An LTE module for the Network Simulator 3

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- 25 March 2011 -

Wns3 2011 – Barcelona (Spain)

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About the Long Term Evolution

Long Term Evolution represents an emerging and promising technology for providing a broadband ubiquitous Internet access.

First 3GPP release: Release 8 (Dec. 2004) *(the "release of the release" is 2008)*

LTE has been designed for guaranteeing high capacity and data rates, low cost deployments for cellular networks.

LTE will be the 4-th generation of cellular networks.

We need for a complete LTE simulator for testing network performance and for implementing newer algorithms/protocols

Development of the LTE module for ns-3

The development of the LTE module for ns-3 was carried out during the Google Summer of Code 2010.

The module is built completely in C++.
It comprises 89 classes and approximately 9000 lines of code.
The module has been merged into ns-3.10 !

LTE is a very complex standard, and for this reason, at this time, it is not yet possible the simulation a complete LTE system ☹

However this contribution is fundamental since it set the basis for developing such a complete tool ☺

LTE module description (1)

What features have been implemented ?

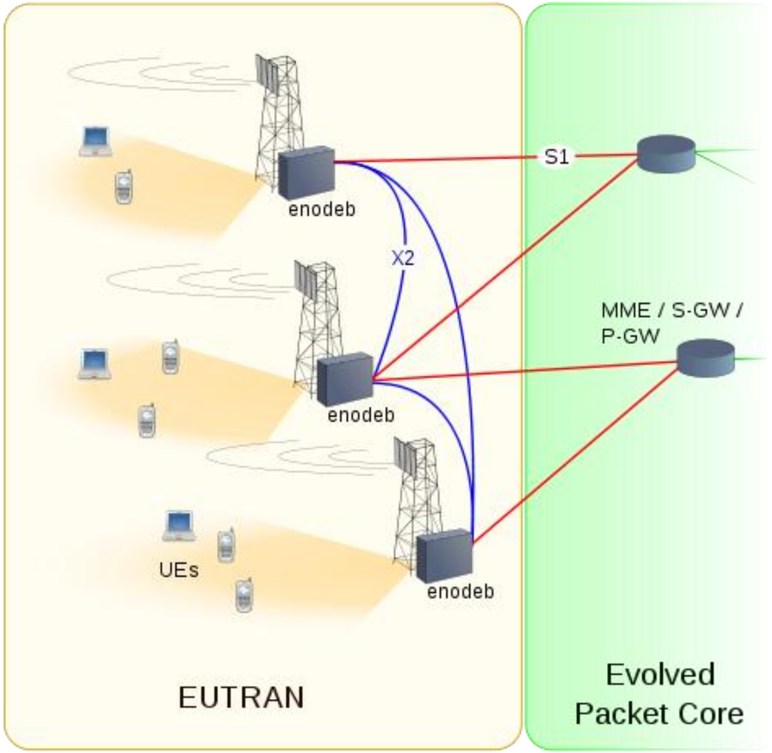
- ❑ Network devices: User Equipment (UE) and enhanced NodeB (eNB)
- ❑ Part of Radio Resource Control (RRC)
- ❑ MAC queues and the RLC instances *(TM)*
- ❑ Data Radio Bearers (with their QoS parameters)
- ❑ PHY layer model with Resource Block level granularity
- ❑ Outdoor E-UTRAN channel model
- ❑ DL Channel Quality Indicator (CQI) management
- ❑ Adaptive Modulation and Coding (AMC) scheme for the downlink
- ❑ Support for the downlink packet scheduler

LTE module description (2)

Implemented E-UTRAN devices: UE and eNB.

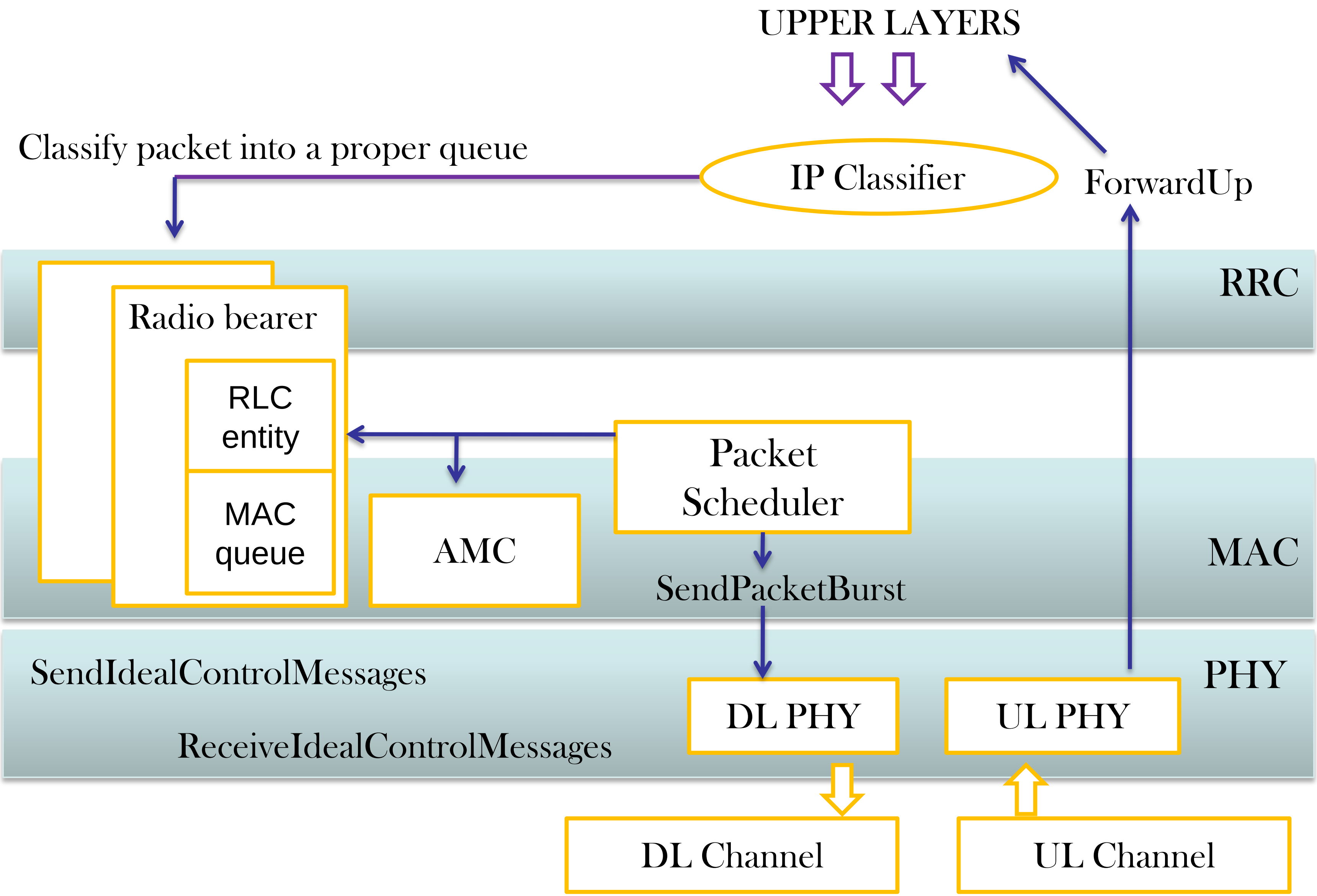
The core of the LTE module is composed by both MAC and PHY layers of an LTE device.

The LTE device has been conceived as a container of several entities:
the IP classifier, the RRC entity, the MAC entity, and the PHY layer.

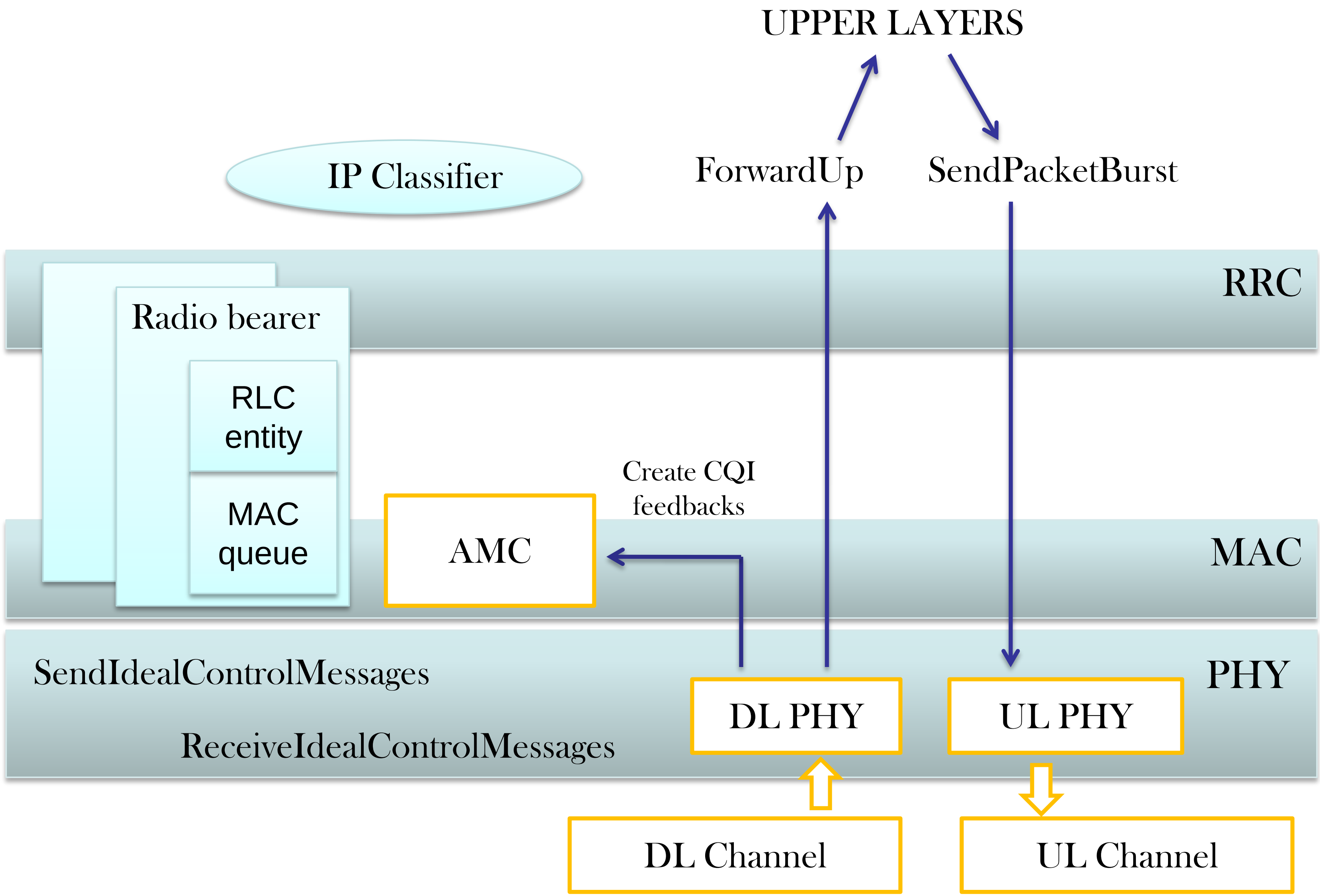


Their actual integration is device-dependent, due the intrinsic ifferences between the entities involved (UE vs. eNB).
The implementation of each of these entities depends on which the device have to do.

The eNB network device



The UE network device



Radio Bearer Management and the RRC Entity

In LTE networks, each flow is mapped into a logical connection named **bearer**.

A Radio Bearer maps a flow into the bearer established between UE and eNB.

We can have different type of radio bearers:

- Default Radio Bearer vs Data Radio Bearer
- GBR Radio Bearer vs non-GBR Radio Bearer

Each Radio Bearer has associated a set of QoS parameters (target delay, minimum guaranteed bit rate, maximum guaranteed bit rate, class identifier), called QoS class identifiers (QCIs).

The RRC entity manages active radio bearers for a given device.

Channel and PHY models (1)

Both Channel and PHY have been developed starting from the Spectrum Framework.

This framework allow us to accurately model the OFDMA PHY layer by:

- defining a set of frequencies used at the PHY layer (Resource Block resolution)
- modeling the Power Spectral Density of the transmitted/received signal
- allowing the computation of the SINR of the received signal

We implemented the FDD channel access → we need for 2 channels (the DL channel and the UL channel) and for 2 PhySpectrum entities in the PHY layer.

We chose to use the *SingleModelSpectrumChannel* for modelling the LTE Channel. The *LteSpectrumPhy* has been implemented extending the *SpectrumPhy* class.

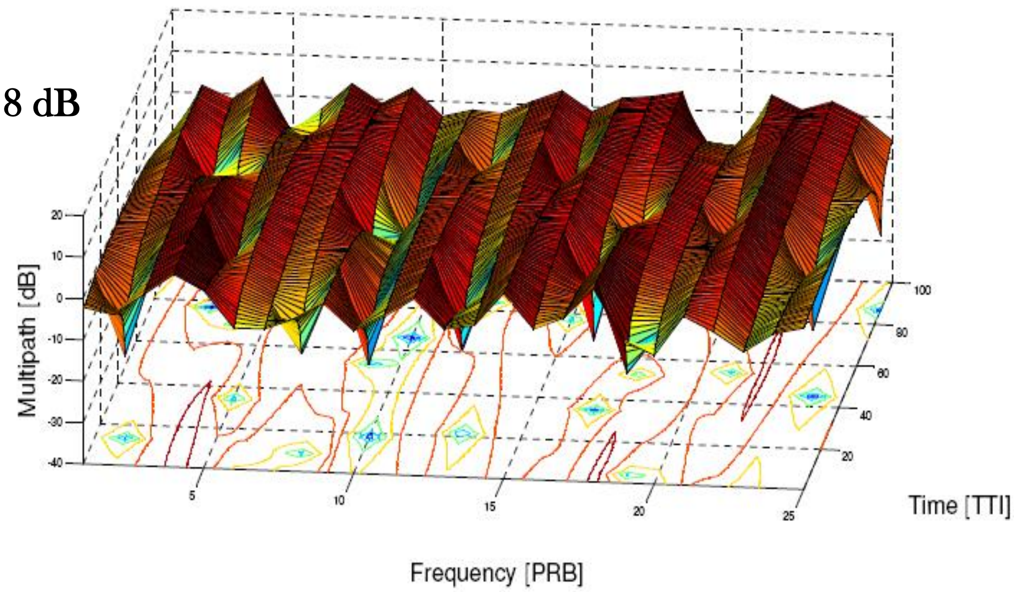
LTE module extends the *PropagationSpectrumModel* for implementing the propagation model for E-UTRAN interface.

Channel and PHY models (2)

Modelling correctly the propagation loss model is a crucial point ! We following the 3GPP guidelines for implementing it.

The propagation loss model is composed by 4 components:

- Pathloss:
  PL = 128.1 + 37.6 log10 (d)
- Penetration Loss:
  PN = log normal distribution, μ = 0 dB, σ = 8 dB
- Shadowing:
  SH = 10 dB
- Fast Fading:
  MLP = precomputed jacks models



The propagation loss model is use for computing the power of the received signal at the received side.

CQI management and AMC module (1)

Every TTI the eNB sends references symbols to the channel. Each UE uses these symbols for measuring the channel quality and for creating CQI feedbacks.

In details, each time the PHY layer of the UE device receives a packet burst from the channel, it in charge of:

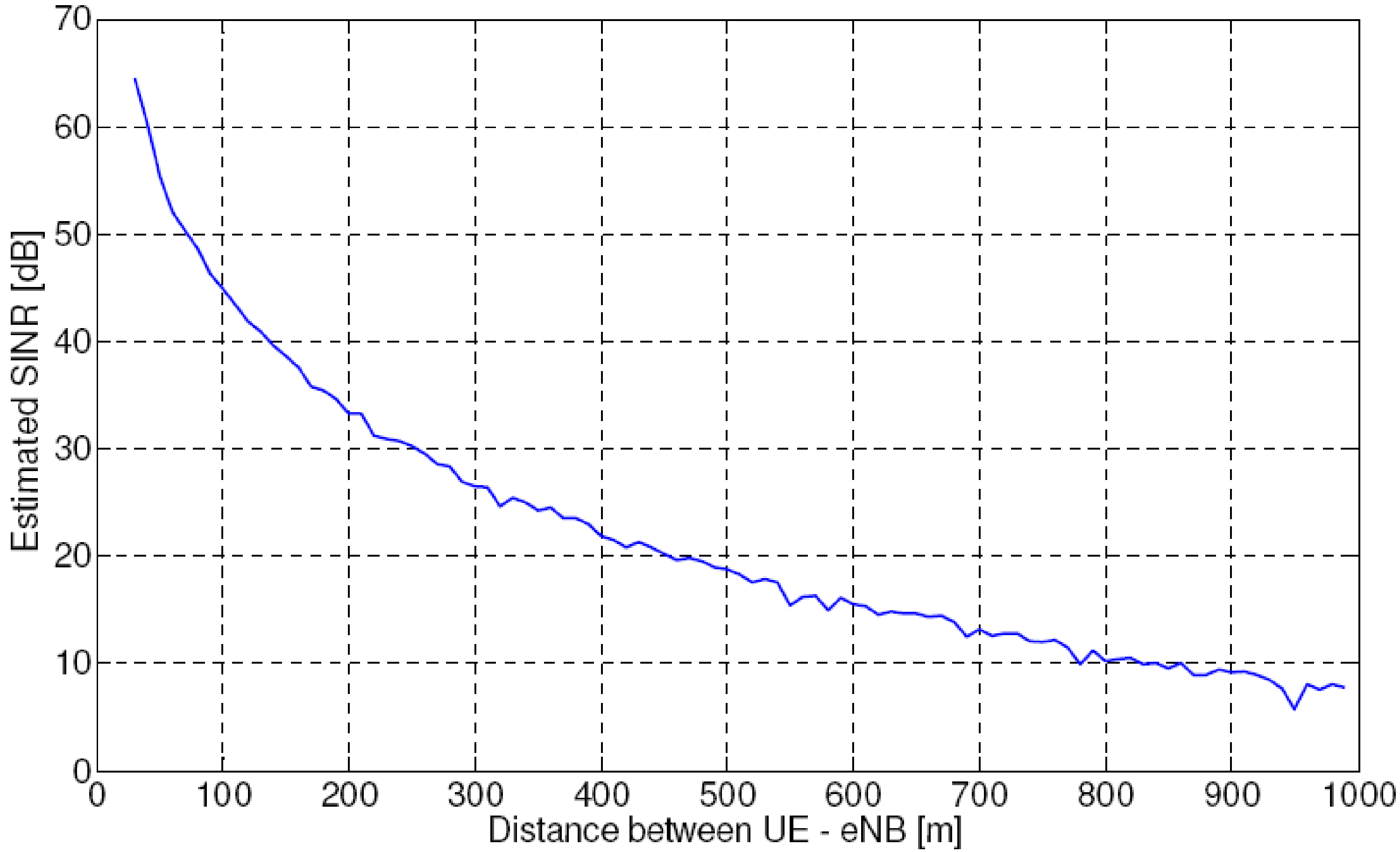
- ❑ compute the receved power from the Power Spectral Density of the received signal
- ❑ compute the SINR for each sub channel
- ❑ converte the SINR value into the spectral effciency value
- ❑ select a CQI index for each sub channel
- ❑ create and send to the eNB the CQI feedbacks

The eNB can use these informations for selecting properly the MCS to use for downlink transmission.

Interval for $\eta_{i,j}$	CQI Index
≤ 0.15	1
$0.15 \div 0.23$	2
$0.23 \div 0.38$	3
$0.38 \div 0.60$	4
$0.60 \div 0.88$	5
$0.88 \div 1.18$	6
$1.18 \div 1.48$	7
$1.48 \div 1.91$	8
$1.91 \div 2.40$	9
$2.40 \div 2.73$	10
$2.73 \div 3.32$	11
$3.32 \div 3.90$	12
$3.90 \div 4.52$	13
$4.52 \div 5.12$	14
≥ 5.12	15

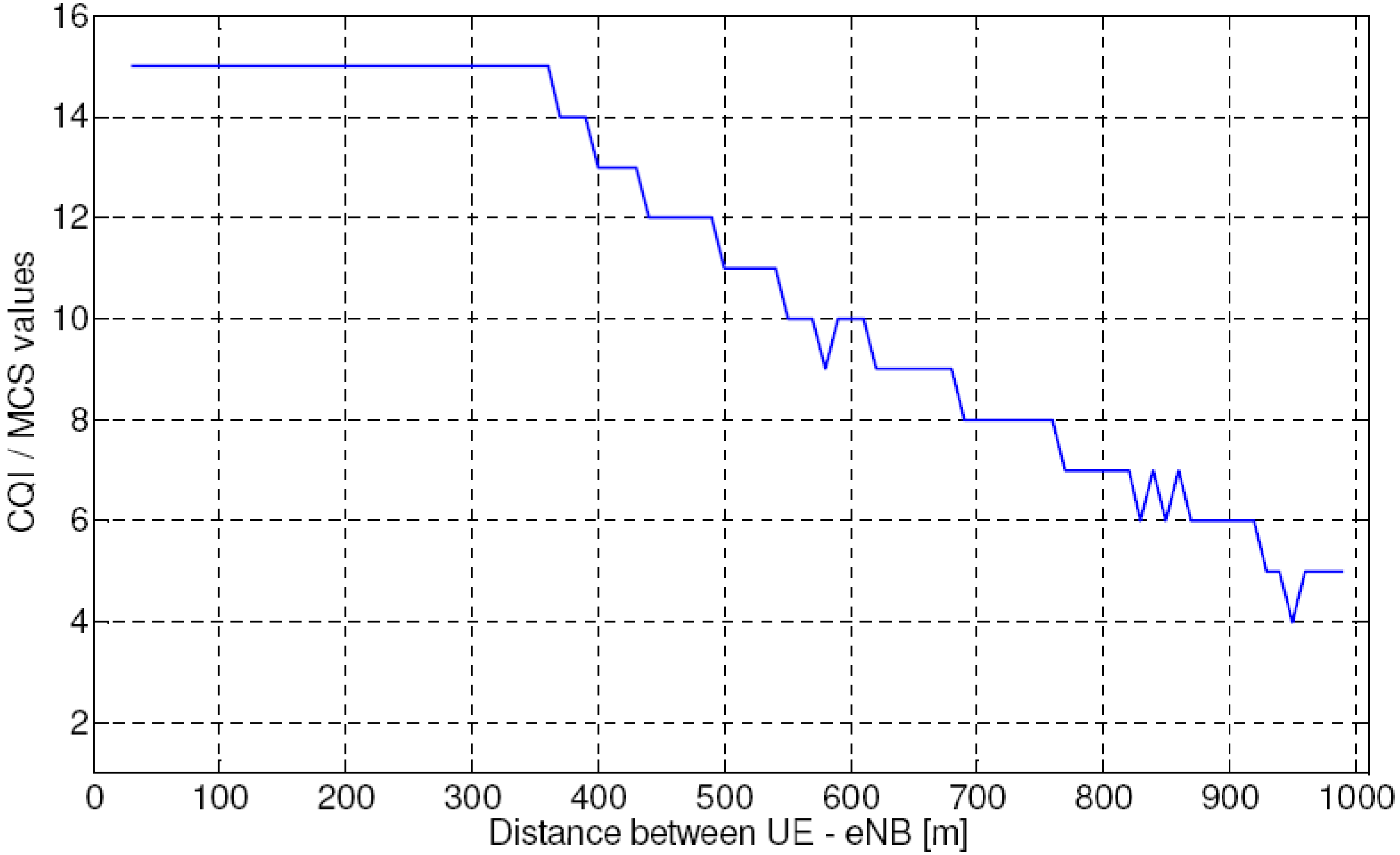
CQI management and AMC module (2)

How changes the quality of the channel when an UE moves away from the eNB ?



CQI management and AMC module (3)

How changes the quality of the channel when an UE moves away from the eNB ?



Control Messages

Two control messages have been implented:

- CQI feedback (feedbacks about the channel quality sends by the UE to the eNB)
- PDCCH messages (descriprion of the resource allocation sends by the eNB to all the UE)

Messages are sent by using an ideal control channel. Why ideal ?

- Information of control messages are not included into the burst of data ... but
- they are exanged by devices directly, without passing follows the *StartTx* and *StartRx* channel methods.

Limitation and Future Works

The LTE module is perfectly integrated into ns-3 ☺ !
We can simulate an LTE scenario with downlink flows.

…. BUT at this moment we have not:

- a standard compliant packet scheduler
- an interference model
- a PHY error model
- other RLC and MAC features (fragmentation, retransmission, ARQ and H-ARQ)
-other !?!

We are working for improve the proposed module.

Thank you for your attention !

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