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WCDMA FOR UMTS

Radio Access For Third Generation Mobile Communications

Edited by Harri Holma and Antti Toskala

IPR2025-00756, OnePlus Ex. 1016
Page 1 of 12

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IPR2025-00756, OnePlus Ex. 1016
Page 2 of 12

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5.2 UTRAN Architecture

UTRAN architecture is highlighted in Figure 5.3.

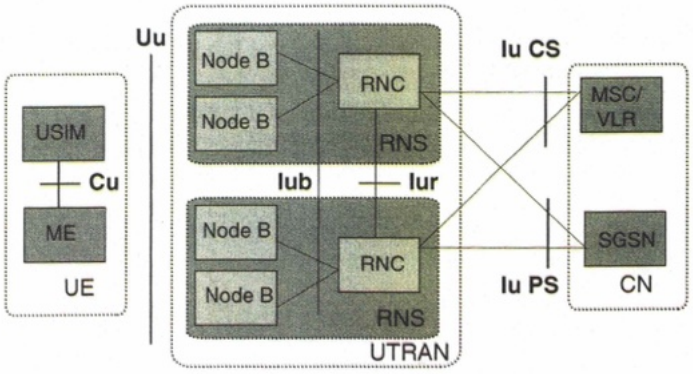


Figure 5.3. UTRAN architecture

UTRAN consists of one or more Radio Network Sub-systems (RNS). An RNS is a sub-network within UTRAN and consists of one Radio Network Controller (RNC) and one or more Node Bs. RNCs may be connected to each other via an Iur interface. RNCs and Node Bs are connected with an Iub Interface.

Before entering into a brief description of the UTRAN network elements (in this section) and a more extensive description of UTRAN interfaces (in the following sections), we present the main characteristics of UTRAN that have also been the main requirements for the design of the UTRAN architecture, functions and protocols. These can be summarised in the following points:

- *Support of UTRA* and all the related functionality. In particular, the major impact on the design of UTRAN has been the requirement to support *soft handover* (one terminal connected to the network via two or more active cells) and the WCDMA-specific *Radio Resource Management* algorithms.

- Maximisation of the *commonalities in the handling of packet-switched and circuit-switched data*, with a unique air interface protocol stack and with the use of the same interface for the connection from UTRAN to both the PS and CS domains of the core network.

- Maximisation of the *commonalities with GSM*, when possible.

- Use of the *ATM transport* as the main transport mechanism in UTRAN.

5.2.1 The Radio Network Controller

The RNC (Radio Network Controller) is the network element responsible for the control of the radio resources of UTRAN. It interfaces the CN (normally to one MSC and one SGSN)

IPR2025-00756, OnePlus Ex. 1016
Page 4 of 12

Second, the base station does not need to increase the downlink power of that connection even if the mobile sends a power-up command. The network can control the quality of the different downlink connections very quickly by not obeying the power control commands from the mobile. This approach could be used, for example, during downlink overload to reduce the downlink power of those connections that have a lower priority, such as background-type services (see load control in Section 9.6). This reduction of downlink powers can take place at the frequency of fast power control, i.e. 1.5 kHz.

9.3 Handovers

9.3.1 Intra-frequency Handovers

9.3.1.1 Handover Algorithms

The algorithms to be presented shortly are the basic cdmaOne algorithm (IS-95A) [3, 4, 5] and the WCDMA soft handover algorithm [4, 6]. Both algorithms use pilot channel E_c/I_0 as the handover measurement quantity, which is signalled to RNC by using layer 3 signalling (see Section 7.7).

The following terminology is used in the handover description:

Active set:

The cells in the active set form a soft handover connection to the mobile station.

Candidate set:

The candidate set is the list of cells that are not presently used in the soft handover connection, but whose pilot E_c/I_0 are strong enough to be added to the active set. The candidate set is not used in the WCDMA handover algorithm.

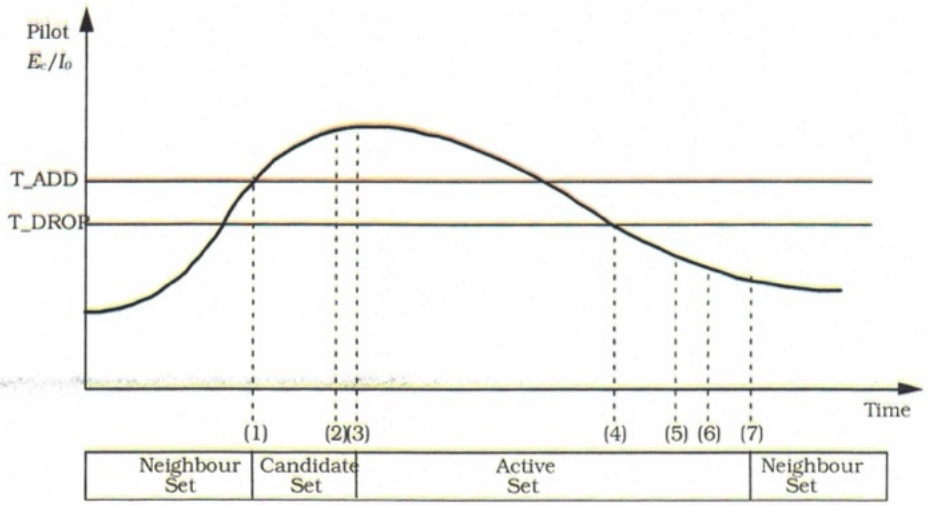
Neighbour set/monitored set:

The neighbour set or monitored set is the list of cells that the mobile station continuously measures, but whose pilot E_c/I_0 are not strong enough to be added to the active set.

Basic cdmaOne algorithm (IS-95A algorithm)

The functionality of the basic cdmaOne algorithm is depicted in Figure 9.17. In the IS-95A algorithm the handover threshold is a fixed value of received pilot E_c/I_0. The problem with the IS-95A algorithm is that some locations in the cell receive only weak pilots (requiring a lower threshold) and other locations receive a few strong and dominant pilots (requiring higher handover thresholds). Therefore an algorithm with dynamic thresholds is proposed [5]. In the modified cdmaOne algorithm (IS-95B) the only difference compared to the basic algorithm is the active set maintenance procedure. Candidate set maintenance is performed in a similar manner as in the basic algorithm.

IPR2025-00756, OnePlus Ex. 1016
Page 5 of 12



(1) Pilot strength exceeds *T_ADD*. Mobile station sends a Pilot Strength Measurement Message and transfers pilot to the candidate set.
(2) Base station sends a Handover Direction Message.
(3) Mobile station transfers pilot to the active set and sends a Handover Completion Message.
(4) Pilot strength drops below *T_DROP*. Mobile station starts the handover drop timer.
(5) Handover drop timer expires. Mobile station sends a Pilot Strength Measurement Message.
(6) Base station sends a Handover Direction Message.
Mobile station moves pilot from the active set to the neighbour set and sends a Handover Completion Message.

Figure 9.17. Basic cdmaOne algorithm (IS-95A)

WCDMA handover algorithm

The WCDMA handover algorithm is described in Figure 9.18. For more detailed information see the 3GPP specification [6].

IPR2025-00756, OnePlus Ex. 1016
Page 6 of 12

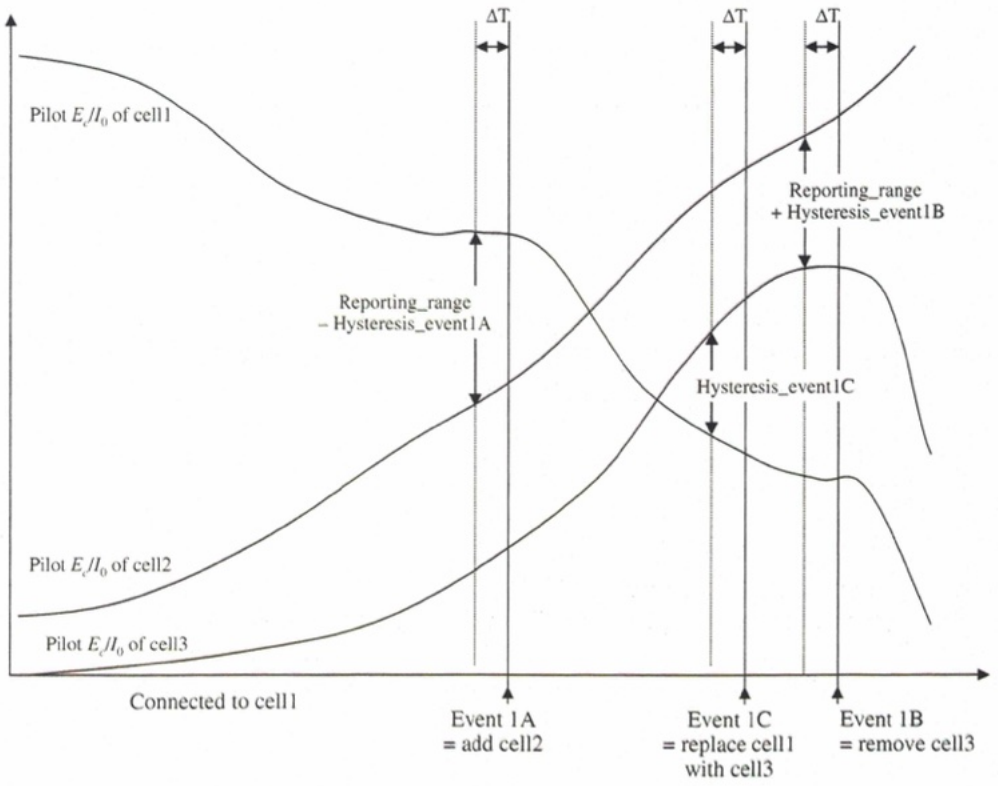


Figure 9.18. General scheme of the WCDMA soft handover algorithm

The soft handover algorithm as described in Figure 9.18 is as follows:

- If $Pilot_E_c/I_0 > Best_\ Pilot_E_c/I_0 - Reporting_range + Hysteresis_event1A$ for a period of ΔT and the active set is not full, the cell is added to the active set. This event is called Event 1A or Radio Link Addition
- If $Pilot_E_c/I_0 < Best_\ Pilot_E_c/I_0 - Reporting_range - Hysteresis_event1B$ for a period of ΔT, then the cell is removed from the active set. This event is called Event 1B or Radio Link Removal
- If the active set is full and $Best_candidate_Pilot_E_c/I_0 > Worst_Old_Pilot_E_c/I_0 + Hysteresis_event1C$ for a period of ΔT, then the weakest cell in the active set is replaced by the strongest candidate cell (i.e. strongest cell in the monitored set). This event is called Event 1C or Combined Radio Link Addition and Removal. The maximum size of the active set in Figure 9.18 is assumed to be two.

where

- *Reporting_range* is the threshold for soft handover
- *Hysteresis_event1A* is the addition hysteresis
- *Hysteresis_event1B* is the removal hysteresis
- *Hysteresis_event1C* is the replacement hysteresis
- ΔT is the time to trigger

IPR2025-00756, OnePlus Ex. 1016
Page 7 of 12

- *Best_ Pilot_E_c/I_0* is the strongest measured cell in the active set
- *Worst_Old_Pilot_E_c/I_0* is the weakest measured cell in the active set
- *Best_candidate_Pilot_E_c/I_0* is the strongest measured cell in the monitored set
- *Pilot_E_c/I_0* is the measured and filtered quantity.

Before the pilot E_c/I_0 is used by the active set update algorithm in the mobile, some filtering is applied, for example an arithmetic mean over a certain number of the last measured values is taken. The measurements of the pilot E_c/I_0 are discussed in Section 9.3.1.2.

In the WCDMA algorithm the relative thresholds are used, while in IS-95A and IS-95B absolute thresholds are used. All three algorithms are based on the pilot E_c/I_0 measurement of the mobile station. The largest benefit of the WCDMA algorithm when compared to the IS-95A algorithm is its easy parameterisation. No parameter tuning is required for high and low interference areas. The benefit is obtained with the relative thresholds.

9.3.1.2 Handover Measurements

The accuracy of the handover measurements, i.e. pilot E_c/I_0 measurements, is important for handover performance. The effect of the filtering length on measurement accuracy is shown in Figure 9.19 with simulation results at 3 km/h and in Figure 9.20 at 50 km/h. The mobile travels the same distance in both figures. Path loss, shadowing and interference are not considered in these examples; only the effect of fast fading is shown. The target of the handover measurement is to obtain a measurement result where the effect of fast fading is averaged out. The example measurement here is done by taking one sample per 10 ms frame. The correct measurement value is 0 dB and the difference from that value is caused only by fast fading which is not completely averaged out. The assumed multipath profile here is one-path Rayleigh fading channel, which is the worst-case assumption. If multipath diversity is available and the mobile can measure with multiple fingers, fast fading causes fewer inaccuracies than in the one-path channel.

The filtering length of 100 ms causes very large measurement errors at 3 km/h, since fast fading cannot be filtered within such a short period, as shown in the uppermost part of Figure 9.19. Due to the measurement errors, unnecessary handovers take place, leading to increased handover signalling and short active set update periods. By increasing the filtering length to 1 s the measurement accuracy can be clearly improved. At low mobile speeds long filtering periods are advantageous.

At 50 km/h the filtering period of 100 ms gives reasonably good performance and only relatively small improvements can be achieved by increasing the filtering period. The drawback of long filtering periods is the delay caused to the handovers. At high mobile speeds fast handovers are important, especially in micro cellular networks where the path loss to the base stations can change quickly when a mobile is driven round a corner.

The effect of a very delayed handover with a fast mobile and a high bit rate connection is shown in Figure 9.21. As long as base station BS2 is not in the active set of the mobile, it cannot control the uplink transmission power, and noise rise peaks can be caused to the base station BS2. This problem can occur only if

- there are long delays in the handovers due to long averaging in the measurements or due to delays in the handover signalling, and
- the mobile is moving very fast, and
- the connection is using high bit rates.

IPR2025-00756, OnePlus Ex. 1016
Page 8 of 12

Therefore, very long filtering periods cannot be used in the handover measurements. The optimal filtering period is a trade-off between measurement accuracy and handover delay.

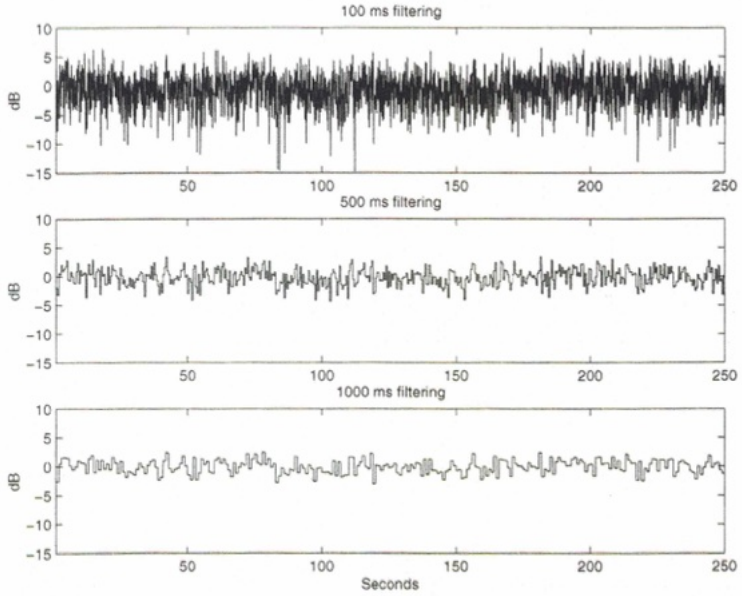


Figure 9.19. Handover measurement accuracy at 3 km/h in one-path Rayleigh fading channel

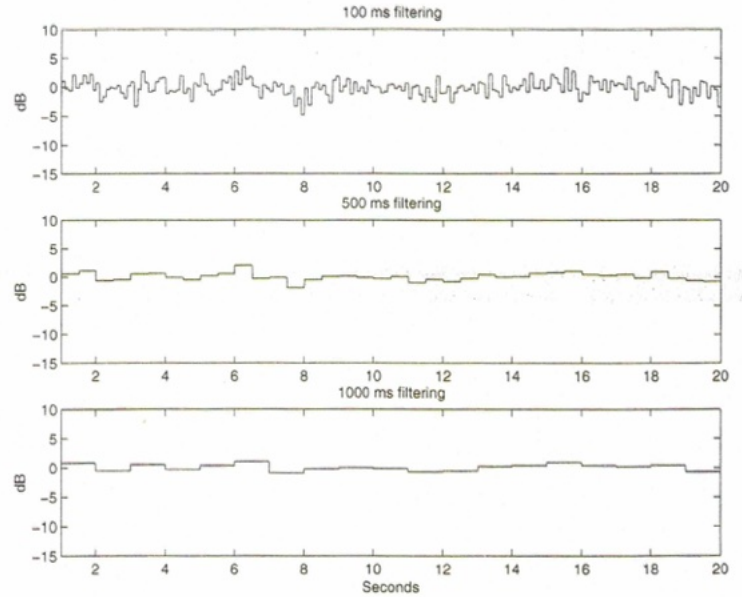


Figure 9.20. Handover measurement accuracy at 50 km/h in one-path Rayleigh fading channel

IPR2025-00756, OnePlus Ex. 1016
Page 9 of 12

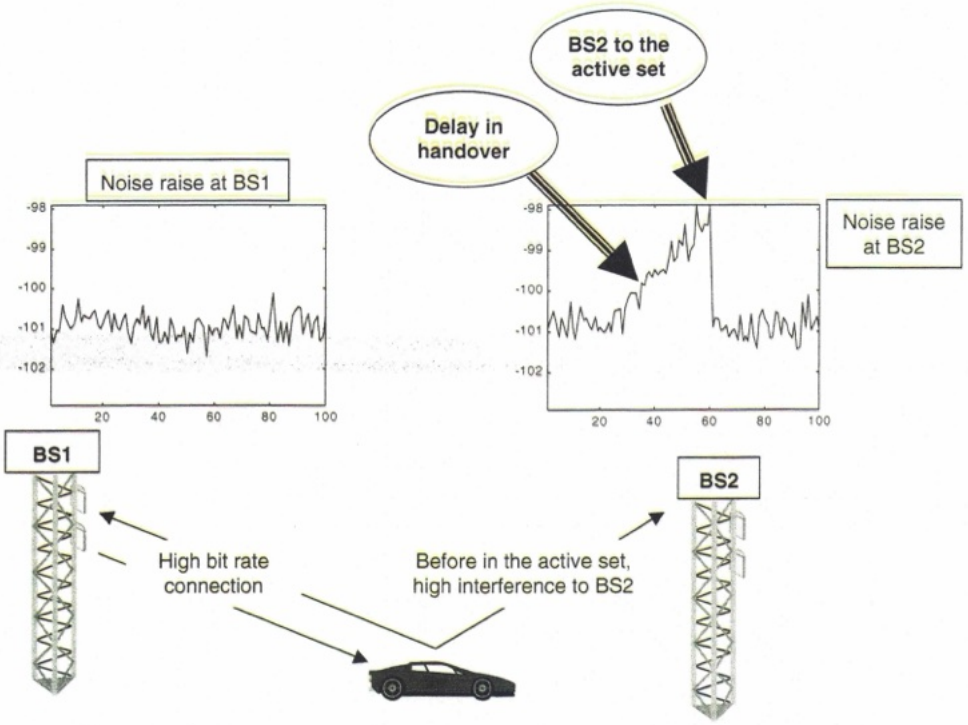


Figure 9.21. Noise rise peaks in the base station reception due to a delayed handover

9.3.1.3 Soft Handover Gains

This section presents some examples of soft handover gains that have been obtained in simulations. The results were presented and discussed in more detail in [7]. The soft handover gains improve the coverage and capacity of the WCDMA network.

Figure 9.22 and Figure 9.23 show the simulation results of 8 kbps speech in ITU Pedestrian A channel, at 3 km/h, with soft handover containing two base stations in the active set. The relative path loss from the mobile to BS1 compared to BS2 was 0, –3, –6 or –10 dB. The highest gains are obtained when the path loss is the same to both base stations, i.e. the relative path loss difference is 0 dB. Figure 9.22 shows the soft handover gain in uplink transmission power with base station receive antenna diversity. Figure 9.23 shows the corresponding gains in downlink transmission power without transmit or receive antenna diversity. The gains are relative to the single-link case. It should be noted that ITU Pedestrian A channel has only little multipath diversity, and thus the soft handover gains are relatively high. With more multipath diversity, the handover gains are lower.

In Figure 9.22 the maximum reduction of the mobile transmission power due to soft handover is 1.8 dB if the path loss is the same to both soft handover base stations. If the path loss difference is very large, the soft handover can cause an increase in the mobile transmission power. This increase is caused by the signalling errors of the uplink power control commands which are transmitted in the downlink. But, typically, the base station would not be in the active set of the mobile station if the path loss were 3–6 dB larger than the path loss to the nearest base station.

IPR2025-00756, OnePlus Ex. 1016
Page 10 of 12

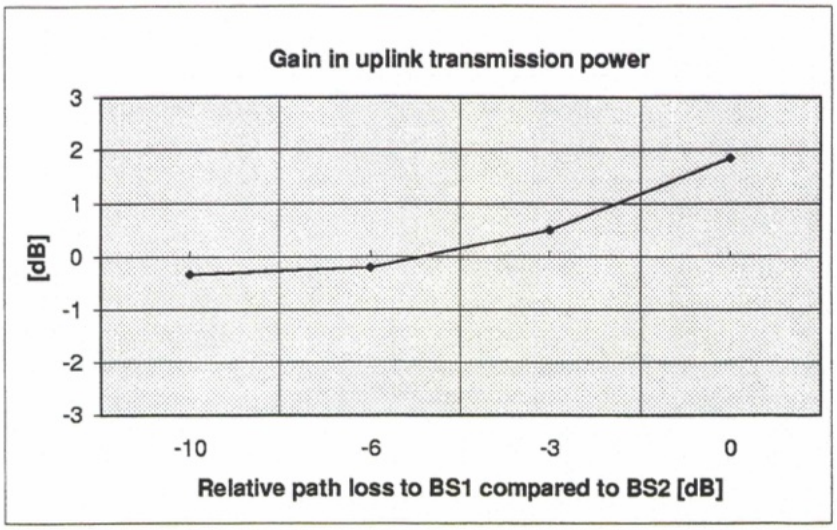


Figure 9.22. Soft handover gain in uplink transmission power (positive value = gain, negative value = loss)

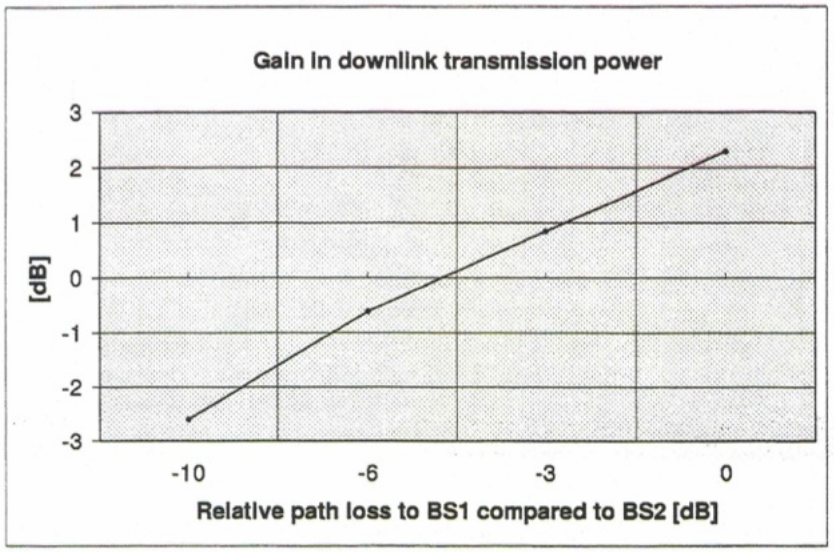


Figure 9.23. Soft handover gain in downlink transmission power (positive = gain, negative = loss)

In the downlink the maximum soft handover gain is 2.3 dB (Figure 9.23), which is more than in the uplink (Figure 9.22). The reason is that no antenna diversity is assumed in the downlink, and thus in the downlink there is more need for macro diversity in soft handover.

In the downlink, soft handover causes an increase in the required downlink transmission power if the path loss difference is more than 4–5 dB in this example. In that case the

IPR2025-00756, OnePlus Ex. 1016
Page 11 of 12

mobile cannot receive effectively the signal from the more distant base station, and no additional diversity gain is provided.

These soft handover gains are example values only. The gains depend on the multipath profile, mobile speed, receiver algorithms and base station antenna configurations. The gains shown in this section are from the capacity point of view, while the soft handover gains for coverage are discussed in Section 11.2.1.4. The difference between these two aspects is that in the case of maximum coverage the mobile is transmitting on constant full power while in the present section fast power control is assumed.

9.3.1.4 Soft Handover Probabilities

Radio network planning is responsible for proper handover parameter setting and site planning so that the soft handover probability does not exceed the desired value. Typically, soft handover probability is required to keep below 30–40%, mainly because excessive soft handover probabilities could decreased the downlink capacity as shown in Figure 9.23. In the downlink each soft handover connection increases the transmitted interference to the network. When the increased interference exceeds the diversity gain, the soft handover does not provide any gain for system performance. Also, in the downlink the soft handover connections use more orthogonal codes than do only single-link connections. In both uplink and downlink the soft handovers require baseband resources in the base station, transmission capacity over the Iub interface, and RNC resources. It is the task of radio network planning and optimisation to keep the soft handover overhead below a desired threshold while still providing enough diversity in both uplink and downlink.

9.3.2 Inter-frequency and Inter-system Handovers

WCDMA supports handovers between different WCDMA carriers and between WCDMA and GSM. These handovers are used for coverage or load balancing reasons. At the start of WCDMA deployment, handovers to GSM are needed to provide continuous coverage. Inter-frequency handovers between WCDMA carriers are needed to balance the loading between carriers if there are several carriers in the base station. The load balancing can be obtained also by inter-system handovers between WCDMA and GSM. Inter-frequency handover also enables handover between different cell layers of the multi-layered cellular network, when the cell layers use different carrier frequencies. This kind of situation is possible, for example, between macro and micro cells. The compressed mode procedure for inter-frequency and inter-system handover measurements is described in Chapter 6.

The needs of the inter-system handover between WCDMA and GSM are taken into account in the WCDMA frame timing definition and GSM-compatible multi-frame structure [6]. For smooth inter-operation, the inter-system information exchange is needed in order to allow WCDMA to notify the mobile station of the existing GSM frequencies in the area, and vice versa [6].

9.4 Measurement of Air Interface Load

If the radio resource management is based on the interference levels in the air interface, the air interface load need to be measured. The estimation of the uplink load is presented in Section 9.4.1 and the estimation of the downlink load is Section 9.4.2.

IPR2025-00756, OnePlus Ex. 1016
Page 12 of 12