Handover

Contents

1 General

The handover main objectives are:

- maintaining a connection in case of a cell change (movement)
- changing a channel in case of severe disturbance (interference)
- designing cell borders and radio network structure

1.1 Steps of the Handover Process

The handover process can be divided into several sub-processes:

No.	Sub-process	Involved Network Element
1.	Measurements: ● DL Level serving cell ● DL Quality serving cell ● DL Level neighbor cells ● UL Level ● UL Quality ● Timing advance	 MS BTSE
2.	Measurement reporting and neighbor cell book-keeping	MS BTSE
3.	Measurement preprocessing	BTSE
4.	Threshold comparison and handover detection	BTSE
5.	Target cell list generation	BTSE
6.	Target cell list evaluation ● intra BSS handover ● inter BSS handover	 BSC MSC
7.	Selection of new channel	BSC
8.	Handover execution	MS, BTSE, BSC, MSC

1.2 Types of Handover

Different types of handover can be distinguished with respect to the changed region: a cell, a BSS area or an MSC area. The different types of handover can be enabled or disabled by several flags.

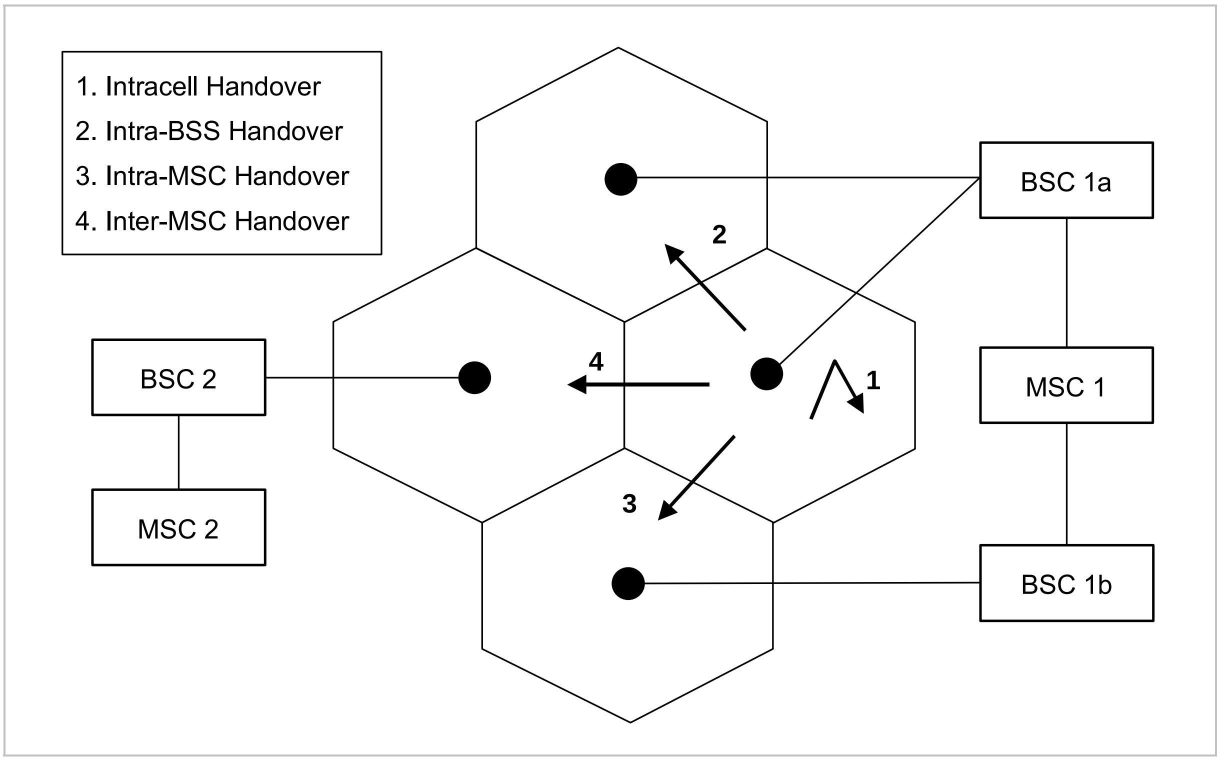

Fig. 1 Types of handover

1.3 Handover Causes

Two criteria groups of different handover causes are defined:

Radio Criteria	received **quality** (too bad that means bit error rate too high)	inter-/intracell HO
	received **level** (too low)	intercell HO
	MS-BS **distance** (too high)	intercell HO
	better cell (power budget: relative received level)	intercell HO
Network Criteria	serving cell **congestion** --> directed retry for call setup, traffic handover for running calls	intercell HO
	MS-BS **distance** (too high/low in extended cells)	intracell HO
	received **level** or MS-BS **distance**	
	(too low/high in concentric cells)	intracell HO

The first three causes are known as mandatory or imperative causes, i.e. if one of these causes occurs, a handover is necessary to maintain the call. This may happen because the MS is leaving the coverage area of the serving cell (intercell handover) or because there is a strong interferer using the same channel in another cell (intracell handover).

The fourth cause is an optional one, i.e. the link quality in the serving cell is sufficiently good, but there are neighbor cells with better received level. Though its not necessary for the link quality of this specific call, there is a benefit for overall network performance to handover the call to the better cell: A call in the better cell causes less interference, especially, if power control is applied. To achieve the same received level in the better cell, a smaller transmit power can be used in this cell.

In a well planned radio network “better cell” should be the overwhelming handover cause. Hence, the locations of a “better cell” handover determine the cell boundaries.

The fifth cause is named forced handover because it is triggered by the BSC due to a congestion situation, and not due to radio conditions on the link. This handover (directed retry) is performed from a SDCCH in the congested cell to a TCH in a neighbor cell during call setup.

The last two causes are intracell handovers in special cell configurations:

- in extended cells handovers are feasible from single to double timeslots and vice versa.
- In a concentric cell handovers are performed between the inner and complete area.

These handover causes can be enabled/disabled separately by corresponding flags.

1.4 Flags to Enable/Disable Handover Types and Causes

The flags to **enable (TRUE) / disable (FALSE)** the different handover types and causes are listed in the table below.

With one exception they are all administered in the **object HAND**.

Specification Name	DB Name	Meaning
EN_INTER_HO	INTERCH	Flag to enable/disable generally intercell handover for this BTS.
EN_INTRA_HO	INTRACH	Flag to enable/disable generally intracell handover for this BTS.
EN_BSS_INTER_HO	LOTERCH	Flag to determine weather inter cell handover are controlled by BSC (TRUE) or MSC (FALSE).
EN_BSS_INTRA_HO	LOTRACH	Flag to determine weather intra cell handover are controlled by BSC (TRUE) or MSC (FALSE).
EN_RXQUAL_HO	RXQUALHO	Flag to enable/disable intercell handover due to quality.
EN_RXLEV_HO	RXLEVHO	Flag to enable/disable intercell handover due to level.
EN_DIST_HO	DISTHO	Flag to enable/disable intercell handover due to distance.
EN_PBGT_HO	PBGTHO	Flag to enable/disable better cell (power budget) handover.
EN_FORCED_HO	ENFORCHO (PKG BSCB)	Flag to enable/disable forced handover.
EN_EXTENDED_CELL_HO	EXTCHO	Flag to enable/disable extended cell handover.
EN_CON_CELL_DIST_HO	CCDIST	Flag to enable/disable concentric cell distance handover.
EN_INNER_INNER_HO	ININHO	Flag to enable/disable inner to inner handover in a sectorized concentric cell.

1.5 Comments

- Enabling BSS internal handover has the following advantages:

  - reduction of signaling load on the A-interface

  - reduction of processor load in the MSC

  - faster handover execution.

  Consequences:

  - BSS internal handover should be enabled,

  - BSS regions should be adapted to the real traffic flow to reduce the inter-BSS handover rate.
- Normally, intracell handover should be enabled to allow a handover from a channel with high interference to another one with less interference within the same cell. However, if random frequency hopping is applied, it may be reasonable to disable intracell handover since interference is approximately the same on all channels and no improvement can be achieved by intracell handover.
- If distance handover is disabled, a MS could largely exceed the planned cell boundaries in the case of favorable radio conditions at the serving cell without causing a handover. As a consequence, neighboring cells may suffer from excessive interference produced by this MS. Furthermore, there is a risk that link quality decreases very suddenly (turn around a corner), i.e. there is the risk of a call drop. Hence, distance handover should be switched on.
- If power budget handover is disabled, no handovers with cause “better cell” are generated. Nevertheless, power budget is calculated and evaluated for the ranking of neighbor cells within the target cell list, which also has to be compiled for mandatory handovers.

2 Measurement Preprocessing

2.1 Measurement Values

The following values are measured and calculated each SACCH multiframe (480ms):

RXQUAL:

The received signal quality is defined according to GSM 05.08 as function of the bit error rate (BER) before channel decoding:

RXQUAL = 0:			BER	<	0.2%	assumed value:	0.14%
RXQUAL = 1:	0.2%	<	BER	<	0.4%	assumed value:	0.28%
RXQUAL = 2:	0.4%	<	BER	<	0.8%	assumed value:	0.57%
RXQUAL = 3:	0.8%	<	BER	<	1.6%	assumed value:	1.13%
RXQUAL = 4:	1.6%	<	BER	<	3.2%	assumed value:	2.26%
RXQUAL = 5:	3.2%	<	BER	<	6.4%	assumed value:	4.53%
RXQUAL = 6:	6.4%	<	BER	<	12.8%	assumed value:	9.05%
RXQUAL = 7:	12.8%	<	BER			assumed value:	18.01%

The RXQUAL values are measured on the dedicated channel for the uplink as well as for the downlink for each TDMA frame (100 frames) within an SACCH multiframe. The measured RXQUAL values are averaged over the respective SACCH period using the assumed values of the table above.

Since there are 104 TDMA frames in each SACCH multiframe (and the measurements in 4 of these frames are optional), the number of samples on each BCCH carrier depends on the number of carriers defined in the BCCH Allocation and therefore can be different:

Number of BCCH carriers defined in the BCCH allocation	**Number of samples per carrier in each SACCH multiframe**
32	3 - 4
16	6 - 7
10	10 - 11
8	12 - 13
...	...

These figures are increased if the MS is able to perform measurements on more than 1 BCCH carrier during each TDMA frame.

RXLEV:

The received signal level is measured on the dedicated channel for the uplink as well as for the downlink for each TDMA frame (100 frames) within an SACCH multiframe. The measured level values in [dBm] are averaged over the respective SACCH period. The average value is mapped on an RXLEV value (refer to GSM 05.08):

RXLEV = 0:	< -110 dBm
RXLEV = 1:	-110 dBm ... -109 dBm
RXLEV = 2:	-109 dBm ... -108 dBm
...	...
RXLEV = 62:	-49 dBm ...-48 dBm
RXLEV = 63:	> -48 dBm

RXLEV_NCELL(n):

The mobile measures the level received on the BCCH frequency of each neighbor cell n. The mapping is as for RXLEV.

MS_BS_DIST:

The distance MS_BS_DIST between the MS and BS is calculated from the timing advance (TA) value measured by the BS and is coded as follows:

MS_BS_DIST = 0, 1, ... 35.   Distance[Km]

Aspects of Discontinuous Transmission

When Voice Activity Detection (VAD) and Discontinuous Transmission (DTX) is applied not all TDMA frames within a SACCH multiframe may be transmitted.

Hence, RXQUAL and RXLEV measurement values (SUB values) for the corresponding SACCH frames are less reliable than those for SACCH multiframes with no silence period (FULL values). Therefore SUB and FULL values have to be distinguished within measurement preprocessing (see below).

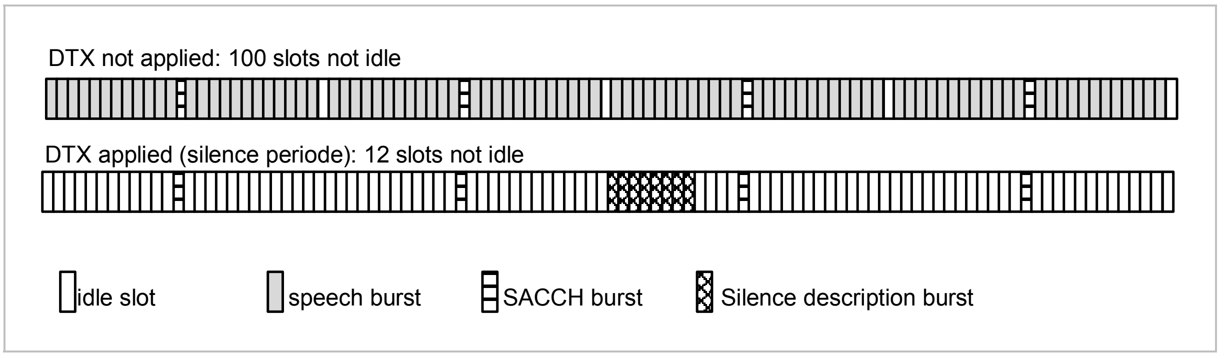

Fig. 2 SACCH multiframe occupancy

2.2 Summary of Measurement Values for Handover

Measurement	Range	Measurement Type Description
RXLEV_DL_FULL	0 - 63	Received signal level on TCH/SDCCH (full set of TDMA frames) downlink
RXLEV_DL_SUB	0 - 63	Received signal level on TCH (subset of TDMA frames) downlink
RXQUAL_DL_FULL	0 - 7	Received signal quality on TCH/SDCCH (full set of TDMA frames downlink
RXQUAL_DL_SUB	0 - 7	Received signal quality on TCH (subset of TDMA frames) downlink
DTX_USED	0.-.1	DTX used/not used on uplink in previous frame
RXLEV_NCELL (1…6)	0 - 63	Received signal level on BCCH of up to 6 neighbor cells (downlink)
BCCH_FREQ_NCELL (1...6)	0 - 31	BCCH RF channel number of up to 6 neighbor cells (downlink)
BSIC_NCELL (1...6)	0-7 (NCC) 0-7 (BCC)	Base Station Identity Code of up to 6 neighbor cells (downlink) Parameter format: NCC-BCC
RXLEV_UL_FULL	0 - 63	Received signal level on TCH/SDCCH (full set of TDMA frames) uplink
RXLEV_UL_SUB	0 - 63	Received signal level on TCH (subset of TDMA frames) uplink
RXQUAL_UL_FULL	0 - 7	Received signal quality on TCH/SDCCH (full set of TDMA frames) uplink
RXQUAL_UL_SUB	0 - 7	Received signal quality on TCH (subset of TDMA frames) uplink
MS_BS_DIST	0 - 35 Km	Absolute MS-BS distance

2.3 Measurement Reporting and Neighbor Cell Book-Keeping

- The MS needs the BCCH frequency of each neighbor cell n:

  Absolute Radio Frequency Carrier Number BCCH_ARFCN_NCELL(n).

- The MS reports to the BTSE the level measured on a certain ARFCN(n) together with the relative BCCH frequency number BCCH_FREQ_NCELL_(n).
- The MS also decodes the Base Station Identity Code BSIC(n).

  Different neighbor cells n1 and n2 which use the same BCCH frequency ARFCN(n1) = ARFCN(n2) have to have different Base Station Identity Codes.

BSIC	= NCC - BCC
NCC:	National Color Code (3 bits)
BCC:	Base Station Color Code (3 bits), has to be chosen by the network operator in accordance with rule given above.

Example

Neighbor Cell	ARFCN_NCELL	BCC	BCCH_FREQ_NCELL
1	4	1	0
2	4	2	0
3	11	1	1
4	18	1	2
5	25	1	3
6	32	3	4
7	39	2	5
8	39	4	5

BCCH_FREQ_NCELL(n) and BSIC(n) → CI_NCELL(n)uniquely!

Measurement Report by MS
reporting of the strongest cells with known and allowed BSIC;
maximum: 6 cells

BCC	BCC_FREQ _NC NELL	RXLEV_NCEL L (n)
1	1	48
2	0	37
3	4	36
4	5	29
1	2	27

each SACCH-Multiframe

Book-Keeping at BS

Neighbor Cell	ARFCN	BCC	BCCH_FREQ_ NCELL	RXLEV_NCEL L (n)
1	4	1	0	0
2	4	2	0	37
3	11	1	1	48
4	18	1	2	27
5	25	1	3	0
6	32	3	4	36
7	39	2	5	0
8	39	4	5	29

For not reported neighbor cells
RXLEV_NCELL is set to 0

Fig. 3

The parameters for measurement reporting and cell book keeping are summarized in the table below.

Specification Name	DB Name / Object	Range	Meaning
CI_NCELL: MCC - MNC - LAC - CI	CELLGLID /ADJC (taken from TGTCELL)	- 4 CHAR - 4 CHAR - 1...65535 - 0...65535	Global cell identifier of the adjacent cell consisting of mobile country code, mobile network code, location area code and cell identity
ARFCN_NCELL	BCCHFREQ /ADJC (taken from TGTCELL)	0...1023	Absolute radio frequency channel number of the BCCH frequency of the neighbor cell.
BSIC $_{NCELL}$ = NCC - BCC	BSIC /ADJC (taken from TGTCELL)	0...7 - 0...7	Base station identity code consisting of national color code and base station color code. Neighbor cell measurements are identified using the BSIC and the relative frequency number of the BCCH.
PLMN_ PERMITTED	PLMNP /BTS	0...255 8 bits	The MS includes only received level values of those cells within the measurement report, which are defined as cells of a permitted PLMN.

2.4 Illustration of Measurement Preprocessing

The measured (and reported) data per SACCH multiframe are preprocessed within the BTSE using a gliding average window.

The size of the window can be set separately for RXQUAL, RXLEV, DIST and PBGT. The measured RXLEV_FULL/SUB or RXQUAL_FULL/SUB values are put into the gliding window with a multiplicity (weight) given by the parameter W_LEV_HO or W_QUAL_HO, respectively.

DTX enabled: Averaging of RXLEV

Example: Average of RXLEV with a gliding window of size **A_LEV_HO = 4** and a weight factor of the full values of **W_LEV_HO = 2**.

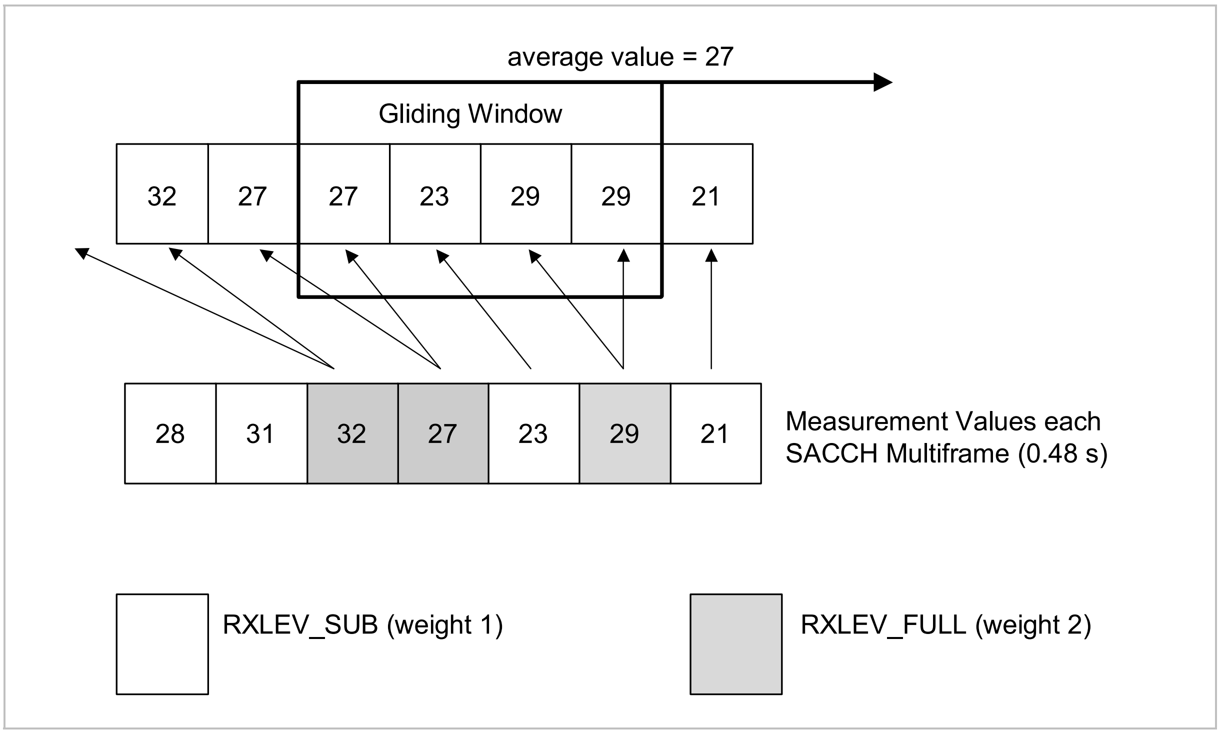

Fig. 4 Illustration of weighting and averaging of measurement values

2.5 Parameters for Measurement Preprocessing

The parameters for measurement preprocessing for handover are administered in the object **HAND** and are listed in the table below.

DB Name	Range (default)	Meaning
HOAVQUAL ***AQUALHO***	1-31 (8)	Averaging window size for RXQUAL values, used for handover decisions due to RXQUAL
HOAVQUAL ***WQUALHO***	1-3 (2)	Weighting factor for RXQUAL_FULL values
HOAVELEV ***ALEVHO***	1-31 (8)	Averaging window size for RXLEV values, used for handover decisions due to RXLEV
HOAVELEV ***WLEVHO***	1-3 (1)	Weighting factor for RXLEV_FULL values
HOAVDIST	1-31 (8)	Averaging window size for Timing Advance values used for handover decisions due to distance.
HOAVPWRB	1-31 (10)	Averaging window size used for power budget calculation.

2.6 Remarks

The adjustment of the averaging window size mainly depends on the change of the radio propagation conditions:

Example:

- path loss (change of 3 dB at a distance of 2000m): → MS movement of ~400 m
- long term fading change of 6 dB: → MS movement of ~5...100 m
- short term fading: → MS movement of ~0.15 m

Hence, at the cell border the main variation of the received level is due to long and short term fading.

Within one SACCH multiframe a MS moves:

0.5 m for MS speed = 1 m/s = 3.6 km/h

5.0 m for MS speed = 10 m/s = 36 km/h

Using an averaging window size of 10 SACCH frames, short term fading is averaged for pedestrians (as well as for “fast” moving MS).

Long term fading is partly averaged for fast moving MS (the degree of averaging depends on the exact speed and the correlation length of long term fading, whereas there is nearly no averaging of long term fading for pedestrians.

The setting of the averaging window size has to be a compromise between a fast decision and a reliable decision.

Therefore it is recommended to use a larger window size for the optional handover (better cell) to do not cause a lot of unnecessary handovers and a smaller window size for the mandatory handover causes (quality, level, distance) to be able to react quickly on a sudden decrease of link quality.

3 Threshold Comparisons and Handover Detection Algorithms

3.1 Decision Criteria

The standard handover algorithm for radio criteria uses the decision criteria listed in the table below.

These criteria will be modified for a speed sensitive handover used within hierarchical cells.

Handover Types	Decision Criteria
Intercell HO due to Quality	1. RXQUAL_XX > L_RXQUAL_XX_H 2. RXLEV_XX < L_RXLEV_XX_IH 3. XX_TXPWR = Min (XX_TXPWR_MAX, P)
HO due to Level	1. RXLEV_XX < L_RXLEV_XX_H 2. XX_TXPWR = Min (XX_TXPWR_MAX, P)
HO due to Distance	1. MS_BS_DIST > MS_RANGE_MAX
HO due to Power Budget	1. RXLEV_NCELL(n) > RXLEV_MIN(n) + Max (0, MS_TXPWR_MAX(n) - P) 2. PBGT(n) > HO_MARGIN(n)
Intracell HO due to Quality	1. RXQUAL_XX > L_RXQUAL_XX_H 2. RXLEV_XX > L_RXLEV_XX_IH

Notes:

- XX: used as variable for both UL (uplink) and DL (downlink)
- MS_TXPWR_MAX: maximum allowed transmit power of the MS in the serving cell,
- MS_TXPWR_MAX(n): maximum allowed transmit power of the MS in the adjacent cell “n“
- P [dBm]: the maximum power capability of the MS (power class)
- An intercell handover due quality or level is only performed if the transmit power of the MS or BS respectively is on its maximum

3.2 Handover Regions

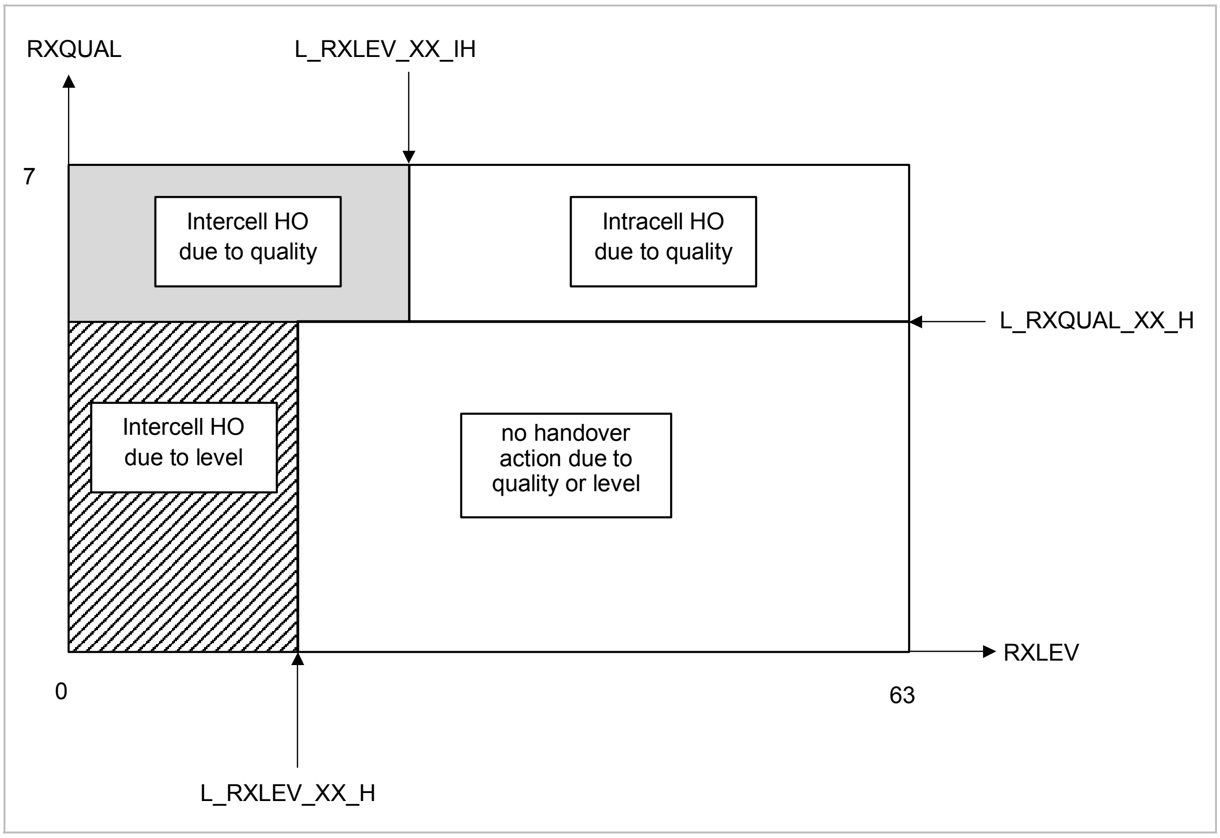

Fig. 5 Regions of handover defined by quality and level thresholds

3.3 Power Budget

The power budget PBGT(n) is calculated in the following way:

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

RXLEV_DL:	averaged value of the measured downlink level in the serving cell,
PWR_C_D:	BS_TXPWR_MAX [dBm] - BS_TXPWR [dBm] averaged difference between the maximum downlink RF power BS_TXPWR_MAX and the actual downlink power BS_TXPWR due to power control in the serving cell.
RXLEV_NCELL(n):	averaged value of the measured downlink level of the adjacent cell “n”
HO_MARGIN(n):	handover margin; if path loss with respect to the serving cell exceeds the path loss with respect to the adjacent cell “n” by this margin, the adjacent cell is considered as the (much) better cell.

3.4 Parameters for Handover Decision

Specification Name	**DB Name / (Object)**	**Range (Default)**	**Meaning**
L_RXQUAL_DL_H L_RXQUAL_UL_H	HOLTHQUDL HOLTHQUUL (HAND)	0...7 (6)	Thresholds for downlink/uplink quality. If RXQUAL is above these thresholds, the received level is low and the transmit power has reached its maximum, a quality intercell handover is initiated.
L_RXLEV_DL_H L_RXLEV_UL_H	HOLTHLVDL HOLTHLVUL (HAND)	0...63 (10) (5)	Thresholds for downlink/uplink level. If RXLEV is below these thresholds and the transmit power has reached its maximum a level handover is initiated.
MS_RANGE_MAX	HOTMSRM (HAND)	0...35 Km (35)	If the measured timing advance value is above this threshold, a distance handover is initiated.
L_RXLEV_DL_IH L_RXLEV_UL_IH	HOTDLINT HOTULINT (HAND)	0...63 (20)	If the quality falls below a threshold, but the received level is high, higher than L_RXLEV_XX_IH, an intracell handover is initiated.
MS_TXPWR_MAX	MSTXPMAXGSM, MSTXPMAXDCS, MSTXPMAXPCS (BTS)	2…15 0…15 0…15, 30-31	Maximum TXPWR a MS is allowed to use in the serving cell: 2 = 39 dBm, 15 = 13 dBm (GSM + R-GSM) 0 = 30 dBm, 15 = 0 dBm (DCS) 0 = 30 dBm, 15 = 0 dBm (PCS) 30 = 33dBm, 31 = 32 dBm (PCS)

MS_TXPWR_MAX(n)	MSTXPMAXGSM, MSTXPMAXDCS, MSTXPMAXPCS (ADJC, taken from TGTCELL or TGTBTS)	2…15 0…15	Maximum TXPWR a MS is allowed to use in the neighbor cell n: 2 = 39 dBm, 15 = 13 dBm (GSM + R-GSM) 0 = 30 dBm, 15 = 0 dBm (DCS) 0 = 30 dBm, 15 = 0 dBm (PCS) 30 = 33dBm, 31 = 32 dBm (PCS)
RXLEV_MIN(n)	RXLEVMIN (ADJC)	0...63 (20)	The level received from a neighbor cell n has to exceed this threshold ● to initiate a better cell handover to that neighbor cell ● to include this cell in the target cell list for a mandatory handover
HO_MARGIN(n)	HOM (ADJC)	0...126 - 63... + 63 dB (69)	The path loss difference between serving and adjacent cell has to exceed this margin for a better cell handover.

3.5 Priorities of Handover Causes

On TCHs it is possible that the condition for more than one handover cause is fulfilled. Therefore it is necessary to rank the evaluation of handover causes. On SDCCH where only one cause is evaluated, no ranking is necessary.

Static ranking is performed according a priority list.

Priority	Handover Cause	HO type	evaluated on
1	Extended Cell Handover Concentric Cell Handover	intracell	TCH
2	Quality Intercell Handover	intercell	TCH
3	Level Handover	intercell	TCH
4	Distance Handover	intercell	TCH
5	Power Budget Handover	intercell	TCH
6	Quality Intracell Handover	intracell	TCH
7	Traffic Handover	intercell	TCH
-	Forced Handover	intercell	SDCCH

Handover Causes Priorities

3.6 Limitation of Intracell Handover Repetition

In a situation, where for a connection in an interfered cell consecutive intracell handovers are performed without improving the quality of the connection (especially if frequency hopping is active), further intracell handovers should be avoided.

In BR4.0, the operator has the possibility to handle this situation with new parameters, which have been introduced:

Parameter	Location	Meaning
`ELIMITCH` Range: TRUE, FALSE Default: FALSE	HAND	This parameter enables the operator to switch on or off the feature of intracell handover limitation.
`TINOIERCHO` Range: 1-254 Default: 60	HAND	This parameter defines the time in seconds, how long an intracell handover is prohibited.
`MAIRACHO` Range: 1-15 Default: 10	HAND	This parameter defines the maximum number of intracell handovers, before further intracell handovers are prohibited.

The following configuration rule should be regarded:

`TINOIERCHO` (BTS timer) > **`THORQST`** (BTS timer) > **`T7`** (BSC timer).

This condition allows the possibility to perform an intercell handover.

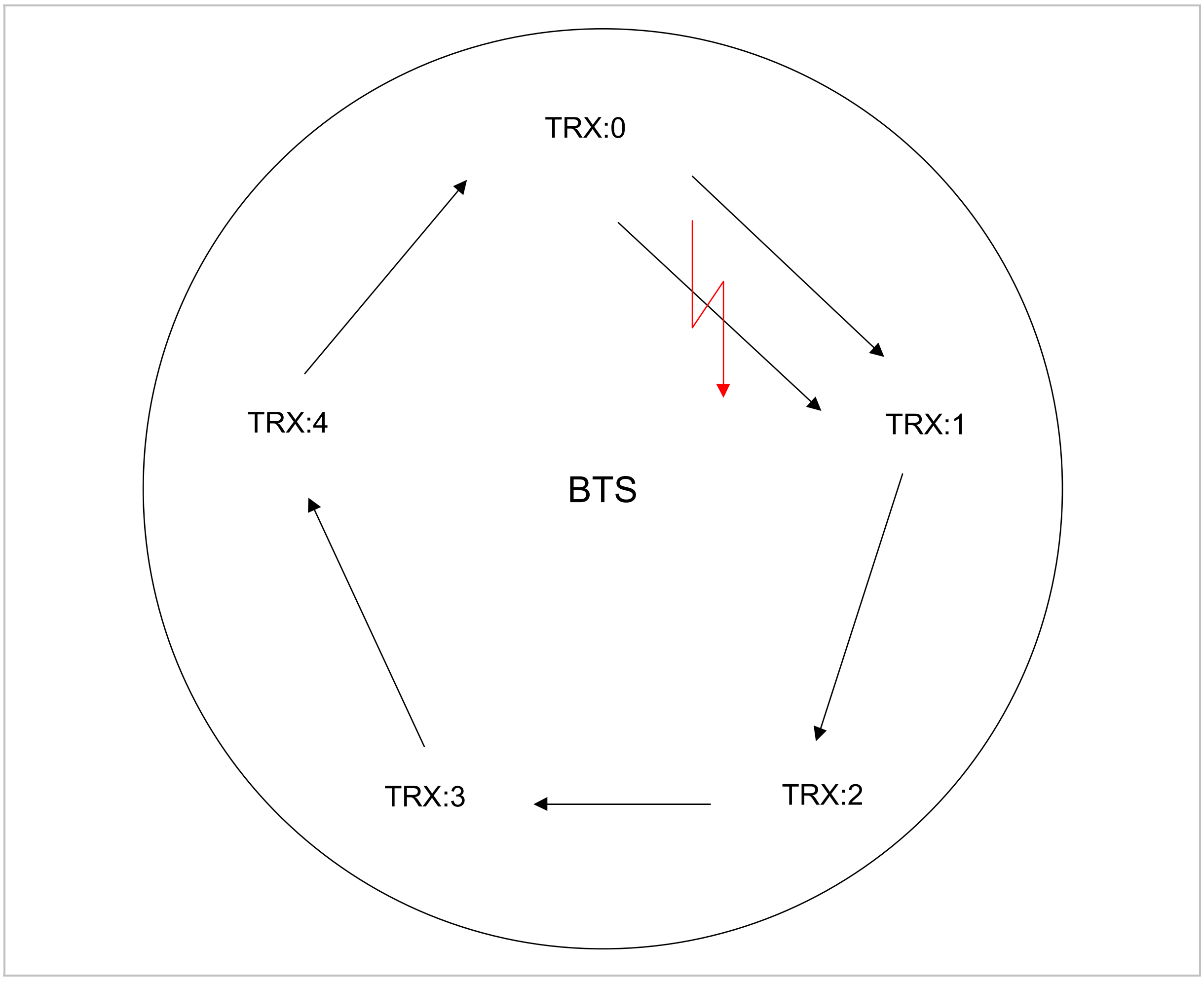

Fig. 6 Limitation of intracell handovers

3.7 Prevention of Back-Handover

In specific cases back handovers, i.e. handovers to a cell just left before, should be avoided. Two different reasons for the first of the two handovers have to be distinguished:

- Imperative Handover

  If an imperative handover occurs, i.e. a handover due to bad quality, excessive distance or low signal level, then a back handover should be avoided if the reason for this second handover is the power budget.

- Forced Handover

  In case of a forced handover, e.g. after a directed retry, a back handover should be avoided only, if the reason for this second handover is the power budget. Up to BR3.7, every back handover was prohibited for a time defined with the parameter **`TIMERFHO`**. Since BR4.0 this timer refers only to handovers due to power budget.

DB Name	Object	Meaning
`NOBAKHO` Range: TRUE, FALSE Default: FALSE	HAND	This parameter enables the operator to switch on or off the feature of back handover prevention.
`TINHBAKHO` Range: 1-254 Default: 30	ADJC	This parameter defines the time in seconds, how long a power budget back handover is prohibited to a cell just left with an imperative handover.
`TIMERFHO` Range: 0-320 Default: 12	ADJC	This parameter defines the time in 10 seconds intervals, how long a power budget back handover is prohibited to a cell just left with a forced handover.

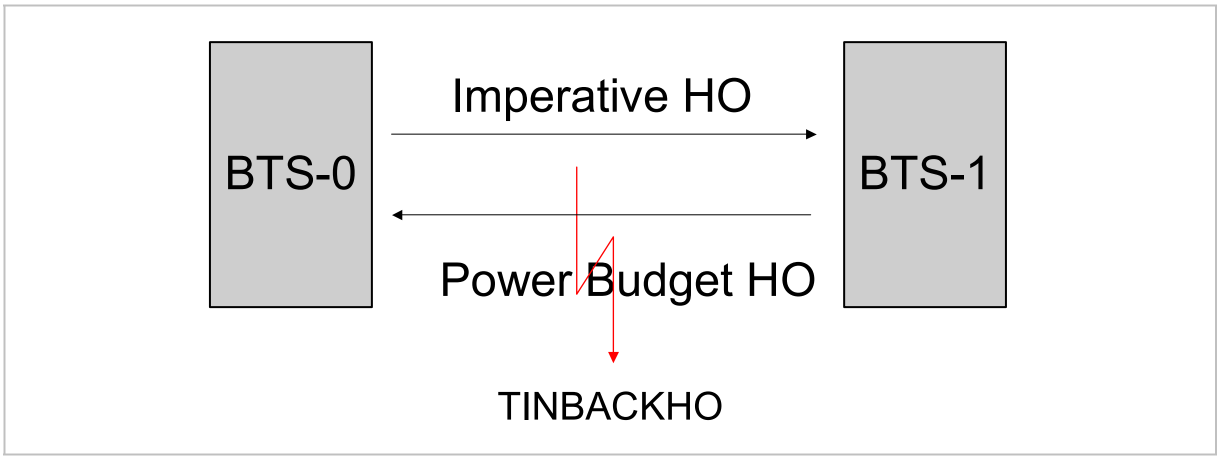

Fig. 7 Prevention of power budget back handover for time TINBAKHO

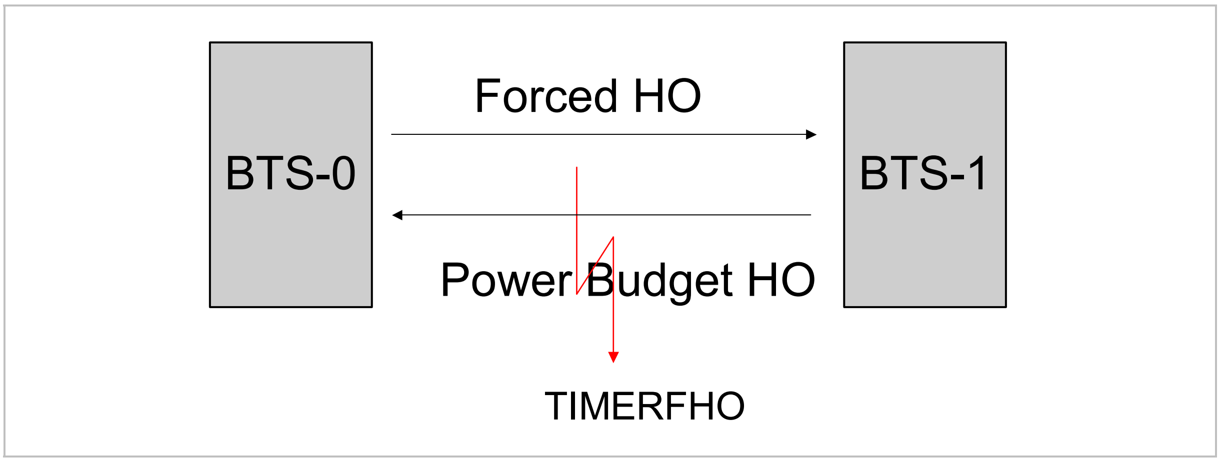

Fig. 8 Prevention of power budget back handover for time TIMERFHO

3.8 Limitation of Handover Failure Repetition

After consecutive handover failures further handovers towards the same cell should be avoided. For this reason the BSC informs the BTS after a number of subsequent Intra-BSC handover failures to exclude the cell from the target cell list. New parameters have been introduced in BR4.0 to enable or disable this feature, to define the maximum number of handover failures and the time period for which a cell is not seen as target for handover.

Parameter	Object	Meaning
NOFREPHO Range: TRUE, FALSE Default: FALSE	HAND	This parameter enables the operator to switch on or off the feature of handover failure repetition prevention.
TINHFAIHO Range: 1-254 Default: 5	ADJC	This parameter defines the time in seconds, how long a cell is removed from the target cell list after a sequence of handover failures.
MAXFAILHO Range: 1-15 Default: 4	HAND	This parameter defines the maximum number of handover attempts, before a cell is removed from the target cell list.

The following configuration rule should be regarded:

TINHFAIHO (BTS timer) > **THORQST** (BTS timer) > **T7** (BSC timer).

This condition allows the possibility to perform the handover towards the second cell indicated in the target cell list.

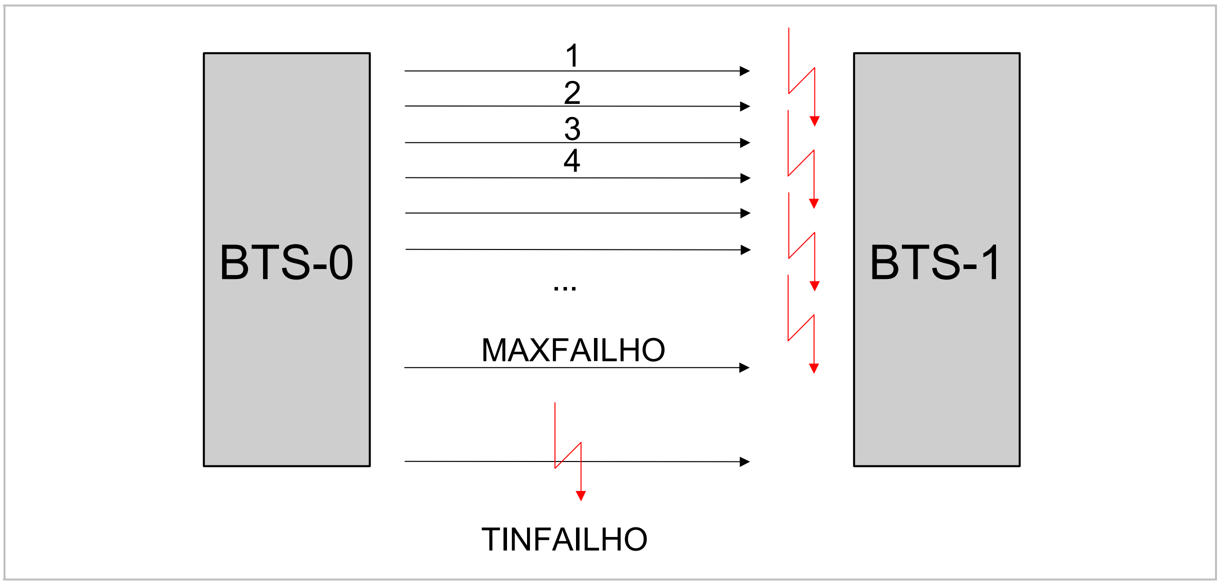

Fig. 9 Concept of handover failure repetition prevention

3.9 Remarks

For adjusting the handover thresholds two scenarios are distinguished:

Scenario A **Noise Limited Scenario:**

Large cells (in rural area) with low traffic load:

received level at the cell border is not much above the receiver limit sensitivity level.

Scenario B **Interference Limited Scenario:**

“Small” cells (in urban area) with high traffic load:

received level at cell border significantly exceeds the receiver sensitivity level, but C/I is not much above the reference interference sensitivity.

In any case intercell handover due to quality should be avoided as far as possible. Therefore:

- set L_RXQUAL_XX_H to highest value for acceptable speech quality,
- set L_RXLEV_XX_IH to a high value so that in case of low RXQUAL an intracell handover is initiated for the locations within the cell area defined by the other thresholds.

Scenario A:

In this scenario the main handover criterion is the level criterion and L_RXLEV_XX_H has to be set to a value just some dB above the receiver limit sensitivity level.

Furthermore, there should be a hysteresis between the threshold RXLEV_MIN for incoming handover and the corresponding threshold L_RXLEV_XX_H for outgoing handover to avoid a lot of unnecessary forward and backward handover:

RXLEV_MIN - L_RXLEV_XX_H = level hysteresis > 0.

The order of magnitude for the level hysteresis is given by the standard deviation of the long term fading,

i.e. RXLEV_MIN > L_RXLEV_XX_H + 4 ... 10 dB.

Scenario B:

In this scenario the better cell criterion should be the main handover criterion, because

- it is the most suitable criterion for designing well defined cell borders,
- it guarantees that the mobile is served by the cell with (nearly) the lowest path loss and therefore offers the greatest potential for power control to reduce interference.

To avoid a lot of unnecessary forward and backward power budget handover caused by long term fading fluctuations of the received levels from the respective BTS, a hysteresis has to be introduced:

HO_MARGIN(cell1 -> cell2) + HO_MARGIN(cell2 -> cell1) = power budget hysteresis > 0.

Usually, the handover margin is chosen symmetrically; its value should be a compromise between ideal power budget handover (low value) and a low rate of forward and backward handovers (high value).

By choosing unsymmetrical values for the handover margin, one can adapt the cell area to the traffic load, e.g. increasing HO_MARGIN(cell1 -> cell2) while keeping the power budget hysteresis constant (i.e. reducing HO_MARGIN(cell2 -> cell1) by the same amount), increases the effective area of cell 1 while reducing that of cell 2.

RXLEV_MIN(n) should be set to a value so that RXLEV_NCELL(n) > RXLEV_MIN(n) for almost all locations where PBGT(n) > HO_MARGIN(n), i.e. a better cell handover is really initiated if the power budget condition is fulfilled.

This means that there should be an overlap of the outgoing power budget area of one cell and the incoming RXLEV_MIN area of the neighbor cell n.

Furthermore, as for scenario A, there should be a level hysteresis between RXLEV_MIN and L_RXLEV_XX_H.

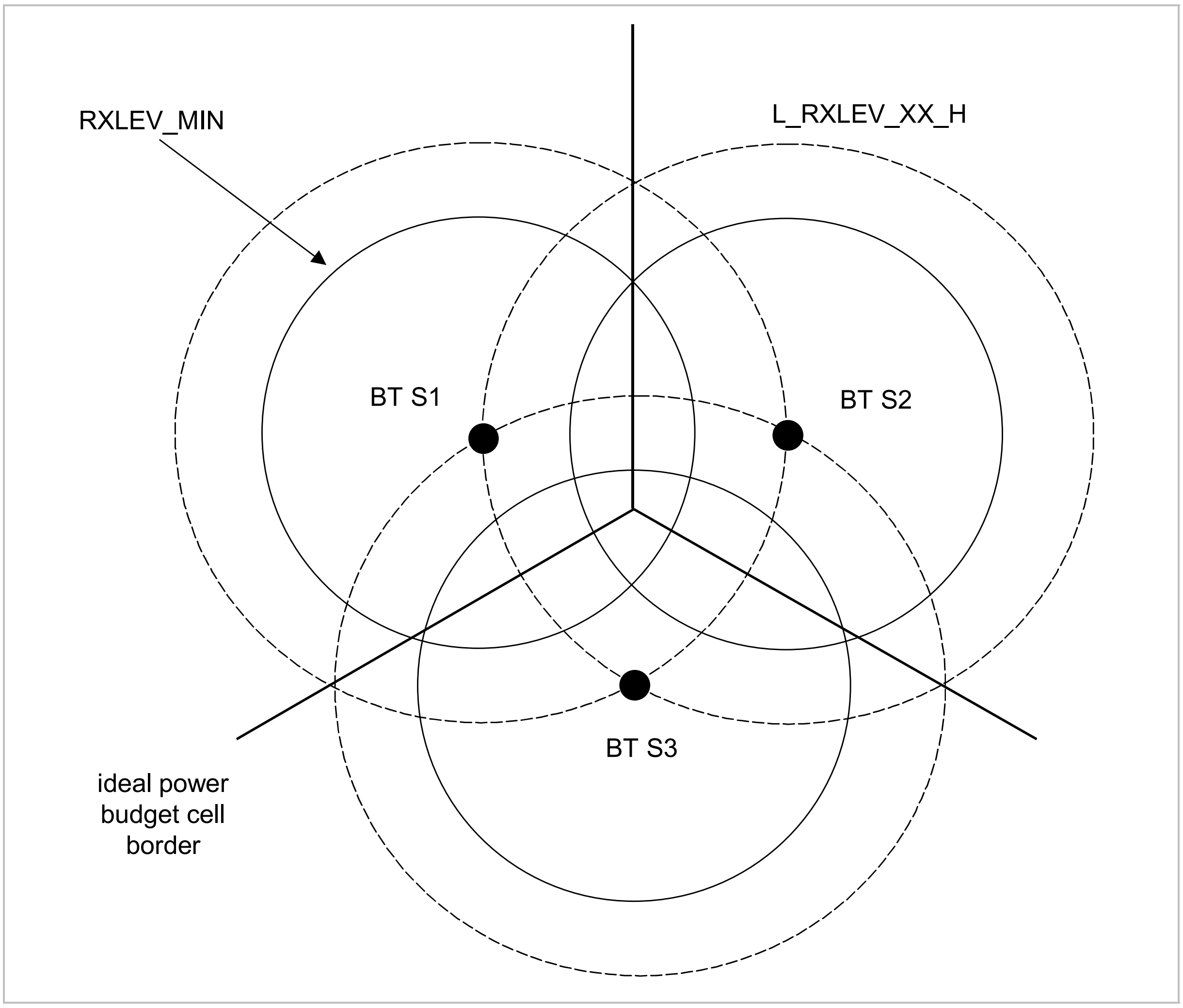

Fig. 10 Cell borders defined by handover thresholds

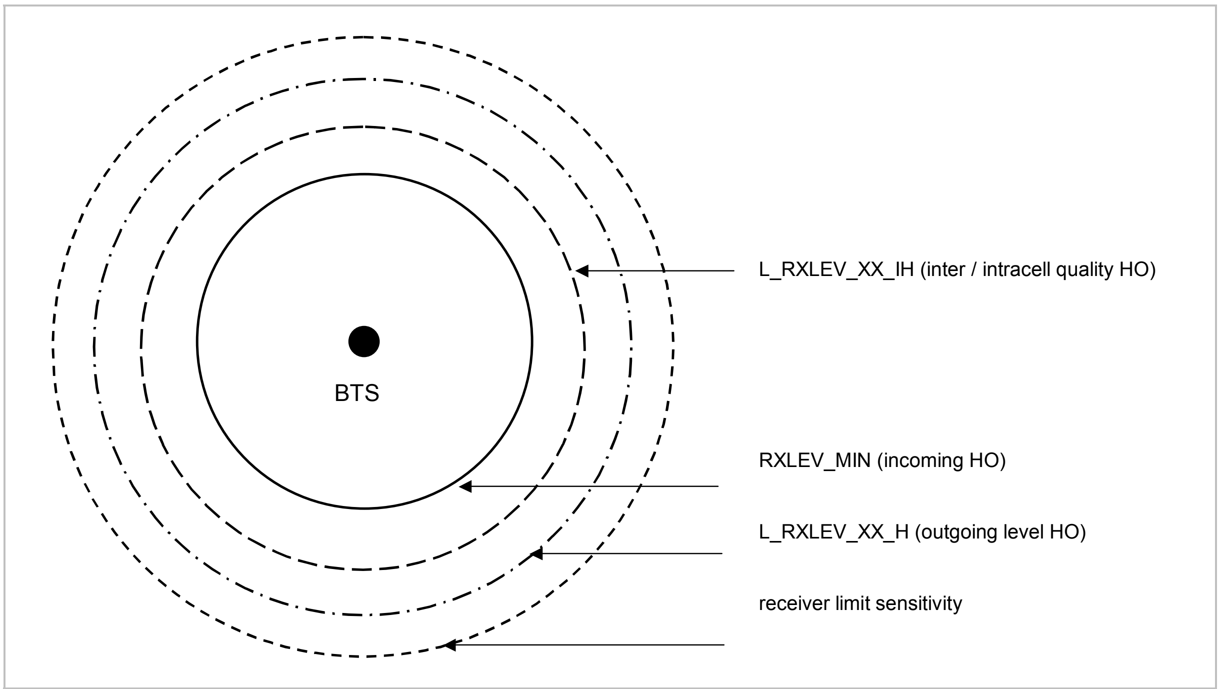

Fig. 11 Relation between handover level thresholds

4 Target Cell List Generation

If the BTSE detects a handover cause it generates a target cell list. This list contains possible handover candidates that mean neighbor cells to where the call can be handed over. The cells in the target cell list are given by their **Cell Global Identifier**.

The maximum number of cells to be included in the target cell list is given by the parameter

N_CELL (Parameter NCELL in object HAND, Range: 0 ... 15).

4.1 Conditions for Neighbor Cells to be included in the Target Cell List

Only those neighbor cells are included in the target cell list which fulfill the following conditions:

- for Quality, Level and Distance Intercell Handover:

  RXLEV_NCELL(n) > RXLEV_MIN(n) + MAX(0, MS_TXPWR_MAX(n) - P)

- for Power Budget Handover:

  RXLEV_NCELL(n) > RXLEV_MIN(n) + MAX(0, MS_TXPWR_MAX(n) - P)

  & PBGT(n) - HO_MARGIN(n) > 0

4.2 Order Criterion for Handover Candidate Cells within the Target Cell List

The ranking of the target cells in the target cell list is performed on the basis of the power budget minus handover margin value:

PRIO_NCELL(n) = PBGT(n) - HO_MARGIN(n)

PBGT(n): averaged value of the power budget

The cell with the highest PRIO_NCELL(n) value will be listed first.

4.3 Evaluation of the Target Cell List

Intracell Handover*:*

A HO Condition Indication message with cause Intracell HO without target cell list is sent from the BTSE to the BSC.

The BSC selects the new channel for the call within the same BTSE.

Intercell Handover

A HO Condition Indication message containing the HO cause and the target cell list is sent from the BTSE to the BSC.

If the first cell within the target cell list is within its BSS area, the BSC selects a channel at the corresponding BTS.

If no channel is available at that BTS, the next cell within the target cell is tried.

If the first target cell (or the ones tried in further steps) does not belong to the own BSS area, a Handover Required message is sent to the MSC.

This message contains a reduced target cell list (without the cells tried internally).

Illustrated of Target Cell Evaluation

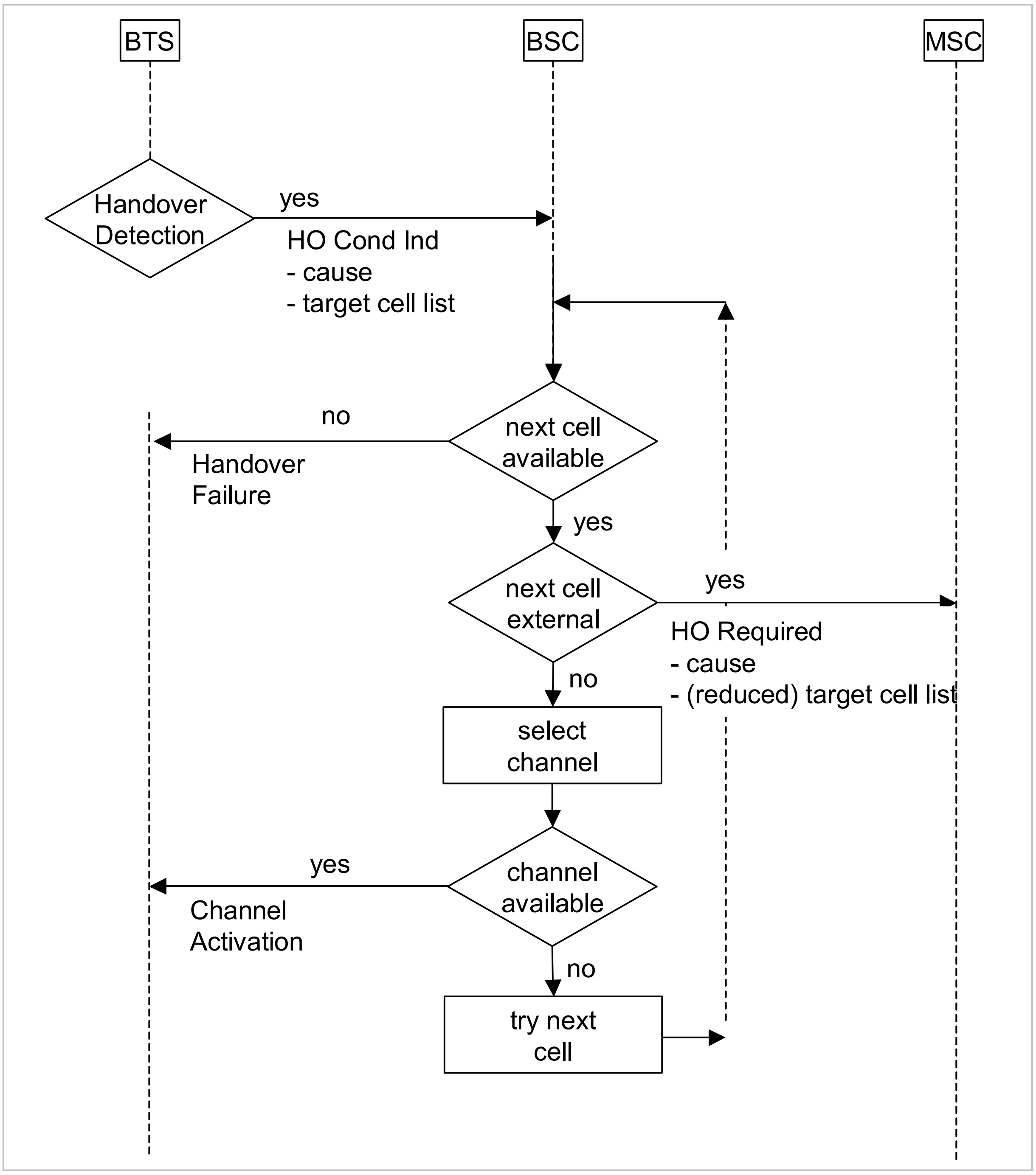

Fig. 12

5 Handover Signaling and Timers

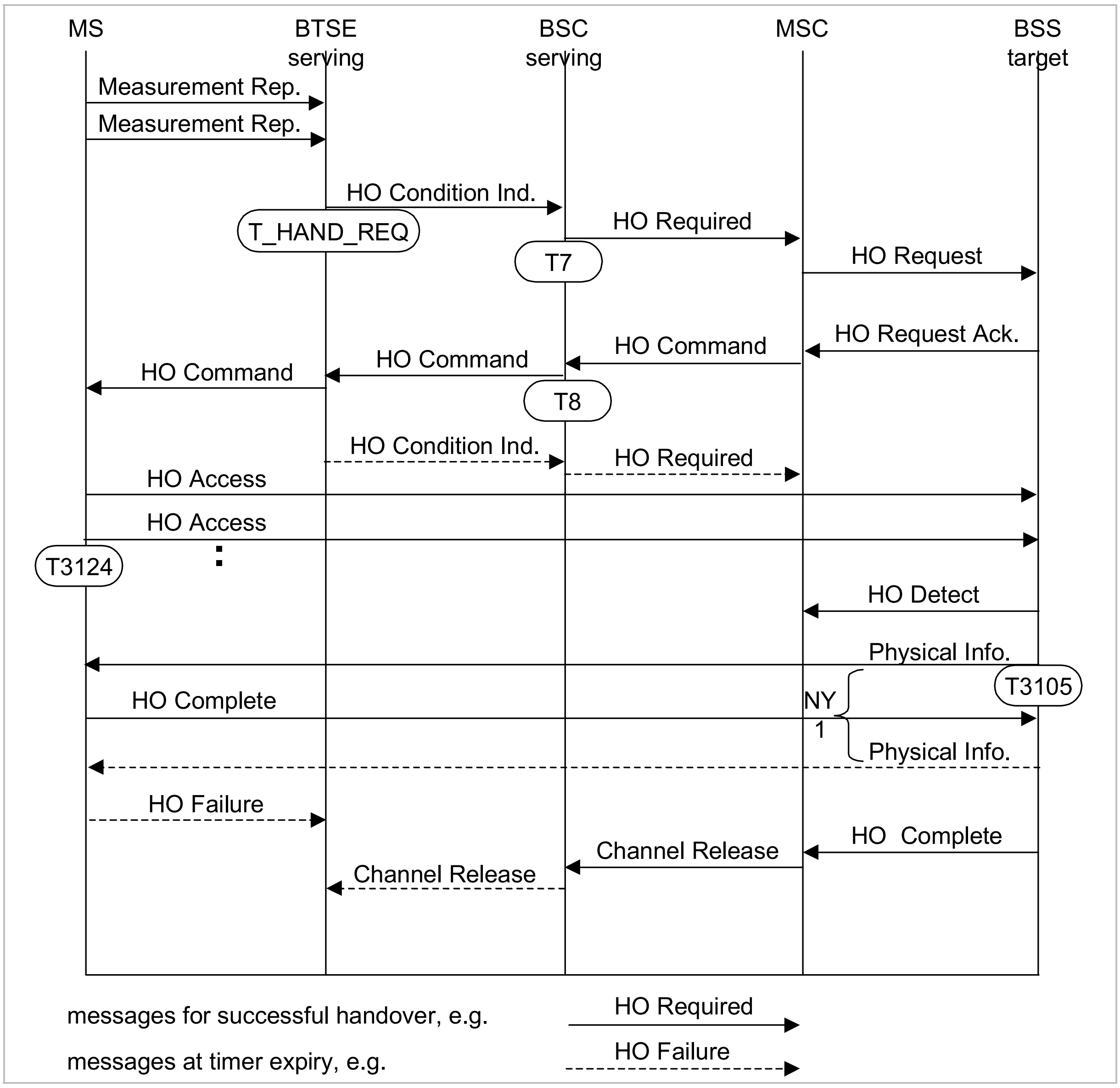

Fig. 13 Example for the signaling of a handover

5.1 Parameters and Timers for Handover Signaling

T3105

Object	DB Name	Range	Step Size	Unit
BTS	T3105	unit * (0...255)	1	MS10 = 10 msec

Purpose: period for repetition of PHYSICAL INFORMATION

Start: sending of PHYSICAL INFORMATION by BTS

Stop: reception of correctly decoded signaling or TCH frame on new channel from MS at BTS

Action expiry: repetition of PHYSICAL INFORMATION; if the maximum number of repetitions has been reached: release of new channel

Default: MS10-10

T3124 - MS Timer, not adjustable by database parameter

Purpose: detect the lack of answer from the network at handover access.

Start: sending of first HANDOVER ACCESS by MS

Stop: reception of PHYSICAL INFORMATION by MS

Action expiry: deactivation of new channel, reactivation of old channel, send HANDOVER FAILURE

Default: 675 msec

T_HAND_REQ

Object	DB Name	Range	Step Size	Unit
HAND	THORQST	0...31	1	2 * SACCH multiframe

Purpose: minimum time for HANDOVER CONDITION INDICATION messages for the same connection

Start: sending of HANDOVER CONDITION INDICATION by BTS

Stop: HANDOVER COMMAND received

reason for handover has disappeared

communication with MS is lost

transaction has ended, call cleared

Action expiry: repetition of HANDOVER CONDITION INDICATION

Default: 5

T7

Object	DB Name	Range	Step Size	Unit
BSC	BSCT7	unit * (0...255)	1	HLFSEC = 0.5 sec MS100 = 100 msec SEC5 = 5 sec

Purpose: minimum time for HANDOVER REQUIRED messages for the same connection

Start: sending of HANDOVER REQUIRED by BSC

Stop:
- HANDOVER COMMAND received
- reason for handover has disappeared
- communication with MS is lost
- transaction has ended, call cleared

Action expiry: repetition of HANDOVER REQUIRED

Default: HLFSEC-4

T8

Object	DB Name	Range	Step Size	Unit
BSC	BSCT8	unit * (0...255)	1	HLFSEC = 0.5 secMS100 = 100 msecSEC5 = 5 sec

Purpose: keep the old channel sufficient long to be able to return to it, and to release the channels if the MS is lost

Start: reception of HANDOVER COMMAND at BSC

Stop: reception of CLEAR COMMAND from MSC or HANDOVER FAILURE from MS at BTS

Action expiry: release of old channels

Default: HLFSEC-20

NY1

Object	DB Name	Range	Step Size	Unit
BTS	NY1	0...254	1	-

NY1 is the maximum number of repetitions of the physical information by the BTS.

Default: 20

6 Preemption, Directed Retry, Queuing

Preemption, directed retry, and queuing allows to assign a TCH when, due to the unavailability of resources, no unused channel can be found within the serving cell:

- Preemption is a means of providing TCH resources for high priority TCH requests.
- Directed Retry is the handover from a SDCCH in one cell to a TCH in another cell.
- Queuing allows the queuing of TCH requests on a per cell and priority basis.

In case of unavailability of resources, two cases can be distinguished (assignment request and handover request):

In case of an Assignment Request, preemption is tried first: The BSC looks for a call in the cell with a priority lower than the new TCH request and, then moves the lower priority call to another cell performing a forced handover (or a forced release if HO fails) in order to free the TCH. The free TCH is then assigned to the new request. If no call with a lower priority is using a TCH or a call with the same priority or higher is already waiting (queued) Directed Retry is performed. If still no free TCH is available, the queuing procedure is carried out, storing the TCH request in the cell queue based on their priority.

In case of Handover Request, preemption is tried first. If preemption is not successful, the directed retry procedure will be skipped and queuing is carried out.

The preemption feature gives the operator the possibility to differentiate subscriptions per user class (e.g. different contracts for high priority classes such as police and other emergency organizations, business people etc.)

Queuing and directed retry improve the network access and, in general, the network QOS.

6.1 Parameters for Preemption and Queuing

EN_PREEMPTION

The parameter Enable Preemption is used to enable/disable the preemption feature.

Object	DB Name	Range	Step Size	Unit
BTS	EPRE	ENABLED DISABLED	-	-

EN_QUEUEING

The parameter Enable Queuing is used to enable/disable the queuing feature:

Object	DB Name	Range	Step Size	Unit
BTS	EQ	ENABLED DISABLED	-	-

QUEUEING_LENGTH

The parameter Queuing Length defines the maximum number of TCH requests that can be queued in the cell.

Object	DB Name	Range	Step Size	Unit
BTS	QL	1...100	1	

T11

The timer T11 defines the maximum queuing time for an ASS_REQ:

Object		DB Name	Range	Step Size	Unit
BSC		BSCT11	unit * (0...255)	1	MS100 = 100 msec HLFSEC = 0.5 sec SEC5 = 5 sec

Start:	ASS_REQ is queued, BSC sends QUEUE_IND to MSC
Stop:	TCH becomes free for assignment or the request is replaced by an other request with higher priority.
Action expiry:	remove ASS_REQ from queue, send CLEAR_REQ to MSC
Default:	HLFSEC-16

Tqho

The timer Tqho defines the maximum queuing time for HO_REQ:

Object		DB Name	Range	Step Size	Unit
BSC		BSCTQHO	unit * (0...255)	1	MS100 = 100 msec HLFSEC = 0.5 sec SEC5 = 5 sec

Start:	HO_REQ is queued, BSC sends QUEUE_IND to MSC
Stop:	TCH becomes free for assignment or the request is replaced by another request with higher priority.
Action expiry:	remove HO_REQ from queue, send HO_FAIL to MSC
Default:	HLFSEC-20

GSM supports the prioritization of calls using 14 priority levels:

A priority level and a queuing allowed indicator is attached to each TCH request in the (optional) priority information element within the assignment request or handover request message

The priority information element is organized in the following way:

Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1
Spare	PCI	PRIORITY LEVEL				QA	PVI

- The PCI (preemption capability indicator) indicates whether or not the preemption shall be applied.

- The PRIORITY LEVEL contains the priority of the call; GSM supports the prioritization of calls using 14 priority levels (1 is the highest and 14 is the lowest priority).

- The QA (queuing allowed indicator) is used to decide on a per call basis whether or not queuing shall be applied.

- The PVI (preemption vulnerability indicator) applies for the entire duration of a connection and indicates whether or not this connection might be preempted by another allocation request (i.e. may become a target of preemption).

The entire procedure is shown in the following figures. These flowcharts basically indicate which algorithms and which checks are necessary in which network entity (BTSE, BSC or MSC) and the message flow that has to be conveyed between the networks entities. It can be seen that, in the best case, an assignment of a TCH in a neighbor cell takes place.

Flowchart of Preemption

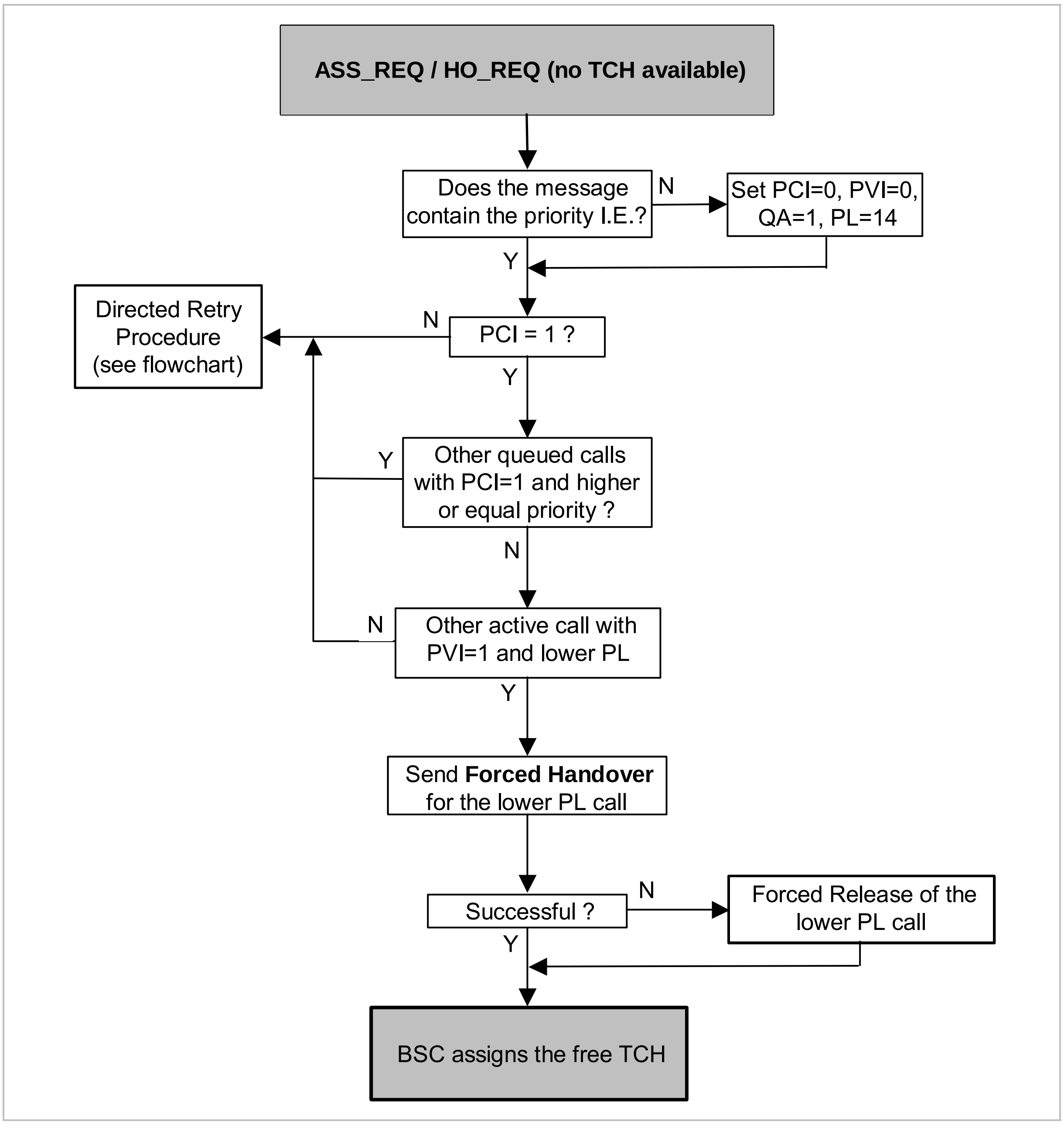

Fig. 14

6.2 Directed Retry

Directed retry is the transition (handover) from a SDCCH in one cell to a TCH in another cell during call setup because of unavailability of an empty TCH within the first cell.

Directed retry is a means to control the traffic distribution between cells and to avoid a call rejection because of congestion in one cell. If Queuing of ASS REQs is not supported within a BSC Directed retry is merely triggered by the BSC by sending a Forced HO Request message to the BTS, which has to respond with a "initiated" Intercell HO Cond. Indic. message.

It can happen that the Intercell HO Cond. Indic. message does contain only an empty target cell list (If triggered by a Forced HO Request message the BTS has to send a Intercell HO Cond. Indic. message even if no suitable neighbor cell exists - in this case the target cell list is empty!). In this case a TCH cannot be assigned and the BSC shall not send a HO RQD message to the MSC of course but shall send an ASS FAILURE (cause "no radio resource available").

If the target cell list contains cells from inside and outside the BSC area and if e.g. the first and second cell is inside, the third outside and the fourth inside the BSC area than the Directed retry attempts shall be carried out as BSC controlled Directed retries to the first and second one. If these Directed retries are not possible for any reason (e.g. no empty TCH) than the third attempt and all following attempts (independently whether the fourth and the following cells lie in- or outside the BSC area) shall be executed as MSC controlled Directed retry.

If in case of a MSC controlled handover the MS cannot access the new cell and the MSC receives a HO FAILURE (cause "radio interface failure, reversion to old channel") from the old BSS, it can happen that the MSC generally releases this SDCCH connection by sending a CLEAR CMD message (cause "radio interface failure, reversion to old channel") to the BSC independently.

If the MSC does not support Directed retry HO´s the BSC may perform BSC controlled Directed retries (approximately 75% of all Directed retries) only. In this case the EN_INTER_SDCCH_HO flag in the BSC shall be set to "disabled" and the BSC has to check the target cell list of Intercell HO_Cond_Ind messages belonging to a SDCCH connection. All cell identifiers not belonging to the BSC area shall be skipped and if there remain cell identifiers belonging to the BSC area the corresponding HO shall be performed to strongest (if impossible to the second strongest, third strongest etc.) remaining cell. If the target cell list does not contain a remaining or any cell identifier of the same BSC area, this Intercell HO Cond. Indic. message shall be discarded and the BSC shall release this SDCCH connection (Sending of an ASS FAILURE with cause "no radio resource available").

6.2.1 Flowchart of Directed Retry

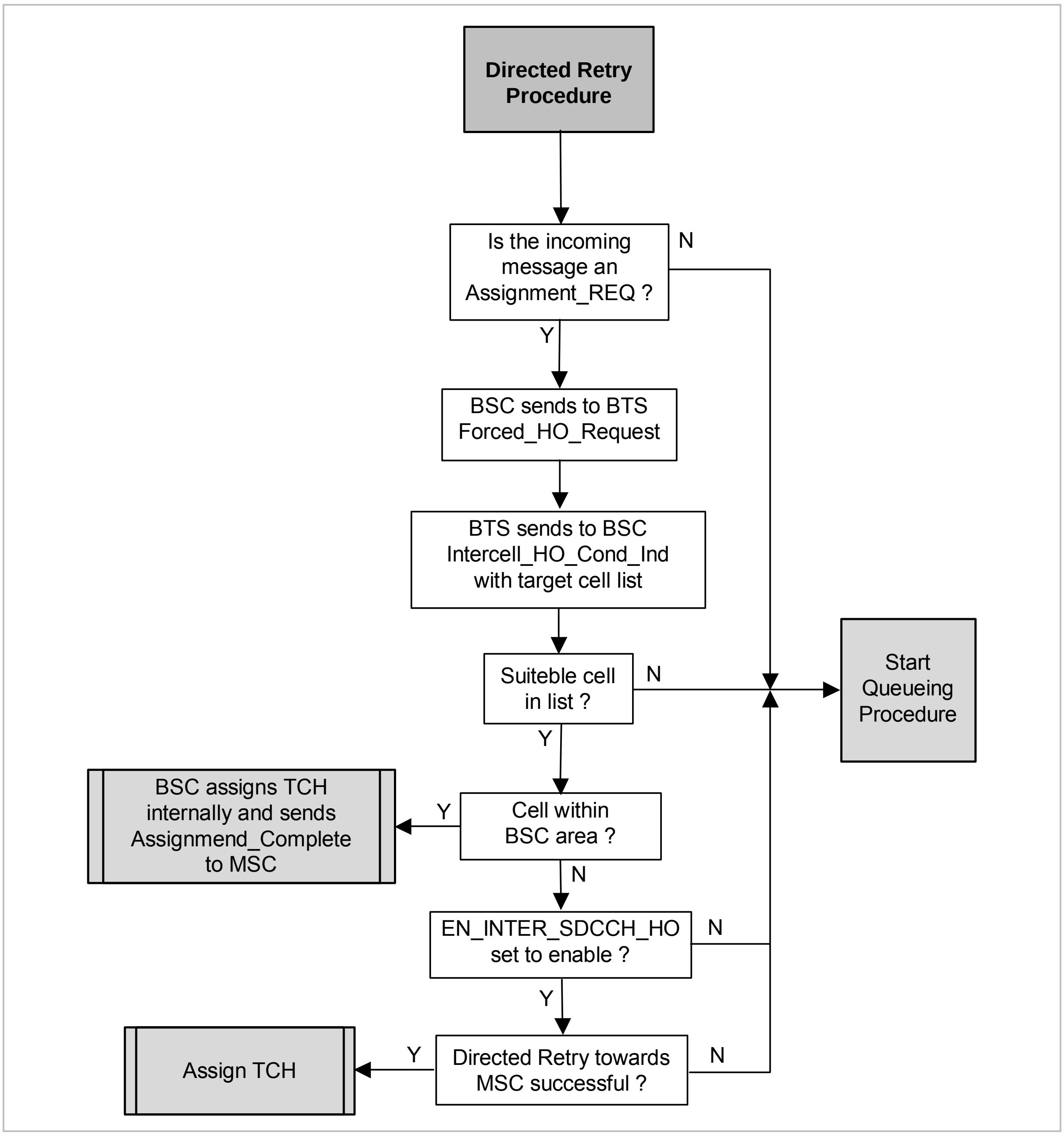

Fig. 15

6.2.2 HO Algorithm and Generation of the Target Cell List for Directed Retry

The BTS has to send the Intercell HO Cond. Indic. messages toward the BSC. For Directed retry the sending of an Intercell HO Cond. Indic. message for a SDCCH may only be triggered by a BTS external event: The BSC sends a Forced HO Request because of "no TCH available".

If an Intercell HO Cond. Indic. message is to be sent, the target cell list shall contain all neighbor cells, which fulfill the following condition:

RXLEV > RXLEV_MIN + Max(0, MS_TXPWR_MAX-P) +
FHO_RXLEV_MIN_OFFSET

The ranking of the neighbor cells in the target cell list is performed in the order of decreasing values of:

PBGT - HO_MARGIN

Additional parameters specific to speed sensitive HO shall be taken into account for the ranking of the target cells.

Even if no suitable neighbor cell exists, the BTS shall send an Intercell HO Cond. Indic. message. In this case the target cell list ("Cell Identif. List Pref. IE") shall be empty!

The cause of the Intercell HO Cond. Indic. message shall be FORCED.
FHO_RXLEV_MIN_OFFSET is a cell specific O&M-parameter to select only target cells for forced HO which the MS can access without any problems. It is a result of radio planning for each individual cell. It allows to influence the amount of Forced HOs failed because of empty target cell list, the amount of HO attempts back to the "old" cell and the success rate of HO ACCESSes to the target cell

6.2.3 Prevention of Back-Handovers

A major general problem of forced HO (Directed retry is one sort of forced HO!) is the probability of HO due to PBGT back to the "old" (congested) cell. Its drawbacks are:

1. increased load at the Abis-interface because of periodic sending of Intercell HO_Cond_Ind messages in intervals of T7
2. increased load at the A-interface in case of inter-BSC-HO because of the same reason
3. additional processor capacity in BSC (and MSC) is required for HO trials for which it is known in advance that they are useless
4. the load in the congested cell will not be reduced for a certain time, but it will be kept at a permanent high level.

For the Channel Activation message a new optional information element "Cell Identifier List (no target)" is defined. This information element contains the cell identifier (CI) of a cell from which a handover request (intra- or inter-BSC) because of forced HO was received. If this information element exists in the Channel Activation message, the BTS

- shall not trigger a (TCH-)HO due to PBGT for the time Tbho if the PBGT condition is fulfilled for the indicated cell only and
- shall not include the indicated CIs in the target cell list in this case for the time Tbho (i.e. for the condition HO due QUAL/LEV/DIST the indicated cell identifier may be part of the target cell list)

Tbho is a timer that limits the mentioned prohibitions. It has to be set by O&M command.

If a HO is necessary the target BSC has to generate the Channel Activation message. The target BSC shall insert the Cell Identifier List (no target) IE into this message

The BSC shall derive the CI for the Cell Identifier List (no target) IE from the stored context in case of intra BSC HO or from the mandatory Cell Identifier (serving) IE of the HO REQ message in case of inter BSC HO with cause "Directed retry".

6.3 Parameters for Directed Retry

EN_FORCED_HO

Object	DB Name	Range	Step Size	Unit
BSC	ENFORCHO	ENABLE DISABLE	-	-

This BSC specific O&M flag allows to enable/disable the sending of Forced HO Request messages for running SDCCH connections (e.g. queued or not queued ASS REQs which do not find an empty TCH). It is used to enable/disable Directed retry. This flag should be set to "disable" by an operator if in a network the MSC which the BSS is connected to or other adjacent BSS do not support the prevention of "back-HO".

EN_INTER_SDCCH_HO

Object	DB Name	Range	Step Size	Unit
BSC	ESDCCHHO	ENABLE DISABLE	-	-

This BSC specific O&M flag allows to enable/disable inter BSC SDCCH-HO (i.e. SDCCH-SDCCH-HO and Directed retry). It simply prevents the sending of HO RQD messages for SDCCH connections to the MSC.

This flag should be set to disable by an operator if in the network the MSC to where the BSS is connected to or other adjacent BSS do not support the prevention of back-HO. If it set to disable the BSC shall skip all cell identifiers of the target cell list of the Intercell HO Cond. Ind. message, which belong to another BSC area.

FHO_RXLEV_MIN_OFFSET

Object	DB Name	Range	Step Size	Unit
ADJC	FHORLMO	0...24	1	1 dB

FHO_RXLEV_MIN_OFFSET ("RXLEV_MIN offset for forced-handover") is a cell specific O&M-parameter used within the BTS to select only target cells for forced HO, which the MS can access without any problems. It is a result of radio planning for each individual cell. It allows to influence the amount of Forced HO failed because of empty target cell list, the amount of HO attempts back to the "old" cell and the success rate of HO ACCESSes to the target cell.

Default: 6

Tbho

Object	DB Name	Range	Step Size	Unit
ADJC	TIMERFHO	1...320	1	10 sec

Tbho (bho=back handover) is a network wide O&M parameter. It is the value of a timer running in the BTS that controls the duration how long a former serving cell from which forced HO was performed to the new serving cell may not be considered in the HO decision algorithm of the new serving cell and may not be contained in the target cell list. It is started at the reception of a Channel Activation message containing a Cell Identifier (no target) IE.

Default: 12

7 Enhancements introduced with BR6.0

7.1 HO Decision due to BSS Resource Management Criteria

7.1.1 General

H/O Decision due to BSS Resource Management Criteria allows to move a connection for **traffic reasons** from one cell to an adjacent cell, even in case that a handover due to radio conditions is not required.

Thus, the traffic during busy hours can be redistributed in the network. It enables to serve a higher number of subscribers by existing equipment, thus increasing the network capacity. H/O Decision due to BSS Resource Management Criteria also provides higher cell planning flexibility and avoids the planning of new resources into a cell or channel reservation in a cell for high traffic situations.

7.1.2 Basics

This feature as well as Directed Retry increases network capacity. Whereas Directed Retry acts on new connections by moving them towards adjacent cells, H/O Decision due to BSS Resource Management Criteria moves connected users towards adjacent cells allowing in the previously used cells new connections to be set up. A connection moved for Directed Retry can be far from the ideal cell border, while the connection moved by H/O Decision due to BSS Resource Management Criteria is chosen near to the ideal cell border.

The priority of H/O Decision due to BSS Resource Management Criteria is below power budget handover cause evaluation. This implies no degradation of service, since the priority of imperative handover is higher than the priority for H/O Decision due to BSS Resource Management Criteria.

When the function is enabled (ETRFHO parameter) in a cell, the following procedure is applied:

1. The BSC starts a timer TRAFCONTROL_TIME for this cell.
2. At the expiry of this timer, the traffic level is evaluated for that cell by the BSC. If the percentage of busy TCHs is higher or equal to TRAFFICOUT, the cell is regarded as high traffic level.
3. If there is a transition in the traffic level in respect to the previous evaluation, the BSC sends via O&M command to the BTSE the indication that the handover due to traffic reason has to be enabled/disabled in the specific cell.

The neighboring cells included in the candidate list are ranked. When the candidate list is ready, the BTS sends to the BSC an inter cell handover condition message that includes the preferred list of candidates and the cause traffic for the handover request. When the BSC receives the request, the list is analyzed and the cells with traffic higher than TRAFFICIN are discarded. In the target cell a back handover for traffic reasons and power budget is inhibited for the TPENTR duration time.

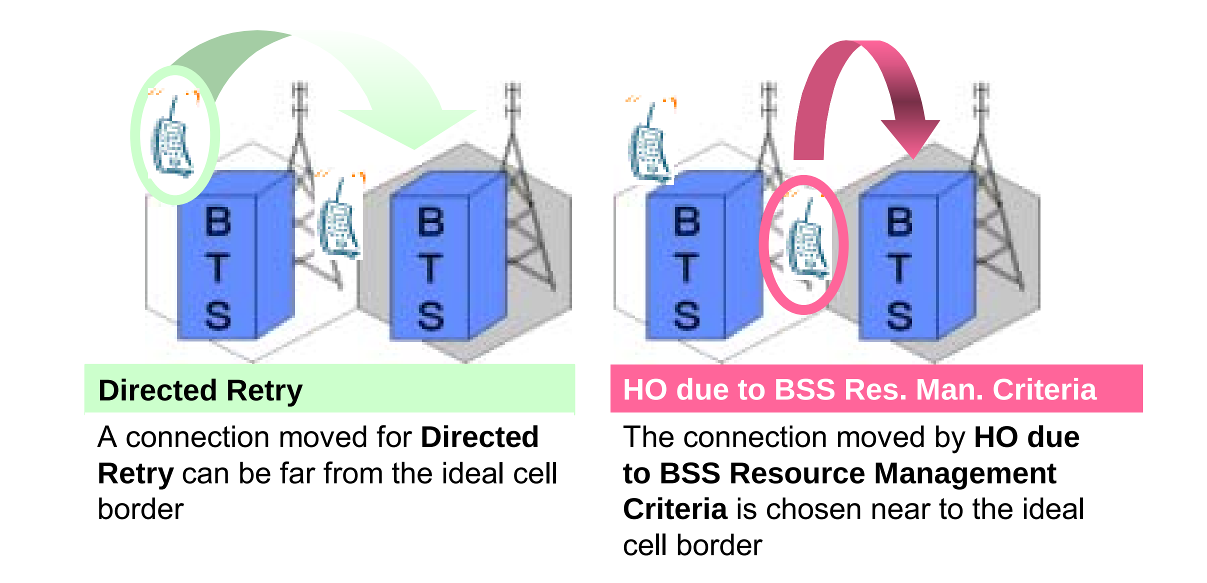

Fig. 16 H/O decision due to BSS resources management criteria

7.1.3 Handover Procedure

- The BSC starts a timer (TRFCT).
- When this timer (TRFCT) expires, if the feature is enabled in the cell the BSC calculates the traffic level (in percentage). In concentric cell cases (in mixed cells too) the traffic load evaluation refers only to the outer area. In extended cell cases the handover for traffic reason procedure is not applied.
- The cell traffic level value is compared with the predefined percentage of high traffic level threshold (TRFHITH).
- If the calculated value is higher or equal to TRFHITH parameter the cell is regarded as a high traffic level cell, otherwise the cell is regarded as a low traffic level cell.
- If the cell is classified as a high traffic level cell and the last evaluation for that cell defined it as low traffic level cell, the BSC sends a message to the BTS (through O&M) to enable the handover for traffic reason.
- If the cell is classified as a low traffic level cell and the last evaluation for that cell defined it as high traffic level cell, the BSC sends a message to the BTS (through O&M) to disable the handover for traffic reason.

7.1.4 Database Parameters

DB Name	Object	Range	Description
BHOFOT	ADJC	1 … 120 (default: 100)	During run-time of this timer a back handover due to PBGT or traffic reason is forbidden (backHoForbiddenTimer).
TRFHOM	ADJC	0 … 126 (step in dB) 0=-63 dB, 126=63 dB, default 67=4 dB	Specifies the nominal border between cells (trafficHoMargin).
TRFHOE	HAND	TRUE, FALSE (default)	Enable / disable the traffic HO feature (trafficHOenabled)
TRFHITH	HAND	50 … 100 % (default: 90 %)	Defines the high traffic level threshold which enables / disables traffic HO from a cell (trafficHighThreshold)
TRFLTH	HAND	0 … 85 % (default: 70 %)	Defines the low traffic level threshold which makes a cell into a candidate to receive handover due to traffic (trafficLowThreshold)
TRFMS	HAND	1 … 6 (dB), default 3 (dB)	Used to establish the minimum reduction for TRFHOM (trafficMarginStep).
TRFMMA	HAND	1 … 48 (dB), default 9 (dB)	Used to establish the maximum reduction for TRFHOM (trafficMarginMaximum).
TRFKPRI	HAND	TRUE, FALSE (default)	It is effective only when HCS is enabled and determines whether candidate cells must be of the same priority as the serving cell (TRFKPRI=YES) or may be of the same or higher priority (TRFKPRI=NO, trafficKeepPriority).

TRFHOT	HAND	2 ... 20 (sec), default: 10	Timer used to establish the period of time to wait before updating the m value. The m value is increased if the handover for traffic reason is enabled and decreased if the handover for traffic reason is disabled, m is updated until it reaches the value 0 (trafficHoTimer). Each time this timer expires, the internal margin (m) for the traffic HO is altered. If enableTrafficHo is set to TRUE then m is increased, if enableTrafficHo is FALSE then it is decreased. As long as m > 0 the BTS evaluates the handover for traffic reason. If m becomes "0" trafficHoTimer is stopped and the handover for traffic reason is no longer evaluated. The maximum value of m is calculated by dividing trafficMarginMaximum by trafficMarginStep.
TRFCT	BSC	5 ... 100 sec, step=0.5 sec (default: 10 sec)	Timer establishing for each BTS the interval between evaluating the traffic level (trafficControlTimer)

7.1.5 Requirements

The "traffic" cause is not foreseen on the A interface and the serving BSC cannot control the channel occupancy of a cell belonging to another BSC, consequently the handover for traffic reason may be performed only between cells belonging to the **same BSC**.

The handover for traffic reason is the lowest priority one because the technically necessary handovers shall be performed first in order not to disturb the normal network behavior too much.

The HO due to resource criteria is not triggered for extended cells. In concentric cells only the outer area is checked for the resource criteria.

H/O Decision due to BSS Resource Management Criteria is a pure software feature. Hardware modifications are not required. Mobile stations and SSS are not affected by this feature.

7.2 Fast Uplink Handover

7.2.1 General

When a mobile enters a shadow area caused by buildings or short tunnels, a call can drop down because of long handover decision time or when the chosen cell is also shadowed by the same building.

Fast Uplink Handover is used as **high-speed handover** to prevent from rapid uplink level loss and is applied to save connections in special places with drop call problems. This behavior is more likely for GSM1800 or GSM1900 MHz systems than for GSM900 systems because of the different characteristics of the diffraction effects depending on the wavelength. When the power level of a mobile decreases rapidly, a handover can be performed to a **predefined cell** to save the connection.

In case that a mobile subscriber is moving out of a micro cell but all adjacent cells are congested, the target cell list, which is generated for Fast Uplink Handover, allows changing the margin to include a higher number of cells to which the handover can be performed. This increased target cell list offers the possibility to save the call.

7.2.2 Basics

In case of an uplink level loss shorter than 3 s the normal handover triggering with averaging windows is too slow (> 4 s). A moving mobile will be lost at cell boundary or in shadowed areas.

The BTS maintains a Fast Uplink Handover specific bookkeeping list for each possible adjacent cell (up to 32) in which the neighbor cell measurements of the mobile, the downlink RXLEV (RXLEV of serving cell measured by the mobile) and the BTS transmit power are compiled and averaged. This bookkeeping list is the basis for generation and sorting of the target cell list.

The Fast Uplink Handover is performed independently of the capabilities of power control when they have been exhausted, i.e. current transmit power of MS / BTS have the **maximum** value. The handover detection is performed for the uplink path and is based on a comparison of the uplink measurement receive level with a (configurable) threshold. The Fast Uplink Handover is detected when the uplink measurement receive level is lower than this threshold.

Because the Fast Uplink Handover provides the last opportunity to maintain a call, the back handover to the old cell and the handover repetitions are allowed to act very fast to changing radio conditions.

7.2.3 SBS Implementation

7.2.3.1 Signal Level

Downlink measurements contain a signal level mapped to the RXLEV (Reception LEVel) according to GSM 05.08. The Received Signal Strength Indication (RSSI) values of uplink measurements sampled (via one multiframe) are mapped by the BTS according to GSM 05.08.

RXLEV	Range in dBm
00	-∞ ... ≤ -110
01	-110 < ... ≤ -109
02	-109 < ... ≤ -108
. . .	. . .
62	-49 < ... ≤ -48
63	-48 < ... + ∞

7.2.3.2 Neighboring Cell Bookkeeping

When triggered by the reception of a SACCH report (either for a TCH or a SDCCH) the BTS stores the downlink measurements in a bookkeeping list.

The hoAveragingPowerBudget averaging size (by default approx. 7.7 s) is not suitable to reflect the current situation related to the event "Fast Uplink Handover" because it is too long. When a FUHO is detected by evaluating the UL measurements (e.g. during the last second), a target cell has to be found that was good during that time (last second) and not during the last 7.7 seconds (during which the measurements of the hoAveragingPowerBudget were averaged).

Thus, a separate average must be calculated for the FUHO, which is based on the window-size for the FUHO on the received UL-level. The window-size in the FUHO's bookkeeping list is one size smaller than that of the FUHO averaging window.

7.2.3.3 Detection of FUHO

During the handover detection procedure, the average e.g. of the UL receive level is calculated and must know which UL measurement to use; the full (in case the mobile station didn't use a DTX) or the partial (in case the mobile station did use the DTX). This is indicated by a "dtx_used" flag included in the SACCH report.

A SACCH report received during the reporting period #n contains data that the mobile station collected during the reporting period #(n-1). Thus, the most recent data for the detection of a normal handover within the measurement period #n (triggered by the reception of the SACCH report) can use origins from the measurement period #(n-1).

To seize the opportunity of saving approx. 400 ms, the FUHO detection is not triggered by the arrival of a SACCH report (as "normal" HO) but by the “end of measurements”. The BTS calculates the average over the averaging window for all of the handover types to find out whether the calculated average is above a certain threshold or not and, if appropriate, send a message to the BSC indicating the need of a handover.

The time saved with this procedure is constant (approx. 400 ms), its gain is high for short averaging windows and diminishes with growing averaging window sizes.

Due to the nature of the “Fast Uplink Handover”, its averaging window size (database attribute averagedLevFastULHo.aLevFuHo; default value 2) is be significantly shorter than the averaging window size hoAveragingPowerBudget (default value 16).

7.2.3.4 Handling of HSCSD Calls

When the condition for a FUHO is detected for any of the timeslots serving a HSCSD call, a FUHO has to be initiated for the main-channel of this HSCSD call (max 4 TS).

7.2.3.5 Generation of the target Cell List

As a candidate for the target cell list, the minimum condition applies for the neighboring cell n:

RXLEV_NCELL(n) > RXLEVMIN(n) + max(0; Pa) + FULRXLVMOFF;

where Pa = MTXPWAX – P

MTXPWAX: maximum RF transmission power that a mobile station is permitted to use on a traffic channel in an adjacent cell.

P: maximum transmission power capabilities of the mobile station

The target cell list is sorted into two sections, the first (high priority) section contains cells marked as "predefined cells" that have the attribute fastULHoCell set to TRUE. The second section contains cells that are not "predefined cells".

Both sections are sorted in decreasing order by the power budget PBGT of the neighboring cells, i.e. the cell with the lowest value of PBGT is ranked last.

7.2.3.6 Prevention of a FUHO

The FUHO is not detected

- until the averaging window averaging window is full (end of measurements)
- as long as the timer for handovers is running (another handover has been triggered and is pending)
- when an assignment is pending (when the call is between assignment command and establish indication and due to these measurements are explicitly not compiled and averaged).

Other handover prevention algorithms (e.g. back-handover to the old cell) are not explicitly implemented so as to reserve the FUHO as a last opportunity to maintain a call.

7.2.3.7 Priority of FUHO

The FUHO is not ranked with the normal handover causes, because its detection is not triggered by the reception of a SACCH_(NO_)REPORT but by the detection of the "end of measurements".

7.2.4 Database Parameters

DB Name	Object	Range	Description
EFULHO	HAND	TRUE, FALSE (default)	Flag used to enable/disable the FUHO. (Note: also internal intercell HO must be enabled, parameter INTERCH)
THLEVFULHO	HAND	0 ... 63	FUHO is possible when (FUHO average) RXLEVUL decreases below THLEVFULHO.
ALEVFULHO	HAND	aLevFuHo=1-31 (1 SACCH multiframe step size, default: 2) wLevFuHo=1-3 (step size 1, default: 1)	Averaging parameters used for FUHO signal strength measurements. aLevFuHo gives averaging window size (smaller than normal window size), wLevFuHo indicates weighting factor for "full" measurements (optional)
FULHOC	ADJC	TRUE, FALSE (default)	When searching for FUHO target cells, cells with attribute FULHOC "TRUE" are preferred to cells with FULHOC "FALSE"
FULRXLVMOFF	ADJC	0, ... , 126 step size 1 dB, where 0=-63 dB, 126=63 dB, default 69=6 dB	RX level necessary for a neighbor cell to be included in the FUHO target cell list.

7.2.5 Requirements

Fast Uplink Handover is a pure software feature. Hardware modifications are not required. Mobile stations and SSS are not affected by this feature.

7.3 Introduction of "Level Handover Margin" Parameter

7.3.1 General

"Level Handover Margin" Parameter offers a new target cell criteria that takes the different requirements for level handover and quality handover into consideration. The creation of the target cell list is based on these new criteria.

With this feature there are fewer dropped calls in poor coverage areas. The new algorithm works in a dynamic and more global way. The level handover is performed to the better cell and is triggered quicker with more safety.

A cell may offer a good outdoor coverage but can also include a poorly covered area for instance within a building or close to a corner. In these cases the previous algorithm does not trigger a level handover if there are no target cells in a certain area of coverage. Instead a quality handover or power budget handover is triggered which are less reliable or slower. In such mixed situations, i.e. good covered and bad covered areas, it is now possible to configure the level handover independently.

7.3.2 Basics

When the handover detection algorithm evaluates a handover condition, a target cell list is generated, i.e. a list of all adjacent cells which are considered as handover candidates. The target cell list is based on the neighbor cell measurements of the mobile. The RXLEV_MIN(n) setting for level handover is optimized concerning the level.

Since quality handover is mainly a protection against interference, not necessarily linked to the level received, a quality handover to a cell with similar or even lower level may save an interfered call. Previously **any** type of handover required a target cell with a level higher than L_RXLEV_XX + x with 3 dBm ≤ x ≤ 6 dBm. This reduces the chance of saving an interfered call in poorly covered (interference sensitive) areas.

To guarantee that a level handover will be performed to a cell with a higher level than that of the serving cell, the candidate cell will now be included in the target cell list if additionally to the previously used condition

RXLEV_NCELL(n) > RXLEV_MIN(n) + max (0,Pa) also

RXLEV_NCELL(n) > RXLEV_DL + LHOMARGIN.

The operator **on a cell basis** can define this **new parameter LHOMARGIN**. The implementation of both conditions offers the operator the choice to prevent level handover below a certain level that the operator defines as not suitable for handover by setting RXLEVMIN. This new algorithm is very flexible since the operator still has the possibility to decide that RXLEVMIN does not impact the level handover by setting it to a low level.

7.3.3 Database Parameter

The operator has the possibility to enable or disable this feature. If this feature is disabled, the traditional solution

RXLEV_NCELL(n) > RXLEV_MIN(n) + max(0,Pa)

is chosen.

Object	DB Name	Range (Default)	Description
HAND	ELEVHOM	TRUE/ FALSE (FALSE)	The attribute EnableLevHOMargin indicates whether the level handover margin (RXLEV_NCELL(n) > RXLEV_DL + LHOMARGIN) is enabled or disabled.
ADJC	LEVHOM	0...126, steps of 1 dB. 0 = - 63 dB, 126 = + 63 dB (69= 6 dB)	The value of this attribute is used as a threshold to guarantee a handover to a target cell with a higher level than the serving cell (thus not meeting the conditions for a subsequent level HO) without altering the behavior of the other imperative HO types. The path loss difference between the serving and the adjacent cell has to exceed this margin for a level handover. In general a positive value should be chosen. But for special applications its possible to choose a negative value to force a HO even in the case of a lower level in the target cell in which case (to avoid oscillating handovers) the LevelhoMargin in the ADJC of the new cell referring to the old cell should be positive.

7.3.4 Requirements

Introduction of ‘Level Handover Margin’ Parameter is a pure software feature. Hardware modifications are not required. The feature does not affect mobile stations and SSS releases.

7.4 Enhanced Pairing for Half-Rate Channels

7.4.1 General

Enhanced Pairing for TCH/H Channels provides the half rate channel pairing in case a TCH/F is requested but (initially) unavailable. This is done by an intracell handover of half rate channels providing capacity for a full rate channel. Enhanced Pairing for TCH/H Channels is also provided for AMR half rate channels.

This feature provides an optimization of radio resources and therefore a reduced blocking probability on the Um interface.

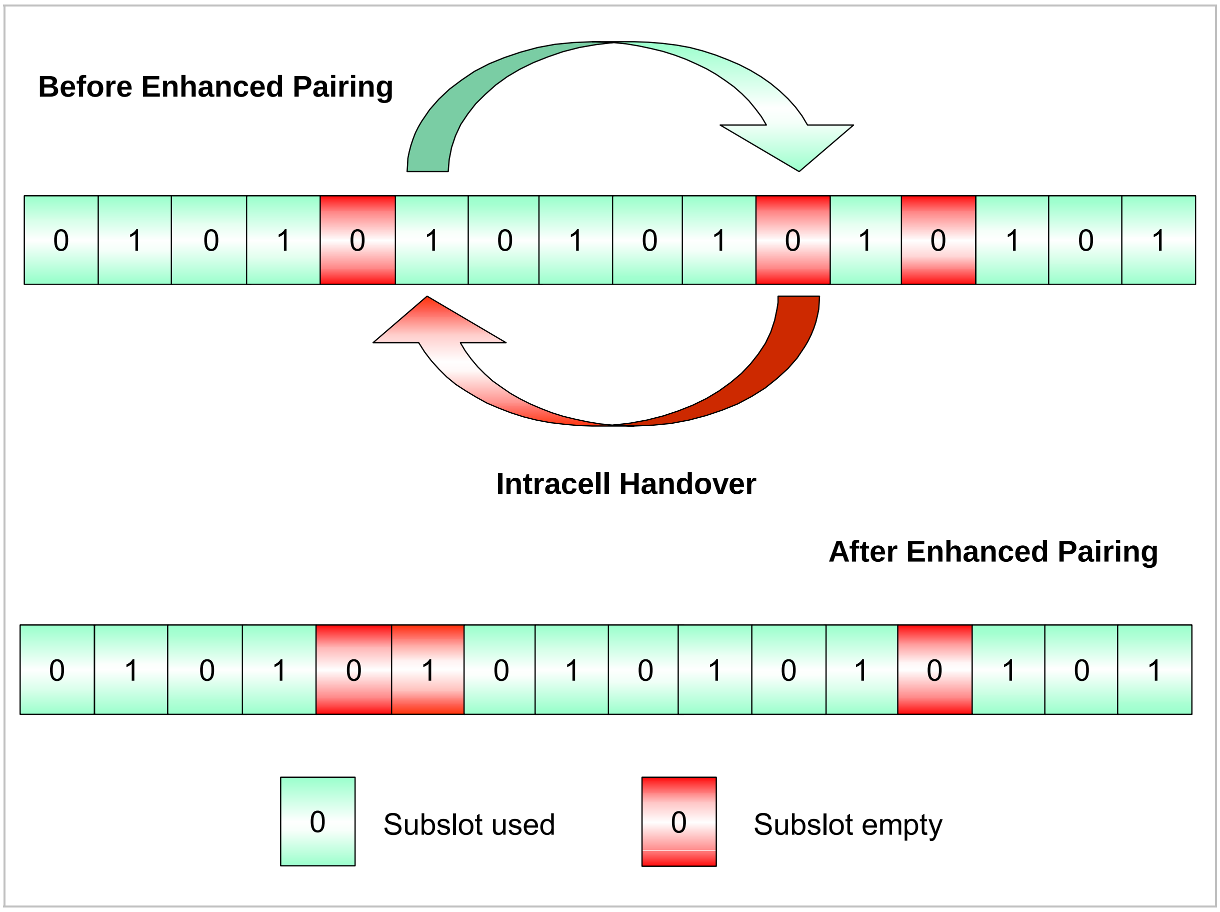

Fig. 17 Enhanced pairing for TCH/H channels: Example

7.4.2 Basics

TCH half rate channels have been introduced to increase the number of traffic channels available in the network. The possible configurations for traffic channels are full rate only traffic channels and dual rate traffic channels. Due to **static** pairing of half rate channels only at call set up, situations may occur in which the radio resources are not fully exploited. If some half rate channels are released it might happen that there is no possibility to allocate a full rate channel, although several half rate channels are free.

In the following example in each dual rate timeslot, the sub slots are discriminated with 0 and 1. Grey color indicated a busy channel, whereas white color indicates a free channel. The time slots are identified as TS-0 to TS-7.

TS#0		**TS#1**		**TS#2**		**TS#3**		**TS#4**		**TS#5**		**TS#6**		**TS#7**	
0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1

When all channels are busy (as half-rate) the occupation is

0	**1**	**0**	**1**	**0**	**1**	**0**	**1**	**0**	**1**	**0**	**1**	**0**	**1**	**0**	**1**

After some half-rate channels are released (e.g. 3), the new occupation is

0	**1**	**0**	**1**	0	**1**	**0**	**1**	**0**	**1**	0	**1**	0	**1**	**0**	**1**

Although there are three half-rate channels free, there is no possibility to allocate a full rate channel if required. This is an inefficient management of radio resources.

A new algorithm avoids this situation and provides an efficient use of radio resources. At the reception of a TCH/F channel request (normal assignment or handover) and if no TCH/F is available, a **reorganization of the half rate channel pairing** is performed in order to free an entire time slot for full rate.

The stable call is moved from TS2-1 to TS5-0 by a forced intra cell handover. After the handover has been successfully completed, TS2 is available to satisfy the TCH/F channel request previously received.

7.4.3 Database Parameters

The **ENPAIRINGINTRAHO** BSC O&M parameter must be set to TRUE to enable the described forced Intracell Handover procedure.

Parameter	Object	Range	Description
EPA	BSC	TRUE, FALSE	Enable channel pairing.

7.4.4 Requirements

Concentric Cells: The forced intra cell handover is allowed only in the same area (inner or complete), i.e. it is not possible to force a "complete to inner" or "inner to complete" intracell handover.

Extended Cells: The forced handover is only allowed between "single" channels (inner area).

No modifications on existing mobiles are required. Dual mode mobiles (full rate/half rate mobiles) are required for the assignment of half rate.

Enhanced Pairing for TCH/H Channels is a pure software feature. Hardware modifications are not required. SSS releases are not affected.

8 Handover related Performance Measurements

In a running network the handover performance can be monitored using the handover performance measurements.

On the one hand, handovers are important for mobility and traffic distribution, on the other hand they are associated with a greater amount of signaling. The evaluation of the handover performance measurements enables weak points to be identified and corrected at an early stage:

- For example in a well planned network handovers with certain reasons should predominate those with other reasons.
- By measuring the number of handovers between cells, locations with greater or lesser handover activity can be localized, and also missing neighbor cell relations in the database can be found out.
- By varying handover threshold values it is possible to force traffic from highly frequented cells into cells, which may be under less pressure earlier. A more uniform distribution of traffic can be achieved in this way.

Handover Performance Measurements

The following table summarizes the handover performance measurements:

Measurement Type	Abbreviation	Functional group
Intracell		
Attempted internal Handovers, intracell, per cause	ATINHIAC	SCANBTS
Successful internal Handovers, intracell, per cause	SINTHITA	SCANBTS
Unsuccessful internal Handovers, intracell	UNINHOIA	SCANBTS
Attempted internal SDCCH Handovers Intracell	AISHINTR	SCANBTS
Successful internal SDCCH Handovers Intracell	SISHINTR	SCANBTS
Unsuccessful internal SDCCH Handovers Intracell	UISHINTR	SCANBTS
Unsuccessful internal Handover, intracell, with loss of MS	UNIHIALC	SCANBTS
Intercell		
Attempted internal Handovers, intercell, per cause	ATINHIRC	SCANBTS
Successful internal Handovers, intercell, per cause	SINTHINT	SCANBTS
Attempted incoming internal intercell Handovers per originating cell	AININIRH	SCANBTSIHO
Successful incoming internal intercell Handovers per originating cell	SININIRH	SCANBTSIHO
Attempted outgoing intercell Handovers per cause, per neighbor-cell relationship	AOUINIRH	SCANBTSOHOI
Successful outgoing intercell Handovers per cause, per neighbor-cell relationship	SOUINIRH	SCANBTSOHOI
Unsuccessful internal Hos, intercell, with reconnection to the old channel, cause, per target cell	UNINHOIE	SCANBTSOHOI

Attempted Internal SDCCH Handovers Intercell	AISHINTE	SCANBTS
Successful Internal SDCCH Handovers Intercell	SISHINTE	SCANBTS
Unsuccessful Internal SDCCH Handovers Intercell	UISHINTE	SCANBTS
Total number of Handover failures, intra BSC	HOFITABS	SCANBSC
Unsuccessful internal Handovers, intercell, with loss of MS	UNIHIRLC	SCANBTS

Inter BSC		
Attempted outgoing inter BSC Handovers per neighbor cell relationship	ATINBHDO	SCANBTSOHON
Successful outgoing inter BSC Handovers per neighbor cell relationship	SUINBHDO	SCANBTSOHON
Number of unsuccessful outgoing inter BSC Handovers per neighbor cell relationship	NRUNINHD	SCANBTSOHON
Attempted MSC controlled SDCCH Handovers	AOINTESH	SCANBTS
Successful MSC controlled SDCCH Handovers	SOINTESH	SCANBTS
Unsuccessful MSC controlled SDCCH Handovers	UOINTESH	SCANBTS
Number of inter BSC Handover failures	NRINHDFL	SCANBSC
Others		
Successful internal Handovers per cause	SINHOBSC	SCANBSC

Queuing related performance measurements

In the following table the queuing related performance measurements are summarized:

Mean TCH queue length (Fullrate/Halfrate)	MTCHQLEN	SCANBTS
Mean duration a TCH is queued (Fullrate/Halfrate)	MDURTCRQ	SCANBTS
Number of messages discarded from the TCH queue per cell (Fullrate/Halfrate)	NMSGDISQ	SCANBTS
Mean packet queue length (on PDCH) per cell	MPDTQLEN	SCANGPRS
Number of packet channel assignment attempts discarded from the packet queue per cell	NPMSDISQ	SCANGPRS

Quality related performance measurement

The performance measurements related to power and quality measurements are listed below:

Power and quality measurements on uplink/downlink busy TCHs	PWRUPDW	SCANCHAN
Correlated RXLEV to RXQUAL measurements (uplink)	CRXLVQUU	SCANTRX
Correlated RXLEV to RXQUAL measurements (downlink)	CRXLVQUD	SCANTRX
Correlated RXLEV to Time Advance measurements (uplink)	CRXLVTAU	SCANTRX
Correlated RXLEV to Time Advance measurements (downlink)	CRXLVTAD	SCANTRX
Correlated FER to RXQUAL measurements	CFERRXQU	SCANTRX

9 Exercise

Exercise

Task 1

Is the handover algorithm strictly defined in GSM?

In which GSM recommendation can you find information about the handover process?

Color all the handover related parameters in the BSC database given in subsection 1.

Task 2

Are all handover performance measurements defined by GSM?

In which GSM recommendation can you find information about performance measurements?

Fill in the meaning of the following key words:

Keyword	**Meaning**
Scanner	
Performance measurement	
Counter	
Trigger event	