SMORE : Software-Defined Networking Mobile Offloading Architecture

Motivation

**Mobile Network**

- eNBs
- SGW
- PGW

- Radio delay
- Core network delay
- WAN delay (PGW <-> web server)

Game server

Internet
Motivation
Motivation

LTE/EPC Mobile Network

Game server

Internet

eNBs

Radio delay

Core network delay

WAN delay (PGW<-> web server)

SGW

PGW

Dominant
Motivation

LTE/EPC Mobile Network

- eNBs
- SGW
- PGW
- Internet
- Game server
- Radio delay
- Core network delay
- WAN delay (PGW<-> web server)
- Distance
Motivation

LTE/EPC Mobile Network

Game server

Internet

WAN delay (PGW<-> web server)

Hierarchical routing

Radio delay

Core network delay
Hierarchical Routing

The number of eNodeBs >>>>>>>>>>>>> The number of S/PGW
LTE/EPC mobile network is still not enough for delay-sensitive applications like online gaming
Potential Solution: Offloading

Internet

Game server

SGW

PGW

UE

eNB

Move
Potential Solution: Offloading

Removing delay between PGW and Internet
Potential Solution: Offloading

Alleviating delay from hierarchical routing
Goals

Provide mobile offloading architecture with traffic offloading and software-defined network
Goals

Provide mobile offloading architecture with traffic offloading and software-define network (SDN)

- Possible fine-grained traffic control on demand
- Selectively offload traffic based on flow rules
However, approaches are not new
Key contributions

• Transparent to existing LTE/EPC mobile network
  – No requirement to modify LTE/EPC architecture and 3gpp standard since it is not easy to change them

• Built working prototype
  – It supports traffic offloading even when handover happens
Sweet Spot for location of offloading servers

• Related to business between mobile carrier and service provider
  – Cost, delay and coverage effective location for offloading servers
Near eNodeBs

LTE/EPC Mobile Network

~ thousands of eNBs

Best latency

A lot of deployment cost
Near PGWs

LTE/EPC Mobile Network

~ low tens of PGW

Small deployment cost

Worst latency
Regional aggregation points

~ 100 – 150 regional aggregation points
- It covers a large metropolitan area
- Reasonable location in terms of cost and delay
Regional aggregation points

LTE/EPC Mobile Network

Radio delay

Core network delay

WAN delay (PGW<-> web server)

Game server

Internet

eNBs

Cloud

Regional aggregation point

SGW

PGW
Offloading Infrastructure

Offload Cloud

Regional Aggregation Point

SDN

eNB

SGW

PGW

MME

Internet
SMORE Architecture

- **SMORE SDN**
- **Regional Aggregation Point**
- **SGW**
- **PGW**
- **MME**
- **SMORE Controller**
- **SMORE Monitor**
- **SMORE DB**
- **Offload Cloud**
- **Internet**

eNB
SMORE Use Cases

• On-demand use case

• Subscription use case
On-demand Use Case

LTE/EPC Mobile Network
Extract Info from Attach Event

1. Attach Request

2. Attach Request
   - Extract UE IMSI, TAI

3. Create Session Request

4. Create Session Response

   - Extract UE IP/GUTI, SGW IP/TEID

6. RRC Conn. Reconfig.


   - Extract eNodeB IP, TEID
On-demand Use Case

LTE/EPC Mobile Network

- eNB
- Regional Aggregation Point
- SGW
- PGW
- Game Frontend Server
- Internet
- Offload Cloud
On-demand Use Case

LTE/EPC Mobile Network
On-demand Use Case

SMORE

SMORE: Software-Defined Networking Mobile Offloading Architecture
On-demand Use Case

SMORE

SMORE SDN

Regional Aggregation Point

eNB

Offload Cloud

SGW

PGW

Internet

Game Frontend Server

SMORE Controller

SMORE Monitor

SMORE DB
On-demand Use Case

SMORE

SMORE SDN

Regional Aggregation Point

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Offload Cloud

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SMORE Controller

SMORE Monitor

SMORE DB

Game Frontend Server

Internet

SMORE : Software-Defined Networking Mobile Offloading Architecture
On-demand Use Case
On-demand Use Case

SMORE

SMORE 

SGW

PGW

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Game Frontend Server

Regional Aggregation Point

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Offload Cloud

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SMORE : Software-Defined Networking Mobile Offloading Architecture

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On-demand Use Case

SMORE

SGW

PGW

Regional Aggregation Point

SMORE SDN

SMORE Controller

SMORE Monitor

SMORE DB

Game Frontend Server

Internet

Game Backend Server

Offload Cloud

SGW

PGW

eNB

8/25/14
On-demand Use Case

SMORE

- Software-Defined Networking Mobile Offloading Architecture

Diagram:
- eNB
- Regional Aggregation Point
- SMORE SDN
- Off-cloud
- Game Backend Server
- SGW
- PGW
- Internet
- Other services

8/25/14
SMORE Components

- SMORE SDN
- SMORE Controller
- SMORE Monitor
SMORE SDN

- Forward traffic based on flow-entries
- Traffic offloading evaluation
- GTP Tunnel en/decapsulation
GPRS Tunnel Protocol (GTP)

GTP Tunnel

<table>
<thead>
<tr>
<th>PAYLOAD</th>
</tr>
</thead>
<tbody>
<tr>
<td>INNER IP</td>
</tr>
<tr>
<td>( src : UE IP, dst : Server IP )</td>
</tr>
<tr>
<td>GTP (TEID : SGW TEID )</td>
</tr>
<tr>
<td>UDP (dst port : 2125 )</td>
</tr>
<tr>
<td>OUTER IP</td>
</tr>
<tr>
<td>( src : eNB IP, dst : SGW IP )</td>
</tr>
<tr>
<td>L2</td>
</tr>
<tr>
<td>L1</td>
</tr>
</tbody>
</table>

eNB

SMORE SDN
Two Possible Paths for Uplink Traffic

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<tr>
<td>L2</td>
</tr>
<tr>
<td>L1</td>
</tr>
</tbody>
</table>

*SMORE : Software-Defined Networking Mobile Offloading Architecture*
Match Rule for Uplink Traffic

- **PAYLOAD**
  - **INNER IP**
    - (src : UE IP, dst : Server IP)
  - **GTP (TEID : SGW TEID)**
  - **UDP** (dst port : 2125)
  - **OUTER IP**
    - (src : eNB IP, dst : SGW IP)
- **Match fields**
- **L2**
- **L1**

**SMORE SDN**
Uplink Traffic Redirection

Flow Table

<table>
<thead>
<tr>
<th>Match</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>GTP (TEID : SGW TEID ) &amp; INNER IP ( src :UE IP, dst : Server IP )</td>
<td>Action 1. Decapsulate GTP, UDP, OUTER IP 2. Forward it to game backend server</td>
</tr>
</tbody>
</table>

PAYLOAD

<table>
<thead>
<tr>
<th>INNER IP ( src :UE IP, dst : Server IP )</th>
</tr>
</thead>
<tbody>
<tr>
<td>L2</td>
</tr>
<tr>
<td>L1</td>
</tr>
</tbody>
</table>
Uplink Traffic

SMORE SDN

GTP Tunnel

PAYLOAD

INNER IP
( src : UE IP, dst : Server IP )

GTP (TEID : SGW TEID )

UDP (dst port : 2125 )

GTP Tunnel

PAYLOAD

INNER IP
( src : UE IP, dst : Server IP )

GTP (TEID : SGW TEID )

UDP (dst port : 2125 )

OUTER IP
( src : eNB IP, dst : SGW IP )

L2

L1

eNB

SGW
Downlink Traffic
Downlink Traffic

SMORE SDN

PAYLOAD

INNER IP
( src : UE IP, dst : Server IP )

L2

L1

Match fields

Game Backend Server
Downlink Traffic

SMORE SDN

Flow Table

Match

Action

1. Encapsulate GTP, UDP, OUTER IP
2. Forward it to eNB

Game Backend Server

PAYLOAD

INNER IP
(src: Server IP, dst: UE IP)

GTP (TEID: eNodeB TEID)
UDP (dst port: 2125)
OUTER IP
(src: SGW IP, dst: eNB IP)

L2
L1
Downlink Traffic

SMORE SDN

GTP Tunnel

**PAYLOAD**

**INNER IP**
( src : Server IP, dst : UE IP )

**GTP (TEID : eNodeB TEID )**

**UDP (dst port : 2125 )**

**OUTER IP**
( src : SGW IP, dst : eNB IP )

L2

L1

--

**PAYLOAD**

**INNER IP**
( src : Server IP, dst : UE IP )

**GTP (TEID : eNodeB TEID )**

**UDP (dst port : 2125 )**

**OUTER IP**
( src : SGW IP, dst : eNB IP )

L2

L1
Implementation

• LTE/EPC testbed: OpenEPC LTE/EPC software

• SMORE SDN : open Vswitch 2.0
  – Extending GTP evaluation, en/decapsulation functions by using vport abstraction mechanism

• SMORE Controller : Ryu controller
  – Extending Ryu API for GTP flow management

• SMORE Monitor : Tshark
  – Detecting attach and detach events
  – Extracting information from events and storing them to DB.
PhantomNet Testbed

- tunneled traffic
- traffic without tunneling

Diagram showing the architecture of the PhantomNet Testbed, including UE, enodeB, SMORE SDN, MME, SGW, PGW, and Offloaded Server.
Evaluation

- SMORE SDN overhead

- End-to-End RTT improvement

- We use ping for evaluation
SMORE SDN Overhead

- Measure overheads from additional functionalities in SMORE SDN
  - GTP evaluation
  - GTP en/decapsulation

- Compare SMORE SDN with native open Vswitch

**SMORE SDN**

```
Packet In
\[\text{In\_port}\] \rightarrow \text{Matches & Actions} \rightarrow \text{Out\_port}\]
```

Elapsed Time

SGW or Offloading server
Uplink SMORE SDN Overhead

- eNB
- Packet In
- In_port
- SMORE SDN
  - Matches & Actions
  - Overheads from
    1. GTP evaluation
    2. GTP decapsulation
- Out_port
- Packet Out
- Game Backend Server

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Uplink SMORE SDN Overhead

In_port

Matches & Actions

SMORE SDN

Out_port

Overhead from GTP evaluation

eNB

Packet In

SGW

Packet Out
Uplink SMORE SDN Overhead

Compared with Native OVS
- SMORE (to CLOUD) : 5.3 us
- SMORE (to SGW) : 1.9 us

Processing time in each port (us)

- ETH input port
- ETH output port
- GTP eval port
- GTP decap port

Compared with Naive OVS
- SMORE (to CLOUD) : 5.3 us
- SMORE (to SGW) : 1.9 us
Downlink SMORE SDN Overhead

SMORE SDN

In_port

Matches & Actions

Out_port

Overhead from GTP decapsulation

Game Backend Server

Packet Out

eNB

Packet In
Downlink SMORE SDN Overhead

Compared with Native OVS
- SMORE (from CLOUD) : 2.1 us

Processing time in each port(us)

- ETH input port
- ETH output port
- GTP encap port

SMORE-SDN (Cloud -> eNB)
SMORE-SDN (SGW -> eNB)
Native OVS (SGW -> eNB)
Feasibility and Limitation of SMORE

• The overall overhead due to processing GTP functionalities in SMORE SDN is not high compared to end-to-end delay in LTE (~70ms)

• May have scalability issue in SMORE SDN
  – Explore scalability in SMORE SDN

• Architectural limitation
  – Limited support for handover (supporting Intra-LTE Handover using the X2 interface)
Conclusion

• We presented SMORE architecture to realize traffic offloading to reduce end-to-end delay
  – No modification of existing LTE/EPC mobile network.
  – Show how offloading for selected traffic of subscribed users can realized even when handover happens

• Prototype realization of SMORE architecture in PhantomNet LTE/EPC testbed.
Thank you!
Questions?

Visit phantomnet.org