eXpress Data Path Extensions for High-Capacity 5G User Plane Functions

SIGCOMM 2023: 1st Workshop on eBPF and Kernel Extensions

Christian Scheich, Marius Corici, Hauke Buhr, Thomas Magedanz
Outline

- Motivation
- Background
- Design
  - XDP GTP-U Extensions
  - XDP RSS
- Evaluation
  - Downlink Throughput
  - Uplink RSS
- Conclusion
Motivation

- Emerging data-intensive use-cases like Virtual Reality and high-quality video streaming challenge the throughput capacity in mobile networks.

[Bar chart showing mobile data volume in GB from 2021 to 2027]

Ericsson Mobility Report June 2022
User Plane Function (UPF) connects Users in the RAN with the Destination Networks (DN)

- UPF is configured from the control plane via Packet Forwarding Control Protocol (PFCP)
- UPF can apply forward, buffer or apply QOS rules to the packets
- Traffic is forwarded in GTP-U Tunnels in the Data Plane
Background: Receive Side Scaling with GTP-U

- GTP header includes a unique Tunnel Endpoint Identifier (TEID)
- Network Interface Card distributes traffic with Receive Side Scaling to the available CPUs
- Sender can vary the UDP Source Port to enable RSS features, but not all Cells support this
- Receiver can be extended to load-balance with the TEID of GTP-U

GTP-U Protocol Stack based on 3GPP TS 29.281 V17.3.0
Design: XDP GTP-U Extensions

- **XDP GTP-U**
  - Parses incoming packets for GTP-U header information
  - Applies actions based on the BPF-Map and the PFCP rules from user space
  - User Space UPF is fallback for buffering and extended QoS
  - Can pass to the network stack, redirect and reflect the packet

- **XDP Redirect**
  - Connect IP networks as router

- **XDP TX:**
  - Share one link on a bridged network
Design: XDP Receive Side Scaling

- Dispatcher selects a CPU based on the GTP-U tunnel information
- XDP-GTP-U execution is balanced on multiple CPUs
- Excludes the CPU-Dispatcher from XDP-GTP-U handling
Evaluation

- Measurement Setup for RFC2544 tests:
  - UPF is Device under test performing GTP-U encapsulation and decapsulation
  - Throughput Measurement Device:
    - sends traffic to the Device under test and counts the received packets
    - Generates traffic for 10,000 GTP-U streams

![Diagram of measurement setup](attachment:measurement_setup.png)
Throughput Comparison Downlink

- Nine-fold improvement of XDP-GTP with pass compared to user space
- Shortening the network stack with XDP-Redirect and XDP-TX improve further
- 15-fold throughput increase with XDP-Action TX in comparison to user space implementation

RFC 2544 Throughput Test: 10.000 Streams - 64 Byte Packets
Throughput Comparison Uplink - RSS

- XDP-Pass is lower compared to the Downlink – Limitation to one CPU
- XDP-Redirect CPU can improve about 2.5 fold

RFC 2544 Throughput Test: 10.000 Streams - 64 Byte Packets
Conclusion

- XDP increases the UPF throughput significantly in comparison to the user space implementation
- XDP CPU load-balancing on application layer for GTP-U traffic can increase the uplink capacity on the receiver side

Further Work:
- XDP with hardware acceleration in Smart NICs
- Evaluate a UPF with XDP enhancements in virtualized environment


Sources

Contact

Christian Scheich
christian.scheich@fokus.fraunhofer.de

Fraunhofer FOKUS
Institute for Open Communication Systems
Kaiserin-Augusta-Allee 31
10589 Berlin, Germany
info@fokus.fraunhofer.de
www.fokus.fraunhofer.de