Modeling and Performance Analysis of Differential CQI Feedback in OFDM Cellular Systems

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Contemporary wireless communication standards such as 4G Long Term Evolution (LTE) use orthogonal frequency division multiplexing (OFDM) in the downlink. OFDM is also likely to be used in 5G. Frequency-domain scheduling and rate adaptation are key techniques employed by these standards to achieve high spectral efficiencies. In scheduling, the base station (BS) determines which user to allocate to each orthogonal subchannel (SC) the system bandwidth is divided into. In rate adaptation, the BS determines the rate for transmission to the scheduled user for each SC. To facilitate this, ideally the BS requires channel state information of all the SCs of all the users. However, since bandwidth available in the uplink for feedback is limited, the very feasibility and efficiency of the above techniques depends on feedback schemes that acquire the channel state information with much less overhead.

Several reduced feedback schemes, which provide the BS with the requisite channel state information while ensuring that the uplink is not overwhelmed by the feedback overhead, have been proposed in the literature and adopted in LTE. Specifically, in LTE, a user feeds back a channel quality indicator (CQI), which indicates the rate that it can decode reliably. In the wideband feedback scheme of LTE, a user reports just a single wideband CQI, which is the rate that can be reliably decoded if the entire system bandwidth is allocated to that user. In eNodeB-configured subband feedback, a 2-bit differential CQI is sent for each subband, where a subband comprises several adjacent SCs, that encodes the difference between the wideband CQI and the rate that the user can receive reliably on the subband in addition to the wideband CQI. Our goal is to analyse the throughput of the widely used eNodeB-configured subband feedback scheme. Such an analysis gives rigorous mathematical insights about the performance of the scheme. Further, it enables a system designer to independently evaluate or verify the throughput over a wide range of system parameter settings without resorting to computationally intensive simulations. It also helps design better feedback schemes. Specifically, our analysis considers the following important features of LTE:

1) It accounts for the impact of scheduling at the BS when there are multiple users in the cell and the different multiple antenna diversity modes that are employed in LTE such as single-input-single-output (SISO), single-input-multiple-output (SIMO), multiple-input-single-output (MISO), and single-stream multiple-input-multiple-output (MIMO).
2) It considers the effect of co-channel interference in a multi-cell scenario.
3) It models wideband CQI using the exponential effective SNR mapping (EESM), which is a widely used link quality metric. This enables us to employ techniques used for analyzing classical link adaptation over flat-fading channels to this more involved model. We also develop a new technique to characterize the joint statistics of the wideband CQI and the differential CQI.

The proposed line of research has applications to both current and next generation cellular systems, which use OFDM as their physical layer.