Integrating OpenFlow to LTE: some issues toward Software-Defined Mobile Networks

Luciano Jerez Chaves¹,²
Vítor Marge Eichemberger²
Islene Calciolari Garcia²
Edmundo R. Mauro Madeira²

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

❖ Introduction
❖ Software-Defined Networking and OpenFlow
❖ Long-Term Evolution
❖ LTE and OpenFlow integration
❖ Performance evaluation
❖ Case study
❖ Conclusions
Introduction

❖ Increasing mobile data traffic
❖ Compound annual growth rate of 57%
❖ Mobile video represents more than half of mobile data traffic

Introduction

❖ Increasing mobile data traffic
❖ Compound annual growth rate of 57%
❖ Mobile video represents more than half of mobile data traffic

Introduction

❖ Increasing number of higher-generation connectivity
❖ 2G devices and connections will be surpass 2G by 2017
❖ 4G devices and connections will surpass 2G by 2019

More base stations
High-connectivity backhaul

Introduction

❖ Increasing number of higher-generation connectivity
❖ 2G devices and connections will be surpass 2G by 2017
❖ 4G devices and connections will surpass 2G by 2019

More base stations
High-connectivity backhaul

Billions of device or connections

Software-Defined Networking

- Decouples the control and data plane
- Simplified forwarding hardware controller by intelligent centralized software
Software-Defined Networking

- Decouples the control and data plane
- Simplified forwarding hardware controller by intelligent centralized software

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

Software Defined Networking (SDN) is an emerging network architecture where network control is decoupled from forwarding and is directly programmable. This migration of control, formerly tightly bound in individual network devices, into accessible computing devices enables the underlying infrastructure to be abstracted for applications and network services, which can treat the network as a logical or virtual entity.

Figure 1 depicts a logical view of the SDN architecture. Network intelligence is (logically) centralized in software-based SDN controllers, which maintain a global view of the network. As a result, the network appears to the applications and policy engines as a single, logical switch. With SDN, enterprises and carriers gain vendor-independent control over the entire network from a single logical point, which greatly simplifies the network design and operation. SDN also greatly simplifies the network devices themselves, since they no longer need to understand and process thousands of protocol standards but merely accept instructions from the SDN controllers.

Perhaps most importantly, network operators and administrators can programmatically configure this simplified network abstraction rather than having to hand-code tens of thousands of lines of configuration scattered among thousands of devices. In addition, leveraging the SDN controller’s centralized intelligence, IT can alter network behavior in real-time and deploy new applications and network services in a matter of hours or days.
OpenFlow

- Basic primitives to program the forwarding plane of OpenFlow switches
  - Flow, group and meter tables
  - Extensible match fields
Long-Term Evolution

- The 4G standard for high-speed wireless communication
- Both the radio access and core networks
- Concept of bearers for IP traffic routing and QoS
LTE and OpenFlow integration

- Motivation:
  - Inefficient coordination among too many eNBs
  - Expensive and complex gateway elements
LTE and OpenFlow integration

- **Motivation:**
  - Inefficient coordination among too many eNBs
  - Expensive and complex gateway elements

<table>
<thead>
<tr>
<th>Solution</th>
<th>LTE Network segment</th>
<th>Contribution</th>
<th>OpenFlow GTP extension</th>
<th>Scalability concerns</th>
<th>Mobility and routing</th>
<th>3GPP LTE Interoperability</th>
<th>Performance evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>MobileFlow [5]</td>
<td>EPC and RAN</td>
<td>New SDN mobile architecture</td>
<td>Yes</td>
<td>Yes (more controllers)</td>
<td>Possible (controller apps)</td>
<td>Yes (controller apps)</td>
<td>Yes (eNB + test bed)</td>
</tr>
<tr>
<td>Hampel et al. [11]</td>
<td>SGW, PGW and MME</td>
<td>Vertical forwarding tunneling</td>
<td>Yes</td>
<td>Yes (few switches)</td>
<td>Yes (link failure)</td>
<td>Yes (controller apps)</td>
<td>No</td>
</tr>
<tr>
<td>SoftCell [12]</td>
<td>EPC and RAN</td>
<td>New cellular flat architecture</td>
<td>No GTP (removed)</td>
<td>Yes (local agents)</td>
<td>Yes (location routing)</td>
<td>No</td>
<td>Yes (test bed)</td>
</tr>
<tr>
<td>Kempf et al. [13]</td>
<td>EPC and RAN</td>
<td>Move EPC control to the cloud</td>
<td>Yes</td>
<td>Not discussed</td>
<td>Yes (TEID routing)</td>
<td>Not discussed (possible)</td>
<td>Yes (test bed)</td>
</tr>
<tr>
<td>Basta et al. [15]</td>
<td>SGW and PGW</td>
<td>Gateway function placement study</td>
<td>Yes</td>
<td>Yes (control channel)</td>
<td>Not discussed</td>
<td>Not discussed (possible)</td>
<td>No</td>
</tr>
<tr>
<td>Said et al. [16]</td>
<td>EPC control plane</td>
<td>New control plane for connectivity</td>
<td>Yes</td>
<td>Not discussed</td>
<td>Yes (load balancing)</td>
<td>No (protocol change)</td>
<td>No</td>
</tr>
<tr>
<td>SDMA [17]</td>
<td>S1 backhaul</td>
<td>Optimize mobile traffic management</td>
<td>No GTP (removed)</td>
<td>Yes (signaling load)</td>
<td>Yes (mobility anchor)</td>
<td>No (protocol change)</td>
<td>Yes (analytical)</td>
</tr>
</tbody>
</table>
LTE and OpenFlow integration

❖ GTP tunnel support:
   ❖ Tunnels are used to address EPC QoS and routing
   ❖ Remove the tunnels to have a flat architecture
   ❖ Extend the OpenFlow protocol with tunnel handling support

❖ Scalability:
   ❖ Centralized or distributed controller hierarchy
   ❖ Limits on hardware table sizes and protocol processing power
LTE and OpenFlow integration

- Mobility and routing
  - Horizontal and vertical handovers
  - Explore geolocation to reduce path changes
  - Speed up control signalling and provide load balancing

- Interoperability:
  - Modify the LTE protocols and keep compatibility
  - Software interoperability at controller
LTE and OpenFlow integration

- Performance evaluation
  - Some related works have no performance validation
  - Only a few works includes some real equipments
  - Use of small software test bed (virtualized environments)
    - Closed implementations
    - Integration problems with existing tools (ex. Mininet)
LTE and OpenFlow integration

- Performance evaluation
  - Some related works have no performance validation
  - Only a few works includes some real equipments
  - Use of small software test bed (virtualized environments)
    - Closed implementations
    - Integration problems with existing tools (ex. Mininet)

There is room from a more generic, flexible and powerful tool to evaluate these integrated networks
Performance evaluation

- **ns-3 Network Simulator**
  - LTE module: both access and core model
  - Outdated OpenFlow module (ver. 0.8.9 from 2008)

- **New ns-3 OpenFlow module: ofswitch13**
  - OpenFlow 1.3 switch device
  - OpenFlow 1.3 controller interface
The ofswitch13 module
The ofswitch13 module

- Complete integration with other ns-3 modules
  - Run over standard Ethernet module (CsmaNetDevice)
- External ofsoftswitch13 library
  - User-space switch datapath implementation
  - Dpctl controller utility

- Currently, no support for channel encryption, multiple controllers, nor auxiliary connections
Case study scenario

- Integrating both LTE and ofswitch13 modules in ns-3
  - Use of an OpenFlow network to replace S1-U backhaul (connecting eNBs to the gateway)
  - Extending the OpenFlow protocol with GTP support
  - New specialized OpenFlow controller for LTE network
- Controller communication with the MME element for bearer management
Case study scenario

- 5 eNBs and 350 UEs
- Unbalanced ring load (200 UEs at switch #3)
- 100 Mbps S1 links
- HTTP, VoIP and video traffic
- Shortest path routing
Case study results
Case study results

- Aggregated network throughput: 82.52 Mbps
Case study results

- Aggregated network throughput: **82.52 Mbps**
- Block ratio: **33.35%**
Case study results

- Aggregated network throughput: 82.52 Mbps
- Block ratio: 33.35%
- Link usage: up to 80% (maximum allowed)
Conclusions

❖ This paper shows the state of the art in integrating OpenFlow to LTE networks
  ❖ Motivation and discussions about open challenges
  ❖ Performance evaluation concerns

❖ New OpenFlow 1.3 module for the ns-3 network simulator
  ❖ Easy integration with LTE (and any other) ns-3 module
  ❖ Validation throughout case study
Future work

- New strategies to improve network QoS and QoE
- Exploit different routing strategies, considering centralized knowledge about network topology and traffic
Acknowledgments

Thank you!

luciano@lrc.ic.unicamp.br