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Investigation of Effect of Communication Bandwidth and Length of Coherence Block on Energy Efficiency and Area Throughput in Massive Multiple-Input and Multiple-Output Systems

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Abstract – The popularity of wireless communication is increasing day by day. This has led to the fact that data transfers via GSM have reached very high levels. Data transfers via GSM, which are continuously growing, increase the density of data traffic, thus necessitating high level of area throughput (TR) performance in the near future. One of the most effective ways to increase area throughput is seen as increasing spectral efficiency (SE). Very high amount of energy required to increase the spectral efficiency. High energy consumption is costly and harmful to the environment so thus makes it necessary to increase the energy efficiency (EE). Massive multiple-input and multiple-output (Massive MIMO) systems are one of the techniques that can be used to increase the both of area throughput and energy efficiency. In this study, length of coherence block – communication bandwidth combinations are investigated by using Massive MIMO systems in cases which there are various numbers of users and active antennas. As a result of the studies, the effects of length of coherence block and communication bandwidth on EE - area throughput tradeoffs were evaluated.

Keywords *– Massive Multiple-Input and Multiple-Output Systems, Spectral Efficiency, Energy Efficiency, Area Throughput*

I. Introduction

The use of wireless communication is becoming increasingly widespread. This has led to the fact that data transfers via GSM have reached very high levels. This situation is expected to have a negative impact on the intensity of wireless data traffic in the near future [1].

According to the estimate put forward by Ericsson, the rate of increase in the use of wireless communications between 2016 and 2022 is expected to be 42% annually [2]. Therefore, future cellular network technologies are expected to have the capacity to increase the area throughput (TR) hundreds of times in order to cope with the increase in data traffic [3].

Area throughput [bit/s/km^2] refers to the number of bits transmitted per second on per unit area successfully and it is directly related to the data traffic. Area throughput is generally formulated to be directly proportional to three factors. These; frequency spectrum, cell density (average number of cells per square kilometer) and spectral efficiency (SE). Since it is not possible to increase the frequency spectrum and cell density factors hundreds of times, area throughput improvement efforts are performed by increasing spectral efficiency.

The spectral efficiency of an encoding or decoding algorithm is equivalent to the average number of bits of each complex valued sample of information [bit/s/Hz] [1]. The transmission power and the number of receiving antennas can be increased or the space division multiple access (SDMA) method can be used to increase spectral efficiency.

Uncontrolled increase in the transmission power and at the number of active antennas will increase the amount of energy consumed to very high levels. This situation is considered to be an important problem because it is harmful to the environment and high cost [4]. Increasing SE with lower energy consumption is possible by increasing energy efficiency (EE). Energy efficiency refers to the amount of bits successfully transmitted using unit energy [bit/Joule].

Massive multiple-input and multiple-output (Massive MIMO) system is one of the preferred methods for increasing spectral efficiency [5], [6]. This system uses hundreds or thousands of antennas at each base station (BS) [7]. In this system, it is intended that the number of active antennas (M) in each cell be greater than the number of active users (K). Massive MIMO system is used in many areas such as increasing energy efficiency, hardware improvement, pilot series improvement, as well as increasing spectral efficiency directly affecting the area throughput. Figure 1 shows an example of Massive MIMO system [8].

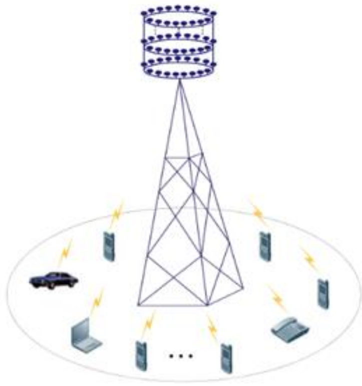

Fig. 1 Example of Massive MIMO system [8]

In the situations which TR and EE values are tried to increase at the same time, it is observed that TR increases continuously as the number of active antennas and the transmission power increase. EE increases to a point and then decreases. Therefore, there is a trade-off between TR and EE. An example of the relationship of TR and EE is illustrated in Figure 2 [1].

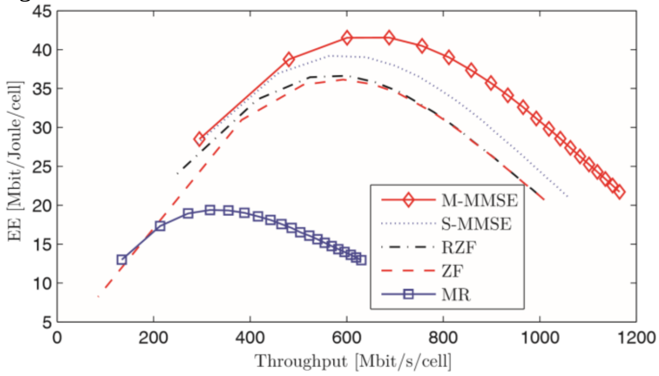

Fig. 2 Example of relationship of TR and EE [1]

Figure 2 shows the situations that different pre-coding methods are used and active antenna numbers are changed. When the figure is examined, it is seen that the change of EE due to TR is unimodal type. This means EE increases monotonously up to the peak and then falls monotonously.

In this study, the effects of bandwidth and length of coherence block on this trade-off were investigated separately.

II. Materials and Method

In this study, multicell minimum mean-squared error (M-MMSE) pre-coding method was used in these examinations performed on cases where two different power sets given in the Table 1 are used also different numbers of user equipment (UE) and different numbers of antennas are used.

Table 1. Values of power sets

Parameter	Value set 1	Value set 2
Fixed power: P_{FIX}	10 W	5 W
Power for BS LO: P_{LO}	0.2 W	0.1 W
Power per BS antennas: P_{BS}	0.4 W	0.2 W
Power per UE: P_{UE}	0.2 W	0.1 W
Power for data encoding: P_{COD}	0.1 W/(Gbit/s)	0.01 W/(Gbit/s)
Power for data decoding: P_{DEC}	0.8 W/(Gbit/s)	0.08 W/(Gbit/s)
BS computational efficiency: L_{BS}	75 Gflops/W	750 Gflops/W
Power for backhaul traffic: P_{BT}	0.25 W/(Gbit/s)	0.025 W/(Gbit/s)

The main formulas used in the calculations are as follows:

$$\mathrm{EE} = \frac{\mathrm{TR}}{\mathrm{ETP} + \mathrm{CP}} \tag{1}$$

In (1) ETP is effective transmit power and CP is circuit power.

$$\mathrm{TR} = B \sum_{k=1}^{K} \left(\mathrm{SE}_k^{\mathrm{UL}} + \mathrm{SE}_k^{\mathrm{DL}} \right) \tag{2}$$

In (2) B symbolizes bandwidth.

$$\mathrm{ETP} = \frac{\tau_p}{\tau_c} \sum_{k=1}^{K} \frac{1}{\mu \mathrm{UE}, k} p_k + \frac{\tau_u}{\tau_c} \sum_{k=1}^{K} \frac{1}{\mu \mathrm{UE}, k} p_k + \frac{1}{\mu \mathrm{BS}} \frac{\tau_d}{\tau_c} \sum_{k=1}^{K} \rho_k \tag{3}$$

$$\mathrm{CP} = P_{\mathrm{FIX}} + P_{\mathrm{TC}} + P_{\mathrm{CE}} + P_{\mathrm{C/D}} + P_{\mathrm{BH}} + P_{\mathrm{SP}} \tag{4}$$

In (4) P_{FIX} symbolizes fixed power, P_{TC} symbolizes power of transfer chains, P_{CE} symbolizes power of channel estimates, $P_{C/D}$ symbolizes power of coding and decoding, P_{BH} symbolizes power of backhaul and P_{SP} symbolizes power of signal processing.

III. Results

In the calculations, two-cell Wyner model was used and varying M from 10 to 200, in steps of 10 and various number of K (50 and 100) were used.

A. Examining of Bandwidth

The results obtained using three different bandwidth values on value set 1 and on value set 2 are shown in figure 3 and figure 4 respectively.

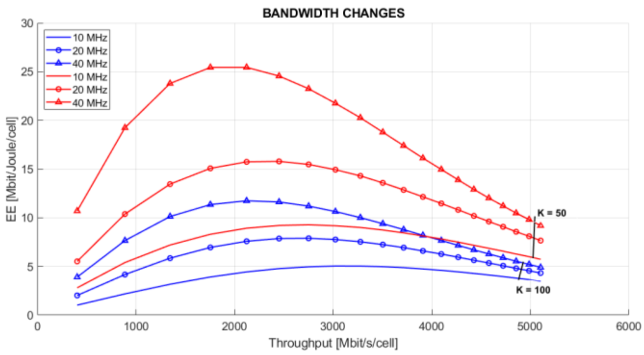

Fig. 3 Curves of TR – EE trade-off on value set 1

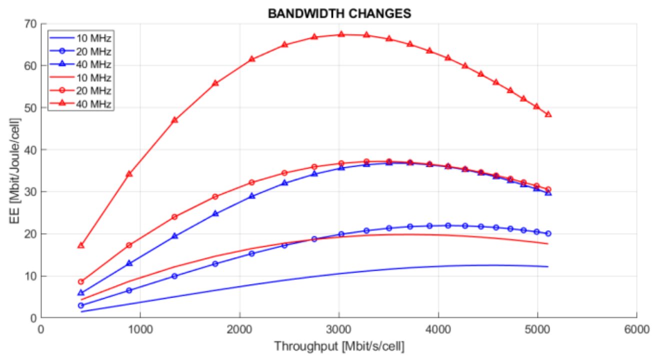

Fig. 4 Curves of TR – EE trade-off on value set 2

Maximum values of EE for different conditions are given in Table 2.

Table 2. Maximum values of EE while bandwidth is changing

Conditions	Value set 1	Value set 2
K = 100, B = 10 MHz	5,040	12,52
K = 100, B = 20 MHz	7,889	21,96
K = 100, B = 40 MHz	11,74	36,79
K = 50, B = 10 MHz	9,274	19,85

K = 50, *B* = 20 MHz	15,79	37,19
K = 50, *B* = 40 MHz	25,44	67,33

B. Examining of Length of Coherence Block

The results obtained using three different length of coherence block on value set 1 and on value set 2 are shown in figure 5 and figure 6 respectively.

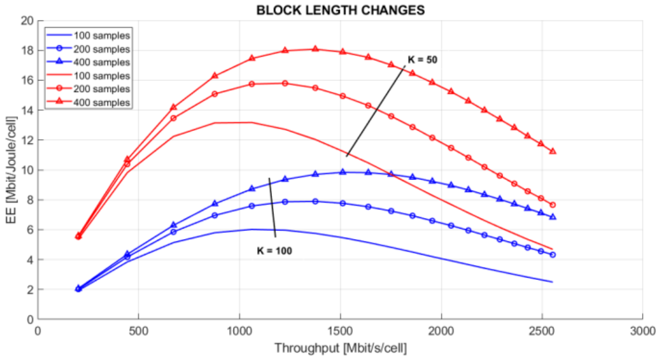

Fig. 5 Curves of TR – EE trade-off on value set 1

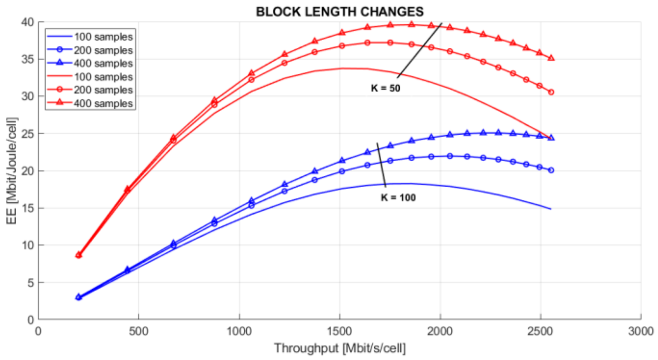

Fig. 6 Curves of TR – EE trade-off on value set 2

Maximum values of EE for different conditions are given in Table 3.

Table 3. Maximum values of EE while length of coherence block is changing

Conditions	**Value set 1**	**Value set 2**
K = 100, 100 samples	6,017	18,26
K = 100, 200 samples	7,889	21,96
K = 100, 400 samples	9,832	25,07
K = 50, 100 samples	13,16	33,72
K = 50, 200 samples	15,79	37,19
K = 50, 400 samples	18,07	39,59

IV. DISCUSSION

When the results obtained are examined, the throughput, which is high when the number of active users is low, has reached to higher levels with increasing bandwidth. It seen increasing the length of coherence block increases the throughput by a certain amount in all conditions. Also, it is observed that when length of coherence block increases peaks of TR – EE curves are shifting to higher TR and to higher EE levels. When the low power set is used it is seen that energy efficiency increases at any conditions and the maximum EE values can be reached at higher TR levels.

V. CONCLUSION

It has been observed that throughput increases with increasing bandwidth or increasing length of coherence block. Also, these two parameters change the throughput levels at which maximum EE values are seen. Since these two parameters cause higher costs or higher workloads it is useful to investigate the ideal values of these parameters for various conditions.

REFERENCES

[1] E. Björnson, J. Hoydis, and L. Sanguinetti, "Massive MIMO Networks: Spectral, Energy and Hardware Efficiency," *Foundation and Trends in Signal Processing*, vol. 11, no. 3-4, pp. 154-655, 2017.

[2] Ericsson. (2017) Ericsson Mobility Report. https://www.ericsson.com/assets/local/mobilityreport/documents/2017/ericsson-mobility-report-november-2017-middle-east-and-africa.pdf

[3] D. Aziz, K. Kusume, and O. Queseth. (2015) D8.4: Metis Final Project Report. https://metis2020.com/wp-content/uploads/deliverables/METIS_D8.4_v1.pdf

[4] A. Fehske, G. Fettweis, J. Malmodin, and G. Biczok, "The Global Footprint of Mobile Communications: The Ecological and Economic Perspective," *IEEE Transactions on Wireless Communications*, vol. 49, no. 8, pp. 55-62, 2011.

[5] Q. He, L. Xiao, X. Zhong, and S. Zhou, "Increasing the Sum-throughput of Cells with a Sectorization Method for Massive MIMO," *IEEE Communications Letters* 18(10), 2346483, pp. 1827-1830, 2014.

[6] G. Yang, C. K. Ho, R. Zhang, and Y. L. Guan, "Throughput Optimization for Massive MIMO Systems Powered by Wireless Energy Transfer," *IEEE Journal on Selected Areas in Communications* 33(8), 7009979, pp. 1640-1650, 2015.

[7] E. Björnson, E. G. Larsson, and M. Debbah, "Massive MIMO for Maximal Spectral Efficiency: How Many Users and Pilots Sholud Be Allocated?" *IEEE Transactions on Wireless Communications*, vol. 15, no. 2. pp. 1293-1308, 2015.

[8] L. Li, W. Meng, and S. Ju, "A novel artificial bee colony detection algorithm for massive MIMO system," *Wireless Communications and Mobile Computing*, vol. 16. pp. 3139-3152, 2016.