# Abstract

Current and next generation wireless cellular systems strive to maximize spectral efficiency and meet the increasing demand for higher data rates despite being severely constrained by the limited availability of spectrum. Rate adaptation and scheduling are two key enabling techniques to achieve these challenging goals. In the former, the modulation and coding scheme (MCS) are adapted as a function of the instantaneous channel conditions, while in the latter, the base station (BS) adapts the user to which it transmits to.

While appealing, several practical challenges arise in implementing rate adaptation and scheduling in current generation cellular systems that employ orthogonal frequency division multiplexing (OFDM). First, the symbols of a transmitted packet can experience different signal-to-noise ratios (SNRs) in a frequency-selective channel. Thus, rate adaptation in these systems is driven by the vector of SNRs experienced by the packets and is referred to as wideband rate adaptation. It is considerably more involved than conventional narrowband rate adaptation, which is based on a single SNR. Second, the channel state information (CSI) at the BS, which it obtains through feedback from the users, is outdated due to the delay between the time of channel estimation and the time of data transmission. This can lead to incorrect adaptations and a significant reduction in system throughput. Third, the CSI feedback in the uplink is limited in order to conserve uplink radio resources. The lack of enough CSI at the BS due to this can also degrade the throughput.

We develop a new analytical framework to characterize the throughput of wideband rate adaptation. The framework employs the exponential effective SNR mapping (EESM), which simplifies the rate adaptation problem by mapping the vector of SNRs into a single equivalent flat-fading SNR. However, even rate adaption using EESM is challenging owing to its non-linear form and its dependence on the MCS and has not been analysed before. Our framework leads to a new upper bound and an accurate approximation for the cell throughput. We then extend the framework to also incorporate feedback delays and co-channel interference from neighbouring cells. We observe that the decrease in throughput with feedback delays is more gradual for wideband rate adaptation compared to narrowband rate adaptation. Further, it depends on the scheduler employed by the BS.

We then propose novel BS-side estimation techniques to mitigate the loss in throughput due to the reduced feedback from the users. We develop a new minimum mean square error estimator-based approach and subsequently a new throughput-optimal adaptation policy for the practically relevant best-M reduced feedback scheme. These approaches exploit the correlation between the subchannels, and the structure of the information fed back to improve the effectiveness of rate adaptation and scheduling without requiring any additional feedback. The throughput-optimal policy leads to a new benchmark for the achievable cell throughput in systems that employ reduced feedback schemes.