

Overview

This 3-hours lab class will focus on the throughput and interference in LTE at the link layer. You will learn how to calculate throughput at LTE's Layer 2 and how to work with the related standards. Then you will explore the effect of the cells around you by measuring their interference level, by computing the Signal-to-Interference-plus-Noise Ratio (SINR), and the reduction in throughput due to interference.

Required material and organization

First, join a group of about 4 people.

At least one of you should have a phone from Table 1 with an LTE data plan. The more of you are equipped with these models and the more diverse this collection is, the more insightful will this session be. Do not worry, we will only use a bit of your LTE data budget but will not modify your phone during experimentation.

You will also need Octave or a similar numerical software package (Matlab, Python, whatever you know best). You can use your own installation or log into our remote-PCs, as described in the previous lab session.

Table 1: Smartphone vendors and field menu codes for this lab session

Vendor	Code
Samsung	*#0011# or *##*197328640#*##
Apple	*3001#12345#*
Xiaomi	*##*4636#*##
Sony	*##*386#*## or *##*585*0000#*##
HTC	*##*7262626#*##

1 Preparation

1. Set up your Smartphone as follows:
 - (a) Install the App *LTE Discovery* [1] on your Smartphone.
 - (b) Switch off WiFi and Bluetooth. Make sure this is a hard switch-off, which may be a bit hidden in the settings. Data traffic and LTE should be activated.
 - (c) Once the phone is connected to LTE, open the field test menu.
2. Make yourself familiar with the topic of this lab class by carefully reading [2].
3. Then have a look at the LTE standard 36.213 [3]. Be careful to get the version that is given in the reference. Now understand what the rows and columns in Table 7.1.7.1-1, Table 7.1.7.2.1-1, and Table 7.2.3-1 mean. You find these tables in file 36213-f30.s06-s07.docx within the ZIP-file from [3]. Finally, have a look at Figure 1 below.

Now answer the following questions:

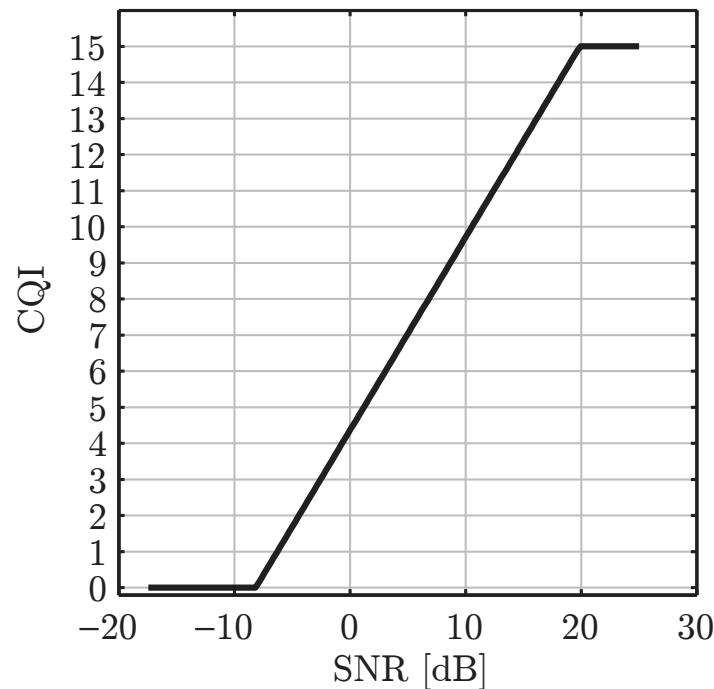


Figure 1: A model for SNR-to-CQI mapping from [4] for a Block Error Rate (BLER) of 10%.

- What are the parameters for LTE throughput calculation? Explain their physical meaning to your peers. Derive an equation to calculate throughput from Transport Block Size (TBS).
- How do you measure these parameters with your Smartphone? Find the respective values in the field test menu or in the LTE Discovery App. Note that some phones require different steps than others and that one of the parameters requires you to use a tool from the previous lab class. Write down your steps to get from the measured quantities to throughput.
- Now read the remainder of this worksheet and make a measurement plan for *all* remaining tasks.
- Present your equation, relevant values in the field test menu (screenshots), and measurement plan to your supervisor.

2 LTE throughput at the link layer

- For each Smartphone in your group, measure the parameters for your LTE throughput calculation 5 times. After each measurement, disconnect from the LTE network (you can use your phone's airplane mode for that) and reconnect again.
- Use your recorded values and your equation to calculate link-layer throughput for all your experiments.
- Visualize your throughput values as a bar plot with 95%-confidence intervals. Use one bar for each propagation environment (indoors, outdoors). Prepare a professional plot, complete with axis titles and units. Hint: If you are using Matlab or Octave, the functions `errorbar()`; `hold on`; `bar()`; `title`; `xlabel()` and `ylabel()` may be useful. Save your plot as an eps or pdf-file and your data as a csv-file or Octave/Matlab workspace.
- Compare the results from the different Smartphones in your group with each other. If you find significant differences, discuss potential reasons. Then present your results to your supervisor.

3 Interference in LTE

1. Open the LTE Discovery App and find the Reference Signal Received Power (RSRP) and Signal-to-Noise Ratio (SNR) of your Smartphone and the RSRP-values of the neighbor cells.
2. For each Smartphone in your group, record the RSRP and SNR from the LTE Discovery App. For the 3 closest neighbor cells, record the RSRP and the Physical Cell ID (PCI). Repeat these measurements at least 5 times, using method from task 2.1.
3. Now compute the Signal-to-Interference-plus-Noise Ratio (SINR) as

$$\text{SINR} = \frac{P_r}{N_0 + \sum_{k=1}^K I_k}$$

where P_r is the RSRP, $N_0 = -134$ dBm the noise power, K the number of neighboring cells, and I_k the RSRP (i.e., interference power) from neighbor cell k (excluding the serving cell). For simplicity we will limit $K = 3$.

4. Separately for each Smartphone in your group: Compare your calculated SINR to the measured SNR. Do you notice any difference? Quantify this difference in dB and explain the reason behind it.
5. Visualize your calculated SINR and your measured SNR as a pair of bars with 95%-confidence intervals. Merge all bar-pairs into one plot for all Smartphones in your group, e.g., a plot with 6 bars for 3 Phones. Save your plot as an eps or pdf-file and your data as a csv-file or Octave/Matlab workspace.
6. Let us now compute how much throughput we lose due to interference. Use Figure 1 to map your SINR to CQI and repeat this step for your measured SNR. Then calculate throughput using [3, Table 7.2.3-1] and the net-bandwidth 9.7872 or 19.5792 MHz, for a total bandwidth of 10 or 20 MHz respectively. Plot your throughput results and the throughput loss as bars for each Smartphone in your group. Hint: Stacked bars would be a useful visualization here.
7. Compare the results from the different Smartphones in your group with each other. If you find significant differences, discuss potential reasons. Highlight the effect of interference in your discussion. Then present plots and interpretation to your supervisor.

4 Wrapping up

1. We will wrap up this session with a short discussion at the end.
2. Write a brief protocol with all your discussion points from the above tasks. Make sure to include the names of all of your groups members on that document.
3. Upload your protocol together with all plots and csv-files in Moodle.

References

- [1] D. Goodwin, "LTE Discovery," Android Application, available: <https://play.google.com/store/apps/details?id=net.simplyadvanced.ltediscovery&hl=en>, Mar. 2022.
- [2] A. Anisimov, "How to calculate LTE throughput," http://anisimoff.org/eng/lte_throughput.html, 2016.
- [3] 3GPP, "Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures (Release 15)," 3rd Generation Partnership Project, Technical Specification TS 36.213, V15.3.0, Sep. 2018. [Online]. Available: <https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=2427>
- [4] J. C. Ikuno, M. Wrulich, and M. Rupp, "System level simulation of LTE networks," in *IEEE Vehicular Technology Conference (VTC-Spring)*, May 2010, pp. 1–5.