Dynamic Tunnel Switching for SDN-Based Cellular Core Networks

Johanna Heinonen
Tapio Partti
Marko Kallio (Tieto)
Kari Lappalainen (Tieto)
Hannu Flinck
Jarmo Hillo
5G – A Dream to Do More with Less?

Expectations:
- Super high bit rates
- Ultra low latencies
- Ultimate reliability
- Infinite capacity ...

Technologies:
- Clouds and virtualization, NFV
  - Dynamicity
  - Resources on-demand
- Programmable networks, SDN

...with costs close to nothing

Virtualized SDN-based Packet Gateway
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- 3GPP network elements:
  - eNB
  - MME
  - S/P-GW:
    - SDN control introduced:
      - Virtualized S/P-GW control
      - User plane processing:
        - Cloud – general purpose HW
        - Fast Path – dedicated HW
    - 3GPP compliant
      - Standard interfaces
      - Full mobility support
**Goal and Focus**

- **Goal:**
  - To extend the dynamic nature of cloud environments to the 3GPP packet gateway element by offering dedicated packet processing resources on-demand.

- **Focus:**
  - Dynamic GTP tunnel switching between the cloud and the fast path.
Gateway Design

- Cloud operating system offers the operating environment:
  - Network functions are implemented in virtual machines:
    - S/P-GW control
    - S/P-GW user plane processing
    - Router functionality

- SDN controller:
  - Communicates with control entities by using JSONRPC
  - Communicates with switches by using OpenFlow1.3 with extensions

- Fast Path elements:
  - Offer dedicated packet processing resources
  - Can be located at a distant site e.g. close to the radio network.
Mobility Management

- SDN control introduces some *extra steps* to the standard 3GPP mobility management procedures:
  - SDN controller allocates UE IP addresses and GTP TEIDs.
    - These values define the user plane switch and the default GTP termination point for the session.
  - SDN Controller installs UE specific flow entries to the switch during an attach procedure and modifies them during a handover.
Packet Processing Pipeline in the User Plane Switches

- Pipeline selection in the Input table:
  - GTP encaps/decap
    - *gtpui* and *gtpuo* OpenFlow logical ports are used to return the packet back to the pipeline with or without GTP header
    - If UE specific flows do not exist, GTP packets are routed to the cloud.
  - Standard routing and ARP

**GTP Encapsulation:**

```
cookie=0x67, duration=54.768s, table=1, n_packets=628, n_bytes=61544, priority=10, ip, nw_dst=10.14.0.1
actions=set_field:0x30d41->tun_id, set_field:10.1.4.2->tun_src, set_field:10.2.11.250->tun_dst, output:102
```

**GTP Decapsulation:**

```
cookie=0x68, duration=54.789s, table=2, n_packets=1723, n_bytes=168854, priority=10, udp, tun_id=0x5000003,
tp_dst=2152 actions=output:101
```
Router Functionality

- Routing protocols are required to advertise UE IP prefixes via the SGi interface.
- Router functionality is implemented according to the SDN principles:
  - Routing daemon is running in the cloud.
  - Fast path is responsible for packet forwarding.

⇒ A method to send/receive routing protocol messages via physical S1-U and SGi interfaces is required:
  - Fast path element is connected to the cloud virtual networking system.
  - These overlay networks are not visible to the physical network infrastructure and therefore they provide means for gateway internal communication in L2.
Dynamic Tunnel switching

- Dynamic GTP tunnel switching means switching the GTP termination point of an *active* session between the cloud and fast path

**Procedure:**
- APN type: dynamic
- Triggers:
  - Subscription based trigger
  - Location based trigger
  - Rate based trigger
  - Manual trigger
- SDN controller adds/removes GTP encap/decap flow entries

- This procedure is *not visible* outside the gateway element:
  - Fast path element is capable of forwarding packets internally via cloud virtual L2 over L3 overlay networks

- Dynamic tunnel switching relocates the mobility anchor of active session (= limited P-GW relocation procedure)
Prototype Implementation

- Our S/P-GW prototype is based on open source software components together with our own software and extensions.
- The prototype consists of:
  - two off-the-shelf servers
  - a fast path element utilizing multi-core networking processors.
The prototype was tested by moving GTP sessions dynamically between the cloud and fast path and sending packets through the GTP tunnel.

As a reference the same measurements were repeated without a GTP tunnel straight through the fast path element.

Results:
- Performance is better in the fast path both in terms of delay and throughput.
- Jitter is about five times larger in the cloud but burstiness is about the same.
- Comparison to the no tunnel case shows that GTP tunnel encap and decap has effect on both delay and throughput.
Conclusions

- SDN and cloud/virtualization are technologies that pave the way for future cellular core networks:
  - SDN allows the control plane and user plane scale independently
  - SDN is the enabler of a distributed user plane
  - Virtualized resources in the cloud can be provisioned on-demand
- We have designed a prototype of a virtualized SDN-based S/P-GW that
  - extends the dynamicity of cloud environments to the 3GPP packet gateway element
  - is capable of switching the mobility anchor of an active session between the cloud and fast path
  - offers dedicated and optimally located packet processing resources on-demand
  - offers embedded router functionality
- More work is needed to understand the scalability, performance and behavior of virtualized SDN-based S/P-GW with real-life networks.