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Improving Energy Efficiency from Regular to Massive MIMO for 5G Cellular Networks

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ABSTRACT

Massive MIMO also as known very large MIMO which defined as a new research filed in wireless communication engineering, where base station are equipped with a very large number of antennas as compared with regular MIMO. The research paper is suggested to improve energy efficiency and increase data rate because the more antennas, the more independent data streams can be sent out and more terminal can be served simultaneously, also study reducing of the interference.

Keywords: MIMO, Massive MIMO, Spectral Efficiency, Throughput, SNR.

1. INTRODUCTION

Massive-multi input multi output (Massive-MIMO) is expected to be one of the essential technologies in meeting the diverse performance requirements of 5G, massive MIMO with hundreds of antennas is considered a key enabler for overcoming challenging propagation conditions.

Many challenges are facing massive MIMO such as reference signal, beam steering and tracking, channel state information feedback, channel quantization, power consumption, beam failure detection & recovery and hardware complexity.

The paper is organized as follows. Section two describes the MIMO technology and important advantages of using MIMO. Section three and four represent the Massive MIMO technology and its benefits. Evolution from MIMO toward Massive MIMO technology in section five. Simulations and analysis results are provided in Section six. Eventually, Section seven concludes the research paper and leads a direction for future research.

2. MIMO TECHNOLOGY

MIMO refers to communication systems that have multiple antennas at both the transmitter and receiver, however, the nomenclature can be a bit confusing on this point and there is not always agreement on the use of terminology. In this section , MIMO can be used to refer to a communication system with multiple antennas at the transmitter side, the receiver side, or both, and MIMO also can be used in referring to systems that have multiple antennas at both ends of the link.

When the system has multiple antennas at the transmitter with one antenna at the receiver side the system is called Multiple Input Single Output (MISO). If the opposite is happened when the system has single antenna at the transmitter and multiple antennas at the receiver, the system is called Single Input Multiple Output (SIMO). These two types are referred as particular types of MIMO configurations. Conventional communication systems that only have a single transmit antenna and a single receive antenna are called Single Input Single Output (SISO) communication systems [1]. One of the main advantages of using MIMO technology isoffering significant increase in data throughput and link range without additional bandwidth or increased transmit power also MIMO technology takes advantage of a natural radiowave phenomenon called multipath, and MIMO makes antennas work smarter.

3. MASSIVE MIMO TECHNOLOGY

Also called very large multi user-MIMO (MU-MIMO), Advanced-MIMO, or full-dimension MIMO systems. A massive MIMO system is typically defined as a system that utilizes a large number, i.e. 100 or more, of individually controllable antenna elements at least at one side of a wireless communications link, typically at the base station (BS) side [2][3] . A massive MIMO network exploits the many spatial degrees of freedom (DoF) provided by the many antennas to multiplex messages for several users on the same timefrequency resource, and/or to focus the radiated signal toward the intended receivers and inherently minimize inter cell and intra cell interference [4][5]. Such focusing of radiated signals in a particular direction is possible by transmitting the same signal from multiple antenna points, but with a different phase shift applied to each of the antennas and possibly a different phase shift for different parts of the system bandwidth, such that the signals interfere coherently at the purposed target location.

4. BENEFITS of MASSIVE MIMO TECHNOLOGY

This paper summarise the main benefits of using Massive MIMO technology in next generation wireless systems as below [2]:

- Capacity will be increased 10 times or more and the radiated energyefficiency will be improved around 100 times .
- Latency will be reduced when massive MIMO is built with low power components.
- multiple-access layer will be simplified.
- The robustness of the system will be increased.
- Signal to noise ratio will be increased.
- Simple signal processing will be depended.

5. EVOLUTION FROM MIMO TOWARD MASSIVEMIMO TECHNOLOGY

Table 1 shows a comparisons between MIMO and MassiveMIMO technology:-

Table 1: Comparisons between MIMO and MassiveMIMO

MIMO	MassiveMIMO
Depends on Orthogonal frequency-division multiplexing (OFDM) and orthogonal division multiple access (OFDMA) methods.	Depends on frequency division duplex (FDD) and time division duplex (TDD) methods [6].
Increase data rate multiplying by (2,3,4 or 8) with respect to the number of antennas.	The average data rate is multiple by (10-100) for (active bits per users).
Used in telecommunication and networking industries.	Evolving network for higher traffic.
Energy efficiency optimization with power transfer and simultaneous wireless information.	Designed for high spectral energy efficiency, multiple by (1000) bit/joule.
Increase the antenna array at base station.	Increase number of base station antennas without increase in the channel estimation overhead and users.
Reduced co channel interference.	There is inter cell interference.
Not limited for wireless communications it can be used in wire line communications.	For next generations.
Complex.	Signal processing at each user is very simple and dropping some users from service does not affect other user's activities.

6. PERFORMANCE EVALUATION & SIMULATION RESULTS

In this research paper, a simulation of all MIMO and MassiveMIMO scenarios is executed and discussed. After that a comparison between systems is done in terms of capacity, average achievable spectral efficiency and throughput [7].

Figure 1 shows the simulation results of computing capacity and throughput using Shannon capacity where the throughput is computed by multiplying the assumed channel bandwidth of 20 MHz by the link capacity [8].

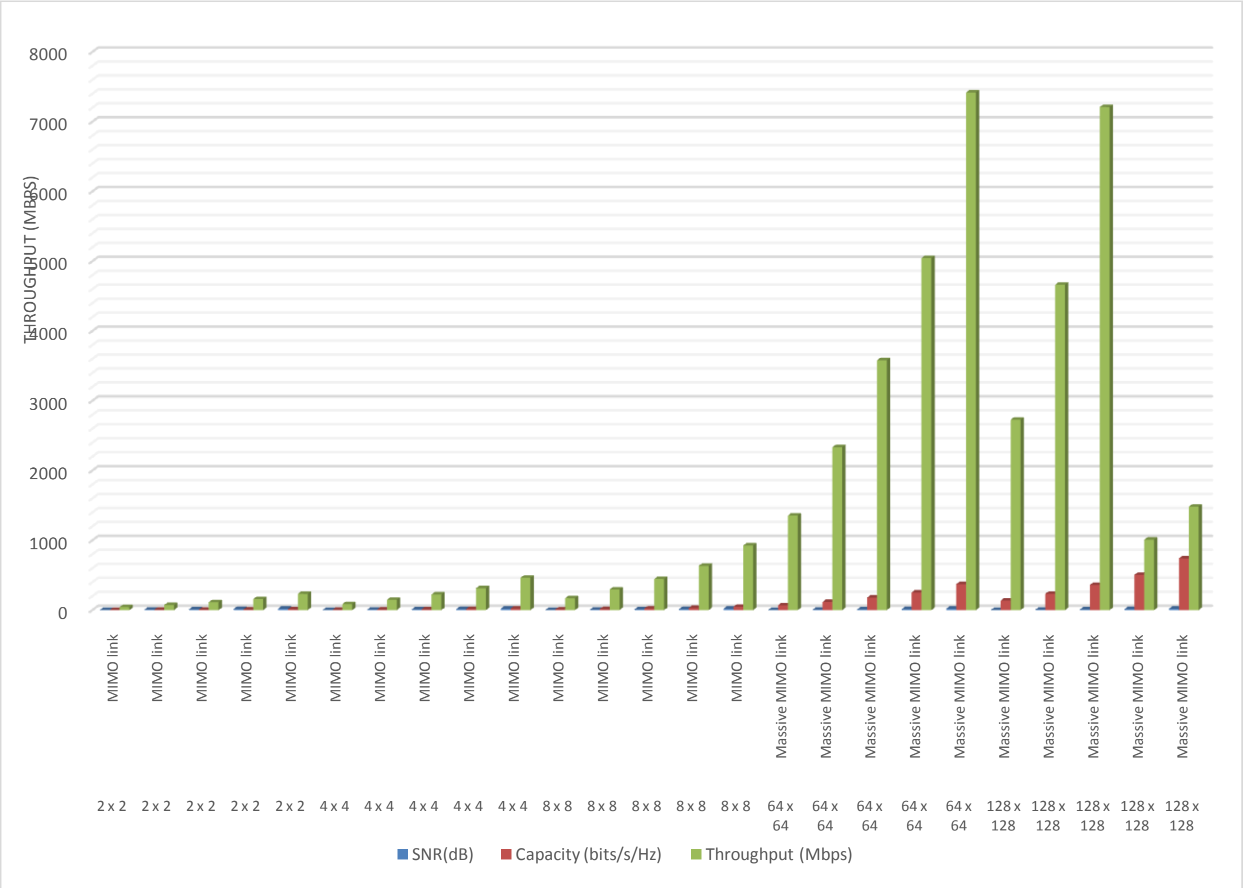

Fig. 1: MIMO and Massive MIMO link capacity due to the SNR.

Figure 2 shows the MIMO capacity due to the signal to noise ratio (SNR) and the relationship when antennas are (2x2, 3x3, 4x4 and 8x8).

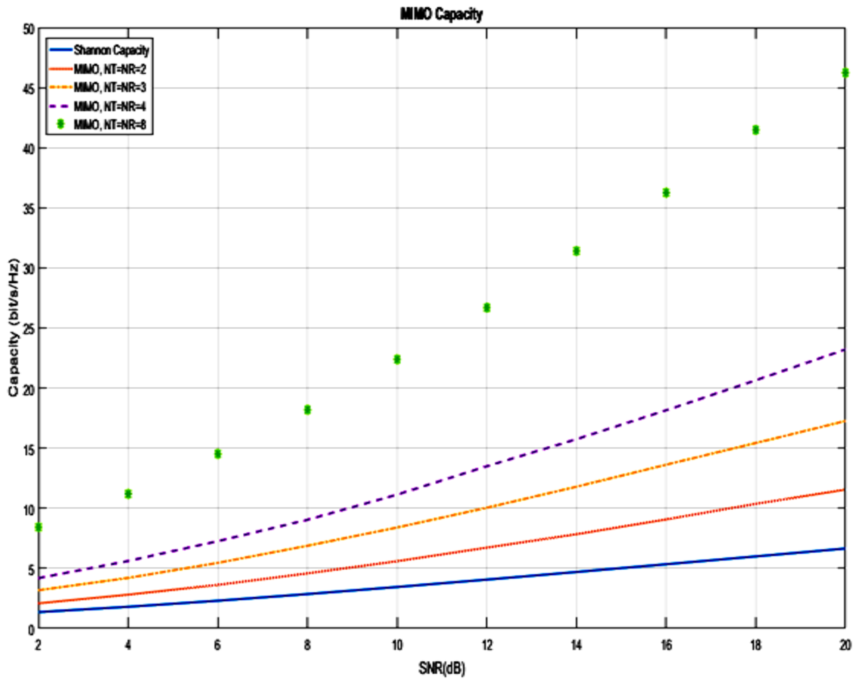

Fig. 2: MIMO capacity due to the SNR.

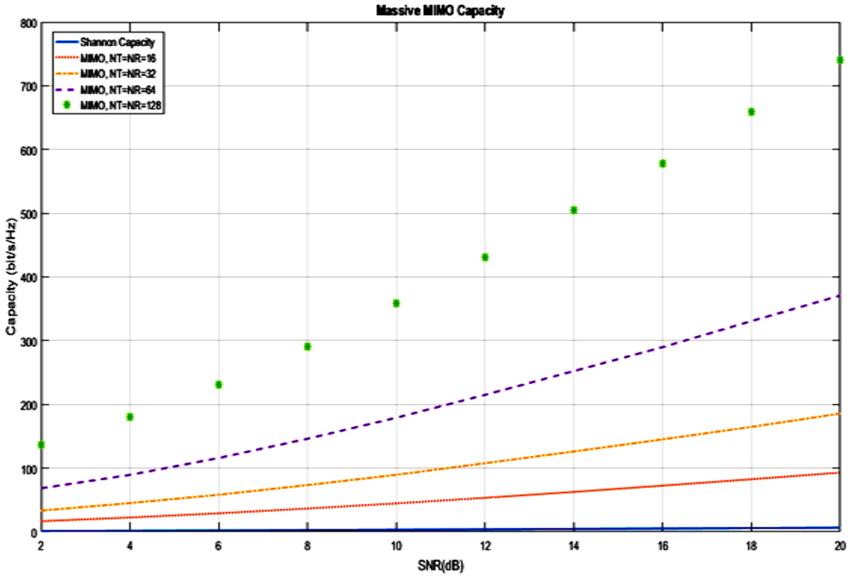

Fig. 3: Massive MIMO capacity due to the SNR.

In Figure 3 the number of the N and M antennas is increased to achieve a higher capacity to implement a massiveMIMO system (large scale array antenna system), the results are plotted for the 16x16, 32x32, 64x64 and 128x128; the results was absolutely amazing.

The throughput of the 8x8 MIMO link increased by 8 times in 64x64 link as shown in Figure 1 which proves that in order to get a higher data rates and channel capacity for wireless cellular communication system the number of the services antennas must be increased at the both transmitter (BS) and receiver (UE).

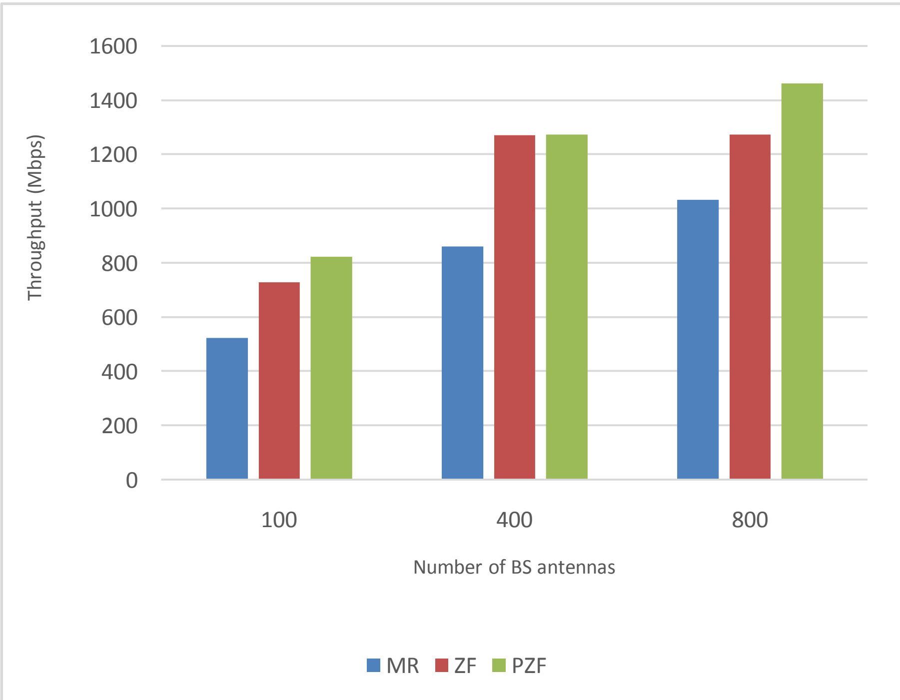

Fig. 4: Comparison of three precoding type (MR, ZF and P-ZF) in term of throughput (Mbps).

The comparison of the three pre-coding types gives the results shown in the Figure 4, conventional linear processing schemes such as maximum ratio (MR) combining/transmission, zero-forcing (ZF), and a new full-pilot zero-forcing (P-ZF) scheme are considered which suppresses intercell interference in a distributed coordinated beam forming scheme. Figure 5 shows the comparison of three pre-coding type (MR, ZF and P-ZF) in term of spectral efficiency (bits/Hz/cell).

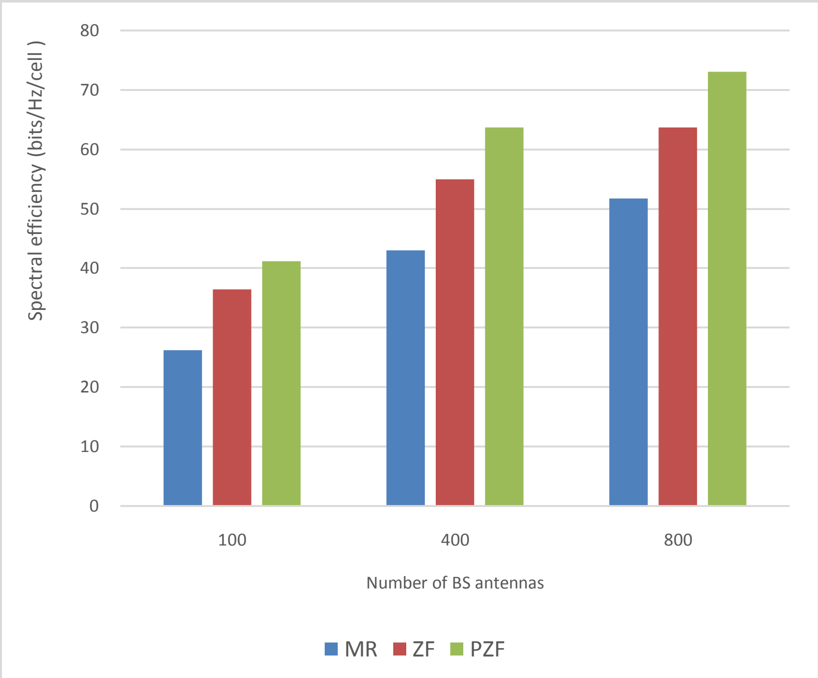

Fig. 5: Comparison of three precoding type (MR, ZF and P-ZF) in term of spectral efficiency (bits/Hz/cell).

While for calculating the spectral efficiency; Figure 6 shows the simulation of maximal spectral efficiency in three pre-coding type (MR, ZF and P-ZF).

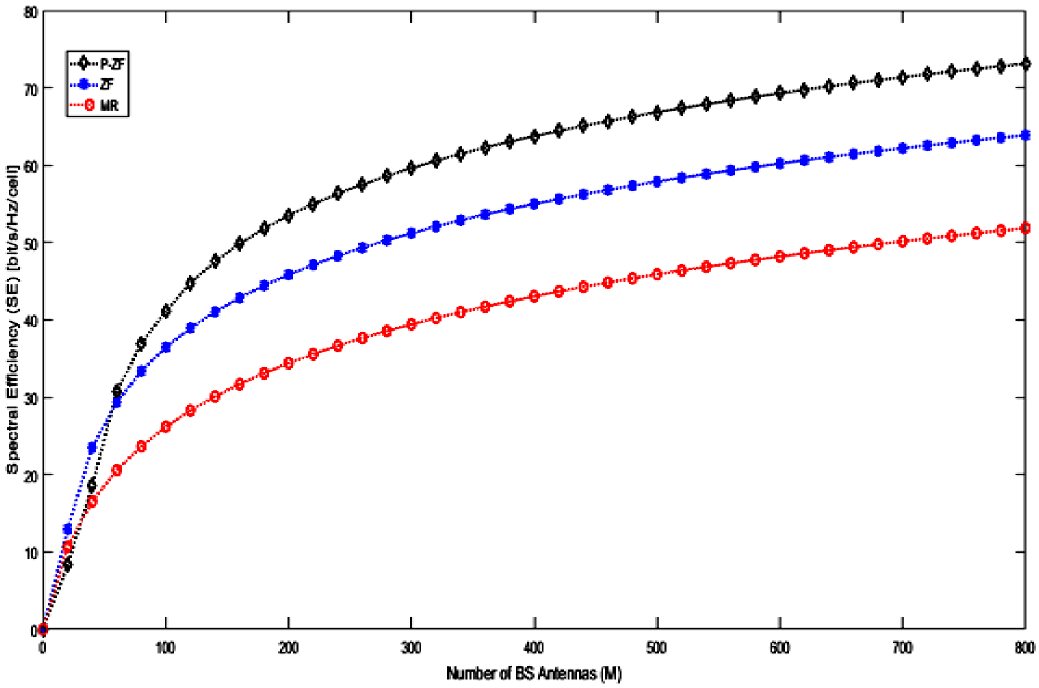

Fig. 6: Maximal spectral efficiency in three precoding types (MR, ZF and P-ZF).

It is clear from the three pre-coding types in Figure 6, scheduling many UEs for simultaneous transmission leads to high spectral efficiency per cell, while the spectral efficiency per UE might only be 1–4 bit/s/Hz.

The simulation results of the system for calculating the spectral efficiency in additional user antennas is shown in Figure 7, calculation is accomplished for the maximum spectral efficiency in the uplink and downlink directions per cell for 6 cases where the range of the BS antennas M varies from 50 to 400 for each case.

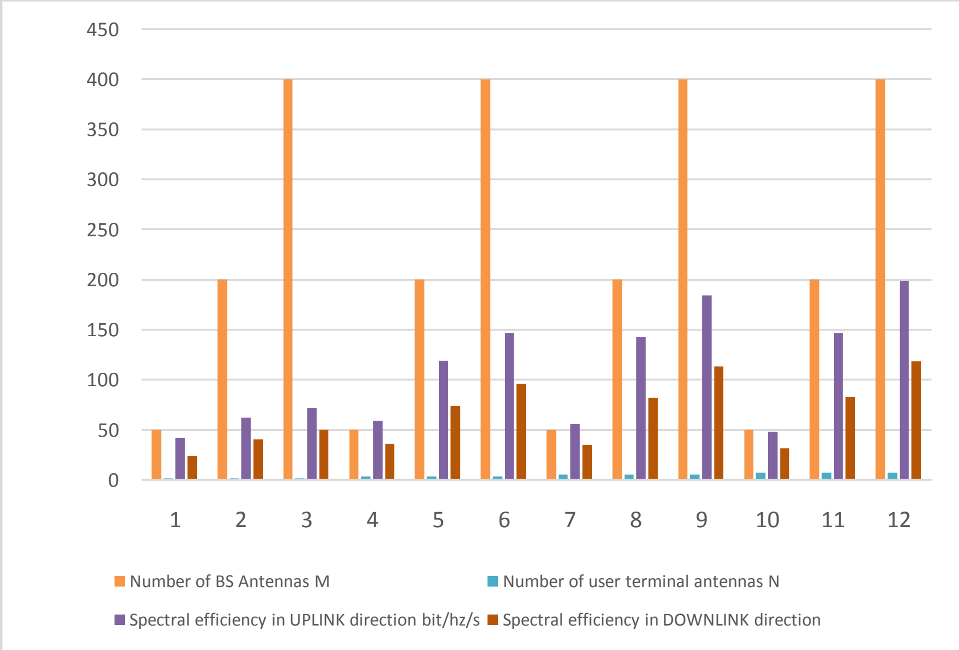

Fig. 7: Maximal spectral efficiency in the uplink and downlink.

The achievable spectral efficiency of single-cell massiveMIMO systems with multi-antenna users is analyzed. With estimated channel state information from uplink pilots, lower bounds on the sum capacity were derived for both the uplink and the downlink, which are achievable by per user minimum mean square error- successive interference cancellation (MMSE-SIC) detectors The uplink and downlink sum spectral efficiency of the MMSE-SIC and minimum mean square error (MMSE) detectors are shown in Figure 8 and Figure 9.

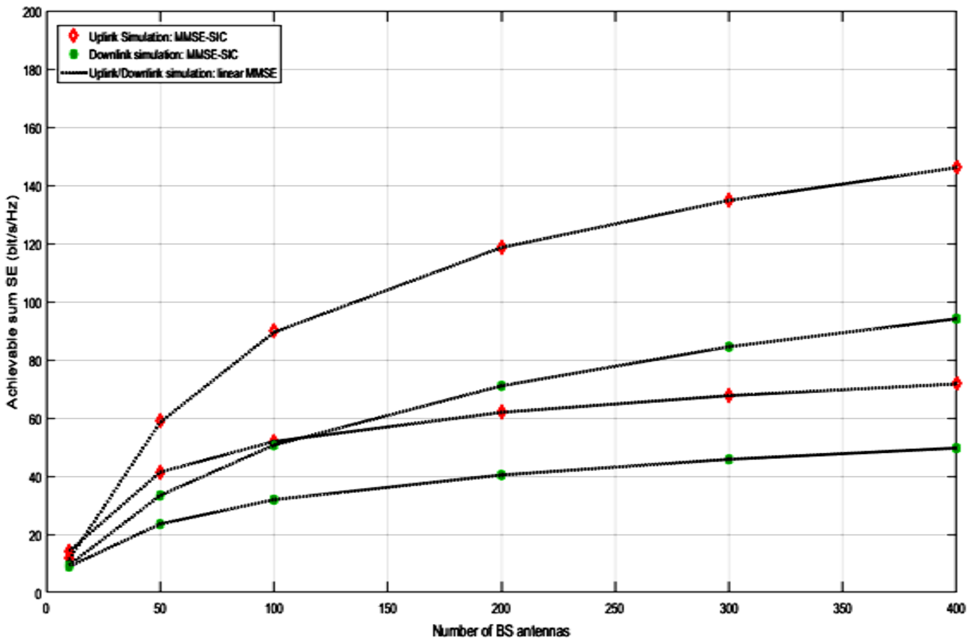

Fig. 8: Maximal spectral efficiency using 1 and 3 antennas at the user terminal.

It shows that the two detectors achieve almost the same spectral efficiency's (SEs) which verifies the conclusion that a linear detector can achieve most of the spectral efficiency improvements from equipping users with multiple antennas in massiveMIMO. Moreover, although the pilot overhead increases, 85% and 70% performance gains are achieved for uplink (UL) and downlink (DL), respectively by increasing N from 1 to 3 and from 5 to 7 and from 8 to 10 for M = 400. The power scaling laws is generalized for massiveMIMO from N=1 to arbitrary N. Spectral efficiency is increased with N, but for a fixed value of NK the highest spectral efficiency is achieved by having NK single antenna users.

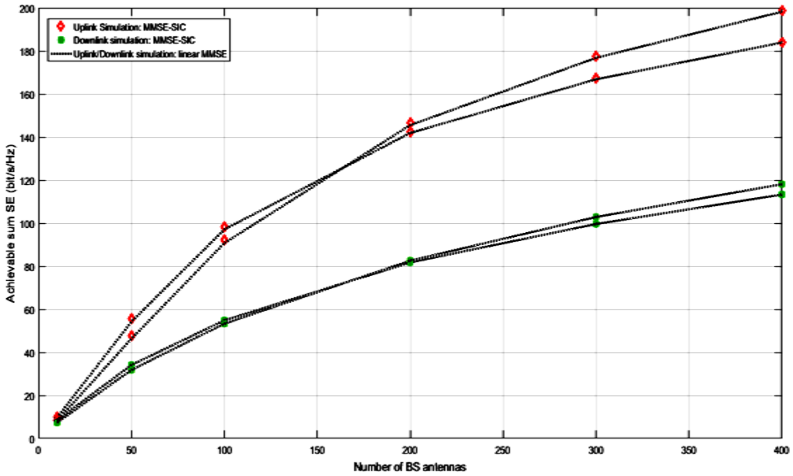

Fig. 9: Maximal spectral efficiency using 5 and 7 antennas at the user terminal.

CONCLUSION

5G mobile communication systems are attracting significant amount of interest from industry and researchers. Compared to 3G & 4G systems which were voice and data oriented, 5G is expected to be used with wide range of users . This research has covered massiveMIMO as one of the clear key technology components for 5G. While the analyzed capacity scaling behavior for large number of antennas and users appears highly promising, it has become clear that massiveMIMO inherits various challenges that have to be overcome. Finally, massive MIMO can be simulated with Advanced Design System (ADS) from Keysight technologies in order to get better performance and more analysis for the system.

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