AUGUST 31, 2020

5G FOR VERTICAL INDUSTRIES

CATALYST– DIGITAL TRANSFORMATION WORLD 2020

THE AVIATOR CATALYST TEAM

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1. Introduction

The advent of 5G technology provides the opportunity for CSPs to provide faster and more responsive network service experiences to their end customers and partners. The consumer opportunity has been well articulated but 5G-enabled solutions uniquely tailored to vertical industries may herald the larger area of opportunity for CSPs and savvy businesses who can identify how and where 5G technology adoption may help them differentiate.

A recent TM Forum Report – "5G FUTURE: TARGETING THE ENTERPRISE"[1] – surveyed CSPs and enterprises in various industries about their motivations and plans for 5G adoption. It illustrated that while CSPs are targeting multiple vertical industries with 5G-based solutions and some clusters of opportunity exist, there is no consistent pattern emerging as yet.

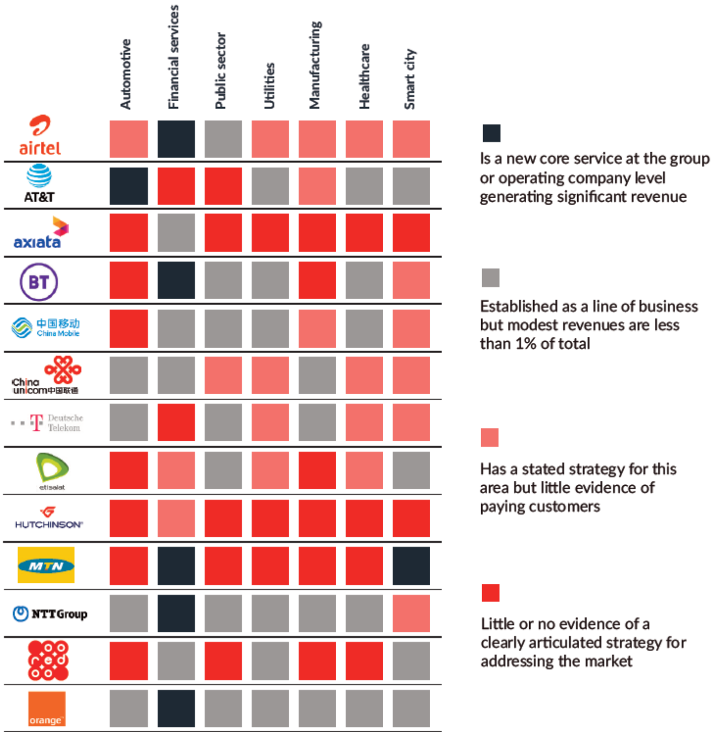


Figure 1: Which industry verticals are CSPs targeting?

Enterprises will be faced with what seems to be two quite different options for 5G-enabled solutions from which to choose – CSPs' proposing solutions leveraging network slices in the public 5G network or solution providers offering similar solutions using private 5G networks.

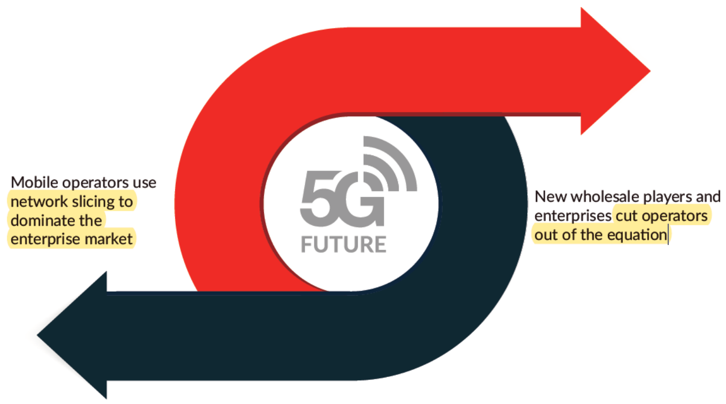


Figure 2: Which path to 5G for enterprises?

[1] Please refer to [8]

CSPs see definite opportunity in the 5G enterprise market leading with tailored enterprise solutions enabled by network slicing from the public 5G network as well as offering solutions based on private 5G networks.

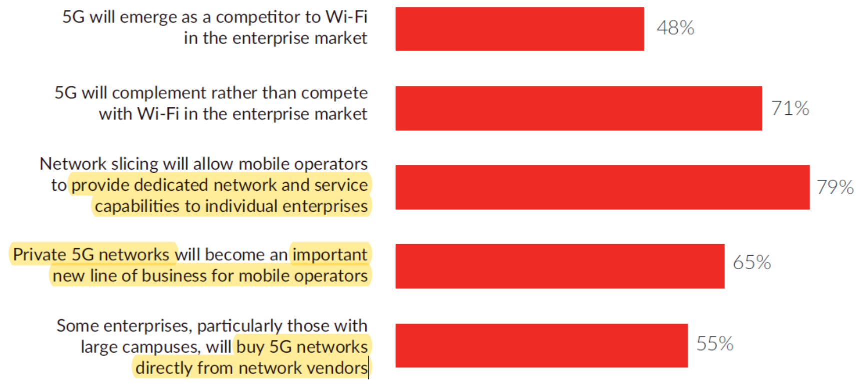


Figure 3: CSPs are bullish about enterprise 5G.

Service co-creation is recognized as being key to developing compelling industry-specific propositions. However, for many industry verticals, CSPs lack a detailed understanding of both the industry and key use cases. Hence, partnerships or acquisitions are essential to gain insights into the vertical industries being targeted by CSPs if CSPs intend to prime delivery of the industry solution.

Benefits	Challenges
Going it alone is untenable	Culture (not every cross-industry team gels)
Shared skill sets & technology	Ill-defined roles & expectations
Development based on use cases	No guarantee of success
Shared R&D costs	Potential for too many individual projects
Building new ecosystems & relationships	IP ownership for development & output
Results in more useful apps	Complex monetization

Figure 4: Benefits and challenges of co-creation.

CSPs are generally positive about the potential for service co-creation with leading enterprises in targeted industries as they continue to seek opportunities to collaborate in this regard.

Finally, on network slicing which is a key part of the overall 5G value proposition, security was identified as the most important aspect characteristic. In summary, it would appear that the QoS and security of 5G networks open up additional opportunities for CSPs to develop compelling propositions into vertical industries.

Figure 5: Anticipated 5G network slicing characteristics.

1.1. Industry 4.0 transformation

Whilst the Telecom Industry is taking rapid strides towards 5G Technologies a plethora of vertical industries (e.g. manufacturing, Healthcare, Banking) are simultaneously embarking on a transformation, popularly known as *Industry 4.0*. As per World Economic

Forum report in collaboration with McKinsey[2], Industry 4.0 can potentially create a value of $3.7 trillion by 2025 - just on the manufacturing vertical alone. Communication services play a vital role in enabling this.

Industry 4.0 will redefine the way that industries operate. Extensive digitization and consolidation of automation systems, combined with active and continuous communication with suppliers, partners, ancillaries as well as with distributors, retailers and consumers etc. can be listed as a few of these changes will have a dramatic impact. Future industries will no longer work in isolation on the contrary they will drive ecosystems to ensure greater efficiency, safety and security, while bringing down the carbon footprint.

For Industry 4.0 communications plays a major role in three areas;

1) Inside manufacturing, or core value generating units which have been the traditional scope of the industries.
2) Ecosystem of partners, suppliers and ancillaries. Similarly, communication with distributors, retailers and consumers.
3) Managing and tracking transfers materials and products, as well as providing services to customer while on the move.

1.2. 5G Capabilities

Today, 5G is primarily associated with its capability to deliver high bandwidth and low latency, and to a lesser extent, its ability to support a high density of connections. This limited view is due the fact that the current consumers of wireless telco services are mostly end-users who are flat subscribers and corporates. Vertical industries rely on executing their mission critical business operations in an efficient manner. Therefore, 5G capabilities of key interest for vertical industries include;

- Differentiated communication services – Capability to provide services which are aligned to specific consumption needs (e.g. bandwidth, Quality of Service (QoS), availability, cost). This will enable the delivery of industry specific use cases and services.
- Guarantee of Service – Capability to provide specific service guarantees as opposed to the current best-effort approach. While not all services may need service guarantees, the ability to provide this functionality opens up a new genre of consumers. Business and mission critical processes as well as operations of verticals can reliably leverage services which require a guarantee of service.
- Seamless connectivity – Unlike the current situation, 5G enables reliable end-to-end communication across technological as well as CSP boundaries. 5G enables consumers to transparently use communication services even if it has to be rendered by, for example, a mix of wireless and satellite communication. Due to this, verticals are not constrained by technological and geographical boundaries of the communication world.
- Ubiquitous presence – 5G is expected to provide coverage beyond what is available today through innovative means and seamlessly integrating with a variety of localized communication systems, thus eliminating communication service related complexities for verticals.

These 5G capabilities are now possible due to technological advances and innovative concepts such as network function virtualization (NFV), software defined networking (SDN), Network Slicing, Massive MIMO and mobile edge computing (MEC).

1.3. Leveraging 5G for Vertical Transformation

The 5G capabilities listed above are essential for verticals to confidently leverage Communication Services as core part of their operations and business processes. As the vertical industries are also experiencing substantial transformation, this is a good opportunity to infuse the innovative solutions that are being tried and deployed as part of 5G.

While the technological advancements within the resource layers (e.g. NFV, SDN, Massive MIMO, Network Slicing, MEC) enable CSPs to support the above mentioned 5G capabilities, the resulting network capabilities need to be exposed to the new genre of

[2] Please refer to [1]

customers as efficient and cost effective services. Furthermore, these services should be presented in a form which is aligned to the specific needs of each industry vertical, for a wide variety of industries.

Differentiation enabling high level of customization and providing service guarantees can inherently result in fragmented deployment of scarce resources; which in turn, can inordinately drive up the cost of the services. Virtualization technologies like NFV and SDN, in theory, can enable CSPs to rapidly alter the deployment plans; however, in practice they need to be well managed to achieve the intended benefits. This management must form a bridge between the varying needs of a plethora of industry vertical use cases with the network capabilities the CSP has at its disposal. Hence telecom management, popularly known as OSS/BSS, plays a vital role in practical uptake of 5G communication services by vertical industries.

2. Bridging the Gap

In a press release published in May 2020, Tareq Amin, Rakuten Mobile's chief technology officer talked about Rakuten's ability to protect its own intellectual properties while going to global market with their Rakuten Communication Platform (RCP), and emphasized this will be especially so in the "focus areas" of BSS/OSS and orchestration[3]. This brings out the important role that BSS/OSS plays not only in ensuring that 5G delivers to the promises to the consumers, but also ensuring the profitability of the CSPs.

The capabilities that make 5G different and endearing for vertical industries also come with the baggage of inherent complexity and factors resulting in inefficient use of scarce resources. For example, in order to meet highly specialized service characteristics required by the consumer, the differentiation in services that 5G offers is not limited to bundles at product level, but requires deployment deep in the network level. This results in fragmentation of resource pools, which can potentially result in inefficiency. Guaranteed services are achievable only if resources can be made available dynamically on demand. A solution which provisions for maximum expected demand for a day would not only result in wasted resources, but due to resource constraints, would also result in lost opportunity to serve a different need. Seamless connectivity involves absorbing complexities at technical and business levels and dependencies between competing CSPs. Similarly, ubiquitous presence demands either deploying networks where it is not economically feasible to do so, or adding complexities very specific and peculiar to a domain or geographic area.

The advances related to virtualization, containerization, digitization of network elements allows extreme flexibility at the network resource layer. However, it is essential that this flexibility is leveraged while rendering services to the consumers. As the CSPs enter a highly fragmented vertical market, they need to efficiently provide value and easy-to-sell services, in contrast to relatively uniform best effort services being provided in the pre-5G era. This requires redefinition of traditional telecom management concepts and enhancements with new functionality.

2.1. Model driven approach

As highlighted in the previous section, 5G Services are complex constructs, requiring sophisticated configuration deep in the network, driven by rich parameterization, with an awareness of the network context and resource availability. Unlike prior generations of wireless technology, which were usually deployed as relatively static instances of network infrastructure, 5G Services are implemented as unique 5G Network Slices with managed life cycles, allowing the dynamic creation, modification and deletion of slice instances.

In modern communications fulfillment systems, handcrafting of individual services instances and managing their life cycles has been replaced by Zero Touch Provisioning (ZTP) approaches in which automated processes configure specific service instances matching a

[3] Please refer to [4]

customer's needs, expressed in terms of well-structured parameter sets. ZTP is essential for 5G services because of the complex, dynamic nature of the service as well as the complex constraints of the network environment.

ZTP automation is best achieved through flexible framework components that are configured using meta-data and policies to support a broad range of services on a single solution platform. Such an approach to configuring the platform's behavior minimizes hard-coded business logic by parameterizing standard orchestration operations and interface payload definitions. This tunes the behavior of the automated components so that it is appropriate to the service or its constituent resources, and the payloads passed across system interfaces are appropriate for the intended operation. Orchestration of a specific service uses the appropriate meta-data to recognize the service type and create service instances as dictated by each service's unique parameterization.

Meta-data and policy driven system components, although essential, do not necessarily ensure a coherent solution configuration. Coordination of a solution can be achieved with an overarching information model to define and align meta-data, interfaces and policies across solution components. A model-driven approach provides an effective, efficient, agile approach for defining services and evolving to support incremental service variants.

Service models may be scarcely specified to match a very specific service variant with very little flexibility or variably beyond the adaptation of the service to the network context. Such an approach requires very few order-time parameters and relatively simple run-time policies. For example, in the 5G context, an enhanced mobile broadband (eMBB) service type could have single pattern of allocating network services to data centers, whereas an ultra-reliable low latency communications (uRLLC) service definition would define a different allocation pattern.

In contrast, an extremely flexible service model could support a broad range of service variants, but would require much greater order-time parameterization and much more sophisticated policies throughout the solution. For example, such a service definition might support Slice Service Type (SST) and 5QI as parameters, and provide the run-time ability at run-time to dynamically allocate network services across data centers as appropriate for the service instance. This approach also enables a service instance to be easily adjusted to meet changing customer requirements, or dynamically modified by the system to balance considerations across multiple services.

For 5G Network Slices, the flexibility required to support rich variations in ordered services and to support dynamic closed loop operations suggests that the most appropriate 5G service model is a flexible one supporting a range of service variants. Thus, instead of defining a set of individual services definitions corresponding to specific SST or 5QI values, a more general parameterized model is defined that, at run-time, drives the instantiation of any one of the individual services definitions based on the input order parameters.

For vertical industries, such a flexible model allows strong reuse of OSS capabilities and 5G service definitions with much of the differentiation achieved through customization of Product Offerings for special verticals.

2.2. Vertical aligned services

A number of innovative automation solutions as well as consolidation of siloed automations are being implemented across different industries. Apart from automation, different silos within the traditional boundaries of industries, including their relationship with the network of partners, suppliers, distributors and consumers are being reexamined to create a cohesive and efficient ecosystem. Communication services can play a vital role by providing in the transformation to this efficient ecosystem. The type of services that are required and the business model associated with consuming these services will vary based on specific vertical use cases.

Embracing platform business models (e.g. Amazon, Uber, Airbnb) is yet another transformation that different verticals need to go through. Platform Business Models is heavily dependent on communication services to transfer information across the ecosystem. Depending on the nature and criticality of the business, the requirements on the type of communication may vary.

The verticals would like to focus on their core business where their expertise, competency and interest lie. The communication services should be exposed in a manner which is aligned with different vertical use cases for ease of implementation of services in the overall solution. The alignment has to be at technical, service and business levels. As there can be a vast number of specific use cases, new approaches need to be explored in exposing vertically aligned services.

2.3. Strategic and Tactical Closed Loop Automation

Given the complexity 5G networks entails, the volume and heterogeneity of vertical application/slices with varying demands, the need to predict resource congestion and SLA impacts, it will be necessary to automate the remediation or conflict management to mitigate risks and ensure 5G business scaling. Placing closed-loop automation on the way to autonomic networks requires use case focus, AI-assistance, and API evolution to increase transparency and trust across systems and network personas.

Implementing closed-loop automation can be seen from two perspectives: a tactical approach to solving seemingly independent SLA breaches and congestions where the main target is to solve the problem right now and a more strategic approach having an overarching view of the overall intent across CSP and Vertical layers and geographies influencing how independent problems are solved to maximize this intent.

There have been different perspectives in TMD ODA and other SDOs to categorize and look at closed loops such as based on time (fast vs. slow) or based on entity layers (Commerce VS production, RFS VS CFS). In order to satisfy vertical requirements, there is also a need to consider business Intent relevance in the design of closed-loop automation.

The use of AI and Analytics to capture verticals data and integrate vertical intents in the closed-loops managing CSP infrastructure resource elasticity needs a careful consideration for placement at the edge.

2.4. Assured Mobility

Assured Mobility enables the customers to stay connected to the networks efficiently for the entire journey, reimagining the mobility ecosystem with new mobility hubs, more connected, shared, autonomous slicing techniques and new strategies to reduce congestion. The following features are leveraged to provide Assured Mobility.

1) Network slices are continuously monitored to provide real-time status at any time and understanding of a given set of nodes including network connections to create a comprehensive map of a dynamic topology.
2) Offering automatic correlation to analyze collected data, determine the impact, root causes of problems, support closed loop feedback to automatically optimize, fix performance issues or service failures by raising Alarms.

Service assurance is of utmost importance to not only provide the experience to those the technology is expected to serve, but also to deliver the business returns that telecom operators have bet on 5G.

2.5. Charging for Guaranteed services

5G Technologies brings in a new concept for the customer – “guarantee of service”, which means that the service provider will be liable for the SLA they have given to their customers.

The introduction of Network Slices as a premium service requires the operator to track the service level received by its customers, and be transparent about the drops in the service level. As part of their contract with the customers, the service provider can either choose to discount the customer on the service charge, give an extra free usage for the service, or provide a credit for the next time the customer purchases the service. A similar setup may be requested by the vertical industries, where the guarantee of service has a paramount importance and the vertical is willing to pay extra for this service.

The introduction of service based charging does not require a replacement of the current charging and billing systems but requires new integrations for capturing the necessary information to track the service levels delivered. The usage of the customer is traced by the charging system with two main parameters: the network slice that is being accessed and the service level assigned by the network. In addition to the core network records, SLA breaches in usage are also pushed by Service Assurance System, where the core network reported an acceptable QoS, but the customer could not receive it. Charging System should be able to track the breaches and create actions to compensate the customer based on business requirements.

2.6. Localization

In order to deal with low latency network slices, certain virtual network functions (NF) need to be placed at the edge where cloud computing technologies allow for scalable and flexible deployments. The below table shows the assumed NF placements on our Catalyst scenarios where Edge placements becomes the majority compared to Regional and National Datacenters.

	Edge DC	**Regional DC**	**National DC**
eMBB-4K	gNB_DU_port	UPF	AMF
	gNB_CU-UP		SMF
	gNB_CU-CP		
eMBB-10G	gNB_DU_port	AMF	
	gNB_CU-UP		
	gNB_CU-CP		
	UPF		
	SMF		
mMTC	gNB_DU_port	gNB_CU-UP	AMF
		gNB_CU-CP	SMF
			UPF
uRRLC	gNB_DU_port	AMF	
	gNB_CU-UP	SMF	
	gNB_CU-CP		
	UPF		

Figure 6: NF Placements in our Catalyst

Placement at the edge is also necessary for Management and Analytics for latency and privacy reasons, as an example AI Models allowing to predict QoS and congestion of network slices and resources while considering exogenous data such as Airport passenger traffic and aircraft turn-around time to ensure accuracy levels would need to be deployed and executed at the edge, to ensure some access to airport data can be granted.

The below diagram describes the type of CSP and Vertical Aviation industry workload that would run at the edge of the mobile network.

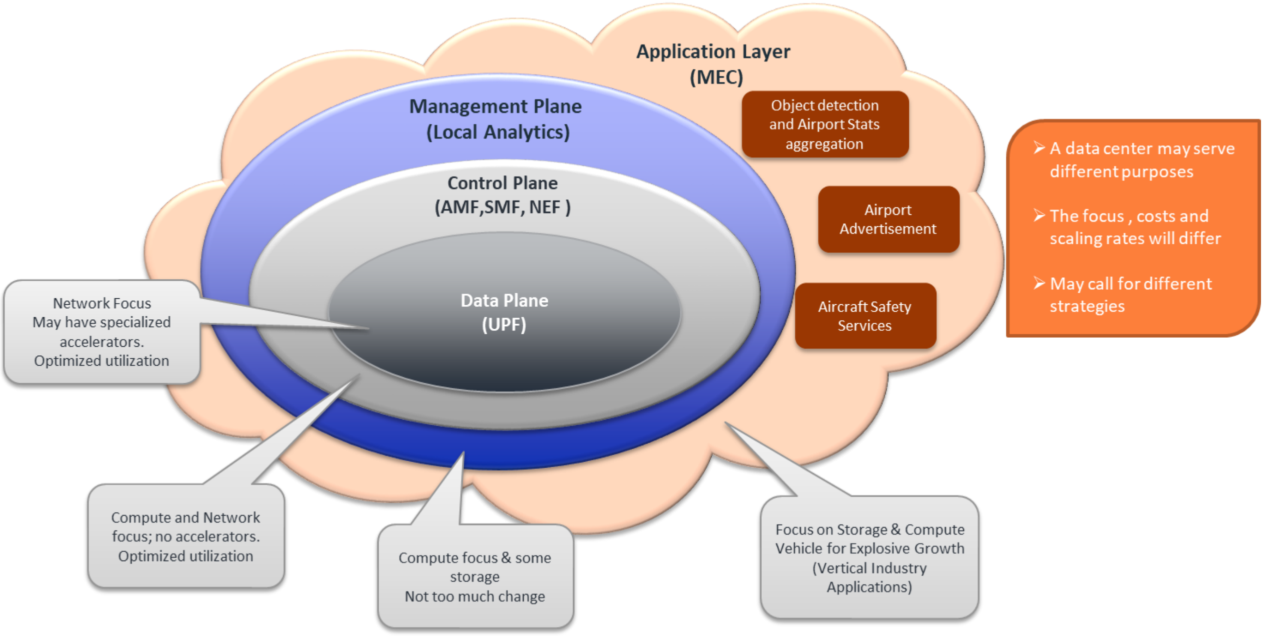


Figure 7: CSP and Aviation Industry Workload

3. 5G for Vertical Industry Transformation

There is a constant demand for flexible bandwidth, latency and better coverage from industries and technologies like Augmented and Virtual Reality, IoT, Automotive and Energy. Creating a separate network infrastructure would prove to be too costly and too complex for any of the industries to support. Thus, the ideal solution for providing the support for various use cases would be “tailoring” the network infrastructure for each specific requirement.

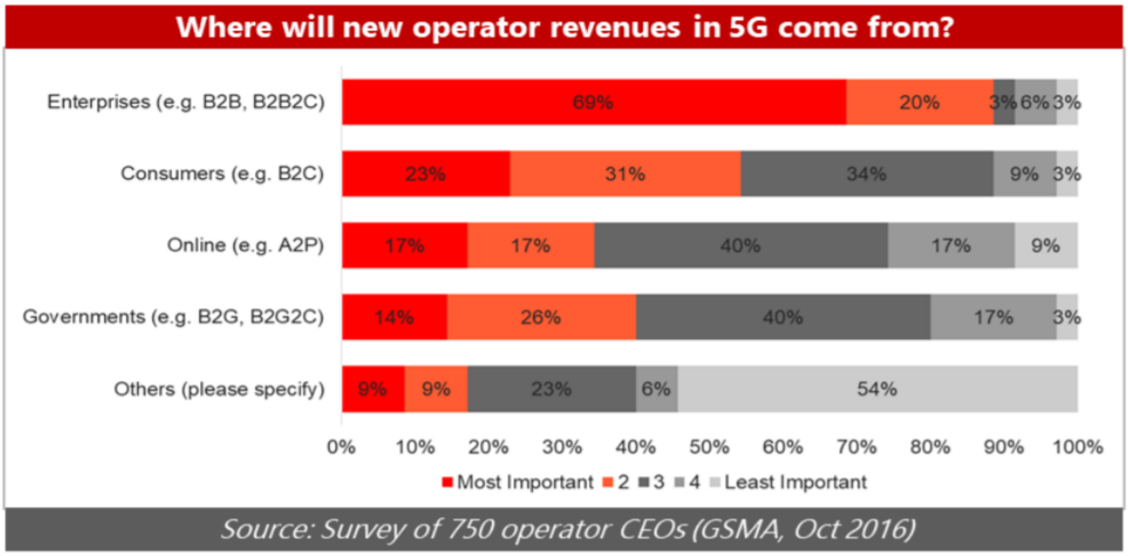


Figure 8: Sources of new operator revenues for 5G[4]

The Vertical Industry transformation is set to happen across the entire production life cycle, starting from the way procurement of input services and material happen, the way value is created in the factories and assembly units, to the point of monitoring consumption of finished products /services by a wide variety of customers. This throws up a huge opportunity for innovative

[4] Please refer to [5]

solutions within the ecosystem of a particular vertical as well as communication services, triggering new advancements (e.g. Global Internet reach and wide spread use of smart phones resulted in innovative app based services).

Learning from their past experiences, CSPs are working together with the verticals in understanding their requirements and adapting go-to market strategies that will enable a smoother transition period. It is also very important that the requirements can be captured rapidly and network capabilities can be packaged based on the needs of different customers. CSPs will also be able to create pre-defined network slices for different enterprise verticals, thus shortening and improving the service activation process.

Current understand of communication services is based on the best effort services being delivered during the 5G era. Hence communication services are being used, in situations where an alternative solution is available in case of failure or in noncritical situations. Potentially 5G with its ability to provide differentiated & Guaranteed services can open up completely new field of applications. However, CSPs will need to actively collaborate in identifying and creating new services. There can be four categories of opportunities:

- Replacement of different types of current communication systems with 5G differentiated services, meeting a wide variety of requirements. This will simplify existing systems, allowing verticals to focus on their core businesses.
- New services to manage industry 4.0 related transformation of extended automation (supported to IoT, robotics) and consolidation of automation, interlinking hitherto silo automations. This will result in greater efficiency of existing systems
- Redefinition of current industry operational and business models (e.g. Amazon refined retail industry) to create substantially different products and services; disrupting the industry towards greater efficiency and transformed customer and partner experience.
- Orchestrating multiple disconnected vertical services and products towards creating new products, significantly enhancing customer convenience.

These improvements will need multi-domain innovation teams, collaborating to relook at many fundamental assumptions and constraints that have been in existence. In this catalyst, we are exploring use cases from some of these categories with specific focus on Aviation Industry.

4. Exploring Aviation Industry Transformation

For this catalyst, we selected the aviation industry as one in which we might explore the possibilities for 5G adoption. We engaged with experts from the aviation industry including Stuart Birrell, the former CIO of London Heathrow Airport. He shared his insights into the opportunities for the aviation industry to leverage 5G.

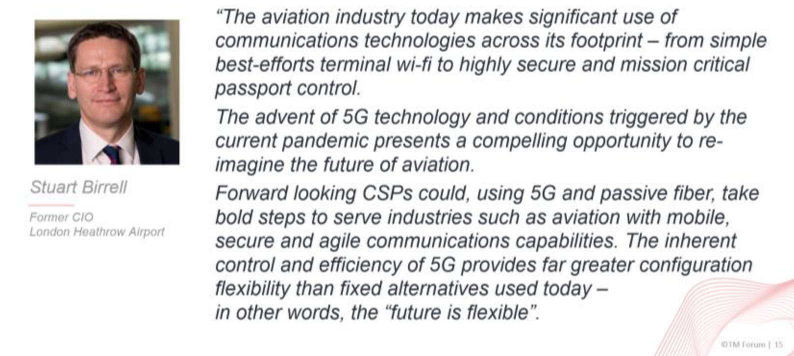


Figure 9: 5G insights from aviation experts

The first realization was the extensive use the aviation industry already makes of many forms of communications and the importance of speed, responsiveness and security. With the emergence of 5G and considering the current pandemic, there never has been a better time to re-imagine the aviation experience of the future. Part of that re-imagination should feature 5G technology quite prominently to provide the flexibility to more dynamically deploy communications intensive systems and capabilities in a quicker, cheaper and secure manner. This theme of a more flexible and secure communications within large fixed structures such as airports was key in a number of identified opportunities. As Stuart himself said, the “future is flexible”.

Based on this input and additional research, the team identified several representative scenarios to explore in this catalyst that would illustrate the opportunity for applying 5G in the aviation context. These are outlined below.

4.1. Transformation Opportunities

When we consider the holistic aviation landscape as illustrated below, there are a number of functions performed every day which would greatly benefit from the application of 5G technology and some new ones now made possible by 5G technology.

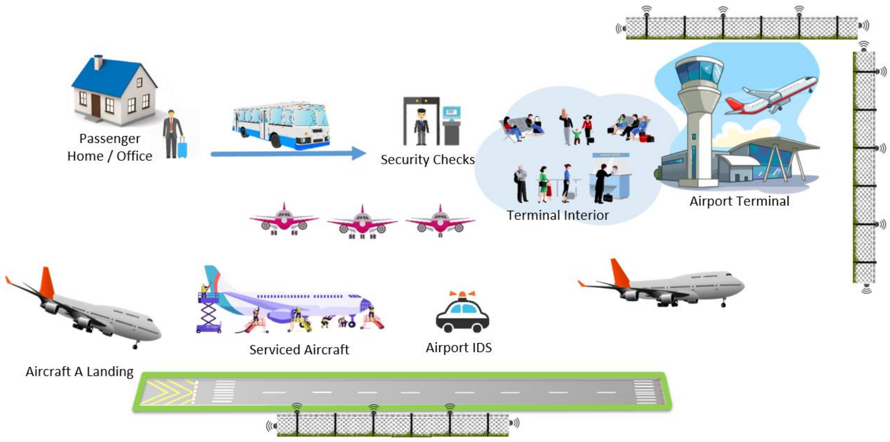


Figure 10: Illustrative aviation communication needs

4.1.1. Flexibility and Mobility of Highly Secure Systems

When we consider some of the more secure, mission critical systems in airports such as automated passport control scanners, the design employed has typically been to fix such systems in a specific location and connect to them using a fixed connection for reasons of speed, latency and security. The result is once in place, any changes to their topology tends to be costly and time consuming which is problematic given how the volume of travelers may vary dramatically over both short and longer periods. The ideal situation would be to have the flexibility to dynamically adjust the location and number of such passport control scanners to better address the passenger demand in terms of volume and distribution (between and within terminals). The benefits range from a faster and optimized customer experience to a more competitive airport able to accept additional traffic confident in its ability to effectively manage it.

Today, there really is no viable wireless option to meet these requirements. However, 5G’s latency and security characteristics provides the opportunity to employ 5G technology to untether such control scanners and similar devices from their fixed connectivity and allow airports to configure themselves far more dynamically and be able to flexibly accommodate changes in passenger volumes and distribution – the “agile airport”.

4.1.2. Airport Commute Experience

In many instances, a traveler spends more time commuting to / from the airport and transferring flights than they do actually flying. Whether they use a train, shuttle bus or a private car, customers spend an average of 45 minutes to an hour commuting each way. For business people travelling frequently by air, it is imperative that they be able to utilize such time in a productive manner.

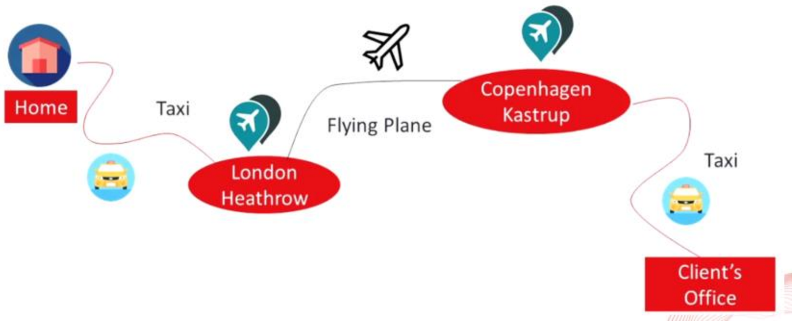


Figure 11: Representative commuting experience of business traveler.

Having ubiquitous 5G coverage en-route to airports may significantly improve traveler productivity during their trip. By having access to reliable, high-speed internet access optimized for their specific applications, travelers may continue to work and stay connected throughout their journey with a communications experience mirroring that of a virtual office.

4.1.3. Passenger Travel Confidence / Safety Experience

Figure 12: 5G-enabled areas to improve traveler safety and confidence.

The current airport, and for that matter airline environment, has highlighted the problems of overly concentrated passenger crowds that should ideally be more evenly distributed for reasonable physical distancing especially in large airport environments. We have also seen the heightened need to screen for, and identify, potentially unwell travelers to increase safety and overall traveler confidence in the aviation experience. In tandem with this, we now recognize there have traditionally been too many physical touch points during each passenger's airport experience such as check in and passport control which again could benefit from a more distributed, expedited and touchless experience.

4.1.4. Customer Engagement Experience

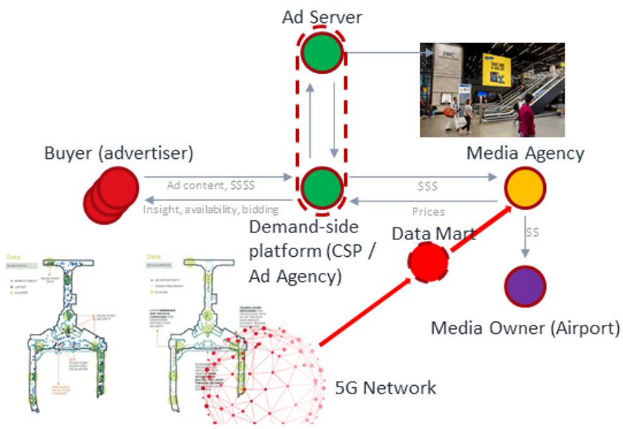


Figure 13: Programmatic advertising for digital billboards – personalized and relevant.

Another area explored in this catalyst is how airports can engage travelers through more relevant and personalized means – in particular the opportunity to enhance programmatic advertising and support more dynamic placement of advertising and informational content on particular billboards or groups of billboards of interest to that audience – based on contextual conditions such as the flight numbers, arrival times, passenger demographics, etc.

This may be enabled by leveraging secure high-speed wireless connectivity to digital billboards and between them and the advertising server for increased speed, agility and billboard mobility.

4.1.5. Personalized Inflight Entertainment Experience

Many short haul planes have already removed (or never had) video entertainment in-seat screens instead providing an in-flight wi-fi entertainment service for use on the traveler's own device. However, most long-haul flights still provide in-seat entertainment systems which adds to the complexity, cost, weight, maintenance and sometimes customer dissatisfaction when the system doesn't work.

Most travelers these days have capable personal video devices, often more so than those in the plane. However, for a long-haul flight, it is difficult or extremely time-consuming to access and rapidly download selected content in the airport before the flight (or during the flight itself) due to poor or overloaded WI-FI service.

5G technology presents an opportunity for airports / airlines / loyalty programs to offer their customers access to media entertainment (via partnerships), intuitive selection and very fast download of selected content for consumption on long haul flights. This could be performed at the airport just before boarding or perhaps in the airplane in the future (see GoGo below). This has the potential to render in-seat entertainment systems obsolete which would reduce airplane weight / cost / maintenance with cost savings across the supply chain that could be passed on to the end customer.

A potential early mover in this field, Gogo, a company which already provides Wi-Fi services for the aviation sector, is planning to launch 5G services within the aircraft[5]. Although this is still in the early stages of planning, a 5G network within an aircraft can be used both for in-flight entertainment and also air to ground network connectivity.

4.1.6. Travel Predictability and Punctuality Experience

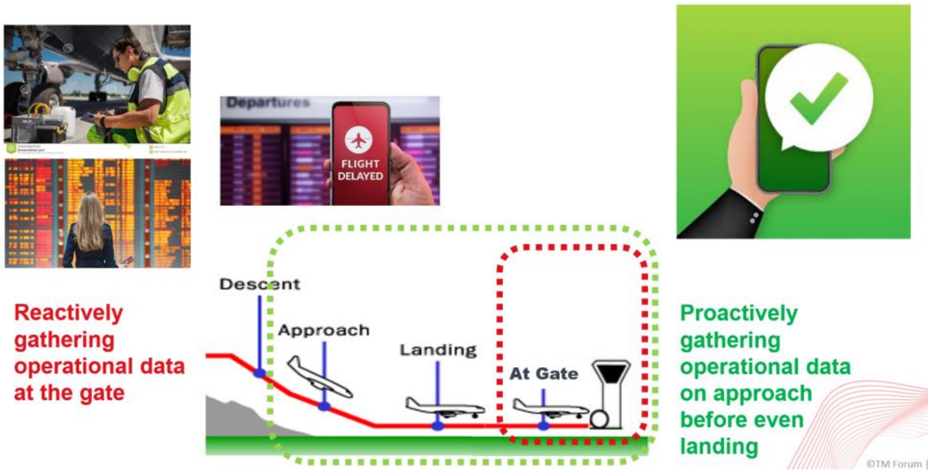


Figure 14: 5G-enabled downloading of aircraft operational data before landing for faster turnaround.

Today, it takes time for airport operations to download diagnostic data from planes at the gate before analyzing the data and undertaking any remediation work that may be required, sometimes leading to unforeseen delays to customer travel plans.

[5] Please refer to [7]

5G technology presents the opportunity for airport operations to download such information faster and earlier after an airplane lands or ideally as the airplane is approaching the airport along one of its main approach paths. This will enable the plane turnaround time to be significantly reduced which will benefit passengers with fewer missed connections and increase the competitive positioning of both airlines and airports. The cost avoidance of fewer delays across the industry is also estimated to be material to the industry.

5. Managing a Network for Aviation Industry

This Catalyst investigates the Aviation industry from a number of different perspectives, like passenger communication and entertainment, perimeter security, aircraft and land crew communication. All of these different functions within an airport require differentiated communication services, which is possible through 5G network slicing technology.

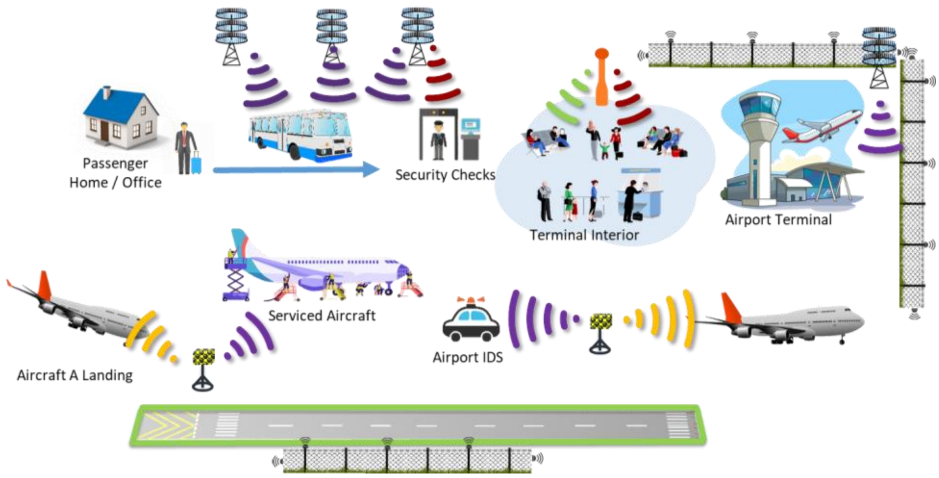


Figure 15: Network slices for dedicated functions within an airport

Different types of 5G slices are rendered through a common network infrastructure with scarce resources that need to be dynamically and optimally allocated across the slices. This requires a management system which exposes vertical use case specific communication services; orchestrates & monitors the network, slices and services being rendered; and finally charges the customers appropriately. While doing so, the management system also ensures that network infrastructure is optimally deployed in tune with rapidly changing needs and priorities.

The Aviator catalyst architecture covers key Telco management use cases that are related to providing appropriate communication services, corresponding to some of the issues and opportunities mentioned in section 4. The OSS/BSS components are provided by five organizations, and they address some of the critical functionalities. Figure 16: The Aviator High Level Architecture diagram depicts the catalyst architecture.

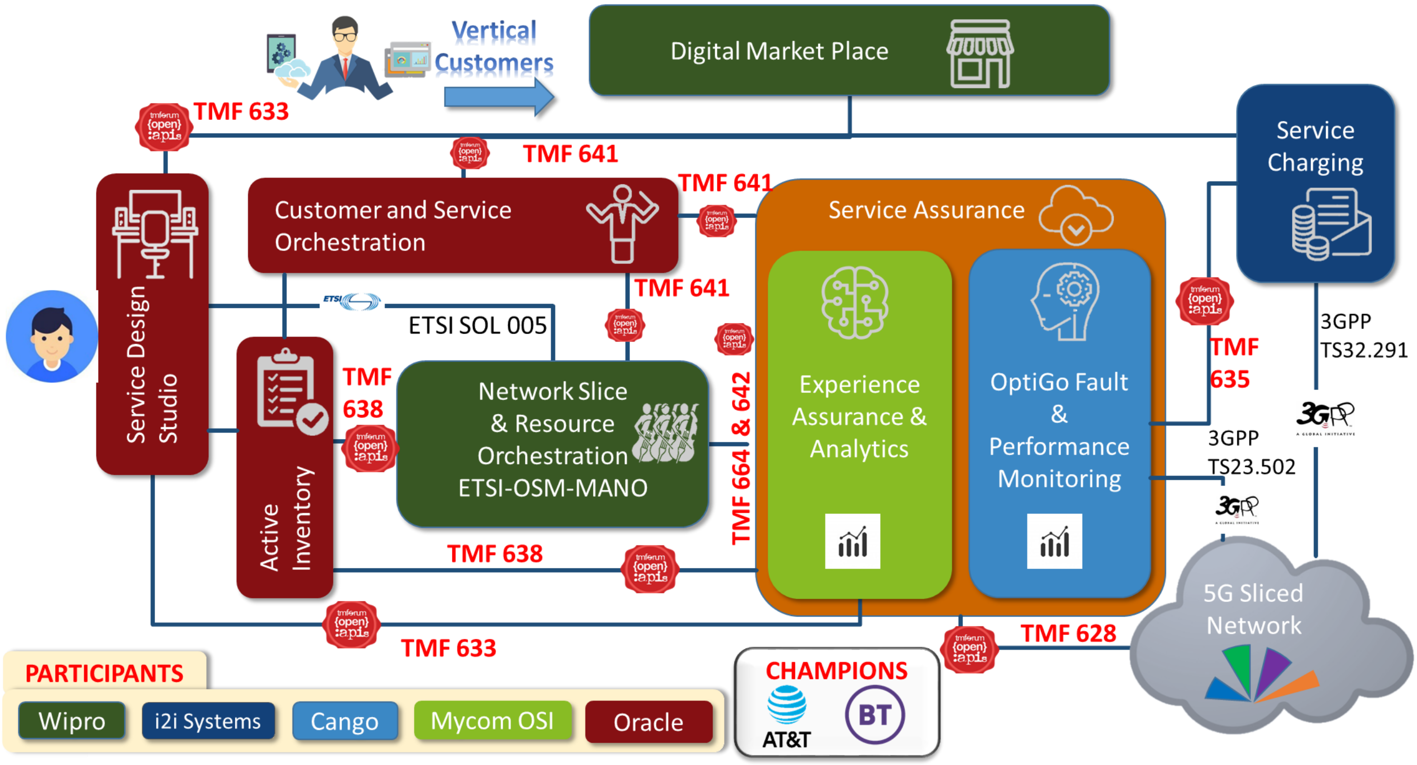


Figure 16: The Aviator High Level Architecture diagram

In order to support the 5G services effectively, traditional OSS/BSS functions had to be extended, along with architectural modifications. The extensions are related to the following aspects:

1) Exposure of communication services aligned with specific vertical industry use cases
2) Orchestration of specialized and guaranteed services in a timely manner.
3) Analysis and reassignment of business critical resources in a constrained context
4) Fulfillment of SLAs guaranteed through process monitoring and charging

Specific changes that are required in the functional areas are addressed in Section 7.1.

AI techniques have been leveraged for predicting change in demand for business critical services, and triggering closed loop mitigating actions for reassignment of constrained resources across different use cases. Additionally, network related technical KPIs that are collected at Network slice instance level, are converted to service instance specific experience KPIs by using AI techniques. This information, in turn, is utilized by the charging system to accurately enforce SLA guarantees.

As described, the catalyst leverages a number of TMF Open APIs along with ETSI and 3GPP standards. Some of the APIs were modified to cater for the management needs of predictive information processing, service guarantees, optimal resource utilization and differentiated services.

6. Catalyst Use Cases

The catalyst use cases are based on specific intents from aviation industry. Certain actions need to be taken in the communications industry in order to achieve the desired outcomes of these intents. Simultaneously, CSPs also have organizational intents such as ensuring customer satisfaction, increasing their market share and using their constrained resources efficiently and optimally. These intents are enforced through policies at different levels and the necessary information is processed and maintained through analytics. Finally, services are rendered, considering the intents of both the customer and CSP's; in such a way that while the customer's needs are met, CSP business priorities are also addressed.

From aviation industry perspective, the user story revolves around providing guaranteed high quality services to the passengers as they commute to the airport, thus mitigating loss of productive time, and in reducing the turnaround flight time, which in turn ensures reduced waiting time and uncertainty for passengers as well as better utilization of airport facilities, aircraft and crew. The overall intent is to make the air travel more attractive, safe and cost effective.

From CSPs point of view, the intent is to expand their market into vertical industries and ensure highly efficient and optimized use of limited communication resources at its disposal. This top level intent of 5G CSPs, is translated in the catalyst into specific intents of exposing vertical industry customized solutions, just in time rendition of differentiated specialized services for efficiency, ensuring service guarantees offered to the consumers and aligning allocation of services resources taking into consideration business priorities of the vertical industry, while simultaneously meeting the CSPs business goals.

6.1. UC1 – Service Definition and marketplace

6.1.1. Aviation Intent:

The aviation industry is in the throes of a transformation to make air travel, safe, secure, simple, and cost effective in its effort to attract flyers in the post-pandemic world. In this context an airport like LHR has started an airport pick-up service from surrounding cities which will operate throughout the day and allow airlines to book seats in the executive shuttle coaches for their passengers. This service will pick-up passengers from airport extension centers located in surrounding cities, where security and check-in formalities are completed. This will not only make it convenient for passengers but also decongest airports. To make it even more productive, the shuttle coaches are equipped with VR facilities on a number of seats and airlines can request activating these for their passengers. The VR facility is supported with guaranteed high bandwidth and QoS required for VR services. The CSP through a third party provides a specialized service aligned to this use case for airports.

6.1.2. CSP Context:

The CSP interacts with its highly varied customers across verticals with specified needs thorough Digital Market Place (DMP). The DMP allows CSP to offer vertical customers services which are completely aligned to specific vertical use cases. The CSP's DMP allows crowd sourcing of well aligned applications (from vertical industry expert companies) which leverage CSPs traditional communication services along with some value adds and customization. Due to this, CSPs can offer aligned services without having to gain specific expertise. In this case, the Aviation Industry communication services creator leverages CSPs communication services, created for the purpose of providing uninterrupted, high band width and 5QI value 2 service for ground vehicle.

6.1.3. Service Definition Flow

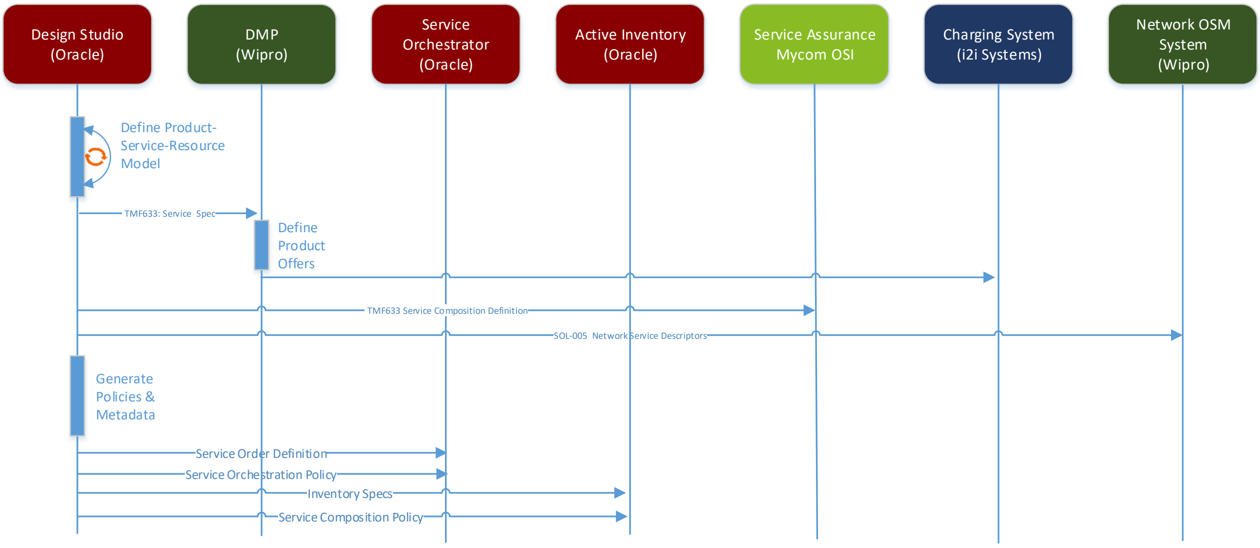


Figure 17: Service Definition Flow

For the definition of the 5G Network Slice service, a service representation is captured as a Product-Service-Resource (PSR) information model aligned with key 3GPP definitions found in TS28.51 and TS28.541. A service model supports a range of possible compositions, with the run-time choice of a specific composition for an instance driven by parameters from the Service Order and constrained by relevant network context details. The 5G Network Slice model is designed with enough flexibility to support the range of 5G Network Slice service configurations and parameters needed for the specific service instances exercised in this Catalyst. For instance, since 5QI is a dynamic parameter used in the Strategic Closed Loop use case, dynamic run-time orchestration policies must support the configuration and reconfiguration of network slice subnets to meet the requirements corresponding to the range of 5QI parameters within scope of the service.

The Product Specification from the overarching information model is used within DMP's commercial design environment as a basis for specializing, bundling with other products and applying pricing to create to create specific Product offers for the Aviation market. The Product information is used within the DMP run-time application to define the product ordering information. Key parameters such as Service Type and the 5QI value within a product offer are also shared with the Charging system.

Within the Service layer, the composition model of the service is provided to Service Assurance, where the information model abstraction drives policies used to identify network information relevant to the service. In addition, the service detail that identifies the correct network service configurations is synchronized with ETSI MANO. Within Service Orchestration itself, the Service Model is used to generate a coordinated set of policies and configurations that define the appropriate behavior of the Service Orchestration solution for the 5G Network Slice service. This includes the definition of the Service Order structure, the Service Orchestration Policy, the Inventory Specification definitions and the Service composition policy.

6.2. UC2 – Service Request

6.2.1. Aviation Intent

In this use case we have focused on a business passenger Mr. Smith, who is planning to travel to client's office in Copenhagen. He is based in BT R&D office at Crawley and books ticket for a BA flight from London to Copenhagen. While booking the ticket, Mr. Smith is offered a free shuttle service and is offered option of a VR facility during the1 hour travel to airport. This offer is extremely attractive to Mr. Smith as it does not only reduce travel cost for his company, but he can also participate in an important board meeting during his travel. He can complete check-in and security formalities at the airport pick up bay, thus avoiding long queues at the airport and also be assured that the specialized shuttle service is mechanically sanitized for his safety. In addition to the above, he is doing his bit in reducing the carbon foot print and traffic congestion by travelling in a shuttle service. Hence Mr. Smith takes up the offer VR facility.

6.2.2. CSP Context

Based on Mr. Smith serviced offered CSP need to have network slice which fulfil the need of Mr. Smith and other customers for the specific date and specific geographical area which comes under the travel route of Mr. Smith and others.

Customer order that have been submitted from the Digital Market Place are passed on to Service Orchestrator (SO) which decompose the incoming order to respective service order. It uses TMF 641 to update the charging system with the required QoS and latency and 5QI parameters. SO plays a role in orchestrating the customer order at service level and network level, interacting with Active inventory and ETSI MANO, which play an important role in instantiating and provisioning the slice and its subnet, across the respected geographical area (Coverage Area). It keeps the milestone updated to the respected systems.

In close loop automation, Service Orchestrator receives order from Service Assurance and coordinate with Active Inventory and MANO in redesigning on the services. Slices with number of respective slice subnets (Core, RAN, Transport) and network functions get created and provisioned through Service Orchestrator. The order is marked as complete once it gets fulfilled in every application as per the orchestration plan generated based on the input service order. The complete solution assures for seamless creation and provisioning of the slice, slice subnet and the corresponding network functions under different data centers. Active inventory manages the policies to allocate the virtual resources in case of all different order scenario types.

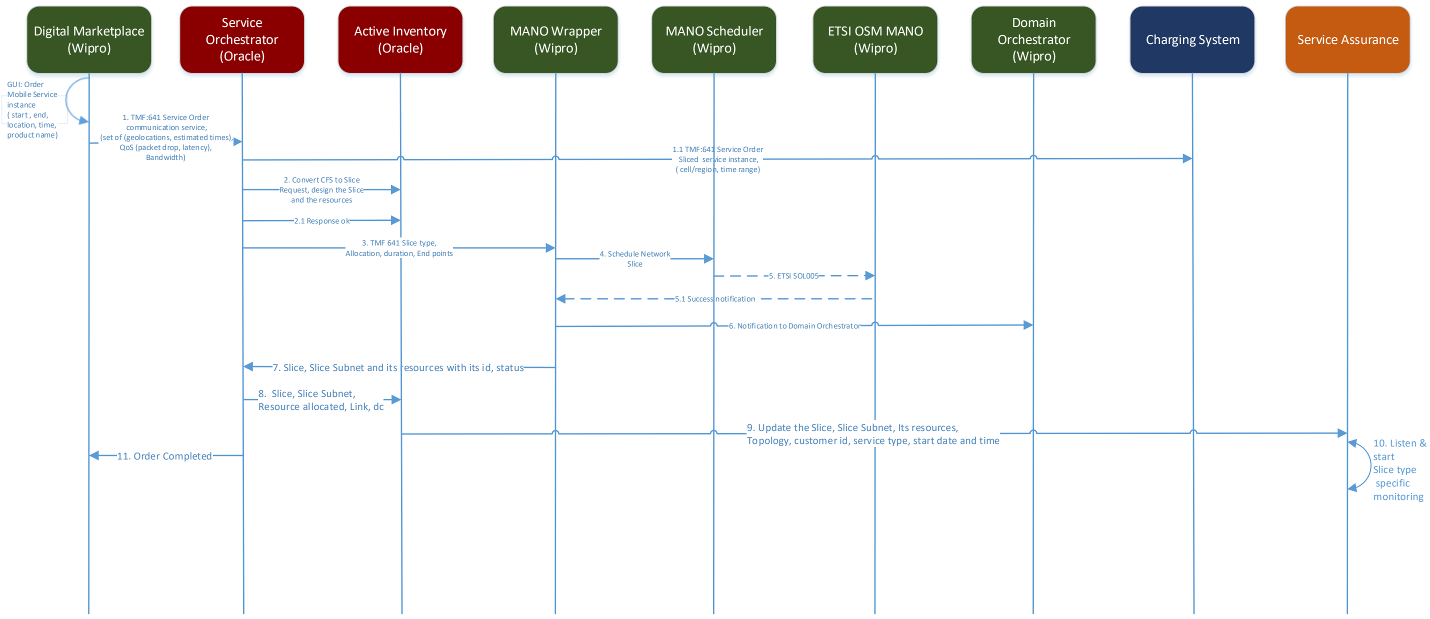


Figure 18: Service Request use case flow

6.3. UC3 – Guaranteed services

6.3.1. Aviation Intent

Use Case 3 continues the user story of the airline passenger Mr. Smith who has accepted the "Complementary high bandwidth assured connectivity" as part of the shuttle service, while purchasing the airline ticket. Mr. Smith clears the security and boarding formalities at the pickup point and is on his way to airport in the executive shuttle coach. While on the coach, he is ensconced in an enclosed seat. Due to the assured communication service availability, he is able to take up a critical meeting with his clients. The airline is assured about the high quality communication service, to its valued customers and in case of any service deterioration, it is compensated for the same.

6.3.2. Telemanagement Intent

The introduction of a premium 5G connection for a subscriber means that the service provider is committing to a guarantee of service rather than a "best effort" delivery, as the subscriber is willing to pay the extra costs associated. Assured Mobility enables the customers to stay connected to the networks efficiently for the entire journey, reimagining the mobility ecosystem with new mobility hubs, more connected, shared, autonomous slicing techniques and new strategies to reduce congestion.

In the cases where the service provider had to shift the network resources to a higher priority slice and cannot deliver the guaranteed SLA, the subscriber needs to be informed and compensated for this fault. This use case is designed to identify those cases where the service received by the customer does not meet the SLA promised by the content provider and compensate the customer.

6.3.3. Charging Flow

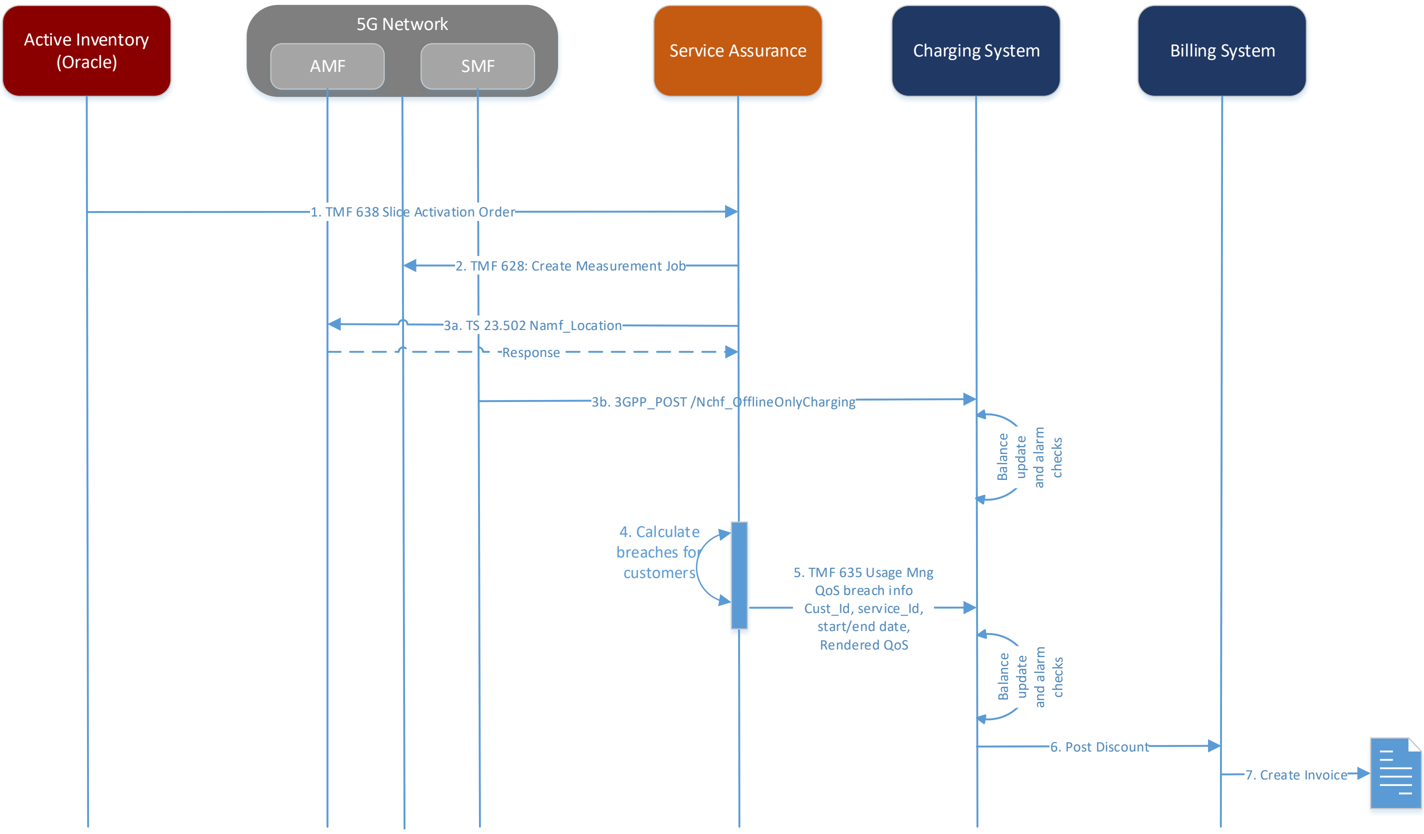


Figure 19 : Sequence flow for Use Case 3

Service Assurance ensures the Network slices are continuously monitored to provide real-time status and understanding of a given set of nodes including network connections at any given time to create a comprehensive map of a dynamic Network topology. It allows the Assurance System to dynamically monitor the Guaranteed QoS (Primarily Packet Loss, Latency, Packet Delay and Jitter) Attributes in Real Time to identify the Service Quality experienced by the Subscriber and calculate the Poor QoS Metrics in cases where the Guaranteed QoS has been breached.

When a customer registers for a network slice with a guaranteed SLA, the order is passed to the charging system with the relevant product information. As the customer uses the service, 5G network node SMF passes the usage information to the Charging system, through the Nchf interface. Although this data contains the assigned quality of service information assigned to the service being used, it does not guarantee the rendered QoS to the customer. Service Assurance system collects customer's service and usage related data from other 5G nodes and pushes the details of the usage that does not meet the promised SLAs.

Charging System is responsible for grouping and accumulating the usage data for each customer based on the network slice id and quality of service levels. These values are managed through different products that are in-line with the product catalogue. As the subscriber requests a slice usage, a one-time charge is issued to the subscriber's account to be billed in the next invoice. If, during the lifetime of the service, the subscriber cannot get the promised quality of service as outlined by the service provider, then a discount is issued. As an example, in this use case, a product with one hour of guaranteed SLA is sold to a subscriber, for an amount of $10. For each "5 minute" interval where the SLA is not met, a refund of $1 is given to the subscriber, which is shown as a discount on the subscriber's invoice.

6.4. UC4 – Orchestration

6.4.1. Aviation Intent

The aviation industry adopting digital transformations seeks for an intelligent connectivity allowing to meet the contracted SLAs but mainly maximize it overall Airport intents such as the Aircraft turn-around time which has costs implications, safety implications and simply overall passenger and staff satisfaction impacts.

6.4.2. Telemanagement Intent

The catalyst use cases around Predictive Closed Loop Orchestration illustrates how the analytics, intelligence, orchestration and inventory eco-system answer the challenge to guarantee SLA's and optimize network resources to contribute to the vertical industry intent. Given the complexity 5G networks entails, the volume and heterogeneity of vertical application/slices with varying demands, the need to predict resource congestion and SLA impacts, it will be necessary to automate the remediation or conflict management to mitigate risks and ensure 5G business scaling. Placing closed-loop automation on the way to autonomic networks requires use case focus, AI-assistance, and API evolution to increase transparency and trust across systems and network personas.

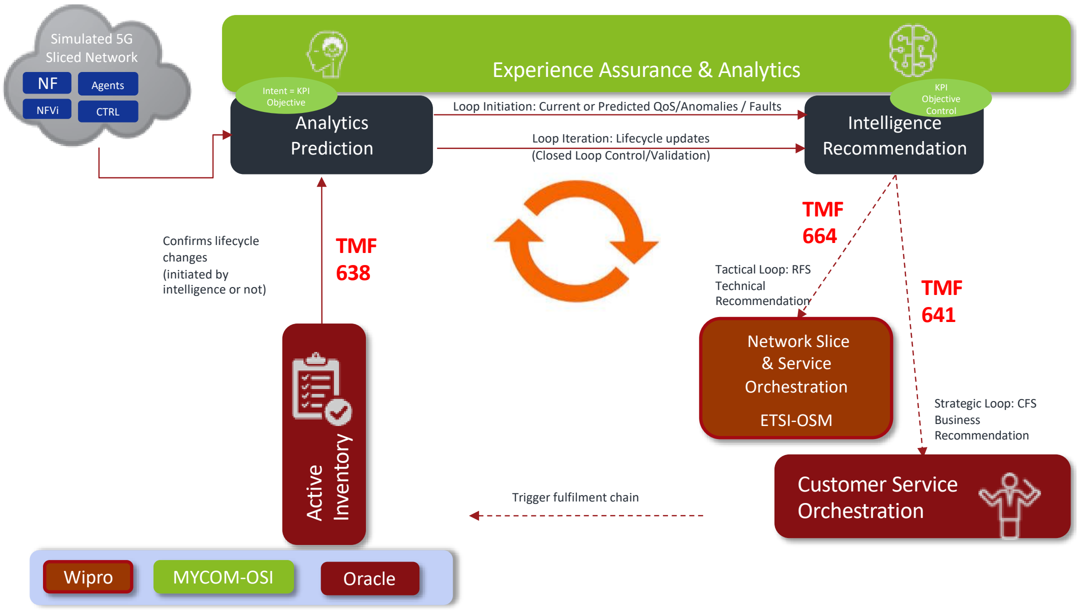


Figure 20: Closed Loop Orchestration

Two scenarios have been considered in the catalyst. First scenario is tactical and technical loops and recommendations which are prescriptive about resource allocation. Second is strategic and business loops and recommendations to modify service orders.

Our scenario is taking place at the connected Heathrow Airport where four different 5G Network slices are being used; at the busiest hour of the day where transit passenger's mobile device slices and aircraft maintenance slices are sharing the same 5G radio, transport and datacenter resources. As the situation faced here is the unusual concentration of plane activities (both landing and taking off), the intent of the closed loops in this scenario to minimize the aircraft turnaround times and SLA Impacts.

6.4.3. Tactical Orchestration Flow

The tactical orchestration flow illustrated below is initiated by a predictive anomaly on the radio cell slice entity, triggering a service intelligence loop to investigate ways of resolving the predicted congestion on the slices that have an impact on Aircraft turn-around times (10G and mMTC used for uploading aircraft maintenance and sensor data). Having identified various recommendation options for re-allocation of resources across slice instances on congested cells, the Service Intelligence system issues a recommendation using TMF664 API call(s) towards the OSM MANO acting as a network orchestrator. From this recommendation, the network orchestrator triggers the relevant lifecycle changes across the simulated orchestration stack (Domain controller, VNF Managers and VIMs). The lifecycle changes are captured and are delivered to Service Assurance /Intelligence by using TMF 638, allowing for the associated closed loop control/validation to take place.

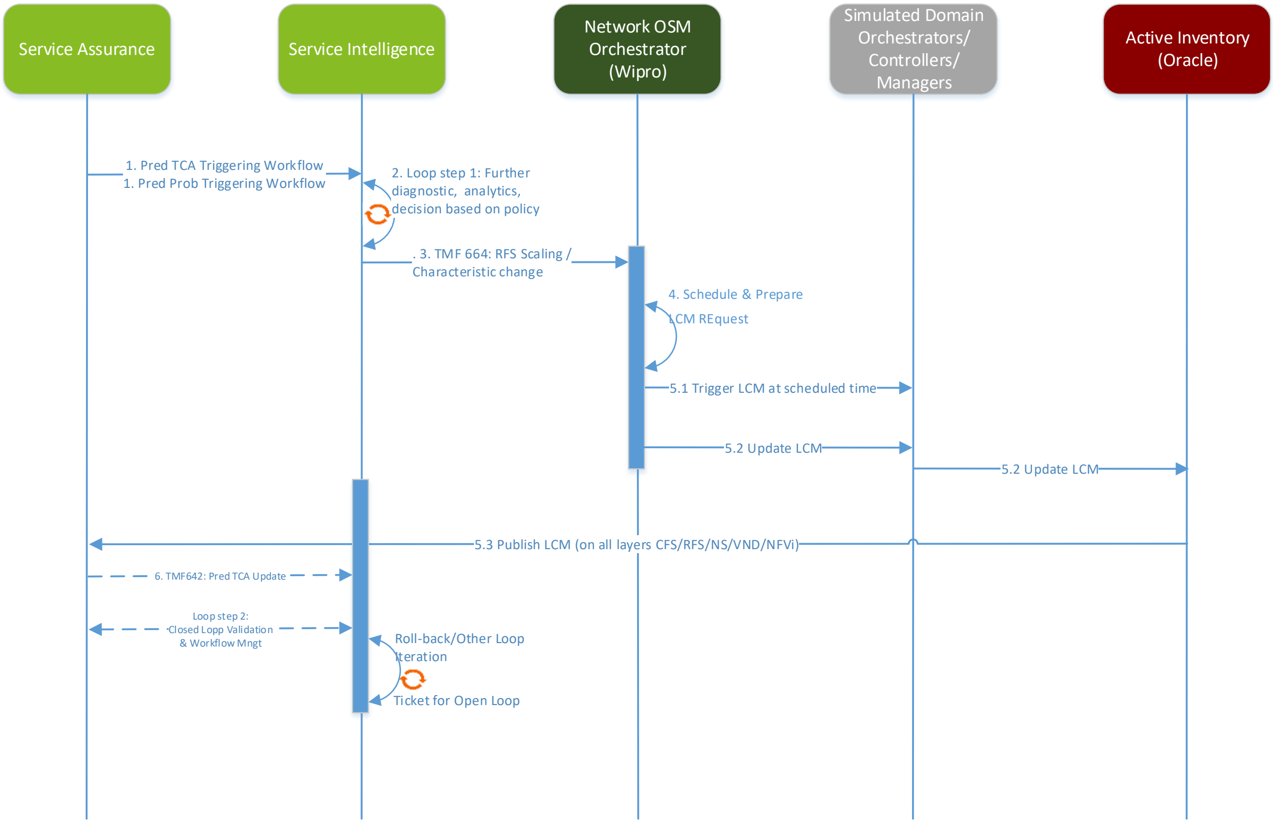


Figure 21: Tactical Loop

6.4.4. Strategic Orchestration Flow

The strategic orchestration flow as illustrated below is initiated by a predictive anomaly on the RAN Network Sub Slices entity, triggering a service intelligence loop, to investigate ways of resolving the predicted breach of intent score on the slices that have an impact on Aircraft turn-around times (10G and mMTC used for uploading aircraft maintenance and sensor data). Having identified business level recommendations, Service Intelligence sends the recommendations to the Customer Service Orchestrator for re-prioritizing SLA/5QI parameters across slices, in order to resolve the intent breach. The recommendation is issued though a TMF 641 order. From this recommendation, Customer Service Orchestrator triggers the relevant lifecycle changes across the orchestration stack (network orchestration, Domain controller, VNF Managers and VIMs). The lifecycle changes are captured and notified to Service Assurance /Intelligence using TMF 638, allowing for the associated closed loop control/validation to take place.

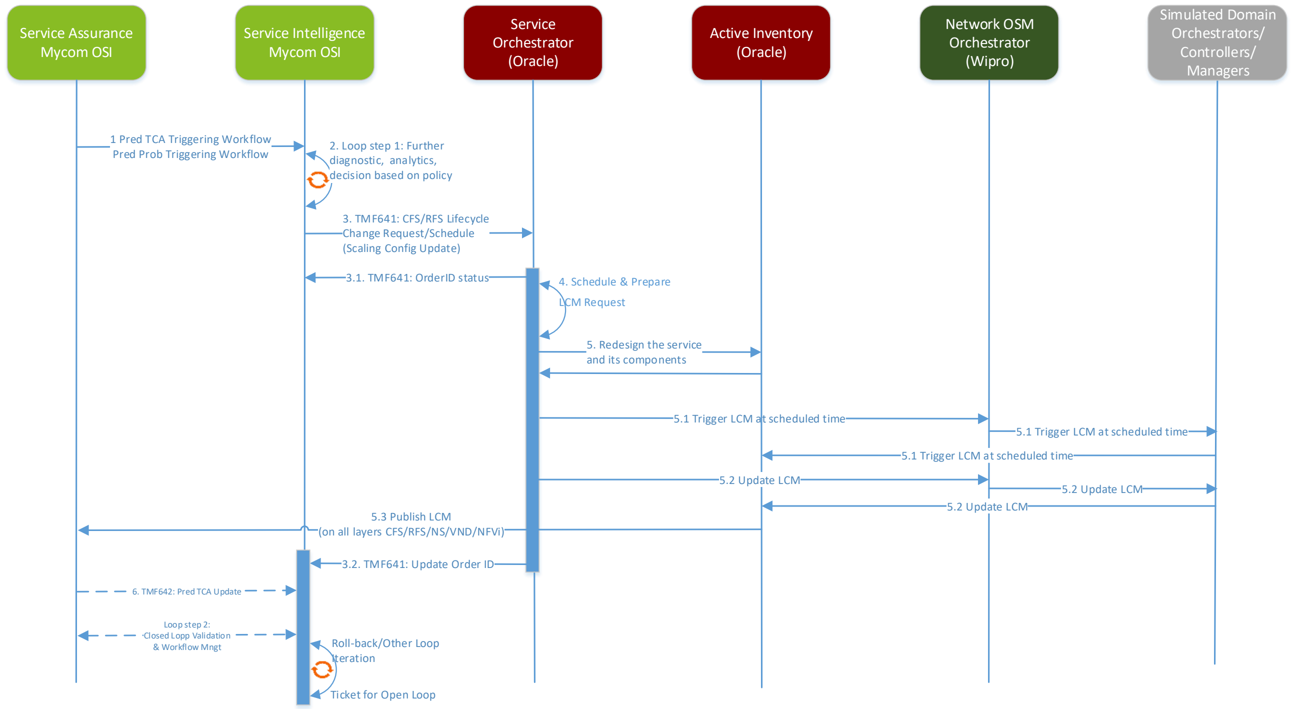


Figure 22: Strategic Loop

7. OSS/BSS Impacts Explored

5G is generally associated with low latency and high bandwidth and, to a small extend, on ultra-high device density. None of these, however, actually has significant impact on OSS/BSS. The hidden characteristics of 5G, which is the differentiated services it provides, such as guaranteed service levels, assured mobility, distinctive security etc., has substantial impact on how a 5G network is managed efficiently, to render rapidly varying communication requirements. The difference starts form the way services are designed and exposed to the way services invoiced and charged.

The catalyst explored multiple of these modifications and the following subsections address the changes form three perspectives, functionality, process and interfaces. These perspectives provide valuable inputs towards standardization that will maximize 5Gs capability.

7.1. Functional impacts

Traditional OSS and BSS management functions have been designed to monitor the operations required to provide best effort services, while efficiently leveraging underlying constrained resources network, spectrum etc. Furthermore, the target customer base has been predominantly individual subscribers and enterprise part of vertical businesses. The advent of new virtualization technologies like NFV and SDN has triggered some changes. However, these changes cannot address the twin concerns providing differentiated high quality services while optimally deploying resources. In the catalyst some of the critical management functionalities were modified and enhanced with above points in view.

7.1.1. CRM

5G's goal[6] addressing core business of Vertical industries results in multiple impacts

[6] Please refer to [9]

1) CSPs need to provide services in specific manner which is aligned to each verticals' features. This will enable early integration of new business and operational processes and automation being carried out in parallel due to the Industry 4.0 transformation.
2) Business and Mission critical application can rely on guaranteed communication services, and in case of potential they need to know ahead of time.
3) Many interactions may be machine to machine, rather than with humans and hence an API layer which provides all the services of traditional CRM layer.
4) Offering guaranteed service also means ability and willingness to expose any drawbacks encountered during rendering of service and accordingly compensating customers for any deficiency. It also means CSP must have sufficient data to handle specific disputes.

7.1.2. Service Design

Service Definitions for 5G Network Slices have been expressed in terms of an abstract information model that is used to coordinate the overall solution configuration and hence, its behavior. Different components in the solution require different subsets of this information model. Therefore, this overall information model plays an essential role when different components rely on a single consistent definition. In this catalyst, the PSR information model developed exposes not only the information required to coordinate end-to-end orchestration, but also exposes the information required to synchronize service assurance definitions with the configuration used within service inventory. This methodology highlights the benefits of a flexible modeling approach that can take into account the needs of the components defining a particular solution.

7.1.3. Orchestration

Resource and Service Orchestration for 5G Network Slices offers the Service Providers the capability to slice the shared physical, logical and virtualized resources across different layer of networks like RAN, core and transport so that they can support different industry verticals for granted SLA, latency and other parameters. Network slicing will allow Service Providers to offer guaranteed services with varying traffic flavors on the 5G infrastructure. Use cases built around are;

- Enhanced mobile broadband with two flavors (eMBB 4K and eMBB 10G) that delivers gigabytes of bandwidth used for different business needs
- Massive machine-type communication (mMTC) that connects millions of sensors and machines within a closed area of a miles or more communicating with each other
- Ultra-reliable, low latency communication (uRLLC) allows immediate transaction and with high reliability and enables real-time transaction.

Slices can be dedicated to such services to deliver on the QoS demands with associated SLAs. Closed loop orchestration enable keeping the promised SLA fulfilled for the respective services by acting on the slice and its associated resources. The Service Orchestrator keeps different systems synchronized with each other so that coordinated actions are taken for maximizing the utilization of resources and fulfilling the promised SLA.

In alignments with TMF and 3GPP the solution fulfils all three layers:

- CSMF (Communication Service Management Function) - converts the Communication Service related requirements to the network slice related requirements (such as network type, network capacity, QoS requirements, etc.). It delegates management of the network slice by providing the network slice requirements to the NSMF.
- NSMF (Network Slice Management Function) - manages the NSIs based on the network slice related requirements received. It converts the network slice related requirements to the network slice subnet related requirements. It delegates management of the network slice subnet by providing the network slice subnet related requirements.
- NSSMF (Network Slice Subnet Management Function) - manages the NSSIs based on the network slice subnet related requirements received from the NSMF.

The overall orchestration dynamically manages different slices and its subnet and physical and network function related to RAN (DU, CU-CP, CU-UP), Core (UPF, SMF, AMF) and Transport (Layer 2/3).

The complete architecture provides flexible model that allows the dynamic re-design of services, affecting only the components directly impacted, as opposed to building a completely new service instance based on a different “template”, which might require tearing down the old one entirely.

7.1.3.1 Multi-level Orchestration

5G solution requires multi-layer orchestration to support different layer of abstraction at the below layers;

- Customer layer orchestration
- Product layer orchestration
- Service level orchestration
- Resource level orchestration

Hierarchal orchestration helps in fulfilment of the service to different IT application, provisioned the services scattered across different geographical area and multi-layer network spread across logical and virtual network functions and resources. It helps in orchestrating with different and multiple controllers at the access, transport and core layer.

7.1.3.2 Closed loop Orchestration

Multilayer orchestration plays an important role in managing 5G service life cycle through close loop automation. Through close loop orchestrations system assures that slice and its respected slice subnet and resources get adjusted based on the promised made and aligned the services and resources with the promised QoS and Latency by redesigning and re-provisioning the resources at slice and slice subnet level. The proposed current architecture takes cares changes or redesigning at slice, slice subnet and even at resources level. Solution and the proposed architecture is aligned to adjust changes at granular level i.e. slice, slice subnet and resources.

7.1.4. Assurance

As per the ETSI ZSM learnings, there is a need to clearly distinguish the analytics and intelligence layers for identification of future problems, in order to receive some level of explanation on the root-causes on the analytics layer, and to identify the remediation options considering business aspects on the intelligence layer.

The use of AI assistance on both analytics and intelligence for predictions and recommendations is the key not only for the aviation industry, but

Specific to this catalyst context, access to Aviation industry vertical data is essential for predictions and recommendations for the network usage, with the aid of AI assistance on both analytics and intelligence. Additionally, privacy issues related to obtaining the aviation data should be considered for moving to Edge Computing.

5G among other things promises Guarantee of Service to end customers, for those who have opted for such an offer. This means that individual customer service instances need to be monitored and assured, and in case of any violation, customer needs to be transparently informed and compensated. Monitoring individual service instances is a humungous task and will require collection of data which may cause privacy issues.

7.1.5. Charging

The minimal requirements for slice charging can be supported currently with the standard charging and billing systems, however in order to provide a more flexible, experience based charging, changes may be required.

Charging functionalities are discussed in three different aspects; charging of the maintenance and support of the slice for verticals who require a dedicated slice; charging of access and SLA management for the slice which would be applicable for the subscribers accessing the slice; and lastly revenue sharing related with the access of a slice.

The Vertical Slice Owner can be charged for the slice with a standard recurring charge, with different tariffs for each pre-created network slice and add-ons for optional services such as V2X, or MMTel Support. However, the pricing for a made-to-order slice can change based on the requirements of the customer and may not be available in advance. One of the two options can be used in this case:

1. When a new slice is requested, Marketing team will provide a charge for this slice and a specific tariff will be created to charge the specific slice owner.
2. For pre-defined slices created for verticals such as Aviation, Automotive, Energy, etc., specific recurring tariffs will be defined. There can be more than one recurring tariff created for any vertical, if there is a requirement to differentiate charging for some of the parameters. Consider the following example, where the recurring charges are assigned based on the vertical and the number of connections included in the slice.
   Different sub-tariffs can be created in advance for each of the chargeable network characteristic. For example, different ranges for “Number of Connections” or “Downlink/Uplink Throughput” parameters may have each have a specific tariff, and based on the selection of the slice owner the appropriate tariff may be assigned to the product. The total charge for the network slice can be the aggregated charge of all the sub-tariffs. Additionally, recurring charge intervals may need to support shorter recurring cycles such as days, hours or even minutes.

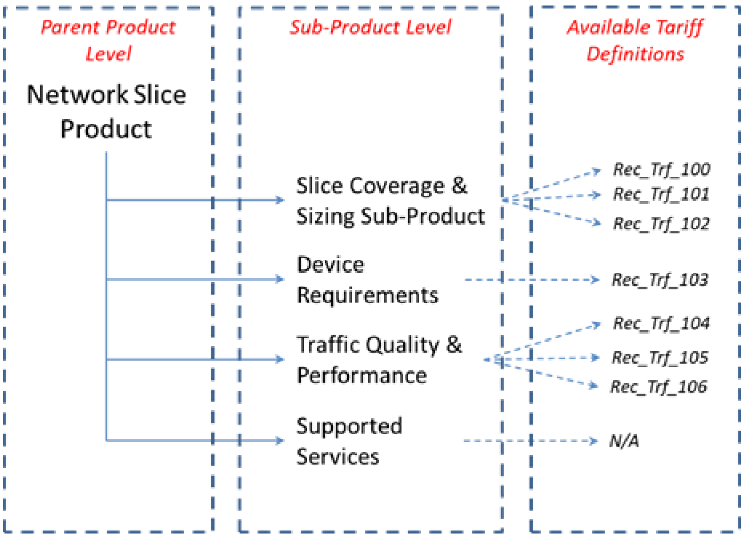


Figure 23: Product, Sub-product and Tariff Eligibility

Charging for the access of the network slice will require new parameters to be included in the tariff structure. For example, QoS parameter which has not been used as a price differentiator until now will be an important input for network slice access charging and SLA Management. These parameters are already made available in the usage details received from 5G network nodes, and on the BSS side, they should be passed in as product characteristics from the product catalogue at the time of sales so that a baseline value could be set for each customer. The characteristics to be used for rating purposes should be agreed by CRM and Billing systems mutually.

Service Provider can also manage a slice for a content provider, such as a user accessing the online entertainment service in an airport slice. In such a case, the user may be billed by their service provider, however, as the content is being delivered by the airport, it would require a revenue sharing agreement between the content provider and the service provider. The content provider is actually giving the service and the service provider is acting as the enabler for the user to access the slice. A usage event received for the particular slice has to be guided both to the user’s account, and the slice owner’s account.

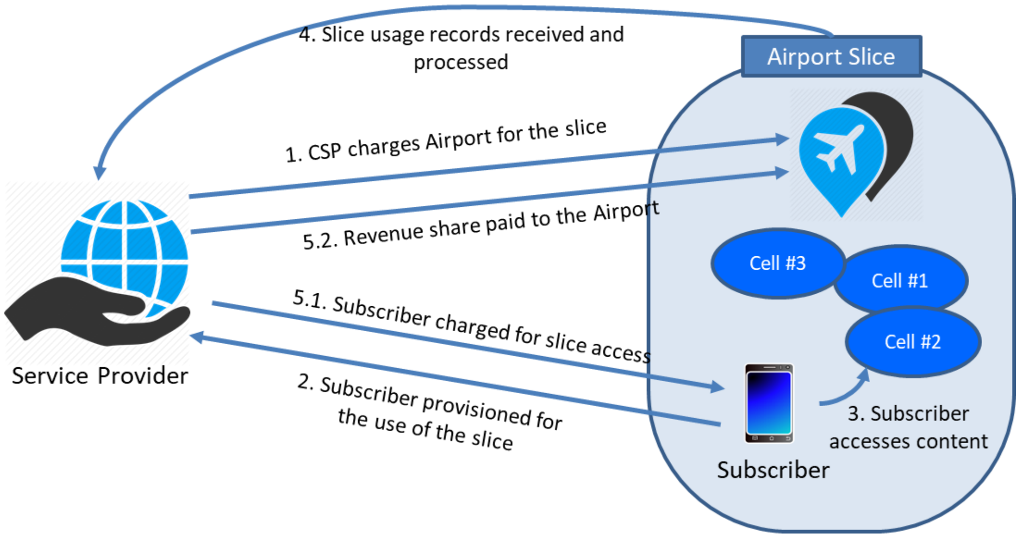


Figure 24: Revenue Sharing model between CSP and slice owner

7.2. Management Process Impacts

Technical use case wise (Process level change rather than a functionality of a component. No functionality talked, refer to the use cases).

7.2.1. Designing and Exposing of 5G Services

As the CSPs venture into the new Vertical Industry Markets, the need to expose 5G services that are precisely aligned to specific use cases brings in additional complexity as well as new opportunities. The 5G's ability to dynamically slice the network into multiple logical networks, each with its own QoS policies, admission, retention and bandwidth arrangements, is the key building block towards providing differentiated and aligned services.

However, the story does not end with 5G slicing, as this only provides us the technical aspect. This flexibility needs to be cascaded to the final consumers to be used as part of their critical operations, who are not in the habit of relaying on "best effort" communication services that have been delivered until now. In order to attract the new market, communication services not only need to be technically capable, but also be easily consumable by the verticals. This requires exposing services in alignment with specific use cases, which in turn, implies a good knowledge of operations related to the use case. Additionally, CSPs also need to consider ongoing transformations that are taking part in another vertical simultaneously. Considering the vast variety of use cases, it is almost impossible for CSPs to create such highly aligned services. In this catalyst, we propose leveraging of market place to the full extent where not only a variety of products are sold, but also variety of solutions created through crowd sourcing of 3rd parties, to provide a rich offering across industry segments.

7.2.2. Orchestrating assured 5G Service

5G Service is all about the assured and promised services for the customers. It's about providing eMBB, uRRLC, mMMTC with the specific QoS and latency throughout the period of service life cycle. To fulfil this promise, the entire architecture of IT system should be modified in a way where dynamic orchestration enables the re-design either at slice level, slice subnet level or at resource level. Below are the points which has been considered in the given architecture and solution.

- Real-time on-boarding and validation of different flavors of slice on the Service Provider environment
- Automating the design, instantiation, configuration and provisioning of network services and their respected resources as VNF and PNF, including all Edge, Regional and National level Data Centers across multiple domains and in multi-vendor scenarios
- Providing scaling and healing based on application specific knowledge

- Monitoring application and infrastructure alarms across different domains, and enabling policy and intelligence based automated self-healing
- Using strategic loops in case of re-designing the services which can have impact at slice, slice subnet or network function level
- Providing an inventory for a real-time topology and service design; while assigning capabilities for physical, virtual and hybrid customer services across multiple domains and through different levels such as RAN, Core and Transport layers.

7.2.3. Prioritizing resource contentions

The key in the notion of intent is typically the link between the monetization of SLAs that the CSPs will be able to get from value-added connectivity of 5G slicing, and the strategic and operational policies of the CSPs for optimizing costs and efficiency. In a fully autonomous network, intents need to be modelled as early as the design-time, scored in run-time and mapped onto actions which have global positive impacts to drive automation policies or tune autonomous agents' behaviors.

As intent modelling captures the subscribers' or aviation industries' interests, as well as the CSPs strategy to balancing SLA guarantees associated to network slice services against giving priority to all services that have a positive impact on turn-around times of aircrafts, conflicts can be resolved either at the technical level when there is no contention or at the business level (degrading SLAs) when there is contention

7.2.4. Monitoring and Charging of Guaranteed services

Assured Mobility enables the customers to stay connected to the networks efficiently for the entire journey, reimagining the mobility ecosystem with new mobility hubs, more connected, shared, autonomous slicing techniques and new strategies to reduce congestion. Network slices are continuously monitored to provide real-time status and understanding of a given set of nodes including network connections at any given time to create a comprehensive map of a dynamic Network topology.

Offering Automated Correlation to analyze collected data and to determine the impact and root causes of problems. It supports continuous closed loop feedback to automatically optimize and to fix performance issues or service failures by raising Alarms.
The Service Assurance System gets the KPI data from Node level, Port level, device level post which we perform arithmetic calculation to get service specific KPI's which are rolled up to Network Sub slice level further to Network Slice level based on the geospatial information from customer movements. It maintains a dynamic relationship between Network Slice instances, Network sub slices and Network services below which the NE has the Network services connected at port level so any level of service information can be drilled down into the network to find the exact RCA of the issue.

The Assured Mobility also generates data for the cases where the RCA cannot be analyzed and corrected at the right time, customers may be compensated for the low quality service they have received. By monitoring the customer KPI's received, Assurance triggers records towards the charging system for monitoring the duration or the volume that needs to be compensated to the customer, according to the rules stated in their contracts or product specifications.

7.3. API Impacts

For each API

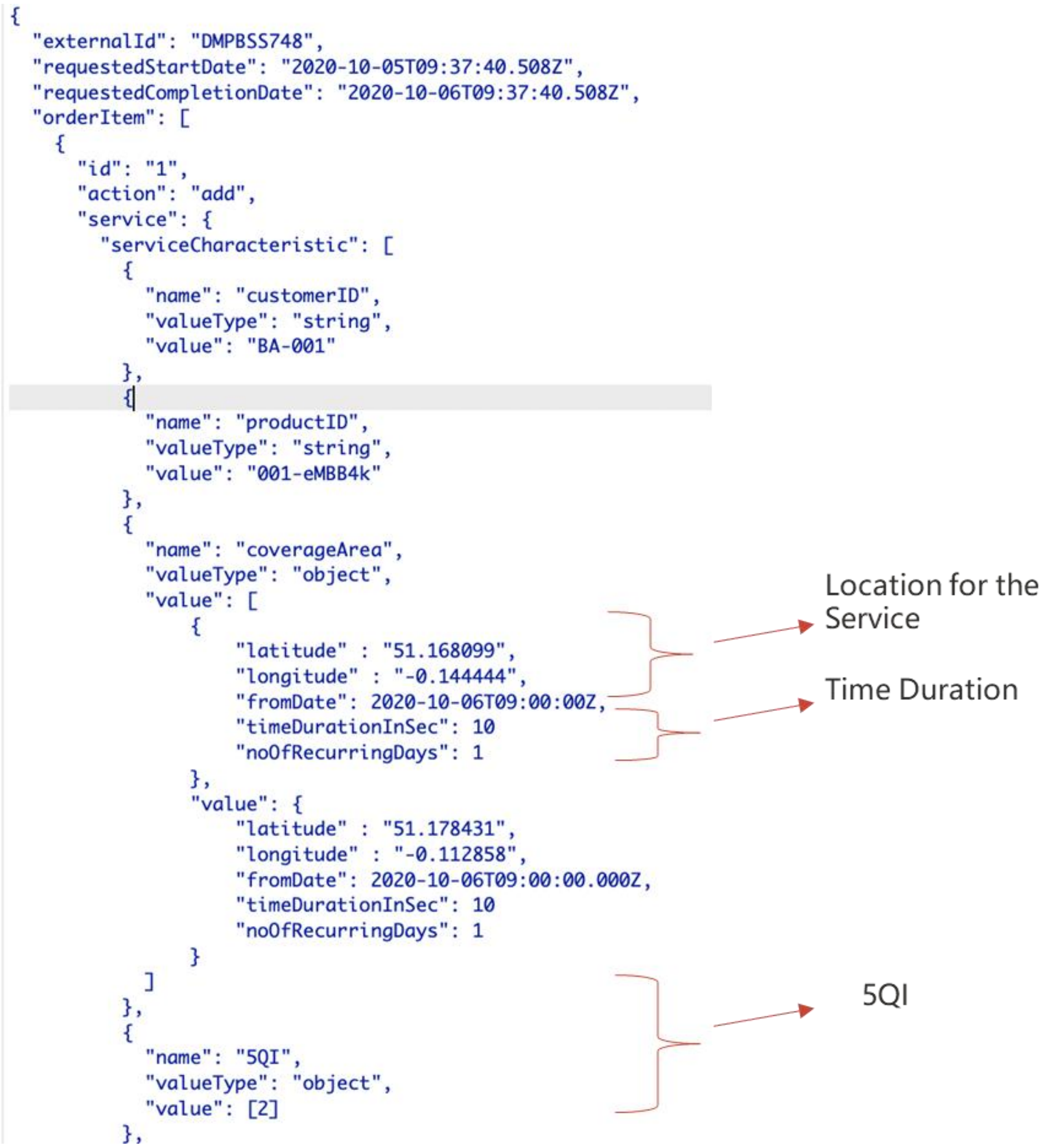
7.3.1. TMF 641

Industry verticals leveraging 5G services expect guaranteed communication services for their business critical needs. In case the service is to be consumed by UEs that are on the move, it is expected that the CSP is able to guarantee connectivity at the required bandwidth and QoS, throughout the duration of mobility of the UE. Currently, various mechanisms are being explored at the network level to provide guarantee of service for UEs on the move. The movement of a UE for a given business critical purpose should not be limited to communication industry conceptual boundaries like cell, tracking area, region etc. that are not the geographical boundaries pertinent to the vertical business scenario.

While business critical applications of verticals pose the above complexity, there are some mitigating factors. Unlike subscriber movements which can be quite random, mobility in business world can be well planned and many a time known ahead of time. For example, for an ambulance service, the route to the nearest appropriate hospital is known as the ambulance starts its journey. Similarly, the movement of cash delivery van is agreed prior to the departure of the vehicle. This fact can be exploited by the communication system to optimally allocate its constrained resource and give guarantee, without having to over provision. This is fundamental in the 5G world, as existing physical resources are bucketed into slices with different QoS characteristics and in spite of virtualization, reallocation times (which is minimum few seconds) are much higher than the time to perceive service disruption (tens of milliseconds).

Hence, it is critical to order service instances with as much accurate information as possible, with desired service characteristics, expected location and time of the UE. With this in mind, TMF 641 Service Ordering API should include the below proposed functionality for 5G services:

1. Capability to provide expected start time and duration of the service. This will enable CSP to allocate resources for a fixed amount of time (possibly with some buffer) and efficiently manage resources taking future demand into consideration. It will also enable CSPs to guarantee resource availability for requests ahead of time.
2. Capability to specify a set of locations to indicate expected movement of the resource, along with expected duration of time the presence of the UE at that location.
3. Since the same QoS and Service Characteristics are required during the entire journey, the service characteristic information for every service order (we will need multiple service order for each location and time duration) is proposed to be extracted into common part of specification.
4. The sequence of service orders is inter-dependent and this needs to be specifiable in the API explicitly.



```
{
  "externalId": "DMPBSS748",
  "requestedStartDate": "2020-10-05T09:37:40.508Z",
  "requestedCompletionDate": "2020-10-06T09:37:40.508Z",
  "orderItem": [
    {
      "id": "1",
      "action": "add",
      "service": {
        "serviceCharacteristic": [
          {
            "name": "customerID",
            "valueType": "string",
            "value": "BA-001"
          },
          {
            "name": "productID",
            "valueType": "string",
            "value": "001-eMBB4k"
          },
          {
            "name": "coverageArea",
            "valueType": "object",
            "value": [
                {
                    "latitude" : "51.168099",
                    "longitude" : "-0.144444",
                    "fromDate": 2020-10-06T09:00:00Z,
                    "timeDurationInSec": 10
                    "noOfRecurringDays": 1
                },
                "value": {
                    "latitude" : "51.178431",
                    "longitude" : "-0.112858",
                    "fromDate": 2020-10-06T09:00:00.000Z,
                    "timeDurationInSec": 10
                    "noOfRecurringDays": 1
                }
            ]
          },
          {
            "name": "5QI",
            "valueType": "object",
            "value": [2]
          },
```


7.3.2. TMF 635

Messaging between the Charging System and SMF has been based on the 3GPP 5G API sets, mostly on TS32291 Converged Charging API. As for the messaging between Service Assurance and Charging System, TMF635_UsageManagement API has been used. This API has been based on a name – value pair structure, and although it suffices for the purpose of the implementation in our catalyst, it lacks a few important points:

- It assumes that the source system is aware of the role and id of the user. However, in some cases the source system may not be aware if the user is a customer or a supplier or it may not be aware of the id assigned to the user in the charging system. Instead, user name or MSISDN or any other network level identifier may be used to differentiate the user
- It also assumes that this API is mainly used between the Charging System and the Billing System, however it is possible to use it between different IT systems as we have done in our catalyst
- For each usage record, there may be multiple sub-parts that affect the charging, hence create sub-records for the same usage event. For example, for a single data session, the charged amount may change as the user moves between different web pages – Facebook usage might be free while streaming will be charged. Although all this information will be included in one singe data usage record, there should be subsections within the record to differentiate these usages.

In order to merge the above points with existing TMF design, the following structure is proposed. TMF resources used in this design, with the corresponding change proposals are as follows:

- Main body, Usage resource: In addition to the current fields already existing in SID, the following fields are proposed to be added to this resource
    - sequenceID
    - partailSeqID
    - originatingHost

  Note that “Place” information on this resource has been moved to Usage Specification sub-resource, as there may be multiple locations associated with the usage.
- usageSpecification sub-resource: In the current SID model, this resource is defined as a set of characteristic values, however there are some specific attributes that need to be defined in each usage. Thus, it is proposed that these are added to the sub-resource, as defined below.
- ratedProductSpecification is a type of Product Specification and it is proposed that minor changes are to be made to this resource (such as having multiple taxes associated with the usage, discount codes and amounts to be added etc.)

7.3.3. TMF 664

It is necessary that intelligence and automation layer issues recommendations to Network orchestration entities as part of AI and rules-based workflows. Within this catalyst, an extension of the TMF664 Resource fulfillment was considered in order to provide

- Ability to pass multiple actions on possibly different sub entities of the main target
- Ability to pass multiple recommendation options

The following specific additions were added in the payload example given below

- New attributes in TMF 664 payload
    - targetType to describe the entity type
    - numberOfOptions to describe number of recommended options
    - type needs a new enumeration: ‘Scaling Recommendations’
- New Structures
    - Options [] which has an id and description attribute and contain actions structure
    - Actions [] which contains the main attributes TMF 664 has today (except the schedule which is for all options and actions

The ability to pass prediction contexts (time, accuracy) or other information that assists the orchestrator to determine the options was not covered here.

```json
{
  "id": "RemediationOptionsForTATImpactingSlices-1",
  "target": "BTCM1101",
  "targetType": "5G_NRCell",
  "numberOfOptions": "2",
  "description": "RemediationOptionsForTATImpactingSlices",
  "type": "Multiple Scaling Options Recommendations",
  "href": "http://localhost:8080/5G_NRCell",
  "schedule": [
    {
      "id": "SC001",
      "action": "later",
      "StartTime": "2020-05-28T10:30:00Z",
      "Duration": "30min",
      "href": "http://localhost:8080/SC001"
    }
  ],
  "Options": [
    {
      "id": "Option1",
      "description": "4K IMPACT ONLY KEEP MAX UE",
      "Actions": [
        {
          "id": "Action1",
          "target": "BTCM1101-SS-RF-11",
          "targetType": "5G_NRCellSlice",
          "description": "Scale-up on eMBB-10G allowing more UE",
          "type": "Scale Up",
          "aspectId": "Max_UE",
          "href": "http://localhost:8080/5G_NRCellSlice",
          "numberOfSteps": "1",
          "additionalParams": [
            {
              "name": "Max_UE",
              "value": "14"
            }
          ]
        },
        {
          "id": "Action2",
          "target": "BTCM1101-SS-RF-21",
          "targetType": "5G_NRCellSlice",
          "description": "Scale-up on eMBB-sensor allowing more UE",
          "type": "Scale Up",
          "aspectId": "Max_UE",
          "href": "http://localhost:8080/5G_NRCellSlice",
          "numberOfSteps": "1",
          "additionalParams": [
            {
              "name": "Max_UE",
              "value": "700"
            }
          ]
        },
        {
          "id": "Action3",
          "target": "BTCM1101-SS-RF-01",
          "targetType": "5G_NRCellSlice",
          "description": "Scale-down on eMBB-4K reducing Max UL / DL per UE",
          "type": "Scale Down",
          "aspectId": "Throughput",
          "href": "http://localhost:8080/5G_NRCellSlice",
          "numberOfSteps": "2",
          "additionalParams": [
            {
              "name": "Max_DL_Throughput_UE",
              "value": "8.5 Mbps"
            },
            {
              "name": "Max_UL_Throughput_UE",
              "value": "1 Mbps"
            }
          ]
        }
      ]
    },
    {
      "id": "Option2",
      "description": "4K ONLY KEEP DL QOS DOWNGRADE MAX UE",
      "Actions": [
        {
          "id": "Action1",
          "target": "BTCM1101-SS-RF-11",
          "targetType": "5G_NRCellSlice",
          "description": "Scale-up on eMBB-10G allowing more UE",
          "type": "Scale Up",
          "aspectId": "Max_UE",
          "href": "http://localhost:8080/5G_NRCellSlice",
          "numberOfSteps": "1",
          "additionalParams": [
            {
              "name": "Max_UE",
              "value": "14"
            }
          ]
        },
        {
          "id": "Action2",
          "target": "BTCM1101-SS-RF-21",
          "targetType": "5G_NRCellSlice",
          "description": "Scale-up on eMBB-sensor allowing more UE",
          "type": "Scale Up",
          "aspectId": "Max_UE",
          "href": "http://localhost:8080/5G_NRCellSlice",
          "numberOfSteps": "1",
          "additionalParams": [
            {
              "name": "Max_UE",
              "value": "700"
            }
          ]
        },
        {
          "id": "Action3",
          "target": "BTCM1101-SS-RF-01",
          "targetType": "5G_NRCellSlice",
          "description": "Scale-down on eMBB-4K reducing Max UL per UE and Max UE",
          "type": "Scale Down",
          "aspectId": "Throughput, Max_UE",
          "href": "http://localhost:8080/5G_NRCellSlice",
          "numberOfSteps": "2",
          "additionalParams": [
            {
              "name": "Max_UL_Throughput_UE",
              "value": "1 Mbps"
            },
            {
              "name": "Max_UE",
              "value": "180"
            }
          ]
        }
      ]
    }
  ]
}
```


8. Leveraging Telecom Standards and Open Source Frameworks

The catalyst covers multiple management aspects and leverages different architectures, opens source solution and standards and concepts. Some of these were designed for pre 5G time, so apart from compliance, the ensuing sub sections provide information on enhancements and modifications that were considered necessary

8.1. TMF ODA

Please see below the mapping of the Catalyst functional blocks considering the ODA Functional Architecture as defined in IG1167_ODA_Functional_Architecture_v5.0

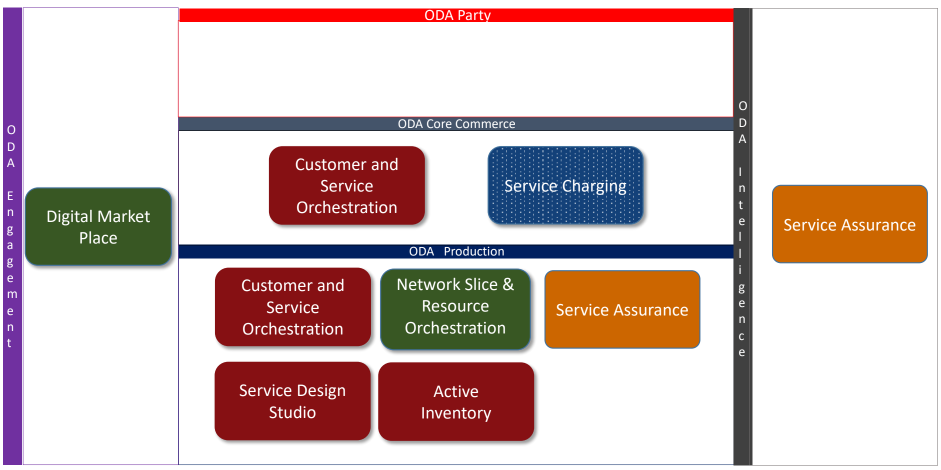


Figure 25: TMF ODA mapping in the Catalyst

The various systems involved in the catalyst are part of the ODA Engagement, Core Commerce, Production and Intelligence:

- **ODA Engagement:** The digital marketplace allows for the enterprise consumers such as aviation vertical partners/customers to order communication services from the ODA Core Commerce functions
- **ODA Core Commerce:** The 'Customer and Service Orchestration' function combined with the service charging function enable activities related to profitable exchange of goods and services specifically in context of the Catalyst for
  - Order Handling, from Order Capture & Configuration to the global orchestration of the Customer Order Delivery
  - Rating of any types of charges and Bill items Calculation
- **ODA Production**: The Production Block is responsible for the delivery and lifecycle management of Customer Facing Services (CFS) and Resource Facing Services (RFS) regardless of the technology type (e.g. physical, virtual, connectivity, end point, etc.) or the operational domain or factory where it originates, including third parties. In context of the Catalyst
  - The 'Customer and Service Orchestration' handles the CFS level lifecycle management and service capability exposure to the ODA Core Commerce and ODA Engagement coordinating and integrating with other ODA Production functions (Service Design Studio, Active Inventory, Network Slice Orchestration and Service Assurance)
  - The 'Network Slice and Resource Orchestration' handles the RFS lifecycle management and service capability exposure to the CFS ODA Production layer coordinating and integrating with other ODA Production functions (Service Design Studio, Active Inventory, Resource/Domain controllers and Service Assurance)
- **ODA Intelligence:** The Service Assurance function as part of the catalyst covered slow control loop for managing Vertical Intent and SLA driven tactical and business centric loops while coordinating with ODA Production functions (CFS / RFS Orchestration), specifically the following loop categorization were explored
  - Tactical loop providing a RFS level technical / prescriptive recommendations to RFS Orchestration using the TMF 664 API
  - Business Loop: provide a CFS level business / prescriptive recommendation to CFS Orchestration using the TMF 641 API

8.2. 3GPP

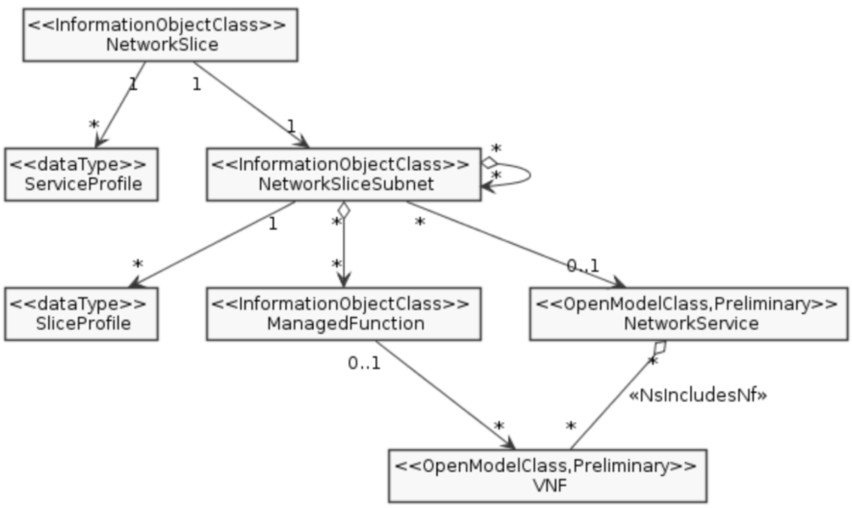


Figure 26: TS28-541 Network slice NRM fragment relationship

The Network Slice provides a strong CFS abstraction under which a single RFS Slice Subnet anchors the common technical aspects of a second layer of Slice subnets, which are represented as RFSs specialized at RAN, TN or Core Slice Subnets. Each Network Slice Subnet is then expressed in terms of a Network Service composed of specialized VNFs.

8.3. ETSI OSM MANO

ETSI Open Source MANO (OSM MANO) is an open source flexible network service orchestrator, adaptable in handling versatile network functions and environments.

OSM MANO offers the end-to-end lifecycle management of hybrid network functions like VNF's, PNF's, KNF's and CNF's in multi-VIM and multi-site environment. The switch from VM based infrastructure to cloud native functions in 5G has amplified the performance and operational efficiencies of the systems by 10 folds. Therefore, OSM MANO new releases supports more than 20,000 cloud native functions to provide an end-to-end communication service.
OSM MANO acts like a slice manager and administers the lifecycle of a network slice.

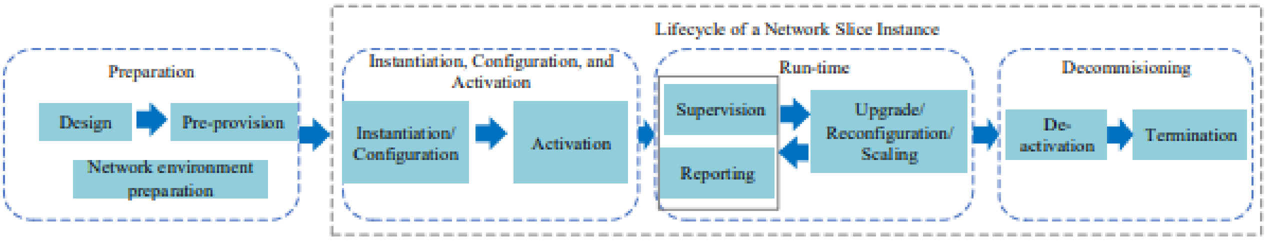


Figure 27: OSM MANO Architecture and customizations introduced for supporting TMF 641

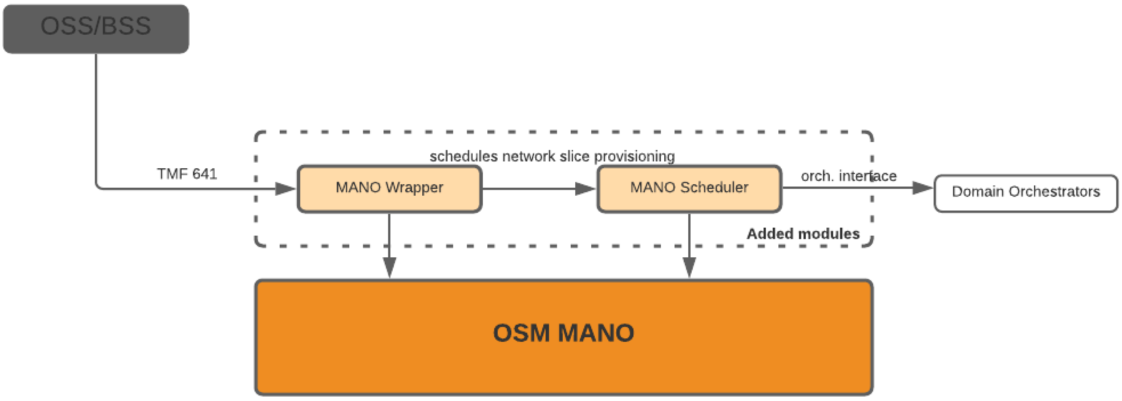


Figure 28: OSM MANO Extensions

OSM MANO is 5G complaint, which provisions and supervises network slicing across the vertical lines, programmable to develop interfaces and plugins across domains, by providing the different levels of abstractions, automation using DEVOPS and service assurance by monitoring, and creating customizable dashboards by systems like Prometheus, Grafana, and ELK stack for log monitoring.

It supports integration with external components through NBI (northbound interfaces) with RBAC policy definitions, are SOL005 complaint for OSS/BSS integration and provides subscription and notification for NS lifecycle events.
The interface implementation in a wrapper allows co-ordination between various domain orchestrators and invoked at the scheduled time to enable the desired network slice for the consumer. Therefore, OSM MANO is very promising and maturing each day with increasing list of contributors and reviewers by sharing insights and feedbacks in the community and Hackfest events. Advanced 5G use cases, micro-service Kubernetes based orchestration and network slicing and its security considerations are the topics being discussed presently for the upcoming releases of OSM MANO.

8.4. ETSI- ZSM

Below is a mapping of the Catalyst building block on the ZSM Observe Orient Decide and Act closed loop model. ETSI ZSM is working on enabling zero-touch automation within the Production Block.

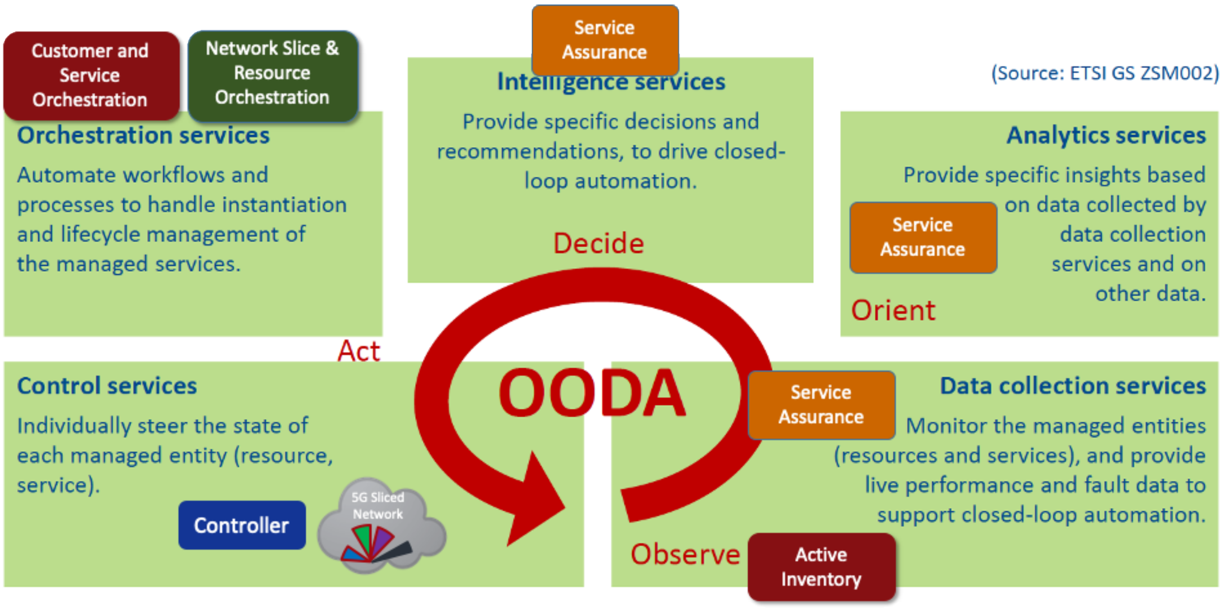


Figure 29: ETSI - ZSM

9. AI Enablers for 5G Efficiency and Experience

The twin goals of providing greater efficiency of rendering differentiated service and ensuring a great experience, through guaranteed service, requires a significant change of approach in management. The vertical industry consumers expect guaranteed services and precise rendering of SLAs at service instance level. Added to this is the fact that the increasing number of services with different types of priorities which itself can change, requires CSPs to be extremely agile and take resource management decisions in real time. Hence, AI techniques are being tried out or analyzed for next catalyst phases to predict future demand for differentiated services, as well as to provide precise information on service instance specific experiences. In this catalyst, effort was made in these two areas.

9.1. Efficiency

As part of the Use Case 4 on orchestration the use of AI was contemplated for the below specific use cases:

- **Prediction**: Predicting Network Slice Usage and QoS level using Vertical industry variables. The usage of network slices relies heavily on user activity, therefore ability to consume passenger density forecasts would greatly help in enhancing accuracies of predictions. For this purpose, deep-learning models need to be placed at the Edge to allow for collection of external data. The outcome of those models provide congestion and QoS near-term predictions and anomaly alarms, allowing to trigger intelligence workflows and also allowing these same workflows to use prediction data for remediation analytics and raising recommendations. Prediction of how vertical industry intent are being met also requires access to Vertical industry data.
- **Recommendation**: Intelligence workflows today and tomorrow will rely on Domain expertise: today, to establish the policies driving the remediation analysis; tomorrow to drive the governance and validation of AI-generated policy or AI-driven autonomous agents' actions. We have drafted a next phase use case to utilize supervised learning to provide AI-Assisted closed-loop policy definition, leveraging the correlation of actions/changes to provide positive outcome learnings.

9.2. Indicating Service instance specific experience

The AI driven model can be used to determine the Customer Experience at the instance level of a service. This is achieved through the combination of Network Slice Level Instance Rollup, as well as an AI driven model for deriving the metrics with the combination of Network Level and Customer Mobile Metrics, including feedback.

During the Learning Phase of the Model, apart from the Network Level QoS, we also collected;

- the actual QoS Values experienced at the User Equipment Level,
- the Customer QoS Feedback obtained from the User post Service Experience,
- Device Information such as Model, Version, Bandwidth, etc.

Apart from the UE Level QoS Parameters, the model also takes into consideration the Customer Mobility Speed, RSRP, SNR, RSRQ, Network Bands Supported, Visual Experience (such as Jitter, FPS, Streaming Buffer, etc.) internally to train the algorithm during the Initial Training Phase. The QoS Metrics (both at the Network Level and UE Level) are continuously compared to calculate the actual customer experience and to retrain the model.

10. Contributors Table

Contributor	Company Name	Project Role
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Glenn Swanson	Oracle Communications	Use Case lead
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Shweta Sachdeva	Wipro	SME ETSI-OSM
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Andrew Baldock	MYCOM-OSI	Demo lead

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13. Glossary

PSR – Product Service Resource

QoS – Quality of Service

CSP – Communication Service Provider

NFV – Network Function Virtualization

SDN – Software Defined Networking

MEC – Mobile Edge Computing

ZTP – Zero Touch Provisioning

14. Appendix A.1 – Company Roles

Wipro brings in its Digital Market Place solution for exposing industry specific services, along with a Slice Orchestration solution based on ETSI-OSM.

Oracle is contributing with its Service Design component for designing differentiated services, a Service Orchestrator to coordinate at Customer Service level and Active Inventory.

Mycom OSI's EAA product focuses on multilayered closed loop assurance towards Intelligent Zero Touch Management.

Cango Network's Optigo Assurance solution focuses on dynamic rollup of QoS parameters to provide instance specific monitoring of Guaranteed services.

i2i Systems brings in its 5G Service Charging solution with focus on rating & charging based on actual rendered QoS.

Document History Table (for internal purpose)

Version Number	Date	Author	Reason for change
1.0	22.09.2020	Aydan Ozenir	First release for internal review
1.1	24.09.2020	Glenn Swanson	Updates to section 6.1
1.2	25.09.2020	Aydan Ozenir	Section 6.4 & 8 updated based on feedback from Yoann Foucher
1.3	18.11.202	Yoann Foucher	Sections 8.1 and 8.3 updated