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Radio Sub-System Link Control

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No changes since the previously distributed version.

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Explanatory notes are contained in brackets {}.

CONTENTS

1. SCOPE :

This recommendation specifies the Radio sub-system link control implemented in the Mobile Station (MS), Base Station (BS) and Mobile Switching Centre (MSC) of the GSM system.

2. GENERAL :

The radio sub-system link control aspects that are addressed are as follows :

- Handover
- RF Power control
- Radio link Failure
- Cell selection and re-selection in Idle mode.

Handover is required to maintain a call in progress as a MS passes from one cell coverage area to another and may also be employed to meet network management requirements, e.g. relief of congestion.

Handover may occur during a call from TCH to TCH, it may also occur from DCCH to DCCH, e.g. during the initial signalling period at call set-up.

The handover may be either from a channel on one cell to another channel on a surrounding cell, or between channels on the same cell. Examples are given of handover strategies, however, these will be determined in detail by the network operator.

Adaptive control of the RF transmit power from an MS and optionally from the BS is implemented in order to optimize the uplink and downlink performance and minimise the effects of co-channel interference in the system.

The criteria for determining radio link failure are specified in order to ensure that calls which fail either from loss of radio coverage or unacceptable interference are satisfactorily handled by the network. Radio link failure may result in either re-establishment or release of the call in progress.

Procedures for cell selection and re-selection whilst in Idle mode (i.e not actively processing a call), are specified in order to ensure that a mobile is camped on a cell with which it can reliably communicate on both the radio uplink and downlink.

Information signalled between the MS and BS is summarised in Tables 1 and 2. A full specification of the Layer 1 header is given in GSM Recommendation 04.04, and of the Layer 3 fields in GSM Recommendation 04.08.

3. HANDOVER :

3.1 OVERALL PROCESS :

The overall handover process is implemented in the MS, BS and MSC. Measurement of radio subsystem downlink performance and signal strengths received from surrounding cells, is made in the MS. These measurements are signalled to the BS for assessment. The BS measures the uplink performance for the MS being served and also assesses the signal strength of interference on its idle traffic channels. Initial assessment of the measurements in conjunction with defined thresholds and handover strategy may be performed in the BS. Assessment requiring measurement results from other BSs or other information resident in the MSC, may be performed in the MSC.

GSM Recommendation 03.09 describes the handover procedures to be used in PLMNs.

3.2 MS MEASUREMENT PROCEDURE :

A procedure shall be implemented in the MS by which it monitors the downlink RX signal level and quality from its serving cell and the downlink RX signal level and BSIC of surrounding BSs. The method of identification of surrounding BSs is described in Section 7.2. The requirements for the MS measurements are given in section 8.1.

3.3 BS MEASUREMENT PROCEDURE :

A procedure shall be implemented in the BS by which it monitors the uplink RX signal level and quality from each MS being served by the cell. A procedure shall be implemented by which the BS monitors the levels of interference on its idle traffic channels.

3.4 STRATEGY :

The handover strategy employed by the network for radio link control determines the handover decision that will be made based on the measurement results reported by the MS/BS and various parameters set for each cell. Network directed handover may also occur for reasons other than radio link control, e.g. to control traffic distribution between cells. The exact handover strategies will be determined by the network operator, a detailed example of a basic overall algorithm appears in Appendix A. Possible types of handover are as follows :

Inter-cell handover :

Intercell handover from the serving cell to a surrounding cell will normally occur either when the handover measurements show low RXLEV and/or RXQUAL on the current serving cell and a better RXLEV available from a surrounding cell, or when a surrounding cell allows communication with a lower TX power level. This typically indicates that an MS that is on the border of the cell area.

Intra-cell handover :

Intra-cell handover from one channel/timeslot in the serving cell to another channel/timeslot in the same cell will normally be performed if the handover measurements show a low RXQUAL, but a high RXLEV on the serving cell. This indicates a degradation of quality caused by interference even though the MS is situated within the serving cell. The intra-cell handover should provide a channel with a lower level of interference. Intra-cell handover can occur either to a timeslot on a new carrier or to a different timeslot on the same carrier.

GSM Recommendation 08.08 defines the causes for handover that may be signalled from BS to MSC.

4. RF POWER CONTROL :

4.1 OVERALL PROCESS :

RF power control is employed to minimise the transmit power required by MS or BS whilst maintaining the quality of the radio links. By minimising the transmit power levels, interference to co-channel users is reduced.

4.2 MS IMPLEMENTATION :

RF power control shall be implemented in the MS.

The RF power level to be employed by the MS is indicated by means of the 5 bit TXPWR field sent either in the layer 1 header of each downlink SACCH message block, or in a dedicated signalling block.

The MS shall confirm the power level that it is currently employing by setting the MS_TXPWR_CONF field in the uplink SACCH L1 header to its current power setting. The value of this field shall be the power setting actually used by the mobile for the last burst of the previous SACCH period.

The MS shall employ the most recently commanded RF power level appropriate to the channel for all transmitted bursts on either a TCH (including handover access burst), FACCH, SACCH or SDCCH.

When accessing a cell on the RACH (random access) and before receiving the first power command during a communication on a DCCH or TCH (after an IMMEDIATE ASSIGNMENT), the MS shall use either the power level defined by the MS_TXPWR_MAX_CCH parameter broadcast on the BCCH of the cell, or the maximum TXPWR of the MS as defined by its power class, whichever is the lower.

4.3 MS POWER CONTROL RANGE :

The range over which a MS shall be capable of varying its RF output power shall be from its maximum output down to 20mW, in steps of nominally 2dB.

GSM Recommendation 05.05 gives a detailed definition of the RF power level step size and tolerances.

4.4 BS IMPLEMENTATION :

RF power control may be optionally implemented in the BS.

4.5 BS POWER CONTROL RANGE :

The range over which the BS shall be capable of reducing its RF output power from its maximum level shall be nominally 30dB, in 15 steps of nominally 2dB.

GSM Recommendation 05.05 gives a detailed definition of the RF power level step size and tolerances.

4.6 STRATEGY :

The RF power control strategy employed by the network determines the TXPWR command that is signalled to the MS, and the RF power level that is employed by the BS.

The RF power level to be employed in each case will be based on the measurement results reported by the MS/BS and various parameters set for each cell. The exact strategies will be determined by the network operator. A detailed example of a basic algorithm appears in Appendix A.

4.7 TIMING :

Upon receipt of a command from the SACCH to change its RF power level (TXPWR field) the MS shall change to the new level at a rate of one nominal 2dB power step every 60ms (13 TDMA frames), i.e. a full range change of 15 steps should take about 900ms . The change shall commence at the first TDMA frame belonging to the next reporting period (as specified in 8.4). The MS shall change the power one nominal 2 dB step at a time, at a rate of one step every 60 ms following the initial change, irrespective of whether actual transmission takes place or not.

In case of channel change the commanded power level shall be applied on the new channel immediately.

5. RADIO LINK FAILURE :

5.1 CRITERION :

The criterion for determining Radio Link Failure in the MS shall be based on the success rate of decoding messages on the downlink SACCH.

5.2 MS PROCEDURE :

The radio link failure criterion is based on the radio link counter S. If the MS is unable to decode a SACCH message, S is decreased by 1. In the case of a successful reception of a SACCH message S is increased by 2. In any case S shall not exceed the value of RADIO_LINK_TIMEOUT. If S reaches 0 a radio link failure shall be declared. The action to be taken is specified in GSM Recommendation 04.08. The RADIO_LINK_TIMEOUT parameter is transmitted by each BS in the BCCH data (see Table 1).

Note: The MS shall continue transmitting as normal on the uplink until S reaches 0.

The algorithm shall start after the assignment of a dedicated channel and S shall be initialized to RADIO_LINK_TIMEOUT.

{The aim of determining radio link failure in the MS is to ensure that calls with unacceptable voice/data quality, which cannot be improved either by RF power control or handover, are either re-established or released in a defined manner. In general the parameters that control the forced release should be set such that the forced release will not normally occur until the call has degraded to a quality below that at which the majority of subscribers would have manually released. This ensures that, for example, a call on the edge of a radio coverage area, although of bad quality, can usually be completed if the subscriber wishes.}

5.3 BS PROCEDURE :

The criteria for determining radio link failure in the BS should be based upon either the error rate on the uplink SACCH or on RXLEV/RXQUAL measurements of the MS. The exact criteria to be employed shall be determined by the network operator.

6. CELL SELECTION AND RE-SELECTION

6.1 Overall process

Whilst in Idle mode (i.e. not engaged in communicating with a BS), an MS shall implement the cell selection and re-selection procedures described in this section.

The procedures ensure that the MS is camped on a cell from which it can reliably decode downlink data and with which it has a high probability of communications on the uplink. The choice of cell is determined by the path loss criterion in section 6.4. Once the MS is camped on a cell, access to the network is allowed.

Definitions.

An available PLMN is one for which the MS has found at least one cell which is unbarred according to the value of Cell_bar_access and which has the parameter C1 (see section 6.4) greater than 0.

A suitable cell is one which:
- Is part of the selected PLMN
- Is unbarred
- Has the parameter C1 > 0

An MS is said to be camped on a cell when it has determined that the cell is suitable (i.e. the conditions specified in Section 6.2 are satisfied) and stays tuned to a BCCH + CCCH of that cell. While camped on a cell, an MS may receive paging messages or under certain conditions make random access attempts on a RACH of that cell, and read BCCH data from that cell.

The MS shall not use the discontinuous reception (DRX) mode of operation (i.e. powering itself down when it is not expecting paging messages from the network) while performing the algorithm of sections 6.2 and 6.3. However use of powering down is permitted at all other times in idle mode.

For the purposes of cell selection and reselection, the MS is required to maintain an average of received signal strengths for all monitored frequencies. These quantities termed the "receive level averages", shall be unweighted averages of the received signal strengths measured in dBm.

The cell selection and reselection procedures make use of the "BCCH Allocation" (BA) list. There are in fact two BA lists which may or may not be identical, depending on choices made by the PLMN operator.

(i) BA (BCCH) - This is the BA sent in System Information Messages on the BCCH. It is the list of BCCH carriers in use by a given PLMN in a given geographical area. It is used by the MS in cell selection and reselection.

(ii) BA (SACCH) - This is the BA sent in System Information Messages on the SACCH and indicates to the MS which BCCH carriers are to be monitored for handover purposes (see Section 7 & 8)

Note: When the MS goes on to a TCH or SDCCH, it shall start monitoring BCCH carriers in BA (BCCH) until it gets its first BA (SACCH) message.

Note: The Access Control Class bit (See GSM rec 04.08) has no impact on the algorithms in section 6 i.e. the MS shall camp on the cell indicated by the algorithm, even if the relevant Access Control Class bit is set.

6.2 Cell Selection - No BCCH Information Available

An MS which is not currently camped on a cell (e.g. at switch-on) shall, in the case where it has no BCCH information stored, perform the following algorithm.

However, if no SIM is present, the MS shall instead perform the algorithm of section 6.8.

The MS shall search all 124 RF channels in the GSM system, take readings of received RF signal strength on each RF channel, and calculate the received level average for each. The averaging is based on at least five measurement samples per RF carrier spread over 3 to 5 s, the measurement samples from the different RF carriers being spread evenly during this period.

The MS shall tune to the carrier with the highest average received level and determine whether or not this carrier is a BCCH carrier (e.g. by searching for frequency correction bursts). If it is a BCCH carrier, the MS shall attempt to synchronize to this carrier and read the BCCH data. The MS shall camp on the cell provided it can successfully decode the BCCH data and this data indicates that the cell is suitable . (If the cell is part of the selected PLMN but is not suitable, the MS shall use the BCCH Allocation obtained from this cell and subsequently only search these BCCH carriers. If the cell is not part of the selected PLMN, the PLMN identity shall be noted for use in any subsequent PLMN reselection.) Otherwise the MS shall tune to the next highest carrier etc.

{CELL_BAR_ACCESS may be employed to bar a cell that is only intended to handle handover traffic etc. A typical example of this could be an umbrella cell which encompasses a number of microcells.}

If at least the 30 strongest RF channels have been tried, but no suitable cell has been found, provided the RF channels which have been searched include at least one BCCH carrier, the available PLMNs shall be presented to the user according to the requirements of GSM Rec 02.11, and the algorithm of section 6.8 shall be performed, otherwise more RF channels shall be searched until at least one BCCH carrier is found.

{30 RF channels are specified to give a high probability of finding all suitable PLMNs, without making the process take too long.}

{Note: If extra frequencies are defined for the GSM system which are allowed to carry BCCH data, then this algorithm may need to be amended.}

GSM recommendation 02.11 describes the requirements for PLMN selection. The location updating procedure is defined in GSM Recommendation 04.08 and the location area identification (LAI) is defined in GSM Recommendation 03.03. Whenever a new PLMN is selected (according to the procedures in GSM recommendation 02.11) the MS shall camp on a suitable cell of the new PLMN if possible.

6.3 Cell Selection - BCCH Information Available

The MS may include optional storage of BCCH carrier information when switched off. For example, the MS may store the BCCH carriers in use by the PLMN selected when it was last active in the GSM network. A MS may also store BCCH carriers for more than one PLMN which it has selected previously (e.g. at national borders or when more than one PLMN serves a country), in which case the BCCH carrier lists must be kept quite separate.

If an MS includes a BCCH carrier list of the selected PLMN it shall perform the same algorithm as in section 6.2 except that only the BCCH carriers in the list need to be searched.

If an MS decodes BCCH data from a cell of the selected PLMN but is unable to camp on that cell, the BA of that cell shall be examined. Any BCCH carriers in the BA which are not in the MS's list of BCCH carriers to be searched shall be added to the list.

If no suitable cell has been found after all the BCCH carriers in the list have been searched, the MS shall perform the algorithm of section 6.2, i.e. acting as if there were no stored BCCH carrier information. Since information concerning a number of channels is already known to the MS, it may assign high priority to measurements on those of the 30 strongest carriers from which it has not previously made attempts to obtain BCCH information, and omit repeated measurements on the known ones.

The BCCH carrier list for a given PLMN stored in an MS shall be reset and updated whenever the MS, camping on a BCCH carrier, retrieves new BCCH data from that PLMN.

6.4 Path Loss Criterion for Cell Selection and Reselection

The path loss criterion parameter C1 used for cell selection and reselection is defined by:

C1 = (A - Max(B,0))

where A = Received Level Average - RXLEV_ACCESS_MIN
B = MS_TXPWR_MAX_CCH - P

RXLEV_ACCESS_MIN = Minimum received level at the MS required for access to the system.

MS_TXPWR_MAX_CCH = Maximum TXPWR level an MS may use when accessing the system until otherwise commanded.

P = Maximum RF output power of the MS.

All values are expressed in dBm.

(This parameter is used to ensure that the MS is camped on the cell with which it has the highest probability of successful communication on uplink and downlink.)

6.5 Downlink Signalling Failure

The downlink signalling failure criterion is based on the downlink signalling failure counter DSC. When the MS camps on a cell, DSC shall be initialized to a value equal to the nearest integer to 90/N where N is the BS_PA_MFRMS parameter for that cell (see GSM Rec 05.02). Thereafter, whenever the MS attempts to decode a message in its paging subchannel; if a message is successfully decoded DSC is increased by 1, (however never beyond the nearest integer to 90/N), otherwise DSC is decreased by 4. When DSC reaches 0, a downlink signalling failure shall be declared.

(The network sends the paging subchannel for a given MS every BS_PA_MFRMS multiframes. The network is required to send a valid signalling frame in every block of every paging subchannel (see GSM Rec 04.08), and the MS is required to attempt to decode a message every time its paging subchannel is sent.)

Downlink signalling failure shall result in cell reselection. (See section 6.6)

6.6 Cell Reselection in Idle Mode

6.6.1 Monitoring of Received Level and BCCH data

Whilst in Idle Mode an MS shall continue to monitor all BCCH carriers as indicated by the BCCH Allocation (BA - See Table 1). A running average of received level in the preceding 5 to 60 seconds shall be maintained for each carrier in the BCCH Allocation.

For the serving cell receive level measurement samples shall be taken at least for each paging block of the MS and the receive level average shall be determined using samples collected over a period of 5 s or five consecutive paging blocks of that MS, whichever is the greater period.

At least 5 received level measurement samples are required per receive level average value. New sets of receive level average values shall be calculated as often as possible.

The same number of measurement samples shall be taken for all non serving cell BCCH carriers, and the samples allocated to each carrier shall as far as possible be uniformly distributed over each evaluation period.

The list of the 6 strongest carriers shall be updated at least every minute and may be updated more frequently.

In order to minimise power consumption, MSs that employ DRX (i.e. power down when paging blocks are not due) should monitor the signal strengths of non-serving cell BCCH carriers during the frames of the Paging Block that they are required to listen to. Received level measurement samples can thus be taken on several non-serving BCCH carriers and on the serving carrier during each Paging Block.

The MS shall include the BCCH carrier of the current serving cell (i.e. the cell the MS is camped on) in this measurement routine.

The MS shall attempt to decode the full BCCH data of the serving cell at least every 30 seconds.

The MS shall attempt to decode the BCCH data block that contains the parameters affecting cell reselection for each of the 6 strongest non-serving cell BCCH carriers at least every 5 minutes. When the MS recognizes that a new BCCH carrier has become one of the 6 strongest, the BCCH data shall be decoded for the new carrier within 30 seconds.

The MS shall attempt to check the BSIC for each of the 6 strongest non serving cell BCCH carriers at least every 30 seconds, to confirm that it is monitoring the same cell. If a change of BSIC is detected then the carrier shall be treated as a new carrier and the BCCH data redetermined.

When requested by the user, the MS shall monitor the 30 strongest GSM carriers to determine, within 15 seconds, which PLMNs are available. This monitoring shall be done so as to minimise interruptions to the monitoring of the PCH.

6.6.2 Reselection Algorithm

The MS shall perform the following algorithm to ensure that it is camped on the most appropriate cell.
At least every 5 s the MS shall calculate the value of C1 for the serving cell and re-calculate C1 values for non serving cells (if necessary). The MS shall then check for conditions (i) and (iv) below.

The MS shall reselect a new cell if any of the following occur:

(i) Path loss criterion (C1) for current serving cell falls below zero for a period of 5 seconds.

(ii) The MS detects a downlink signalling failure (see 6.5).

(iii) The current serving cell becomes barred as indicated by the BCCH data.

(iv) The calculated value of C1 for a non-serving suitable cell exceeds the value of C1 for the serving cell for a period of 5 seconds, except in the case of the new cell being in a different location area in which case the C1 value for the new cell shall exceed the C1 value of the serving cell by at least CELL_RESELECT_HYSTERESIS dB as defined by the BCCH data from the current serving cell, for a period of 5 seconds.

(v) A random access attempt is still unsuccessful after "MAX retrans" repetitions; "MAX retrans" being a parameter broadcast on BCCH.

In case (iv) above, cell reselection shall not take place if there was a cell reselection within the previous 15 seconds. In the other cases, the cell reselection shall take place immediately, but the cell that the MS was camped on shall not be returned to within 5 seconds if another suitable cell can be found.

If the chosen new cell is in a different location area to the location area (old LA) of the last cell on which the MS was camped, (old serving cell) and there is a suitable cell of the old LA, the new cell shall only be selected if C1 on the new cell exceeds C1 on every suitable cell of the old LA by at least CELL_RESELECT_HYSTERESIS as defined by the BCCH data from the current serving cell.

In all cases, the cell with the highest value of C1 (among the cells being monitored according to the algorithm in section 6.6.1) which is suitable and which satisfies the other constraints shall be used.

Before camping on the cell after re-selection, the MS shall attempt to decode the full set of data of the BCCH . The MS shall check that the parameters affecting cell reselection are unchanged. If a change is detected the MS shall check if the cell re-selection criterion is still valid using the changed parameters.

If these conditions are all fulfilled, the MS shall camp on the cell. It may then be required to attempt a location update. (See GSM Rec 04.08.). If the conditions are not satisfied, the MS shall repeat this process for the cell with the next highest value of C1.

Once the MS has re-tuned to the chosen cell, it shall monitor its paging subgroup (if known) for that cell. If the MS receives a page before having decoded the full BCCH data for the new cell, the MS shall store the page and respond, if permitted, once the full BCCH data has been decoded. If not permitted, no page response shall be made.

If no suitable cell is found within 10 seconds, the cell selection algorithm of section 6.2 shall be performed. Since information concerning a number of channels is already known to the MS, it may assign high priority to measurements on those of the 30 strongest carriers from which it has not previously made attempts to obtain BCCH information, and omit repeated measurements on the known ones.

Note - The tolerance on all the above timings is +/-10%.

6.7 Release of TCH and SDCCH

6.7.1 Normal Case

When the MS releases a TCH or SDCCH and returns to idle mode, it shall as quickly as possible camp on a cell of the selected PLMN which is not barred and has C1 greater than zero. If such a cell exists in the "stored location area" (see GSM Rec 04.08), that cell shall be used, otherwise a cell in a new location area shall be used. However, before camping on the cell, the BCCH data for that cell shall be checked.

(The received level measurements on surrounding cells made during the last 5 seconds on the TCH or SDCCH may be averaged and used, where possible, to speed up the process. However, it should be noted that the received level monitoring while on the TCH or SDCCH is on carriers in BA (SACCH), while the carriers to be monitored for cell reselection are in BA (BCCH).)

Thereafter the MS shall perform cell reselection as specified in section 6.6

{The MS design should allow for the finite time that the cell reselection task takes. For example the user may want to originate a new call very soon after the end of a previous call, and the MS design should make this possible, e.g. by storing the origination until a cell has been selected.}

6.7.2 Call Reestablishment

In the event of a radio link failure, call re-establishment may be attempted (according to the algorithm in GSM Rec 04.08). The MS shall perform the following algorithm to determine which cell to use for the call re-establishment attempt.

(i) The received level measurement samples taken on surrounding cells and on the serving cell BCCH carrier in the last 5 seconds shall be averaged, and the carrier with the highest average received level which is part of a permitted PLMN (see section 7.2) shall be taken.

(ii) A BCCH data block containing the parameters affecting cell selection shall be read on this carrier.

(iii) If the parameter C1 is greater than zero, it is part of the selected PLMN, the cell is not barred, and call re-establishment is allowed, call re-establishment shall be attempted on this cell.

(iv) If the conditions in (iii) are not met, the carrier with the next highest average received level shall be taken, and the MS shall repeat steps (ii) and (iii) above.

(v) If the cells with the 6 strongest average received level values have been tried but cannot be used, the call re-establishment attempt shall be abandoned, and the algorithm of section 6.7.1 shall be performed.

6.8 Abnormal Cases and Emergency Calls

The MS shall perform the algorithm in this section if one of the following conditions exists:

(i) There is no SIM.

(ii) The MS cannot find a suitable cell of the selected PLMN to camp on.

(iii) The MS receives a "PLMN not allowed", "IMSI unknown" or illegal MS" response from the network.

Some of the following tasks shall be performed, depending on the conditions, as given in the Table below:

(a) The MS shall continually monitor the signal strength of all 124 GSM RF channels, and search for a BCCH carrier which has C1 >0 and which is not barred. When such a carrier is found, the MS shall camp on that cell, irrespective of the PLMN identity.

(b) The MS shall search the 30 strongest GSM RF channels to determine which PLMNs are available. This information shall be processed according to the PLMN selection algorithm defined in GSM recommendation 02.11.

(c) The MS shall perform cell reselection at least among the cells of the PLMN of the cell on which the MS has camped, according to the algorithm of section 6.6, except that a zero value of CELL_RESELECT_HYSTERESIS shall be used, and location updating shall not be performed.

Condition			Tasks to be performed as a minimum:		
SIM Present	Other	MS camped on a cell	(a)	(b)	(c)
X	X	No	Yes	No	No
No	X	Yes	No	No	Yes
Yes	"IMSI Unknown" "illegal MS"	Yes	No	No	Yes
Yes	No suitable cell of selected PLMN or "PLMN not allowed"	Yes	No	Yes	Yes

X = "Don't care state"

In this mode, only emergency calls may be made (and these may only made if task (c) was being performed). Powering down of the MS is permitted.

The MS shall leave this mode of operation and perform the cell selection algorithm (section 6.2 or 6.3) when either:

(i) A new PLMN is selected by the user (or other means within the MS)

(ii) The selected PLMN becomes available

(iii) The SIM is inserted.

7. NETWORK PRE-REQUISITES :

7.1 BCCH CARRIERS :

The BCCH carrier shall be continuously transmitted on all timeslots and without variation of RF level. However, the RF power level may be ramped down between timeslots to facilitate switching between RF transmitters. Unused signalling blocks on the CCCH/BCCH shall contain L2 fill frames. Other unused timeslots shall transmit dummy bursts.

{This BCCH organization enables MSs to measure the received signal level from surrounding cells by tuning and listening to their BCCH carriers. Providing that an MS tunes to the list of BCCH carriers indicated by the network it will, providing the list is sufficiently complete, have listened to all possible surrounding cells, i.e. the surrounding cell list for handover purposes is effectively defined by the MS.

This can be achieved without inter-base station synchronization}.

7.2 IDENTIFICATION OF SURROUNDING BSs FOR HANDOVER MEASUREMENTS :

{It is essential for the MS to identify which surrounding BS is being measured in order to ensure reliable handover. Because of frequency re-use with small cluster sizes, the BCCH carrier frequency may not be sufficient to uniquely identify a surrounding cell, i.e. the cell in which the MS is situated may have more than one surrounding cell using the same BCCH frequency. Thus is it necessary for the MS to synchronize to and demodulate surrounding BCCH carriers and identify the Base Station Identification Code (BSIC).}

The MS shall use at least 4 spare frames per SACCH block period for the purpose of decoding the BSICs (e.g. in the case of TCH/F, the four idle frames per SACCH block period). These frames are termed "search" frames.

A 6 bit Base Station Identity Code (BSIC), as defined in GSM Recommendation 03.03, shall be transmitted on each BCCH carrier. The PLMN part of the BSIC can be regarded as a "PLMN colour code".

The MS shall demodulate the SCH on the BCCH carrier of each surrounding cell and decode the BSIC as often as possible, and as a minimum at least once every 10 seconds. A list containing information about the timing of the surrounding cells at the accuracy required for accessing a cell, see Rec 05.10, 6, including the absolute times derived from the parameters T1, T2, T3 shall be kept by the MS. This information may be used to schedule the decoding of BSIC and shall be used in connection with handover in order to keep the switching time at a minimum.

If, after averaging measurement results over 2 SACCH block periods, the MS detects one or more BCCH carriers, among the 6 strongest, whose BSICs are not currently being assessed, then the MS shall as a matter of priority attempt to decode their BSICs.

Thus an MS shall, for a period of up to 5 seconds, devote all search frames to attempting to decode these BSICs. If this fails then the MS shall return to confirming existing BSICs. Having re-confirmed existing BSICs, if there are still BCCH carriers, among the six strongest, with unknown BSICs, then the decoding of these shall again be given priority for a further period of up to 5 seconds.

If either no BSIC can be demodulated on a surrounding cell BCCH carrier, or the BSIC indicates that the carrier belongs to a PLMN which is not one of the permitted PLMNs, then the signal strength measurements on that channel shall be discarded. The permitted PLMNs are defined by the PLMN_PERMITTED parameter transmitted in the BCCH data. This is an 8 bit map that relates to the PLMN part of BSIC. (e.g. PLMN_PERMITTED = 01101001, defines that carriers having a BSIC with PLMN part = 000,011,101,110 shall be reported.)

If a change of BSIC is detected on a carrier, then any existing signal strength measurement shall be discarded and a new averaging period commenced.

{This occurs when the MS moves away one surrounding cell and closer to another co-channel cell.}

If the BSIC cannot be decoded at the next available opportunities reattempts shall be made to decode this BSIC. If the BSIC is not decoded for more than three succesive attempts it will be considered lost and any existing signal strength measurement shall be discarded.

Details of the synchronization mechanisms appear in GSM Recommendation 05.10. The procedure for monitoring surrounding BSs with respect to HO measurement shall begin at least at the time of assignment of a dedicated channel.

When a BCCH carrier is found to be no longer one of the 6 strongest, timing and BSIC information shall be retained for at least 10 seconds. (This is in case a handover is commanded to this cell just after the MS stops reporting RXLEV and RXQUAL on this cell).

8. RADIO LINK MEASUREMENTS :

Radio link measurements are used in the handover and RF power control processes.

In particular, radio-subsystem directed handover is defined as a change of channel during a call either because of degradation of the quality of the current serving channel, or because of the availability of another channel which can allow communication at a lower TX power level, or to prevent a MS grossly exceeding the planned cell boundaries.

The measurements are made over each SACCH multiframe, which is 104 TDMA frames (480 ms) for a TCH and 102 TDMA frames for an SDCCH.

8.1 SIGNAL STRENGTH:

8.1.1 The received signal level shall be employed as a criterion in the RF power control and handover processes.

8.1.2 Physical parameter :

The R.M.S received signal level at the receiver input shall be reported by the MS and the BSS over the full range of -110dBm to -48 dBm with a relative accuracy of 1dB within any 20dB portion of the total measurement range, and an absolute accuracy of 4dB from -110 dBm to -70dBm under normal conditions and 6dB over the full range under both normal and extreme conditions.

MS's and BS's need not necessarily measure signal levels below the reference sensitivity. If the received signal level falls below the reference sensitivity level for the class of MS or BS then the MS or BS shall report a level between the reference sensitivity level and the actual received level.

8.1.3 Statistical parameters :

The reported parameters (RXLEV) shall be the average of the received signal level measurement samples in dBm taken within the reporting period of length one SACCH multiframe defined in 8.4. In averaging, measurements made during previous reporting periods shall always be discarded.

When assigned a TCH or SDCCH the MS shall make a received signal level measurement:

* in every TDMA frame on at least one of the BCCH carriers indicated in the BCCH allocation (BA), one after another. Optionally, measurements during up to 4 frames per SACCH multiframe may be omitted.
(Note: These four frames are those immediately preceding the search frames, in order to allow the MS to search for BCCH synchronization over a full TDMA frame.

* on all bursts of the associated physical channel (see rec. 05.02), including those of the SACCH. If frequency hopping is being used on the associated physical channel and if, in the BCCH Cell Options, the Power Control Indicator PWRC is set, measurements on the bursts on the BCCH frequency shall not be used in the RXLEV averaging process.

Unless otherwise specified by the operator, for any TCH or SDCCH assigned to an MS, the BS shall make a received signal level measurement on all time slots of the associated physical channel including those of the SACCH.

8.1.4 Range of parameter :

The received signal level shall be mapped to an RXLEV value between 0 and 63, as follows :

RXLEV 0 = less than -110dBm.
RXLEV 1 = -110 dBm to -109 dBm.
RXLEV 2 = -109 dBm to -108 dBm.
:
:
RXLEV 62 = -49 dBm to -48 dBm.
RXLEV 63 = greater than -48 dBm.

6 bits are required to define RXLEV for each carrier measured.

8.2 SIGNAL QUALITY:

8.2.1 The received signal quality shall be employed as a criterion in the RF power control and handover processes.

8.2.2 Physical parameter :

The received signal quality shall be measured by the MS and BSS in a manner that can be related to an equivalent average BER before channel decoding (i.e chip error ratio), assessed over the reporting period of 1 SACCH block (480 ms).

For example, the measurement may be made as part of the channel equalization process, decoding process, pseudo-error rate measurement etc.

8.2.3 Statistical parameters :

The reported parameters (RXQUAL) shall be the received signal quality, averaged over the reporting period of length one SACCH multiframe defined in 8.4. In averaging, measurements made during previous reporting periods shall always be discarded.

Contrary to RXLEV measurements, in calculating RXQUAL values, measurements on bursts on the BCCH carrier shall always be included in the averaging process.

8.2.4 Range of parameter :

When the quality is assessed over the full-set and sub-set of frames defined in 8.4, eight levels of RXQUAL are defined and shall be mapped to the equivalent BER before channel decoding as follows :

RXQUAL_0	BER less than 0.2%	Assumed value = 0.14%
RXQUAL_1	BER = 0.2% to 0.4%	Assumed value = 0.28%
RXQUAL_2	BER = 0.4% to 0.8%	Assumed value = 0.57%
RXQUAL_3	BER = 0.8% to 1.6%	Assumed value = 1.13%
RXQUAL_4	BER = 1.6% to 3.2%	Assumed value = 2.26%
RXQUAL_5	BER = 3.2% to 6.4%	Assumed value = 4.53%
RXQUAL_6	BER = 6.4% to 12.8%	Assumed value = 9.05%
RXQUAL_7	BER greater than 12.8%	Assumed value = 18.10%

The assumed values may be employed in any averaging process applied to RXQUAL.

The BER values used to define a quality band are the estimated error probabilities before channel decoding, averaged over the full set or sub set of TDMA frames as defined in 8.4. The accuracy to which an MS shall be capable of estimating the error probabilities when on a TCH is given in the following table :

Quality Band	Range of actual BER	Probability that the correct RXQUAL band is reported by MS shall exceed		
		Full rate Channel	Half rate Channel	DTX Mode
		RXQUAL_FULL 104 TDMA frames	RXQUAL_FULL 52 TDMA frames	RXQUAL_SUB 12 TDMA frames
RXQUAL_0	Less than 0.1%	90%	90%	65%
RXQUAL_1	0.26% to 0.30%	75%	60%	35%
RXQUAL_2	0.51% to 0.64%	85%	70%	45%
RXQUAL_3	1.0% to 1.3%	90%	85%	45%
RXQUAL_4	1.9% to 2.7%	90%	85%	60%
RXQUAL_5	3.8% to 5.4%	95%	95%	70%
RXQUAL_6	7.6% to 11.0%	95%	95%	80%
RXQUAL_7	Greater than 15.0%	95%	95%	85%

The MS assessment accuracy will be tested under both static and TU50 channel conditions.

The method of test is given in Recommendation 11.10 and 11.20. It should be noted that in the testing, the System Simulator (SS) or (BSST) Base Station System Test Equipment will have to measure the average error rate over a large number of TDMA frames. Thus the SS will not measure exactly the same error rate parameter as the MS.

To allow for this, the test limits given in Recommendation 11.10 and 11.20 for TU50 are not the same as in the Table above. The Table above is used in 11.10 for the static channel case only.

8.3 Aspects of Discontinuous Transmission (DTX)

When DTX is employed on a TCH, not all TDMA frames may be transmitted, however,the following subset shall always be transmitted, and hence can be employed to assess quality and signal level during DTX.

Type of channel	SID Message Block frames TDMA frame number (FN) modulo 104
TCH/F	52,53,54,55,56,57,58,59
TCH/H,subchannel 0	52,54,56,58,60,62,66,68
TCH/H,subchannel 1	53,55,57,59,61,63,65,67

On any TCH speech channel this subset of TDMA frames is used during DTX for transmission of the SID (Silence Descriptor) speech frame defined in the 06.xx series.

When no SID information is required to be transmitted, e.g. on data channels, the L2 fill frame (see rec. 04.06 section 5.4.2.3) shall be transmitted as a FACCH in place of the SID frames.

On the SDCCH, where DTX is not allowed, or during signalling on the TCH when DTX is not used, the same L2 fill frame shall be transmitted in case there is nothing else to transmit.

8.4 Measurement reporting

For a TCH, the reporting period of length 104 TDMA frames (480ms) is defined in terms of TDMA frame numbers (FN) as follows:

Timeslot number (TN)		TDMA frame number (FN) modulo 104	
TCH/F and TCH/H,subch.0	TCH/H,subch.1	Reporting period	SACCH Message block
0	7	0 to 103	12, 38, 64, 90
1	0	13 to 12	25, 51, 77,103
2	1	26 to 25	38, 64, 90, 12
3	2	39 to 38	51, 77,103, 25
4	3	52 to 51	64, 90, 12, 38
5	4	65 to 64	77,103, 25, 51
6	5	78 to 77	90, 12, 38, 64
7	6	91 to 90	103, 25, 51, 77

When on a TCH, the MS shall assess during the reporting period and transmit to the BS in the next SACCH message block the following:

* RXLEV for the BCCH carrier of the 6 cells with the highest RXLEV among those with known and allowed BSIC.

Note: Since there are 104 TDMA frames in each SACCH multiframe (and measurement in 4 frames is optional), the number of samples on each BCCH carrier will depend on the number of carriers defined in the BCCH Allocation (BA) and may be different. The following table gives examples of this:

Number of BCCH carriers in BCCH Allocation	Number of samples per carrier in SACCH multiframe
32	3-4
16	6-7
10	10-11
8	12-13
:	:
:	:

These figures are increased if the MS is able to make measurements on more than one BCCH carrier during each TDMA frame.

* RXLEV_FULL and RXQUAL_FULL:
RXLEV and RXQUAL for the full set of TCH and SACCH TDMA frames. The full set of TDMA frames is either 100 (i.e. 104 - 4 idle) frames for a full rate TCH or 52 frames for a halfrate TCH.

* RXLEV_SUB and RXQUAL_SUB:
RXLEV and RXQUAL for the subset of 4 SACCH frames and the 8 SID TDMA frames defined in 8.3.

Note: If measurement on the BCCH frequency is not used, the number of TDMA frames used in the RXLEV averaging process may be lower than the number of TDMA frames in the set.

Note: Some TCH speech, data or SID message blocks are spread over two reporting periods. In these cases, the RXLEV and/or RXQUAL information from the TCH message blocks may either be sent as part of the measurement report of the second period, or shared between the reports of the two periods.

For a SDCCH, the reporting period of length 102 TDMA frames (470.8 ms) is defined in terms of TDMA frame numbers (FN) as follows:

	TDMA frame number (FN) modulo 102
SDCCH/8	12 to 11
SDCCH/4	37 to 36

When on a SDCCH, the MS shall assess during the reporting period and transmit to the BS in the next SACCH message block the following:

* RXLEV for the BCCH carrier of the 6 cells with the highest RXLEV among those with known and allowed BSIC.

Note: With only 102 TDMA frames in each SACCH multiframe, the number of samples used to calculate RXLEV per BCCH carrier may be slightly different from the case of TCH described above.

* RXLEV and RXQUAL for the full set of 12 (8 SDCCH and 4 SACCH) frames within the reporting period. As DTX is not allowed on the SDCCH, -SUB values are set equal to the -FULL values in the SACCH message.

Note: If measurement on the BCCH frequency is not used, the number of TDMA frames used in the RXLEV averaging process may be lower than the number of TDMA frames in the full set.

Whether the MS is on a TCH or a SDCCH, if the next SACCH message block is used for a different Layer 3 message, the averaged data which would otherwise be sent in that block is discarded and a new average started for the current block. I.e., any SACCH message will report the average data for the previous reporting period only.

The MS shall also transmit a bit (DTX_USED) in the next SACCH message block, which indicates whether or not it has employed DTX during the reporting period. This bit shall be set even if just one burst in a TDMA frame in the reporting period was not transmitted due to DTX.

Note: A speech or user data frame subject to DTX may cross the 'border' between two reporting periods, in which case both of the associated SACCH message blocks will have the DTX_USED flag set.

Unless otherwise specified by the operator, the BS shall make the same RXLEV (full and sub) and RXQUAL (full and sub) assessments as described for the MS for all TCH's and SDCCH's assigned to an MS, using the associated reporting periods. These values, together with the reported values from the MS's, shall be transmitted to the BSC as described in the 08.xx series.

8.5 ABSOLUTE MS-BS DISTANCE :

8.5.1 The Absolute MS-BS distance may be employed by the network as a criterion in the handover processes.

8.5.2 Physical parameter :

The information being used by the BS to perform "adaptive frame alignment" (Recommendation 05.10) in the MS is a representation of the absolute distance of the MS to the serving BS.

This absolute distance may be used by the BS to prevent MSs from grossly exceeding the planned cell boundaries.

The allowable distance is administered on a cell by cell basis by the network operator.

9. CONTROL PARAMETERS :

The parameters employed to control the radio links are shown in Tables 1 and 2.

PARAMETER NAME	DESCRIPTION	RANGE	BITS	CHANNEL	
BSIC	Base station Identification Code	0-63	6	SCH	D/L
BA	BCCH Allocation.	-	124	BCCH	D/L
BA_IND	Sequence number of BA	0/1	1	BCCH	D/L
MS_TXPWR_MAX_CCH	The maximum TX power level an MS may use when accessing the system until otherwise commanded. (Coded the same as TXPWR).	0/31	5	BCCH	D/L
RXLEV_ACCESS_MIN	Minimum received level at the MS required for access to the system.	0-63	6	BCCH	D/L
RADIO_LINK_TIMEOUT	The maximum value of the radio link counter 4-64 SACCH blocks, 15 steps of 4 SACCH blocks	-	4	BCCH	D/L
CELL_RESELECT_HYSTERESIS	RXLEV hysteresis for required cell re-selection. 0-14dB, 2 db steps, i.e. 0=0dB, 1=2dB, etc.	0-7	3	BCCH	D/L
PLMN_PERMITTED	Bit map of PLMNs for which the MS is permitted to report measurement results. Bit map relates to PLMN part of BSIC.	-	8	BCCH	D/L
CELL_BAR_ACCESS	Bars all initial accesses to a cell. MS will not camp on a cell when set (1 = barred).	0/1	1	BCCH	D/L

TABLE 1: RADIO SUB-SYSTEM LINK CONTROL PARAMETERS

PARAMETER NAME	DESCRIPTION	RANGE	BITS	MESSAGE
MS_TXPWR_REQUEST	The TX power to be used by an MS on TCH. downlink	0-31	5	L1 header
MS_TXPWR_CONF.	Confirmation of the TX power level in use by the MS. uplink	0-31	5	L1 header
RXLEV_FULL_ SERVING_CELL	The RXLEV in the current serving cell accessed over all TDMA frames	0-63	6	Measurement results
RXLEV_SUB_ SERVING_CELL	The RXLEV in the current serving cell accessed over a subset of TDMA frames	0-63	6	Measurement results
RXQUAL_FULL_ SERVING_CELL	The RXQUAL in the current serving cell, assessed over all TDMA frames.	0-7	3	Measurement results
RXQUAL_SUB_ SERVING_CELL	The RXQUAL in the current serving a cell, assessed over subset of TDMA frames.	0-7	3	Measurement results
DTX_USED	Indicates whether or not the MS used DTX during the previous measurement period.	-	1	Measurement results
BA_USED	Value of BA_IND for BCCH allocation used	0/1	1	Measurement results
RXLEV_NCELL_ (1-6)	The RXLEV assessed on BCCH carrier as indicated in the BCCH Allocation	0-63	6	Measurement
BCCH_FREQ_NCELL_ (1-6)	The BCCH carrier RF channel number in NCELL.	0-31	5	Measurement results
BSIC_NCELL_(1-6)	Base station identification code for NCELL.	0-63	6	Measurement results

TABLE 2: HANDOVER AND POWER CONTROL PARAMETERS - SLOW ACCH

Notes : 1) RXLEV and RXQUAL fields are coded as described in section 8.

2) BCCH_FREQ_NCELL_(1-6) is coded in relation to the BCCH Allocation (BA) bit map as follows:

RF channel freq :	000	001	002	003	004	. . .	123	124
BCCH Allocation :	0	1	1	0	1	. . .	0	1
BCCH_FREQ_NCELL :	-	0	1	-	2	. . .	-	31 (max)

3) This overall coding requires 115 bits to report measurements from the serving cell and 6 surrounding cells in the. Measurement Results message.

i.e. RXLEV_SERVING_CELL	6 bits	)	
RXQUAL_FULL_SERVING_CELL	3 bits	)	= 13 bits
RXQUAL_SUB_SERVING_CELL	3 bits	)	
DTX_USED	1 bit	)	
RXLEV_NCELL_(1-6)	6 bits	)	
BCCH_FREQ_NCELL(1-6)	5 bits	)	x 6 = 102 bits
BSIC_NCELL_(1-6)	6 bits	)	

APPENDIX A :

DEFINITION OF A BASIC GSM HAND-OVER AND RF POWER CONTROL ALGORITHM

1) Scope

This appendix specifies a basic overall handover algorithm and RF power control process that may be implemented in the GSM system.

The specification includes a set of algorithms that are sufficient to allow the successful implementation of an initial GSM system, and from which more complex algorithms may be developed.

The basic solution is not mandatory for network operators.

2) Functional Requirement

The present algorithm is based on the following assumptions :

- Single cell BSS
- The necessity to make a hand-over according to radio criteria is recognised in the BSS. It can lead to either an (internal) intracell hand-over or an intercell hand-over.
- Evaluation of a preferred list of target cells is performed in the BSS.
- Cell allocation is done in the MSC.
- Intracell hand-over for radio criteria (interference problems) may be performed directly by the BSS.
- The necessity to make a hand-over because of traffic reason (network directed hand-over) is recognised by the MSC and it is performed by sending a "hand-over candidate enquiry message" to BSS.
- The RF power control algorithm shall be implemented in order to optimize the RF power output from the MS (and BS if power control is implemented) ensuring at the same time that the level received at the BS (MS) is sufficient to keep adequate speech/data quality.
- All parameters controlling the hand-over and power control processes shall be administered on a cell by cell basis by means of O&M. The overall hand-over and power control process is split into the following stages :

i) BSS preprocessing and threshold comparisons.
ii) BSS decision algorithm.
iii) MSC cell allocation algorithm.

A BSS decision algorithm is specified such that the BSS can fulfil the mandatory requirement of being able to produce a preferred list of target cells for handover.

It should be noted that since measurement results can also be sent to the MSC in the "handover required" message, the hand-over decision algorithm may be implemented in either the MSC or the BSS.

3) BSS preprocessing and threshold comparisons

For the purpose of hand-over and RF power control processing the BSS shall store the parameters and thresholds shown in Table 1. These shall be administered on a cell by cell basis and downloaded to the BSS by O&M procedures.

The parameters and thresholds related to the downlink power control process are stored and used only if BS RF power control is implemented.

The following measurements shall be continuously processed in the BSS :

i) Measurements reported by MS on SACCH
- Down link RXLEV
- Down link RXQUAL
- Down link surrounding cell RXLEV (RXLEV_NCELL (n) on BCCH as indicated in the BCCH Allocation.

ii) Measurements performed in BS
- Uplink RXLEV
- Uplink RXQUAL
- MS-BS distance
- Interference level in unallocated time slots

Every SACCH multiframe (480 ms) a new processed value for each of the measurements shall be calculated.

3.1 Measurement averaging process :

The BSS shall be capable of pre-processing the measurements by any of the following processes :

- Unweighted average.
- Weighted average, with the weightings determined by O&M.
- Modified median calculation, with exceptionally high and low values (outliers) removed before the median calculation.

The timing of the processing shall be controlled by parameters, set by O&M, as follows :

a) RXLEV_XX (XX = DL or UL):

For every connection and for both links at least the last 32 samples shall be stored (a sample is the value evaluated by the MS and BS during a period of 480 ms).

Every 480 ms, with these samples, the BSS shall evaluate the averaged value of the received power as defined by the parameters Hreqave and Hreqt, applicable to RXLEV.

b) RXLEV_DL on BCCH carriers (RXLEV_NCELL (n)):

For every connection and for each of up to 16 defined cells the BSS shall store the values related to the last 32 samples. The BSS shall average these samples as defined by the parameters Hreqave, Hreqt, applicable to RXLEV.

c) RXQUAL_XX (XX = DL or UL) :

For every connection and for both links at least 32 samples shall be stored (a sample is the value calculated by the MS and BS during period of 480 ms).

Every 480 ms, with these samples, the BSS shall evaluate the received signal quality as defined by the parameters Hreqave and Hreqt, applicable to RXQUAL.

d) MS-BS distance :

For every connection the BSS shall average the adaptive frame alignment value as defined by the parameters Hreqave and Hreqt, to derive an estimate of the MS-BS distance.

e) Interference level in unallocated time slots :

The BSS shall average the interference level in unallocated timeslots as defined by the Intave parameter.

The averaged results shall be mapped into five interference categories (see Rec 08.08) whose limit O-X5 are adjusted by O&M.

f) Power Budget :

This assessment process may be employed by the network as a criterion in the hand-over process, by setting a flag in the BSS by O&M command. If the process is employed, every 480 ms, for every connection and for each of allowable 16 adjacent cells, the BSS shall evaluate the following expression :

```
PBGT(n) = (Min(MS_TXPWR_MAX,P) - RXLEV_DL   - PWR_C_D)
             -  (Min(MS_TXPWR_MAX(n),P) - RXLEV_NCELL(n))
```

Where the values of RXLEV_NCELL(n) and RXLEV_DL are obtained with the averaging processes defined above. PWR_C_D is the difference between the maximum downlink RF power permitted in the cell and the actual downlink power due to the BS power control. MS_TXPWR_MAX is the maximum RF TXPWR an MS is permitted to use on a traffic channel in the serving cell. MS_TXPWR_MAX (n) is the maximum RF TXPWR an MS is permitted to use on a traffic channel in adjacent cell n. P is the maximum TXPWR capability of the MS.

3.2 Threshold comparison process:

3.2.1 RF Power control process:

Every SACCH multiframe, the BSS shall compare each of the processed measurements with the relevant thresholds. The threshold comparison processes and the actions to be taken are as follows :

a) Comparison of RXLEV_XX with L_RXLEV_XX_P (XX = DL or UL)

The algorithm shall be applied to the averaged RXLEV values (defined in 3.1:a). The comparison process shall be defined by the parameters P1 and N1 as follows :

- Increase XX_TXPWR if at least P1 averages out of N1 averages are lower than L_RXLEV_XX_P. (e.g. P1 = 10 and N1 = 12)

b) Comparison of RXLEV_XX with U_RXLEV_XX_P (XX = DL or UL)

The algorithm shall be applied to the averaged RXLEV values (defined in 3.1:a). The comparison process shall be defined by the parameters P2 and N2 as follows :

- Decrease XX_TXPWR if at least P2 averages out of N2 averages are greater than U_RXLEV_XX_P. (e.g. P2 = 19 and N2 = 20)

c) Comparison of RXQUAL_XX with L_RXQUAL_XX_P (XX = DL or UL)

The algorithm shall be applied to the averaged RXQUAL values (defined in 3.1:c) The comparison process shall be defined by the parameters P3 and N3 as follows :

- Increase XX_TXPWR if at least P3 averaged values out of N3 averaged values are greater (worse quality) than L_RXQUAL_XX_P. (e.g. P3 = 5 and N3 = 7)

d) Comparison of RXQUAL_XX with U_RXQUAL_XX_P (XX = DL or UL) The algorithm shall be applied to the averaged RXQUAL values (defined in 3.1:c) The comparison process shall be defined by the parameters P4 and N4 as follows :

- Decrease XX_TXPWR if at least P4 averaged values out of N4 averaged values are lower (better quality) than U_RXQUAL_XX_P. (e.g. P4 = 15, N4 = 18)

3.2.2 Handover Process:

Every SACCH multiframe, the BSS shall compare each of the processed measurements with the relevant thresholds. The threshold comparison processes and the actions to be taken are as follows :

a) Comparison of RXLEV_XX with L_RXLEV_XX_H (XX = DL or UL)

The algorithm shall be applied to the averaged RXLEV values (defined in 3.1:a). The comparison process shall be defined by the parameters P5 and N5 as follows :

- If at least P5 averaged values out of N5 averaged values are lower than L_RXLEV_XX_H a hand-over, cause XX_RXLEV, might be required. (e.g. P5 = 10 and N5 = 12)

b) Comparison of RXQUAL_XX with L_RXQUAL_XX_H (XX = DL or UL)

The algorithm shall be applied to the averaged RXQUAL values (defined in 3.1:c) The comparison process shall be defined by the parameters P6 and N6 as follows :

- If at least P6 averaged values out of N6 averaged values are greater (worse quality) than L_RXQUAL_XX_H a hand-over, cause XX_RXQUAL, might be required. (e.g. P6 = 5 and N6 = 7)

c) Comparison of RXLEV_XX with RXLEV_XX_IH (XX= DL or UL)

The algorithm shall be applied to the averaged RXLEV values (defined in 3.1:a). The comparison process shall be defined by the parameters P7 and N7 as follows :

- If at least P7 averaged values out of N7 averaged values are greater than RXLEV_XX_IH an internal hand-over might be required if RXQUAL_XX is also greater (worse quality) than L_RXQUAL_XX_H (e.g. P7 = 10 and N7 = 12).

d) Comparison of MS-BS distance with the MAX_MS_RANGE

This comparison process may be employed by the network as a criterion in the hand-over process by setting a flag in the BSS by O&M. If the process is employed, the algorithm shall be applied to the averaged values defined in Sec 3.1:d.

The comparison process shall be defined by the parameters P8 and N8 as follows :

- If at least P8 averaged values out of N8 values are greater than MS_RANGE_MAX a hand-over, cause DISTANCE, might be required. (e.g. P8 = 8 and N8 = 10)

e) Comparison of PBGT(n) with the HO_MARGIN(n)

If the process is employed, the action to be taken is as follows :

- If PBGT(n) > 0 and PBGT(n) > HO_MARGIN(n) a hand-over, cause PBGT(n), might be required.

This comparison enables handover to be performed to ensure that the MS is always linked to the cell with the minimum path loss, even though the quality and level thresholds may not have been exceeded.

4) BSS Decision Algorithm :

Recognising the necessity to request a hand-over the BSS shall send a "hand-over required message" to the MSC containing the preferred list of target cells.

The "hand-over required message" shall be also generated in answer to a "hand-over candidate enquiry message" sent by the MSC.

The BSS decision algorithm shall be based on the following strategy :

1. RXLEV_NCELL(n) > RXLEV_MIN(n) + Max (0, Pa)

where: Pa = (MS_TXPWR_MAX(n)-P)

2. (Min(MS_TXPWR_MAX,P) - RXLEV_DL - PWR_C_D) -

(Min(MS_TXPWR_MAX(n),P) - RXLEV_NCELL(n)) - HO_MARGIN(n) > 0

All these expressions shall be evaluated using the averaged values defined by the parameters Hreqt and Hreqave.

The BSS shall evaluate the equation (2) for each of the adjacent cells that satisfies the expression (1) and shall compile the list of the preferred adjacent cells ordinated depending on the value of equation (2) (i.e in the first position is the cell for which the value is the maximum, in the second position is the cell with the second best value and so on).

If there are any adjacent cells for which the values of RXLEV_MIN(n), HO_MARGIN(n) and MS_TXPWR_MAX(n) are not known, i.e the MS has reported values from an undefined adjacent cell, then the default parameters shall be used to evaluate equations 1 and 2, i.e RXLEV_MIN_DEF, HO_MARGIN_DEF, MS_TXPWR_MAX_DEF. This enables handover to occur in situations where a call is set up in unexpected coverage area of a cell, without defined adjacent cells.

If there are several cells that satisfy the equation (2) with the same results, the first cell in the list will be that one with the best "positive trend". The trend shall be evaluated by the BSS using the last Hreqt averaged values of RXLEV_NCELL(n).

If the hand-over is considered imperative, that is one of the following events is verified as the cause :

a) The power level (UL and/or DL) is below the thresholds despite power control (the MS or/and the BS have reached the maximum allowed power).

b) The quality of the link (UL and/or DL) is below the threshold while at the same time the RXLEV approximates the threshold.

c) The distance between MS and BS exceeds the MAX_MS_RANGE

The list of the preferred cells shall be compiled including any candidates for which the result of the equation (2) is lower than 0. Also in this case the list shall be compiled in a decreasing order of priority.

4.1 Internal intracell hand over according to radio criteria : (Interference problems)

The two conditions RXQUAL_XX > L_RXQUAL_XX_H (bad quality) and RXLEV_XX > RXLEV_XX_IH, if verified at the same time, indicate a high probability of the presence of co-channel interference.

This situation can be solved by changing the channel within the cell with an intracell hand-over.

If internal intracell hand-over is supported by the BSS it shall be performed as described in Rec. 08.08 Sec 3.1.6.

If the BSS does not support internal intracell hand-over, then the handover shall be initiated by sending a "hand-over required message" to the MSC in which the serving cell is indicated as first priority.

4.2 Internal hand-over according to other criteria:

Apart from radio criteria there are other criteria that may require internal hand-over :

- O & M criteria
- Resource management criteria

In these cases internal hand-over shall be triggered by the OMC or by the resource management of the BSS.

4.3 General considerations:

Since the RF power control process and the hand-over process are closely linked, particular care shall be taken in order to avoid undesired interactions between them.

In particular the following interactions should be avoided, where possible :

- A "power increase command" or a "hand-over for RXLEV or for RXQUAL" subsequent to a "power reduction command" (e.g. by checking that the averaged power level reduced by the

Pow_Red_Step_Size plus the tolerances is greater than the L_RXLEV_XX_P or L_RXLEV_XX_H).

- A "power reduction command" subsequent to a "power increase command".

After an action of power control the set of samples related to the previous power level, in the corresponding link, shall not be used in the processing.

If, during the decision process, the condition for the "hand-over required message" is satisfied at the same time by different reasons. The "cause field" in the "hand-over required message" sent to the MSC, shall contain the reasons taking account of the following order of priority :

- RXQUAL
- RXLEV
- DISTANCE
- PBGT

5) Channel allocation

As described in Rec 08.08 the available channels shall be divided into five interference categories whose limits O-X5 are adjusted by O&M command.

For hand-over, the channel allocated should be from the category with the lowest interference level, since determination of the expected value of C/I is not possible by the new BSS.

6) Hand-over decision algorithm in the MSC

The MSC shall select the cell to which an MS is to be handed over by the following criteria :

- Hand-over for radio criteria shall be handled taking into account the following order of priority :

  - RXQUAL
  - RXLEV
  - DISTANCE
  - PBGT

e.g. If there are more handover bids to a cell than there are free traffic channels, then the bids with cause "RXQUAL" shall take highest priority.

- In order to avoid overload in the network, for every cell and with reference to each of 16 adjacent cells, it shall be possible to define (by O&M) for each adjacent cell one of at least 8 priority levels. These shall be considered together with the list of candidates and the interference levels in the choice of the new cell. For example, if there are two cells which meet the criteria for handover, then the cell with the highest priority shall be used. This enables umbrella cells, for instance, to be given a lower priority, and only handle calls when no other cell is available.

- Channel congestion on the best cell shall cause the choice of the second best cell, if available, and so on. If no cell is found and call queuing is employed in the MSC, then the MSC shall queue the request on the best cell for a period equal to H_INTERVAL (H_INTERVAL < T_Hand_RQD shall be set by O&M). This handover shall have priority over the queue handling new calls.

TABLE 1

All thresholds shall be able to take any value within the range of the parameter to which they apply. Typical operating ranges are given for some thresholds.

L_RXLEV_UL_P	:	RXLEV threshold on the uplink for power increase. Typical range - 103 to - 73 dBm.
U_RXLEV_UL_P	:	RXLEV threshold on the uplink for power reduction.
L_RXQUAL_UL_P	:	RXQUAL threshold on the uplink for power increase.
U_RXQUAL_UL_P	:	RXQUAL threshold on the uplink for power reduction.
L_RXLEV_DL_P	:	RXLEV threshold on the downlink for power increase. Typical range - 103 to - 73 dBm.
U_RXLEV_DL_P	:	RXLEV threshold on the downlink for power reduction.
L_RXQUAL_DL_P	:	RXQUAL threshold on the downlink for power increase.
U_RXQUAL_DL_P	:	RXQUAL threshold on the downlink for power reduction.
L_RXLEV_UL_H	:	RXLEV threshold on the uplink for hand-over process to commence. Typical range - 103 to - 73 dBm.
L_RXQUAL_UL_H	:	RXQUAL threshold on the uplink for hand-over process to commence.
L_RXLEV_DL_H	:	RXLEV threshold on the downlink for hand-over process to commence. Typical range - 103 to - 73 dBm.
L_RXQUAL_DL_H	:	RXQUAL threshold on the downlink for hand-over process to commence.

MS_RANGE_MAX : Threshold for the maximum permitted distance between MS and current BS. Range (2, 35 Km); step size 1.0 Km.

RXLEV_UL_IH : RXLEV threshold on uplink for intracell (interference) hand-over. Typical range - 85 to - 40 dBm.

RXLEV_DL_IH : RXLEV threshold on downlink for intracell (interference) hand-over; typical range - 85 to - 40dBm

RXLEV_MIN(n) : Minimum RXLEV required for an MS to be allowed to handover to cell "n".

RXLEV_MIN_DEF : Default value of RXLEV_MIN, used to evaluate handover to undefined adjacent cells.

HO_MARGIN(n) : A parameter used in order to prevent repetitive hand-over between adjacent cells. It may be also used as a threshold in the power budget process. Range (0, 24 dB); step size 1 dB.

HO_MARGIN_DEF : Default value of HO_MARGIN, used to evaluate handover to undefined adjacent cells.

N_CELL list : List of allowable adjacent cells for hand-over. Range (0, 16).

MS_TXPWR_MAX : Maximum TXPWR a MS may use in the serving cell. Range (13, 43 dBm); step size 2 dB.

MS_TXPWR_MAX(n): Maximum TXPWR a MS may use in the adjacent cell "n". Range (13, 43 dBm); step size 2 dB.

MS_TXPWR_MAX_DEF: Default value of MS_TXPWR_MAX, used to evaluate handover to undefined adjacent cells.

BS_TXPWR_MAX : Maximum TXPWR used by the BS.

O .X5 : Boundary limits of five interference bands for the unallocated time slots. Typical range -115 to -85 dBm. (See Rec. 08.08)

Hreqave : RXLEV, RXQUAL and MS_BS Distance averaging periods defined in terms of number of SACCH multiframes. Range (1, 31); step size 1. (See Rec. 08.08)

Hreqt : The number of averaged results that can be sent in a "hand-over required message" from BSS to MSC. Range (1, 31); step size 1. (See Rec. 08.08)

Intave : Interference averaging period defined in terms of the number of SACCH multiframes. Range (1, 31); step size 1.

N1..N8,P1..P8 : The number of samples used in the threshold comparison processes. Range (1, 31); step size 1.

P_Con_INTERVAL : Minimum interval between changes in the RF power level. Range (0, 30 s) step size 0.96s.

T_Hand_RQD : Minimum interval between hand-over required messages related to the same connection. Range (0, 30 s); step size 0.96 s.

Pow_Incr_Step_Size: Range 2, 4 or 6 dB.

Pow_Red_Step_Size: Range 2 or 4 dB.