# Dynamic Tunnel Switching for SDN-Based Cellular Core Networks

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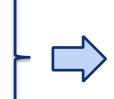
# 5G

## – 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

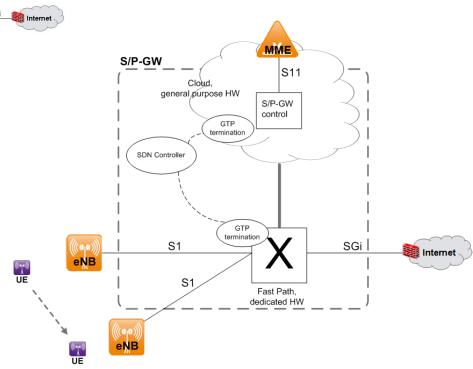


#### Virtualized SDN-Based Packet Gateway

Lte.

• 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:

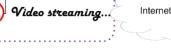
- To extend the dynamic nature of cloud environments to the 3GPP packet gateway element by offering dedicated packet processing resources on-demand.

#### • Focus:

- Dynamic GTP tunnel switching between the cloud and the fast path.



S/P-GW



Report.

GTP termination

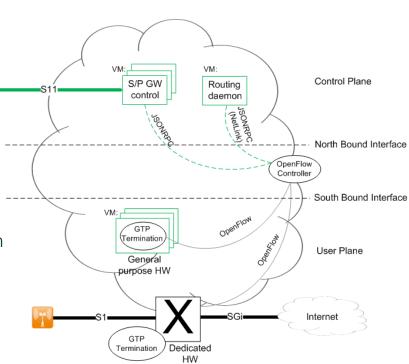


#### Gateway Design

 Cloud operating system offers the operating environment:

Network functions are implemented in virtual machines:

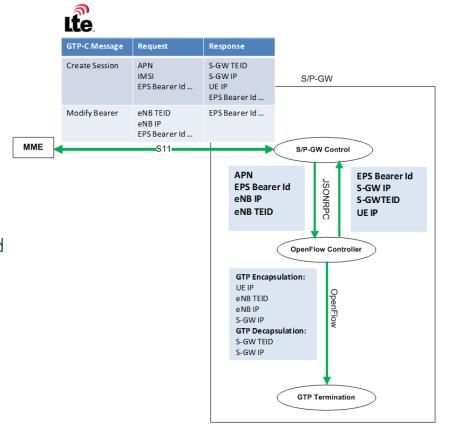
- S/P-GW control
- S/P-GW user plane processing
- Router functionality
- SDN controller:
  - Communicates with control entities by using JSONRPC
  - Communicates with switches by using OpenFlow1.3 with extensions
- Fast Path elements:
  - Offer dedicated packet processing resources
  - Can be located at a distant site e.g. close to the radio network.





#### Mobility Management

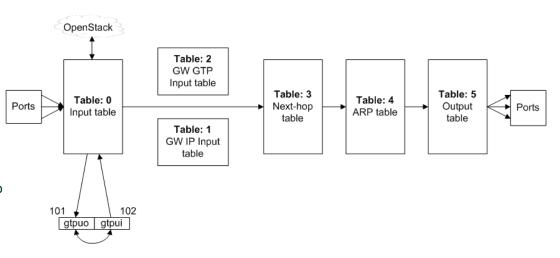
- SDN control introduces some *extra steps* to the standard 3GPP mobility management procedures:
  - SDN controller allocates UE IP addresses and GTP TEIDs.
    - These values define the user plane switch and the default GTP termination point for the session.
  - SDN Controller installs UE specific flow 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:

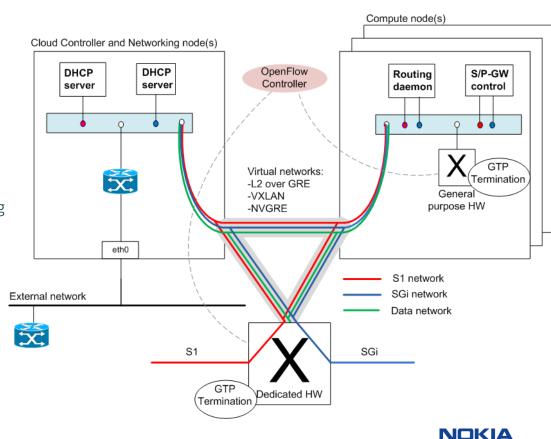
cookie=0x67, duration=54.768s,table=1, n\_packets=628, n\_bytes=61544, priority=10,ip,nw\_dst=10.14.0.1
actions=set\_field:0x30d41->tun\_id, set\_field:10.1.4.2->tun\_src, set\_field:10.2.11.250->tun\_dst, output:102
GTP Decapsulation:

cookie=0x68,duration=54.789s,table=2, n\_packets=1723,n\_bytes=168854, priority=10,udp,tun\_id=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

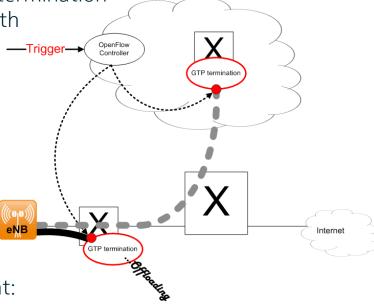
 Dynamic GTP tunnel switching means switching the GTP termination point of an active session between the cloud and fast path

Procedure:

- APN type: dynamic

- Triggers:

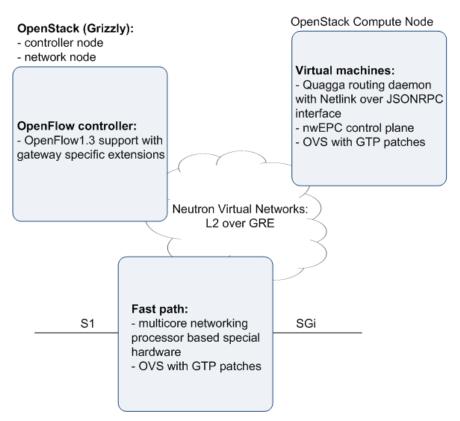
- Subscription based trigger
- Location based trigger
- Rate based trigger
- Manual trigger
- SDN controller adds/removes GTP encap/decap flow entries
- This procedure is *not visible* outside the gateway element:
  - Fast path element is capable of forwarding packets internally via cloud virtual L2 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.



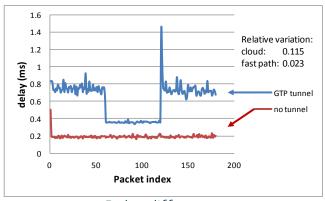


#### **Evaluation**

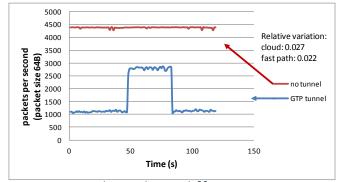
- The prototype was tested by moving GTP sessions dynamically between the cloud and fast path and sending packets through the GTP tunnel.
- As a reference the same measurements were repeated without a GTP tunnel straight through the fast path element.

#### 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 5cellular 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.