

Dynamic Tunnel Switching for SDN-Based Cellular Core Networks

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5G – A Dream to Do More with Less?

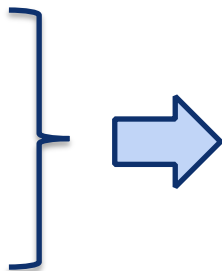
- Expectations:

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

...with costs close to nothing

- Technologies:

- Clouds and virtualization, NFV
 - Dynamicity
 - resources on-demand
- Programmable networks, SDN



Virtualized SDN-based
Packet Gateway

Virtualized SDN-Based Packet Gateway

- 3GPP network elements:

- eNB

- MME

- **S/P-GW:**

- SDN control introduced:

- Virtualized S/P-GW control

- User plane processing:

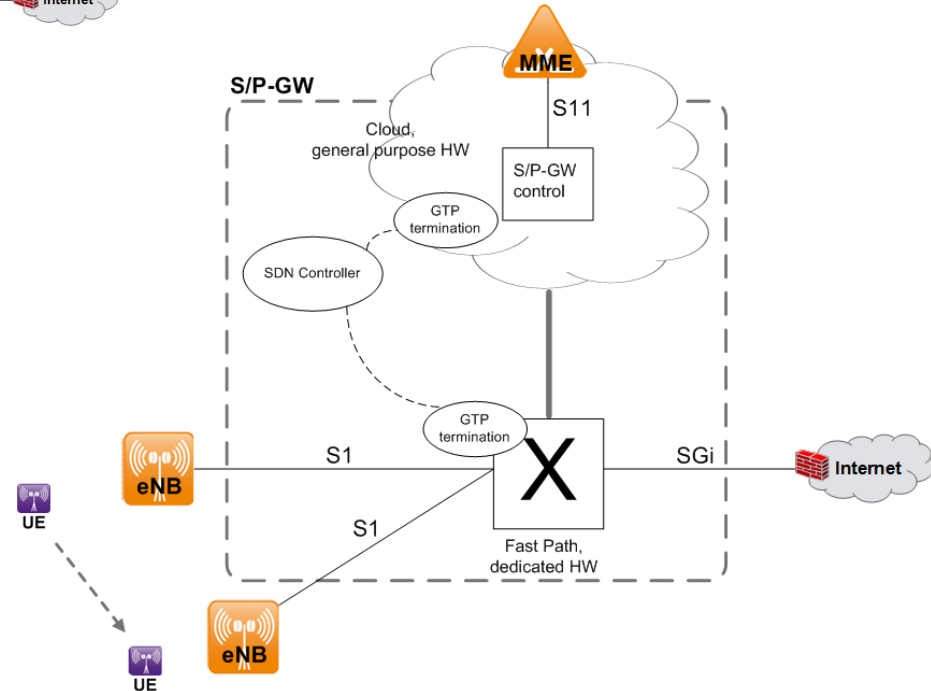
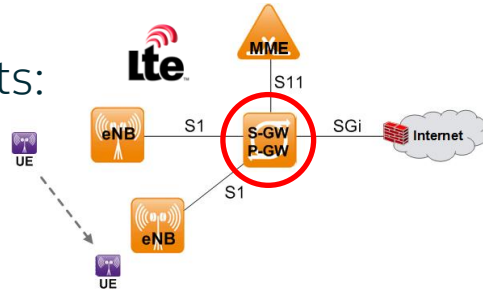
- Cloud – general purpose HW

- Fast Path – dedicated HW

- 3GPP compliant

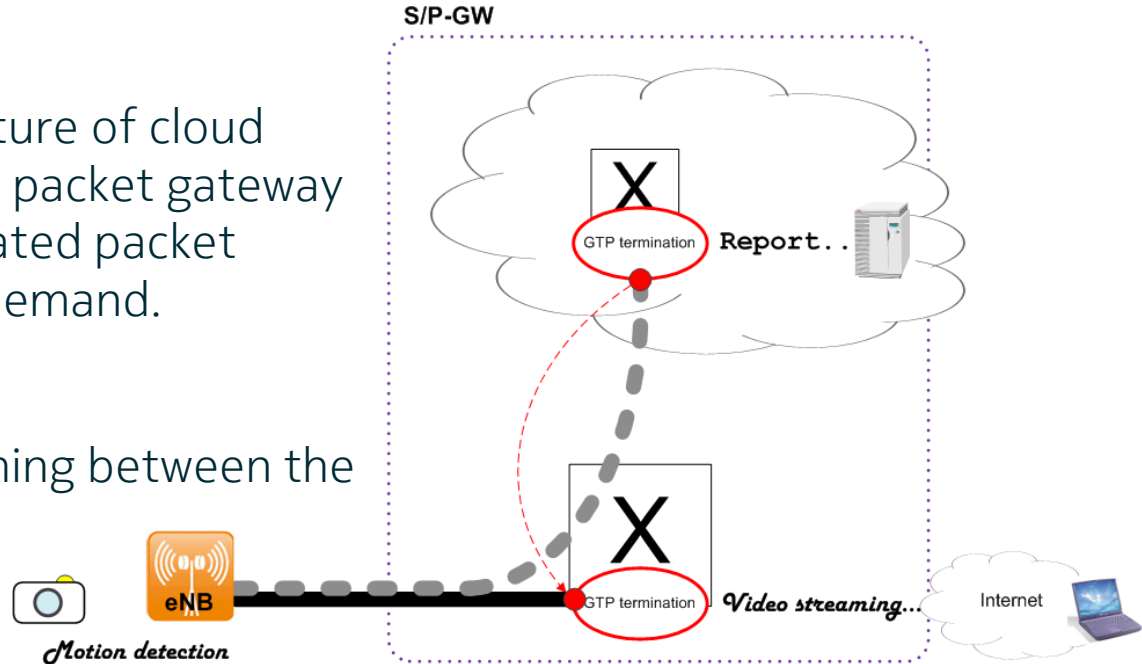
- Standard interfaces

- Full mobility support



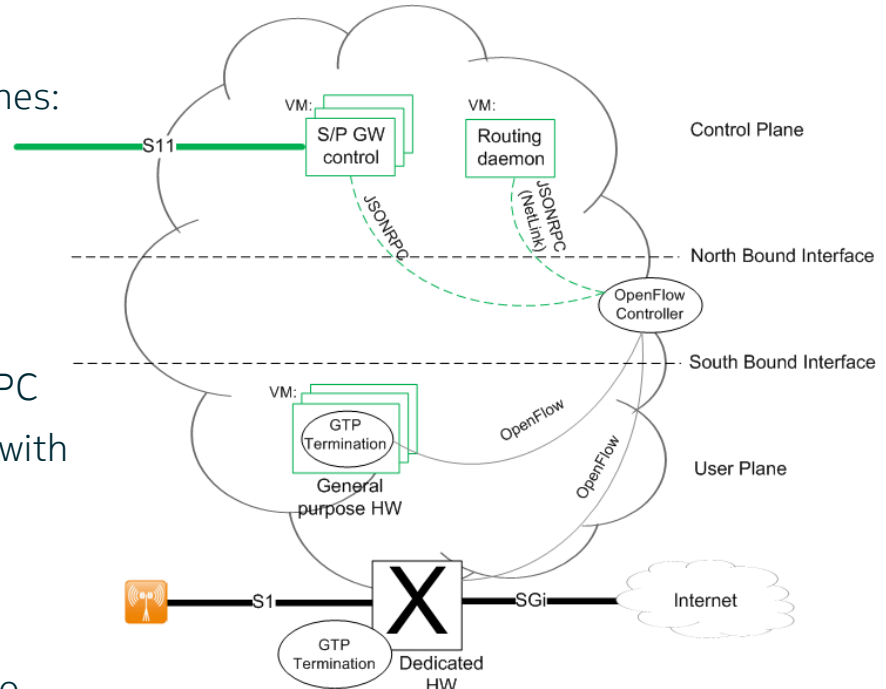
Goal and Focus

- 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.



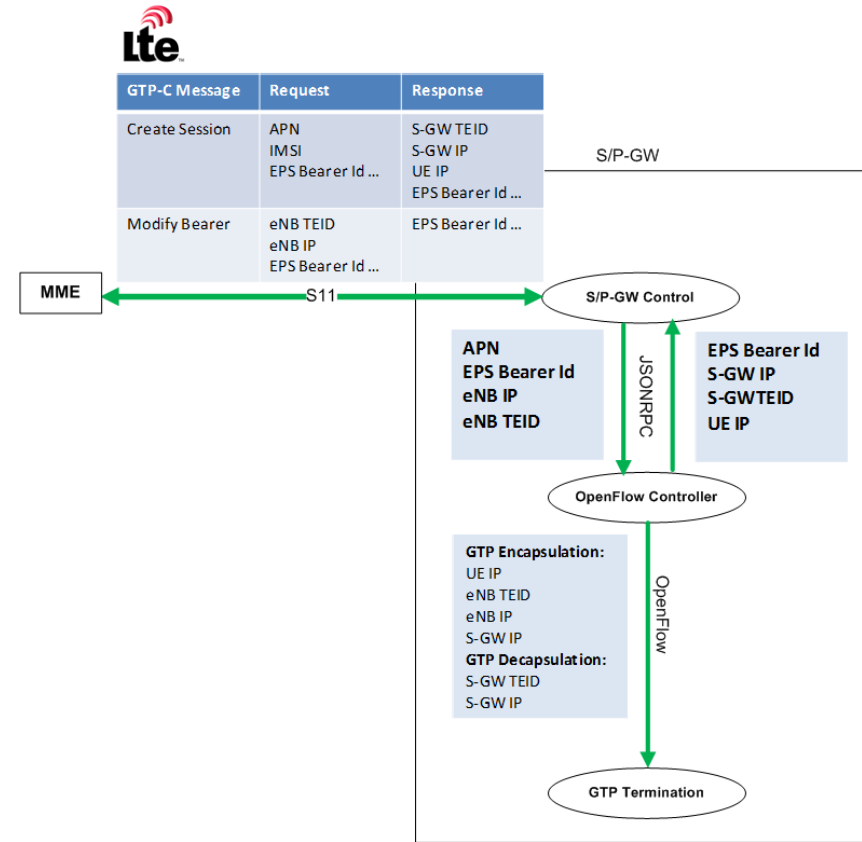
Gateway Design

- 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.



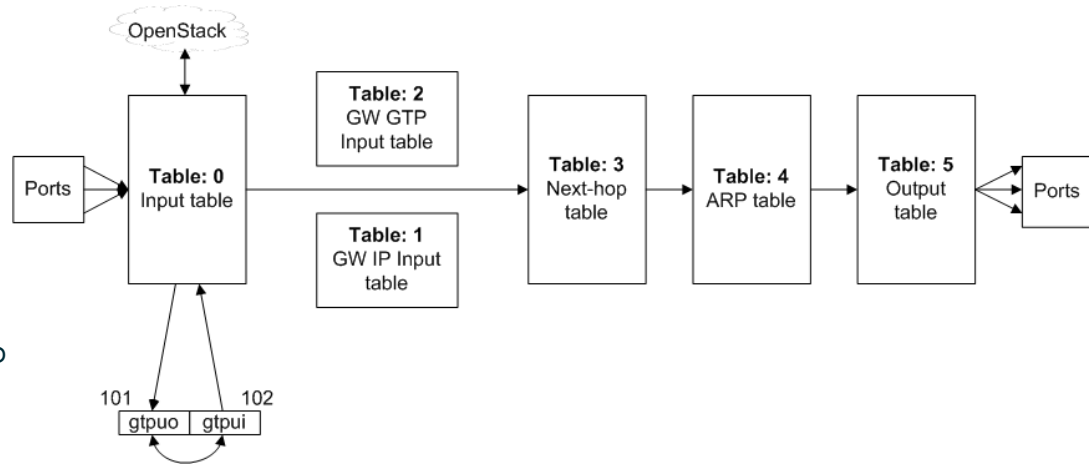
Mobility Management

- 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 encap/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:

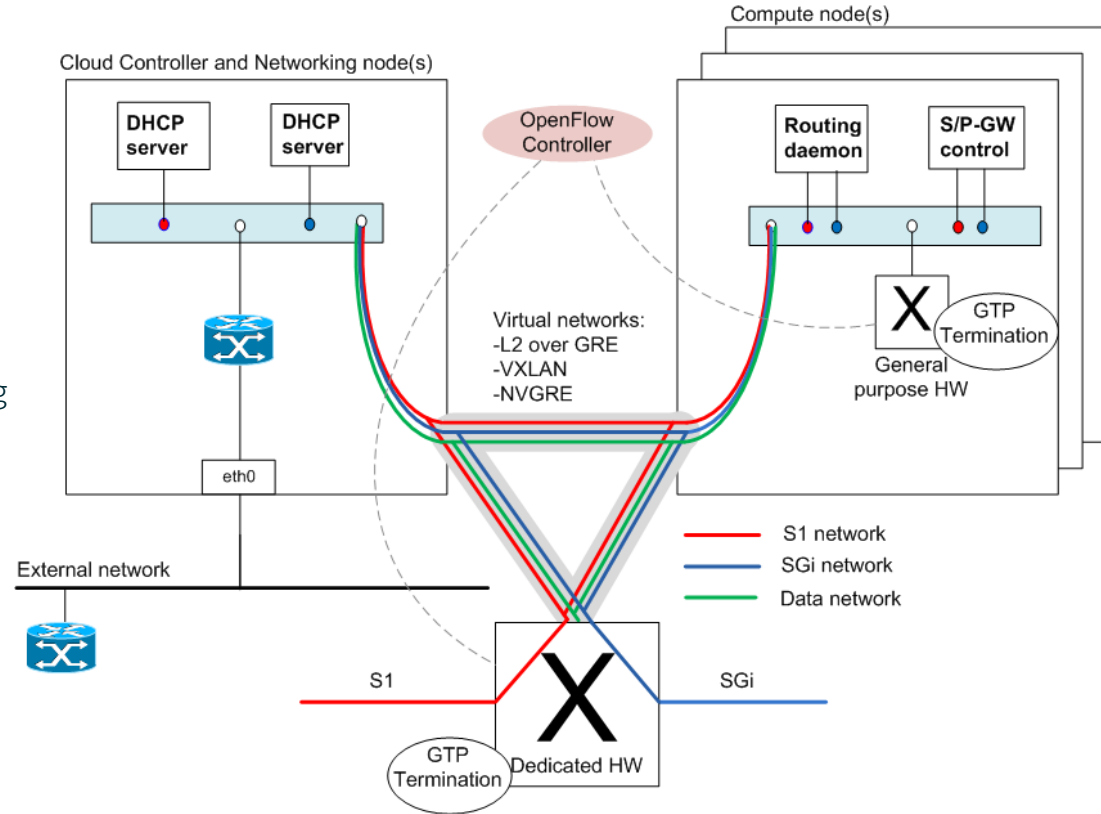
```
cookie=0x67, duration=54.768s, table=1, n_packets=628, n_bytes=61544, priority=10, ip, nw_dst=10.14.0.1
actions=set_field:0x30d41->tun_id, set_field:10.1.4.2->tun_src, set_field:10.2.11.250->tun_dst, output:102
```

GTP Decapsulation:

```
cookie=0x68, duration=54.789s, table=2, n_packets=1723, n_bytes=168854, priority=10, udp, tun_id=0x50000003,
tp_dst=2152 actions=output:101
```

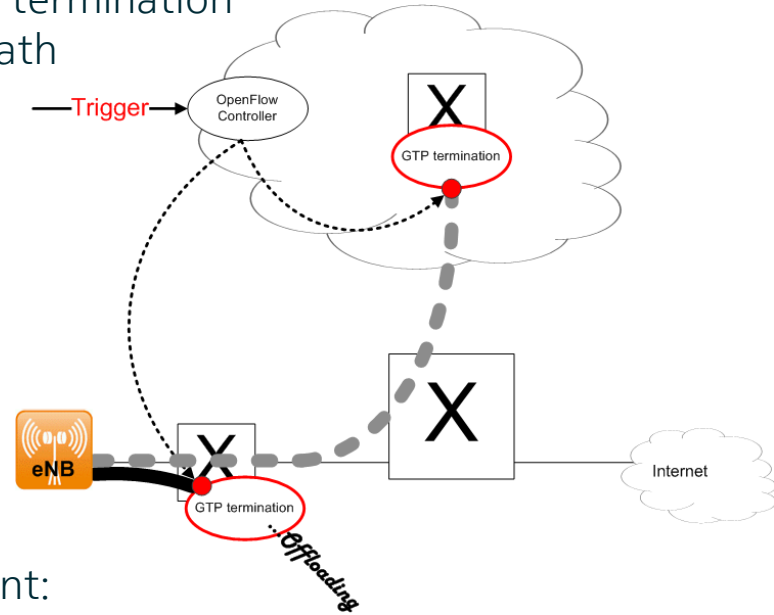
Router Functionality

- 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.



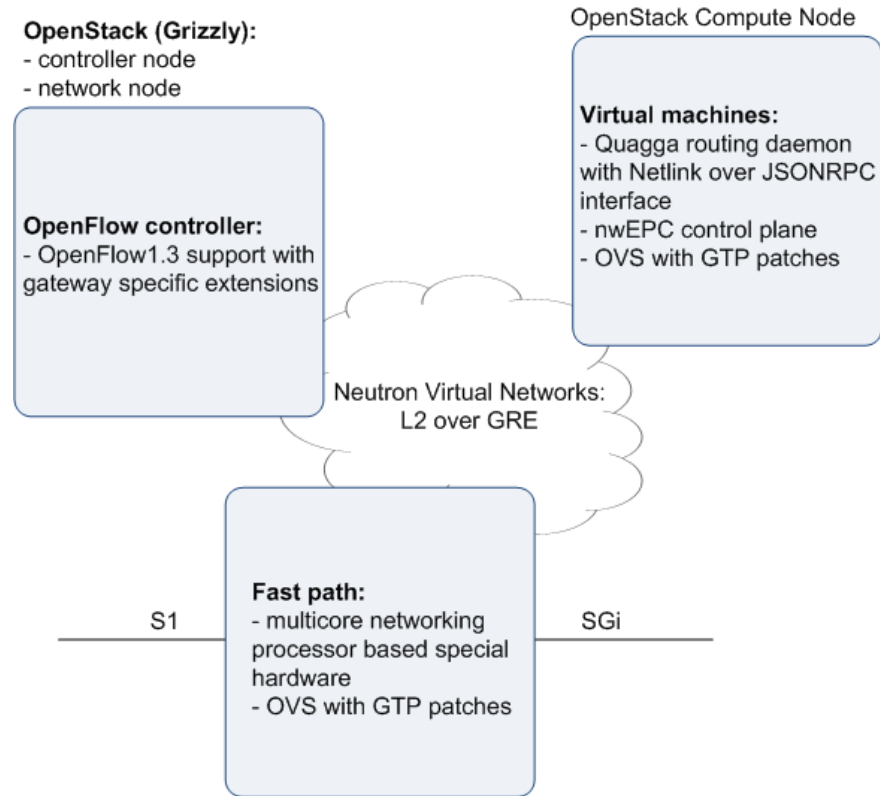
Dynamic Tunnel switching

- 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)



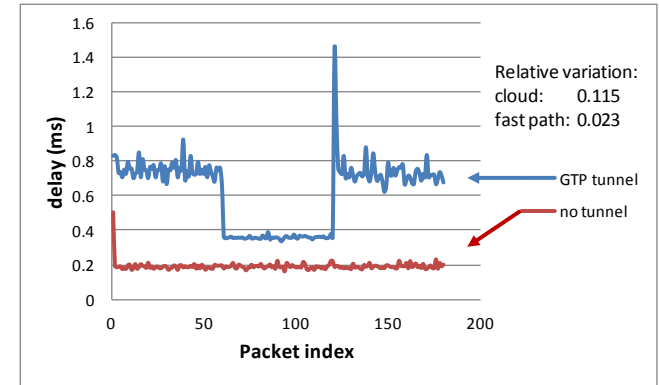
Prototype Implementation

- 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.

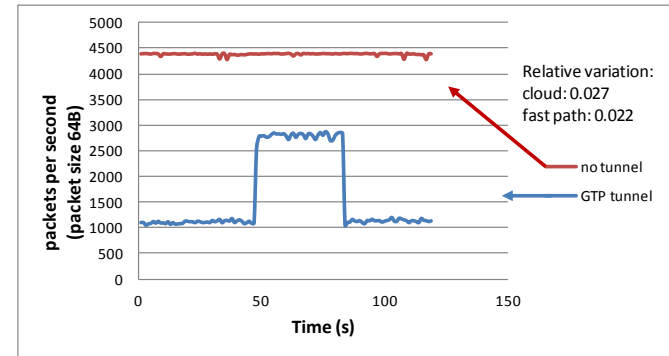


Evaluation

- 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:
 - The 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.



Delay difference



Throughput difference

Conclusions

- SDN and cloud/virtualization are technologies that pave the way for future 5G cellular core networks:
 - SDN allows the control plane and user plane scale independently
 - SDN is the enabler of a distributed the 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.