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LTE
The UMTS Long Term Evolution

FROM THEORY TO PRACTICE

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SECOND EDITION

Including Release 10 for LTE-Advanced

LTE – The UMTS Long Term Evolution

From Theory to Practice

Second Edition

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The timing advance update commands are generated at the Medium Access Control (MAC) layer in the eNodeB and transmitted to the UE as MAC control elements which may be multiplexed together with data on the Physical Downlink Shared CHannel (PDSCH). Like the initial timing advance command in the response to the Random Access CHannel (RACH) preamble, the update commands have a granularity of 0.52 μs; in the case of the update commands, the UE is required to implement them with an accuracy of ±0.13 μs. The range of the update commands is ±16.6 μs, allowing a step change in uplink timing equivalent to the length of the extended CP (i.e. 16.67 μs). They would typically not be sent more frequently than about 2 Hz. In practice, fast updates are unlikely to be necessary, as even for a UE moving at 500 km/h the change in round-trip time is not more than 0.93 μs/s. The eNodeB must balance the overhead of sending regular timing advance update commands to all the UEs in the cell against a UE's ability to transmit quickly when data arrives in its transmit buffer. The eNodeB therefore configures a timer for each UE, which the UE restarts each time a timing advance update command is received; if the UE does not receive another timing advance update command before the timer expires, it must then consider its uplink to have lost synchronization.[6] In such a case, in order to avoid the risk of generating interference to uplink transmissions from other UEs, the UE is not permitted to make another uplink transmission of any sort without first transmitting a random access preamble to reinitialize the uplink timing.

One further use of timing advance is to create a switching time between uplink reception at the eNodeB and downlink transmission for TDD and half-duplex FDD operation. This switching time can be generated by applying an additional timing advance offset to the uplink transmissions, to increase the amount of timing advance beyond what is required to compensate for the round-trip propagation delay. Typically a switching time of up to 20 μs may be needed. This is discussed in more detail in Section 23.4.1.

18.3 Power Control

18.3.1 Overview

Uplink transmitter power control in a mobile communication system serves an important purpose: it balances the need for sufficient transmitted energy per bit to maintain the link quality corresponding to the required Quality-of-Service (QoS), against the needs to minimize interference to other users of the system and to maximize the battery life of the mobile terminal.

In achieving this purpose, the power control has to adapt to the characteristics of the radio propagation channel, including path-loss, shadowing and fast fading, as well as overcoming interference from other users – both within the same cell and in neighbouring cells.

The requirements for uplink interference management in LTE are quite different from those for WCDMA. In WCDMA, the uplink is basically non-orthogonal,[7] and the primary source of interference which has to be managed is intra-cell interference between different users in the same cell. Uplink users in WCDMA share the same time-frequency resources,

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[6]Note that loss of uplink synchronization is possible without leaving RRC_CONNECTED state (see Chapter 3).

[7]The later releases of WCDMA do, however, introduce a greater element of orthogonality into the uplink transmissions, by means of lower spreading factors and greater use of time-division multiplexing of different users in HSDPA and HSUPA.

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and they generate an interference rise above thermal noise at the NodeB receiver; this is known as 'Rise over Thermal' (RoT), and it has to be carefully controlled and shared between users. The primary mechanism for increasing the uplink data rate for a given user in WCDMA is to reduce the spreading factor and increase the transmission power accordingly, consuming a larger proportion of the total available RoT in the cell.

By contrast, in LTE the uplink is basically orthogonal by design, and intra-cell interference management is consequently less critical than in WCDMA. The primary mechanisms for varying the uplink data rate in LTE are varying the transmitted bandwidth and varying the Modulation and Coding Scheme (MCS), while the transmitted Power Spectral Density (PSD) could typically remain approximately constant for a given MCS.

Moreover, in WCDMA the power control [5] was primarily designed with continuous transmission in mind for circuit-switched services, while in LTE fast scheduling of different UEs is applied at 1 ms intervals. This is reflected in the fact that power control in WCDMA is periodic with a loop delay of 0.67 ms and a normal power step of ± 1 dB, while LTE allows for larger power steps (which do not have to be periodic), with a minimum loop delay of about 5 ms (see Figure 18.5).

With these considerations in mind, the power control scheme provided in LTE employs a combination of open-loop and closed-loop control. This in theory requires less feedback than a purely closed-loop scheme, as the closed-loop feedback is only needed to compensate for cases when the UE's own estimate of the required power setting is not satisfactory.

A typical mode of operation for power control in LTE involves setting a coarse operating point for the transmission PSD[8] by open-loop means, based on path-loss estimation. This would give a suitable PSD for a reference MCS in the prevailing path-loss and shadowing conditions. Faster adaptation can then be applied around the open-loop operating point by closed-loop power control. This can control interference and fine-tune the power setting to suit the channel conditions (including fast fading). However, due to the orthogonal nature of the LTE uplink, the LTE closed-loop power control does not need to be as fast as in WCDMA – in LTE it would typically be expected to operate at no more than a few hundred Hertz.

Meanwhile, the fastest and most frequent adaptation of the uplink transmissions is by means of the uplink scheduling grants, which vary the transmitted bandwidth (and accordingly the total transmitted power), together with setting the MCS, in order to reach the desired transmitted data rate.

With this combination of mechanisms, the power control scheme in LTE in practice provides support for more than one mode of operation. It can be seen as a 'toolkit' from which different power control strategies can be selected and used depending, for example, on the deployment scenario or system loading.

18.3.2 Detailed Power Control Behaviour

Detailed power control formulae are specified in LTE for the Physical Uplink Shared CHannel (PUSCH), Physical Uplink Control CHannel (PUCCH) and the Sounding Reference Signals (SRSs) [6]. The formula for each of these uplink signals follows the same basic principles; though they appear complex, in all cases they can be considered as a summation of two main terms: a basic open-loop operating point derived from static or semi-static parameters

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[8]In LTE, the PSD is set as a power per Resource Block (RB); if multiple RBs are transmitted by a UE in a subframe the power per RB is the same for all RBs.