Demo: an LTE compatible massive MIMO testbed based on OpenAirInterface

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***Abstract*—Massive MIMO is one of the key technologies enabling the next generation of wireless communications, offering high spectrum efficiency, saving transceivers energy and providing many other advantages. The OpenAirInterface massive MIMO testbed is the world's first open source LTE compliant base station equipped with large antenna array, which can directly provide services to commercial user equipments (UEs). The testbed performs TDD channel reciprocity calibration to acquire accurate channel state information at transmitter (CSIT). It shows the feasibility of using massive MIMO already in current generation LTE standard by using Transmission mode (TM) 7-10, indicating the possibility of smoothly evolving the wireless network from 4G to 5G. We show here an innovation platform for solving 5G massive MIMO challenges, by giving the possibility of advanced algorithm testing, concept validation, channel measurements, etc.**

***Index Terms*—5G, Massive MIMO, LTE, OpenAirInterface, Open source**

I. Introduction

Massive MIMO is one of the key 5G technology candidates, involving hundreds of antennas installed at the base station. It promises significant gains in wireless network capacity, spectrum efficiency as well as offering the possibility of greatly reducing energy consumption, enhancing the reliability and reducing latency [1], [2]. The great potential of massive MIMO has motivated many researchers and engineers to bring the technology from theoretical domain to practical deployments.

In order to validate theoretical concept and address the potential challenges of massive MIMO, prototyping is of essential importance. Hence, based on OpenAirInterface, we have built a LTE compliant massive MIMO testbed. It integrates massive MIMO technology into the LTE standard and thus can interoperate with commercial user equipments (UEs) using Transmission Modes (TMs) 7-10. To overcome the challenges of accurate channel state information (CSI) acquisition, the system is based on the channel reciprocity in a TDD system [3]–[5]. With its 64 antenna array, the system can serve up to 4 UEs on the same frequency-time domain resource.

Our testbed is the world's first open source real-time massive MIMO testbed, with the 3GPP LTE protocols implemented from the physical layer to the network layer. It demonstrates that massive MIMO can be perfectly used in LTE and its usage in 5G can be a smooth evolution starting from the current 4G standard. It provides a platform based on which engineers can innovate and test their concepts on the challenges in making massive MIMO more efficient, such as common channel beamforming, new reference signal design and the design of CSI feedback schemes.

II. Key parameters

Figure 1 illustrates the flexible and scalable TDD based OpenAirInterface massive MIMO system. It can support a large antenna array of 64 elements with 5MHz bandwidth at the frequency of 2.6GHz, serving up to 4 users on the same time and frequency resource. The bandwidth limitation can be easily removed by upgrading the FPGA of EXMIMO2 RF platform or by using other RF platforms such as Ettus USRP B210, Ettus USRP x310 or LimeSDR. OpenAirInterface natively supports multiple RF platforms (USRP B210, USRP x310, LimeSDR) which have support much higher transmission bandwidth and can be easily synchronized to support higher bandwidth massive MIMO platform using the same software architecture. The key parameters of the system are summarized in Table I.

TABLE I
Key parameters of OpenAirInterface massive MIMO testbed

Paramters	Value
Number of antennas	Up to 64
Center frequency	2.6GHz
Bandwidth	5MHz
Sampling Rate	7.68MS/s
FFT Size	512
Number of used subcarriers	300
Slot time	0.5ms
Maximum simultaneously served UEs	Currently 4, extendable

III. TDD reciprocity calibration

One of the key challenges in bring massive MIMO from a theoretic concept to the real world is the acquisition of accurate channel state information at the transmitter (CSIT), which is essential to perform advanced beamforming algorithms. Traditionally, the base station (BS) sends pilots to UEs which then feedback the downlink (DL) channel estimation to the BS. However, such a scheme can not scale with the antenna number increase at the BS, since the uplink (UL) overhead will become so high that by the time when BS gets the feedback, such CSIT are very probably outdated.

Fig. 1. OpenAirInterface massive MIMO testbed

Time division duplex (TDD) mode is used in our testbed, as the channel reciprocity property can be used to overcome the above challenge. In fact, for a TDD system, DL and UL propagation channel in the air are reciprocal within the channel coherence time that the BS can get the knowledge of the DL channel from its estimation of the UL based on UE's pilots.

However, the real channel seen in transceiver's digital domain is a combination of the the propagation channel in the air and the RF chains in the transceiver. When the former is reciprocal, the transmit and receive RF chains are not. In order to compensate the hardware non-symmetry, the testbed uses a cost effective Over-The-Air (OTA) calibration method [3]–[5] to acquire CSIT with near optimal accuracy.

IV. LTE compatible massive MIMO Testbed

Massive MIMO can also be smartly and perfectly fit into the current LTE standard. In fact, 3GPP has defined the notion of Transmission Modes (TMs) for different usage of MIMO in LTE, which can be categorized as transmit diversity, spatial multiplexing and beamforming. TM 7 is defined in Release 8, where an arbitrary number of physical antennas at base station can be used as a logical antenna port (port 5) to create a narrow beam for the targeted user. Release 9 extended TM 7 to TM 8, giving the possibility of transmitting a dual stream to a single or two users, whereas in release 10, this is further extended to TM 9 where up to 8 layers for a single user transmission and up to 4 layers for multiuser transmission is supported. Release 11 adds TM 10, similar to TM 9 with up to 8 layers transmission but the transmit antennas can physically locate on different base stations. In Release 13, no new transmission mode is defined, but CSI Reference Signal (RS) has been extended to 16 ports [6]. Moreover, the ongoing work item in release 14 [7] on the enhancement of Full-Dimension MIMO (special case of massive MIMO in 3GPP) for LTE has defined the objective of extending the CSI-RS to 32 ports with enhancement on CSI reports and support for providing higher robustness against CSI impairments.

The OpenAirInterface massive MIMO testbed relies on the implementation of TM 7-9 to use the large number of antenna array, and can be easily extended beyond. Currently only TM 7 has been implemented. Commercial UE supporting this transmission mode can be connected to the massive array BS, and use Internet service through our massive MIMO testbed.

V. Demo Description

In this demo, we will show a reduced scale version of the Openaireinterface massive MIMO testbed with a 4 antenna based station enabled by one ExpressMIMO2 card communicating with a commercial UE. We demonstrate how the CSIT is acquired at the base station based on our TDD channel reciprocity calibration scheme. Calibration coefficients are estimated, which are later used together with instantaneously estimated UL channel to obtain the CSIT. We then illustrate the beamforming communication between the BS and the UE based on TM7. With the full solution of OpenAirInterface on the access and core network, the UE is able to access the Internet via our massive MIMO BS.

VI. Conclusions

OpenAirInterface massive MIMO testbed is the world's first open source real-time full LTE protocol stack compatible massive MIMO system. Having OpenAirInterface as its core, the testbed can establish communications directly with commercial UEs, showing the possibility of using massive MIMO in LTE. It opens the possibility of testing future innovations in a real and practical environment and will have a non negligible meaning in helping researchers and engineers in designing 5G.

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