SimuLTE – A Modular System-level Simulator for LTE/LTE-A Networks based on OMNeT++

Antonio Virdis
Giovanni Stea
Giovanni Nardini
University of Pisa
SimuLTE

• What
• How
• Where
• Why
WHAT is SimuLTE?

- Simulator of LTE networks
- resource Allocation/Management
- Based on OMNeT++
- Over 40K lines of code
- Designed to be easily extended
- Open Source (LGPL)
Related Work

• Physical Layer simulators

• Ikuno et al.
  – Based on Matlab

• LTE-Sim
  – Standalone (C++)

• NS-3
  – A lot of LTE features
OMNeT++ Simulation Framework

• Highly modular

• Support for Simulation Automation

• Data collection/analysis

• Large set of ready-to-use models
OMNeT++ Simulation Framework

Compound module

Simple module 1

Simple module 2

gates

connections

Description

Parameters

Behavior

.ned

.ini

.cpp

Antonio Virdis - SimuLTE - A modular System-Level Simulator For LTE/Lte-A Networks based on Omnet++
HOW is SimuLTE made?

Antonio Virdis - SimuLTE - A modular System-Level Simulator For LTE/Lte-A Networks based on Omnet++
Layer to Modules

atomic

Data Path

RLC

getValue(...) setValue(...)getValue(...) setValue(...)

MAC

atomic

Cross Layer

Antonio Virdis - SimuLTE - A modular System-Level Simulator For LTE/Lte-A Networks based on Omnet++
Modules Inheritance

- eNB NIC
- UE NIC
- eNB RLC
- UE RLC
- eNB MAC
- UE MAC
- eNB PHY
- UE PHY

Modules and/or C++ Classes

Antonio Virdis - SimulTE - A modular System-Level Simulator For LTE/Lte-A Networks based on Omnet++
WHERE is SimuLTE

Antonio Virdis - SimuLTE - A modular System-Level Simulator For LTE/Lte-A Networks based on Omnet++
Messages *between* Nodes

Available Data

- **MAC**
- **Allocator**
  - UE1
  - UE2
  - UE1
  - UE1

- **PHY**
  - Channel Model

- **OFDM**

---

Antonio Virdis - SimuLTE - A modular System-Level Simulator For LTE/Lte-A Networks based on Omnet++
Channel Models

Pathloss
Fading
Interference
...

ChannelModel

Dummy ChannelModel

Realistic ChannelModel

Your ChannelModel
Here

getSINR(...)

error(...)

Antonio Virdis - SimuLTE - A modular System-Level Simulator For LTE/Lte-A Networks based on Omnet++
Nodes and Networks

Antonio Virdis - SimuLTE - A modular System-Level Simulator For LTE/Lte-A Networks based on Omnet++
Workflow

repeat = 2
pktSize = { 10, 100 } bytes
interval = { 10, 20 } ms

x2
Optimization techniques

Input 1, Input n → optimizer → Output 1, Output n

System Status → optimizer

Antonio Virdis - SimuLTE - A modular System-Level Simulator For LTE/Lte-A Networks based on Omnet++
• Academic license
• Input: *LP files*
  – Text files describing the opt. problem
  – Easy to build
• Output: *xml files*
  – Well known format
  – Easy to parse
Validation/Verification

1) Base scenario evaluation

![Simulation Vs Theoretical](image)

<table>
<thead>
<tr>
<th>Distance from eNB (m)</th>
<th>Reference</th>
<th>Scenario I</th>
<th>Scenario II</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>2500</td>
<td>2000</td>
<td>1500</td>
</tr>
<tr>
<td>1000</td>
<td>2000</td>
<td>1500</td>
<td>1000</td>
</tr>
<tr>
<td>1500</td>
<td>1500</td>
<td>1000</td>
<td>500</td>
</tr>
<tr>
<td>2000</td>
<td>1000</td>
<td>500</td>
<td>0</td>
</tr>
</tbody>
</table>

Antonio Virdis - SimuLTE - A modular System-Level Simulator For LTE/Lte-A Networks based on Omnet++
Validation/Verification

2) Event Traces

3) Degeneracy Test
   – Extreme cases

4) Anti-bugging techniques
   – ASSERTS
5) Structured testing via

- hash

- dummy modules
Work In Progress

• Extending Validation

• Detailed Comparison between simulators

• Improving usage of solvers

• Adding new LTE / LTE-Advanced features
  – D2D / CoMP / C-RAN
Conclusions

• **What:**
  • Simulator for LTE networks
  • Resource allocation/management

• **How:**
  • Modular

• **Where:**
  • System/Node level

• **Why**
  • Designed to be easy to extend

• **Validation/Verification**
• **PAPERS**
  - "A comprehensive simulation analysis of LTE Discontinuous Reception (DRX)“, G. Stea, A. Virdis, COMNET 2014

• **Other Projects**
  - VANETS
  - Robotic Swarm

• **Link**  [simulte.com](http://simulte.com)  or  [github](https://github)
Conclusions

• **PAPERS**
  
  – "A comprehensive simulation analysis of LTE Discontinuous Reception (DRX)“, G. Stea, A. Virdis, COMNET 2014
  
  

• **Other Projects**
  
  – VANETS
  
  – Robotic Swarm

• **Link** [simulte.com](simulte.com) or [github](github)
Tx/Rx modeling

OFDM

frequency

RB

K bit

CQI

1 ms

UE

eNB

RB

K bit

CQI

1 ms

frequency

OFDM

eNB

UE

RB

K bit

CQI

UE 1

UE 2

UE 3

Antonio Virdis - SimuLTE - A modular System-Level Simulator For LTE/Lte-A Networks based on Omnet++
Implementation: Channel model

PHY
getSINR(...) ⇐ Channel Model
error(...) ⇐

PHY
getSINR(...) ⇐ Channel Model
error(...) ⇐

CQI

MSG

Antonio Virdis - SimuLTE - A modular System-Level Simulator For LTE/Lte-A Networks based on Omnet++
Scheduling

Available Data

Scheduling Policy

Allocator

N bit

User Tx Params

Pilot

M bit

AMC

Downlink Scheduling

Schedule List

UE Reports

Antonio Virdis - SimuLTE - A modular System-Level Simulator For LTE/Lte-A Networks based on Omnet++
Scheduling Hierarchy

• Scheduler Type and

  eNB
  Scheduler

  eNB
  Scheduler UL

  eNB
  Scheduler DL

• Scheduling Policy

  Scheduling Policy

  MAX C/I

  PF

  DRR
Scheduling

- Two stages scheduling
  - Prepare schedule
  - Commit schedule
Allocation Flexibility

Scheduling Policy \( \text{getBlocks}(n) \) Allocator

Scheduling Policy \( \text{getBlocks}(n, \text{limit}) \) Allocator

Joint Scheduler / Allocator

Antonio Virdis - SimuLTE - A modular System-Level Simulator For LTE/Lte-A Networks based on Omnet++

29
Example: *multiband scheduling*

![Diagram showing multi-band scheduling](image)

**Schedule?**

*Antonio Virdis - SimuLTE - A modular System-Level Simulator For LTE/Lte-A Networks based on Omnet++*
**multiband scheduling**

\[
\max \sum_{i=1}^{N} \left( r_i \cdot \sum_{j=1}^{M} x_{i,j} - p_i \right)
\]
Analysis of multiband scheduling

Avg Allocated RBs per cell

Number of UEs per cell

Antonio Virdis - SimuLTE - A modular System-Level Simulator For LTE/Lte-A Networks based on Omnet++