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# Foreword

This Group Specification (GS) has been produced by ETSI Industry Specification Group Experiential Networked Intelligence (ENI).

# Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the [ETSI Drafting Rules](https://portal.etsi.org/Services/editHelp%21/Howtostart/ETSIDraftingRules.aspx) (Verbal forms for the expression of provisions).

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# Executive summary

The present document specifies a high-level functional abstraction of the process of intent policy Multi-Stage translating in ENI system in terms of Functional Modules, Internal Reference Points and working pipelines.

# Introduction

Space-ground cooperative network includes the mobile communication network on the ground and the satellite network in the space, and the slicing configuration rules of the two networks are different. A slicing adaptation technology connecting mobile communication network and satellite network can effectively support the requirement of the end-to-end slicing service guarantee for space-ground cooperative network. Through the adaptation mapping of data plane and the collaborative management of control plane for NS, it can improve the customized service capability of space-ground cooperative network for differentiated services.

# 1 Scope

The present document provides information concerning space-ground cooperative network slicing. This GR intends to describe a method of network architecture and slicing mapping for the interconnection between the mobile communication network slicing and satellite network slicing. The detailed plan include:

Support identity resolution such as VLAN and IP address on the data plane, support precise identification and control for user services, and realize the slicing adaptation between mobile communication network and satellite network.

Exchange the slicing control information with the control plane of ground mobile communication network and satellite network (5GC and satellite network operation control center SNOCC), optimize the global service quality of network slicing, and ensure the consistency and continuity of slicing service in space-ground cooperative network environment.

The present document will encompass research and investigation activities that will further explore the related techniques that can be used to employ connection improvement for space-ground network slicing.

# 2 References

## 2.1 Normative references

Normative references are not applicable in the present document.

## 2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non‑specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long-term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] ETSI GR ENI 004: "Experiential Networked Intelligence (ENI); Terminology for Main Concepts in ENI".

[i.2] ETSI GS ENI 005 (V2.1.1): "Experiential Networked Intelligence (ENI); System Architecture".

[i.3] ETSI GR ENI 008: "Experiential Networked Intelligence (ENI); Evaluation of categories for AI application to Networks"

# 3 Definition of terms, symbols and abbreviations

## 3.1 Terms

For the purposes of the present document, the terms given in ETSI GR ENI 004 [i.1], ETSI GS ENI 005 [i.2].

## 3.2 Symbols

Void.

## 3.3 Abbreviations

For the purposes of the present document, the abbreviations given in ETSI GR ENI 004 [i.1], ETSI GS ENI 005 [i.2], ETSI GR ENI 008 [i.3].

# 4 Overview of

## 4.1 Introduction

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## 4.2 Architecture

## 4.2.1 Space-Ground Cooperative Network Slicing Architecture

The space-ground cooperative network slicing architecture is shown in the Fig. 1. We have deployed the programmable slicing gateway and the space-ground cooperative slicing control system between the terrestrial mobile communication network and the satellite network. Among them, the programmable slicing gateway is the transit channel for the slicing service data flows of space-ground cooperative network. With definable Message parsing, processing and forwarding capabilities, the gateway accurately identifies and controls slicing services, and achieves the data mapping between slices according to the configuration policy provided by the control system. It can ensure the service consistency and continuity of service data in space-ground cooperative network slicing and realize the adaptation of heterogeneous network slices. The space-ground cooperative slicing control system interacts with the space-ground network slicing control planes respectively, to open up the slicing session channel between the space and ground network cooperatively. Aiming at the differences between mobile communication network and satellite network in slicing service classification, slicing quantity and slicing construction form, the control system can optimize the matching mode of service traffic and network resources, and intelligently generate the configuration policy of the programmable slicing gateway, thus improving the end-to-end quality of slicing service in space-ground cooperative network.



Figure 1: Space–ground cooperative network slicing architecture

## 4.2.2 Space-ground Slicing Session Collaboration

The main function of slice-session collaboration is to coordinate the management of PDU sessions in mobile communication network and satellite network, and establish PDU session channels from UE to ground-based 5G mobile communication network, space-based satellite network and up to Data Network.



Figure 2: Slicing session collaboration architecture

As shown in Fig. 2, the functional modules of slicing session collaboration unit include slicing mapping management module, session collaborative processing module, ground-based core network interface module, and space-based core network interface module. The slice mapping management module is mainly responsible for maintaining the mapping relationship between ground-based PDU sessions and space-based PDU sessions. The session cooperative processing module can cooperate with the process of establishing, modifying and releasing sessions of ground-based and space-based networks, according to the mapping relationship maintained by the slice mapping management module. The interface module of ground-based core network is responsible for the interface with the core network of ground-based 5G mobile communication network. The space-based core network interface module is responsible for the interface with the space-based satellite network core network.

The establishment process of UE-initiated PDU sessions is used as an example to illustrate the slicing session collaboration process. In the following example, assuming that the mapping rule is based on service type, UE1 and UE2 initiate PDU sessions of the same type to access Data Network. The process is as follows:



Figure 3: Data channel establishment process of UE1

For the PDU session initiated by UE1, the data path establishment includes three stages, as shown in Fig. 3.

The first stage is PDU session establishment process from UE to ground mobile communication network. Step1: UE1 initiates a PDU session establishment request. Step2: The request is processed by the ground-based core network, and select the ground-based SMF and UPF for the session. Step3: The ground-based core network establishes an N4 session with the selected ground-based UPF. Step4: The ground-based core network notifies the space-ground cooperative session management unit of the currently established ground-based session information. The ground-based core network notifies the information about the current ground-based session to space-ground session management unit. At the same time, the ground core network notifies RAN and users to build RAN tunnels.

The second stage is the slicing session collaborate unit for slicing mapping. Step5: After receiving the notification from the ground-based core network, the slicing session coordination unit carries out the space-based session mapping. Since the session of UE1 is a new service type, a new space-based session ID needs to be assigned to the session of UE1.

The third stage is the PDU session establishment process of the satellite network. Step6: The slicing session collaboration unit notifies the establishment of a new space-based session to the space-based core network. Step7: The space-based core network selects the space-based SMF and UPF for the session after receiving a session establishment notification. Step8: The space-based core network establishes the N4 session with the selected space-based UPF.

At this point, for the PDU sessions of UE1, The channel from UE1 to ground-based 5G mobile communication network, space-based satellite network and up to Data Network has been established and opened.



Figure 4: Data channel establishment process of UE2

As shown in Fig. 4, after UE1 has established the channel to the Data Network, and when UE2 intends to access the Data Network, the establishment of the data channel also includes three stages, as shown in Figure 4.

The first stage is the process of PDU session establishment from UE to ground-based mobile communication network. Step1~Step4: The process of ground-based network for the session establishment request of UE2 is the same as that of UE1.

The second stage is the slicing session collaborate unit for slicing mapping. Step5: The slicing session cooperative unit carries out the space-ground session mapping after receiving the notification of the ground-based core network. Based on resource allocation, it judges that the sessions of UE2 and UE1 can be aggregated, and maps the ground-based sessions of UE2 and UE1 to the same space-based session

The third stage is the PDU session establishment process of the satellite network. Step6: The slicing session cooperative unit notifies the space-based core network to modify the space-based session, and the modification can be for QoS parameters. Step7: The space-based core network performs a modification operation for the session after receiving the session modification notification. Step8: The space-based core network notifies the corresponding space-based UPF to perform session modifications.

At this point, for the PDU sessions of UE2, The channel from UE2 to ground-based 5G mobile communication network, space-based satellite network and up to Data Network has been established and opened. PDU sessions of the same service type in UE1 and UE2 are allocated to the same slice, and the slicing sessions finish collaboratively.

## 4.2.3 Intelligent Slice Mapping

In the space-ground cooperative network, there are many types of service requirements and wide coverage. The performance requirements of services such as real-time voice, data transmission, control signaling, and short message have different performance requirements, and the service delay, bandwidth, and security requirements all change in real time. To meet the differentiated application requirements of wide-area information networks, the space-ground cooperative network needs to dynamically construct differentiated network slices involving different service characteristics, accurately match the resource requirements of different service data, and realize multi-service converged application. This proposes an intelligent slice mapping mechanism based on spatio-temporal correlation. Through traffic predictionto establish the prediction model of resource demand of network services, it can respond to the service characteristics and the transformation of access node in real time. Thus, the slices of network resources can be matched as needed with the wildly fluctuating traffic in the space-ground cooperative network.



Figure 5: Intelligent slice mapping based on spatial-temporal correlation

Figure 5 shows the smart slice mapping diagram based on spatial-temporal correlation. Graph Convolutional Network (GCN) and Gated Recurrent Unit (GRU) are used to extract the temporal-spatial characteristics of the historical traffic load of each node in the space-ground cooperative network slicing, which is to provide a decision basis for slice mapping. Firstly, the network topological features are captured by GCN to obtain the spatial dependence. Secondly, the dynamic changes of node attributes are captured by GRU to obtain the local time trend of traffic load. Finally, the multi-output fully connected layer of artificial neural network is used to realize the transformation from traffic load to resource demand, and output the predicted result. The system monitors the network resource status in real time, slices are allocated network resources based on the predicted results of slicing service requirements to complete slicing adaptation decisions and ensure the service requirements of the business.

Following the earlier discussions, the desired system performance suggests that the slicing can benefit from an adaptive mechanism. As the trade offs between the bandwidth and power efficiency are non avoidable, A well designed slicing algorism may fit seamlessly to its designated applications whilst may not necessarily handle a similar environment with altered system parameters The slicing scheme here was initially intended to mitigate the data rate drop in a random link, where interference is present. The candidate switching schemes have been chosen based on the merit of combined power and bandwidth efficiency. More realistic models will also be addressed in this section. For model simplicity and discussion continuity, the following assumptions are made:

1. The channel is a direct link channel.
2. Synchronisation is maintained
3. The system operates in 2 data rate (moderate and high)

In the test model two sets of BER test data will be used. The first set will range from 10-9 to 10-7, to represent moderate degradation and second set will range from 10-8 to 10-6, to represent severe degradation. The data rate will be chosen as a realistic 4Mbps and a higher rate of 250Mbps.

Data rate degradation in Space Ground network

|  |  |
| --- | --- |
| Moderate Degradation (BER)10-9 → 10-7 | Severe Degradation (BER)10-8 → 10-6 |
| Initial Rb (Mbps) | Final Rb (Mbps) | Initial Rb (Mbps) | Final Rb (Mbps) |
| 4 | 3.0 | 4 | 2.9 |
| 250 | 187.9 | 250 | 179.4 |

In above Table, whilist in the moderate degradation, the data rates have fallen for 4Mbps and 250Mbps respectively to 3Mbps and 187.9Mbps, which is about 25% of throughput lost. For severe degradation, the data rate fell for 4Mbps and 250Mbps respectively to 2.9Mbps and 179.4Mbps, which is about 28% of throughput lost.

Comparing data rate loss for systems operating at 4Mbps, the difference between the moderate and severe model is not significant. In contract, for a system operating at 250Mbps, the data rate loss between the moderate and severe model indicates a large departure from the operating speed. This suggests that systems operating at a higher speed are more susceptible to environmental change than their lower speed counterparts. The comparisons between these two data rate bands can be further demonstrated.

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