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Editorial

Massive MIMO Systems: Present and Future

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1. Introduction

We are going to see the first decade since the fundamental concept of massive multiple-input multiple-output (MIMO) (also called large-scale MIMO) has emerged [1]. Massive MIMO is expected to be one of the most promising technologies towards the fifth generation mobile communications (5G) and beyond. Implementation [2,3] and trials [4,5] are actively proceeded. Especially, massive array beamforming has a good match to millimeter wave communication [6] which suffers from link budget shortfall due to its high frequency. Further, thanks to its excessive degree of freedom (DoF), massive MIMO has unlimited potentiality to further enhance system capabilities [7] and still expands various research topics with depth. It should be further discussed and believed to break limitations in wireless communications such as spectral and energy efficiencies for better support of continuously increasing mobile data traffic, as well as terminals driven by Internet of things (IoT). The key contribution of this special issue is to provide readers with new insights and facilitate plentiful discussions in this field.

2. The Present Issue

This special issue consists of nineteen papers covering wide and important topics in the field of massive MIMO systems, including both fundamental regions such as computation complexity, energy efficiency, pilot contamination, channel estimation, antenna design, non-orthogonal multiple access (NOMA) and millimeter-wave beamforming, as well as emerging topic such as machine learning incorporation. From the system model aspect, variety of scenario have also been covered such as single/multi-cell, distributed antennas, heterogeneous network, IEEE802.11ac and long term evolution (LTE) standards.

Distributed antenna systems (DAS) or base station (BS) cooperation have actively investigated since it can provide array diversity or multiplexing gain due to low spatial correlation of distributed antennas. Its extension to massive MIMO was analyzed in terms of spectral and energy efficiencies with considering hardware impairment such as phase noise [8] and analog-to-digital converter (ADC) resolution [9]. In the distributed massive MIMO structure, sounding reference signal (SRS) design and channel estimation scheme were proposed in order to mitigate the pilot contamination impact [10].

Work in [11] proposed a path loss based pilot allocation strategy and pseudo-random code pilot design. In [12], a modified heuristic pilot assignment algorithm was proposed. Its optimization criteria is to maximize the minimum uplink signal-to-interference plus noise power ratio (SINR). Efficient channel state information (CSI) estimation scheme was proposed in [13]. It exploits prior CSI of the previous timeslot having temporal correlation in the angular domain. Differential modulation unnecessitates channel estimation and is preferable especially in massive MIMO systems. In [14], incoherent detection for differential modulation was expanded to multiple symbols in the single cell scenario. For further capacity enhancement, multiplexing in the power domain, i.e., NOMA enabled by successive interference cancellation (SIC), was introduced [15].

In millimeter-wave communication, almost line-of-sight (LoS) channel or Ricean fading channel is expected. Exploiting CSI of the LoS component, spectral efficiency of equal gain transmission and combining (EGT/EGC) was analyzed in Ricean fading frequency selective fading channel with cooperative relaying scenarios [16]. Such relaying approach is also effective in heterogeneous network where small cell BSs play a role of relay the macro cell BS and user terminals. Reference [17] proposed eigenvector decomposition based hybrid beamforming in the above scenario.

In the practical viewpoint, limited statistical CSI feedback constraint was considered and machine learning based user grouping aided hybrid beamforming was proposed [18]. Further, CSI estimation elimination approach, which applies a blind adaptive array signal processing, has been proposed and its practical performance was evaluated with considering medium access control (MAC) layer overhead of IEEE802.11ac and frequency division duplex (FDD) based LTE standards [19].

Computation complexity for pre/post coding is also significant problem on massive MIMO systems. Suppose uplink transmission, iteration-based new detection algorithms were proposed. One is the extension of linear minimum mean squared error (MMSE) post coding and log-likelihood ratio (LLR) calculation [20] and another is based on the maximum likelihood (ML) detection and iterative discrete estimation approaches [21].

Focusing on energy efficiency, reference [22] proposed simplified beamforming as well as power allocation strategies for the scenario wherein unicast and multicast users are non-orthogonally multiplexed. Discontinuous reception can also contribute to improve the energy efficiency. Authors in [23] introduced an artificial intelligence (AI) approach, i.e., recurrent neural network (RNN), to adapt sleep cycles of user terminals.

In realization of large-scale antenna arrays, we should pay attention to antenna manufacturing. Reference [24] developed Bayesian compressive sensing based planar array diagnostic tool for efficient and reliable testing. New antenna structures were designed; dual-polarized diamond-ring slot antenna array exhibiting wide bandwidth [25], and leaky-wave antenna array incorporating metamaterial shield [26] which can suppress the mutual coupling.

3. Future

Now discussions towards 6G has started. Massive MIMO is still expected as a promising contributor for 6G [27–29], e.g., referred as 'ultra massive MIMO'. Its potentiality will be truly realized through relentless effort on R&D including the advance of hardware performance. Variety of massive MIMO technologies, which were widely addressed in this special issue, could be one of the most important solutions to bring a breakthrough towards beyond 5G or 6G.

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Abbreviations

The following abbreviations are used in this manuscript:

MIMO	Multiple-Input Multiple-Output
5G	Fifth generation mobile communications
DoF	Degree of freedom
IoT	Internet of things

NOMA	Non-orthogonal multiple access
LTE	Long term evolution
DAS	Distributed antenna systems
BS	Base station
ADC	Analog-to-digital converter
SRS	Sounding reference signal
SINR	Signal-to-interference plus noise power ratio
CSI	Channel state information
SIC	Successive interference cancellation
LoS	Line-of-sight
EGT	Equal gain transmission
EGC	Equal gain combining
MAC	Medium access control
FDD	Frequency division duplex
MMSE	Minimum mean squared error
LLR	Log-likelihood ratio
ML	Maximum likelihood
AI	Artificial intelligence
RNN	Recurrent neural network

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