Tutorial

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

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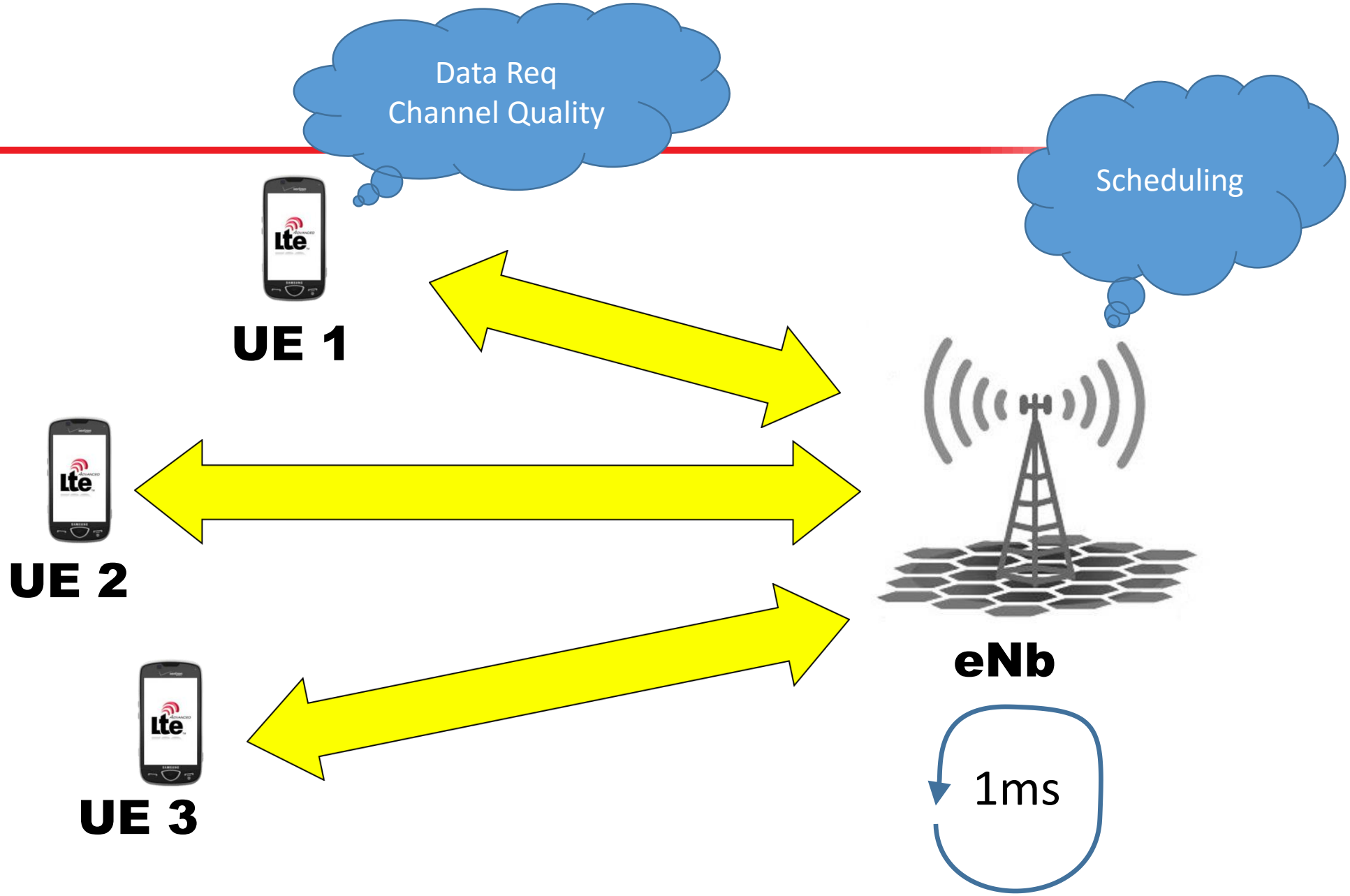
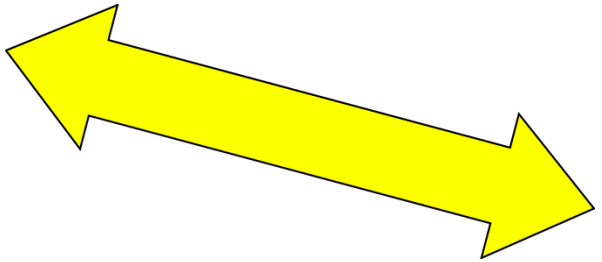
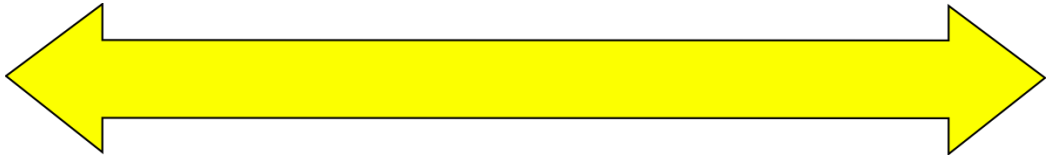
Outline

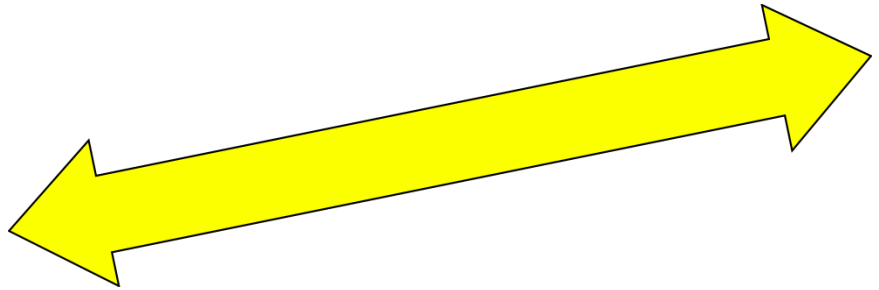
- LTE Context
- Simulator structure
- Examples
  - LTE
  - LTE-Advanced
  - Towards 5G: D2D


Data Req
Channel Quality
Scheduling
UE 1
UE 2
UE 3
eNb
1ms

LTE





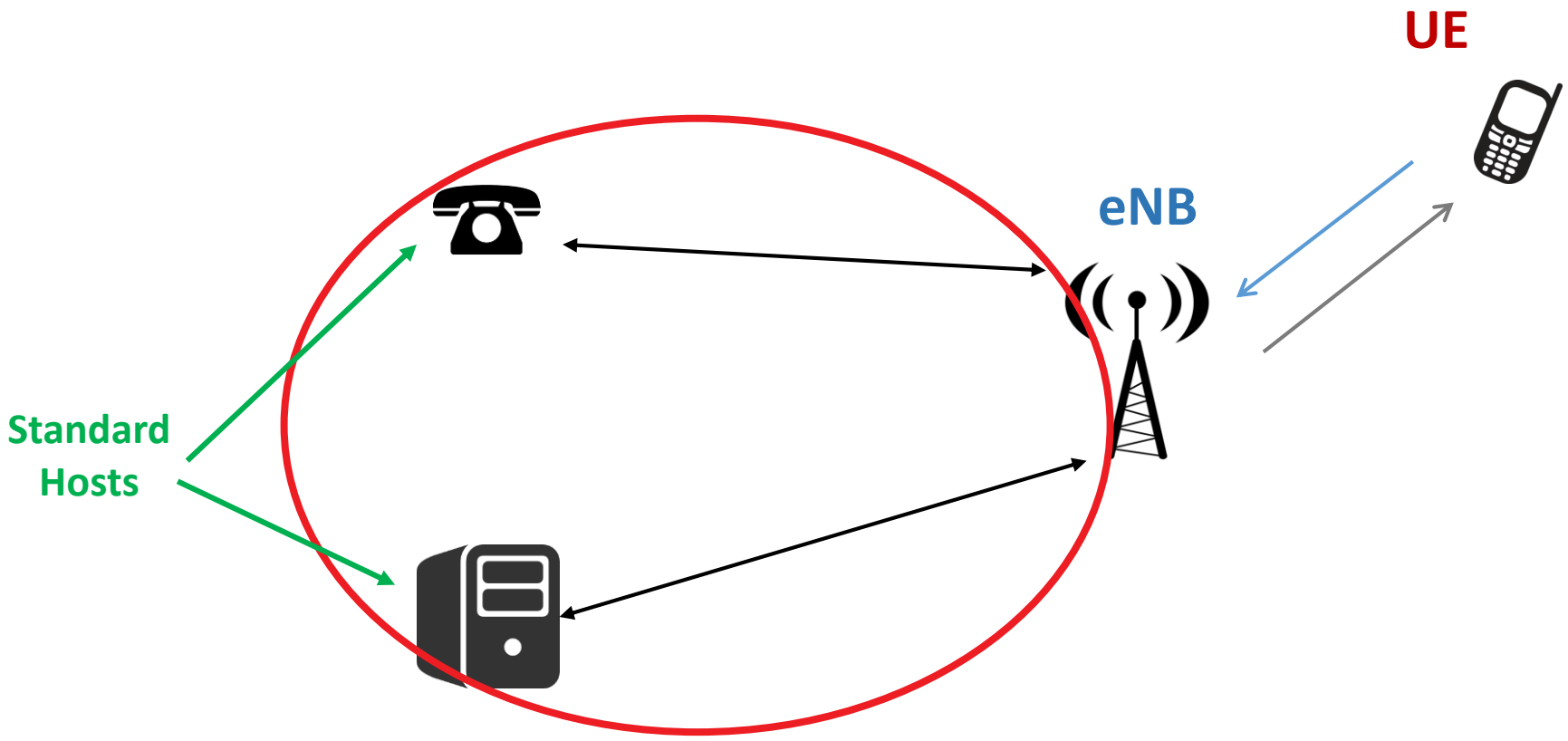


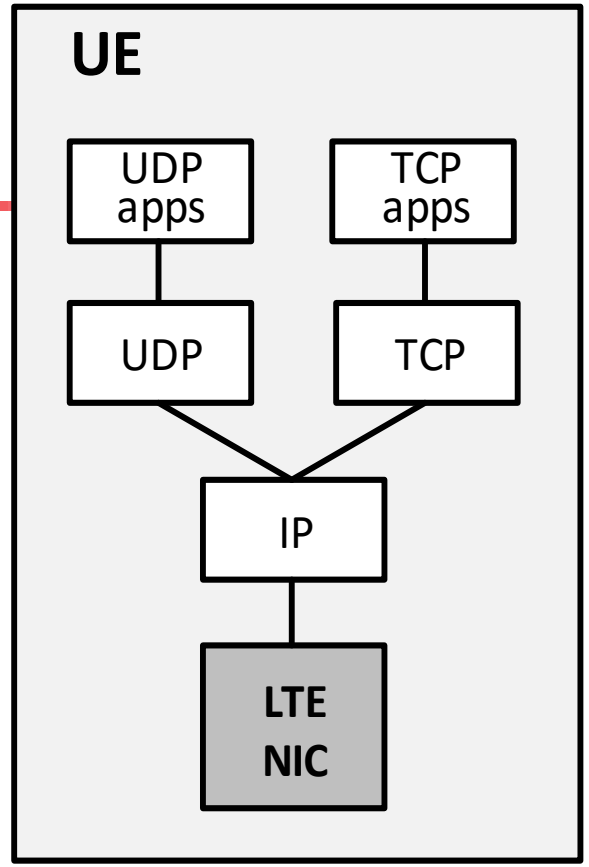
eNb

SimuLTE

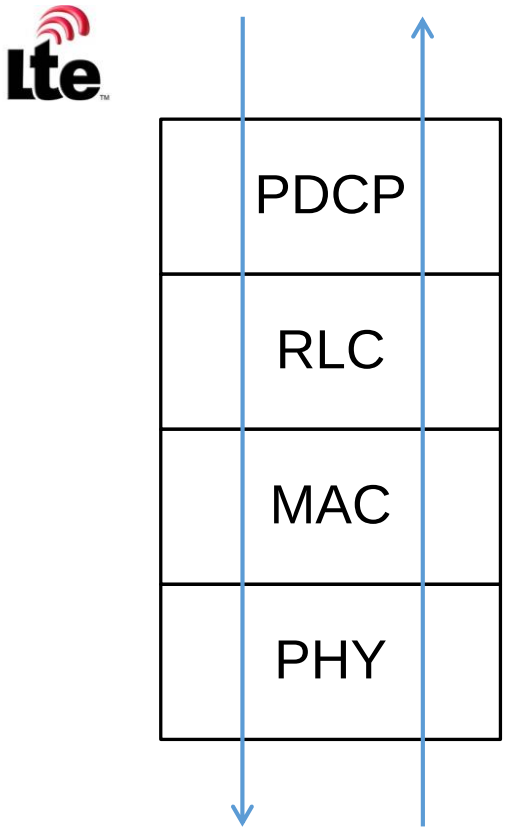
- OMNeT-based system-level simulator of LTE networks
- Focused on testing **algorithms for resource scheduling** at large scale
- INET based
- Built as an additional **NIC interface**
- Follow the **evolution** of cellular communications

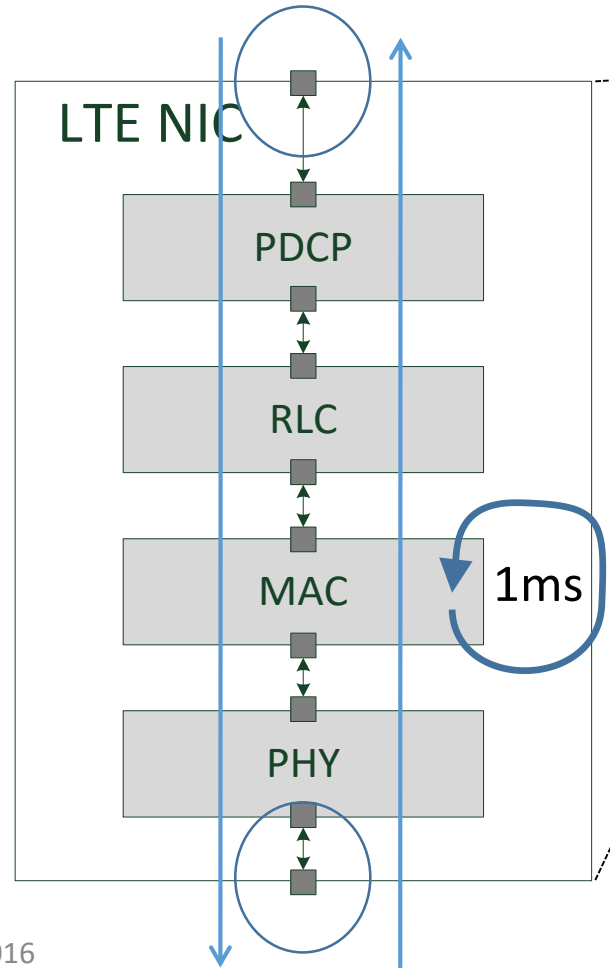
Nodes

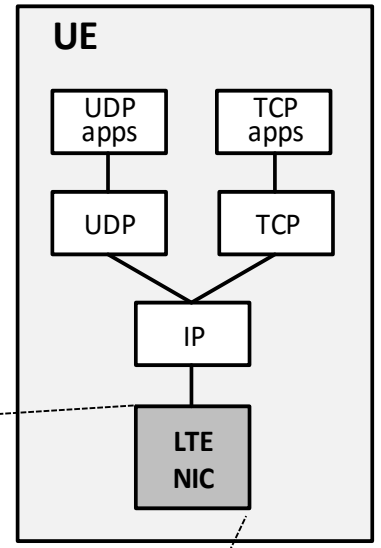




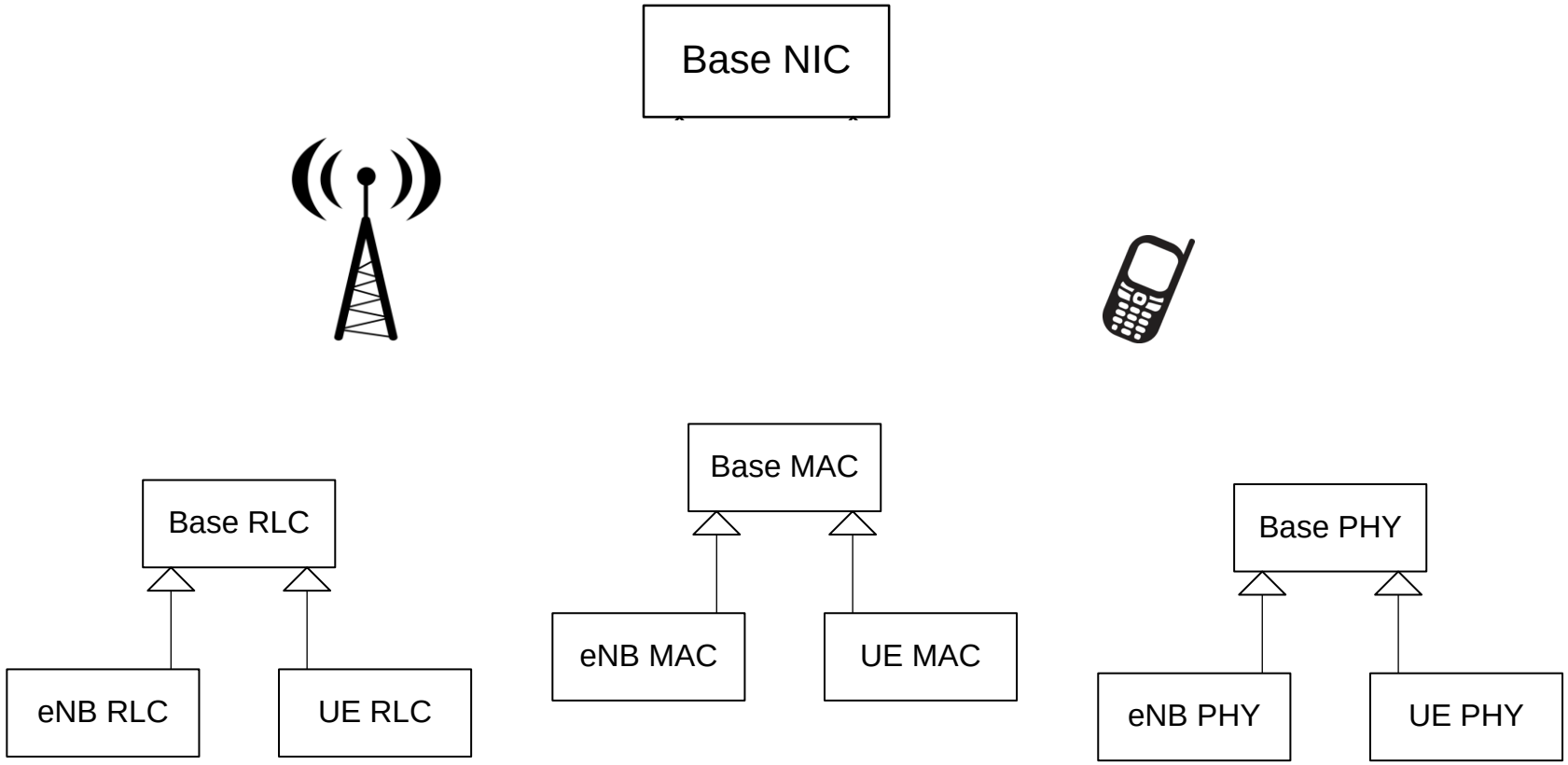
Layering


PDCP
RLC
MAC
PHY


SimuLTE
LTE NIC
PDCP
RLC
MAC
1ms
PHY


UE
UDP apps
TCP apps
UDP
TCP
IP
LTE NIC

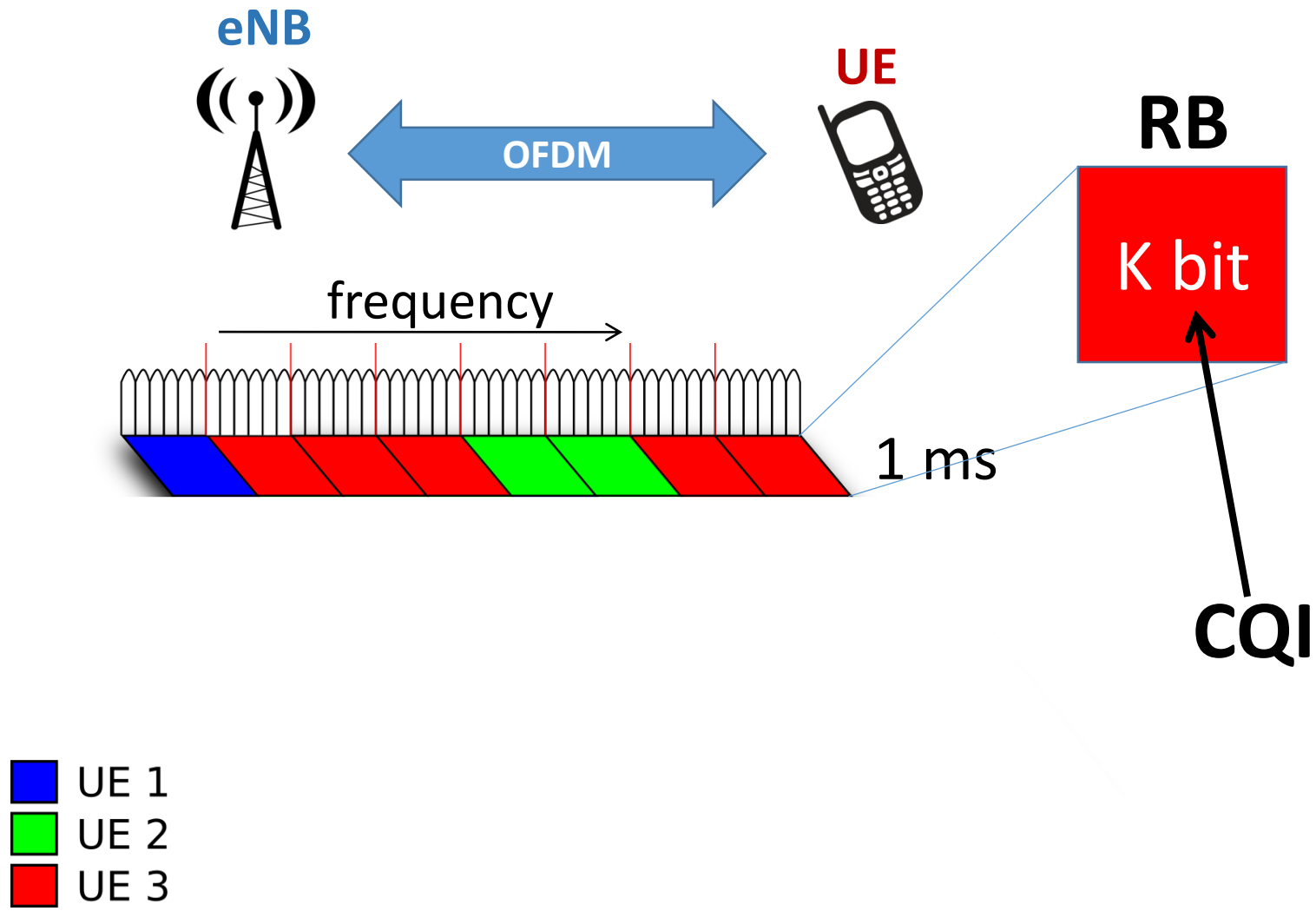
Common Structure: Inheritance



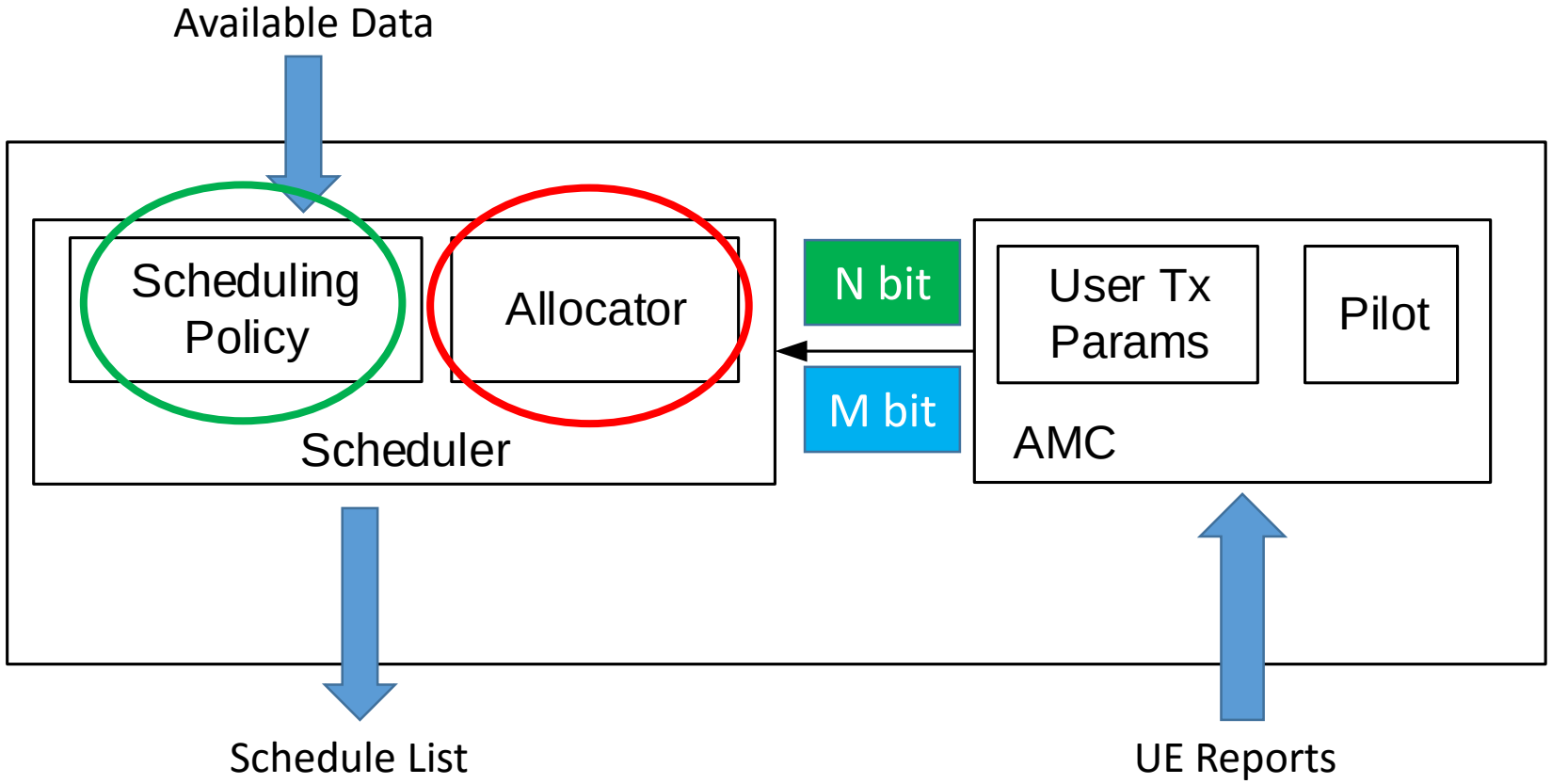
Goal: algorithms

- Aim at implementing and testing resource-scheduling algorithms
- Model **resources**.
- Model resource **management**
- Provide an **API** to users

Tx/Rx modeling

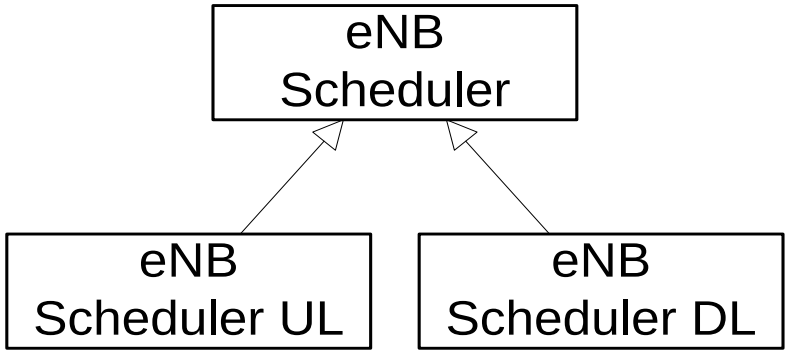


Scheduling

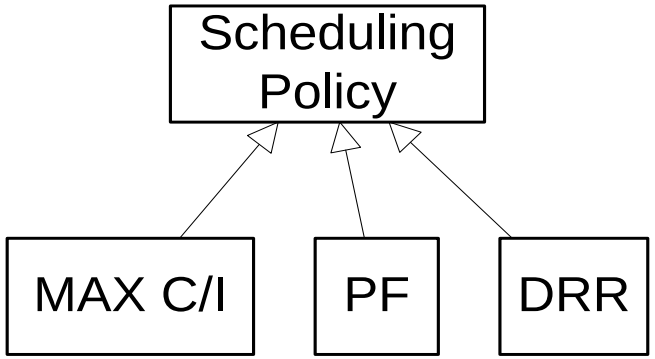

Available Data
Scheduling Policy
Allocator
Scheduler
N bit
M bit
User Tx Params
Pilot
AMC
Schedule List
UE Reports

Scheduling Hierarchy

- Scheduler Type and

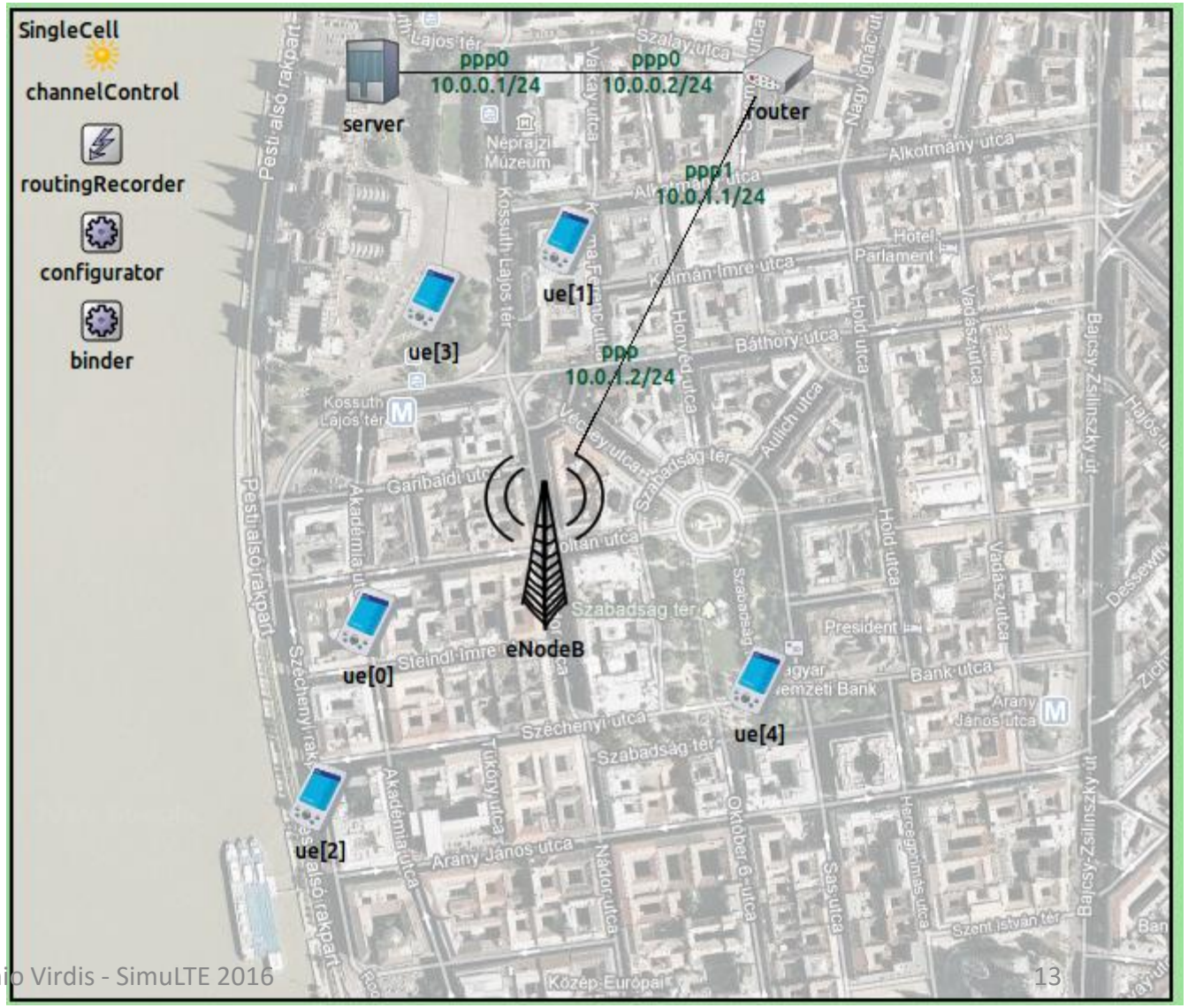


- Scheduling Policy



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
```

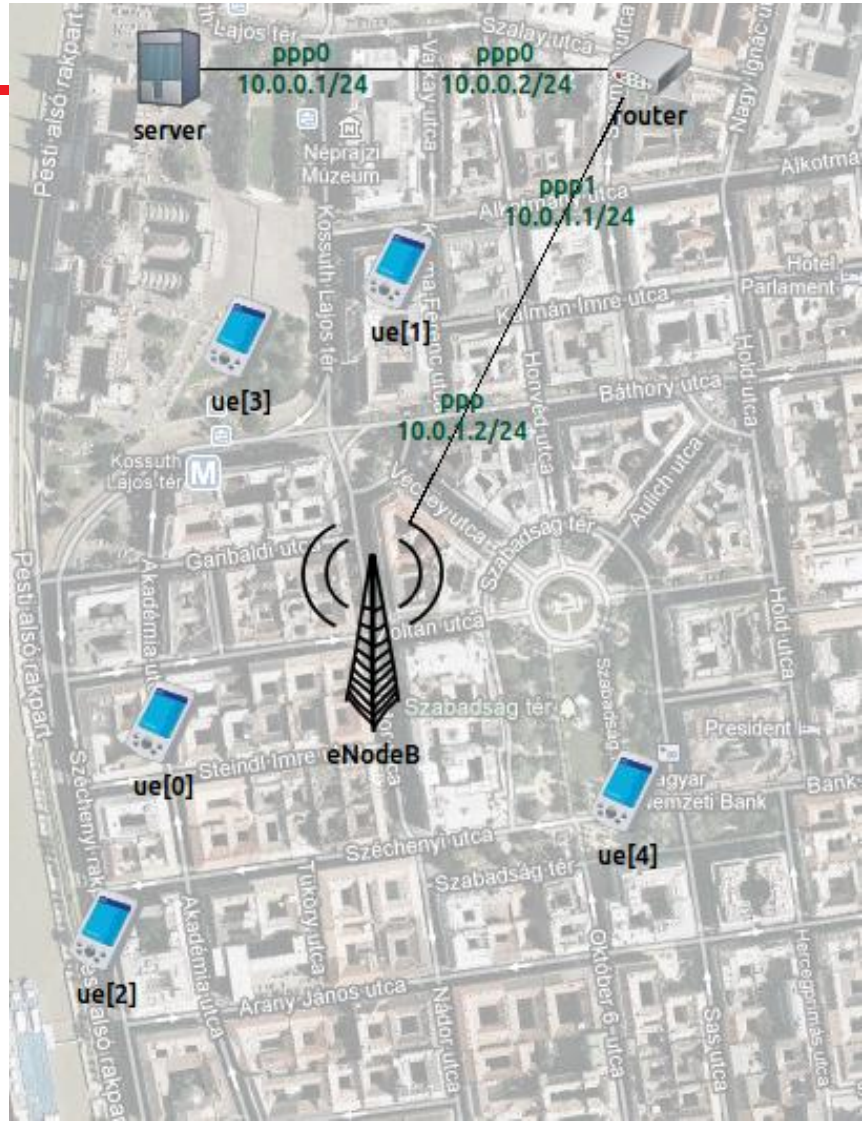
Association

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

 # Resources

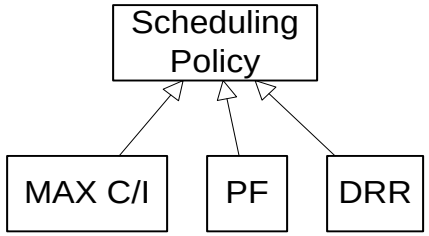
```
**.nic.phy.channelModel = xmldoc("config_channel.xml")
```

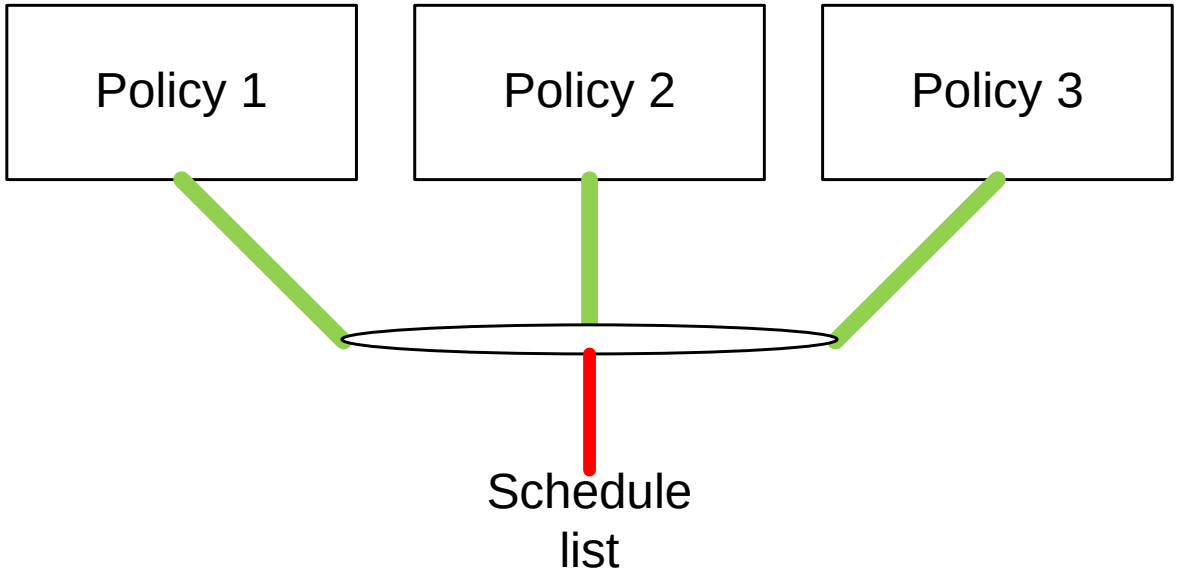
```
**.mac.schedulingDisciplineDl = "MAXCI"
```



Custom Scheduling

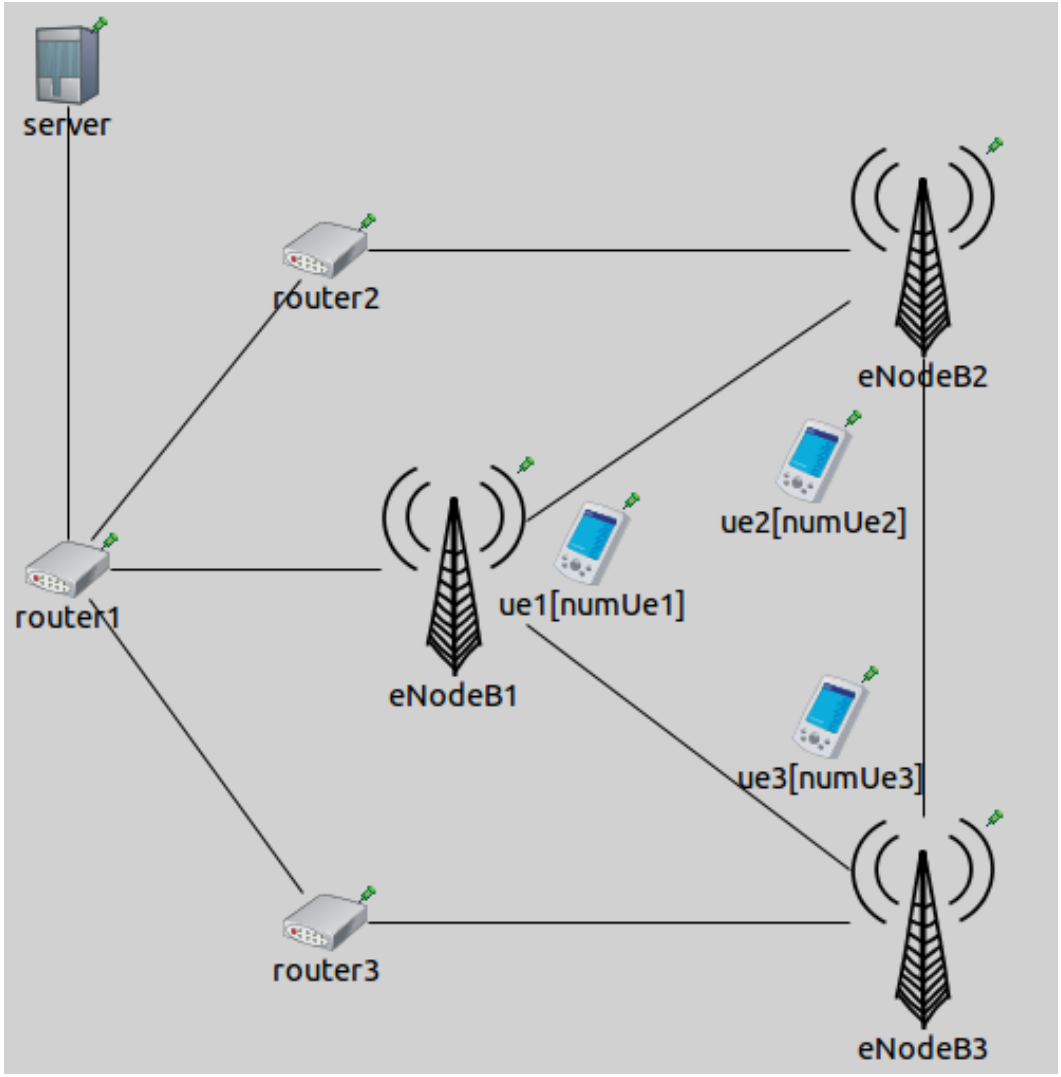
- Inherit a scheduling policy (LteScheduler Class)
- Two stages scheduling
  - **Prepare** schedule list
  - **Commit** schedule list





Example 2: ~2013 rel 10-11

- **LTE-advanced**
  - Multiple cells
  - CoMP techniques
  - X2 Communication
- **Heterogeneous** Networks
- **Dense** Networks

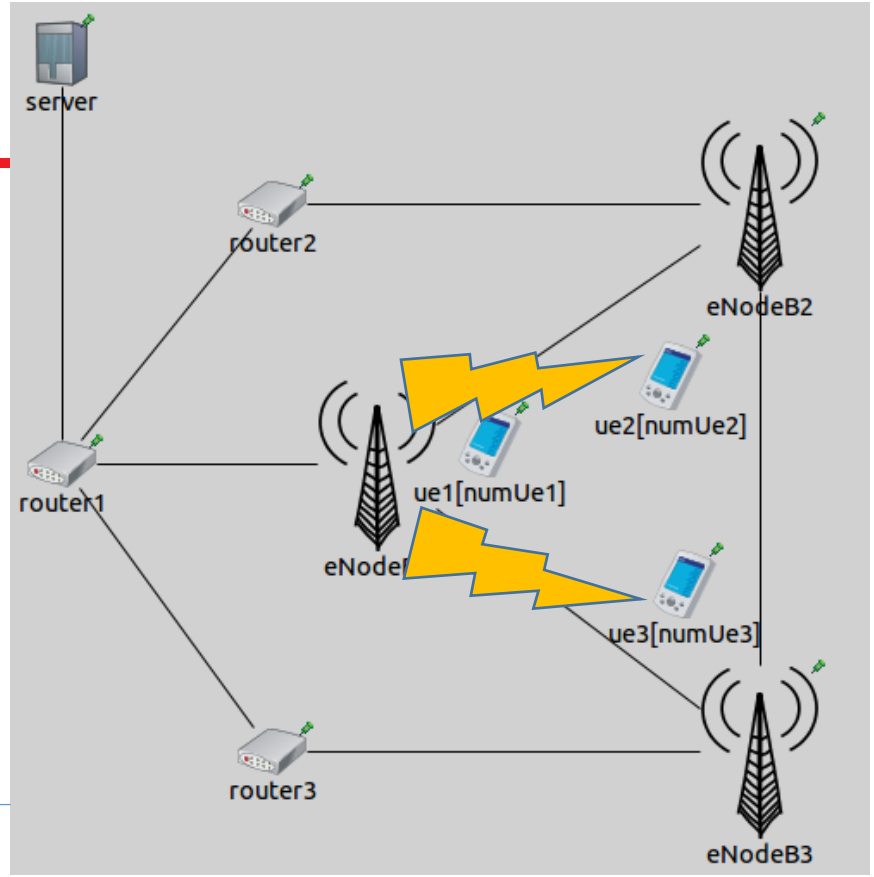


Example 2: ~2013 rel 10-11

```
**.ue1*.macCellId = 1
**.ue1*.masterId = 1
**.ue2*.macCellId = 2
**.ue2*.masterId = 2
**.ue3*.macCellId = 3
**.ue3*.masterId = 3

**.eNodeBTxPower = 40
```

Association

Transmission Power

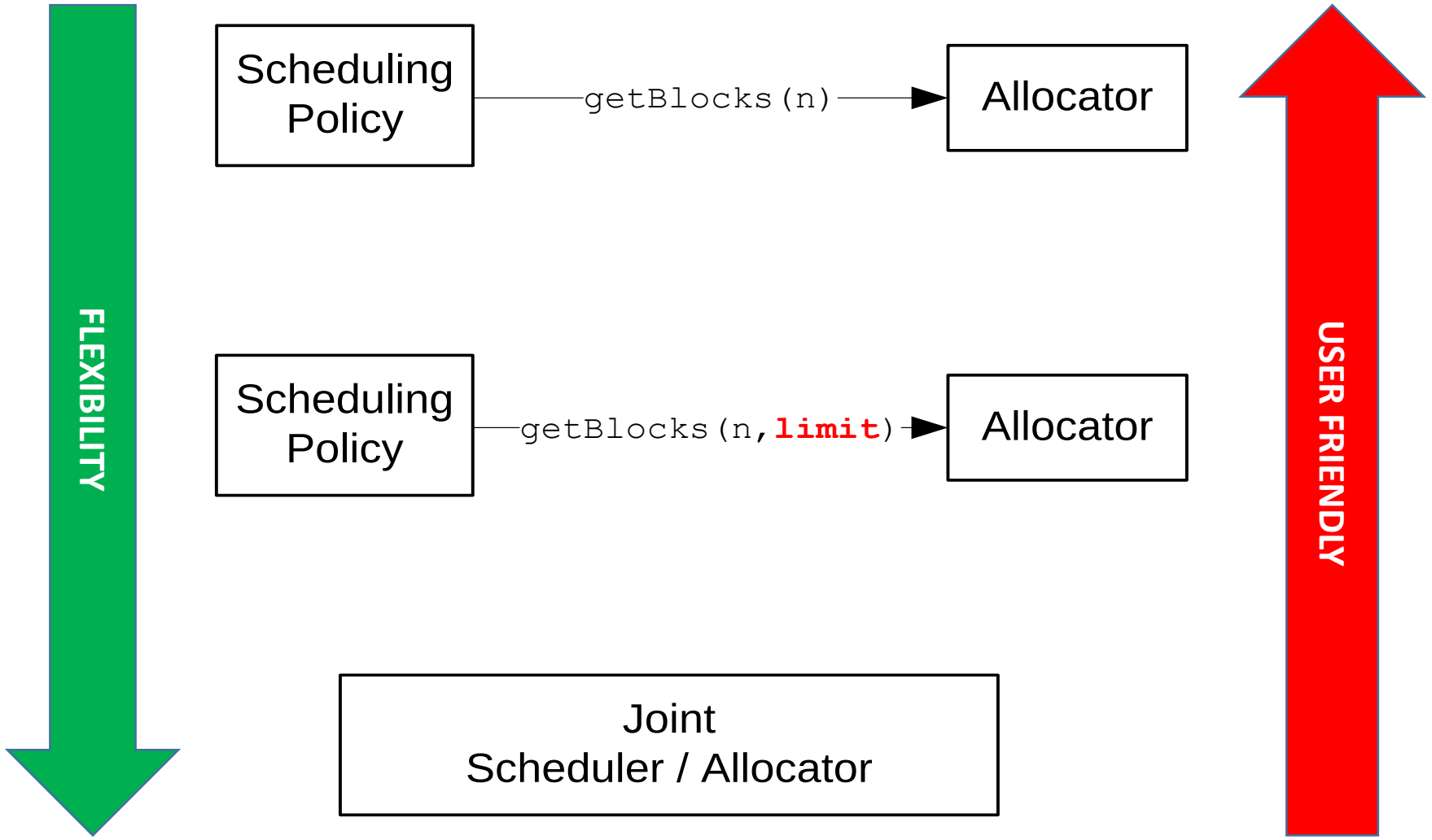


In config_channel.xml

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

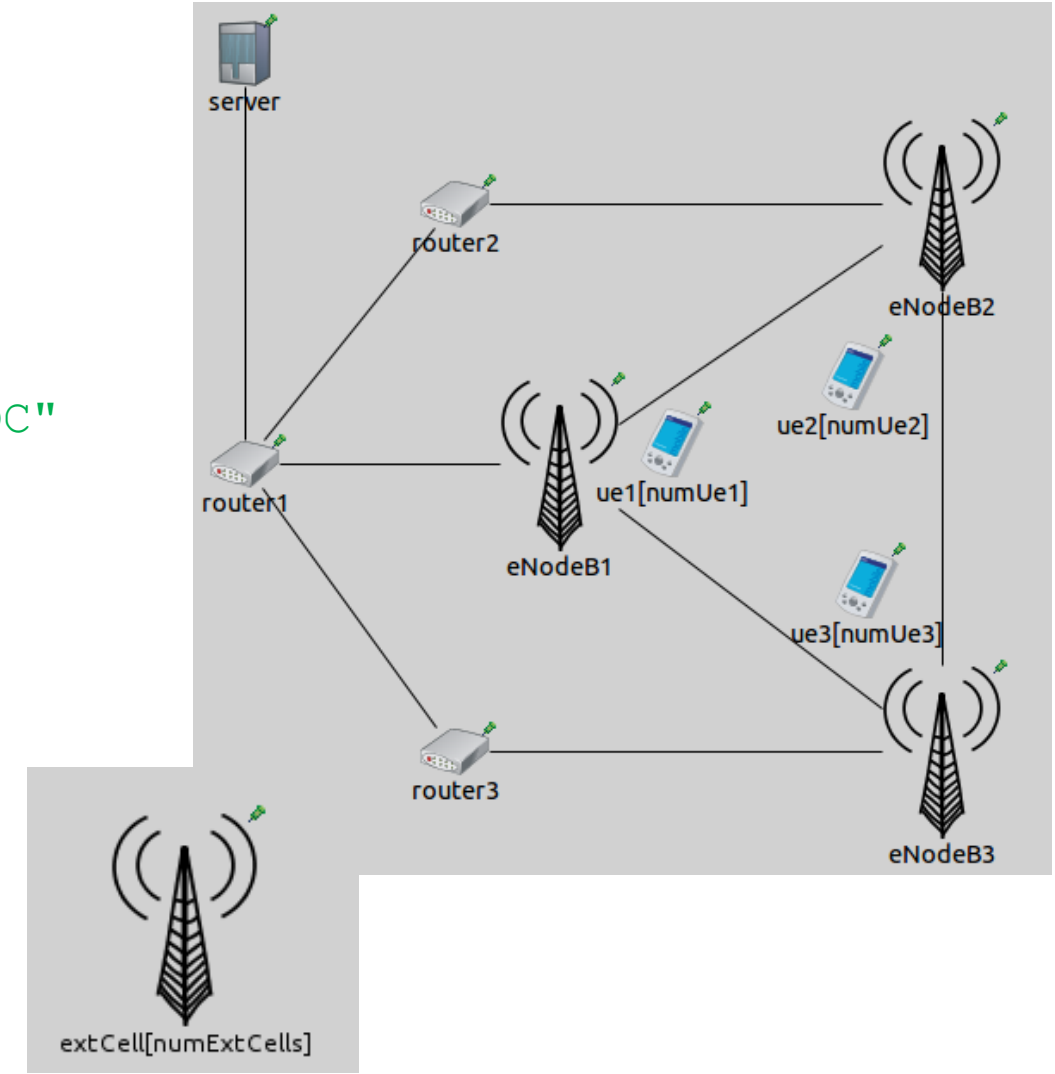
Interference? → Coordination! (CoMP)

Allocation Flexibility

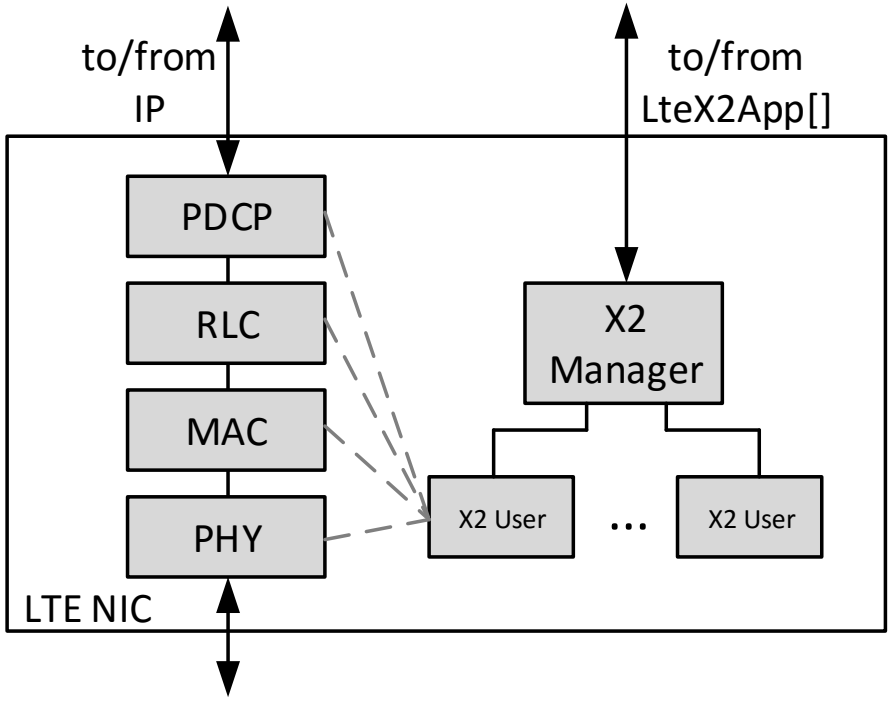


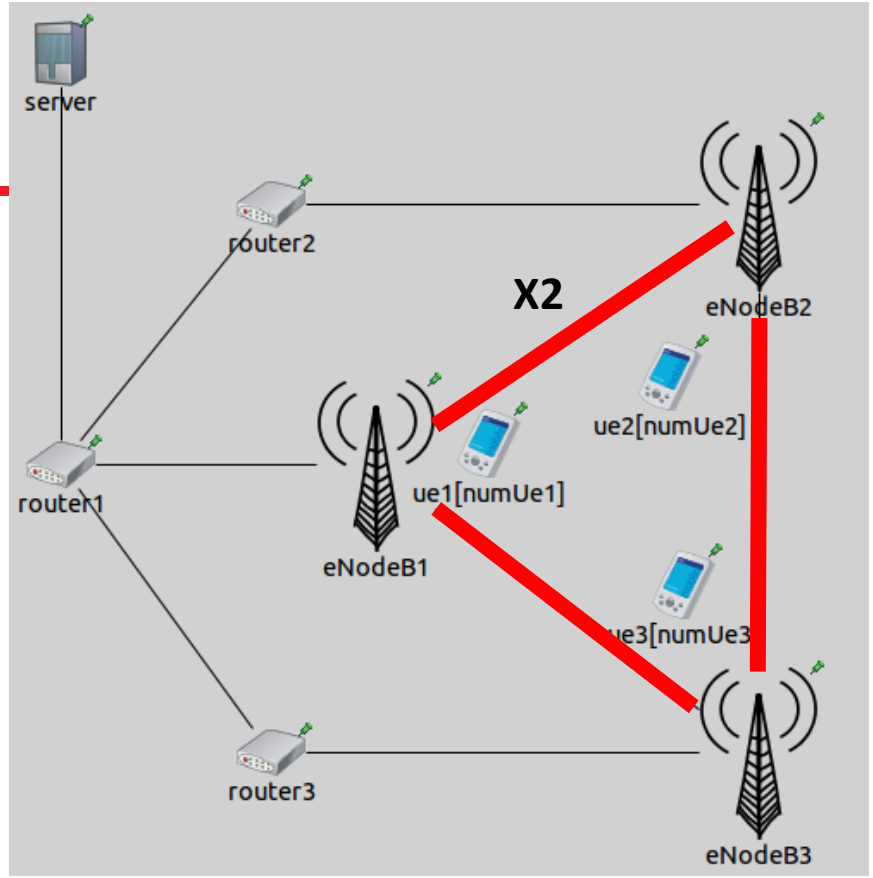
External Cells: lightweight eNBs

```
*.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
```



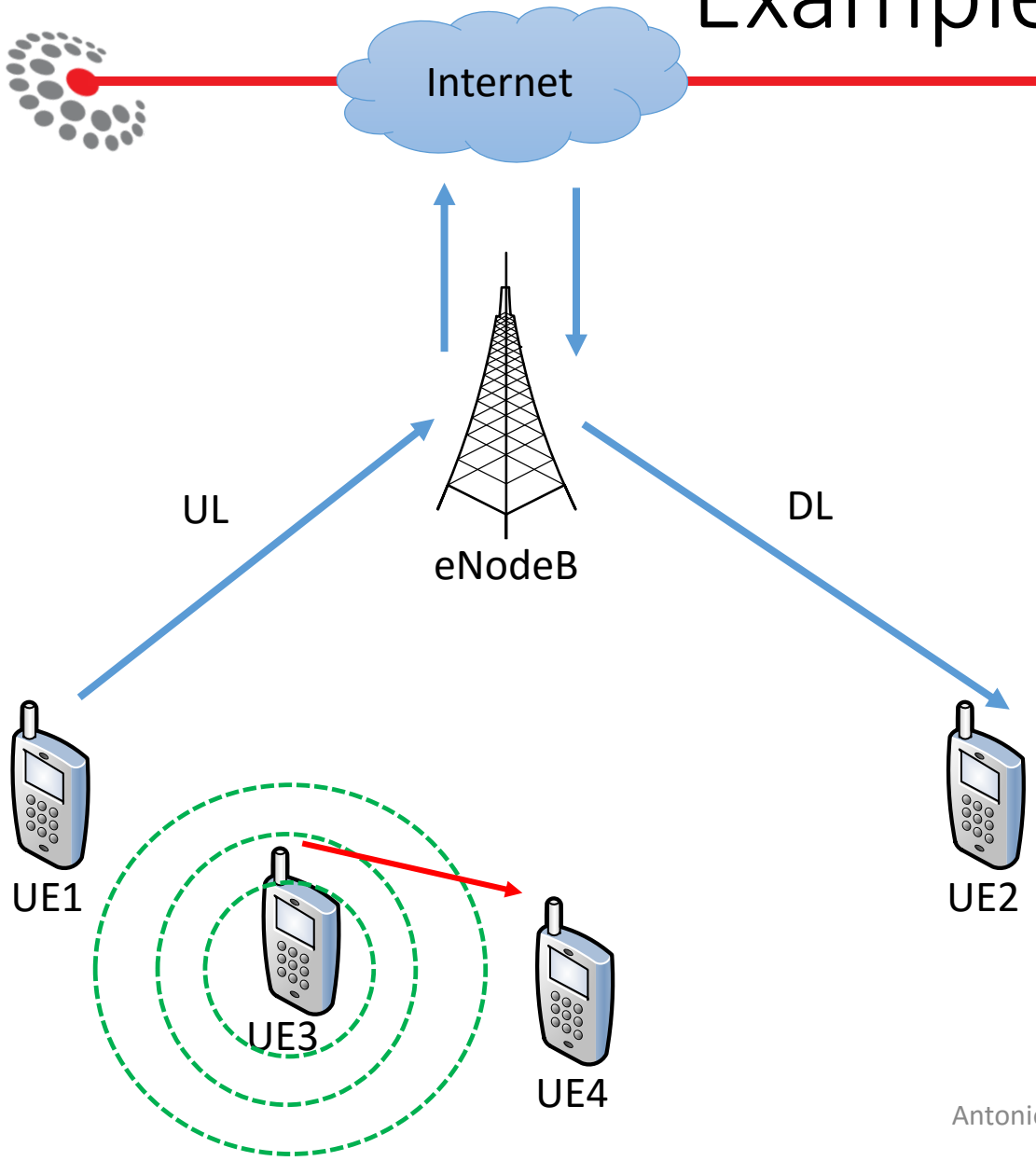
Example 2: ~2013 rel 10-11






```
**.x2Enabled = true

*.eNodeB*.numX2Apps = 2
*.eNodeB*.x2App[*].server.localPort = 5000 + ancestorIndex(1)
```

Example 3: NOW towards 5G



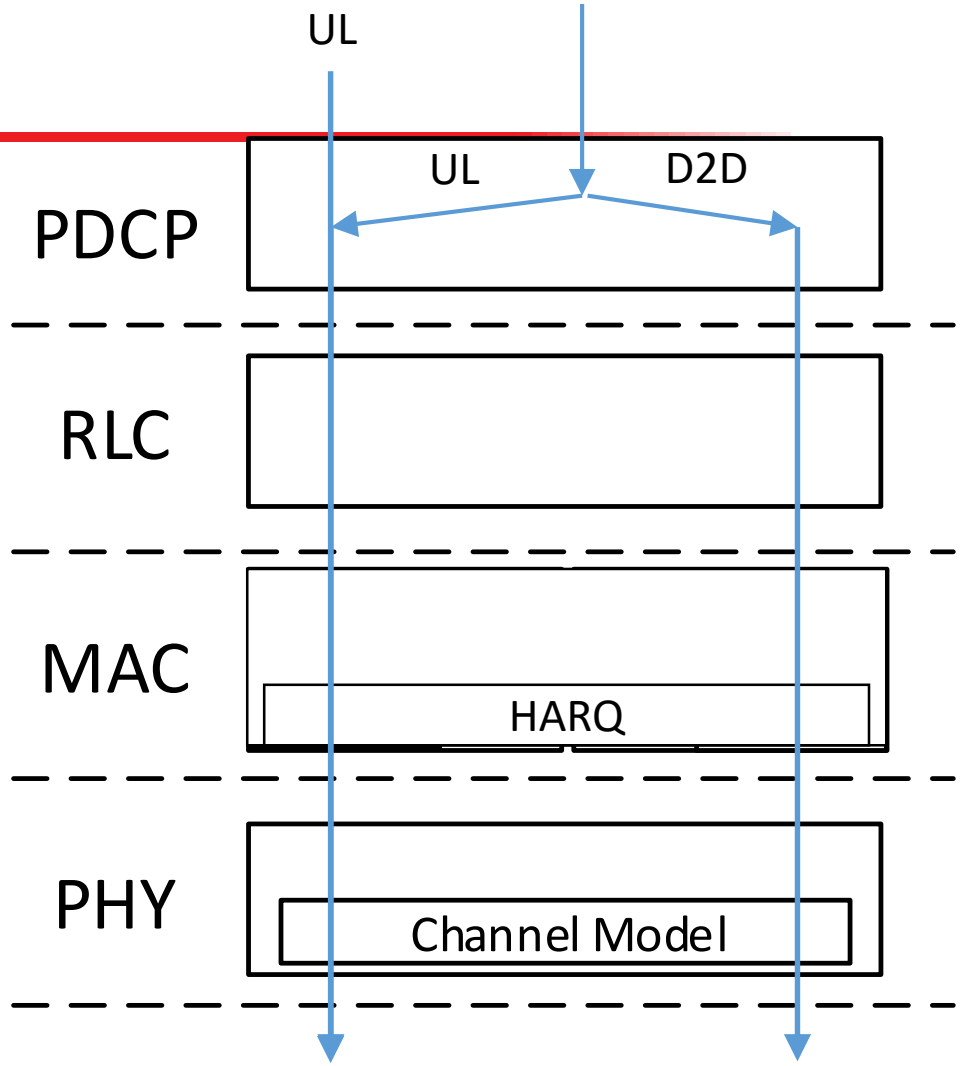
- **Infrastructure** vs **D2D**
- **Multicast** or **Unicast**

- 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

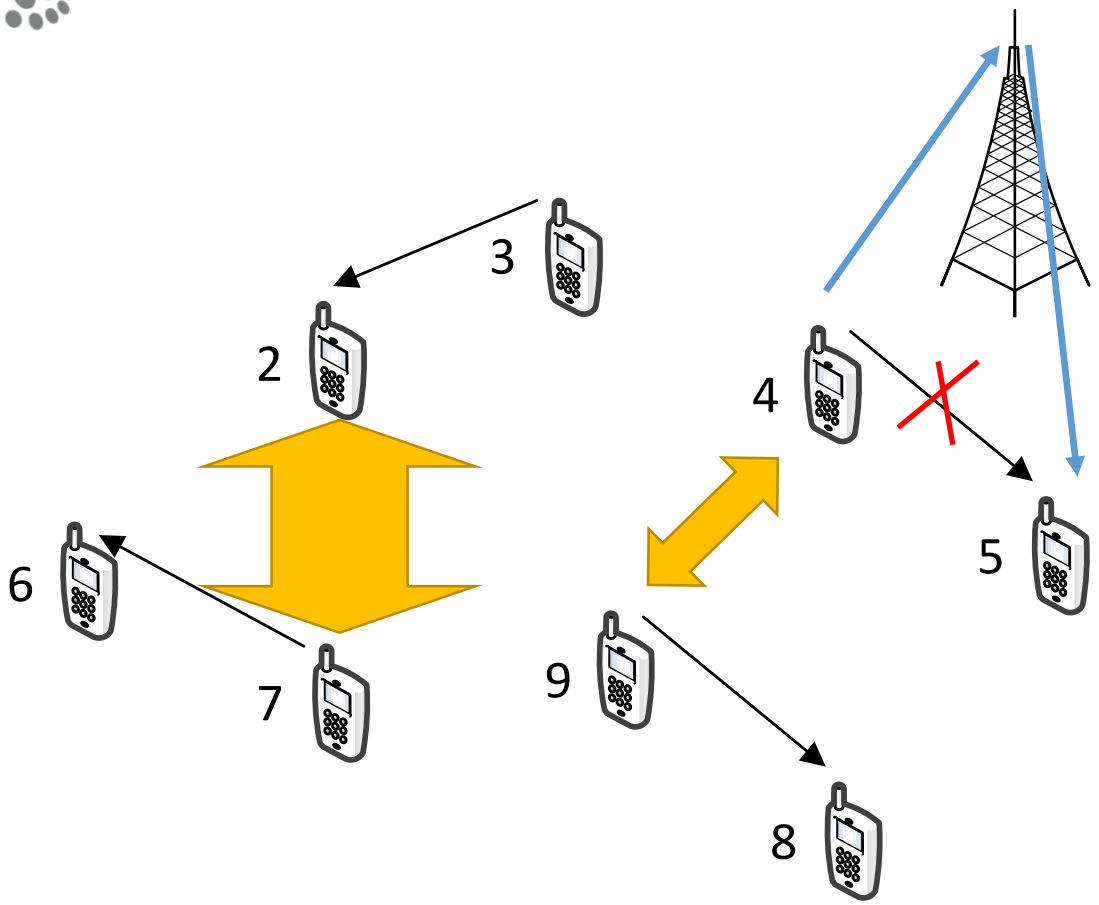


D2D: one-2-one

- 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
```

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**

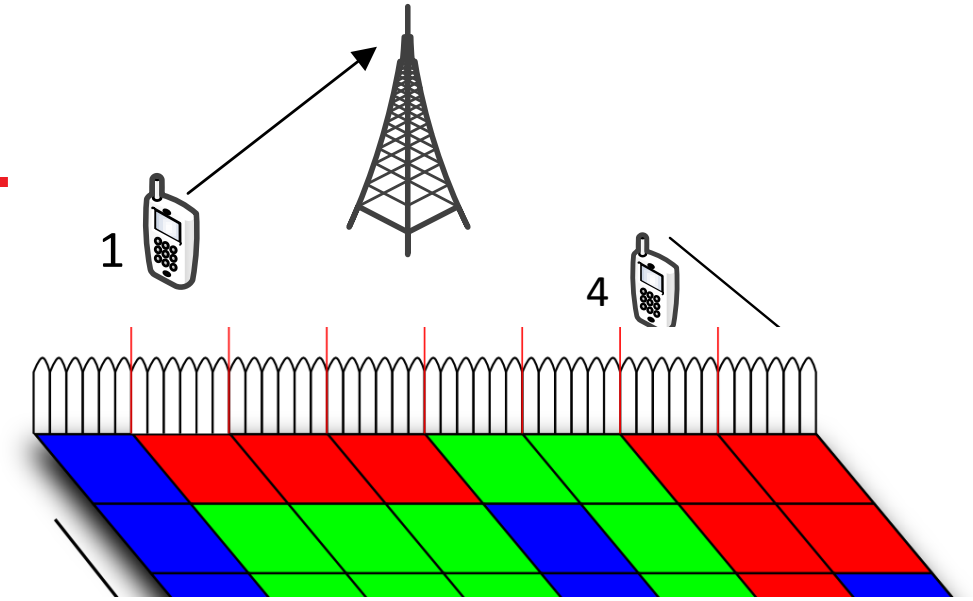
?

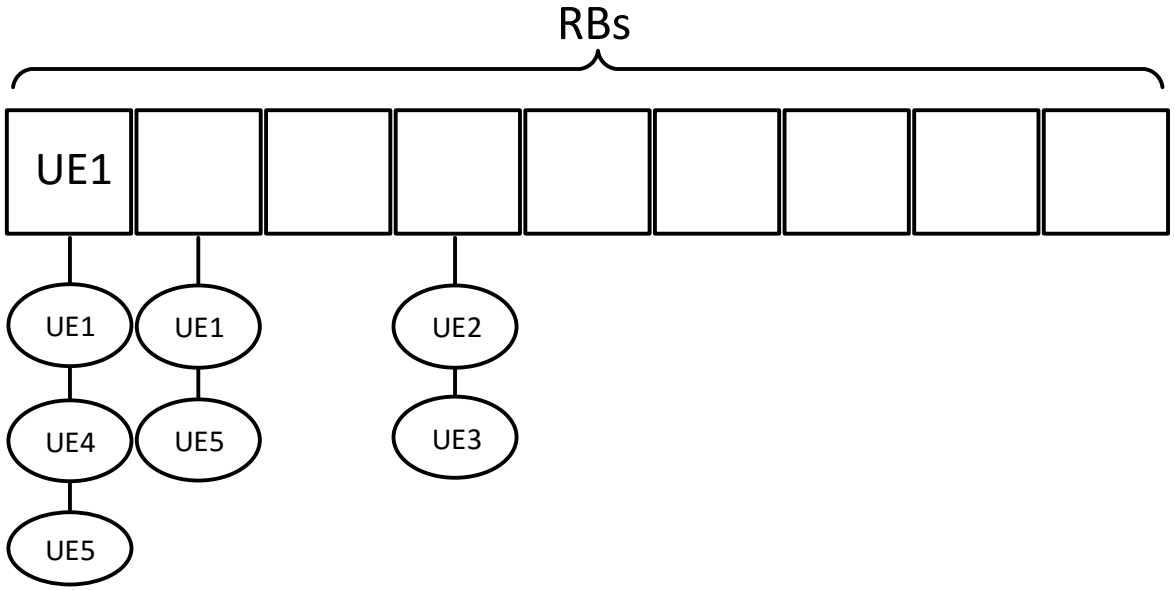
Data TX/RX

- Data is sent in unicast
- Interference is broadcast

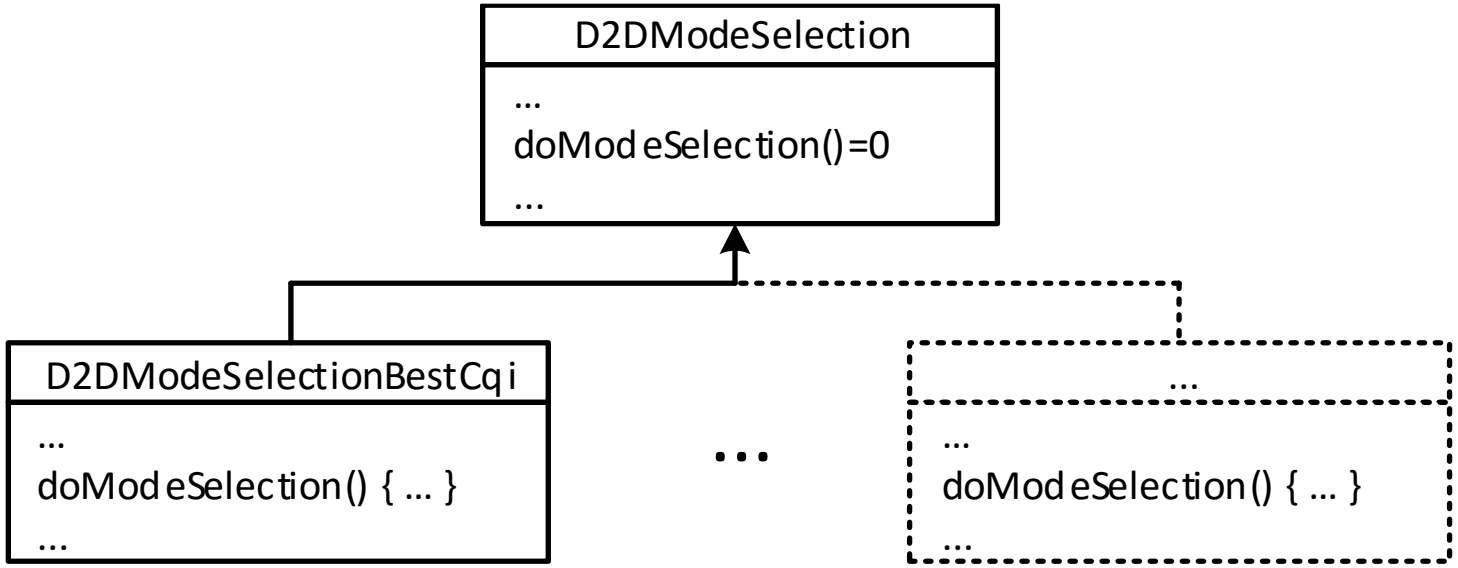
- Infra: each used RBs is tagged with the ID of a UE

- D2D: each RB has a **list** of the UEs' IDs
- SINR is computed taking interference into account





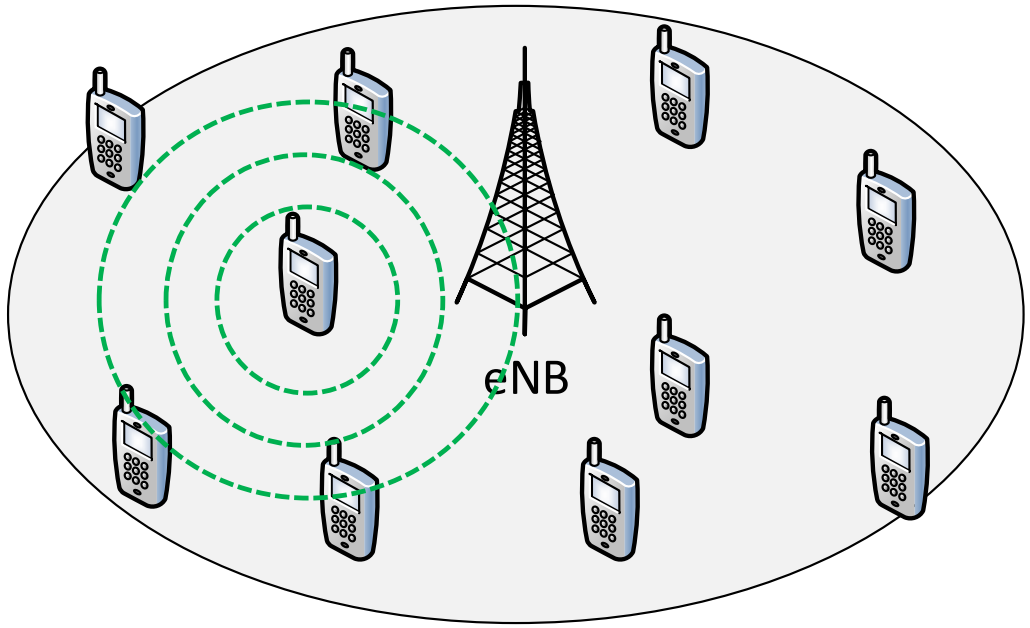
Mode selection: custom algorithms



- Read status
- Decides whether to switch or not

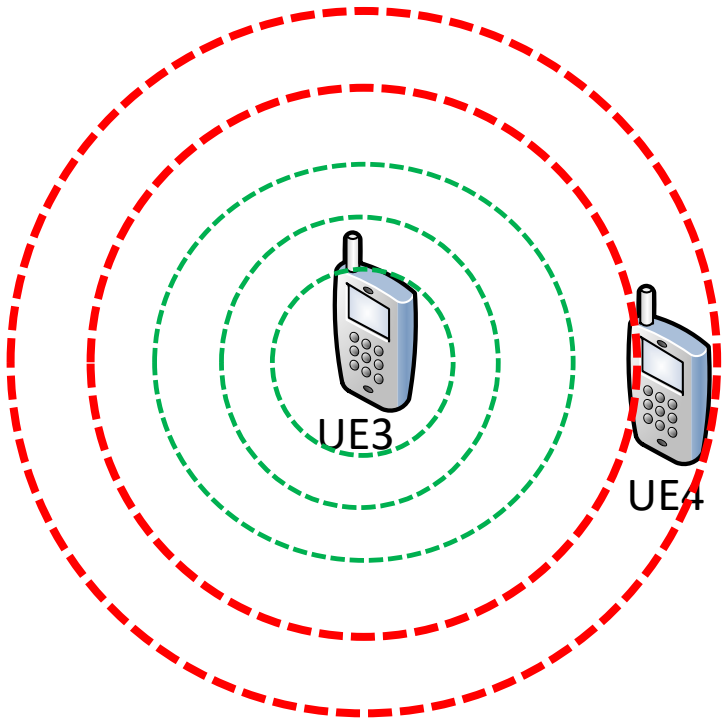
D2D: multicast

- Predefined CQIs only




```
<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



Larger range
Lower data rate

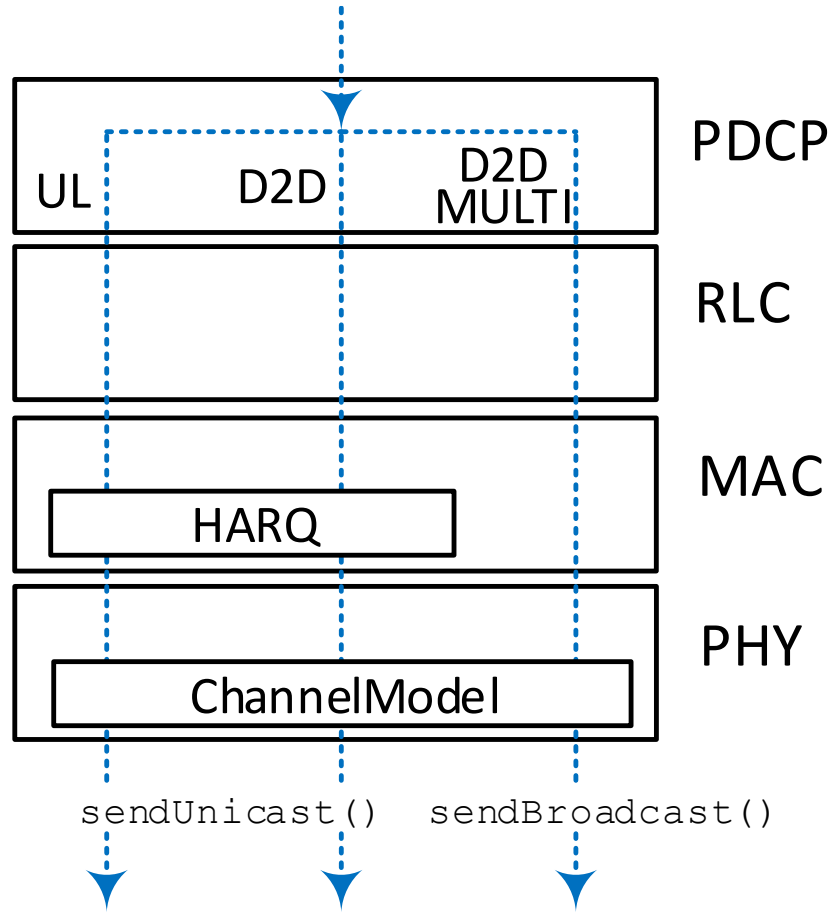
```
**.d2dCqi = 7
```

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