Coordinated Beam Discovery, Association, and Handover in Ultra-Dense Millimeter-Wave Network

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RESEARCH OBJECTIVES

Millimeter-wave (mmWave) radio spectrum is considered as the key enabler of 5G cellular networks due to large available bandwidth. However, high channel propagation loss and higher probability of signal blockage in the mmWave band, as compared to the microwave band, have introduced new challenges in establishing and maintaining the link between base stations (BSs) and user equipments (UEs). In order to compensate for the propagation loss and signal blockage, BSs and UEs in mmWave band use a very large number of antennas capable of creating narrow beams that can achieve high beamforming gains needed to establish the link. Further, ultra dense BS deployment is needed to provide satisfactory coverage. As a result, the mmWave cellular networks face the new design challenges: as shown in Figure 1. First, initial access procedure for BS beam discovery with low complexity, low delay, and low signaling overhead is needed. Next, in order to use the channel gain and beam alignment information obtained during initial access it is required to optimally decide association between UEs and BSs as well as to allocate BS resources to UEs. Finally, mobility management techniques are necessary to reduce the number of handovers in a mobile network with a high BS density.

Figure 1 Three research tasks in coordinated beam management for mmWave UDN. Task 1: Discovery of BSs by UEs followed by CSI estimation. Task 2: Association between UE beams and BS beams and allocation of resources from BSs. (The BS coverage area is not circular due to blockages.) Task 3: Design of a low cost link update procedure and BA/RA to reduce the number of handovers to enable seamless data transfer.

OUR APPROACH

This project will develop an initial access procedure based on compressive sensing measurements in order to reduce the delay in link establishment. This method enables discovery of BSs and estimation of beam alignment parameters. Practical aspects of mmWave transceivers will be considered, including architectures with smaller number of RF chains as compared to the number of antennas, RF impairments such as carrier frequency offset (CFO), phase noise, and amplifier non-linearity. Additionally, we will develop a procedure for interleaved beam discovery and data transfer, where only one RF chain is used for beam discovery at any given instant while other RF chains are used for data transfer. In this approach, the beam alignment parameters estimated using one RF chain can be reused for data transfer in all other RF chains. This method will reduce the overhead of beam discovery and increase network throughput. Further, the estimated beam alignment parameters will be used to associate UEs with BSs and allocate time domain resources at BSs to corresponding UEs. The novel association technique will allow multiple BSs to simultaneously serve one UE using different RF chains at the UE. Optimum beam widths will be computed in order to keep the links between BSs and UEs active while taking into account the errors in estimation of the beam alignment parameters. This approach reduces the probability of outage and increases the network throughput. Finally, link update and handover mechanisms will be developed to maintain required data rate at UEs, while minimizing the number of required handovers in the ultra-dense network (UDN) with a high BS density. We will develop low complexity algorithms to solve the underlying optimization problems for association, resource allocation, and handovers. Theoretical framework will be developed to analyze the proposed algorithms under different BS density and mobility models.

PI BACKGROUND

PI Danijela Cabric leads the Cognitive and Reconfigurable Embedded System Lab in UCLA. She is PI on NSF-CNS CAREER grant Cognitive Co-existence in Heterogeneous Wireless Networks ($420k; no. 1149981; 7/12-6/17). She is also co-PI on NSF-EARS grant titled Enabling Algorithms, Signal Processing, and Circuits for Agile Cognitive Radio in CMOS Technology ($1.2M; no. 1343389; 9/13 - 9/15), where digital algorithms are designed to correct hardware impairments in wideband spectrum sensing.

PRELIMINARY FINDINGS

We have studied compressive sensing based beam discovery algorithm under CFO and phase noise. We discovered that the algorithm using extended Kalman filter provides reliable phase measurement for beamforming training. We also studied the impact of nonlinearity of PAs on hybrid precoding, and a digital pre-distortion algorithm is proposed to compensate for loss due to non-linearity. In our work on massive MIMO networks, we developed user selection and power allocation algorithms in order to serve maximum number of users from a BS while maintaining certain minimum data rate. We developed low-complexity selection algorithms which achieve near optimal performance. These algorithms also take into account the estimation error in the channel parameters. Following this line of work, we plan to solve the aforementioned user association and resource allocation problem in mmWave networks by developing low-complexity association and allocation algorithms.