



LTE

The UMTS Long Term Evolution

FROM THEORY TO PRACTICE

Edited by: Stefania Sesia • Issam Toufik • Matthew Baker

SECOND EDITION

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From Theory to Practice

Second Edition

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Link Adaptation and Channel Coding

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10.1 Introduction

The principle of link adaptation is fundamental to the design of a radio interface which is efficient for packet-switched data traffic. Unlike the early versions of UMTS (Universal Mobile Telecommunication System), which used fast closed-loop power control to support circuit-switched services with a roughly constant data rate, link adaptation in HSPA (High Speed Packet Access) and LTE adjusts the transmitted information data rate (modulation scheme and channel coding rate) dynamically to match the prevailing radio channel capacity for each user. Link adaptation is therefore very closely related to the design of the channel coding scheme used for forward error correction.

For the downlink data transmissions in LTE, the eNodeB typically selects the modulation scheme and code rate depending on a prediction of the downlink channel conditions. An important input to this selection process is the Channel Quality Indicator (CQI) feedback transmitted by the User Equipment (UE) in the uplink. CQI feedback is an indication of the data rate which can be supported by the channel, taking into account the Signal-to-Interference-plus-Noise Ratio (SINR) and the characteristics of the UE's receiver. Section 10.2 explains the principles of link adaptation as applied in LTE; it also shows how the eNodeB can select different CQI feedback modes to trade off the improved downlink link adaptation enabled by CQI against the uplink overhead caused by the CQI itself.

The LTE specifications are designed to provide the signalling necessary for interoperability between the eNodeB and the UEs so that the eNodeB can optimize the link adaptation,

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but the exact methods used by the eNodeB to exploit the information that is available are left to the manufacturer's choice of implementation.

In general, in response to the CQI feedback the eNodeB can select between QPSK, 16QAM and 64QAM¹ schemes and a wide range of code rates. As discussed further in Section 10.2.1, the optimal switching points between the different combinations of modulation order and code rate depend on a number of factors, including the required quality of service and cell throughput.

The channel coding scheme for forward error correction, on which the code rate adaptation is based, was the subject of extensive study during the standardization of LTE. The chapter therefore continues with a review of the key theoretical aspects of the types of channel coding studied for LTE: convolutional codes, turbo codes with iterative decoding, and a brief introduction of Low-Density Parity Check (LDPC) codes. The theory of channel coding has seen intense activity in recent decades, especially since the discovery of turbo codes offering near-Shannon limit performance, and the development of iterative processing techniques in general. 3GPP was an early adopter of these advanced channel coding techniques, with the turbo code being standardized in the first version of the UMTS as early as 1999. Later releases of UMTS (in HSPA) added more advanced channel coding features with the introduction of link adaptation, including Hybrid Automatic Repeat reQuest (HARQ), a combination of ARQ and channel coding which provides more robustness against fading; these schemes include incremental redundancy, whereby the code rate is progressively reduced by transmitting additional parity information with each retransmission. However, the underlying turbo code from the first version of UMTS remained untouched. Meanwhile, the academic and research communities were generating new insights into code design, iterative decoding and the implementation of decoders. Section 10.3.2 explains how these developments impacted the design of the channel coding for LTE, and in particular the decision to enhance the turbo code from UMTS by means of a new contention-free interleaver, rather than to adopt a new LDPC code.

For the LTE uplink transmissions, the link adaptation process is similar to that for the downlink, with the selection of modulation and coding schemes also being under the control of the eNodeB. An identical channel coding structure is used for the uplink, while the modulation scheme may be selected between QPSK, 16QAM and, for the highest category of UE, also 64QAM. The main difference from the downlink is that instead of basing the link adaptation on CQI feedback, the eNodeB can directly make its own estimate of the supportable uplink data rate by channel sounding, for example using the Sounding Reference Signals (SRSs) which are described separately in Section 15.6.

A final important aspect of link adaptation is its use in conjunction with multi-user scheduling in time and frequency, which enables the radio transmission resources to be shared efficiently between users as the channel capacity to individual users varies. The CQI can therefore be used not only to adapt the modulation and coding rate to the channel conditions, but also for the optimization of time/frequency selective scheduling and for inter-cell interference management as discussed in Chapter 12.

¹Quadrature Phase Shift Keying (QPSK) and Quadrature Amplitude Modulation (QAM).

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