Dual-Identifier Configuration for 5G LBO Roaming Using UERANSIM and open5GS

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***Abstract*—This paper proposes a method to enable seamless LBO roaming and data service between Visited PLMN (VPLMN) and Home PLMN (HPLMN) using open-source mobile core, gNB and UE. The proposed approach addresses two key challenges: the PLMN-ID check failure at the VPLMN AMF, and issues related to SUCI based authentication. Suggested dual configuration approach effectively resolves both issues, as demonstrated by successful gNB attachment and data network service delivery via the V-UPF.**

Keywords—5G Roaming, LBO, UERANSIM, Open5GS

I. Introduction

According to current 3GPP standards, both Home Routed (HR) roaming and Local Breakout (LBO) roaming services are supported. In HR roaming, user data is forwarded from the User Equipment (UE) to the Data Network (DN) via the Home UPF, necessitating coordinated registration and session establishment between the VPLMN and the HPLMN under established roaming agreements. In contrast, LBO roaming enables user data to be routed directly through the Visited UPF (V-UPF), thereby eliminating the need to maintain N9 tunnel between the V-UPF and the Home UPF (H-UPF). The mobile core should inherently support this routing functionality[1][2].

When constructing and testing roaming services using open-source mobile core platforms such as Free5GC or Open5GS [4], it is common to employ open-source UE and gNB. While these tools differ in the emulation layers they support, most do not fully emulate the Radio Access Network (RAN) layer, which poses challenges in conducting successful roaming test on the simulated network such as gns3[7].

II. 5G Roaming Test Environments

A. Open5GS based LBO Roaming Service

5G emulation tools such as Packet Rusher, UERANSIM [3], and srsRAN are widely used, each supporting different emulation layers. Among these, UERANSIM enables gNB connectivity through configuration parameters, however, it presents limitations when attempting to connect from the Visited PLMN (VPLMN) to the Home PLMN (HPLMN) in a roaming context [5]. In contrast, Packet Rusher enables roaming tests by bypassing the RAN layer, combining the functionalities of both the UE and gNB [6].

To enable roaming service functionality, it is necessary to configure environmental parameters that facilitate gNB connectivity within the VPLMN while incorporating essential information elements from the HPLMN. Fig. 1 illustrates the architecture of the implemented LBO roaming environment. In this configuration, the VPLMN mobile core is deployed alongside a V-UPF, which provides an independent Data Network (DN) within the 10.45.0.0/24 subnet. The gNB in the VPLMN enables connectivity for both visited UEs and UEs belonging to the same PLMN-ID. On the HPLMN side, a server hosts the core Network Functions (NFs) required for HPLMN services. A dedicated H-UPF connects to its DN within the 10.46.0.0/24 subnet. The VPLMN and HPLMN are clearly separated by distinct IP subnets, ensuring domain-level isolation and network segmentation between the two PLMNs.

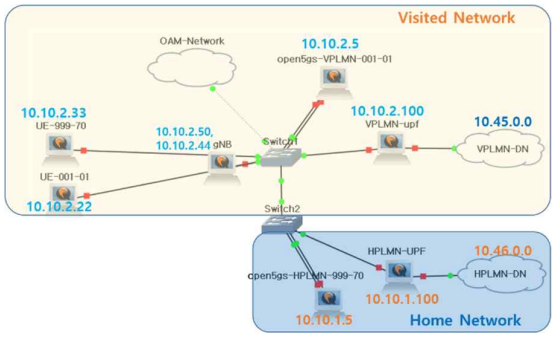

Fig. 1. A Test Environment of LBO Roaming Service

B. Issues of UE to connect VPLMN AMF

In the test environment shown in Fig. 1, the UE-999-70, configured with MCC 999 and MNC 70, attempts to connect to the AMF via a VPLMN gNB that uses PLMN-ID of MCC 001, MNC 01. However, due to a mismatch in the MCC/MNC configuration at the gNB, for no priori allocation 'allowed PLMN list as 999, 70', the UE fails to establish a *RegistrationRequest*. This occurs because the gNB performs a PLMN-ID check whether the registration requesting UE is allowed to connect based on the PLMN(MCC/MNC) values.

Furthermore, when generating the SUPI (Subscription Permanent Identifier) for authentication at the HPLMN UDM, the UE-999-70 constructs the SUPI by combining its IMSI with the configured MCC/MNC. If this combination uses the VPLMN identifiers for connecting V-AMF, a mismatch arises with the expected identifiers stored in the HPLMN's UDM, resulting in SUCI verification failure during authentication.

Due to these challenges, constructing a complete roaming test environment using current UERANSIM UE alone becomes infeasible. As a workaround, Packet Rusher is employed to configure the LBO roaming testbed, leveraging its ability to bypass the RAN layer by internally integrating UE and gNB functionalities. This method effectively avoids MCC/MNC validation conflicts during registration and authentication procedures.

III. Extension of UE Information and Configuration

Two issues encountered in the 5G roaming test environment involve the use of a single MCC/MNC within the UE configuration. This approach fails to simultaneously fulfill

two essential requirements: (1) the PLMN-ID check enforced during registration through the VPLMN gNB as allowed PLMN list, and (2) the SUCI verification performed during initial registration with the Home Network's UDM, where subscriber data is managed based on the HPLMN's identifiers.

To resolve these, the present study extends the UE configuration to support dual MCC/MNC management. This allows the UE to utilize the VPLMN's MCC/MNC for access and connectivity to the AMF, while employing the HPLMN's MCC/MNC during SUCI generation for authentication with the Home UDM. This dual-context handling enables both successful gNB attachment in the visited network and proper subscriber identity validation for LBO roaming services in the home network.

TABLE I. EXTENSION OF UE CONFIGURATION PARAMETERS

Issue	AS-IS	To-Be
AMF PLMN-ID check	mcc	VPLMN mcc VPLMN mnc
SUCI/SUPI Authentication	mnc	HPLMN mcc HPLMN mnc

Accordingly, the UE configuration file (yaml) was extended to support separate entries for vmcc, vmnc, hmcc, and hmnc, enabling an explicit distinction between VPLMN and HPLMN identifiers. The environment variable parsing logic was modified to interpret these new parameters, allowing accurate construction of both VPLMN and HPLMN contexts within the UE configuration.

Furthermore, to resolve the SUCI authentication issue during *RegistrationRequest*, the logic responsible for generating the SUPI was modified to explicitly use the HPLMN's MCC/MNC values, rather than relying on the default MCC/MNC used for gNB attachment. This ensures that the generated SUPI correctly corresponds to the subscriber profile stored in the Home UDM. The resulting SUPI is then converted into a SUCI, which is embedded within the *RegistrationRequest* message and transmitted to the AMF during the initial registration procedure.

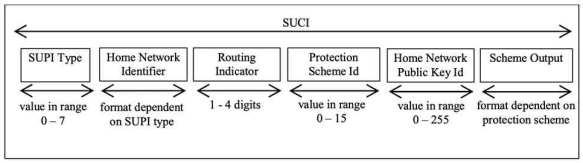

Fig. 2. SUCI Information in the Registration Request

As shown in Fig. 2, the Home Network Identifier portion of the SUCI is generated using the MCC/MNC values derived from the SUPI or IMSI, ensuring accurate identification and successful validation by the HPLMN.

Fig. 3 illustrates that, by using the modified UERANSIM UE, a successful connection is established with the UERANSIM gNB and the Open5GS mobile core, enabling the formation of a tunnel with the V-UPF under the LBO roaming service. It also confirms that actual data packets are successfully transmitted and received by a ping test, demonstrating the operational validity of the roaming configuration.

The visited UE-999-70 is assigned the IP address 10.45.0.3 by the Visited DN and is served by the V-UPF. Meanwhile, UE-001-01, an home subscriber of VPLMN, is assigned 10.45.0.7 from its own UPF. The results shown in Fig. 3 demonstrate successful bidirectional ping test between UE-999-70 (10.45.0.3) and UE-001-01 (10.45.0.7). Each UE is gracefully performed internet service too.

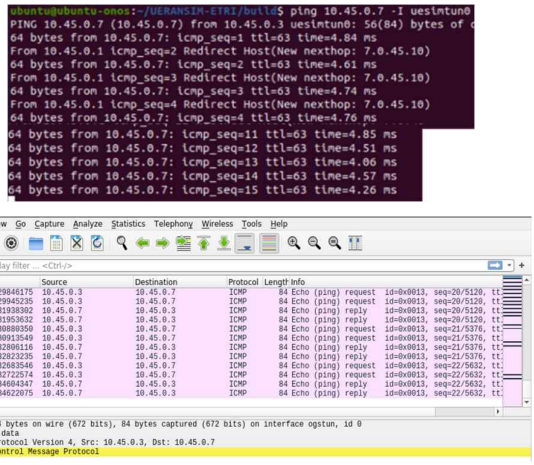

Fig. 3. Wireshark Capture of a Successful PING Test

IV. CONCLUSION

This paper demonstrates that, in an open-source 5G mobile core Open5GS environment utilizing UERANSIM as the UE, two critical issues emerge when testing Open5GS based LBO roaming services: (1) the MCC/MNC based PLMN-ID check failure at the VPLMN gNB as allowed PLMN list, and (2) the SUPI authentication failure at the HPLMN.

To address these problems, the UERANSIM's UE configuration was extended to support distinct MCC/MNC sets for both the VPLMN and HPLMN. This dual-configuration approach effectively resolves both issues, enabling reliable LBO roaming functionality and confirming that data network services can be successfully delivered via the V-UPF.

ACKNOWLEDGMENT

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