computing) solution to support hologram and multi-angle online streaming services in April 2019.

CHT has a strong R&D capability of in-house BSS/OSS for years. One of the main R&D focuses is to leverage TM Forum ODA, cloud, and SDN/NFV technologies to develop the end-to-end service and resource orchestrators for the fulfillment and assurance of a variety of 5G network slices. This will help CHT speed up the 5G commercialization and creation of 5G innovative business models.

13.1.3 Deutsche Telekom

Deutsche Telekom (DT) is one of the world's leading integrated telecommunications companies and front-runners for 5G commercialization.
In Skynet the focus of Deutsche Telekom's contribution was on Product- & Service Modelling of cross-carrier Network Slices and related catalogue-driven B2B2X order/provisioning processes.
Deutsche Telekom brought in GSMA-NEST's Generic Slice Template (GST) as a means for a standardized, customer-facing slice description, initiated the dialogue between GSMA and TMF regarding Network Slicing and drives Skynet's GSMA contribution. Instead of capturing Customer's slice requirements in one flat list of GST-attributes, a structuring of the GST-Attributes in a set of modularly bookable services and service endpoints was suggested. That would foster a catalogue driven CPQ-Process, flexible service change orders, easier service order decomposition and flexible pricing.
Furthermore, the importance of modelling SIM subscriber slice access as a dedicated CFS at SIM level was introduced, to enable flexible B2B2X Business Models.

13.1.4 Du

du is a vibrant and multiple award-winning telecommunications service provider serving more than 9 million individual customers with its mobile, fixed line, broadband internet, and Home services over its 4G LTE network. du also caters to over 100,000 UAE businesses with its vast range of ICT and managed services.

du is ideally placed to support the realisation of UAE Vision 2021 and transformation of Dubai into a Smart City. du is also the official strategic partner of the Smart Dubai Office and the platform provider for Smart Dubai.

du is 39.5 percent owned by Emirates Investment Authority, 19.75 percent by Mubadala Development Company PJSC, 19.5 percent by Emirates Communications and Technology LLC and the remaining by public shareholders. Listed on the Dubai Financial Market (DFM), the company trades under the name 'du'.

More information is available on www.du.ae

13.1.5 NTT

NTT led the Business Concept for Skynet. In Japan, there is a growing need for remote health care services to provide more efficient medical care for people on remote islands and disaster areas. While the number of elders is increasing, there are few available medical-care locally in rural area. In addition, the recent experiences in natural disaster encourages the public opinion to prepare for the incident. For this reason, NTT has been engaged in this field for several years. In order to realize the remote medical care services, communication service providers should offer flexible, guaranteed, dynamical and secured network services such as 5G network service in parallel with the platform capabilities to interact with other verticals. To expand the 5G network service quickly and at low cost, it is necessary to not only use a newly built network but also a legacy network and to provide the service on the hybrid network. We brought in a hybrid network in Skynet and developed a domain orchestrator to manage such a network.

13.1.6 Orange

In France and in African affiliates where Orange is present, the need for health care networking services as well as the need for international coordination in case of epidemic is growing. Orange is highly involved in those subjects through its corporate entities as well as its enterprise business unit Orange Business Services. In addition, its wholesales activity is a key asset.
Orange supports the ODA and TMF modelling for its IT architecture. The set-up of remote health care services across multiple operators through 5G and automation across hybrid networks will enable Orange to envision the next generation of 5G services based on slicing. Implementing is key but monitoring as well to ensure that the SLAs are met and that the network can be healed manually or automatically.
The vision of Skynet is an "End-to-end service orchestration and monetization on a hybrid network for large enterprises with multiple global locations" which can be extended to different types of verticals (medical remote services, education, industry 4.0, transport, ...). It shows in a context of countries (Ivory coast, India, UK, France, Japan, USA,) that the introduction of 5G network will be articulated progressively with legacy networks.
In Skynet, Orange assured together with NTT the leadership of the project. Orange also provided its ONAP Open Lab and worked on the service assurance concept with on-demand vProbes for active and passive monitoring.

13.1.7 TIM

This is the era of digital life and technology is a fundamental asset to allow it. -
TIM enables access to digital life because it creates innovation and offers the possibility to be always connected with innovative telecommunication services, cloud, multimedia contents everywhere and on any device with simplicity and safety. Digital also means smart services for enterprises, citizen, and public administration that TIM provides.
Not just technology, but culture also changes, mutually modifying and we believe that ICT technologies are relevant for a smart, sustainable and inclusive growth.
http://www.telecomitalia.com/tit/en.html
http://www.telecomitalia.com/tit/en/about-us/branding/brands/our-brands.html

13.1.8 Verizon

Verizon operates America's most reliable wireless network and the nation's premier all-fiber network, and delivers integrated solutions to businesses worldwide. In April, 2019 Verizon turned on its 5G Ultra Wideband network in select areas of Minneapolis and Chicago in the US, providing the 5G commercial mobility service with 5G enabled phone. 5G Home, the first commercial broadband service for home subscribers were launched in October, 2018 in several US markets.
Verizon contribution to Skynet Catalyst is focused on areas of Orchestration and Service Assurance of 5G Network Slices:

1. Architecture recommendations on Orchestration & Service Assurance:
   - Service Orchestrator to Domain Orchestrator interactions and standards that can be followed on those interactions
   - Service Assurance and Analytics module to Orchestrator interactions for closed loop automation in order to maintain the SLA of a Network Slice
   - How a 5G Network Slice can be maintained end to end within the operator domain and importance of RAN KPI in maintaining the SLA of an inter-operator slice
2. Demonstration on 5G Network Slice Service Assurance
   - Domain level Service Assurance with Verizon RAN performance KPI in partnership with Vodafone and Ericsson
   - Impact of RAN performance in overall SLA maintenance of an inter-operator slice
3. Post-demo Standardization Effort and Collaboration target
   a. RAN KPI standardization for SLA maintenance
   b. API/Data Model for RAN KPI reporting
   c. Service Orchestrator to Service Orchestrator API

13.1.9 Vodafone

Vodafone Group, one of the world's largest telecommunications companies, with mobile operations in 25 countries, partnerships with mobile networks in 44 more, and fixed broadband operations in 19 markets. In UK, Vodafone will launch 5G in 19 towns and cities during 2019. Vodafone became the first UK company to carry 5G traffic over a commercial mobile network in October 2018 from a location in Salford, Greater Manchester. Now sites in Bristol, Cardiff and Liverpool have been switched on and are streaming live 5G mobile data traffic to and from the Internet, using the latest compatible routers.
5G could transform our lives at home, at work and beyond. In particular, one of the most exciting areas for 5G is the enablement of healthcare capabilities. It's already possible today for a surgeon to provide virtual help in real time to a surgeon located elsewhere via AR, and the technology will improve further with the low latency that 5G enables. Another way businesses could benefit from 5G is by deploying drones. For example, utilities could send drones to examine infrastructure in remote areas, so that engineers can carry out routine inspections without having to travel far. Vodafone is looking into the possibilities of enabling drones to deliver services across multiple sectors, from farming to smart cities, through 5G "network slicing" – – using the same physical network to accommodate a wide range of applications with different reliability and data requirements. 5G could provide even more reliable connectivity and high quality video transmission by drone. For more information on how 5G could improve the quality of our lives please refer to the link below
https://mediacentre.vodafone.co.uk/5g/five-ways-5g-transform-lives/
In Skynet, Vodafone provided guidance on many topics like TMF Open APIs (Northbound &East/West), ETSI for telco cloud standards (Southbound APIs), MEF3.0 LSO APIs, and ONAP External API usage and the related mapping among them and the exchanged data. Given the complex architecture setup of Skynet this also resulted in guidance in the layering of the Skynet architecture. The experience of Vodafone helped keeping Skynet realistic and it heavily contributed in making the proposed setup viable for real-life implementation

13.2 Partners

13.2.1 Amartus

Amartus is a software development and integration company helping Service Providers and Software Vendors maximize their benefit from network automation and software-centric networks. The company developed a Blockchain based Intercarrier Settlement Platform for wholesale voice and data and connectivity service providers. Apart from product development Amartus offers professional services, designing and building logic for different inter-system API endpoints in various languages, using Swagger and model-to-model mediation. Amartus is active in open standard bodies and projects for telco and cloud orchestration, such as MEF, OpenDaylight, TM Forum, ETSI-MANO and ONAP. The company is involved in industry alliance implementation projects such as multi-vendor SD-WAN service implementation or Security as a Service (SECaaS).

13.2.2 BearingPoint //Beyond

BearingPoint//Beyond helps organizations reinvent their business model and grow from efficiency to innovation. Our digital platform solutions provide CSPs the start-up advantage to capitalize on Cloud, IoT, 5G and AI and move rapidly from ideas to concept to revenue, with minimum risk and cost. BearingPoint//Beyond is part of BearingPoint, an independent management and technology consultancy with European roots and a global reach. A worldwide consulting network with more than 10,000 people, BearingPoint supports the world's leading companies and organizations in over 75 countries, engaging them to achieve measurable and sustainable success.

BearingPoint//Beyond's Infonova Digital Business Platform is a pre-integrated, multi-tenant platform with full BSS capabilities supporting multiple business partners on a single platform. Each of the 4 operators was set up as a separate tenant on the platform including its dedicated product catalogue and customer order management. Based on its partnering capabilities the relationships between the operators were modelled and set up to facilitate the onboarding of partner product specifications on each tenant to build the product offerings exposed by each operator to the Skynet Marketplace. Infonova Order Management handles the order decomposition to trigger the individual service fulfillment and orchestrates the fulfillment processes across all partners.

Therefore, Infonova is the enabler for the partner ecosystem and end-to-end order orchestration required in the 5G scenario explored in the Skynet catalyst.

13.2.3 Ericsson

Ericsson is one of the leading providers of Information and Communication Technology (ICT) to service providers, with about 40% of the world's mobile traffic carried through our networks. We enable the full value of connectivity by creating game-changing technology and services that are easy to use, adopt and scale, making our customers successful in a fully connected world. For more than 140 years, our ideas, technology and people have changed the world: real turning points that have transformed lives, industries and society as a whole.

Ericsson is showcasing the roles of orchestration, assurance and charging in the multi-operator and multi-vendor ecosystem. Ericsson took also a key role in defining the way of collaborating of the future networks, in order to achieve global orchestration required to set up the inter-carrier network slices from a business and technical perspective.

Ericsson Dynamic Orchestration is the key enabler for the network slice life cycle management providing orchestration through Ericsson Orchestrator and service assurance through CENX for the hybrid cross-domain and cross-operator network. Ericsson Orchestrator and CENX are integrating to the ecosystem through standard APIs. Using standard models provides a set of common policies/rules to serve the needs of closed loop automation through assurance and orchestration systems across different enablers.

Ericsson Charging supports the complex inter-operator and customer business models needed for monetization of the use case by providing real-time convergent charging and policy control for the network slices and rapid creation of the relevant commercial offers.

13.2.4 EXFO

EXFO provides end-to-end (e2e), independent, equipment vendor agnostic, visibility into the virtual network through both active (real-time) e2e service and network test and monitoring, as well as passive (in depth) monitoring and correlation of call data records (CDRs), to generate the key performance indicators (KPIs) and key quality indicators (KQIs) required to drive policy-driven operations. This visibility enables both real-time alerting to network issues, such as failures and degradation, and early warning for slowly degrading performance of the e2e customer experience.

EXFO Worx, along with the EXFO virtual verifier (vVerifier), provides for the orchestration of e2e active test and monitoring to: 1.) provide activation testing of both the network slice instance and the e2e service being requested, to ensure the service can be built as specified and; 2.) provide the ongoing monitoring of the e2e service to ensure service level agreement (SLA) requirements continue to be met, and generate alerts when they are not.

EXFO Nova Element Manager along with the EXFO virtual passive probe (vProbe) continuously monitor CDRs within the network, correlating records from different systems to generate a complete view of every service, e2e, identifying failures associated with the SLAs in place and reporting those failures.
Both EXFO Worx and Nova Element Manager use open, restful APIs to communicate events northbound.

13.2.5 Infosys

Infosys is driving the design, orchestration and usage generation of services leveraging Clearwater IMS via ONAP. Infosys is leveraging ONAP Casablanca release for this PoC. ONAP is used as domain orchestrator and service orchestrator for France stack for the purpose of

- Onboarding Clearwater IMS and EXFO vProbes on ONAP
- RFS and CFS Design and CFS Distribution to run time environments and Bearing Point CRM
- Instantiating Services and associated VNFs on Openstack Via ONAP
- Configuring subscriptions on IMS
- Managing Active and Available Inventory
- Configuring EXFO for traffic mirroring for the purpose of passive monitoring

ONAP is also playing the role of domain orchestrator for Ivory Coast stack
Additionally, Infosys is also generating the IMS CDRs and distributing the same to Ericsson Charging

13.2.6 RIFT

RIFT, Inc provides an open sourced and standards-based platform designed to automate the deployment and operation of virtualized network services and functions. RIFT's technology, RIFT.ware™, is used as the Service Orchestrator in the Japan and Ivory Coast domains, to coordinate service instantiation between Bearing Point CRM and the Japan-native Domain Orchestrator and the Ivory Coast ONAP-based Domain Orchestrator. In both cases, TM Forum Service Order Open API (641) is used between CRM and SO for service creation and also between SO and DO for resource facing service creation.

14 Conclusions and Outlook

Skynet built on foundation built by Blade Runner and extended this for

- Business Models and Solution Options for Remote Health Care Offerings
- Connectivity Across Partners Delivered via 5G Network Slices and Physical Transport Network (Design and Orchestration)
- E2E Service Monitoring and Closed Loop Automation Scenarios
- Leveraging blockchain for trust and traceability across diverse partner ecosystem
- Apart from ONAP, TMF, OASIS TOSCA, ETSI SOL, MEF, this catalyst also explored the standards from 3gpp and GSMA and possibilities of collaboration with TMF

Team would like to take this journey forward from here

- Possibility to work with Telecom Client / Medical Care Organizations to do concrete PoC (validate the work and feedback for continuation)
- Assurance is extremely critical in such services and there is scope to deep dive further on E2E automation

15 References

ID	Source
TMF-1	GB999 User Guide for Network Slice Management R18.5.1 April 2019
GSMA-1	GSMA Report “From Vertical Industry Requirements to Network Slice Characteristics” August 2018
GSMA-2	"Generic Slice Template" Draft version as provided to TMF with, a liaison statement December 2018
3GPP-1	3GPP TS 28.530 V15.0.0 Management and orchestration; Concepts, use cases and requirements
3GPP-2	3GPP TS 28.533 V15.0.0 Management and orchestration; Architecture framework