ESTIMATION OF THROUGHPUT IN LTE NETWORK, DEPENDING ON MIMO ANTENNA SYSTEMS

ИЗСЛЕДВАНЕ НА СКОРОСТТА НА ПРЕНОС НА ДАННИ В LTE МРЕЖА В ЗАВИСИМОСТ ОТ ВИДА НА MIMO АНТЕННАТА СИСТЕМА

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Резюме – В мобилните комуникационни мрежи от четвърто поколение и по-конкретно в LTE мрежите за постигане на високоскоростен пренос на данни се използват MIMO антени. Характерно за тази технология е използването няколко антени за приемане и предаване на данни едновременно. Скоростта, с която се пренася информацията зависи от броя на използваните антени и избраната модулация. За да се отговори на изискванията на потребители за високо качество на мобилните услуги в LTE мрежите е необходимо да се направи оценка за скоростта на пренос на данни, която може да бъде постигната. В нашия доклад сме представили резултати за скоростта на пренос на данни в зависимост от вида на антенната система, модулацията и използваната честотна лента.

Abstract – Multiple-input-multiple-output (MIMO) technology is used by fourth generation mobile networks, especially in Long Term Evolution standard in order to achieve very high data rates in both the uplink and downlink channels. MIMO is based on the use of multiple antenna systems within the mobile terminal and the base station. The throughput depends on the number of the used antennas and the type of modulation. The estimation of the throughput is necessary in order to meet the users' requirements for high quality of mobile services in LTE network. In our paper we present results for the throughput dependence on the antenna systems ,the specific type of modulation and bandwidth.

1. INTRODUCTION

Long-Term Evolution (LTE) is a standard for wireless communication, which provides of high-speed data for mobile devices. The standard is developed and introduced by 3rd Generation Partnership Project (3GPP) and is poised to dominate the 4th generation (4G) of mobile telecommunication networks [1]. The main features of a 4G LTE network are higher data rate with reduced latency, improved system capacity and coverage, efficient spectrum utilization, flexible spectrum allocation and reduced cost for mobile operators [2]. The fundamental radio access design parameters in LTE systems are OFDM (Orthogonal Frequency Division Multiplexing) waveforms, in order to avoid the inter-symbol interference that typically limits the performance of high-speed systems, and Multiple-Input Multiple-

Output (MIMO) techniques to boost the data rates [2]. To improve the overall capacity of LTE, MIMO techniques have been proposed, allowing users to reach a high spectral efficiency through an intelligent allocation of electromagnetic spectrum by OFDMA. MIMO systems allow for the creation of multiple streams of information that would lead to an increase of the capacity of the system using the same number of resources [3].

4G LTE`s goals are optimisation for packet switched services in general, support for higher throughput required for higher end user bit rates, and improvement in the packet delivery delays.

2. CALCULATION OF THROUGHPUT IN LTE NETWORK

LTE network uses Orthogonal Frequency-Division Multiple Access (OFDMA) for the downlink and Single Carrier Frequency Division Multiple Access (SC-FDMA) for the uplink, both with Cyclic Prefix (CP) [4]. CP is a simple prefix added to the OFDM symbol, copied from the end of the same symbol. The signal will gain a periodic nature, allowing discrete Fourier operations, hence avoiding Inter-Symbol Interference. In an OFDM system, the available bandwidth is divided into various sub-carriers that can be modulated independently. The main reason that justifies different access techniques for the downlink and uplink is the fact that SC-FDMA optimises range and power consumption at the mobile devices, while OFDMA minimises receiver complexity and enables frequency domain scheduling with flexibility in resource allocation [4]. OFDMA is a multi-carrier transmission scheme in opposition to SC-FDMA. Both allow multiple user access to BS, depending on the available bandwidth, by dynamically allocating each user to a specific time-frequency resource, depending on which duplexing is deployed. LTE systems are supported both types of duplexing - Frequency Division Duplexing (FDD) and Time Division Duplexing (TDD), as FDD is the most adopted technique in the majority of European mobile networks.

Important parameters for estimation of data throughput in LTE networks are frequency bandwidth, modulation, coding rate and CP. In LTE systems are used OFDMA as access technology to increase the spectral efficiency in downlink and SC-FDMA due to low Peak to Average Power ratio (PAPR) advantage in uplink [5].

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The Resource element (RE) is the smallest unit of transmission at LTE, in both downlink and uplink. Each RE consists of 1 symbol in time domain vs. 1 sub-carrier in frequency domain [5]. In LTE subcarrier spacing is the space between the individual sub-carriers and it is 15 KHz. REs are aggregated into Resource Blocks (RB). The dimensions of RB are 7 symbols by 12 subcarriers. Therefore 84 RE makes a RB (with Normal CP), if extended CP used there are 72 REs. In RB are used

12 OFDM subcarriers, hence the bandwidth of RB is 180 KHz. The number of RB is determined of occupied bandwidth.

LTE standard supports six different channel bandwidth options – 1.4 MHz, 3 MHz, 5 MHz, 10 MHz, 15 MHz and 20 MHz. In LTE 10% of total bandwidth is used for guard band, but it is not valid for 1.4 MHz bandwidth.

Therefore for bands 3 MHz, 5 MHz, 10 MHz, 15 MHz and 20 MHz, occupied bandwidth is [5]:

$$\mathrm{BW_{occupied}} = 90\%\ \mathrm{BW}, \quad (1)$$

where $\mathrm{BW_{occupied}}$ is an occupied bandwidth and BW is a channel bandwidth.

Number of RB is calculated by the following equation:

$$\mathrm{N_{RB}} = \frac{\mathrm{BW_{occupied}}}{180\ \mathrm{kHz}}, \quad (2)$$

The number of sub-carriers in occupied Bandwidth can be calculated by:

$$\mathrm{N_{subcarriers}} = \frac{\mathrm{BW_{occupied}}}{15\ \mathrm{kHz}} \text{ or} \quad (3)$$

$$\mathrm{N_{subcarriers}} = 12\ \mathrm{N_{RB}}\ , \quad (4)$$

TABLE 2.1 LTE TRANSMISSION BANDWIDTH CONFIGURATION

Bandwidth [MHz]	1,4	3	5	10	15	20
Occupied Bandwidth [MHz]	1,08	2,7	4,5	9	13,5	18
Number of RB	6	15	25	50	75	100
Number of Sub-carriers	72	180	300	600	900	1200

Table 2.1 presents number of RB and sub-carriers in different LTE bandwidth.

LTE systems use several modulation techniques to modulate data and control information - QPSK (2 bits per symbol), 16QAM (4 bits per symbol), and 64QAM (6 bits per symbol) [5].

MIMO is a key component of next-generation wireless technologies and provides the LTE's peak throughput gains when compared with older technologies. MIMO gains can only be realized on a fully optimized network. MIMO optimization requires a different approach to traditional network optimization, with assessment of multipath conditions playing a key role in determining the potential throughput provided by a MIMO in LTE network.

MIMO antenna system has ability to turn multipath propagation, traditionally a problem in wireless communication, into a benefit for the user. MIMO effectively takes the advantages of random fading [3]. In the presence of random fading, the probability of losing the signal decreases with the number of uncorrelated antenna elements being used [3]. Thus, in MIMO, one of the key parameters which determines the performance is the spatial correlation between the antenna elements. This spatial correlation determines the independency between antenna elements and thus the amount of spatial diversity that can be exploited.

In LTE systems the data throughput depends on the available bandwidth and the parameter of the OFDM signal, like the number of sub-carriers and the modulation order (QPSK, 16QAM, 64QAM). The maximum data throughput in LTE network can be calculated by the following equation:

$$Throughput = \frac{N_{RB}\, N_{SC}\, N_{OFDM}\, N_{bit}\, N_{streams}\, ECR}{T_{SF}} \text{ [bps]}, \quad (5)$$

where N_{RB} is the number of RB in occupied bandwidth, N_{SC} is the number of sub-carriers in one RB, N_{OFDM} is the number of OFDM symbols per sub-frame, N_{bit} is the number of bits used in the modulation, $N_{streams}$ is the number of streams to consider in MIMO antenna systems, ECR the Effective Code Rate, T_{SF} is the duration of sub-frame in [s].

3. RESULTS

In this paper we present results of throughput in downlink at LTE network depending on different antenna systems, type of modulation and bandwidth used. For calculation of throughput equation (5) has been used.

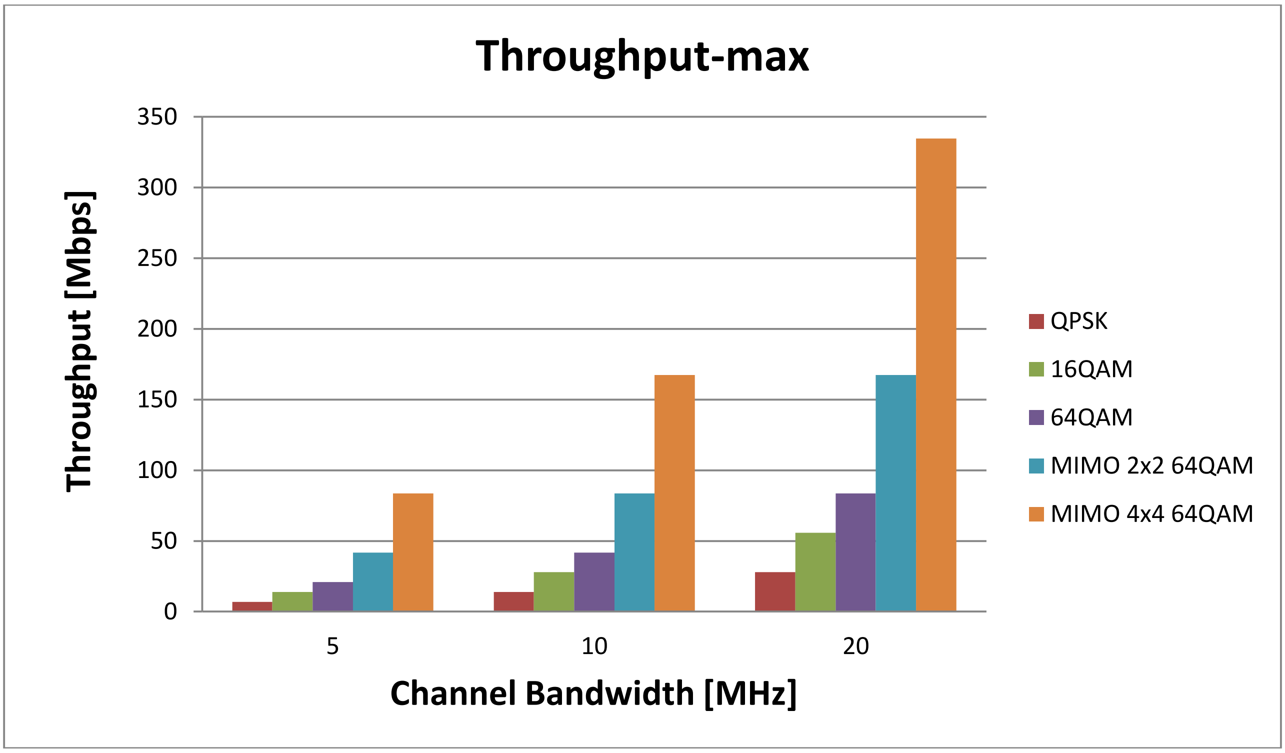

Fig. 3.1 Results of maximum throughput

The results of maximum data throughput in downlink are presented in fig. 3.1. When using the normal CP there are 14 OFDMA symbols during each 1 ms sub-frame. The results still assume a coding rate of 0,83. The single streams throughputs in fig. 3.1 have been generated by multiplying the modulation symbol rate by the number of bits per symbol. When modulation symbol rate is increased, data throughput is increased too. LTE has adaptive modulation and coding, which greatly improves data throughput. The variation of the downlink modulation coding scheme, based on the channel condition for each user, results in one of LTE's greatest features: self-optimisation. With the capability of changing the modulation scheme to a higher order (more bits per symbol) when the link condition is good, the network capacity is increased. The MIMO throughputs in fig. 3.1 have been generated by multiplying the 64QAM throughputs by the relevant MIMO rank, i.e. the throughputs have been doubled for 2×2 MIMO and quadrupled for 4×4 MIMO.

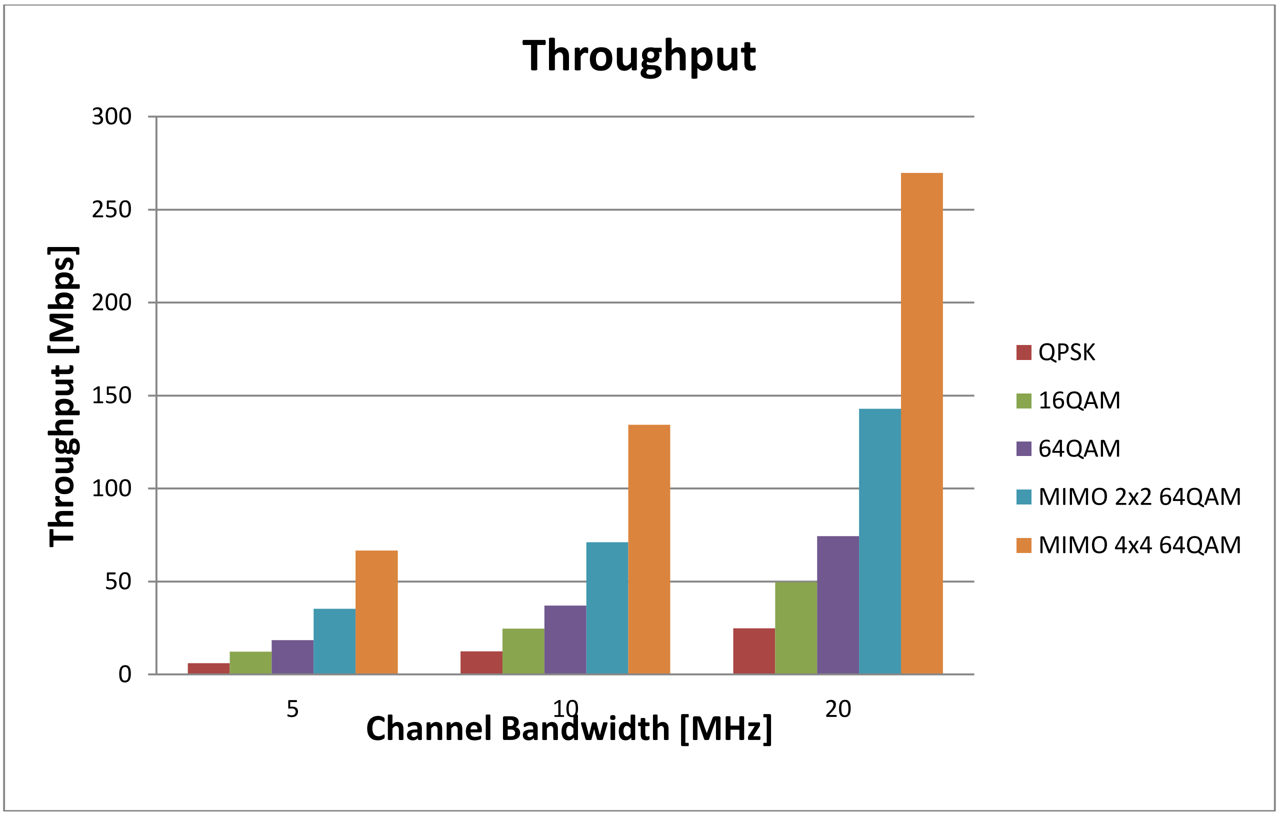

Fig. 3.2 Results of throughput with overheads removed

Fig. 3.2 presents a results of throughputs with these overheads removed in downlink, as the overheads generated by the other physical channels and physical signals. The throughput is increased, when MIMO rank growths.

4. CONCLUSION

In this paper, we presented results of LTE system throughput calculation in downlink. The paper describes the main factors which affect the data throughput in LTE systems like bandwidth, modulation, multiplexing, and antenna system configuration. The paper describes the estimation of throughput in LTE network, depending on the MIMO antenna systems. The results show how we can obtain data throughput 270 Mbps in downlink.

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