OpenFlow-based Mechanisms for QoS in LTE Backhaul Networks

Luciano Jerez Chaves\textsuperscript{1,2}, Islene Calciolari Garcia\textsuperscript{2}, Edmundo R. Mauro Madeira\textsuperscript{2}

\textsuperscript{1}Federal University of Juiz de Fora (UFJF), Brazil
\textsuperscript{2}University of Campinas (Unicamp), Brazil
Outline

❖ Introduction
❖ Software-Defined Networking
❖ Long-Term Evolution networks
❖ SDN and LTE integration
❖ Proposed QoS mechanisms
❖ Conclusions and future work
Introduction

- Mobile data traffic is increasing at a compound annual growth rate of 57%.
- Increasing number of higher-generation connectivity.
- Multimedia streaming represents more than 50% of mobile data traffic.

Future networks

- 5G networks for people and things
- Lower latency and higher data rates
- Heterogeneous Networks (HetNets)
- High-connectivity backhaul and core networks for more base stations

Software-Defined Networking will be a key differentiator of 5G systems
Contributions

❖ **This work contributes with...**

❖ OpenFlow protocol integrated into LTE backhaul networks
❖ Specialized OpenFlow EPC controller for LTE traffic control
❖ Network traffic routing
❖ Bearer admission control
❖ LTE QoS realization
Software-Defined Networking

- Decouples the control plane from the data plane
- Network intelligence is centralized in software
- Simplified distributed forwarding hardware
- More agile and cost-effective networks
OpenFlow protocol

- SDN southbound interface
- Basic primitives to program the forwarding plane of OpenFlow switches
- Concepts of flows to identify network traffic
- Switch datapath specification
Long-Term Evolution networks

❖ 4G standard for high-speed wireless communication
❖ Maintained by the 3rd Generation Partnership Project
❖ Evolved Packet System (EPS)
  • Evolved Universal Terrestrial Radio Access Network (E-UTRAN)
  • Evolved Packet Core (EPC)
EPS architecture

- Packet domain only
- Standardized interfaces
- GPRS Tunneling Protocol (GTP)
LTE QoS and EPS bearers

- EPS bearers identify packet flows with common QoS treatment
- Bearers are associated with a QoS Class Identifier (QCI)
  - Minimum Guaranteed Bit Rate (GBR)
  - Non-Guaranteed Bit Rate (Non-GBR)
SDN and LTE integration

❖ Proposed integration

❖ OpenFlow switches in the backhaul network (S1 interfaces)
❖ New OpenFlow match fields for GTP TEID routing
❖ No changes in EPC elements for tunnel handling
Network topology

- **Wired backhaul topology**
  - Ring with arbitrary number of OpenFlow switches
  - Unified S-GW/P-GW gateway element
  - Ethernet full-duplex links

- **Wireless access topology**
  - Hexagonal grid with inter-site distance of 500 m
  - UEs scattered closed to the eNBs
OpenFlow EPC controller

- **LTE traffic control mechanisms**
  - Network traffic routing
  - Bearer admission control
  - LTE QoS realization
- Controller communicates with the MME element for bearer management procedures
Network traffic routing

- Look for routing paths and install GTP TEID match rules
- For the ring topology, the routing options are reduced to clockwise or counter-clockwise paths
- Different routing policies
  - Shortest Path Only
  - Shortest Path First
Bearer admission control

- Reserve the requested bandwidth for accepted GBR bearers
  - *Shortest path only* routing policy blocks GBR requests when there is no available bandwidth in the shortest routing path
  - *Shortest path first* routing policy checks on the other routing path for the required bandwidth before blocking the GBR request
LTE QoS realization

- Translate from bearer-level QoS (QCI) to transport-level QoS
  - LTE is IP-based, so it can leverage DiffServ to provide QoS
  - OpenFlow match the DiffServ Code Point (DSCP) header filed
- OpenFlow meters are used for GBR/Non-GBR traffic coexistence
  - Limit the GBR bearer throughput to the maximum bitrate
  - Limit the aggregated Non-GBR throughput over each link
- Dedicated output queue for VoIP traffic improvement
Performance evaluation

- **Network Simulator 3 + OFSwitch13 module**
- **Backhaul ring size**: 4/10 OpenFlow switches connected to eNBs
- **UE load distributions**: balanced or unbalanced (30% of UEs in one half of the ring, 70% on the other half)
- **Admission control**: up to 40% of link bandwidth for GBR traffic

<table>
<thead>
<tr>
<th>Traffic applications</th>
<th>Traffic type</th>
<th>Bearer QCI</th>
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</thead>
<tbody>
<tr>
<td>VoIP</td>
<td>UDP</td>
<td>GBR (1)</td>
</tr>
<tr>
<td>Live Video Streaming</td>
<td>UDP</td>
<td>GBR (2)</td>
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<tr>
<td>Buffered Video Streaming</td>
<td>TCP</td>
<td>Non-GBR (6)</td>
</tr>
<tr>
<td>Live Video Streaming</td>
<td>UDP</td>
<td>Non-GBR (7)</td>
</tr>
<tr>
<td>HTTP</td>
<td>TCP</td>
<td>Non-GBR (8)</td>
</tr>
</tbody>
</table>
Traffic routing and admission control

4 OpenFlow switches in the ring
Unbalanced load configuration

Improved block ratio for the shortest path first routing policy
LTE QoS realization
(GBR/Non-GBR coexistence)

10 OpenFlow switches in the ring
Balanced load configuration
Shortest path first routing policy

GBR throughput without Non-GBR interference

Traffic throughput and GBR reserved bandwidth

Packet drop ratio by OpenFlow meters
LTE QoS realization (VoIP improvements)

10 OpenFlow switches in the ring
Balanced load configuration
Shortest path first routing policy
VoIP mapped onto high-priority output queues
Conclusions and future work

❖ This paper shows…
❖ How the OpenFlow protocol can be used to assist LTE traffic control management
❖ Backhaul traffic routing
❖ Bearer admission control
❖ LTE QoS realization

❖ As future work…
❖ Improve the proposed mechanisms to support UE mobility