Towards Software Defined Cellular Networks

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Outline

• Critiques of LTE Architecture
• CellSDN Use Cases
• CellSDN Architecture
• Related Work
• Conclusion and Future Work
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

Path setup for UE by SDN controller
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
Monitoring for Network Control & Billing

- Packet handling rules in SDN switches can efficiently monitor traffic at different level 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>+ mask</td>
<td>Packet + byte counters</td>
<td></td>
</tr>
</tbody>
</table>

1. Forward packet to port(s)
2. Encapsulate and forward to controller
3. Drop packet
4. Send to normal processing pipeline

<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>
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Seamless Subscriber Mobility

- SDN provides a common control protocol 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

Internet and Other IP Networks
Inter-Cell Interference Management

- Central base station control: better interference management

- LTE distributed interference management is suboptimal

Global view and more computing power
CellSDN Architecture

• CellSDN provides scalable, fine-grain real time control with extensions:
  – Controller: *fine-grain* policies on subscriber attributes
  – Switch software: local control agents to improve control plane *scalability*
  – Switch hardware: *fine-grain* packet processing to support DPI
  – Base stations: remote control and virtualization to enable flexible *real time* radio resource management
CellSDN Architecture (Cont’d)

Central control of radio resource allocation

- DPI to packet classification based on application
- SCTP instead of TCP to avoid head of line blocking
- Offloading controller actions, e.g. change priority if counter exceed threshold
- DPI to packet classification based on application

Network Operating System: CellOS

- Radio Resource Manager
- Mobility Manager
- Subscriber Information Base
- Policy and Charging Rule Function
- Infrastructure Routing

Cell Agent

Radio Hardware

Cell Agent

Packet Forwarding Hardware

Cell Agent

Packet Forwarding Hardware
CellSDN Virtualization

Slicing Layer: CellVisor

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

Cell Agent
- Radio Hardware
- Packet Forwarding Hardware

Slice semantic space, e.g. all roaming subscribers, all iPhone users
Related Work

• 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
Conclusion and Future Work

• CellSDN advantages:
  – Simple and easy to manage
  – Simple and easy to introduce new services
  – Easy to inter-operate with other wireless technologies

• Future work: detailed CellSDN design