Performance Analysis of a Programmable Intelligent Mobile Core Network System for 6G

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***Abstract*— This paper proposes a Programmable Intelligent Mobile Core Network System (PIMS) architecture in preparation for the 6G era and presents its potential for performance improvement through comparative analysis with the existing 5G architecture. Based on Segment Routing over IPv6 (SRv6) technology, PIMS enables dynamic path configuration according to the requirements of each application service, ensuring both flexibility in service quality and efficiency in network resource utilization. This study conducts Proof-of-Concept (PoC) experiments using a testbed and provides quantitative comparisons of performance metrics such as the number of session control messages and their processing time. The results demonstrate the superiority of the PIMS architecture over 5G in terms of control signal efficiency and network adaptability.**

Keywords—6G Mobile Core Network, Programmable Network Architecture, SRv6, Session Control Optimization, Service Continuity under MEC Failures

I. Introduction

With the advent of the 6G era, network traffic is becoming increasingly diverse, and application services are demanding a wide range of Quality-of-Service (QoS) requirements such as latency, reliability, and bandwidth. However, the current 5G core network, which is based on a fixed path setup using GPRS Tunneling Protocol (GTP), has inherent limitations in flexibly responding to these varied demands.

To address this, we have designed a next-generation network architecture called PIMS (Programmable Intelligent Mobile Core Network System), which enables dynamic and optimized path control based on the characteristics of each application service. Preliminary experimental results on network efficiency have also been presented [1].

In this paper, we aim to provide a more in-depth analysis of the key features of PIMS, specifically its use of SRv6 (Segment Routing over IPv6) technology [3] to configure individual paths per service flow. This enables greater flexibility in traffic engineering, reduces control signaling overhead, and improves service continuity. In other words, we compare the service provision mechanisms and session control efficiency between the conventional 5G and the proposed PIMS architecture, and validate the performance improvements through PoC (Proof-of-Concept) experiments on a testbed.

II. Comparison of Service Provision Architectures

This section compares the service provision structures of traditional 5G and the proposed PIMS architecture under the assumption that one Protocol Data Unit (PDU) session is created per User Equipment (UE).

In 5G, each flow's QoS is managed using QoS Flow Identifier (QFI) over a single GTP tunnel per PDU session, as illustrated in Fig. 1. Consequently, all service flows share the same tunnel path regardless of their individual QoS needs. This fixed-path approach makes it difficult to accommodate diverse application requirements or differentiate service quality flexibly.

In contrast, PIMS leverages SRv6 in the user plane, enabling dynamic and flexible routing based on application service requirements by embedding path information in packet headers. [2, 3]. As shown in Fig. 2, PIMS can assign a high-reliability premium path to mission-critical services, a low-latency path to autonomous vehicles, and a resource-efficient path to general data services. This flexibility enables optimized traffic engineering and efficient resource utilization across the entire network.

III. PoC Testbed Configuration

To compare the performance of service provision architectures, a testbed is built comprising UE, Radio Access Network (RAN), Mobile Core Network (MCN), and Data Network (DN). The MCN includes Control Plane (CP) Network Functions (NFs) such as the Session Management Function (SMF) and User Plane (UP) components like Intermediate-User Plane Function (I-UPF) and (Local-)PDU Session Anchor ((L-)PSA).

The PIMS-based MCN additionally incorporates an open gateway to accommodate various external requirements and service nodes (Service-UPF (S-UPF)) that perform functions such as video optimization, real-time interpretation, and in-network computing.

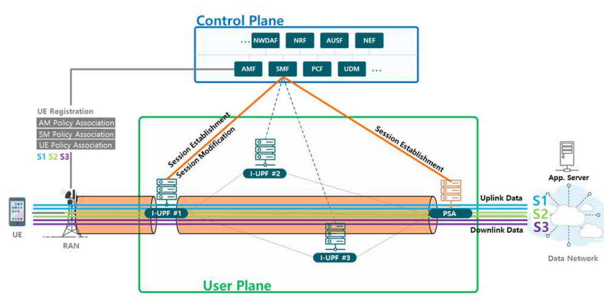

Fig. 1. 5G-based Service Provision Structure

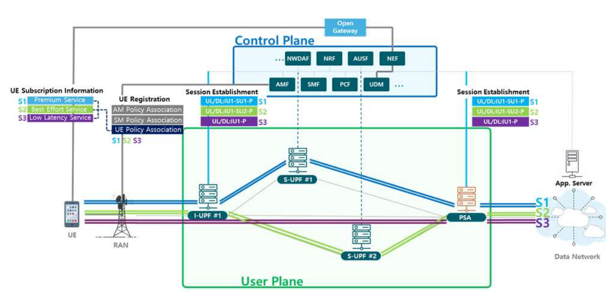

Fig. 2. PIMS-based Service Provision Structure

The experiment scenarios are as follows:

A. Analyze the message flow during session establishment process when a UE requests video services from Mobile Edge Computing (MEC) #1 and the DN.

B. Analyze the message flow during session modification process when the service becomes unavailable due to errors or failures in MEC#1 and is switched over to MEC#2, which provides the same service.

C. When a total of 100 UEs request services, compare the following for scenarios A and B:

- the types and number of session control messages required by each UPF
- the total number of session control messages and the total time taken for control procedures

IV. Performance Analysis Results

As illustrated in Fig. 3, in the 5G architecture, a session establishment message is required for each GTP tunnel segment, and in particular, the I-UPF also requires a session modification message for RAN tunnel information [4]. When MEC#1 fails, both the MEC#2 and DN paths (including I-UPF#3) must be changed, necessitating session establishment, modification, and release messages, during which both video services are temporarily interrupted.

On the other hand, as shown in Fig. 4, the PIMS architecture requires session establishment messages only at the start and end nodes of the path, while SRv6 path setup messages are used for intermediate nodes. In the event of a failure in MEC#1, only the path to MEC#2 needs to be updated, and the DN path remains unchanged. Thus, video service continues uninterrupted from DN, even if MEC service is briefly interrupted.

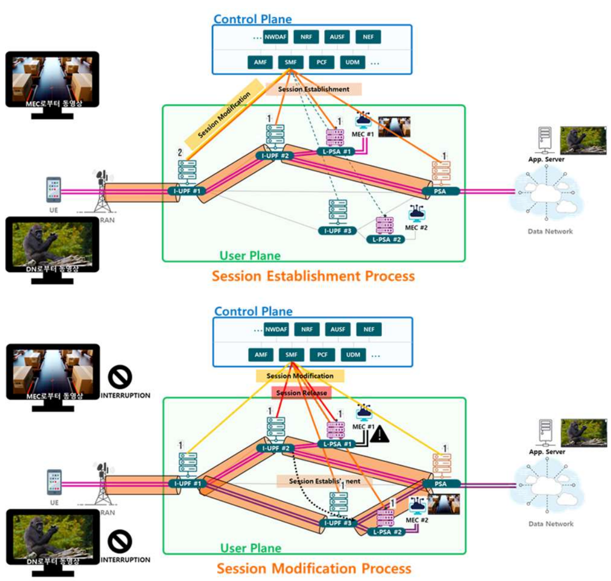

Fig. 3. PoC Results for 5G-based Service Provision

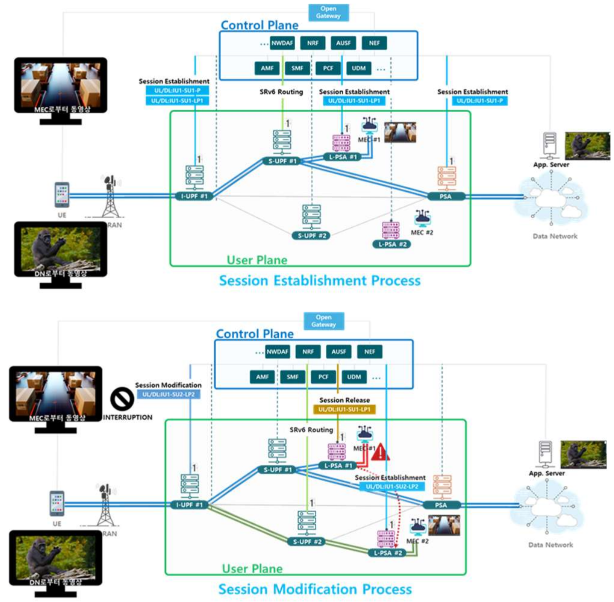

Fig. 4. PoC Results for PIMS-based Service Provision

When 100 UEs request services (Scenario C), the types and number of session control messages required by each UPF are analyzed for both the 5G and PIMS architectures, as summarized in Table 1. The total number of messages and the total time (in seconds) required for session control are presented in Fig. 5.

TABLE I. Comparison of Session Control Message Types and Count (5G vs. PIMS)

5G Architecture		I-UPF#1	I-UPF#2	L-PSA#1	I-UPF#3	L-PSA#2	PSA
Session Establishment	Message Types	E&M	E	E			E
	Message Count	200	100	100			100
Session Modification	Message Types	M	R	R	E	E	M
	Message Count	100	100	100	100	100	100
PIMS Architecture		**I-UPF#1**	**S-UPF#1**	**L-PSA#1**	**S-UPF#2**	**L-PSA#2**	**PSA**
Session Establishment	Message Types	E	SR	E			E
	Message Count	100	100	100			100
Session Modification	Message Types	M		R	SR	E	
	Message Count	100		100	100	100	

E: Session Establishment, M: Session Modification, R: Session Release, SR: SR Routing

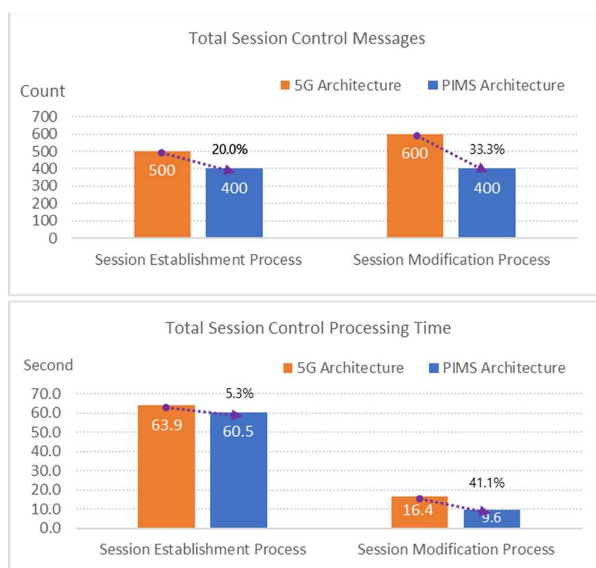

Fig. 5. Comparison of Total Session Control Messages and Processing Time (5G vs. PIMS)

The results are as follows:

- In session establishment, the PIMS architecture reduced the number of session control messages by 20.0% and the total processing time by 5.3% compared to the 5G architecture.
- In session modification, PIMS reduced the number of session control messages by 33.3% and the total processing time by 41.1% compared to 5G.

These findings suggest that the PIMS architecture significantly reduces signaling overhead and greatly improves network operational efficiency.

V. CONCLUSIONS AND FUTURE WORK

This paper proposed PIMS, a programmable intelligent mobile core network architecture for the 6G era, and analyzed its structural and performance differences compared to the conventional 5G network. The experimental results demonstrated that PIMS can flexibly accommodate diverse application service requirements through dynamic path control, while also achieving superior performance in terms of control signaling efficiency by significantly reducing session control overhead.

Notably, it was confirmed that service continuity can be maintained even in the event of an MEC failure through partial path reconfiguration. This suggests that PIMS is a promising architecture that can evolve into a real-time optimized mobile core system when combined with intelligent services and network slicing technologies in the future.

ACKNOWLEDGMENT

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