MEASUREMENT OF THE REFERENCE SIGNAL IN 4G LTE NETWORK IN SOFIA

ИЗМЕРВАНЕ НА РЕФЕРЕНТНИЯТ СИГНАЛ В 4G LTE МРЕЖА В СОФИЯ

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Резюме – LTE мрежите предоставят използването на референтен сигнал с предварително определена структура в направление от базовата станция към мобилната станция, като този сигнал е пилотен. Този референтен сигнал се излъчва от базовата станция с постоянна мощност и мобилните устройства го използват, за да оценят състоянието на радио канала за връзка. Мобилните устройства осъществяват измерване на три ключови параметъра на референтния сигнал – RSRP, RSSI и RSRQ. В LTE мрежите всяко мобилно устройство измерва RSRP и RSRQ, като тези измервания се използват за определяне на нивото и качеството на сигнала от различните LTE клетки, като на базата на измерените стойност за RSRP и RSRQ се взема решение за избор на клетка и осъществяване на хендоувър. В тази статия са представени резултати от измерването на RSRP и RSRQ в LTE мрежа в София.

Abstract – Long Term Evolution (LTE) networks provide a downlink reference signal with a predetermined structure, known as a downlink pilot signal. This reference signal (RS) is transmitted from the eNodeB with a constant power and the user equipment (UE) uses the RS to estimate the instant downlink channel conditions. The UE measures three reference signal key parameters in the LTE downlink - RSRP (Reference Signal Received Power), RSSI (Receive Strength Signal Indicator) and RSRQ (Reference Signal Received Quality). In LTE networks each UE measures RSRP and RSRQ, as these measurements are used mainly to rank different LTE candidate cells according to their signal strength and quality. The handover and reselection decisions are taken on the basis of these measurements. In this paper are presented RSRP and RSRQ measurement results in a real LTE network in Sofia.

1. INTRODUCTION

Downlink channel (DL) conditions can be measured by all UEs in eNodeB covered areas by simply observing the reference signals transmitted by the eNodeB and all UEs can share the same reference signal for channel quality estimation purposes. Estimating the uplink channel quality, however, requires a sounding reference signal transmitted from each UE for which the eNodeB wants to estimate the uplink channel quality [1]. In the LTE networks, when a mobile subscriber moves from cell to cell, it has to measure the signal strength of the neighbor cells. In the

LTE network, a UE measures three parameters of the reference signal: RSRP (Reference Signal Received Power), RSSI (Receive Strength Signal Indicator) and RSRQ (Reference Signal Received Quality) [2]. RSRP and RSRQ are key measures of the DL signal level and quality for LTE networks. Two measurement criteria such as RSRP and RSRQ are used to make a handover decision or cell reselection. RSRP is an important LTE physical layer measurement performed by the UE and is also mostly utilized during the decision-making in the intra-frequency and inter-frequency handovers [2].

2. LTE DOWNLINK

1.1 Resource management in LTE downlink

The downlink LTE air interface is based on Orthogonal Frequency Domain Multiplexing Access (OFDMA), a multi-carrier scheme that allocates radio resources to multiple users based on frequency (subcarriers) and time (symbols) [3]. OFDMA uses Orthogonal Frequency Division Multiplexing (OFDM), as it is specifically designed for multi-user access [4]. OFDM meets the LTE requirement for spectrum flexibility and enables cost-efficient solutions for many carriers with high peak rates. OFDM uses a large number of narrow subcarriers for multi-carrier transmission. The spacing between the OFDM subcarriers is 15 kHz [4]. The OFDM subcarriers (or symbols) are grouped into Resource Block (RB). The RB is the smallest unit of the radio resource that can be allocated to an individual user for the purpose of data transmission [5]. The basic LTE downlink physical resource at a time-frequency grid is illustrated in Figure 1.

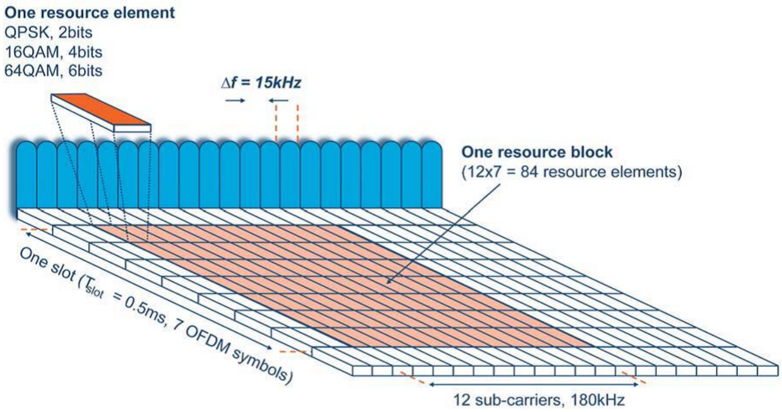

Figure 1. Resource management in LTE downlink

The RB has a total size of 180 kHz with 12 consecutive subcarriers in the frequency domain and 0.5 ms with 7 OFDM symbols (with the normal cyclic prefix) in the time domain. The smallest unit of resource is the Resource Element (RE), which consists of one subcarrier for a duration of one OFDM symbol [4]. An RB thus comprises of 84 REs in the case of the normal cyclic prefix length (see figure 1). The RB size is the same for all bandwidths. The number of RBs for the different LTE bandwidths is presented in Table 1.

TABLE 1 RELATION BETWEEN LTE FREQUENCY BANDWIDTH AND NUMBER OF RESOURCE BLOCKS

Channel Bandwidth	Usable Bandwidth	Usable Bandwidth in number of subcarriers	Usable Bandwidth in number of resource blocks	Measurement Window Size
1.4 MHz	1.08 MHz	72	6	1.1 MHz
3 MHz	2.7 MHz	180	15	2.7 MHz
5 MHz	4.5 MHz	300	25	4.5 MHz
10 MHz	9 MHz	600	50	9.1 MHz
15 MHz	13.5 MHz	900	75	13.5 MHz
20 MHz	18 MHz	1200	100	18.1 MHz

1.2 LTE radio frame structure

In LTE, there are defined two types of frame in the Physical layer channels, because LTE supports both time (TDD) and frequency (FDD) division duplexing modes. LTE standard defines two types of frame structures, which are type 1, for FDD, and type 2, for TDD. LTE FDD systems use frame structure type 1, where radio frames are divided into sub-frames, times slots, and symbols [5]. TDD systems use a frame design similar to type 1, but are referred to as having frame structure type 2, in which both the uplink and the downlink share timeslots in a common block of allocated bandwidth [5]. In this paper, we show only frame structure type 1. Figure 2 illustrates FDD frame structure.

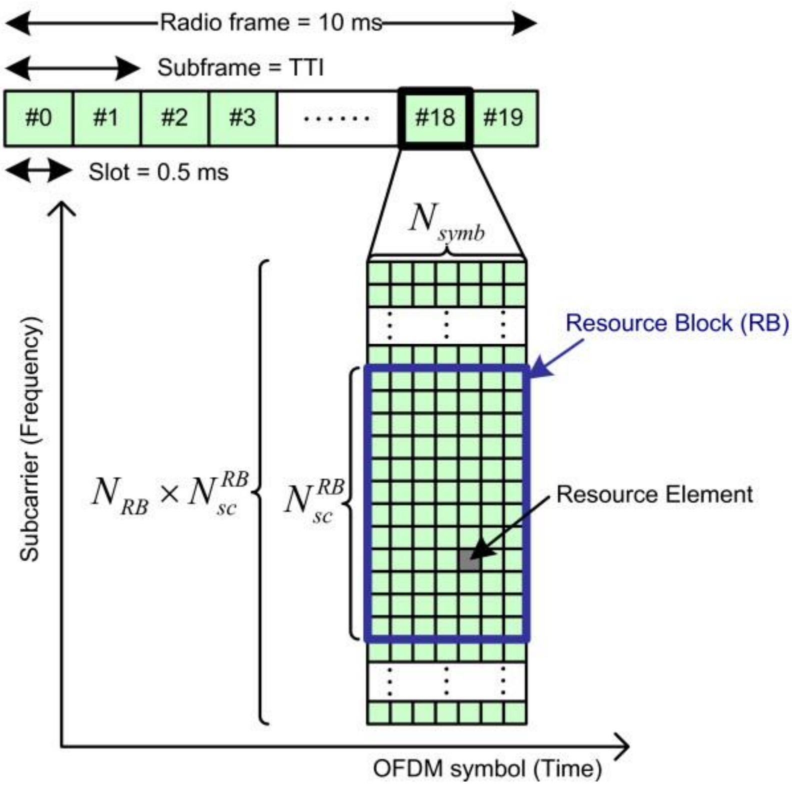

Figure 2. FDD frame structure

In LTE, downlink and uplink transmissions are organized into frames with a duration of 10ms. A frame is divided into 10 subframes with a duration of 1ms each, and a subframe is divided into 2 slots with a duration of 0.5ms each [6]. The frame, subframe, and slot structure for LTE is illustrated in Figure 2.
The smallest unit of the LTE frame structure is called a slot, and has a duration of 0.5ms. Each slot contains 7 symbols: two consecutive slots are defined as a 1ms subframe and 20 slots comprise of a 10ms radio frame. (see figure 2). The LTE Resource element is the smallest unit of resource assignment. The number of symbols in a RB depends on the Cyclic Prefix (CP) that is being used. When a normal CP is used, the RB contains seven symbols [7].

1.3 Reference Signal

The eNodeB determines the downlink transmission energy per RE. UE may assume downlink cell-specific RS energy per resource element (EPRE) to be constant across the downlink system bandwidth and constant across all subframes, until different cell-specific RS power information is received.

Three types of downlink RSs are defined [5]:

1. Cell-specific reference signals, associated with non-multimedia broadcast multicast service single frequency network (MBSFN) transmission

2. MBSFN reference signals, associated with MBSFN transmission

3. UE-specific reference signals

Cell-specific RS shall be transmitted in all downlink subframes in a cell supporting non-MBSFN transmission. In case the subframe is used for transmission with MBSFN, only the first two OFDM symbols in a subframe can be used for transmission of cell-specific reference symbols [3]. Cell-specific reference signals are transmitted on one or several antenna ports ranging from 0 to 3. (see figure 3)

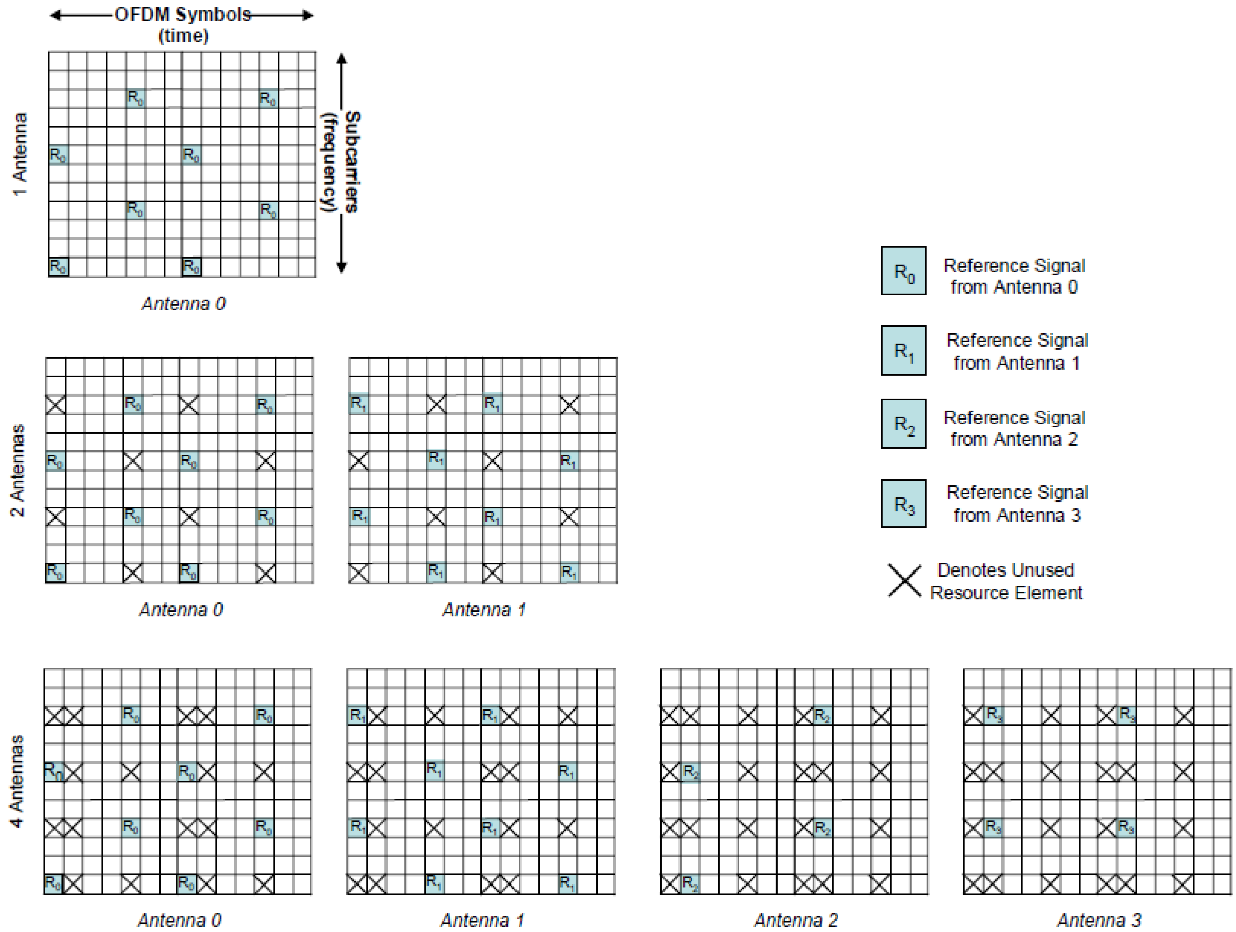

Figure 3. Mapping of reference signal

1.4 Measurement of LTE downlink

Power fluctuations make it impossible to directly measure maximum power while the eNodeB is in service. Power measurements of the RS, which UEs use for downlink channel estimation, can provide surprisingly accurate proxy measurements. This is because the RS power is a static value that closely correlates to maximum transmitted output power of the eNodeB.

For the UE the following measurements are to be performed inside the LTE network:

- The Reference Signal Received Power (RSRP) is a cell-specific signal strength related metric that is used as an input for cell resection and handover decisions. RSRP is defined as the average power in watts of the REs that carry cell-specific RSs within the considered bandwidth [1]. RSRP measurement, normally expressed in dBm, is utilized mainly to make ranking among different candidate cells in accordance with their signal strength. Generally, the RSs on the first antenna port are used to determine RSRP, however, the RSs sent on the second port can also be used in addition to the RSs on the first port if the UE can detect that they are being transmitted [1,2].
- The Reference Signal Received Quality (RSRQ) measurement is a cell-specific signal quality metric. Similar to the RSRP measurement, this metric is used

mainly to provide ranking among different candidate cells in accordance with their signal quality. This metric can be employed as an input in making cell reselection and handover decisions in scenarios in which the RSRP measurements are not sufficient to make reliable cell reselection or handover decisions. It is defined as [1]:

$$RSRQ = N\,\frac{RSRP}{RSSI}, \tag{1}$$

where N is the number of RBs of the measurement bandwidth.

- The Received Signal Strength Indicator (RSSI) is a linear average of the total received power observed only in OFDM symbols carrying reference symbols by a UE from all sources, including co-channel non-serving and serving cells, adjacent channel interference and thermal noise, within the measurement bandwidth over number of RBs [1, 2]. RSSI is used as an input to compute the LTE RSRQ measurement discussed above.

From the above Eq. (1), it is observed that due to the inclusion of RSSI, RSRQ is considered the combined effect of signal strength and interference. It can also be observed that mathematically RSRQ is proportional to RSRP.

3. RESULTS

In this paper, we present measurement results of RSRP and RSRQ in an existing LTE network using a UE. The measurement is performed in Sofia, Studentski grad, where two eNodeBs are currently positioned. Measurement is carried out in the Bulsatcom 4G LTE network in Sofia, Studentski grad. In this area, the coverage is provided by two eNodeBs. The RSRP and RSRQ were measured as the UE was moving from cell to cell with low speed in the area of coverage. As it moves, the UE also measures the signal strength and quality of the signal of the neighboring cell.

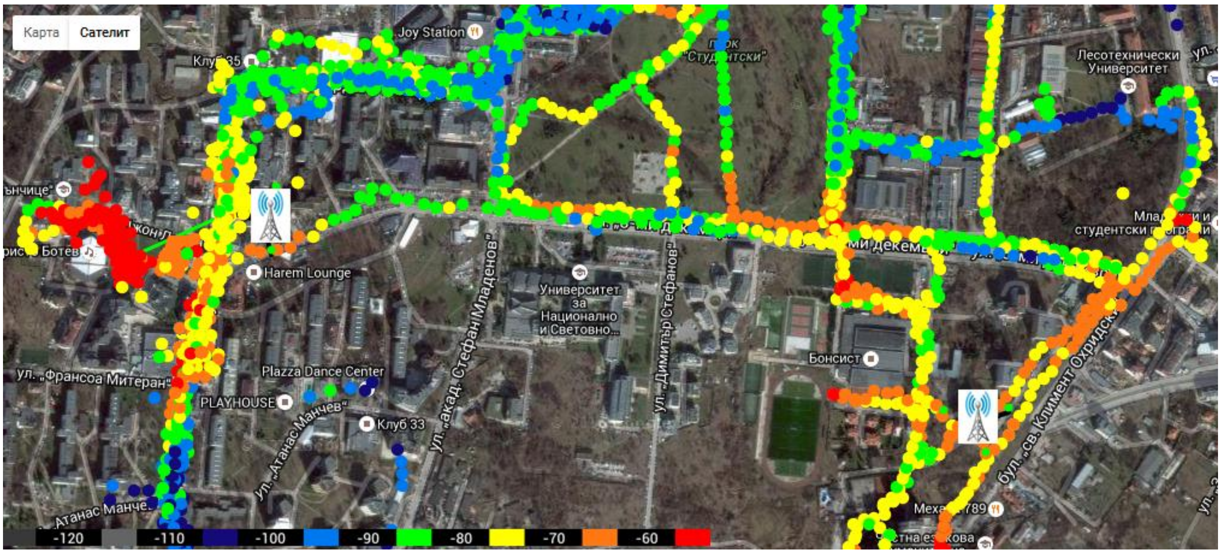

Figure 4. Measurement results of RSRP

Figure 4 shows measurement results of RSRP in dBm. For the LTE downlink, RSRP is the downlink pilot or the downlink reference signal. RSRP is only measured in the REs carrying reference signal. This reference signal is transmitted from the base station with a constant power, which can be used by the UE to estimate the instant downlink channel conditions.
RSRP levels for usable signal typically range from about -60 dBm (red color) close in to an LTE cell site to -120 dBm (gray color) at the edge of LTE coverage. RSRP is greater than – 60 dB, where there is line-of-sight (LOS) between the eNodeB and the UE, but when there is Non-line-of-sight (NLOS) case the value of RSRP falls into the range of – 70 dBm - 100 dBm, as it could be observed in Figure 4. Results show that the radius of the cell coverage depends on the terrain profile and the buildings density. The radius is greater where there are wide boulevards and parks. The radius is narrower where the terrain is hilly, or the housing estates have high density.

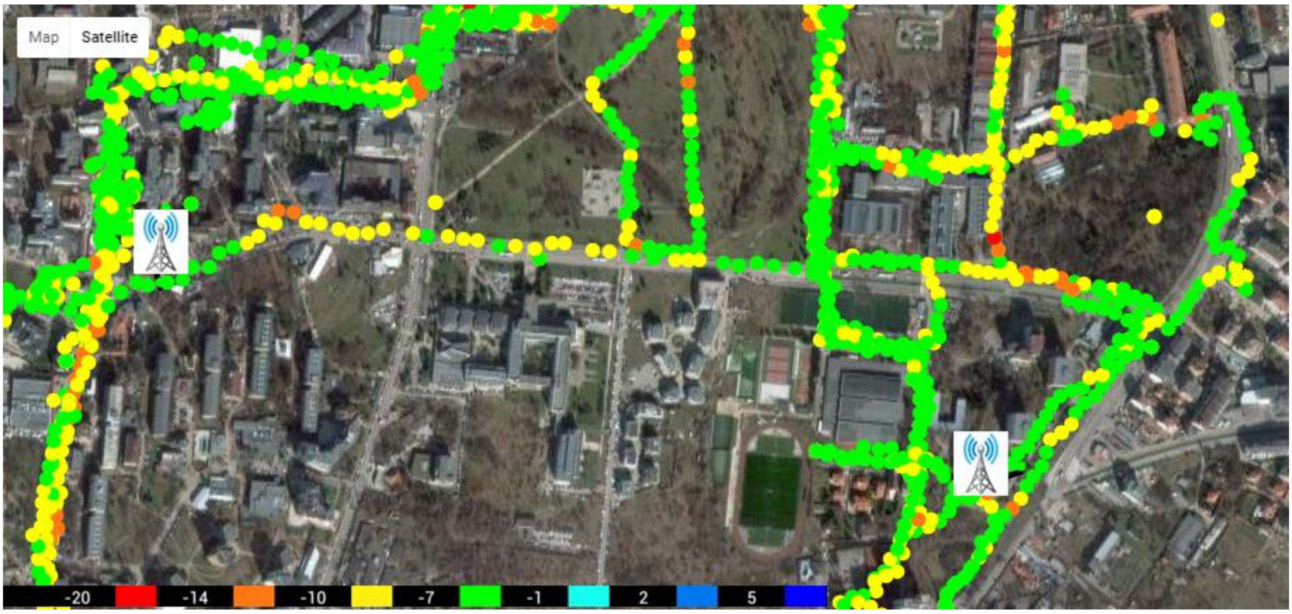

Figure 5. Measurement results of RSRQ

Figure 5 shows measurement results of RSRQ in dB. In the LTE network the better metric to measure is RSRQ for channel quality and the whole bandwidth. RSRQ is a C/I type of measurement and it indicates the quality of the received reference signal. The RSRQ measurement provides additional information when RSRP is not sufficient to make a reliable handover or cell reselection decision. As can be seen in Figure 5 the RSRQ is greater than -10dB and lower than -3dB, which shows low level of co-channel interference and noise.

4. CONCLUSION

Measurements of RSRP and RSRQ by a UE with specialized mobile application give a possibility for mapping of the coverage of the Bulsatcom 4G LTE network in the area of Studentski grad in Sofia. Results show that the cell radius depends on terrain profile and buildings density.

5. REFERENCES

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