# ENI ISG - PoC Proposal

# 1 PoC Project Details

## 1.1 PoC Project

PoC Number (assigned by ETSI): PoC#19

PoC Project Name: Space-Ground Cooperative Network Slicing

PoC Project Host: China Telecom

Short Description: This PoC intends to demonstrate the interconnectivity and service guarantee capability of network slicing between ground mobile communication network and satellite network under the framework of the space-ground cooperative network, with special attention to the Artificial Intelligence / Machine Learning (AI/ML) aspects, in the context defined by ENI.e.

In particular, this PoC solves the adaptation of slicing protocol between 5G mobile communication network and satellite network. For the classification of business method, the number of slices and the form of slicing construction, there are differences between 5G mobile communication network slicing and satellite network slicing. As a result, the slices of the two networks cannot be directly interconnected. For this purpose, this PoC is to construct slicing adaptation function between mobile communication network and satellite network, which realizes the service guarantee between the ground mobile communication network slicing and satellite network slicing.

Note that we begin with to demonstrate the use case [#2-5: Elastic Resource Management and Orchestration] and [#3-2: Intelligent network slicing management] discussed in GS ENI 001 [1]. In general, we aim to achieve these objectives based on a common reference implementation built with open source components. Thus, this ENI system architecture implementation even can be applicable to other user cases.

## 1.2 PoC Team Members

**Table 1.1**

| | Organization name | ISG ENI participant (yes/no) | Contact (Email) | PoC Point of Contact (see note 1) | Role (see note 2) | PoC Components |
|---|---|---|---|---|---|---|
| 1 | China Telecom AI Research Centre | Yes | Yu Zeng (zengyu@chinatelecom.cn) | X | Service Provider | - User Stories / Use Cases definition<br>- PoC development<br>- PoC documentation<br>- PoC demos |
| 2 | National Digital Switching System Engineering and Technology Research Center | | Dan Li(pkulidan@163.com)<br>Bo Chen(ndscshen@163.com)<br>Juan Shen(ndscshen@163.com)<br>Le Tian(xxgctianle@163.com) | | Academy | -Help with the architecture design, implementation of algorithm, testbed setup and discussion about intelligent solution |
| 3 | Asiainfo | Yes | Shoufeng Wang wangsf11@asiainfo.com | | Vendor | -Help with architecture verification |
| 4 | Huawei | Yes | Aldo Artigiani aldo.artigiani@huawei.com | | Vendor | -Help with concept refinement and use case |
| 5 | CAICT | Yes | Ziruo Liu liuzhiruo@caict.ac.cn | | Academic | -Help with simulation and architecture optimisation |
| | | | | | | |

NOTE 1: Identify the PoC Point of Contact with an X.
NOTE 2: The Role will be network operator/service provider, infrastructure provider, application provider or other as given in the Definitions of ETSI Classes of membership.

All the PoC Team members listed above declare that the information in this proposal is conformant to their plans at this date and commit to inform ETSI timely in case of changes in the PoC Team, scope or timeline.

## 1.3 PoC Project Scope

### 1.3.1 PoC Goals

The PoC will demonstrate aspects of various Use Cases that were identified by in GS ENI 001, namely:
Use Case #2-5: Elastic Resource Management and Orchestration
Use Case #3-2: Intelligent network slicing management
The PoC will also demonstrate aspects of various requirements that were identified in GS ENI 002, including:
Network planning and deployment
 Network optimization
 Data Collection and Analysis
 Policy Management
 Data Learning

This PoC 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 goals include:

 **PoC Project Goal #1: Network Slice Data Plane Adaptation Mapping**. Demonstrate how to 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.

 **PoC Project Goal #2: Space-Ground Network Slice Cooperative Control.** Demonstrate how to exchange the slicing

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

### 1.3.2 PoC Topics

PoC Topics identified in this clause need to be taken for the PoC Topic List identified by ISG ENI and publicly available, i.e. the three topics identified in clause 4.5 of the ENI PoC Framework. PoC Teams addressing these topics commit to submit the expected contributions in a timely manner.

**Table A.2**

| PoC Topic Description (see note) | Related WI | Expected Contribution | Target Date |
|---|---|---|---|
| Network Operations -> Intelligent Network application | GS ENI 002 Requirements (release 4)<br>GS ENI 001 Use Cases (release 4) | 1.Functional blocks for this PoC.<br>2.Intelligent network slicing management.<br>3.The feasibility of elastic resource management and orchestration. | 30/10/2023 |
| | | | |
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| | | | |
| | | | |
| NOTE: This column should be filled according to the contents of table 1. | | | |

## 1.4 PoC Project Stages/Milestones

**Table A.4**

| PoC Milestone | Stages/Milestone description | Target Date | Additional Info |
|---|---|---|---|
| P.S | PoC Project Start | 06/2023 | Presentation during #ENI 26 |
| P.D1 | PoC Demo 1 | 08/2023 | Venue, F2F / Webinar |
| P.D1 | PoC Demo 1 | 09/2023 | Venue, F2F / Webinar |
| … | … | | |
| P.C1 | PoC Expected Contribution 1 | 10/2023 | contributions to ENI requirements. |
| P.C2 | PoC Expected Contribution 2 | 10/2023 | contributions to ENI use case. |
| … | … | | |
| P.R | PoC Report | 12/2023 | PoC-Project-End Feedback |
| P.E | PoC Project End | 01/2024 | Presented to ISG ENI for information |
| NOTE: Milestones need to be entered in chronological order. | | | |

## 1.5 Additional Details

# 2 PoC Technical Details

## 2.1 PoC Overview

With the continuous increasing network services, the supply and demand problem of the network resources and services is more and more obvious. Users have higher requirements for network operation efficiency, isolation degree, automation and capability opening. Network Slicing (NS) technology brings an excellent solution for the contradiction between supply and demand of network capability. NS virtualizes multiple network slices within a network to provide differentiated services. It can not only meet the performance requirements of different services, but also maximize the network resource utilization, save the cost of network construction, and improve the profitability of operators. Finally it achieve the network service and cost-benefit balance, kill two birds with one stone. To meet user requirements, NS integrates various network elements vertically on the same physical platform to virtualize an independent end-to-end

service subnets. NS flexibly combines various network capabilities for users through pipelinization. Based on loosely coupled new network architecture, NS provides tightly coupled network services for different business demands.

In recent years, NS technology has gained wide attention and rapid development in wireless access network, mobile core network, IP bearer network, satellite network and other network environments. However, the slicing interconnection problem between heterogeneous networks has not been solved effectively. 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. Therefore, 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.

This PoC intends to describe a network architecture and a slicing mapping method for the interconnection between mobile communication network slicing and satellite NS, in order to ensure the quality of slicing service between heterogeneous networks.

## 2.2 PoC Architecture

### 2.2.1 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.

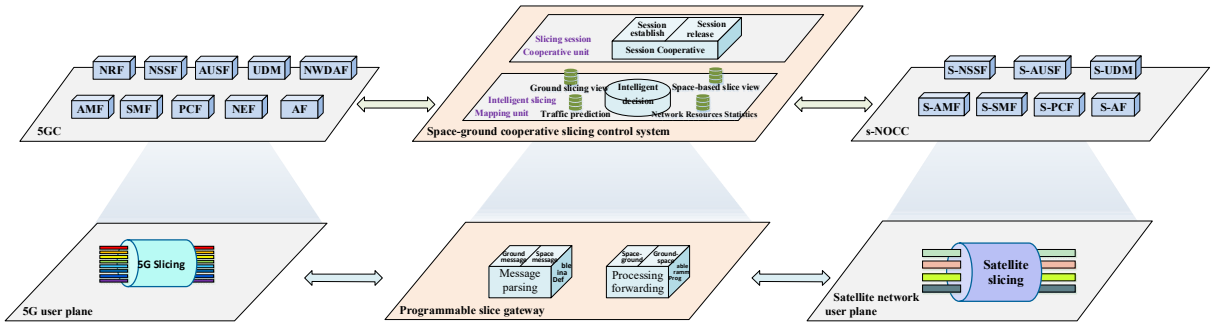


Figure 1: Space–ground cooperative network slicing architecture

### 2.2.2 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.

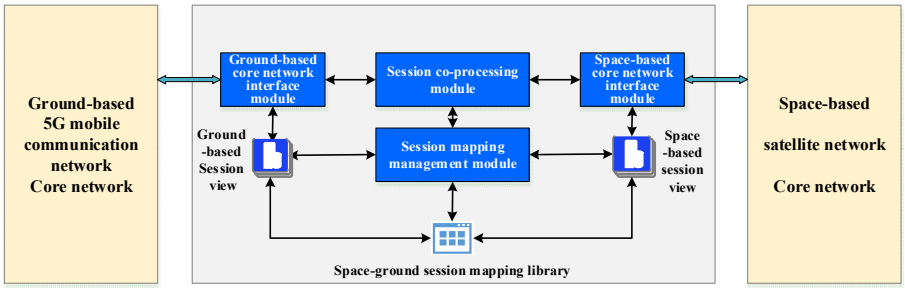


Figure 2: Slicing session collaboration architecture

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 DataNetwork. The process is as follows:

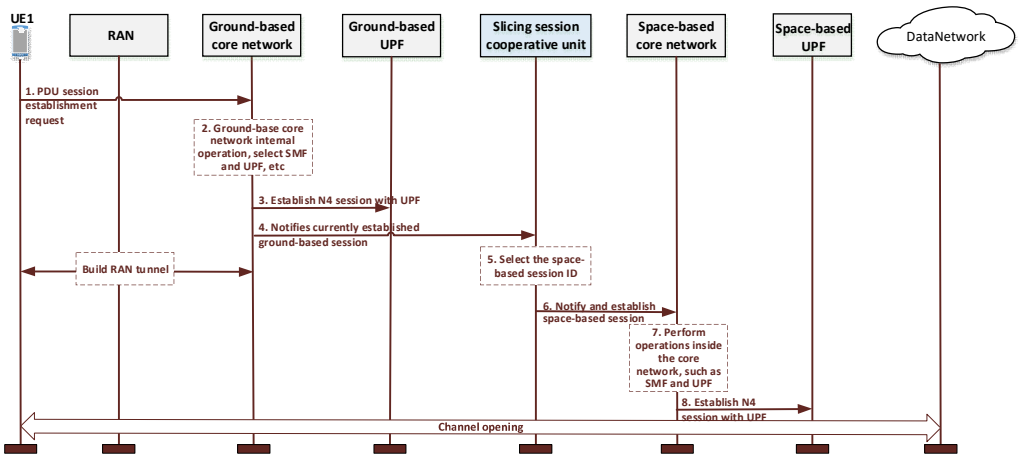


Figure 3: Data channel establishment process of UE1

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.

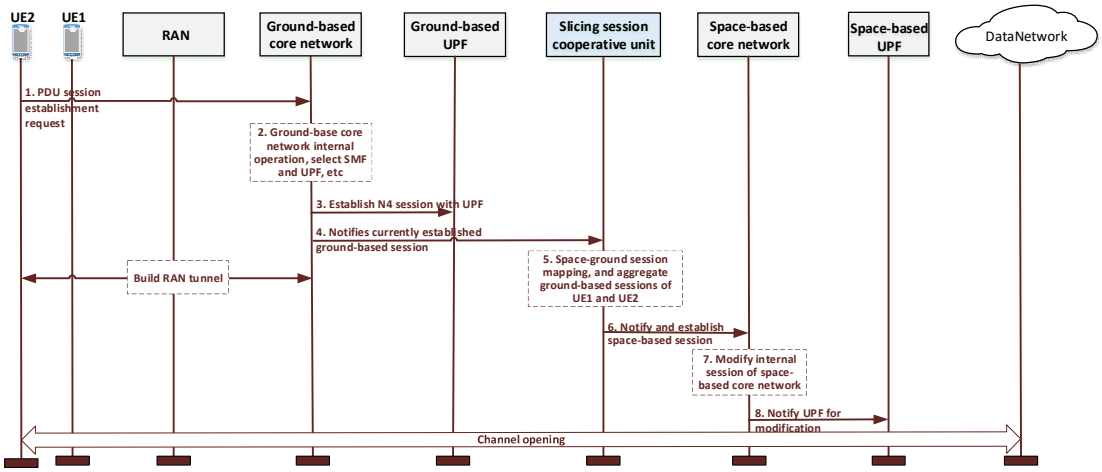


Figure 4: Data channel establishment process of UE2

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.

## 2.2.3 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 PoC 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.

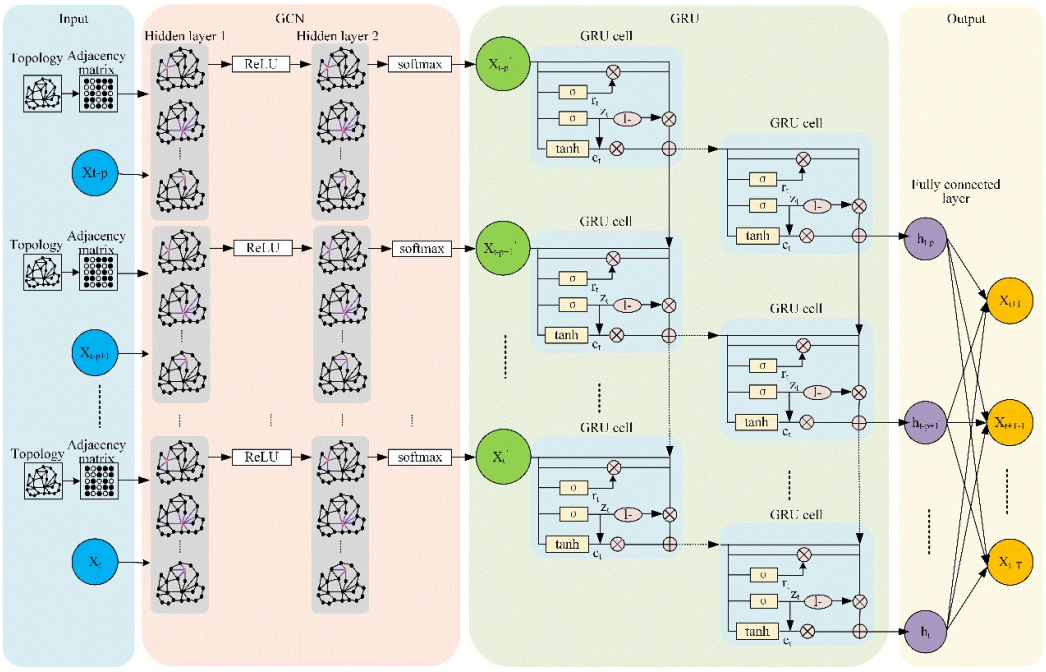


Figure 5: Intelligent slice mapping based on spatial-temporal correlation

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.

## 2.3 PoC Success Criteria

Explain how the proposal intends to verify that the goals are presented in clause A.1.2 have been met.

EXAMPLE: Functional (demonstration shown network slicing of PoC proposal worked), Performance (comparing to current application, the resources of the ground mobile communication network slicing and satellite network slicing can adapt according to service requirements ), Availability(can be improved by traffic scheduling optimization).

## 2.4 Additional information

[1] RGS/ENI-008 (GS ENI 001), “Experiential Networked Intelligence (ENI); ENI use cases”, v3.1.15, Sec 5.3.
[2] RGS/ENI-007 (GS ENI 002), “Experiential Networked Intelligence (ENI); ENI requirements”, v3.2.0.