# Wireless Network Evolution Toward 5G Network

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***Abstract:*** *In this paper, we discuss about the technical issues toward 5G and introduce the recent advances in distributed antenna cooperative signal transmission techniques which provides high quality broadband data services over an entire macro-cell area.*
***Keywords:*** *5G, LTE/LTE-A, distributed antenna, cooperative signal transmission*

## I. Introduction

After 35 years from its birth in Dec. 1979, mobile communications networks have evolved into the 4th generation (4G) in 2015 and have become an infrastructure of our modern society. We witnessed the new generation approximately every 10 years. In 1G and 2G, the coverage expansion was the most important target. From 2G to 3G, there was a big leap in the radio transmission data rate. The major communications service was the voice in 1G and 2G networks. In 3G, high speed data communication of up to 2Mbps was targeted. Since the start of 3G services, video communications have been getting increasingly popular. In 3.9G long-term evolution (LTE) and 4G LTE-Advanced (LTE-A), much higher quality video communications and close-to-1Gbps broadband data services will become more and more popular. LTE-A services started in March 2015 in Japan. In 5G, much broader data services (>1Gbps/user) are expected.

In this paper, we discuss about the technical issues toward 5G and then, introduce the recent advances in distributed antenna cooperative signal transmission techniques which provides high quality broadband data services over an entire macro-cell area.

## II. Technical Issues Toward 5G

The mobile data traffic volume in 2020 will reach about 1,000 times of 2010 owing to the increasing popularity of smartphones. Therefore, the energy-efficiency (bits/J) will become an important technical issue as well as the spectrum-efficiency (bps/Hz/km$^2$). Furthermore, in addition to traditional trend to enrich the broadband data services, new services are expected, e.g., IoT related massive device connections and mobile machine control by wireless. Therefore, the radio resource management will become another important technical issue in 5G.

5G networks will be a small-cell network. By reducing the cell size (i.e., small-cell network), the same frequency can be reused at near locations and the transmit power of user terminal (UE) can be significantly lowered, thereby, the spectrum- and energy-efficiencies can simultaneously be improved. Beside straightforwardly reducing the cell size, there are two promising approaches. One approach is to use a large number of collocated antennas at the macro-cell BS (MBS), i.e., massive MIMO beamforming. Another approach is to spatially deploy a large number of antennas over a macro-cell area [1]. This is called distributed MIMO or distributed antenna small-cell network. Distributed antennas are connected with a virtual MBS by low latency coherent optical link to forms a virtual macro-cell as illustrated in Fig. 1. Radio signal processing and resource management (e.g., scheduling) are performed at the virtual MBS. One or more distributed antennas close to a user are selected for signal transmission; this can be considered an advanced version of coordinated multipoint (CoMP) transmission [2] of LTE-A.

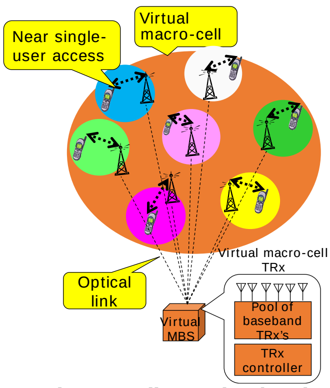


Fig. 1 Virtual macro-cell using distributed antennas.

The optical link between a virtual MBS and each distributed antenna can be implemented by using either radio over fiber (RoF), common public radio interface (CPRI) for optical transmission of digitized baseband I/Q signals, or fully coherent optical transmission. The use of RoF link allows all radio signal processing to be implemented at a virtual MBS. However, nonlinearity of RoF link causes a serious problem. Using CPRI, distributed antenna side needs simple RF modulator/amplifier only, but very high speed digital transmission of multi-Gbps is required over fiber. On the other hand, the use of fully coherent optical communication allows to treat the optical transmission and radio transmission similarly; the difference between two is only the carrier frequency (Fig. 2). The concatenation of optical link and radio link can be treated as an equivalent radio link if the same data modulation is used over both the optical link and radio link.

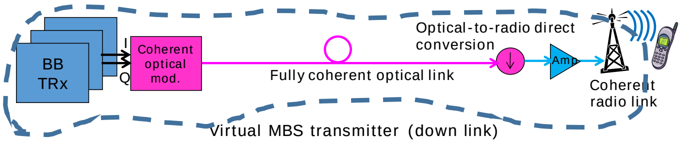


Fig. 2 Fully coherent optical link (downlink).

## III. Distributed Antenna Cooperative Signal Transmission

To provide high quality broadband data services over an entire macro-cell area, cooperative signal transmission using one or more distributed antennas can be employed. Since antennas are spatially distributed unlike massive MIMO, the shadowing loss problem can be alleviated as well as multipath fading problem. Below, transmission performance of distributed antenna cooperative signal transmission techniques (space-time block coded (STBC) diversity, multiuser MIMO (MU-MIMO), and blind selected mapping (SLM)) (Fig. 3) is presented. 7 virtual macro-cells consisting of 7 distributed antennas each are considered. Frequency-domain block signal transmission (OFDM downlink and SC-FDE uplink) of 128 subcarriers/100MHz band is assumed. FDMA is assumed as the multi-access technique for STBC diversity. 2 UEs having 2 antennas each is randomly located in each virtual macro-cell area. 4 distributed antennas are selected out of 7 distributed antennas based on the instantaneous received signal strength criterion. The transmission performance is measured at UE of the center virtual macro-cell. The OFDM downlink transmission performances with STBC diversity and MU-MIMO, obtained by computer simulation, are plotted in Fig. 4. Figure 5 plots the peak-to-average power ratio (PAPR) of uplink SC signal with blind SLM.

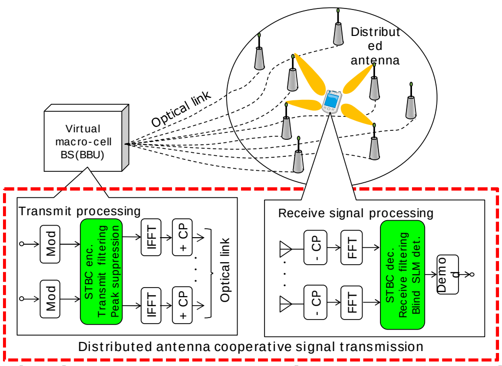


Fig. 3 Distributed antenna cooperative signal transmission (OFDM downlink).

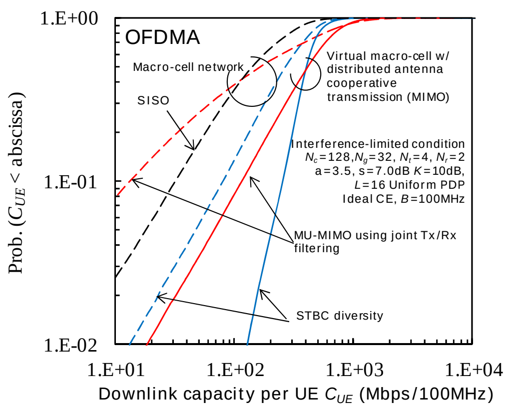


Fig. 4 Transmission performance (OFDM downlink).

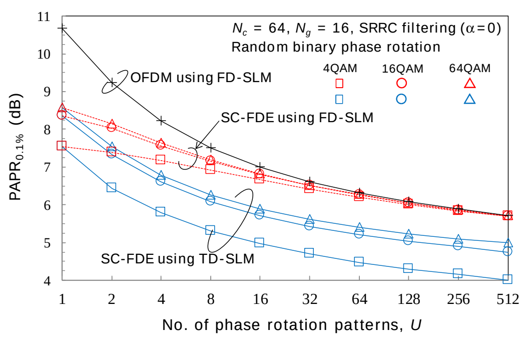


Fig. 5 PAPR reduction by blind SLM.

### *A. STBC diversity and MU-MIMO*

Simple Alamouti code [3] can be used for STBC diversity. By combining transmit frequency-domain equalization (FDE) with downlink STBC diversity (by combining receive FDE with uplink STBC diversity), an arbitrary number of distributed antennas can be used to obtain the full spatial diversity gain although limiting the number of UE antennas to 6 [4]. It can be seen from Fig. 5 that STBC diversity can significantly improves the downlink capacity compared to the case of collocated antennas at the MBS.

In MU-MIMO, multiple users simultaneously transmit their signals using the same frequency unlike FDMA. Inter-user interference (IUI) and inter-antenna interference (IAI) as well as inter-symbol interference (ISI) due to the channel frequency-selectivity limit the achievable transmission performance. Hence, suppression of IUI, IAI, and ISI becomes an important issue for MU-MIMO. Recently, the author's group proposed two distributed antenna MU-MIMO schemes: BD-SVD and MMSE-SVD [5]. Similar to STBC diversity, it can be seen from Fig. 4 that MU-MIMO significantly improves the downlink capacity compared to the case of collocated antennas at the MBS. MU-MIMO provides lower outage probability than STBC diversity in a high downlink capacity region. However, in a low downlink capacity region, the outage probability is higher with MU-MIMO than with STBC diversity. This is due to strong co-channel interference (CCI) from adjacent virtual macro-cell. Suppression of CCI is our future study.

### *B. Blind SLM*

When the distributed antenna cooperative transmission is used, the transmit signal PAPR increases. Therefore, some PAPR reduction technique is still necessary for uplink transmission if the mm wave band is used. SLM is an efficient PAPR reduction technique which multiplies an appropriate phase rotation sequence to the transmit signal either in the frequency-domain or in the time-domain. SLM requires the side information (phase-rotation sequence information) for signal detection at a receiving side. Recently, the author's group proposed a blind SLM which requires no side information and hence, causes no spectrum efficiency degradation [6]. The blind SLM can reduce the transmit signal PAPR by about 3 dB with a slight bit error rate performance degradation (ideal transmit filtering of zero roll-off factor is assumed) (see Fig. 5).

## IV. CONCLUSIONS

In this paper, after overviewing the wireless evolution of mobile communications technology over the past 35 years, we discussed about the technical issues toward 5G. Then, we introduced the recent advances in distributed antenna cooperative signal transmission techniques. The target of mobile communications technology is to achieve as high speed data transmission as possible under the limited available bandwidth and power while suppressing the CCI to a certain degree (no perfect cancellation of co-channel interference is intended). A key of realizing 5G networks is the advanced utilization of spatial domain (massive MIMO and distributed antennas). The antenna will become one of radio resource in addition to frequency, time, and power. The scheduling algorithm which efficiently allocates the limited resource among a huge number of mobile communications devices is a paramount technical issue in 5G and beyond.

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