LTE - Can SDN paradigm be applied?

Source of this presentation:

Towards Software Defined Cellular Networks
Li Erran Li (Bell Labs, Alcatel-Lucent) Morley Mao (University of Michigan) Jennifer Rexford (Princeton University)
LTE Data plane is too centralized

- Data plane is too centralized

- UE: user equipment
- eNodeB: base station
- S-GW: serving gateway
- P-GW: packet data network gateway

Scalability challenges at P-GW on charging and policy enforcement!
LTE Control plane is too distributed

- No clear separation of control plane and data plane

- Problem with Inter-technology (e.g. 3G to LTE) handoff
- Problem of inefficient radio resource allocation
Advantages of SDN for Cellular Networks

• Advantage of logically centralized control plane
  – Flexible support of middleboxes
  – Better inter-cell interference management
  – Scalable distributed enforcement of QoS and firewall policies in data plane
  – Flexible support of virtual operators by partitioning flow space

• Advantage of common control protocol
  – Seamless subscriber mobility across technologies

• Advantage of SDN switch
  – Traffic counters enable easy monitoring for network control and billing
Flexible Middlebox Support

- SDN provides fine grained packet classification and flexible routing

- Easy to control flow to middleboxes for content adaptation, echo cancellation, etc

- Reduce traffic to middleboxes

UE 1

UE 2

UE 3

Middlebox

SDN Switch

Path setup for UE by SDN controller

Internet and Other IP Networks
Flexible Middlebox Support (Cont’d)

- SDN switch can support some middlebox functionality

  - Easy to satisfy policy for traffic not leaving cellular network
  - Reduce the need for extra devices
  - SDN switch can support some middlebox functionality

Path setup for UE by SDN controller

Internet and Other IP Networks
Monitoring for Network Control & Billing

- Packet handling rules in SDN switches can efficiently monitor traffic at different levels of granularity
  - Enable real-time control and billing

<table>
<thead>
<tr>
<th>Rule</th>
<th>Action</th>
<th>Stats</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Packet + byte counters</td>
</tr>
<tr>
<td></td>
<td>1. Forward packet to port(s)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Encapsulate and forward to controller</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Drop packet</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4. Send to normal processing pipeline</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Switch Port</th>
<th>MAC src</th>
<th>MAC dst</th>
<th>Eth type</th>
<th>VLAN ID</th>
<th>IP Src</th>
<th>IP Dst</th>
<th>IP Prot</th>
<th>TCP sport</th>
<th>TCP dport</th>
</tr>
</thead>
</table>

+ mask
Seamless Subscriber Mobility

- SDN provides a common control protocol that works across different cellular technologies.
- Forwarding rules can be pushed to switches in parallel.

_path setup for UE by SDN controller_
Distributed QoS and ACL Enforcement

- LTE’s PCEF is centralized at P-GW which is inflexible

Access policy checked in SDN switches distributedly

Path setup for UE by SDN controller

Internet and Other IP Networks
Virtual Operators

• Flexible network virtualization by slicing flow space

Virtual operators may want to innovate in mobility, billing, charging, radio access.
Inter-Cell Interference Management

- Central base station control: better interference management

- LTE distributed interference management is suboptimal

Global view and more computing power

Network Operating System: CellOS

Radio Resource Manager

SDN Switch

Internet and Other IP Networks
Virtualization

Slicing Layer: CellVisor

Network OS (Slice 1)  Network OS (Slice 2)  ...  Network OS (Slice N)

Cell Agent  Cell Agent  Cell Agent
Radio Hardware  Packet Forwarding Hardware  Packet Forwarding Hardware

Slice semantic space, e.g. all roaming subscribers, all iPhone users
State of Art

• Stanford OpenRoad
  – Introduced openflow, FlowVisor, SNMPVisor to wireless networks
• Stanford OpenRadio
  – Programmable cellular data plane
• NEC base station virtualization
  – Slicing radio resources at the MAC layer
• Ericsson CloudEPC
  – Modify LTE control plane to control openflow switches
• Bell labs - Alcatel CellSDN
  – Provides scalable, fine-grain real time control and extensions: