Simulating device-to-device communications in OMNeT++ with SimuLTE: scenarios and configurations

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Outline

• LTE Context

• Simulator structure

• Examples
  • LTE
  • LTE-Advanced
  • Towards 5G: D2D
LTE

Data Req
Channel Quality

Scheduling

UE 1

UE 2

UE 3

eNb

1ms

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SimuLTE

• OMNeT-based system-level simulator of LTE networks

• Focused on testing algorithms for resource scheduling at large scale

• INET based

• Built as an additional NIC interface

• Follow the evolution of cellular communications
Nodes

Standard Hosts

UE

UDP apps
TCP apps
UDP
TCP
IP
LTE NIC

eNB

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Layering

SimuLTE

LTE NIC

UE

UDP
TCP

UDP apps
TCP apps

IP

LTE NIC

1ms

PDCP
RLC
MAC
PHY

UE
IP
UDP
TCP
UDP apps
TCP apps
IP

LTE NIC

1ms

PDCP
RLC
MAC
PHY

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Common Structure: Inheritance

Base NIC

Base RLC

Base MAC

Base PHY

eNB RLC

UE RLC

eNB MAC

UE MAC

eNB PHY

UE PHY
Goal: algorithms

- Aim at implementing and testing resource-scheduling algorithms
- Model resources.
- Model resource management
- Provide an API to users
Tx/Rx modeling

- eNB
- UE
- OFDM
- RB
- K bit
- CQI
- frequency
- 1 ms
- UE 1
- UE 2
- UE 3
Scheduling

Available Data

Scheduler

Scheduling Policy

Allocater

N bit

User Tx Params

Pilot

M bit

AMC

Schedule List

UE Reports

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• Scheduler Type and

• Scheduling Policy
Example 1: ~2010 rel 8-9

- Simple network
- Common parameters
  - Mobility
  - Application type
- SimuLTE Parameters
  - Number of RBs
  - Scheduler type
Example 1: ~2010 rel 8-9

# connect each UE to the eNB
**.ue[*].macCellId = 1
**.ue[*].masterId = 1

**.deployer.numRbDl = 6
**.deployer.numRbUl = 6

**.nic.phy.channelModel = xmldoc("config_channel.xml")

**.mac.schedulingDisciplineDl = "MAXCI"
Custom Scheduling

• Inherit a scheduling policy (LteScheduler Class)
• Two stages scheduling
  • Prepare schedule list
  • Commit schedule list

Policy 1  |  Policy 2  |  Policy 3

Schedule list

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Example 2: ~2013 rel 10-11

- **LTE-advanced**
  - Multiple cells
  - CoMP techniques
  - X2 Communication

- **Heterogeneous** Networks

- **Dense** Networks
**.ue1*.macCellId = 1
**.ue1*.masterId = 1
**.ue2*.macCellId = 2
**.ue2*.masterId = 2
**.ue3*.macCellId = 3
**.ue3*.masterId = 3

**.eNodeB TxPower = 40

**Example 2: ~2013 rel 10-11**

In config_channel.xml

<parameter name="multiCell-interference" type="bool" value="true"/>

Interference?  ➔  Coordination! (CoMP)
Scheduling Policy $\text{getBlocks}(n)$ \rightarrow Allocator

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

Joint Scheduler / Allocator
External Cells: lightweight eNBs

*.numExtCells = 2

#============= Configuration =============
*.extCell[*].txPower = 20
*.extCell[*].txDirection = "ANISOTROPIC"
*.extCell[*].bandAllocationType = "RANDOM_ALLOC"
*.extCell[*].bandUtilization = 0.5

#============= Positioning =============
*.extCell[0].position_x = 100m
*.extCell[0].position_y = 600m
*.extCell[0].txAngle = 315
*.extCell[1].position_x = 600m
*.extCell[1].position_y = 600m
*.extCell[1].txAngle = 225
**.x2Enabled = `true`

*.eNodeB*.numX2Apps = 2

*.eNodeB*.x2App[*].server.localPort = 5000 + ancestorIndex(1)
Example 3: NOW towards 5G

- **Infrastructure** vs **D2D**
- **Multicast** or **Unicast**

- Scheduling remains under control of the eNB
- UEs still need to request resources to the eNB
- Enables frequency reuse
Data Flow

• Data in the UL direction travels the whole stack
  • Segmentation/concatenation
  • Error control
• It follows a reverse path during reception
• D2D is given a separated path
D2D: one-2-one

• Enabling D2D
• AMC mode: D2D
• Peering relation
  • Static peering
  • Dynamic peering not available

• Channel measurement
  • Dynamic
  • Static

1  # enable D2D capabilities
2  *.eNodeB.d2dCapable = true
3  *.ueD2D*[*].d2dCapable = true

4  # select the AMC mode
5  *.eNodeB.nic.mac.amcMode = "D2D"

6  # set peering relationship
7  *.ueD2DTx[0].nic.d2dPeerAddresses = "ueD2DRx[0]"

8  # select the CQI for D2D transmissions
9  *.eNodeB.nic.phy.enableD2DCqiReporting = true
10  **.usePreconfiguredTxParams = false

11  # set Tx Power
12  *.ueD2DTx[0].nic.phy.ueTxPower = 26  # in dB
13  *.ueD2DTx[0].nic.phy.d2dTxPower = 20  # in dB

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Simultaneous Transmissions

- Transmitting UE can reuse the same frequencies
- Interference between pairs can occur
- Infra or D2D? [Switch?]
- Decide if 2 pairs can transmit simultaneously

Algorithms

- Resource Scheduling
- Mode Selection

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Data TX/RX

- Data is sent in unicast
- Interference is broadcast

- **Infra**: each used RBs is tagged with the ID of a UE

- **D2D**: each RB has a list of the UEs’ IDs
- SINR is computed taking interference into account
Mode selection: custom algorithms

- Read status
- Decides whether to switch or not
D2D: multicast

- Predefined CQIs only

```xml
<multicast-group hosts="ueD2D[*]"
    interfaces="wlan" address="224.0.0.10"/>

*.ueD2D[0].udpApp[*].destAddress = "224.0.0.10"

# select the CQI for D2D transmissions
*.eNodeB.nic.phy.enableD2DCqiReporting = false
**.usePreconfiguredTxParams = true
**.d2dCqi = 7

# set Tx Power
*.ueD2DTx[0].nic.phy.ueTxPower = 26    # in dB
*.ueD2DTx[0].nic.phy.d2dTxPower = 20    # in dB
```
Controlling the TX Range

**.d2dCqi = 7

Larger range
Lower data rate

Smaller range
Higher data rate

# set Tx Power

*.ueD2DTx[0].nic.phy.ueTxPower = 26  # in dB
*.ueD2DTx[0].nic.phy.d2dTxPower = 20  # in dB
D2D: layering and new modules

• An additional data path
• No HARQ
• Send Broadcast
Further Developments

• Handover (actually released)

• Native support to Veins

• Moving towards 5G
  • CRAN deployments
  • Mobile Edge Computing applications
Conclusions

• SimuLTE: focused on resource scheduling

• Modeling
  • Layering
  • Resources
  • Scheduling

• Case studies
  • Simple LTE network
  • LTE Advanced
  • D2D communications towards 5G
Thanks for your attention