Business Interoperability Framework for Integrated Terrestrial-Satellite Network

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Abstract— **This paper presents a framework for business interoperability with specific focus on the performance indicators and SLA models between terrestrial and satellite operators. It discusses relevant performance metrics currently used in satellite and terrestrial networks as well as the correlation between them and concludes that new KPIs and SLA models as enablers for service delivery over an integrated network are required. We further introduce a framework for criteria comparison on key issues to consider and what could be a bad fit and good fit for the integrated terrestrial-satellite architecture. We believe this guide will also help Virtual Network Operators (VNO) better informed of the opportunities and ease of service delivery over these networks.**

Keywords—Service level agreement, Quality of service, KPI

I. INTRODUCTION

Interoperability framework is a set of standards and guidelines which describes how organizations, operators or service providers should interact with each other [1]. It thus emphasizes that it is only a guideline and should continuously be adapted depending on the technologies, use cases and parties involved. The key objective thus centers around what information and resources are shared, how they are shared and the level of trust between the entities. Interoperability framework is identified as a key element towards digital agenda for Horizon 2020 [2].

Interoperability between satellite operators and terrestrial operators requires an open framework as well as linkage to other activities on the business plane. Current efforts have focused on standardization of interfaces at points of interconnect. However, standardization will not automatically lead to seamless interoperability. In reality, complex specifications and standards are usually embraced by all domains and where there are no clear benefits (both technically and from a business perspective), are often bypassed. This leads to operators defining new use cases for their solutions and thus these alternative solutions end up being more expensive in regards to the time and resources.

Given a good understanding of the specifications and standards, linkage to business case and benefits to all parties via an open framework which can be adapted for unique use cases will lead to a seamless interoperability. This means that highlighting the business benefits of these specifications and standards to stakeholders would serve as a major step towards removing the interoperability barriers. The rest of this paper is structured as follows: section II directly describes Service Level Agreement (SLA) models specifically for satellite and terrestrial operators and key points to consider when drafting such agreements, section III provides a discussion on the performance metrics with sections IV and V focusing on terrestrial and satellite networks respectively. We conclude in section VI by proposing the need for composite Key Performance Indicators (KPIs), points of monitoring the KPIs as well as deployment phases.

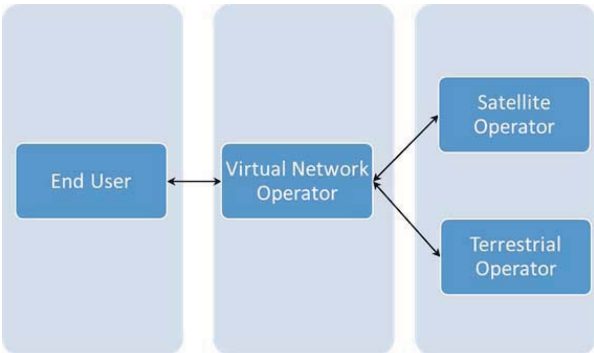

Figure 1 Parties involved in SLA Agreements

II. QOS AND NETWORK AGREEMENTS

The need for having QoS and network agreements is akin on the relationship between the parties involved. Two models exist. One involves having an alliance/federation of operators who have a common agreement of their objectives and try to maximize profit for the global alliance. Such an alliance can be managed by an Independent Virtual Network Operator (IVNO).

IVNOs can be described as a single service provider that is responsible for the multiple access network infrastructures (satellite and terrestrial) as shown in Figure 1. The virtual operator could be any operator with existing SLA agreements between satellite and terrestrial operators. The IVNO is thus able to monitor the performance both networks by utilizing a set of agreed composite KPIs.

Based on the generic model presented in [3], we depict an overview of the interrelationships involved in having SLA agreements for an integrated terrestrial and satellite systems in Figure 2. The end-user has a single SLA agreement with the retail service provider. However for assured service delivery or to meet Quality of Service (QoS) requirements such as availability in remote areas, the retail service provider has two separate SLA agreements with a satellite service provider and a terrestrial one.

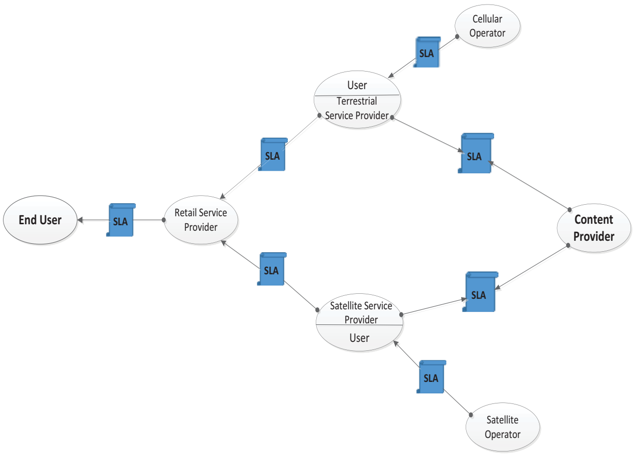

Figure 2 Chain of SLA for End-to-End QoS Delivery in Integrated Satellite and Terrestrial System

This is a chain of SLAs as the satellite service provider for example also has an agreement with a satellite operator. Considering these chains of SLAs, there should be a level of tolerance when the retail service provider drafts the SLA with the end user in order to accommodate for any variations in the individual SLAs in each domain.

In the described model for an end-to-end QoS, there exists the notion of one stop responsibility [4]. This basically ensures that responsibilities of each provider in the chain is clearly defined and coordinated. The end user in Figure 2 sees the retail service provider as the single responsible entity for the overall QoS received. Similarly the retail service provider places certain demands only on its direct sub providers using this one stop responsibility model. The drafting of these SLAs especially for services that requires splitting traffic flows over different domains still need further evaluations. Another area that should be explored is the relationship between content providers, Satellite and terrestrial service providers on who takes the role as User/Provider.

There may be risks and challenges associated with managing an integrated terrestrial and satellite system. The key for posing a viable business case is an understanding of these challenges by all parties and taking these into consideration when drafting SLAs. Three conditions are pertinent:

1. Specifying the exact conditions upon which services are to be delivered must be clearly stated in terms of Quality of Service (QoS) requirements and corresponding QoS architecture for each individual NSP;
2. Translation of these QoS requirements into high level requirements that are agnostic to the type of network architecture;
3. Further translation of these parameters to a high level SLA that are meaningful to the end user and directly relates to their Quality of Experience (QoE).

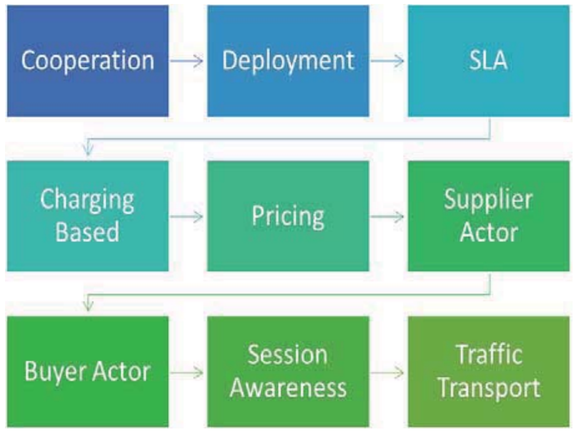

Figure 3 Chain of SLA for End-to-End QoS Delivery in Integrated Satellite and Terrestrial System

In the drafting of Service Level Specification (SLS), mapping of higher-level QoS requirements (such as bit error rate, coding and modulation scheme) onto low level SLA terms (such as high speed downloads) and vice versa determines the relevance of the SLA to the end user.

However, due to the interdependencies of the different network providers, the flow of information such as key performance indicators for their network must be reflected and should be easy to monitor by the virtual network operator. The responsibility of mapping these high level QoS requirements onto low level SLA terms lies with the independent virtual network operator (Retail Service Provider).

In order to integrate a satellite network into existing terrestrial systems a framework is required encompassing each criterion and the issues to consider. A detailed analysis for particular scenarios is provided in [5]. The key Criteria that should be analysed are shown in Figure 3. In the cooperation level, there will be multiple organizations that need to co-operate and this requires one to take the lead or allowing an IVNO to manage the relationship. A summary of each criteria, issues to be considered and what constitutes a bad or good fit is provided in Table 1.

The overall challenge is to maintain a service oriented network infrastructure consisting of different network operators and still support a consistent SLA across all entities involved. A key component for SLAs is not just having them in place but monitoring and enforcing via set of agreed performance metrics. An understanding of these metrics is presented in the following sections.

III. Performance Metrics

Performance metrics are used to determine and assess the quality of links, connections across a network and services offered through them. Every network has performance indicators on various aspects of the network. Furthermore, some form of performance management analytics helps to define, measure and analyse the specific "key" performance indicators that are pointers to the business objective or the type of service being offered. This leads to the credence that for a

Table 1: Framework for Comparison Criteria

Comparison criteria	Issues to consider	Bad Fit	Good Fit
Cooperation	Who would need to be involved to set up	Too many different parties	One or two parties with existing relationships
Deployment	Reach, installation issues, competition	Well served locations Regionally close locations Large amounts of unique data to each location	Remote or poorly served locations Locations across multiple countries Multiple sites requiring same data
SLA	QoS, QoE management	No interface for SLA requirements	Well defined SLA interface(s)
Charging based	What data needs to flow from the satellite network	Requires information not readily available	Uses readily available and commonly used data
Pricing	Cost / affordability	Satellite solution cost prohibitive for the service in question	Satellite provides cost effective and affordable solution
Supplier actor	Who will supply the end user? What relationships do they need to supply the end user?	Suppliers unaware of satellite services/solutions	Suppliers already use satellite for some part of their service
Buyer actor	What does the end user need from their supplier?	Locations unsuitable for satellite connection	Locations suitable for satellite connection
Session awareness	What information needs to be communicated with the satellite connections per session?	Requires information on application needs not readily available to satellite network	Uses readily available and commonly used data
Traffic transport	Are the traffic types suitable for satellite transport?	Applications very sensitive to latency	Most applications

single network, various performance metrics are available and thus a selected number are identified as unique and key performance indicators (KPIs). Furthermore in the context of an integrated network unique KPIs are important as evaluation of what would be key indicators may vary for different networks across different domains by different operators.

For a holistic categorization, performance metrics can be categorized as either network centric or user centric performance metrics. The network centric performance metrics are important for the network provider to dimension, monitor and assess the quality of their link provided. It is also required for monitoring the system and grading its performance. On the other hand, the user centric performance metrics helps to quantify the quality of the service being offered by the network as perceived by the user. This is often more challenging to measure or determine and depends on a varied number of factors. Network performance metrics may be categorized under four major groups as outlined in [6]. These are Availability, Loss, Delay and Utilization. All KPIs used in different networks and by various service providers can be grouped in these categories. It is important to clearly define these performance metrics to gain a clear insight into how they can affect the network and their relevance to the target use cases being considered.

In general, when KPIs are defined or agreed on, the counters collected and analysed in order to achieve four major objectives:

1. To gather information that helps network management teams understand the network behaviour under certain conditions through log files, events and alarms generated.
2. Detect and identify faults in the network in order to trigger actions, for network analysis and reconfiguration. This can be done autonomously through self-organisation functionality [7].
3. Predict the network, and in direct synchronisation with customer service unit to help the management team define new marketing policies and strategies.
4. Monitor and understand the extent of system changes as it relates to the load distribution, traffic model and effect of scheduled maintenance (software and hardware upgrades or modifications).

These objectives are common to all networks and valid for all operators. We now focus on KPIs used in terrestrial networks using LTE as an example.

IV. KPIs in Terrestrial Networks

There are over 10,000 KPIs used in terrestrial networks depending on the type of network, network management system and overall system objective. KPI values are based on counters to give a status of the system performance from the network perspective and from the user experienced quality.

With the evolution towards 3G and 4G, 3GPP in [8] further defined these categories as accessibility, retainability, integrity and mobility. ITU together with ETSI further provided a model for user centric QoS models. We briefly describe these four relevant KPI categories with a use case.

A. Accessibility

This measures the ease at which users can obtain services within specified service levels. For data networks, session setup success rate is an example and gives an indication of service coverage. For an integrated network, responsibility for ensuring accessibility (especially in the access network) will lie solely on the Virtual Network Operator who specifies the points of responsibility to each constituent part of the end-to-end network.

A typical use case is to further support applications as part of service offering to end users. After completion of network deployment, the network operator can include in its commission tests, the QoE perceived by the end user for such applications. In scenarios where the user cannot access the service from that location, the operator can make necessary reconfiguration to improve accessibility of such service as against hitherto focus on access to the network. This is also important for customer retention.

B. Retainability

This measures the service continuity and is more closely tied with the end user experience as well as a relevant input for evaluating the revenue opportunities. It describes the ability of an already in-session service to continue running efficiently without any unscheduled interruptions for a requested period. An example of such KPI is the session abnormal release rate (referred to as dropped calls in 3G networks).

A typical use case includes critical services that have developed into a habit for everyday use for the end user. This may be current Over The Top (OTT) applications for everyday communication or e-health solutions using high resolution video streaming with interactive text. It is important that such service is not interrupted or aborted. Measurements can reveal how this impacts the ability to retain end users of such service provider.

C. Integrity

The integrity of the service delivery by a network describes the level at which an operational service runs without major events anomaly. This shows the efficiency at which the network operates. Examples include throughput, latency and packet loss. The integrity of the network is important both to other service providers as well as the end users.

A typical use case is the achievable throughput in delivery of IP packets. When a specific data rate is specified to the end user, this should not be the theoretical maximum throughput under no load conditions. The typical rate during peak and off peak hours should also be stated. This directly gives an indication on the quality of service that can be provided.

D. Mobility

This describes all handover types. Examples include the handover success rate and handover between different Radio Access Technology. This includes the both the preparation phase and execution phase. Typically, the preparation phase includes the period in which the evolved NodeB (eNB) makes reservation of a resource for a user in another cell or utilising another type of access network. The execution phase is graded as success after the initiating eNB receives information that the user is successfully connected to another cell or access technology and can be disconnected from the initiating node.

A typical use case is handovers triggered by mobility between different radio access technologies. The service should not be disrupted and bearers should not be dropped until there is a seamless handover between the eNB and the satellite network for example. This gives an indication how integrated and seamless the underlying technologies should be in the service delivery.

E. Examples of KPIs used in Terrestrial networks

<u>Coverage:</u> The radio coverage area of a network is how farther away from the main serving transmitter users achieve a minimum signal to noise ratio considering interference from neighbouring transmitters.

<u>Spectral Efficiency:</u> This gives a measure of the throughput achieved by the network with the given bandwidth. As frequency is a scarce and expensive resource from an operator's perspective, the maximum throughput in bit/s (bps) that can be pushed per unit Hz is desired. Its unit is in bps/Hz.

<u>Area Spectral Efficiency:</u> A more accurate indicator especially in dense network areas is the area spectral efficiency which gives an indication of the spectral efficiency per unit area (bps/Hz/km^2).

Others include Signal to Interference plus Noise Ratio (SINR), Signal to Noise Ratio (SNR), Traffic Channel Availability (TCHA), etc. In summary, cellular operators employ a combination of KPIs in order to be able to identify the actual state of their network and aid troubleshooting, reconfiguration and optimisation decisions. A detailed analysis of KPIs used in terrestrial cellular networks can be found in [8]. Based on the KPIs discussed a subset are also relevant in satellite networks. These include the Throughput, Round trip time, Latency, coverage area and the spectral efficiency. In section V, we address which of these are relevant in integrated satellite and terrestrial networks.

V. KPIs in Satellite Networks

Satellite networks have two major sets of KPIs. The first group is focused on the satellite, and earth station while the second group on the type of use cases being served. For both categories, it is important to forecast performance degradation especially in scenarios where the managed network begins to grow due to increased service demands. The satellite payload performance is maintained in stable pre-defined state (in terms of its capacity) by the operator and has little impact on the overall service management. However, it does heavily impact on the service definition.

The network performance is characterized by the availability, delay, satellite throughput, packet loss rate, coverage area, delay as well as the delay variation. These are described below:

Availability: A major strength of satellite networks is their reliability and service availability. This is demonstrated in specification of their reliability in decimal places as good as 99.999%. It indicates the time the satellite link is operational or above the minimum acceptable functional threshold. This is synonymous to the coverage performance indicator for terrestrial networks.

Delays (Propagation and Processing): The transmission delay (in seconds) describes the time it takes for a packet to travel from source to destination at a given transmission rate (bit rate). The transmission delay for different systems is thus dependent on the transmission rate. The propagation delay specifies the time it takes for communication signals to travel through the communication medium assuming a fixed transmission rate. It is thus dependent on the physical distance between the sender and receiver and the transmission medium (free space). Other delays associated with an end-to-end communication link are classified as processing delays and include the queuing delays, frame delays and Forward Error Correction (FEC) associated delays.

Latency: is the key performance metric related to delay that could serve as the determinant on the type of service a satellite network can support. The satellite network is usually specified to help service providers understand what points in the network is affected and alternatives or types of applications that are indifferent to such delays. Latency is a measure of the propagation delay and processing delays. A more effective measure of the latency is the 'service level latency'. This is the time required for the user to receive content with the latency requirement of that particular service as the benchmark. Tools such as Performance Enhancing Proxies (PEP) are used and can provide significant mitigation of the effects of round trip delays. Recent developments on TCP window management and SPDY also reduce the need for PEP.

Coverage Area: This is associated to the footprints of the satellite transponders over a given area. It gives an indication of the maximum Effective Isotropic Radiated Power (EIRP) in dBW, within the area based on coverage contours. The coverage of a satellite footprint is usually specified by the EIRP at a given location. This is particularly important in the link budget design and system troubleshooting. Irrespective of the system design and optimisation schemes employed the satellite coverage and resulting EIRP at remote's location places a cap on the received signal strength.

Throughput: This gives an indication of the total data transmitted in bits per second (bps) as measured from the egress point. Despite the advertised throughputs a more realistic measure is the effective throughput per user. In practice, a number of users share the network capacity which reduces that actual throughput per user. This is usually the KPI most end users can understand to have a direct impact on the services their broadband connection can support.

Energy Efficiency: This gives an indication of the energy consumption in provision of a service. Typically energy estimates in the one-off deployment such as satellite launch are not considered. Focusing on network level energy consumption and power requirements of the end user terminals, this metric gives a measure of the total power consumption in service delivery. It is also directly correlated to the cost of the service and physical architecture of the end user terminals. Services provided on devices with a low energy index are usually preferred. This metric in isolation does not give an overall indication on the network performance. Of more interest is the amount of energy savings without degradation of service delivery.
Other studies such as that provided in [9] have evaluated specific KPIs for video delivery via an integrated network. In Table 1 however, we summarize generic KPIs used in both networks. It can be observed that there exists a high similarity though different acronyms are used in some cases. This leads to the call for having a unified KPI for an integrated network.

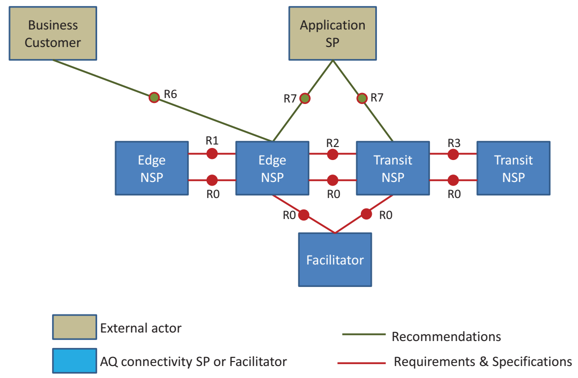

Figure 4: Updated Actor Model showing Reference points for QoS Monitoring [10]

There will be agreed point of reference for monitoring theses KPIs. Adopting the actor model in Figure 4, the reference points can also be defined as interfaces used for this purpose. Points R0, R1, R2 and R3 are recommended for monitoring the KPIs while points R7 provides QoS requirements for the service delivery. Point R6 could include service differentiation points as well as payment classes to the customer. Guaranteed interconnection can be achieved using assured quality paths and end-user Assured Service Quality (ASQ) connectivity. For ASQ paths, the SLA will define the boundaries, point of interconnect (PoI), KPIs and traffic identifiers between the operators. The SLA would include specification of the availability and bandwidth at the PoI between the Network Service Providers (NSP) as well as PoI between different underlying technologies [11].

VI. THE NEED FOR COMPOSITE KPIS

The key design objective presented here is the need for a determination of KPIs for the entire system that not only presents the technical functionality of network elements but also takes the operator's policy. An overview is depicted in Figure 5. This could be a virtual network operator and the operator's objective of either determine wider coverage or for maximising revenue in target markets and areas or the nature of clients would tailor which metrics are of more priority. For example, some terrestrial operator's main objective is to ensure maximum coverage reach of their network as opposed to capacity optimization while for others it is the reverse.

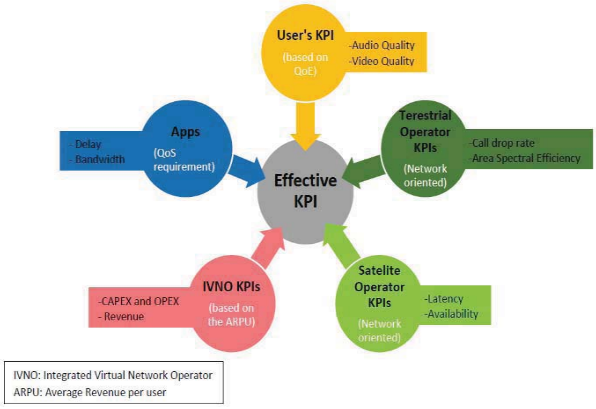

Figure 5: Formulating Effective KPIs for Future Integrated Architectures

There already exists a high correlation between both set of KPIs even though some are defined differently. For example, as future communication networks begin to play vital role in everyday life, drifting from providing optional applications to consumers to necessary applications including emergency services, the reliability is a performance indicator to consider is how reliable and its availability. A KPI for terrestrial operators will be coverage area while satellite will be availability. This new paradigm can help improve the quality of experience of the end users. It can be achieved by the provider getting information on the range of applications/services that will be run over the network and thus able to prioritize traffic, defining possible paths and provision resource reservation for individual applications.

For example, a user which we may classify as 'senior citizen' is more concerned in making skype calls to family and have no interest in heavy gaming. The KPI for such user should be different for another user in a student campus who plays a lot of games. Similarly, some companies are more concerned with security of connecting their remote networks and can tolerate the latency for file transfers if it transverses over the satellite link.

From a service provider's perspective, it is also pertinent to design future integrated network architecture with consideration of the associated business case. The initial CAPEX, OPEX and Average Revenue Per User (ARPU) should be considered in presenting new solutions. A key enabler for this stems from the fact that the data plane of future internet architecture will consist of virtualised network slices that are programmable over open application plugins. This enables easier implementation of cost aware metric and support for network sharing between virtual network operators.

In order to ensure service delivery over an integrated architecture, performance metrics that are user centric are first considered as these are transparent to the underlying technology.

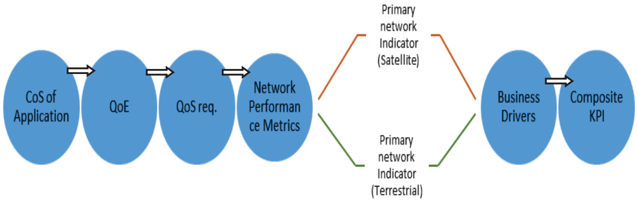

Figure 6. Mapping from End User to network in formulating composite KPIs

A mapping of Class of Service (CoS) for each application is made to the QoE via subjective test. Furthermore, a mapping of these QoE based metrics such as Video quality to QoS requirements (such as minimum data rate and bandwidth) is done. These generic QoS requirements are also focused on achieving an efficient service delivery without relying on a specific underlying technology. However these QoS requirements are correlated to existing state-of-the-art performance metrics in terrestrial and satellite systems such as mobility based KPIs (measure of successful handovers between cells and between both technologies) as well as retainability (such as session setup success rate). A subset of these correlated KPIs such as the energy per bit per unit area (J/bit/km^2) which reflects the energy consumption to achieve a given throughput in a given area are then selected. This is shown in Figure 6.

In summary, the measure in which KPIs directly impacts on the ARPU of the service provider as well as the integrity of the service being provided. Point of Interconnection for monitoring these KPIs should be clearly defined. An analytical evaluation of these set of composite KPIs that will be a function of:

1. Category of user
2. Applications priority
3. Network traffic path
4. Average Revenue per user (ARPU)
5. Estimated cost per bit transmitted.

VII. CONCLUSION

In this paper we have brought to focus that for integrated satellite terrestrial network architectures there is a need for a unified framework in monitoring the performance of the networks. These must be metrics relevant to both the satellite and terrestrial service provider. A review of performance metrics and KPIs was provided and a unified framework for defining an effective set of KPIs that would take into consideration the cost as well as technical performance metrics of heterogeneous nature was investigated. We have shown how KPIs for satellite networks can be correlated with those of terrestrial networks via a down-up mapping (from QoE to QoS to primary network indicators).

Cooperation models developed using SLA models for service delivery over integrated architectures are desired and standards concerning SLA negotiations in multi-operator agreements that spans across multiple domains. Future work would include defining case studies in order to specify new composite KPIs as well as derive analytical expressions for them. Based on these case studies, KPIs and SLAs using alliance and federation models can be presented highlighting their pros and cons.

In summary, to efficiently operate an integrated satellite-terrestrial network that will be of interest and benefit to both operators as well as have common performance indicators, two key notions should be considered: Interoperability framework across all place (Service and business planes) as wells defining and utilizing new contextual KPIs.

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