Technical Documentation
Visualization of LTE cellular networks in a JAVA-based radio network simulator

Version 0.4

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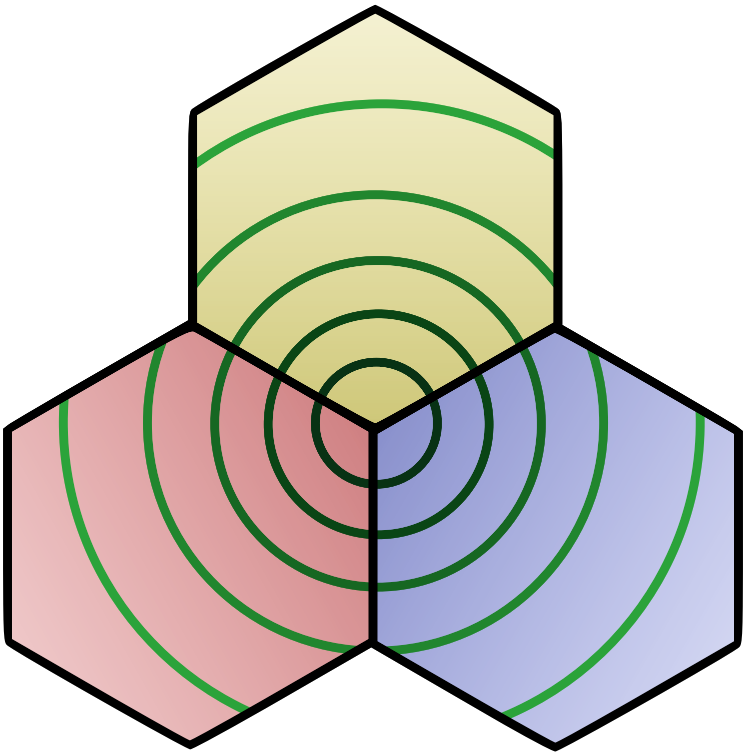

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Document History

Version	Date	Changes made	Sign	Reviewer
0.1	2011-12-03	First draft.	JN	JL
0.2	2011-12-07	Proof read.	JN	JL
0.3	2011-12-07	Added definitions of abbreviations as well as some more text	ST	JL
0.4	2011-12-13	Updated according to comments from JL	MK	JL
1.0	2011-12-20	First version	MK	JL

Contents

List of Abbreviations

16QAM	16 point Quadrature Amplitude Modulation
64QAM	64 point Quadrature Amplitude Modulation
ARQ	Automatic Repeat Request
CDIO	Conceiving – Designing – Implementing – Operating
IP	Internet Protocol
LTE	Long Term Evolution
MIMO	Multiple Input, Multiple Output
OFDM	Orthogonal Frequency Division Multiplexing
PDCCH	Physical Downlink Control Channel
PDCP	Packet Data Convergence Protocol
PHY	Physical
QPSK	Quadrature Phase Shift Keying
RLC	Radio Link Control
SC-FDMA	Single Carrier - Frequency Division Multiple Access
SINR	Signal to Interference-plus-Noise Ratio
TCP	Transmission Control Protocol
VoIP	Voice over IP

1 Introduction and Background

Simulations are a crucial part in the development of cellular systems. With larger and more complex systems it becomes important to be able to visualize the output in an organized manner. The goal of the project is to enable Ericsson's radio network simulator to visualize either the text based outputs which it produces or to visualize the simulation results in real-time while the simulator is running [1].

This technical documentation contains descriptions of the elements in LTE that are visualized by the Visualization Tool developed by this project group. It also contains motivations of why these elements are chosen. Focus is put on the aspects of LTE which are visualized by the software. Description of the UI is left to the User Manual document, and the inner workings of the software is covered by the code documentation extracted through JavaDoc, which is included in this document as appendix **??**.

The project is performed as a part of the TSKS05 Communication Systems CDIO course, given at Linköping University, in cooperation with Ericsson Research, Linköping.

2 Overview of the system

The Visualization Tool consists of three separate *views*. Each one of these views consists of a graphical visualization of some aspects of a cellular LTE network. The *Map View* visualizes the geographical location of the user equipments and base stations. The *Physical Resource Grid* visualizes the resource allocation in form of a frequency time grid. The *Protocol Stack View* presents the flow of data in the system, as well as information about the internal state of user equipments and the server that the user is connected to.

3 Map View

The Map view is responsible for displaying the geographical location of user equipments and base stations. Since LTE is a cellular network, initial colour coding of the user equipment is done according to the cell to which they belong. With the help of the entity list, the user is given the option to choose a base station or user equipment that needs to be highlighted in the map. An example of the map view is shown in figure 1.

3.1 Cellular Network

In a cellular network, the total area being serviced is split into several smaller cells. Cellular networking architecture will help in reusing the allotted frequency spectrum more efficiently. Each base station will consist of several base cells (sectors) and in order to avoid interference with other base cells that might be reusing the same frequency range, highly directional antennas are used. This architecture comes at the cost of having more hand overs at the boundaries of the base cells; this includes handover between two base cells within the same base station and hand over between two base cells from different base stations. Hence, it is essential to have a good trade off between the number of base cells and the handover overhead of the total system.

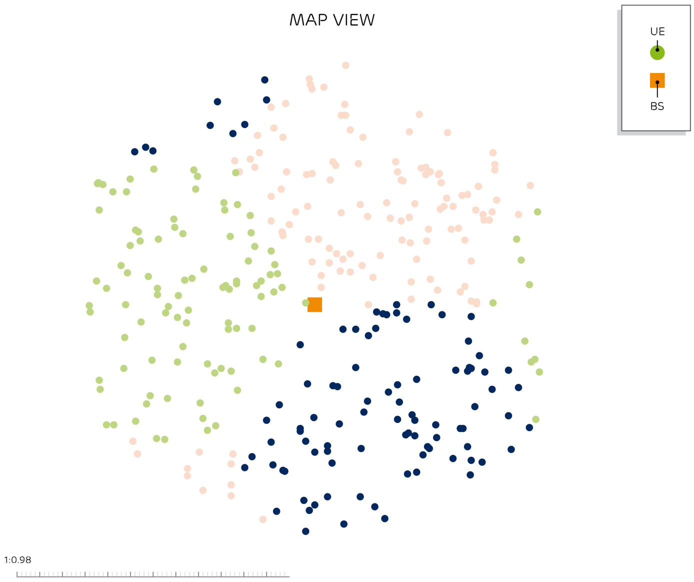

Figure 1: Example of the map view.

3.2 Handover

Since a user equipment will be connected to only one base cell at a given time, in the implemented visualization system, the colour coding will hence change suddenly from the colour of initial base cell to the colour of the destination cell during a handover.

4 Physical Resource Grid View

The Physical Resource Grid View visualizes the resource allocation for cells in the cellular system. The frequency/time grid is divided into resource blocks in both time and frequency. Each block is 1 ms wide in time, called subframes, and the frequency band is divided into sub-bands. Each sub-band is divided into sub carriers. Normally, each sub-band is 180 kHz wide and consists of 12 sub carriers spaced 15 kHz apart [2, ch 9.1]. The reason for splitting the frequency spectrum into sub-bands and the time into subframes is to achieve frequency diversity and give higher flexibility when allocating resources. Each resource block can be transmitted at QPSK, 16QAM, or 64QAM. Resource allocation has undergone a major change from earlier cellular systems. LTE allows a very dynamic resource allocation which is well suited for packet switched traffic since it tends to be bursty. Older cellular systems use a static resource allocation which is more suited for circuit switched voice connections. Visualizing the Frequency Time grid is a major improvement over reading the raw log files since they can be very cryptic and hard to get a good over all picture. An example of the Physical Resource Grid View is shown in figure 2. The numbers and color in the figure correspond to the user. More information about the user interface can be found in [3].

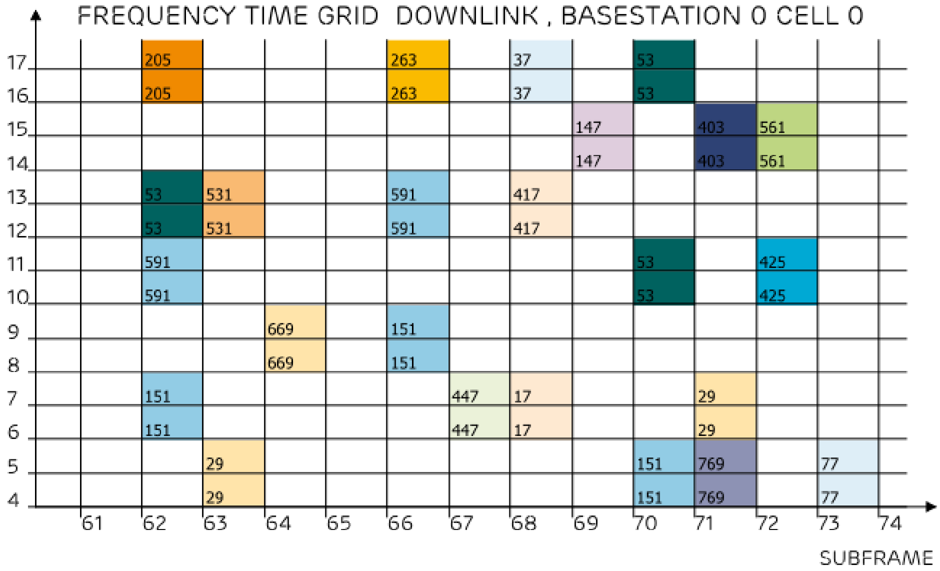

Figure 2: Example of the physical resource grid view.

4.1 Downlink

Downlink allocations for a user can be grouped into sections of at least two resource blocks. The downlink will always be transmitted at full power so there is no need for a power display in the downlink. The first part of each subframe is devoted to the PDCCH. The length of the PDCCH can be different for different subframes, but for a given subframe, the length of the PDCCH channel will be the same.

4.2 Uplink

Uplink allocations for a given UE must be allocated continuously in the frequency domain, in other words there cannot be any gaps in the allocation for a specific user. Since User Equipments have a very stringent battery capacity and power requirement, the uplink is transmitted at different power levels depending on modulation scheme and signal to noise ratio, this can be visualized in the uplink section of the Physical Resource Grid View.

5 Protocol Stack View

The Protocol Stack View displays information about the TCP transport layer and the IP network layer for the communication between a user and an Internet server. All transmission of data can be supervised in this view, as well as the changes in the internal state of the layers, e.g. the TCP congestion window size which keeps the load on the network within reasonable limits and also ensures fairness between multiple users on the same link. The view can easily be extended to show information about all communication layers used in LTE. In the complete LTE system, the user plane protocol stack consists of the layers described in the following sections. The layers are presented in order with the highest layer (that is closest to the IP layer) first. Note that this is only a very brief description of the responsibilities for the different layers. The complete function can be found in the LTE specification [2]. An example of the Protocol Stack View can be seen in figure 3. The details of the view are explained in [3].

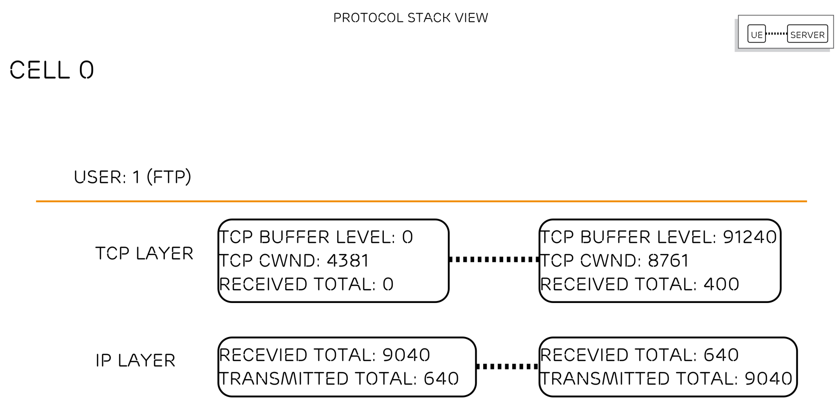

Figure 3: Example of the protocol stack view.

5.1 Packet Data Convergence Protocol Layer

The PDCP layer is reducing the number of bits that are transmitted over the radio interface by performing IP header compression. This is done by using a standardized header compression algorithm called Robust Header Compression. This is an important part of the LTE system, since all voice data is now sent as IP packets (VoIP), small headers reduce the additional latency. In addition, the PDCP layer is responsible for managing sequence numbers, as well as for encryption and decryption of data.

5.2 Radio Link Control Layer

The RLC layer is responsible for the segmentation/concatenation, retransmission handling, and duplicate detection. Moreover, it ensures in-sequence delivery to higher layers.

5.3 Medium Access Control Layer

The MAC layer is responsible for the multiplexing of logical channels, uplink scheduling, downlink scheduling, and also together with the physical layer, hybrid ARQ retransmissions. The HARQ system is a way of ensuring reliable transmission, by performing retransmissions whenever data was lost or corrupted. Even if the retransmitted data contains errors as well, a clever combination of the original packet and the retransmitted one can recover the complete packet. Note that this is much more sophisticated than the way TCP ensures reliability, and the reason for this is the much greater probability for error in the wireless cellular system than in the wired Internet.

5.4 Physical Layer

The PHY layer is responsible for coding/decoding, modulation/demodulation, multi-antenna mapping, and together with the medium access control layer, hybrid ARQ retransmissions. For the downlink, LTE is using OFDM and for the uplink, SC-FDMA. For a detailed description of these, we refer to [2]. Note that different releases of the LTE specification differs.

6 Future Work

6.1 MIMO View

Multiple antenna techniques are used to enhance the performance in terms of achievable data rate and also in terms of quality of reception. In order to illustrate the changes in data rate and quality of reception under different MIMO modes, a dynamically updating plot can be used. This will be indicating the instantaneous data rate and also the SINR at the user equipment with different colour coding is being used for different MIMO modes.

References

[1] Lasse Alfredsson, *Visualization of Cellular Networks in a JAVA-Based Radio Network Simulator*, TSKS05 Communication Systems, Project Directive. Version 1.1, 2011.

[2] Erik Dahlman, Stefan Parkvall, and Johan Sköld, *4G LTE/LTE-Advanced for Mobile Broadband*, Academic Press, 2011.

[3] Per Sundström, *User Manual*, TSKS05 Communication Systems, User Manual Version 1.0 2011.