**Abstract of Ph.D. Thesis**
**"Methods for Reduction in ACK/NACK Signaling and Channel Estimation Overhead in Massive MIMO Systems"**
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The central idea of fifth generation (5G) wireless communication systems is to create a wireless world which is free from all barriers and limitations of the past generations. Not only industries but also governments of nearly all nations are showing huge interest for 5G, which is not just a simple enhancement of mobile broadband in 4G. 5G communication systems are expected to meet quality of service (QoS) requirement of new communication scenarios like ultra reliable low-latency communication (URLLC) systems for new applications like automatic driving, remote surgery, etc. 5G communication systems incorporates many promising technologies such as visible light communication (VLC), massive multiple-input multiple-output (MIMO), millimeter-wave communication, and heterogeneous network (HetNet) so forth. Massive MIMO is one of the most promising technologies to fulfill the need of the ever increasing traffic demand.

High spectral efficiency and low latency are key features in 5G communication systems. Both of these aspects of 5G are immensely affected by the overheads in communication systems. These overheads help to meet higher quality of services (QoS) requirements of end users by improving performance of the system, at the expense of available time and frequency resources. It includes authentication of mobile unit by the network, training data for channel measurement, allocation of traffic channels, acknowledgment of correct reception of data, cyclic prefix etc. Some common transmission overheads in 4G/5G wireless communication systems are control signals, channel estimation and cyclic prefix. In this thesis, we have proposed new transmission methods for massive MIMO systems, in which ACK/NACK control signaling and channel estimation overhead are significantly less compared to current communication systems.

Firstly, we consider the ACK/NACK control signaling overhead. In 4G LTE, Hybrid Automatic Repeat Request (HARQ) based transmission methods are used which retransmit information until it gets correctly decoded. In stop-and-wait type HARQ, a lot of delay and overheads are introduced as for every retransmission the transmitter needs to wait for the receiver to decode the codeword and signal the acknowledgement (ACK/NACK) . The signaling of ACK/NACK increases the overall system overhead. *To reduce overhead, we have proposed an uplink transmission method for massive MIMO systems called as the "Low Control Signaling and CSI Feedback" (LSF) method.* The proposed method is based on the

fact that channel capacity varies slowly over time, due to channel hardening in massive MIMO systems. We utilize this fact, for deciding the proper length of the codeword only once based on an initial estimate of the uplink channel capacity fed back by the base station (BS). The user terminal (UT) encodes the information into a codeword of the appropriate length and then transmits it over consecutive coherence intervals (CIs) without waiting for any acknowledgement (ACK/NACK) from the BS. Decoding is performed by the BS only once after the entire codeword has been received. After decoding, BS sends only a single ACK/NACK to the UT. Hence, the proposed LSF method has less latency and signaling overhead when compared with HARQ methods used in LTE uplink.

Next, we consider the overhead due to channel estimation, specially for time varying and frequency selective channel. Accurate channel estimates are required for coherent detection, beamforming, resource allocation etc. In pilot based channel estimation, known pilot symbols, are transmitted, and the receiver uses the received pilots to estimate the channel. High mobility (upto 500 km/hr) is one of a key feature of 5G communication systems. In high mobility scenarios, due to high Doppler spread, the channel coherence interval (CI) is small. Small CI leads to low data rate and high channel estimation overhead. The performance of orthogonal frequency division multiplexing (OFDM) based multi-user massive MIMO systems degrades severely with increasing mobility induced Doppler spread. Recently, a new modulation technique known as orthogonal time frequency space (OTFS) has been introduced which provides robustness towards mobility induced Doppler spread. In OTFS, the channel impulse response in the delay-Doppler (DD) domain changes far slowly than its equivalent time domain impulse response. Due to this, the effective CI of OTFS based systems is large in comparison to that of OFDM based massive MIMO systems, reducing the need for frequent channel estimation. So the channel estimation overhead is less in OTFS based systems relative to OFDM based systems.

In OTFS based systems, information symbols are embedded in the DD domain where they are jointly modulated to generate the time-domain transmit signal. Since multi-path delay and Doppler shift can spread information in the DD domain, information symbols need to be jointly demodulated. We can achieve high spectral and energy efficiency in OFDM based massive MIMO system with low complexity multiuser precoding in the downlink. But it is very challenging in case of the downlink of an OTFS based massive MIMO systems due to the requirement for joint demodulation of all information symbols at the UT irrespective of the amount of delay and Doppler spread. *To resolve this problem, we have proposed*

*a novel OTFS based multi-user massive MIMO precoder at the BS and a corresponding low complexity detector (LCD) at the UT.* The sum spectral efficiency achieved by the proposed low complexity LCD is very close to that achieved by optimal joint demodulation at each UT. Numerical simulation results verify our analytical results and also show that proposed OTFS based massive MIMO precoder along with LCD detector achieves significantly better spectral efficiency and low frame/codeword error rate (FER) compared to OFDM based massive MIMO systems, with a much smaller channel estimation overhead.

In this dissertation, we have addressed the problems of overhead/latency due to ACK/NACK signaling and the channel estimation overhead of multi-user massive MIMO systems in high mobility scenarios. We have proposed novel methods to overcome these problems, to realize the vision of 5G.