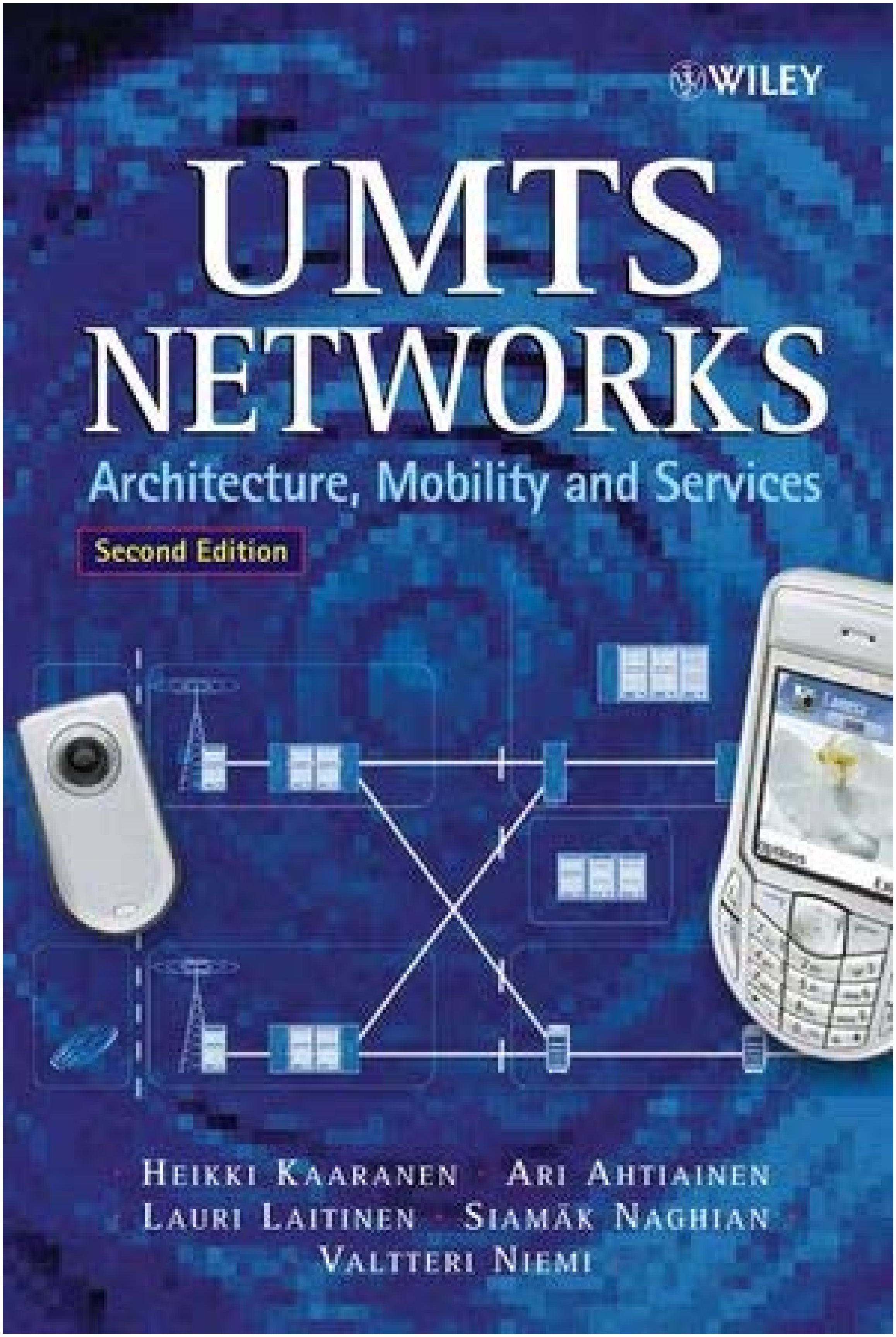
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HEIKKI KAARANEN · ARI AHTIAINEN
LAURI LAITINEN · SIAMÄK NAGHIAN
VALTTERI NIEMI

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- Intra-BS/inter-cell handover (softer handover).
- Inter-BS handover, including hard and soft handovers.
- Inter-RNC handover, including hard, soft and soft–softer handovers.
- Inter-MSC handover.
- Inter-SGSN (Serving GPRS Support Node) handover.
- Inter-system handover.

5.3.1.2 RRM—Power Control

Power control is an essential feature of any CDMA-based cellular system. Without utilising an accurate power control mechanism, these systems cannot operate. In the following subsections we first describe why power control is so essential for these cellular systems and outline the main factors underlying this fact. We then describe the kinds of power control mechanisms utilised in WCDMA-FDD radio access.

The main reasons for implementing power control are the near–far problem (see p. 119), the interference-dependent capacity of WCDMA and the limited power source of the UE. Unlike Frequency Division Multiple Access (FDMA) and Time Division Multiple Access (TDMA), both of which are bandwidth-limited multi-accesses, WCDMA is an interference-limited multiple access. In FDMA and TDMA power control is applied to reduce inter-cell interference within the cellular system which arises from frequency reuse, while in WCDMA systems the purpose of power control is mainly to reduce intra-cell interference. Meeting these targets requires optimisation of radio transmission power (i.e., that the power of every transmitter is adjusted to the level required to meet the requested QoS). Determining the transmission power level is, however, a very sophisticated task due to unpredictable variation of the radio channel.

Whatever the radio environment, power received should be at an acceptable level (e.g., at the BS for the uplink to support the requested QoS). The target of power control is to adjust the power to the desired level without any unnecessary increase in UE transmit power. This ensures that transmit power is just within the required level (neither higher nor less), taking into account the existing interference in the system.

The influence of the multipath propagation characteristics and the technical characteristics of the WCDMA system (e.g., simultaneous bandwidth sharing and near–far phenomena) has the effect of power control being essential for the WCDMA system, to overcome the drawbacks caused by the radio environment and the nature of electromagnetic waves. Without power control such phenomena as fading and interference will drive down system stability and ultimately degrade its performance dramatically.

Maximising system capacity is an invaluable asset for both advanced cellular technology suppliers and cellular network operators. System capacity is maximised if the transmitted power of each terminal is controlled such that its signal arrives at the BS with the minimum required SIR. If a terminal's signal arrives at the BS with a power value that is too low, then the required QoS for radio connection cannot be met. If the received power value is too high, then, although the performance of this terminal is good, interference to all the other terminal transmitters sharing the channel is increased and may result in unacceptable performance for other users, unless their number is reduced.

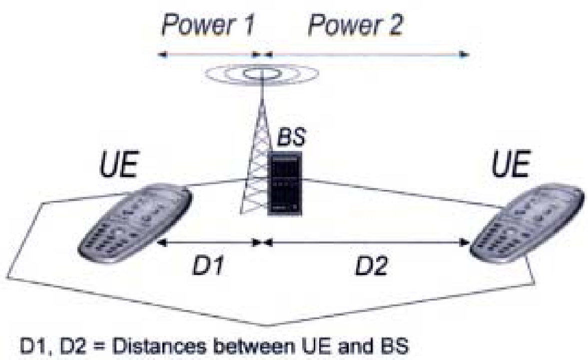

Figure 5.22 Near–far effect in the CDMA system

Due to the fact that the total bandwidth in the WCDMA system is shared simultaneously, other users can be experienced as a noise-like interference for a specific user. When the power control mechanism is missing or operates imperfectly, common sharing of the bandwidth creates a severe problem, called the "near–far" effect. In near–far situations the signal of the terminal that is close to the serving BS may dominate the signal of those terminals that are distant from the same BS. Figure 5.22 illustrates a situation in which the near–far problem could occur. The main factors that cause the near–far problem include the path loss variation of simultaneous users at different distances from the BS, the fading variation and other signal power variation of users caused by radio wave propagation mechanisms (described in Chapter 3).

In WCDMA the near–far effect can be mitigated by applying power control mechanisms, diversity techniques, soft handovers, multi-user receivers and, more generally, near–far resistance receivers. Because of the crucial drawback of the near–far effect on the performance of the WCDMA system, its mitigation is one of the pivotal purposes of power control mechanisms. These mechanisms have a considerable impact on WCDMA system capacity.

5.3.1.2.1 Basic Approaches Used in Power Control

For the reasons just outlined, it is relatively easy to determine that the optimal situation in the uplink case, from the BS receiver point of view, is that the power representing one UE's signal should always be equal to another UE's signal regardless of their distance from the BS. If so, the SIR will be optimal and the BS receiver able to decode the maximum number of transmissions. In reality, however, the radio channel is extremely unstable and radio services requested vary for different users (even for the same user and during the same radio connection). Therefore, the transmission power of UE should be controlled very accurately by utilising efficient mechanisms.

To achieve this, power control has been thoroughly investigated and, as a consequence, many power control algorithms have been developed since the advent of the CDMA scheme. These include distributed, centralised, synchronous, asynchronous, iterative and non-iterative algorithms. Most current algorithms either utilise SIR or transmit power as a reference point in the power control decision-making process.

The primary principle of Centralised Power Control (CPC) schemes is that they keep the overall power control mechanism centralised. As a result they require a central controller, which should have knowledge of all the radio connections in the RAN.

In contrast to CPC methods, distributed power control methods do not utilise a central controller. Instead, they distribute the controlling mechanism within the RAN and toward its edge. This feature makes them of special interest. CPC approaches bring about added complexity, latency and network vulnerability. The main advantage of a distributed power control algorithm is that it can respond more adaptively to a variable QoS, which is greatly important for cellular systems with packet-based transmission characteristics, like WCDMA.

5.3.1.2.2 Power Control Mechanism in UTRAN (WCDMA-FDD)

In WCDMA, power control is employed in both uplink and downlink directions. Downlink power control is basically for minimising interference with other cells and compensating for the interference from other cells, as well as achieving an acceptable SIR. However, power control for the downlink is not as vital as it is for the uplink. It is still implemented for the downlink, because it improves system performance by controlling interference from other cells.

The main target of uplink power control is to mitigate the near–far problem by making the transmission power level received from all terminals as equal as possible at the home cell for the same QoS. Therefore, uplink power control is used for fine-tuning terminal transmission power, resulting in mitigation of intra-cell interference and the near -far effect. Note that the power control mechanism specified for WCDMA is, in principle, a distributed approach.

The power control mechanisms used in the GSM are clearly inadequate to guarantee this situation in WCDMA and, thus, WCDMA takes a different approach to the matter. In the GSM, power control is applied to the connection once or twice per second, but, due to its critical nature in WCDMA, the power used in the connection is adjusted 1,500 times per second (i.e., the power control cycle is repeated for each radio frame in association with the DCH). Therefore, power adjustment steps are considerably faster than in the GSM.

To manage power control properly in WCDMA, the system uses two different power control mechanisms, as defined in Figure 5.23. These power control mechanisms are:

- Open Loop Power Control (OLPC).
- Closed Loop Power Control (CLPC), including inner and outer loop power control mechanisms.

By applying all these different power control mechanisms together, the UTRAN benefits from the advantages of CPC as well by overlaying the inner CLPC with the outer CLPC mechanism in order to keep the target SIR at an acceptable level.

5.3.1.2.3 Open Loop Power Control (OLPC)

In OLPC, which is basically used for uplink power adjusting, the UE adjusts its transmission power based on an estimate of the received signal level from the BS

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