

Performance Analysis of SRv6 Forwarding for 6G Mobile User Plane

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Abstract— To meet the stringent performance demands of 6G mobile networks—such as ultra-low latency, high bandwidth, and massive connectivity—the mobile user plane (UP) must be significantly enhanced. While current 5G systems rely on GTP-U (GPRS Tunneling Protocol - User Plane), its session-based architecture poses scalability and operational challenges. Segment Routing over IPv6 (SRv6), with its stateless and programmable source-routing paradigm, has emerged as a promising alternative. However, practical integration with existing GTP-U infrastructures remains difficult due to tight 3GPP interdependencies. IETF has proposed stateless translation mechanisms to facilitate coexistence between GTP-U and SRv6. Yet, quantitative performance evaluations have been limited.

This paper presents a comprehensive performance analysis of SRv6 forwarding and GTP-U interworking using a VPP-PPDK based programmable switch and the TRex traffic generator. Under high-load conditions (up to 200 Gbps), SRv6 forwarding and SRv6-GTP-U translation achieved throughput up to 109 Gbps and 120 Gbps, respectively, with no packet loss. The results confirm the feasibility and efficiency of SRv6 for next-generation mobile UP architectures, providing valuable insights into practical coexistence strategies with GTP-U and potential migration paths toward fully SRv6-native user planes in 6G core networks.

Keywords—SRv6, 6G Mobile Network, GTP-U, PDU Session, Measurement

1. INTRODUCTION

Next-generation mobile networks are expected to support Ultra-Reliable Low Latency Communication (URLLC), Enhanced Mobile Broadband (eMBB), and massive Machine-Type Communication (mMTC). To achieve these goals, mobile user planes (UP) have evolved through decentralization and virtualization. In this context, the User Plane Function (UPF) plays a central role in data forwarding. However, GTP-U, the predominant protocol used for user plane tunneling, introduces inefficiencies due to session-based tunnel management and stateful processing.

Segment Routing over IPv6 (SRv6), an alternative that uses IPv6 extension headers and source routing principles, offers a stateless approach with programmable path control. While SRv6 offers numerous benefits, including simplified state management and improved scalability, a complete replacement of GTP-U in existing 5G networks is not straightforward due to dependencies among 3GPP-defined network functions.

To address this, IETF proposed stateless translation mechanisms that enable SRv6 to coexist with GTP-U. However, real-world evaluations comparing the two protocols are limited. This study conducts quantitative performance testing of SRv6-based forwarding and GTP-U translation functions using a programmable switch platform.

2. ARCHITECTURE DESIGN

In the 3GPP-defined mobile core network, GTP-U (GPRS Tunneling Protocol - User Plane) serves as the user plane protocol and is a tunnel-based, connection-oriented protocol. GTP-U tunnels are used to transmit encapsulated transport protocol data units (T-PDUs). The GTP header contains a Tunnel Endpoint Identifier (TEID), which uniquely identifies the tunnel to which a particular T-PDU belongs. TEID values are assigned at each endpoint and indicate which tunnel a given T-PDU session is associated with. Using this method, GTP-U performs packet multiplexing and demultiplexing between a specific pair of tunnel endpoints. As a result, the same number of TEIDs as the number of active sessions is required for processing.

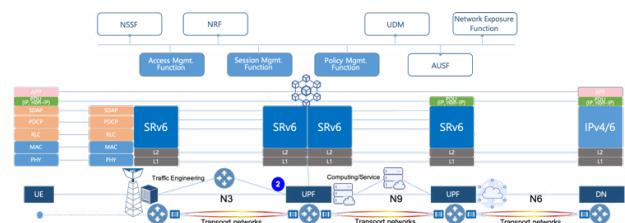


Figure 1. SRv6-based Mobile System Architecture

In contrast, Segment Routing [4] leverages the concept of source routing and uses Segment Identifiers (SIDs), which abstract network resources into segments. In SR, the ingress node determines packet forwarding paths by specifying an ordered list of SIDs—referred to as the SID list—as instructions (Figure 1). A SID is represented as a 128-bit IPv6 address composed of a Locator, Function, and Argument. Each SID can be bound to a specific function or service, enabling SRv6 to achieve networking goals beyond simple packet forwarding.

A. SRv6 based Mobile User Plane

To facilitate the integration of SRv6 into existing systems, IETF propose two operational modes that differ in their utilization of SRv6 functionalities [5]. In the Traditional Mode, SRv6 segments directly replace GTP-U tunnels, requiring both the gNB and UPF to be SRv6-capable, thus establishing a fully SRv6-native user plane.

The Enhanced Mode extends this capability by allowing multiple UPFs to be chained via SRv6 segments, thereby facilitating advanced use cases such as distributed UPF architectures and end-to-end service path optimization. Lastly, the SR Gateway (SRGW) or Interworking Mode is designed to support gradual migration by enabling interoperability with legacy gNBs that continue to use GTP-U. In this mode, a gateway UPF performs protocol translation between GTP-U and SRv6, preserving compatibility while introducing SRv6 benefits at the core network level.

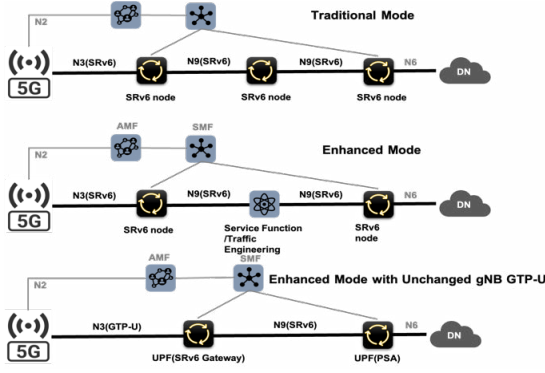


Figure 2. Mobile User-Plane Modes

B. Advantages of SRv6 over GTP-U

SRv6 provides key architectural benefits that overcome the limitations of traditional user plane protocols. By leveraging stateless source routing with Segment Identifiers (SIDs), it removes the need for per-session state management, thereby simplifying control operations and improving resiliency and failure recovery. Its inherent network programmability enables dynamic path control, supporting functions such as service function chaining, policy-based routing, and traffic engineering. Furthermore, as an IPv6-native protocol, SRv6 can operate seamlessly within existing infrastructures without additional encapsulation or translation, making it well-suited for scalable and efficient deployment in next-generation mobile networks.

3. PERFORMANCE EVALUATION

A. Source Routing-based SRv6 Platforms

Multiple hardware and software platforms have demonstrated support for SRv6, which can generally be categorized into two types: CPU-based and ASIC-based SRv6 platforms. Within the CPU-based category, two primary approaches exist—Linux kernel-based implementations and DPDK-based frameworks [10]. While several SRv6 functions [11] have been integrated into the Linux kernel, they are processed through the traditional network stack, resulting in additional overhead and reduced efficiency in packet handling.

In contrast, FD.io VPP [6], which is built upon DPDK, offers a high-performance packet processing platform capable of achieving low latency and high throughput, particularly when an adequate number of CPU cores are provisioned. However, under constrained CPU core conditions—such as in embedded or resource-limited environments—it becomes challenging to precisely evaluate its pure forwarding or translation performance. Additionally, as the number of VPP graph nodes increases, packet processing performance tends to degrade. This is especially evident when GTP-U and SRv6 functionalities are implemented after L2 and L3 nodes within the VPP pipeline, where the accumulation of processing nodes contributes to a notable performance bottleneck.

B. Measurement Scenarios

We prepared high traffic load condition for measurement: high traffic load (200 Gbps * 2). Under the condition, the sending and receiving PPS values are comparable, indicating balanced performance, and no packet loss was observed. Furthermore, short (frame size 256 bytes) and long (frame size 1500 bytes) packet sizes were utilized to assess how variations in packet length influence system performance. Given that

short packets are frequently observed in WiFi-IoT applications [8] and multimedia traffic in mobile networks [9], it is both reasonable and contextually appropriate to evaluate the system's performance under short-packet scenarios.

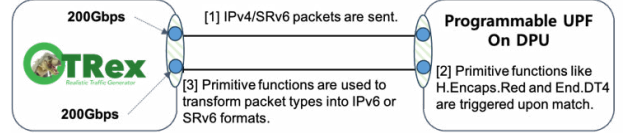


Figure 3. Evaluation method on a local machine

C. Evaluation Results

We evaluate system performance using widely accepted metrics, including packets per second (PPS), packet loss, and throughput. These metrics were derived from statistical data collected by the traffic generator. Throughout the experiment, no packet loss was observed under either low traffic load or high traffic load conditions. A summary of the average results for each metric is provided in TABLE I. To ensure fair comparison, the traffic generator was configured to produce an equivalent PPS across all measurement scenarios.

We evaluated the system performance using three widely adopted key performance indicators (KPIs): packets per second (PPS), packet loss, and throughput. These KPIs were derived from statistical measurements collected by the TRex traffic generator, ensuring reproducibility and accuracy. The evaluation was conducted under both low and high traffic load conditions, with peak traffic reaching 200 Gbps. Across all scenarios, no packet loss was observed, indicating stable forwarding performance.

To enable a fair and consistent comparison among different test cases, the traffic generator was configured to produce an equivalent PPS across all measurement scenarios, regardless of packet size or protocol mode. The average values for each KPI, including short-packet (256 bytes) and long-packet (1500 bytes) cases, are summarized in TABLE I, highlighting the comparative performance of GTP-U encapsulation/decapsulation, SRv6 encapsulation/decapsulation, and SRv6-GTP-U translation.

TABLE I
Result of Performance Metrics (PPS & Throughput)

	PPS (short/long)	Throughput (short/long)
GTP-U en/decap	9.9/10.1 Mpps	19/111 Gbps
SRv6 en/decap	8.7/9.4 Mpps	19/109 Gbps
Translation	10.2/11.3 Mpps	21/120 Gbps

4. CONCLUSION

This study conducted a quantitative performance evaluation of SRv6-based packet forwarding and SRv6-GTP-U interworking functions using an open-source VPP/DPDK platform. The evaluation, performed under both low and high traffic load conditions (up to 200 Gbps), measured key performance indicators such as throughput, packets per second (PPS), and packet loss using the TRex traffic generator. The results demonstrated that both SRv6 forwarding and translation maintained stable operation with no packet loss,

achieving up to 109 Gbps in pure SRv6 forwarding and up to 120 Gbps in SRv6–GTP-U translation scenarios.

These findings validate SRv6 as a viable alternative to GTP-U for future mobile user plane architectures, offering advantages in scalability, operational simplicity, and network programmability. Furthermore, the evaluation results provide practical insights into coexistence strategies between SRv6 and GTP-U, as well as potential migration paths toward fully SRv6-native user planes in 6G core networks. Future work will include large-scale, multi-site testing and integration with advanced traffic engineering functions to further explore deployment readiness.

ACKNOWLEDGMENT

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