Poster Abstract: Enabling Concurrent IoT Transmissions in Distributed C-RAN

Xiaoran Fan
WINLAB, Rutgers University
North Brunswick, NJ, USA
ox5bc@winlab.rutgers.edu

Zhenzhou Qi
WINLAB, Rutgers University
North Brunswick, NJ, USA
zq52@scarletmail.rutgers.edu

Zhenhua Jia
WINLAB, Rutgers University
North Brunswick, NJ, USA
zhenhua@winlab.rutgers.edu

Yanyong Zhang
WINLAB, Rutgers University
North Brunswick, NJ, USA
yyzhang@winlab.rutgers.edu

ABSTRACT

As rapid expansion of the low-cost next billion devices, wireless sensor networks (WSN) undertake much denser low-end internet of things (IoT) nodes nowadays. In the meantime, the future next 5 generation (5G) radio base stations (BS) are granted more capabilities. Distributed cloud radio access network (C-RAN) is becoming available for the future massive WSN. However, real-world distributed C-RAN is less explored for low-end IoT based WSN due to its difficulties in implementation. In this paper, we built a distributed C-RAN which has tens of distributed radio frontends using USRP N210s in a $20 \times 20 \times 3\ m^3$ area. By exploiting the inherent hardware properties of low-end IoT devices and the spatial diversity of distributed C-RAN system, we show the distributed C-RAN can potentially decode collided signals from low-end IoT devices with all signal processing been done on the cloud.

CCS CONCEPTS

• **Networks → Network protocols**;

KEYWORDS

WSN, distributed beamforming, C-RAN, IoT

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1 INTRODUCTION

AT&T recently spent 1.6 billion to boost their 5G spectrum holdings. Spectrum resources become much more expensive than those low-end IoT devices. With the sheer density of future IoT WSN, limited spectrum seriously challenges the design of such networks. Interference and collisions are inevitable and becoming a daunting problem left to be addressed. Multiple input and multiple output (MIMO) technology expands the spectrum efficiency by exploring the spatial diversity in radio transmitter-receiver architecture. It however requires accurate time and frequency alignments among transmitters and receivers, and also requiring training procedures to obtain immediate channel state information (CSI). Such design invokes high complexities for transmitter hardware design, as well as introducing overhead in the training phase. It is merely possible to implement MIMO for the massive produced low-cost IoT devices. Interestingly, instead of eliminating the large carrier frequency offsets (CFO) on the low quality IoT devices, [1] leverages the CFO to decode the collision in chirp spreading sequence (CSS) modulated signals. However, the throughput of such system is inherently limited by its extremely narrow bandwidth. In this paper, we explore the possibilities of enabling concurrent low-end IoT device communications with recent advances in the distributed C-RAN. We demonstrate the prototype of our proposed system, show such system can decode collided signal without referencing sequences.

2 DISTRIBUTED RECEIVER BEAMFORMING FOR DECODING CONCURRENT TRANSMISSIONS

The system proposed in this work is deployed the same as the distributed C-RAN, i.e. multiple synchronized distributed radio frontends pick up signals and sending them to a centralized cloud. Our previous works in [2, 3] show that we can establish an asymmetric energy distribution with only high energy at the target receiver (where the IoT device is) across the entire space, by aligning the phases (perform distributed beamforming) among distributed transmitters. The key to our distributed C-RAN design is to look at our previous distributed energy beamforming system in a reversed way. Instead of sending signals to IoT devices, the distributed radio frontends receive signals from IoT devices, and applying phase combining on the cloud. As a result, similar as shooting energy at the intended location, the system now receives signals from the intended location. Further, due to the phase combining procedure is done on the cloud, the clod can easily decode signals from multiple transmitters simultaneously by running multiple threads. Moreover, the uniqueness of the peak energy location is proven in [3], which translates to the optimal phase combinations for each signal source could be *blindly searched* on the cloud by peaks finding. For

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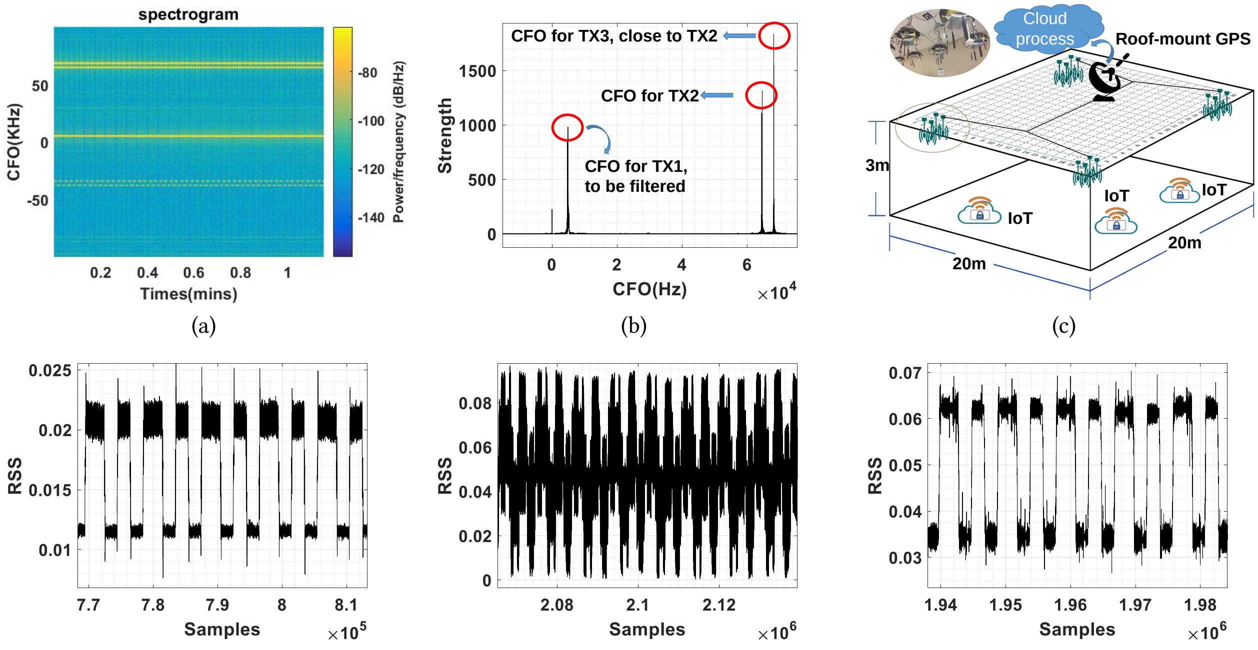

(a) (b) (c)

(d) (e) (f)

Figure 1: (a) Spectrogram of the received signal from three transmitters shows three different CFOs. (b) Frequency domain of the received signal. (c) Illustration of our real-world C-RAN testbed. (d) The waveform of original PAM bits from TX2. (e) The resumed waveform (the cloud performs receiver beamforming) for TX2 without filtering. It's yet to be decodable. (f) The resumed waveform for TX2 after filtering. It becomes clean with 0 BER.

example, with two IoT devices concurrently transmit, and adequate amounts of receivers, the system will witness two energy peaks as it traverses all possible phase combinations for each radio frontend.

According to our simulations, given 14 receivers, with transmitters sending simple pulse amplitude modulated (PAM) bits, only 2 transmitters can be supported concurrently with a reasonable bit error rate (BER, less than 1%), which is far from the state of the art MIMO technic. The reason is, compared to a MIMO system, we don't have the precoding due to the simplicity of IoT hardware. Also, in order to blindly combine phases on the cloud, our distributed receiver beamforming process doesn't manipulate amplitude information like the traditional receiver beamforming does.

3 EXPLOIT THE INHERENT HARDWARE CFO FOR SEPARATION ENHANCEMENT

We built a testbed that have 14 synchronized USRP N210s used as radio frontends. As shown in Fig 1 (c), the radio frontends are sparsely located at four corners in a $20 \times 20 \times 3\ m^3$ area testbed. Another three un-synchronized USRP are randomly placed within the testbed area, concurrently transmitting different PAM bits at the same frequency. The received signals at radio frontends are sent to a centralized cloud node through Ethernet cables for further filtering and phase combining.

Low-end IoT devices experience tens to hundreds KHz CFO for ISM band operations due to their inferior built-in oscillators. This also happens in USRPs with their built in clocks, which can be seen in Fig. 1(a) and (b). Consequently, CFO naturally diverse low-end IoT devices in frequency domain. Therefore we can first apply filter banks to filter out signals which have distinct frequency offsets, then we use our distributed C-RAN to further separate signals that have very close CFO.

Fig. 1(d) (e) and (f) shows our experimental results, where (d) shows the received waveform of the PAM signal with only TX 2 transmitting. It follows a 1,1,0,1,0,1,1... pattern. In (e), all three transmitters are turned on, the cloud performs phase combining for the signal from TX 2. But we only get muffled waveform compared with its original form. The BER is 15 % in (e). In (f), all transmitters are turned on, the cloud first applies a simple high pass filter (HPF) which has the cut off frequency at 10 KHz to filter out signal from TX 1, and then proceeding the phase combining for the signal from TX 2. We can now clearly see the resumed waveform from TX 2. The BER drops to 0 in (f).

Conclusion: To summarize, we build a distributed C-RAN based WSN, show its salient properties in supporting concurrent IoT transmissions, demonstrate it can decode collided signals without reference sequences, and we further refine the separation by leveraging the inherent CFO from low-end IoT devices.

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