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Massive MIMO for Next Generation Wireless Sensor Networks

K.Jayavarman[#1], S.Narasimman[*2]
[1&2] *Department of Computer Applications, S.A.Engineering College,*
kjvs1111@gmail.com, narsinandhu14@gmail.com

***Abstract*—**Multi-user Multiple-Input Multiple-Output (MIMO) offers big advantages over conventional point-to-point MIMO: Extra antennas help by focusing energy into ever-smaller regions of space to bring huge improvements in throughput and radiated energy efficiency. The challenge of making many low-cost low-hardware components, speed increased in data that work. The large potential massive of MIMO systems is a key enabling technology for future beyond 5G cellular systems. The technology offers advantages in terms of energy efficiency, robustness and reliability of the antenna units. MIMO and OFDM technologies, energy-efficient wireless networks were introduced. Propagation channel models for three scenarios that will be of great importance for next-generation wireless systems: multi-link, FD-MIMO and mm-wave. Identifies the challenges for the key 5G area at the intersection of waveform design and large-scale multiple antenna systems, also known as Massive MIMO. New research avenue towards a better understanding of waveform design for 5G with a particular Emphasis on FBMC-based Massive MIMO sensor networks. This gives researchers both are academic and industry a goldmine of entirely new research problems to taken.

Key words*—*MIMO, OFDM, MM-WAVE, EE

1. Introduction

Massive MIMO (also known as “Large-Scale Antenna Systems”, “LARGE MIMO”, “Hyper MIMO”, “Full-Dimension MIMO” and “ARGOS”) makes a clean break with current practice through the use of a large excess of service-antennas over active terminals and time division duplex operation.

MU-MIMO in cellular systems brings improve on four reasons:

- increased data rate,
- enhanced reliability,
- improved energy efficiency,
- decrease interference,

MU-MIMO technology for wireless communications in its conventional form is incorporated into recent and evolving wireless broad band standards like 4G LTE and LTE-Advanced (LTE-A).4G to move the 5G wireless sensor system [2].

2. Massive MIMO

Massive MIMO can increase the capacity 15 times or more and simultaneously, improve the radiated energy-efficiency in the order of 100 times [6]. The capacity increase results from the aggressive spatial multiplexing used in massive MIMO.

The fundamental principle that makes the increase in energy efficiency possible is that with very large number of antennas.

The relation for the uplink, from the terminals to the base station (the downlink performance is similar).Shows the tradeoff for two cases: system with 150 antennas serving a single terminal using conventional beam forming (green), massive MIMO system with 150 antennas simultaneously serving multiple terminals (red using maximum-ratio combining and blue using zero forcing).

We use optimal max-min power control which confers an equal signal-to interference-and-noise ratio on each of the 900 terminals and therefore equal throughput. Numerical averaging over random terminal locations and over the shadow fading shows that 95% of the terminals will receive a throughput of 21.2 Mb/s/terminal. Overall, the array in this example will offer the 1000 terminals a total downlink throughput of 20 GB/s, resulting in a sum-spectral efficiency of 1000 bits/s/Hz. This would be enough. Massive MIMO can be built with expensive, low-power components Massive MIMO is a game-changing technology both theory the systems and implementation. Massive MIMO, expensive, ultra-linear 100 Watt amplifiers used in conventional systems are replaced by two hundreds of low-cost amplifiers with output power in the milli-Watt range. A massive MIMO system has a large surplus of the freedom sensor networks. For ex, with 200 antennas serving 40 terminals, 160 degrees of freedom are unused [6].

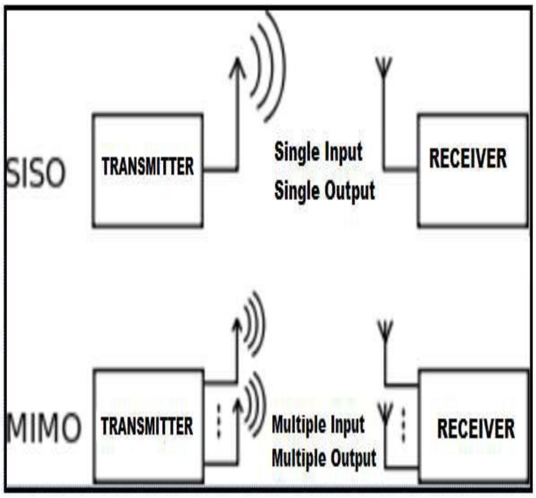

Fig. 1: Block diagram of SISO and MIMO systems

3. Massive MIMO: Golden of Research Problems

While massive MIMO renders many traditional problems in communication theory less relevant, it uncovers entirely new problems that need research [2].

• *Fast and distributed signal processing*

Massive MIMO arrays generate vast amounts of the baseband data that need to be processed in real time. On the downlink, there is enormous potential for precoding schemes in MIMO. For examples of recent work in this direction include.

• *The challenge of low-cost hardware components*

Building two hundreds of RF chains in MIMO, up/down converts, A/D–D/A converters, and so forth, will require economy of scale in manufacturing comparable to what we have seen for mobile handsets.

• *Hardware impairments*

Massive MIMO relies on the law of large numbers to average noise and some extent, interference. In reality, massive MIMO must be built with low-cost components.

• *Internal power consumption*

Massive MIMO offers the potential to reduce the *radiated* power a thousand times, and at the same time scale up data rates. But in practice, the *total* power consumed must be considered, that includes the cost of baseband signal processing. Much research must be invested into highly parallel, perhaps dedicated, hardware for the baseband signal processing.

• *Channel characterization*

There are additional properties of the channel to consider when using massive MIMO instead of conventional MIMO. To facilitate a realistic performance assessment of massive MIMO systems, necessary to have channel models. A similar way of thinking could probably be adopted for massive MIMO channel modeling.

• *Cost of reciprocity calibration*

TDD will require reciprocity calibration and in terms of additional hardware components needed.

• *Pilot contamination.*

It is likely that pilot contamination imposes much more severe limitations on massive MIMO than on traditional MIMO systems. We discussed some of the issues in detail, and outlined some of the most relevant research directions [3].

3.1 Advantages

- High spectrum efficiency->Large multiplexing gain and array gain
- High energy efficiency->Radiated energy can be concentrated on UE
- High reliability->Large diversity gain
- Efficient linear precoder/detector->Favorable propagation condition for i.i.d. Rayleigh channel.
- Weak interuser interference and enhanced physical security->Orthogonal UE channels and extremely narrow beam
- Simple scheduling scheme->Channel harden phenomenon averages out the fast fading
- Robust to individual element failure->Large number of antenna array elements

3.2 Disadvantages

- Pilot contamination->Limited orthogonal pilots as of bounded coherent interval and bandwidth
- High signal processing complexity->Large number of antennas and multiplexing UE
- Sensitive to beam alignment->Extremely narrow beam is sensitive to UE moving or antenna array swaying
- Poor broadcast channel->Be blind to UE positions [2].

4. Channel Measurement

Lots of channel measurements have been carried out in order to discriminate the main properties of massive MIMO channel. These measurements mainly focus on the impacts of antenna numbers on the small-scale propagation characteristics. Further measurements should be implemented to validate the two properties for the spherical, cylindrical, and rectangular antenna array configurations. Channel measurements for both the cylindrical and linear antenna array with 128-antenna were implemented, when the space of adjacent antennas is half a wavelength and the bandwidth is 50MHz. Similar to, the non-stationary phenomenon can be observed over the linear antenna array. Meanwhile, large power variation can also be experienced over the cylindrical antenna array as of both the polarization and directional pattern [1].

5. OFDMA

Orthogonal frequency division multiple access (OFDMA) will be the dominant multiple access scheme for next generation wireless networks since both of the two accepted 5G standards (Long Term Evolution-Advanced and 802.16m) have adopted OFDMA as the multiple access technology. OFDMA is distinguished by its simplicity and high spectral efficiency.

OFDMA systems, multi-user diversity can be exploited not only to increase network capacity but also to reduce energy consumption. When a “good” channel is allocated to the corresponding user, the transmit power can be drastically decreased.

Based on these observations, the authors further propose energy-efficient link adaptation (rate and corresponding transmit power) and resource allocation (subcarriers) scheme for OFDMA systems. Simulation results show that the EE scheduler performs approximately 50% better than a round-robin scheduler in terms of EE [3].

6. Waveform Design For 5G

This section presents the state of the art about candidate waveforms for 5G.Best possible performance of each waveform, with OFDM with cyclic prefix (CP-OFDM) used as benchmark.

6.1. The Baseline OFDM and its Enhancements

MmWave deployment may also prove hard due to the difficulty to develop efficient amplifiers. Spectral efficiency can be improved by means of shorter CP lengths, and Frequency and Quadrature Amplitude Modulation (FQAM) to boost DL throughput for cell-edge users. TFS and faster-than-Nyquist signaling have been claimed able to offer efficiency gains on the order of 25% over conventional OFDM. Other drawbacks of CP-OFDM are sensitivity to phase noise and asynchronous signaling, poor spectrum localization, large OOB emissions, and long round-trip time (RTT).

Another option consists of manipulating OFDM to mimic SCM to reduce PAPR and provide robustness against frequency offsets. Discrete Fourier Transform spread OFDM (DFT-s-OFDM) enhances noise in faded channels, offers poor spectral containment, and allows neither frequency-selective scheduling nor link adaptation.

These limitations are overcome by employing zero-tail DFT-s-OFDM, exploiting receiver diversity, and applying the DFT spread at the physical resource blocks level. Improved flexibility (dynamic overhead adaptation instead of CP hard coding) and OOB emissions (smoother transitions between adjacent symbols) are additional advantages of zero-tail DFT-s-OFDM over CP-OFDM.

6.2. Filter Bank Multicarrier

FBMC introduced multicarrier techniques over two decades before the introduction of OFDM in wireless communications systems. While OFDM relies on the CP to prevent ISI and to convert the channel into a set of flat-gain subcarriers, FBMC exploits the fact that narrow and numerous subcarriers can be characterized by a flat gain.

Fast-convolution based highly tunable multirate filter banks are investigated. Capable of implementing waveform processing for multiple single-carrier and/or multicarrier transmission channels with non uniform bandwidths and sub channel spacing simultaneously, this method is a competitive option in terms of spectral containment and complexity [4].

6.3. "Born-to-be-5G" Waveforms

In contrast to FBMC or OFDM, which apart from enhancements like CC-OFDM and DFT-s-OFDM were not originally designed bearing 5G requirements in mind, we have recently witnessed the outbreak of waveforms crafted for MTC and the Tactile Internet. Biorthogonal Frequency Division Multiplexing (BFDM), waveforms [4].

7. FBMC-Based Massive MIMO Sensor Networks

Networks resulting from the combination of Massive MIMO and FBMC are of the almost importance as in these systems spectrum not only can be reused by all the users, *i.e.* advantage of Massive MIMO, but can also be used in an efficient manner, As a result, FBMC can leverage various benefits that place it in a strong position as a candidate for 5G systems. Linear combining of the received signals in different receive antennas at BS averages channel distortions between the users and BS antennas. As M increases, the channel distortions over each subcarrier are smoothed through linear combining, so a nearly equalized gain across each subcarrier band can be achieved. Analytical SINR relationships are derived for MMSE and MF linear combiners under the assumption of a flat channel over each subcarrier band. This self-equalization property of FBMC relaxes the large L requirement to obtain an approximately flat gain over each subcarrier band, so wider subcarriers can be used. The use of a smaller L in a given bandwidth:

- Reduces the latency caused by synthesis/analysis filter banks.
- Improves bandwidth efficiency due to the absence of the CP and to shorter preambles;
- Decreases computational complexity due to the smaller FFT and IFFT blocks needed for implementation;
- Provides robustness to frequency offsets;
- Reduces PAPR.

Cosine Modulated Multitone (CMT), *viz.* a particular FBMC form, has a blind equalization capability, which can be used to decontaminate erroneous channel estimates in multi cellular Massive MIMO networks caused by pilot contamination. This approach, which is somewhat similar to the Godard blind equalization algorithm can be easily extended from single antenna to Massive MIMO systems [4].

8. Millimeter-Wave Propagation

While the amount of available spectrum in the microwave range is very limited, the mm-wave range offers a large amount of hitherto unused spectrum. In the 60 GHz band, up to 7 GHz bandwidth (depending on the spectrum regulations in the different regions) has been made available unlicensed wireless systems. For the 28 and 38 GHz bands about 1GHz of bandwidth is available as well. A major reason why this spectrum has been unused for a long time is the cost of mass-producing chips for mm-wave frequencies; for a long time Gallium

Arsenide and other costly materials had to be used. However, recent years have seen the emergence of CMOS technology that is capable of handling these high frequencies. Thus, low-cost production for mass-market consumer application has become feasible [4].

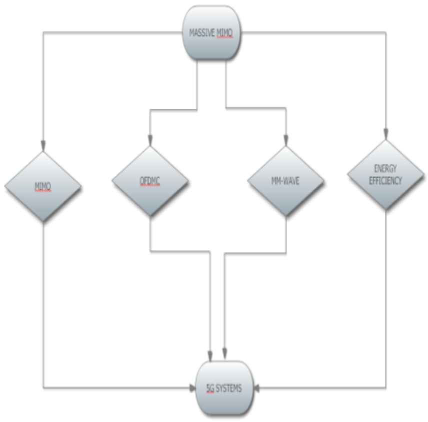

Fig. 2:Flow chart for Massive MIMO

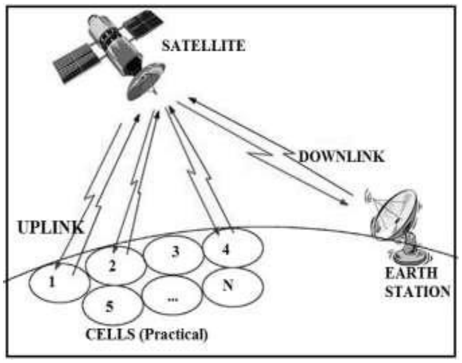

Fig.3: Satellite-cellular communication system showing uplink and downlink

Another long-standing obstacle for the realization of mm-wave systems has been the high free-space pathloss. By using high-gain antennas, the pathloss may be compensated. As a consequence, cellular outdoor communication (over a range of some 200m to 300m) seems feasible, in addition to short-range in door applications for consumer electronics and directional microwave links for backhaul.

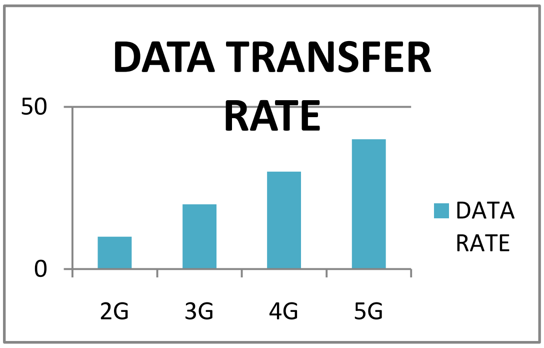

Fig.4: Chart for compare with previous generation

9. Conclusions

In this paper we have highlighted the large potential of massive MIMO systems as a key enabling technology for future beyond 5G cellular systems. The technology offers huge advantages in terms of energy efficiency, spectral efficiency, robustness and reliability. At the base station the use of expensive and powerful, but power-inefficient, hardware is replaced by massive use of parallel low-cost, low-power units that operate coherently together. great importance for next-generation wireless systems: multi-link, device-to-device, FD-MIMO, and mm-wave. The property of self-equalization was introduced for FBMC-based Massive MIMO systems. New research avenue towards a better understanding of waveform design for 5G with a particular emphasis on FBMC-based Massive MIMO networks. EE metric, network deployment strategies, energy-efficient network resource management, various relay and cooperative communications, MIMO and OFDM technologies.EE metric, network deployment strategies, energy-efficient network resource management, various relay and cooperative communications, MIMO and OFDM technologies.

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[1] Kan Zheng,1 Suling Ou,1 and Xuefeng Yin2 1Wireless Signal Processing and Network Lab, Key Laboratory of UniversalWireless Communication, Ministry of Education,Beijing University of Posts and Telecommunications (BUPT), P.O. Box 93, No., Haidian District,Beijing 100876, China2Department of Electronics Science and Technology, Tongji University, Shanghai, China

.[2] Erik G. Larsson, ISY, Linköping University, Sweden Ove Edfors, Lund University, Sweden Fredrik, Lund University, Sweden Thomas L. Marzetta, Bell Labs, Alcatel-Lucent, USA.

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[4] ArmanFarhang∗, Nicola Marchetti∗, Fabr´ıcio Figueiredo†and Jo˜ao Paulo Miranda†∗CTVR - The Telecommunications Research Centre, Trinity College, Ireland. Email: [farhanga, marchetn]@tcd.ie†CPqD - Research and Development Center on Telecommunication, Brazil. Email: [fabricio, jmiranda]@cpqd.com.br

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