BASE STATION SUBSYSTEM PARAMETERS

BSSPAR

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1 Introduction

This material contains explanations and examples of Base Station Subsystem (BSS) Parameters, including parameters related to Radio Network Planning. The material contains parameters, which are available in a Nokia BSS. There are already some GSM Phase 2 parameters implemented, with a separate note that they are working only in GSM Phase 2.

All the parameters, which can be found in BSC/OMC, are written in **bold** format. After the name of each parameter there is a range of values, for example **cellReselectHysteresis (0 ... 14 dB).**

2 Nokia Software Numbering

This document includes features and parameters in the BSS system release BSS9, consisting of BSC software release S9 and BTS software releases B11.1/B12 and DF4.1/DF5.0.

Compatibilities for individual NE releases are the following:

BSC S9	B12.0, B11.1, B11.0 DF5.0, DF4.1, DF4.0	Nokia Base Stations
	T13, T12,T11.1	Nokia NMS2000 (OMC)

Base Stations DF5, B12.0	BSC with S9,S8 NMS2000 with T13,T12 and T11.1

3 Reference Data

Ned (Customer Documentation in CD-ROM) (NED S9 available in March)

BSS Parameter Dictionary

BSC Manuals

OMC Manuals

GSM Specification

4 Channel Configurations

4.1 Time Allocation, TDMA frame structure

GSM is based on TDMA technology, which means that channels (for traffic and signalling) are separated from each other by time. This means that in radio path between the antennas of a Mobile Station (MS) and a Base Station (BTS), every channel has a specific time on each frequency during which it can act. The basic division is that one frequency is divided into eight Time Slots or Bursts and each of these Bursts is an individual channel. More precisely, each frequency has eight channels, either traffic channels or signalling channels. These eight channels have their own "time slots" related to the time for transmitting or receiving data. So, every channel has a 'right' to act every eighth time slot.

Each burst lasts 0.577 ms (exactly 15/26 ms) and thus eight bursts last 4.615 ms. There are a couple of different kinds of bursts for different purposes. The contents of the burst can vary, but the time duration of each burst is always the same. The structure of the eight bursts is called TDMA frame and the duration of a TDMA frame is called the Burst Period. The TDMA frame is the smallest and actually the basic unit of a TDMA frame structure. The whole TDMA structure is based on TDMA frames, which are placed continuously after each other's as in figure 1.

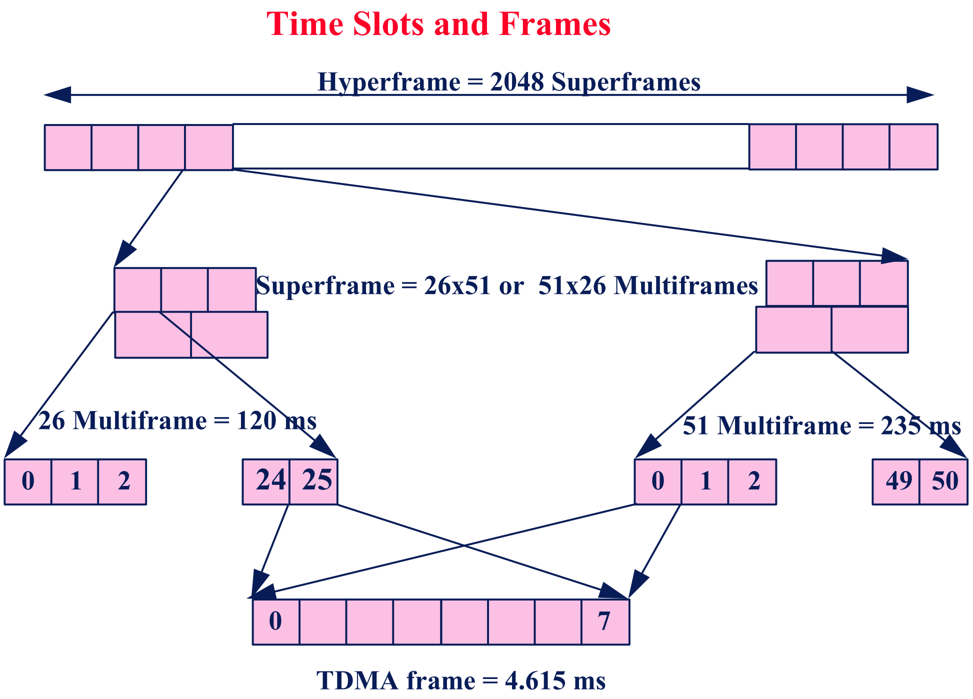


Figure 1. TDMA frame structure.

As we can see, the TDMA frame is cyclically repeating itself time after time. Now, other higher level frames are needed for the GSM channel structure. In figure 1, two different kinds of superframes can be seen, repeated time after time: the 26 x 51 Superframe and the 51 x 26 Superframe. These Superframes have been used so that the 51 x 26 Superframe is used for time slots with traffic channel configuration, and 26 x 51 Superframe is used for time slots with signalling channel configuration. Finally, these Superframes are repeated so that the result is a Hyperframe, which is the highest level of the frames in the GSM.

As mentioned above, there are two main types of channels: traffic channels and signalling channels. Traffic channels are used for sending data such as speech or data service fax, etc. and signalling channels are used for negotiations between a Mobile Station and the Network, in order to handle the management of the network. A Mobile Station and the Network are sending different kinds of messages between each other through signalling channels.

The other division between channels is between full rate and half rate. In a full rate channel, speech has been coded at a rate of 13 kBit/s, and in half rate, around 7 kBit/s. In both rates, data can be sent at the rate of 3.6 or 6.0 kBit/s and in full rate also 12 kBit/s. In the whole material, the full rate will be discussed, but if needed, also half rate has been mentioned. All these channels (traffic and signalling, full and half rate) have a common name: Logical channels.

4.2 Signalling Channels

4.2.1 Logical Channels

A Mobile Station and a Base Station negotiate with each other, as mentioned above. This negotiation contains messages of lots of information, such as messages needed for different operations described in GSM Specifications (e.g. call assignments, handovers, location updates). Through these signalling channels, information such as the parameters needed for the above-mentioned processes, measurement results made by Mobile Station (field strength level and quality), and Short Messages, are all sent.

As we can see, quite a lot of information is sent between a Mobile Station and a Base Station, and different kinds of signalling channels are needed to fulfil all these needs. So, different channels have been reserved for different purposes. These channels can be divided into two classes: broadcasting control channels and dedicated control channels. Broadcasting control channels are used all the time (also in idle mode) and dedicated control channels are used only in dedicated mode. Both these channels will be described in both directions (uplink and downlink) separately.

In downlink direction, Base Stations use four types of broadcasting channels for different purposes: Frequency Correction Channel (FCCH), Synchronisation CHannel (SCH), Paging CHannel (PCH) and Access Grant Channel (AGCH). On FCCH, the Base Station sends frequency corrections, and on SCH, synchronisation messages are sent. PCH and AGCH are used for call assignment so that PCH is used for the paging of a Mobile Station, and on AGCH, information of SDCCH (coming later) is sent to Mobile Station before assigning a traffic channel to a Mobile Station.

Base Stations use three different types of dedicated channels to communicate with a Mobile Station: Slow Dedicated Control Channel (SDCCH), Fast Associated Control Channel (FACCH) and Slow Associated Control Channel (SACCH). SDCCH is used for call assignment procedure before giving a traffic channel to a Mobile Station. SDCCH is used also for Location Updates. Short Messages is also sent on SDCCH, if there is enough capacity left. FACCH is used mainly for sending Handover Messages and SACCH is used for sending System Information and Short Messages. In phase 2, FACCH can also be used for the call assignment process: answer to paging, call re-establishment, emergency call set-ups or even in normal call set-ups (BSS 5).

CBCH (Cell Broadcast CHannel) is also implemented in phase 2 and it allows sending text messages to all mobiles within a certain area and user group. The area can be as small as one cell and as big as the whole network. Messages are not acknowledged and the maximum length is 1395 characters. The user can filter part of the messages to be received. There's another mode of operation called discontinued reception. In this mode the MS only listens to CBCH when there's valid information for that particular user (scheduled messages).

In uplink direction, a Mobile Station sends information to the Base Station by using partly the same channels as in downlink direction. The biggest difference compared to downlink is that the Mobile Station sends to the Base Station just one broadcasting channel which is called Random Access Channel (RACH). On this channel, the Mobile sends a request for service to the Base Station (or to the Network) in both mobile originating and mobile terminating cases. The dedicated channels that the mobile uses are the same as in downlink direction. However the use of these channels is a little bit different. SDCCH is used in the same way as in the downlink direction: mainly for call assignment and for location updates. FACCH is also used like it is used in the downlink direction for Handover purposes and in phase 2 for call assignment process. So, the only channel used differently is the SACCH, which is used in uplink direction, mainly for sending measurement results made by Mobile Station.

4.2.2 Channel Combinations

Time Slots 0 and 1 in each TRX are usually needed for the use of all of these above-mentioned channels. Due to capacity reasons, there are two main configurations for these channels.

Combined Channel Structure BCCH/SDCCH (up to max. 2 TRXs/Cell, figure 2.)

TS0: BCCH+CCCH /3 + SDCCH/4 in both directions (uplink, downlink)

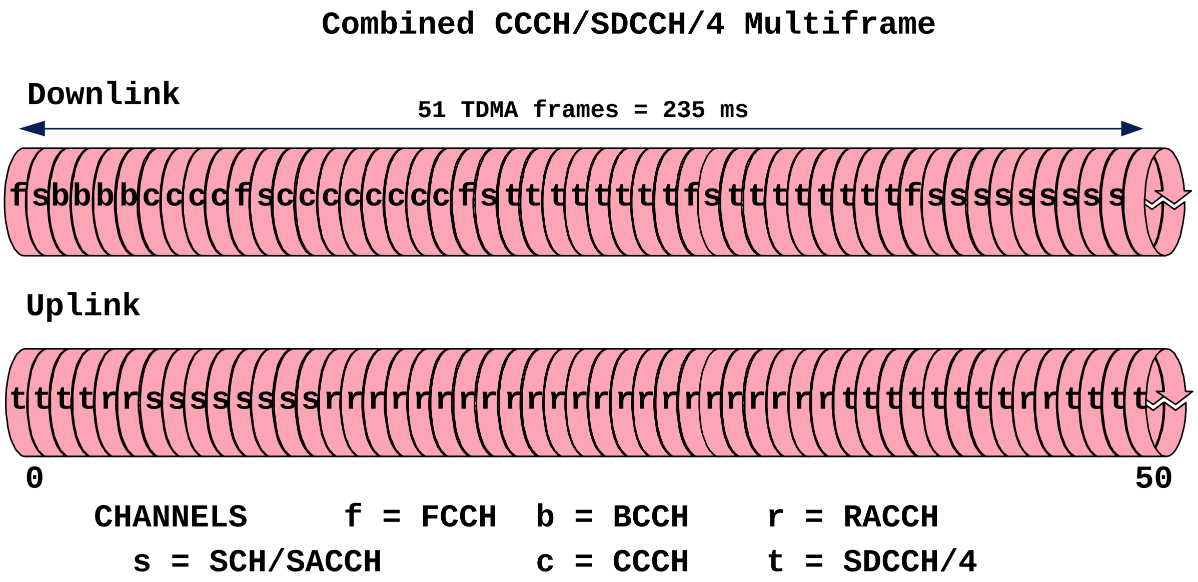


Figure 2. BCCH/SDCCH/4 channel structure.

Separated Channel Structure BCCH + SDCCH/8 (3-4 TRXs/Cell, figures 3-4.)

TS0: BCCH+CCCH/9
TS1: all SDCCH/8s (uplink, downlink).

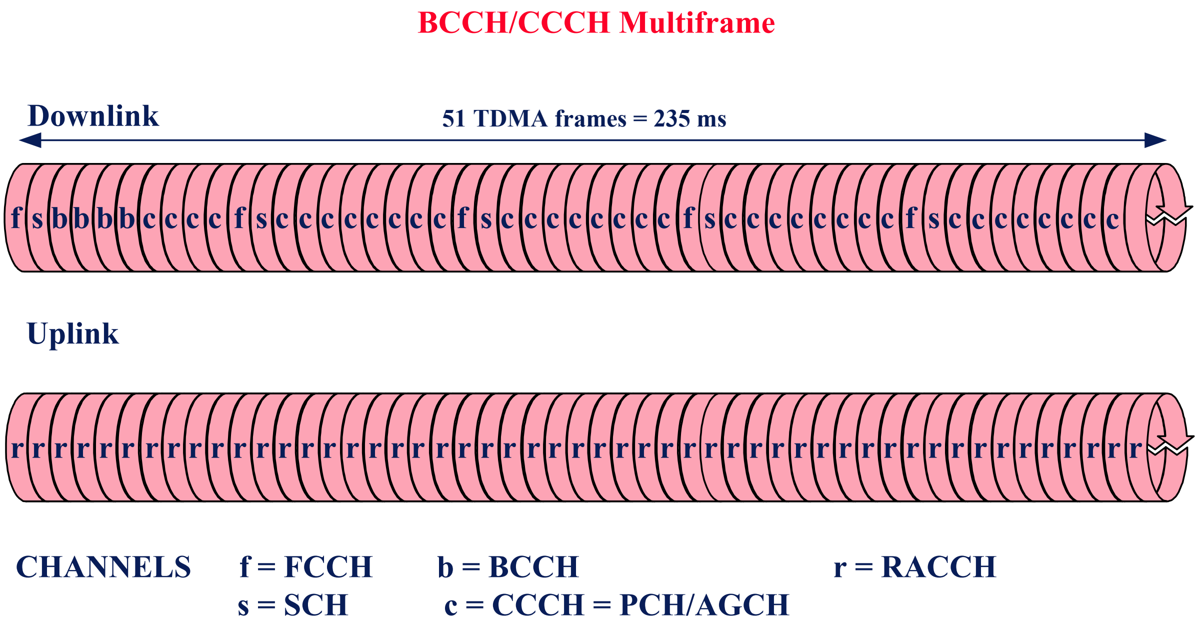


Figure 3. BCCH multiframe

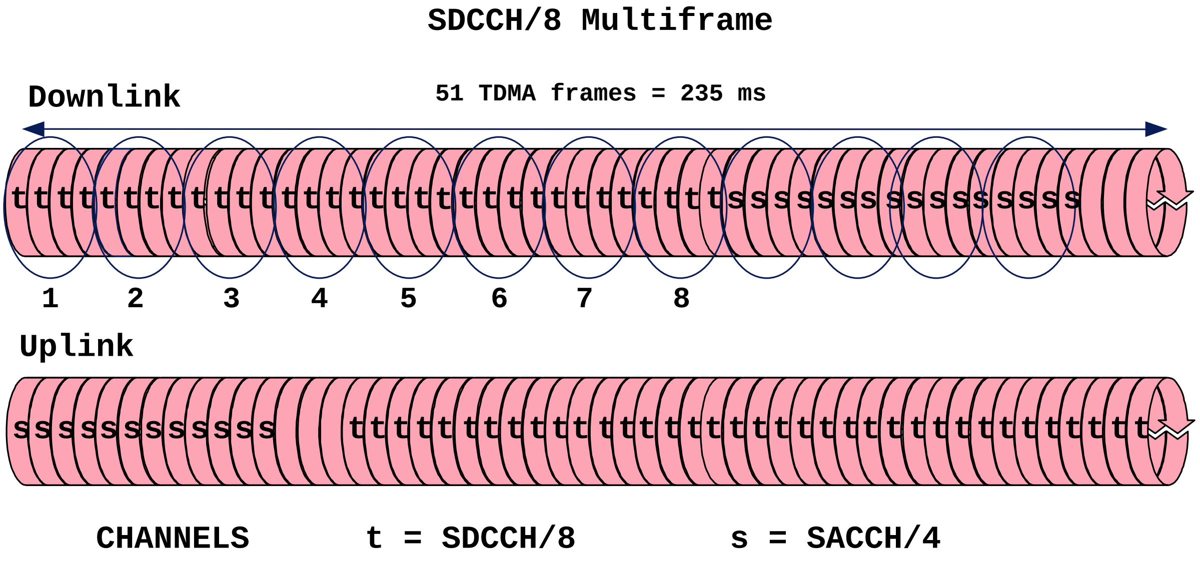


Figure 4. SDCCH/8 Multiframe.

Hybrid Channel Structure BCCH/SDCCH/4 + SDCCH/8 (3-4 TRXs/Cell, figures 2 and 4)

TS0: BCCH + CCCH/3 + SDCCH/4 (uplink, downlink)
TS1: SDCCH/8 (uplink, downlink).

This configuration give more SDCCH capacity for call set-ups and location updates but less for paging and channel assignment (access grant AGCH).

So, as seen above, usually 1-2 time slots are needed for signalling. Finally, the signalling capacity and the need of signalling channels depend on paging (PCH) and the need of SDCCH. Examples of these channel capacities are presented later.

4.3 Traffic Channels

Traffic channels use the 51 x 26 Superframe, which means that the structure of the 26-frame Multiframe is always the same as in figure 5.

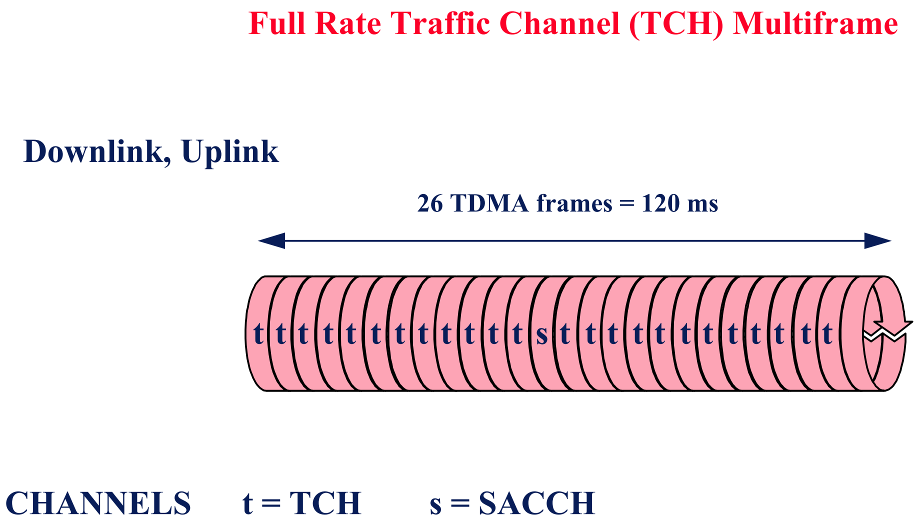


Figure 5. TCH configuration.

4.4 Capacity (SDCCH, PAGCH)

Signalling capacity depends mostly on the paging channel (PCH) capacity and on the SDCCH capacity. Both capacities can be calculated very easily, and based on these calculations, the final channel configuration (combined BCCH/SDCCH or separated BCCH and SDCCH) can be decided upon.

Paging is performed when a call or short message is directed to a mobile unit.
The paging message contains the subscriber identity (IMSI/TMSI number). The mobile recognises an incoming call or short message by this number.
The MSC sends a paging query (VLR asks the MSC to page a certain mobile-IMSI/TMSI) to all the BSCs inside the location area where the MS is registered.
There are counters in the VLR for both successful and failed paging messages, which can be read by traffic measurements.

Paging capacity is related to the number of paging groups, which depends on the frame/channel structure and the parameters **noOfMultiframesBetweenPaging** and **NumberOfBlocksForAccessGrant**, explained later.

Paging capacity also gives a very good vision about the size of location areas, because pages (from BTS to MS) are sent over the whole location area every time. Examples of the capacities of both channels will clarify the situation:

Example of the capacity of SDCCH

2 TRXs/Cell => 9.01 Erl/Cell
2% blocking probability
1.5 min/call/subs/BH

SDCCH used for
location updates once in 60 min.
call assignment (7 s/Call including ciphering and authentication)

Traffic density 25 mErl/Subs => 360 Subs/Cell

Call establishment time
SDCCH reservation time 7 sec / 3600 sec = 1.94 mErl
=> 360 calls/cell *1.94 mErl/Call = 0.699 Erl/Cell (SDCCH)
Location update
Location update once in 60 minutes
=> 360 calls/cell *1.94 mErl/Call = 0.699 Erl/Cell (SDCCH)

=> Needed SDCCH capacity 0.699 Erl/Cell + 0.699 Erl/Cell = 1.398 Erl/Cell (SDCCH)

Transformation to channels by using Erlang B-table
Blocking probability 1% (usually set below 1%, for example 0,2%)
= 6 SDCCHs
In this case result shows that it is not possible to use combined channel structure up to 2 TRXs/Cell. However, if the location update is done only once in six hours then the needed SDCCH capacity is 0,816 Erl/Cell. When the blocking probability for SDCCH is 1%, there is needed 4 SDCCHs/cell. This time the combined channel structure would be possible, but we have to remember to take into consideration also the capacity what is needed for short messages.

Example of the capacity of PCH

Combined BCCH/SDCCH signalling channel configuration
1 block used for AGCH -> 2 blocks for paging
Maximum 4 paging messages/block, (TMSI) used, 3 in average
In average we have to send 2 paging messages to page a mobile.

So, in average we sent 3 pages/block but we have reserved2 blocks for paging. This give us totally 6 paging messages in every 51 frame Multiframe which means 6 paging messages in every 235 ms.

- ⇨ If we now calculate how many paging messages we can get during busy hour:
  3600 sec. / 0.235 sec * 6 paging messages= 91915 paging messages
- ⇨ now we can calculate how many mobiles we can page during busy hour while in average we have to send 2 paging messages to page a mobile:
  91915 / 2= 45 957 mobiles/BH.

To ensure that the paging message reaches the MS, the paging message is sent several times. The repetition procedure is defined in the MSC. MSC parameters: Repaging_Internal (Time between paging attempts) and Number_of_Repaging_Attempts can be modifies in the MSC.

The parameters are defined in a per location area basis. The repaging internal must be configured so that there's enough time between consecutive paging messages. This is to avoid that the messages are sent over the same message in the air interface (paging block).

Average page time information for a certain cell can be collected in the traffic measurement report (in the MSC).

During the paging and call establishment procedure, if no SDCCH channels are available, the BSC will command the MS to stay in the idle state for a certain period (wait indication). During that time the MS will not send any channel_request message or answer to any paging messages. The parameters should be defined so that no repaging attempts are lost during this period (i.e. the repaging interval in the MSC should a few seconds longer than the wait indication time in the BSC).

Experimental results from live networks show that more than 3 paging attempts are usually unnecessary.

4.5 Dynamic SDCCH Allocation, optional

The BTS should be configured with the minimum static SDCCH capacity that is sufficient to handle the normal SDCCH traffic. Extra SDCCH resource is allocated from free TCH only when the actual SDCCH congestion situation has been fallen into after the last free SDCCH is allocated. Consequently, when the dynamic SDCCH radio resource is totally free again it is immediately configured back for TCH use. Thus the maximum number of TCHs are always in traffic use depending on the actual need of the SDCCH resources at each moment.

A particular benefit is derived from this feature in traffic cases where the signaling is the only transmission mode during the connection to the network. Short Message service (SMS) traffic as well as location updatings are counted among them. In some special places - airports, ports - the location updatings can produce sudden short time SDCCH traffic peaks which can now be handled without any need to configure extra permanent SDCCH capacity for safety's sake only.

Dynamic SDCCH resource can be configured only when SDCCH is allocated for Immediate Assignment, during the SDCCH handover it is not allowed (restriction concerns the BSC). However, channels of the already existing dynamic SDCCH resources can be used in handovers. Placement of the new dynamic SDCCH is depending on the following factors:

- SDCCH resource is configured only to regular TRX.A RTSL of least uplink interference should be selected.
- The SDCCH is configured to a TRX, which does not yet have any SDCCH resources or has least of them.
- Priority is given to the TRX, which has least working channels.
- When in a particular TRX and a different type of TCH resource must be selected, then the preference order is the following: first HR then FR, DR TCH resource.

These requirements must be compromised according to the actual TCH occupation situation in the TRXs.

CBCH carrying SDCCH can not be configured dynamically.

Principles in radio channel allocation from the SDCCH resources of the BTS are:

- SDCCH is always allocated from static SDCCH resource if there is any free channel left.

- When SDCCH is allocated from the dynamic SDCCH resources then the one shall be used which has least idle channels left.

These rules are for minimising the consumption of the TCH resources.

When the feature FACCH call set-up is activated, in situations of SDCCH congestion of the BTS, the MS can be assigned a TCH from the CCCH at the time of Immediate Assignment. This feature can be applied also with the Dynamic SDCCH in some special cases:

- The FACCH call set-up is used in true SDCCH congestion when it is not possible to configure any dynamic SDCCH resource in the BTS.
- When the last TCH resource of the BTS is going to be taken in use and the connection requires a TCH then it is reasonable to use the FACCH call set-up.

The upper limit for the number of SDCCHs, which are possible to configure in BSC are determined by the number of TRXs connected to the BSC Signaling Unit (BCSU). With maximum TRX configurations the average SDCCH capacity is determined to be 12 SDCCH channels per TRX. For 1-32 TRX BCSU the max number of the SDCCH channels is 384.

Dynamic SDCCH resources can be shared between all TRXs of the BTS. The absolute limit is that the maximum SDCCH number in a TRX must not exceed 16 channels; while this limit value is reached then at least one of the two SDCCH/8 resources must be dynamic one.
The capacity restriction of the 16 kbit/s Telecom signaling link produces additional constraints. The uplink capacity is not sufficient in the worst traffic load cases. Main reason for the capacity loss is the increased uplink load in measurement result reporting. The maximum number of dynamic and static SDCCH channels together is limited to 12 subchannels (i.e. SDCCH/4 and SDCCH/8).

This restriction is sufficient when the configuration of TRX consists of 18 radio channels maximum, i.e., 12 SDCCH and 6 TCH. This channel configuration can be exceeded with half rate traffic channels. Where the 16 kbit/s TRXSIG is used and the Dynamic SDCCH option used there the half rate configuration of TRX is recommended to be done so that the requirement of max 18 channels is fulfilled. The bit-rate of the TRXSIG is checked in the creation of dynamic SDCCH resource.

4.6 Parameters related to Channels

Channels can be configured with different parameters. There are parameters directly related to PCH, AGCH, FACCH and RACH.

Parameter **noOfMultiframesBetweenPaging (2 ... 9)** tells how often paging messages are sent to Mobile Stations. There is a direct influence on the battery saving of a Mobile Station. The Mobile Station will only need to listen the paging sub-group it belongs to (Discontinuous Reception, DRX), which will make the mobile spend less power. However this makes the call assignment time longer.

The mobile unit listens for a possible incoming paging message once every **noOfMultiframesBetweenPaging,** therefore min. every 0.47 seconds and max. every 2.1 seconds when the **noOfMultiframesBetweenPaging** is 9. This means that if in average it takes 2 paging messages to page a mobile, it'll take from 1 to 4 seconds.

NumberOfBlocksForAccessGrant (0 ... 7) is a parameter for reserving the number of CCCH blocks for AGCH (figure 6). CCCH blocks are used either for PCH or for AGCH.

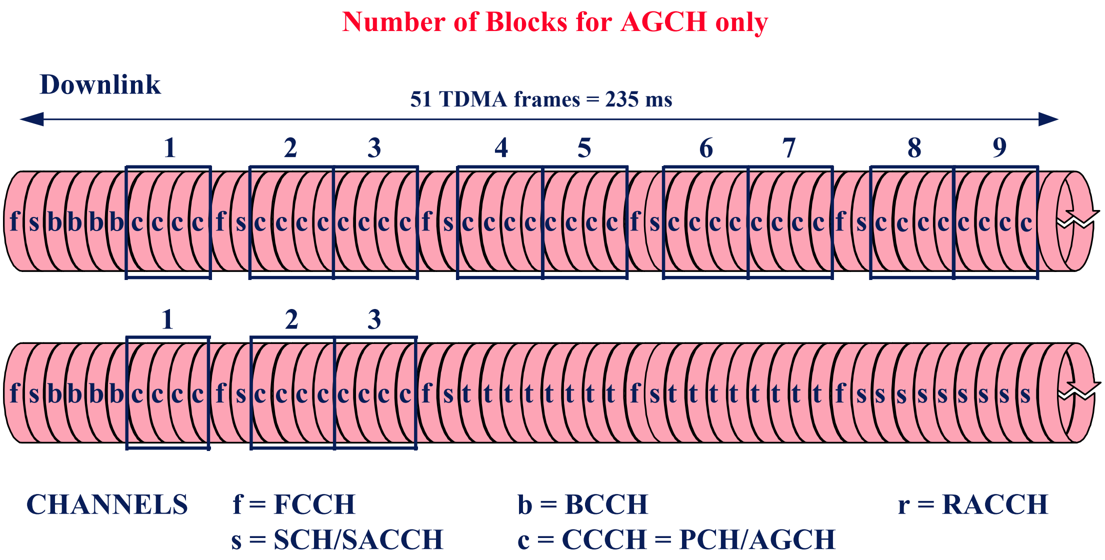


Figure 6. Combined and Non-Combined Multiframes.

The configuration of RACH takes two parameters; **maxNumberOfRetransmission (1, 2, 4 or 7)** and **numberOfSlotsSpreadTrans (3 ... 12, 14, 16, 20, 25, 32, 50**. **NumberOfSlotsSpreadTrans** describes a window when Mobile Station tries to send random access to Base Station. **MaxNumberOfRetransmission** describes the maximum amount of times the Mobile Station can send random access to the Base Station, whenever the previous time failed.
So if **MaxNumberOfRetransmission** is set to "2", the MS will try a first time to send the message within the window defined within a first 51-TDMA RACH multiframe. Then if no reply comes from the network, the MS will try a second time (or as many times as needed till a maximum as specified in the **MaxNumberOfRetransmission** parameter) within a window of another 51-TDMA RACH multiframe.

All the above mentioned parameters belong to the GSM phase 1. The last parameters used for channel configurations are **newEstabCallSupport (Yes/No)** and **facchCallSetup (0 ... 4),** which are used only in GSM phase 2. The parameter itself contains information concerning the possibility to use FACCH in call assignment procedure as SDCCH or not.

4.7 CCCH Improvements

The CCCH scheduling algorithm

The CCCH scheduling algorithm is improved to allow priority for access grant messages over paging messages when BS_AG_BLKS_RES equals zero. For non-zero values the situation will remain the same as now, i.e. paging messages have priority over access grant messages on PCH. This greatly improves the PCH throughput especially for combined-BCCH-CCCH channel structure.

Modified buffering mechanism

For PCH the target is to offer a buffering mechanism in which the paging buffer capacity per paging group is dependent on the CCCH-configuration and on the used identity type (IMSI/TMSI) in such a way that a configuration independent maximum paging delay for a paging message can be offered.

In current scheme each paging group buffer has a fixed depth (8 Abis page messages) regardless of the paging group repetition rate (BS_PA_MFRMS). In the worst case, (when buffers are full and BS_PA_MFRMS = 9 and IMSI used), a page arriving to BTS may have to wait for transmission 4 paging multiframes (approx. 8.4 seconds). The page is clearly outdated by the time it gets transmitted to air.

Since page repetition is done at the MSC, after some point in time it is better to discard excessive pages rather than store them for very long time. In this new mechanism a page is not deleted because of insufficient buffering space but because it cannot be transmitted to air within the defined maximum paging delay.

5 Idle Mode Operation

5.1 Idle Mode Control

When Mobile Station is in Idle mode it needs some information about network in order to be capable of knowing right frequencies and finding right cells. This information is actually related to Radio Resource Management and to Mobility Management because information contains frequencies, ID’s of cells, location area ID’s and cell access parameters.

5.1.1 Access/Mobility Management

The parameter **notAllowedAccessClasses (0 ... 9, 11 ... 15)** tells which mobile user classes can not use that particular cell. Dividing the subscriber database into different Access Control Classes gives the operator some control over the existing load and allows having priority users.

The **plmnPermitted (0 ... 7)** parameter (broadcast on the BCCH) is not meant to define whether the MS can use the network or not. It's used by the mobile to report measurements only of that PLMN. Therefore this parameter is used after the network selection has been done. The BSIC (Base Station Identity Code) is broadcasted on the SCH, so when the mobile pre-synchronises it knows if the BTS belongs to the right PLMN or not (BSIC is screened by **plmnPermitted**).

5.2 PLMN selection

When the Mobile is switched on, it tries to locate a network. If the Mobile is in the home country, it naturally tries to find the home network, and if there is coverage, the Mobile is camped on that. If there is no coverage, the other possibility is to try other networks of competitive operators, which is called national roaming. Usually this is not possible because different operators are in hard competition with each other. So, the only possibility to find a network in home country is to find the home network.

When the Mobile is abroad, international roaming is usually used. The Mobile can select any operator offering GSM service in the foreign country with which the operator of the home network has a roaming agreement. The issue is how the Mobile selects the network in a foreign country. The answer is simple: the home operator can make a list on preferred operators in different countries, or the Mobile just selects the network with the best field strength level in the place where mobile is switched on. The Mobile camps on the network selected and stays in it as long as service (coverage) is available. Usually no list of preferred networks is used, and the selection is made based on the field strength level only. Another option is that the home operator can give a list of forbidden networks.

The PLMN selection criteria mentioned above are chosen by the operator and they cannot be affected with the parameters. The parameter **plmnPermitted (0 ... 7),** doesn't affect the PLMN selection, it is only used for measurements reporting.

5.3 ID's and ID codes

Mobile also needs information about cell identities. First of all, there is identity of the each cell (cell-ID) and in addition to this cell-ID more IDs, which are used for location information. Parameter **locationAreaId** including **Mobile Network Code, mnc (0 ... 99)**, **Mobile Country Code, mcc (0 ... 999)** and **Location Area Code, lac (0 ... 65535)** describes each location area as shown in figure 7.

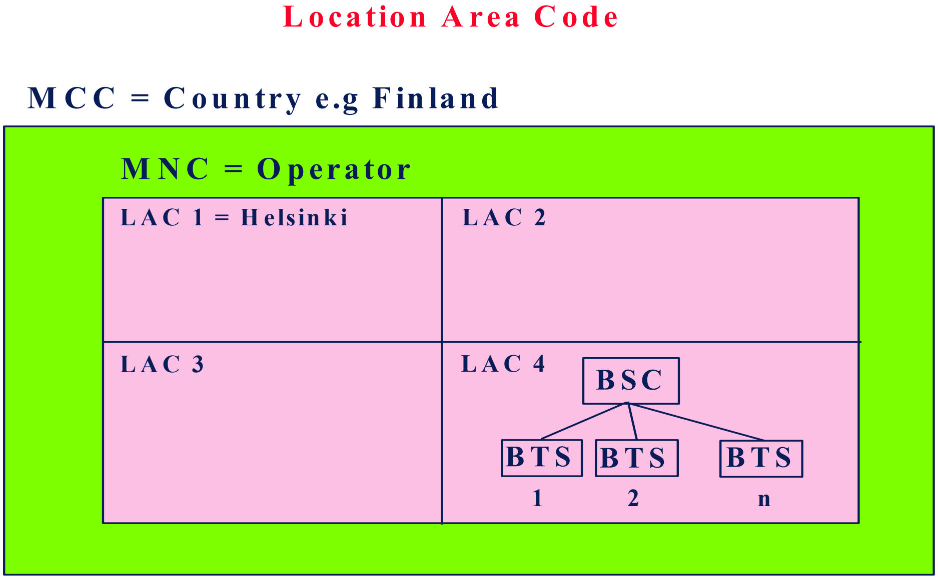


Figure 7. Description of a location area.

There is also other information actually meant for Radio Channel Management. Some information is needed in order to separate co-channels used in different Base Stations. Parameter **baseStationIdentityCode** including **Network Color Code, ncc (0 ... 7)** and **Base Station Color Code, bcc (0 ... 7)** is used for that purpose as shown in figure 8. In S6 it is possible to set parameters into the Background Database as is explained in chapter 18.

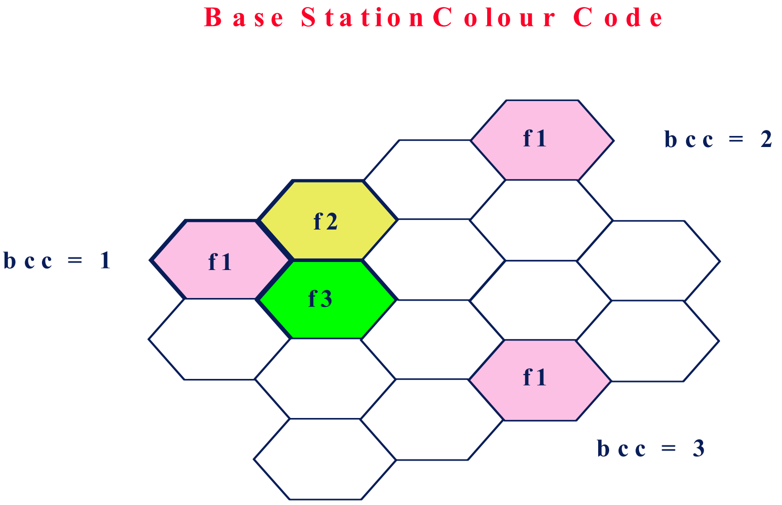


Figure 8. Base Station Color Code.

After Mobile accesses one network it reports the measurements to the BTS it is camped. But there are also some other requirements to access one cell. Having coverage might not be enough to access some particular cells. The parameter **RxLevAccessMin (-110 ... -47 dBm)** describes the minimum value of received field strength required by the MS to get any service from the network in that cell in idle mode. But there are still some cases, even if there is good field strength where, the operator may want to make some tests to keep a cell out of use. For this kind of purposes the cell can be changed to barred state by using **cellBarred (Yes/No)** parameter. An example of using cell barring for test measurements is given in figure 9. Any normal Mobile can not use any cell for call establishment, which is in barred state. One more option can be found namely **emergecyCallRestricted (Yes/No)** parameter which tells if the mobile has right to use the network for emergency calls even if it has not right to use the network for normal calls. Only for MS classes 11 to 15.

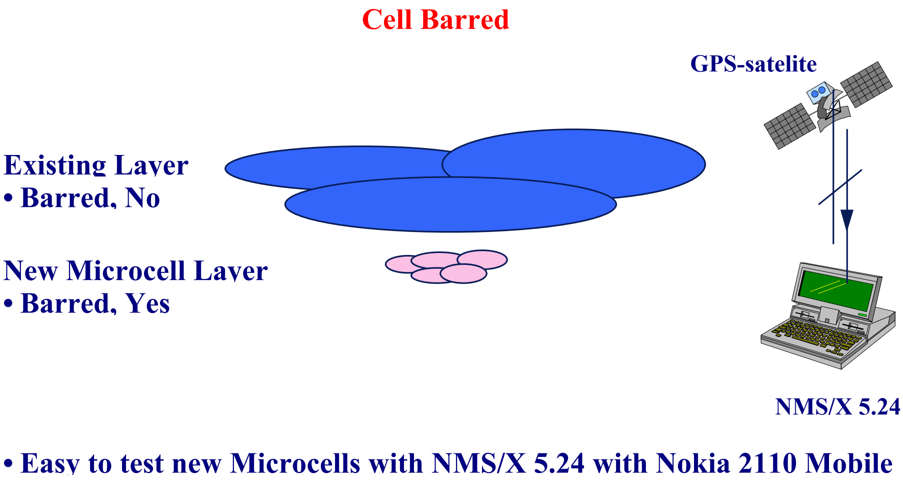


Figure 9. Use of Cell Barring for test measurements.

NOTE! All adjacent cells have to be also barred.

The network also broadcasts (on the BCCH) some parameters related partly to network planning to mobiles. When the mobile is moving in Idle mode it has to know which is the best cell offering service in each area. **CellReselectHysteresis (0 ... 14 dB)** is a parameter that the mobile uses as a margin in the comparison of the field strength levels of the adjacent cells in different Location Areas in Idle mode. This margin prevents ping-pong location updates, which uses SDCCH capacity. The other parameter which is actually directly related to frequency planning is **msTxPwrMaxCCH (13 ... 43 dBm)** which tells the mobile the maximum transmitting power when accessing to the system.

5.4 Cell selection

One basic idea in the GSM system is that the Mobile Station is always within the cell offering the best coverage. In Dedicated mode this is handled by handovers, but in Idle mode the Mobile has to find the best cell in each area. There is a process for this purpose called Cell Selection, based on C1 or C2 comparison. The idea is that the Mobile compares field strength levels coming from different cells with each other and selects the best one from them. The mobile uses the **cellReselectHysteresis (0 ... 14 dB)** parameter between cells that belong to different Location Areas in order to avoid the "Ping-Pong" phenomenon, which means that before the mobile changes to a different cell in Idle mode, between different location areas, the field strength level of the cell has to be at least the value of cellReselectHysteresis better than the value of the serving cell.
There is no margin between the cells that belong to the same Location Area. The equation for the cell selection is presented in figure 10.

Cell Selection in IDLE Mode, based on C1

- **Radio Criteria**

$$C1 = (A - \mathrm{Max}(B,0))$$

A = Received Level Average - p1

B = p2 - Maximum RF Power of the Mobile Station

p1 = rxLevelAccessMin

p2 = msTxPowerMaxCCH

Figure 10. Radio criteria based on C1.

As seen above, the Mobile takes into account the minimum access level to the cell and the maximum transmitting power allowed to the Mobile in each cell when starting a call. A practical example of C1 radio criteria is shown in figure 11.

Cell Selection based on C1 in practise

- **cellReselectHysteresis (mentioned in RR Management in IDLE mode Control)**

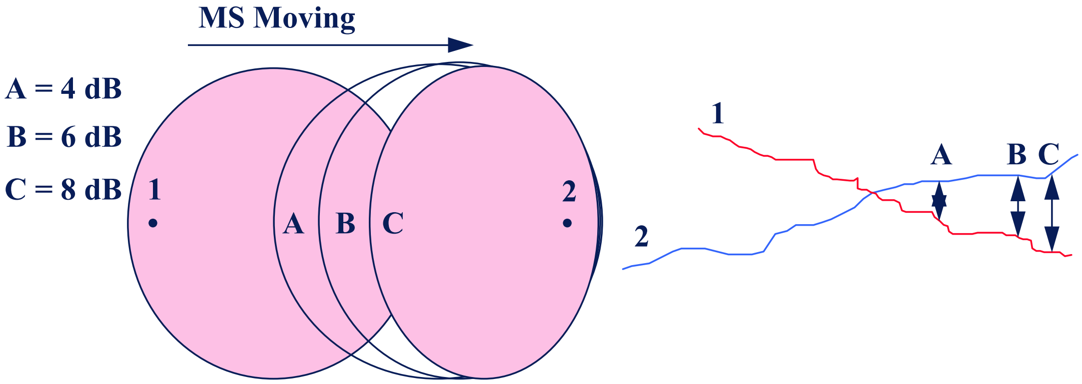


Figure 11. Cell selection based on C1 in practice.
(There is a margin only between cells that belong to different location areas.)

The comparison based on C1, is used at this point and the comparison based on C2 is in use in GSM phase 2 with more features for the use of two-layer (micro/macro cell) architecture.

In comparison based on C2, more parameters are needed. The parameter **cellReselectParamInd (Yes/No)** becomes activate, if C2 parameters are sent to the Mobile (activates C2) and the parameter **cellBarQualify (Yes/No)** controls if the cell barring can be overridden.

The rest of the C2 parameters are related to microcellular planning. Parameter **penaltyTime (20 ... 640 s)** describes the time delay before the final comparison is made between two cells. Parameter **temporaryOffset (0 ... 70 dB)** describes how much field strength could have been dropped during this penalty time, and parameter **cellReselectOffset (0 ... 126 dB)** describes an offset to cell reselection. C2 cell reselection is calculated by equation

C2 = C1 + cellReselectOffset - temporaryOffset x H(penaltyTime-T) when penaltyTime≠640
or
C2 = C1 - cellReselectOffset when penaltyTime=640

Where
H(x)=1 when x>=0
and
H(x)=0 when x<0

Let's take an example on C2.

The network consists of two cellular layers: GSM macro layer and microcellular layer. In order to prevent unnecessary camping between layers, C2 will be introduced. The idea is: the micro cell, having good DL signal strength and therefore very attractive, has to belong to one of the best cells of the neighbour list for the time set as **penaltyTime**, say 20 sec, in order to allow the MS to camp on that micro cell.

The parameter **temporaryOffset** has been set to be 30 dB and **cellReselectOffset** has been set to 20 dB. Let's assume that C1 of both serving cell and the neighbour cell has been measured as 32. Therefore two alternative cases are possible:

1. during time 0 ... 19 sec (within the set penaltyTime) :
   C2 =C1+cellReselectOffset-temporaryOffset * H(penaltyTime-T)
   C2 =32+20 -30*1
   C2=22
   => C2 < C1, so MS will be kept in macro layer i.e. target cell (micro cell) is NOT attractive.

2. during time 20 ...∞ (penaltyTime over):
   C2=C1 +cellReselectOffset-temporaryOffset*H(penaltyTime-T)
   C2=32+20-30*0
   C2=52
   => C2 > C1, now target cell is very attractive and the idle mode MS will camp on the microcell.

If the C2 > C1 before the penalty time is over, the cell reselection will be done immediately.
If the C2 = C1 before the penalty time is over, the cell reselection will be done not until the penalty time is expired.

Note that C2 is just meant for idle mode.

5.5 Location updates

The Mobile Station updates its location information to the network every now and then. This is necessary for the paging carried out by the network. Paging is carried out in each cell of one location area.

Location updates are carried out every time a Mobile changes its location area under one MSC, or between two different MSCs. When the location area changes between two MSCs, the HLR is updated. An automatic location update occurs when the Mobile is switched on (If **IMSIAttachDetach** is used).

One type of location update that is described by parameters is periodic and carried out by the Mobile Station. It is used to check that the location information in MSC/VLR is correct, because by error in the MSC/VLR, the location information of Mobile Station can disappear. Periodic location update is controlled by the **timerPeriodicUpdateMS (0.0 ... 25.5 hours)** parameter.

5.6 IMSIAttachDetach

The **IMSIAttachDetach (Yes/No)** parameter is used to decrease signalling load. The Mobile Station sends a message to MSC telling if it is switched on or off. When the MSC knows that the Mobile Station is switched off it does not try to page it, and useless paging is avoided.

6 Protocols

Protocols have been described in GSM specifications very carefully. The purpose of the protocols (in Radio Resource) is to describe the signalling between the Mobile Station and the Base Station in different situations. In the following, the protocols of the most usual situations are presented.

6.1 Call Assignment

Call assignment takes place when a Mobile Station makes a call (Mobile Originating Call) or receives a call (Mobile Terminating Call).

6.1.1 Mobile Originating Call

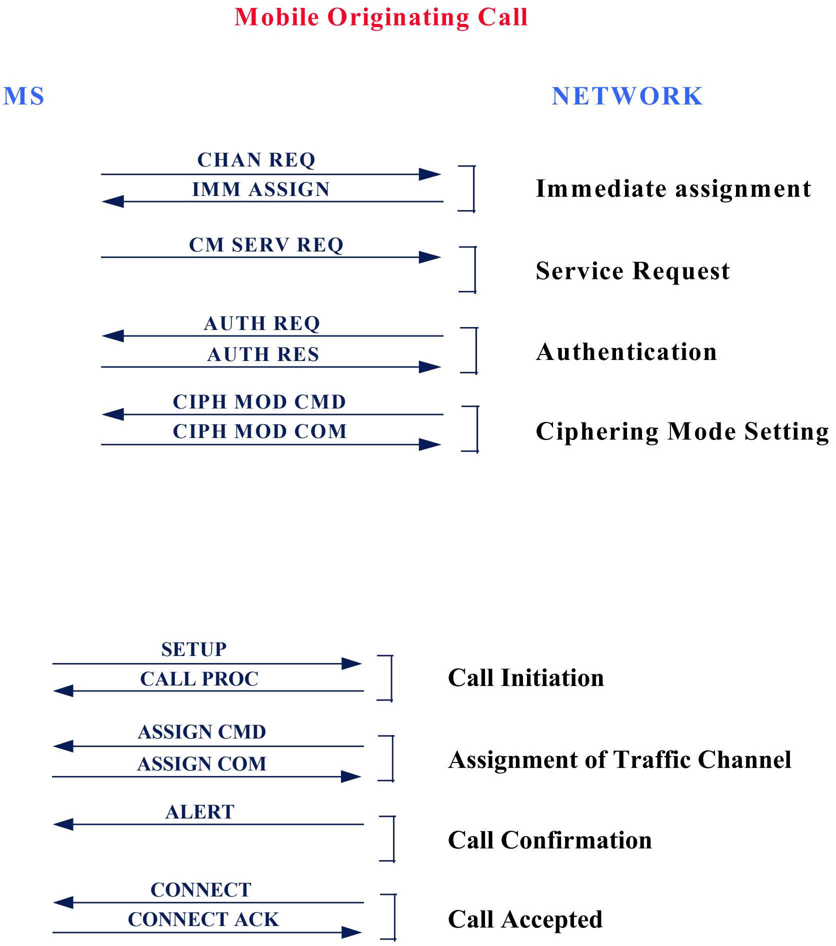


Figure 12. Mobile Originating Call.

As seen above, the main phases can easily be separated: Immediate Assignment, Service request, Authentication, Ciphering Mode, Call Initiation, Assignment of Traffic Channel, Call Confirmation and Call Acceptation. The same phases can actually be found in the Mobile Terminating Call, which is described below.

6.1.2 Mobile Terminating Call

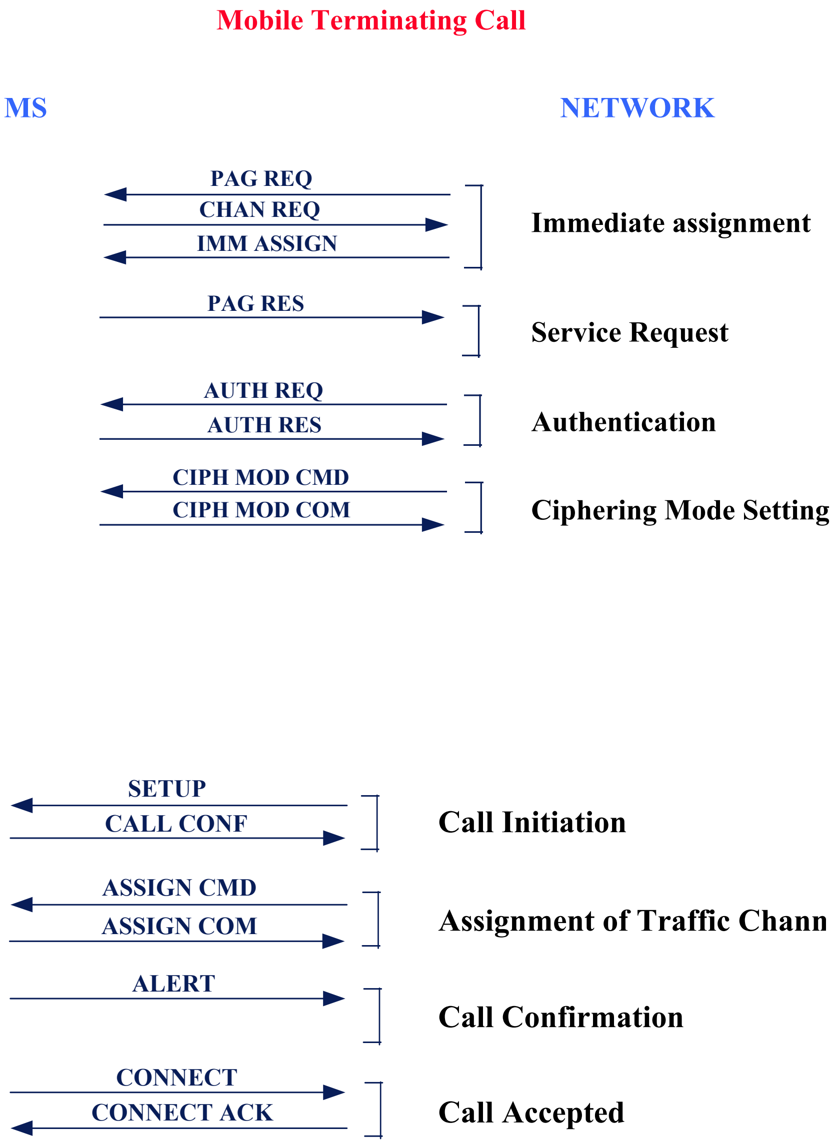


Figure 13. Mobile Terminating Call.

6.2 Location Update

The MSC needs to know under which location area the Mobile Station can be reached. Location updates are needed for this reason and this information is needed for the paging made by the BTS.

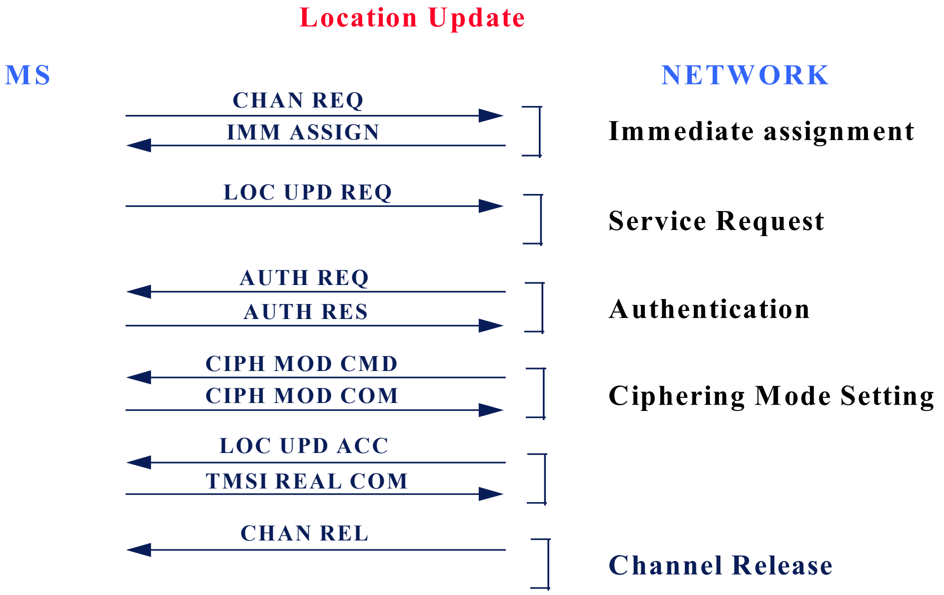


Figure 14. Location Update.

6.3 Disconnect

The disconnect protocol is needed when the Mobile Station or the Network want to finish a call for some reason.

6.3.1 Network Initiated

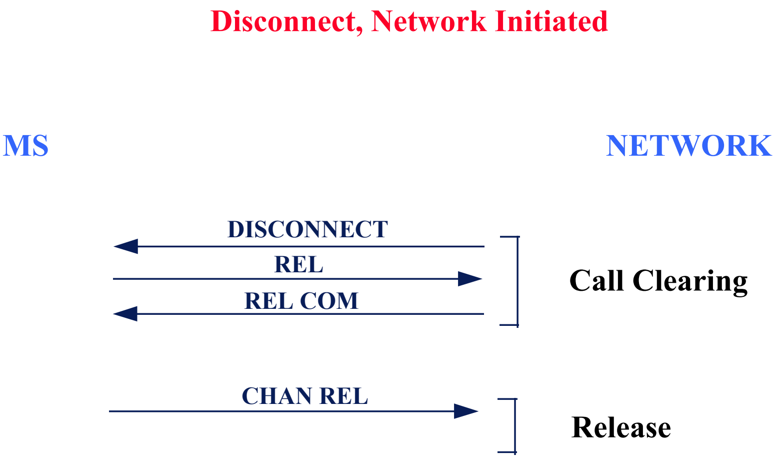


Figure 15. Disconnect, Network Initiated.

6.3.2 Mobile Station Initiated

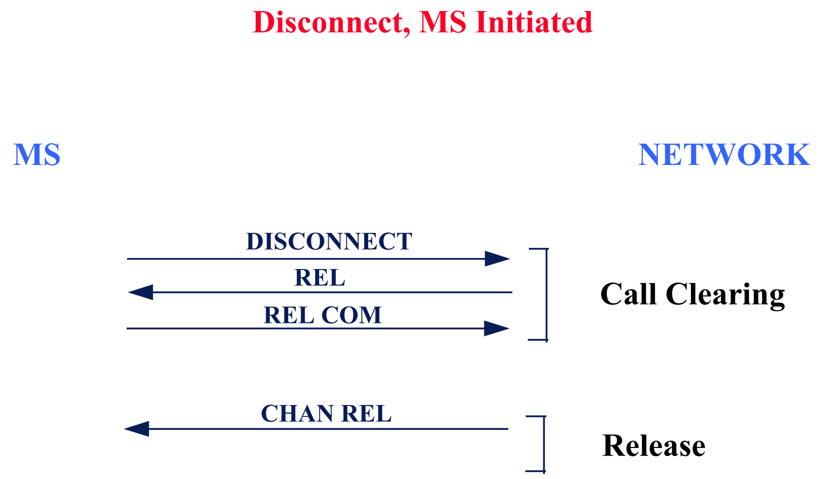


Figure 16. Disconnect, Mobile Initiated.

6.4 Handovers

In the different handover processes, the protocols are slightly different because in synchronised handover, no timing advance information is needed. This decreases the protocol so that no physical information needs to be sent. Both handover cases - synchronised and non-synchronised - are presented separately. Handover failure procedure has been presented as well.

6.4.1 Synchronised Handover

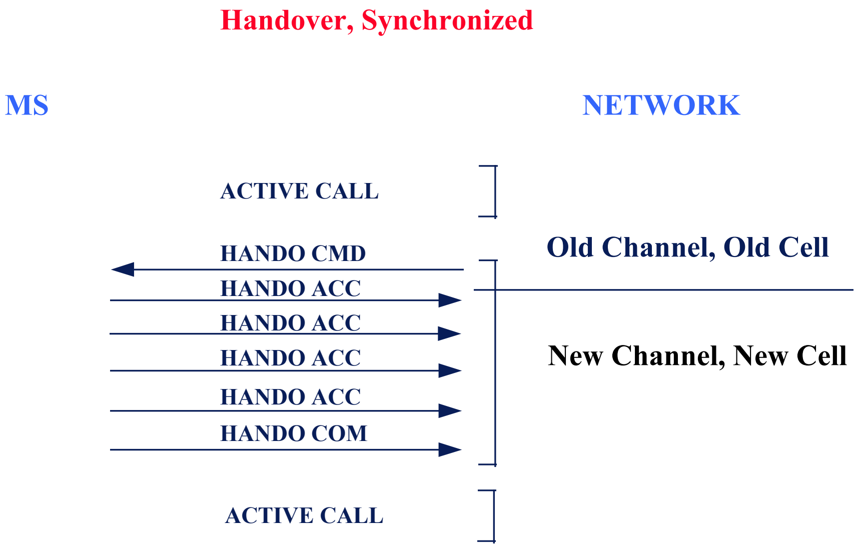


Figure 17. Synchronized Handover.

6.4.2 Non-Synchronised Handover

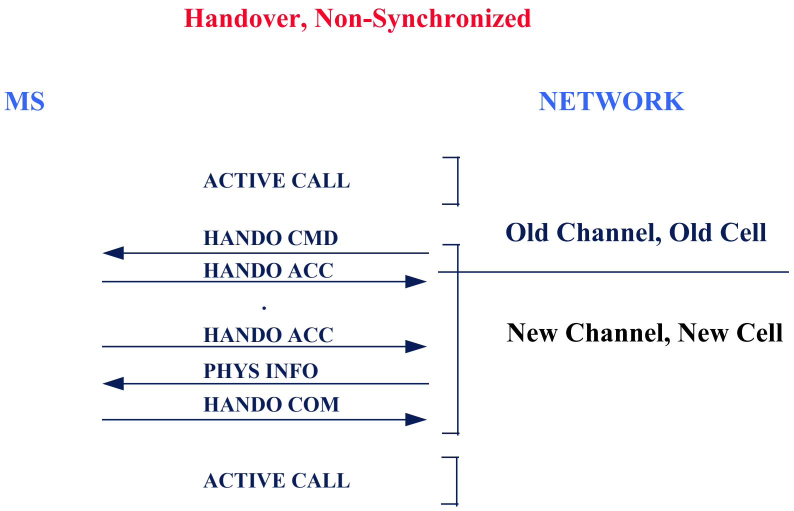


Figure 18. Non-Synchronized Handover.

6.4.3 Handover Failure

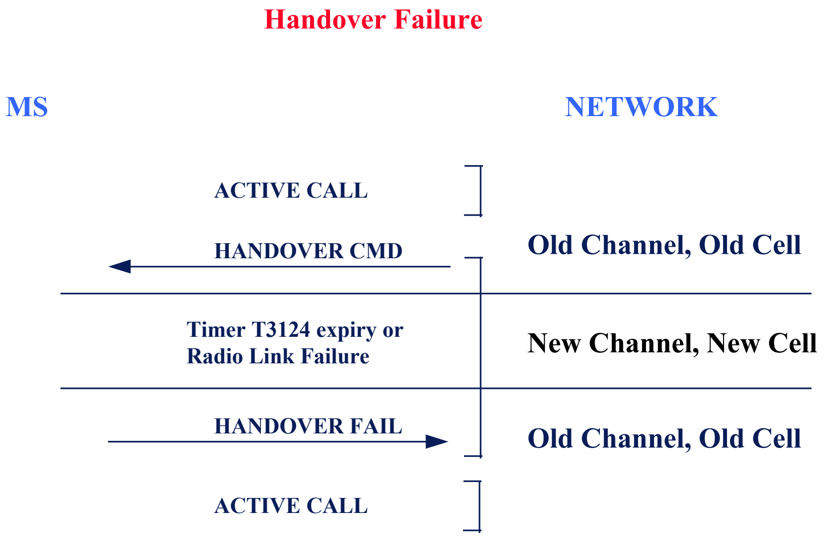


Figure 19. Handover Failure.

7 Radio Resource

Number of radio channels and time slots are usually limited and use of them has to be as efficient as possible. The target is to have all the Mobiles on the best radio channel at all times and to have Mobiles offered service all the time. In order to fulfil these conditions some algorithms and parameters are needed for traffic channel allocation, for dropped call control and for queuing.

7.1 Traffic Channel Allocation

When network allocates a traffic channel to a Mobile Station, the principal is that a traffic channel with lowest interference level is allocated at each time. This means that Base Station measures all the time all the time slots in uplink direction and compares these measurement results by putting them different boundaries. These boundaries can be given by parameter **interferenceAveragingProcess.**

The parameter InterferenceAveragingProcess is used for calculating averaged values from the interference level in the active/unallocated time slots for the traffic channel allocation procedure:

- **AveragingPeriod** is the number of SACCH multiframes from which the averaging of the interference level in the active/unallocated time slots is performed. The range is from 1 to 32.

- **Boundary1** - **Boundary4** are the limits of five interference bands for the active/unallocated time slots. The range is from -110 dBm to -47 dBm.

Boundary0 and **Boundary5** are fixed, the first one to –110 dBm and the last one to –47 dBm.

The best class is the lowest receiving level class because the probability of the interference is the lowest.

Calls that are assigned to a channel under heavy interference can be dropped and then these channels can be allocated again for other calls with same consequences. Applying the method of minimum acceptable uplink interference in TCH allocation, (**cnThreshold**) offers sufficient protection against these cases.

7.1.1 Maximum interference level

A) During call set-up:

1) MAX_INTF_LEV = RXLEV_UL + (**MsTxPwrMax** - MS_TXPWR) - **CNThreshold**

RXLEV_UL is the current uplink signal level and it is measured during the initial signalling period of call set-up or just before the handover attempt. **MsTxPwrMax** -MS_TXPWR is the difference between the maximum RF power that an MS is permitted to use on a channel in the cell and the actual transmitting power of the mobile station.

2) If the optimum uplink RF signal level, which both ensures adequate speech/data quality and does not cause uplink interference, is employed, the maximum interference level is calculated as shown below.

MAX_INTF_LEV = MAX (MIN (RXLEV_UL+ (**MsTxPwrMax** - MS_TXPWR), OptimumRxLevUL), RXLEV_UL- (MS_TXPWR- **MsTxPwrMin**)) - **CNThreshold**

MS_TXPWR- **MsTxPwrMin** is the difference between the actual transmitting power of the mobile station and the minimum RF power that an MS is permitted to use on a channel in the cell. The parameter **OptimumRxLevUL** indicates the optimum uplink RF signal level, which both ensures adequate speech/data quality and does not cause uplink interference.

If the value of the parameter **OptimumRxLevUL** varies between the TRXs of the cell, the BSC selects the greatest value for the calculation.

B) During intercell handover:

The S7 release introduces a new parameter **RxLevBalance (0 … 20 dB)** used together with **cnThreshold** and / or **MsPwrOptLevel** when calculating the maximum acceptable interference level for intercell handover. **RxLevBalance** indicates the difference between the uplink signal level and the downlink signal level within the BSC coverage area. The parameter indicates that, for example, if the **RxLevBalance** is 5, the downlink signal is 5 dB stronger than the uplink signal level.

The BSC then compares the maximum acceptable interference level MAX_INTF_LEV with 5 interference bands. The comparison indicates the interference band recommendation, which will be used in the channel allocation procedure.

Example:
CNThreshold = 20 dB Interference band 0 -110 ... -105 dBm
RXLEV_DL = -78 dBm Interference band 1 -104 ... -100 dBm
RxLevBalance = 5 dB Interference band 2 - 99 ... - 95 dBm
Interference band 3 - 94 ... - 90 dBm
Interference band 4 - 89 ... - 47 dBm

MAX_INTF_LEV = RXLEV_DL - **RxLevBalance** - **CNThreshold**
= -78 dBm -5 dB - 20 dB
= - 103 dBm

⇨ Interference band recommendation is band 0

The interference band is always a cell-associated recommendation. In a handover attempt where there are several target cells, the interference band recommendation does not change the order of preference of the target cells.

The BSC allocates for a call or for an intra-BSC handover attempt primarily a TCH whose uplink interference level is within the recommended interference band.

MAX_INTF_LEV (UL) = MAX (MIN (AV_RXLEV_NCELL (n)-**RxLevBalance**, **MsPwrOptLevel** (n)), (AV_RXLEV_NCELL (n)- **RxLevBalance**) - (**MsTxPwrMax** (n) - **MsTxPwrMin** (n))) - **CNThreshold** (n)

MsTxPwrMax (n)-**MsTxPwrMin** (n) is the difference between the maximum RF power that an MS is permitted to use on a traffic channel in the target cell (n) and the minimum RF power which an MS is permitted to use on a traffic channel in the target cell (n). The parameter **MsPwrOptLevel** (n) indicates the optimum uplink RF signal level on a channel in the adjacent cell after a handover.

When the BSC calculates the optimised RF power level of the MS, it presumes that the uplink signal level is equal to the downlink signal level, measured by the MS, within the coverage area of the adjacent cell. If the downlink signal is, for example, 5 dB stronger than the real uplink signal, the value for the parameter **MsPwrOptLevel** should be selected 5 dB higher than the desirable uplink signal level. Correspondingly, if the downlink signal is weaker than the real uplink signal, the value of the parameter **MsPwrOptLevel** should be lower than the desirable uplink signal level.

7.1.2 Active Channel Interference Estimation (S6)

In the IUO concept it is important to know the interference level of channels. Especially when the channel is released, there is currently a time interval of 1-32 sec., depended on the parameter settings in the BTS, in which no information about the interference band to which the channel belongs to is available.

This problem can be solved if the BTS reports the idle channel interference's also from incomplete measurement periods and active channel interference's, if they are measured as well. Active channel interference estimation is realized by utilizing idle TDMA frames with TCH/F connections and also the silent periods in mobile transmission during uplink DTX. BTS calculates the interference levels and reports them to the BSC. The reporting is done with RF_RESOURCE_INDICATION message, which originally contained the interference band information for idle channels only. Now the results of an active channel are included in this message when there are enough interference level measurements available.

Measurement for active channel interference level is possible only during the speech connections, not during data connections. If the uplink DTX is not activated, then the active channel interference cannot be measured for half rate calls. However, idle channel interference can be measured from incomplete measurement periods in every case.

7.2 Priority in TCH Allocation

Sometimes it can be reasonable to favour the BCCH carrier in call assigning. General reason can be found from the fact that the BCCH TRX is transmitting in all time slots all the time, so allocation of TCHs primarily from BCCH carrier does not increase the network interference. Other reason can be the quality of BCCH TRX channels in those cases when the BCCH carrier frequencies are not reused so efficiently than the other carriers.
The RF hopping can reduce the average interference experienced by the MS. RF hopping can not be applied to BCCH carrier. For this reason sometimes, for quality reasons, it can be reasonable to assign call primarily to the other TRXs than the BCCH carrier. However, RF hopping actually makes possible to reuse the non-BCCH carrier frequencies more frequently so the favouring of BCCH TRX due to uplink interference can still be reasonable.

TCH allocation between TRXs in one cell is managed by the parameter **trxPriorityInTCHAlloc (0, 1, 2),** that defines whether the prioritization is determined or not. If it is, the parameter defines whether the BCCH TRX or the non-BCCH TRXs are preferred.

Allocation of traffic channels from specific preferred group of TRXs is reasonable if the TCHs of the group are clean enough.

7.3 Preferred BCCH TRXs, optional

The TRXs are not always similar within a cell as regards to the antenna power, Abis transmission or for example to the safety of the power feed. This may result in a requirement of keeping the BCCH on a certain physical TRX always when possible.

This feature enables the recovery system to return the BCCH automatically to its original TRX after the fault has been eliminated. Manual actions are not needed any more to keep the BCCH permanently on a particular TRX. The feature utilises the forced handover procedure to avoid cutting any calls.

The feature is controlled by a TRX parameter **preferredBCCHMark**, which forces the recovery system to configure the BCCH back to a particular TRX of a cell. It is possible to mark more than one TRX of a cell as preferred, in which case the recovery system selects one of the marked TRXs for the BCCH.

Figure 1. Preferred BCCH TRX and TRX fault/cancel

1a) preferred BCCH mark in one TRX

	first	**after TRX-1 fault**	**after TRX-1 fault cancel**
pB TRX-1	BCCH	TCH faulty	BCCH
TRX-2	TCH	BCCH	TCH

1b) preferred BCCH mark in two TRXs

	first	**after TRX-1 fault**	**after TRX-1 fault cancel**
pB TRX-1	BCCH	TCH faulty	TCH
TRX-2	TCH	TCH	TCH
pB TRX-3	TCH	BCCH	BCCH

Figure 2. preferred BCCH TRX and BCF unlock, supposition: faulty TRX is repaired before unlock.

	first	**after BCF lock**	**after BCF unlock**
pB TRX-1	TCH faulty	TCH	BCCH
TRX-2	TCH	TCH	TCH
TRX-3	BCCH	BCCH	TCH

BSC may change the traffic channel configuration in the following situations:

1. If Half rate feature is in use and Abis timeslot allocation is optimized so that BCCH RTSL don't have Abis allocation, then BCCH recovery may decrease the number of traffic channels. If the BSC reconfigures BCCH to the original TRX then the BSC sets the swapped traffic channels always as full rate channels though they may have been half rate channels.

2. If Half rate feature is in use and all TRXs in cell do not support half rate then BCCH recovery may decrease number of traffic channels.

E-Rach recovery is not possible in fault cancel, if BSC has to move BCCH to preferred BCCH TRX, because BSC can not handle two reconfigurations in one scenario. E-RACH stays blocked even though there is working TCH TRX.

7.4 Frequencies and Frequency Hopping

The radio interface of GSM/DCS uses slow frequency hopping. Frequency hopping consists of changing the frequency used by a channel at regular intervals.

Frequencies used in each transceiver are defined by parameter **initialFrequency (1 ... 124 in GSM)**. When Mobile is in Idle state there are two possible ways to listen BCCH frequencies of adjacent cells. Traditional way is that Mobile listens to the same BCCH frequencies of the adjacent cells of the serving BTS as in Idle mode. An alternative solution to listen BCCH frequencies of adjacent cells is to use improved list (known as Double-BA list).
This list can be described by the two following parameters:
the **bCCHAllocationList (1 ... 124)** (where GSM up to 124 ARFN can be specified) and the **idleStateBCCHAllocation (0, 1 ... 128)** (where "0" means that the normal list based on the BCCH of adjacent cells is considered, and where 1…128 means that one of up to 128 possible improved lists can be considered instead, with frequencies as specified with the previous parameter) when MS is in idle mode .In dedicated mode by the parameter **measurementBCCHAllocation (ADJ, IDLE)** it is possible to specify the list to be used in handover (where ADJ means that the normal BCCH list of the adj cells is considered and IDLE means that the BCCH list specified for idle mode is used instead).

There are two different kinds of frequency hopping in the BTSs; Baseband Hopping and Synthesised Hopping, controlled by parameter **btsIsHopping** (BB, RF, N). Below both of the frequency hopping methods are described

7.4.1 Baseband Hopping (BB Hopping)

BB Hopping refers to a particular implementation of frequency hopping algorithm in which the baseband digital signal streams are multiplexed between transmitters and receivers using fixed frequencies. In Baseband Hopping the Base Station is actually changing TRXs.

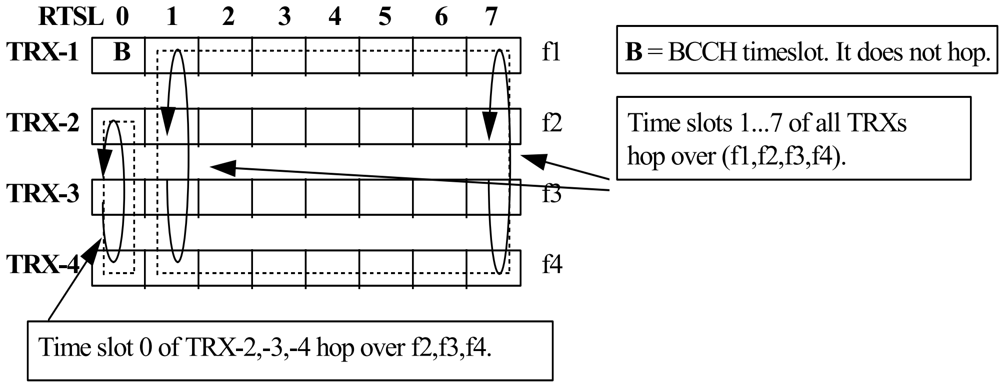


Figure 1. BB hopping on 4 TRXs. Also the BCCH TRX is hopping except on RTSL-0.

7.4.2 Radio Frequency Hopping (RF Hopping)

RF Hopping (Synthesised hopping) refers to a particular implementation of frequency hopping algorithm in which the synthesisers of BTS transmitter and receiver are tuned on every time slot to the frequency specified by the hopping algorithm. Number of frequencies to hop over is up to 63.

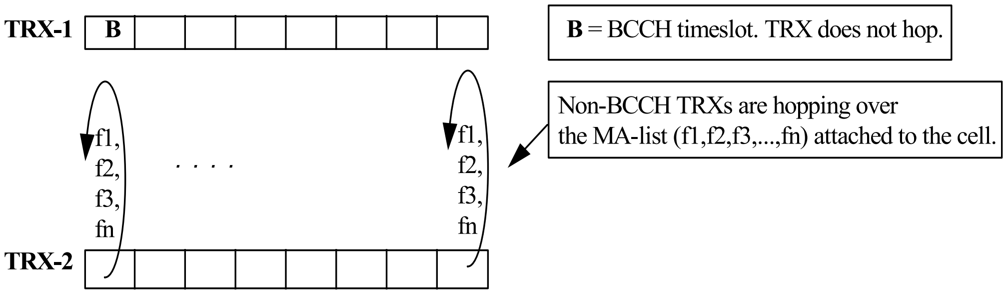


Figure 2. RF hopping in 2-TRX cell.

The BCCH TRX cannot hop because the BCCH frequency must be continuously transmitted in a cell.

In Synthesised Hopping, it is possible to use many frequencies in the same TRX controlled by parameter **usedMobileAllocation (0 ... 128)** and **mobileAllocationList (1 ... 124)**. This means that the maximum number of hopping frequencies lists that can be specified are 128, and the maximum number of frequencies that can be specified within a list is 124 in GSM.

Hopping Sequence Numbers (**HSN1 (1 ... 63)** for time slot 0, **HSN2 (1 ... 63)** for time slots 1-7) are needed in case of both hopping in order to tell hopping sequences. (Chapter 18 Background database).

7.4.3 Freeform RF-Hopping (S6)

In BSS S6 the frequency hopping for sectorized network can be planned by using MAIO offset parameter. The parameter is defined that the RF-hopping would be more flexible. If **maioOffset (0 ... 62)** -parameter is used, it is possible to use the same MA frequency list for two or more sectors of the site without collisions. The MAIO-Offset parameter defines the lowest hopping frequency for the cell and it can be bigger than zero thus synchronising the sectors. (See chapter 18 Background database).

The following example will show the principle of maioOffset parameter. A three- sector site with 4 TRXs per cell needs at least nine hopping frequencies in MA (available maios 0...8). The number of available TRXs for hopping defines the minimum amount of frequencies in MA list. In this case there is 1 BCCH-TRX and 3 RF Hopping TRXs per cell. All three sectors can use the same MA-list when maioOffsets are set for sectors. HSN must be equal between sectors otherwise collisions will occur regularly. The following table shows the maioOffsets and maios for TRXs. Note that there are nine RF-hopping frequencies per sector!

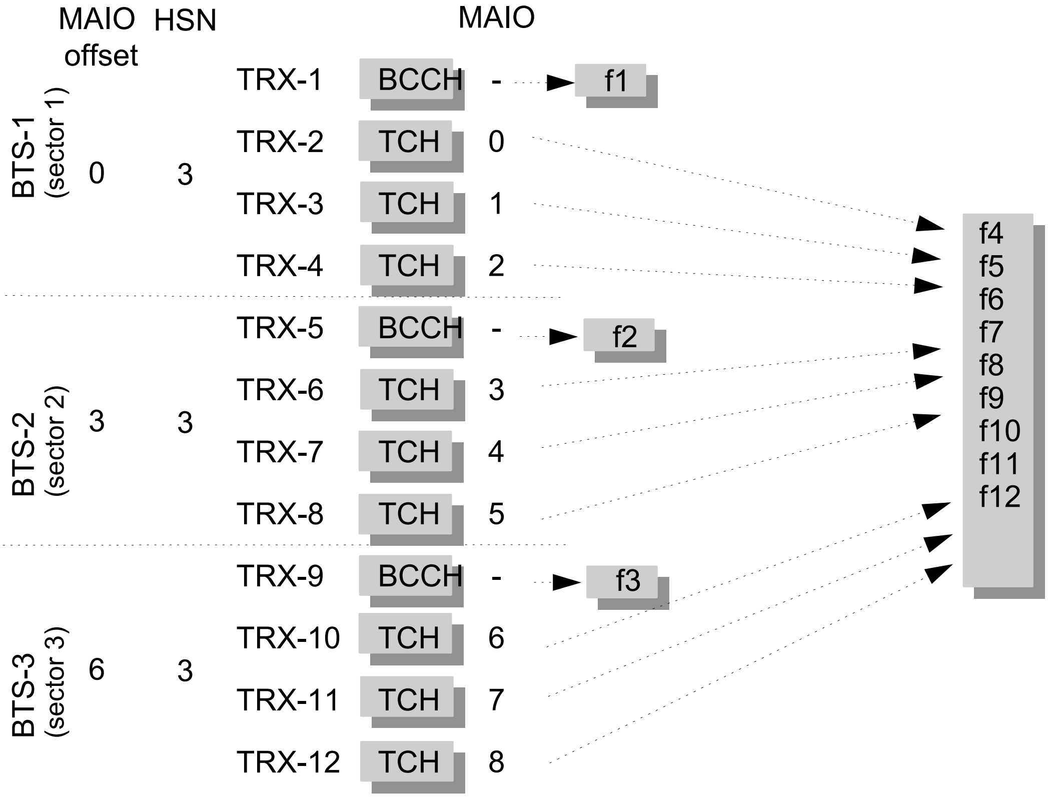


Table 1. MAIO values for a 3-sector site, 4 TRXs per sector.

The number of frequencies allowed in a hopping group is increased to 63. This development is new for III-gen. only; IV-gen. supports 63 frequencies in a hopping group right from the beginning.

The number of TRX’s supporting RF hopping in a cell is no more limited by two. RF hopping can be used only with AFE. This is because wide band combiner is needed with RF hopping.
Note: 2nd generation BTS does not support RF hopping.

7.4.4 Flexible MAIO management (S7)

With this feature it will be possible to arrange MAIOs within a cell in a way that using successive frequency channels becomes possible without continuous in-cell adjacent channel interference.

This functionality is of vital importance for success of RF hopping with tight reuse (so it becomes essential feature in Intelligent Frequency Hopping, see in IUO chapter) because commonly the operators will be forced to allocate successive channels in MA list. In order to use RF hopping with

more flexibility the operator needs the management access to all the hopping parameters including MAIOs.
The new parameter added for more flexibility in RF hopping parameters set is **MaioStep** (MS), with a range 1..62. With this parameter the MAIOs can be chosen not to be allocated successively for the cell, but for instance every second or third value.

See the below table for a better understanding:
A 3-sector site, 4 TRXs per sector (i.e., 3 RF hopping TRXs per sector). HSNs for each sector must be equal. MAIO offsets are set as follows: '0' for sector-1, '6' for sector-2 and '12' for sector-3. MAIO steps are set 2 for all sectors. MA frequency list must contain at least 18 frequencies (available MAIOs: 0…17).

Sector	HNS	MAIO-offset	MAIO-step	TRX	MAIO value for all RTSLs
1	N	0	2	TRX-1 TRX-2 TRX-3 TRX-4	BCCH, not allowed to hop MAIO=0 MAIO=2 MAIO=4
2	N	6	2	TRX-5 TRX-6 TRX-7 TRX-8	BCCH, not allowed to hop MAIO=6 MAIO=8 MAIO=10
3	N	12	2	TRX-9 TRX-10 TRX-11 TRX-12	BCCH, not allowed to hop MAIO=12 MAIO=14 MAIO=16

7.4.5 Terminology

Random Hopping
Frequencies change according to a pseudo-random sequence. HSN = 1...63.

Cyclic Hopping
Frequencies are used one after another in ascending order in the hopping sequence. HSN = 0.

Slow Frequency Hopping (SFH)
The frequency change rate is slower than the modulation rate. In GSM the frequency changes burst by burst (156 bits), thus GSM hopping is clearly slow hopping.

Hopping Group
Set of Radio Timeslots using the same MA and HSN in a cell.

Hopping Sequence Number (0...63) (HSN)

A parameter used in randomising the hopping sequence. If HSN = 0, it means cyclic hopping, 1...63 means random hopping. Each hopping group may have an HSN of its own.

Mobile Allocation (MA)
List of Absolute Radio Frequency Channel Numbers, which are used in a particular hopping sequence.

MA-list
Mobile allocation frequency list. This is an object in the BSC's database. It defines the MA for a RF hopping cell.

Mobile Allocation Index Offset (MAIO)
Hopping sequence starting point for each RTSL using the same MA. MAIO synchronises the RTSLs, which use the same MA, to use different frequencies at a time.

MAIO step (MS)
MAIOs can be allocated every second or every third value, for example. Range from 1 (the old management) to 62.

7.5 Directed Retry and Intelligent Directed Retry

Directed retry is a procedure which is used in call setup phase in assigning a traffic channel to a mobile station from a cell (no matter if macro or micro) other than the serving cell, in situations when the first attempt fails due to tch congestion allowing the mobile subscriber to make a second attempt at gaining access. Directed retry is an handover from SDCCH to other cell's TCH and it can be controlled by parameter **drlnUse (Yes / No**).

Directed Retry can be used in both Mobile Originating Calls and in Mobile Terminating Calls.
The target cell selection for Directed Retry is made according to the imperative handover criteria (explained later in Imperative Handovers chapter) so that the criteria itself is not as strict as in normal HO algorithm analysis.

The following items are taken into account during the candidate cell selection:
- the Rx signal level compared to the threshold value defined by the parameter RxLevMinCell
- the MS classmark and
- the maximum power level in the cell.

In other words it means that all adjacent cells with RX level greater that **RXLEV_MIN (n),** are considered as target cells. These cells are sorted according to their RX level values.
In **S7** though, in order to set stricter criterion during the candidate cell list creation procedure, two new parameters are introduced:

drMethod	0..1	(cell access parameter)
drThreshold	-110..-47 dBm	(adjacent cell parameter).

The first parameter is the switch type of parameter with value 0 when the improved criterion is not in use (so the old criterion will be followed) and value 1 when the new target cell selection criterion is selected and then the second parameter **drThreshold** will be taken into account together with the old parameter **RxLevMinCell** when selecting the candidates.
drThreshold is recommended to be set higher than the existing adj cell parameter **RxLevMinCell** in order to decrease logically the radius of the area in the adjacent cell where the Dr (IDR) is able to perform so that it's possible to set a higher quality standard for the signal strength in the adj cell.

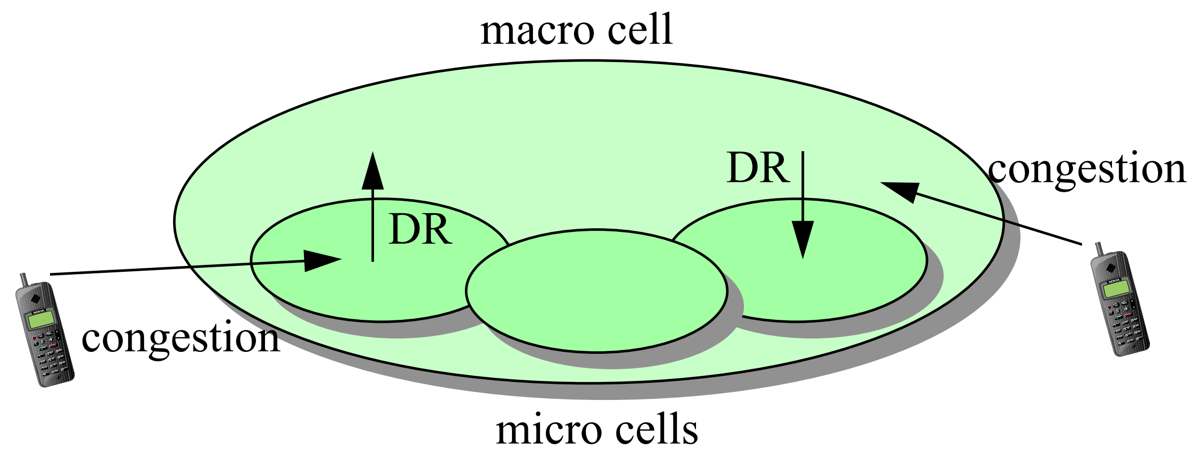
Due to this new threshold value the quality of the signal in the cell is better after DR is performed successfully.

If the value of **drThreshold** parameter has been set below the adj cell parameter **RxLevMinCell**, the measured signal strength is compared with the **RxLevMinCell** only, instead (we actually ignore the improved method of selection even if is enabled).
The feature consisting of the two new parameters is related to the existing optional features DR and IDR usage. Both parameters are visible only when the features DR and/or IDR are in use in the cell.

When DR procedure is initiated, the following two timers (improvement in S6) control the creation procedure for a HO candidate list:

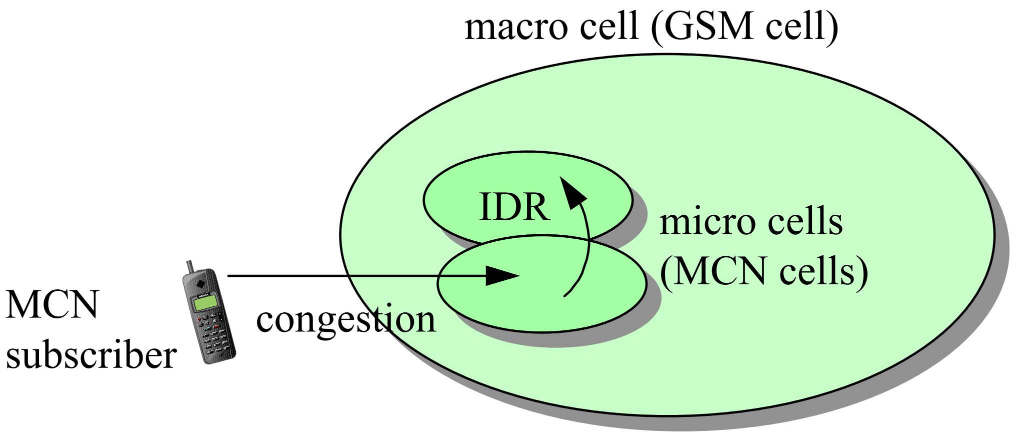
- It is possible to determine the period starting from the assignment request during which the DR is not allowed. The BSC can start the target cell evaluation for the DR handover after the time supervision has expired. This period is allowed to the MS to decode the BSIC of the adj cell before the target cell evaluation. The time supervision is controlled on a cell by cell basis with the parameter: **MinTimeLimitDR**.
- The BSC can continue the target cell evaluation for the DR handover until the maximum time allowed for the start of the DR handover expires. The time supervision is controlled on a cell-by-cell basis with the parameter: **MaxTimeLimitDR**.

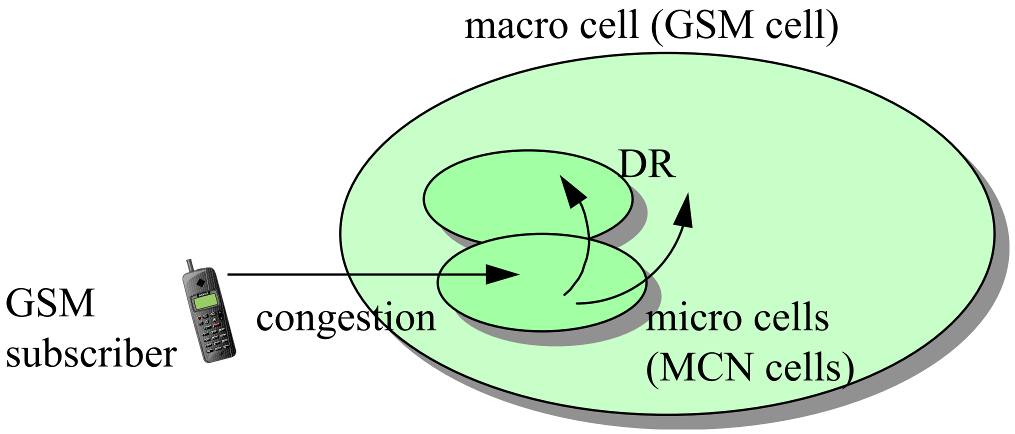
Note: The queuing is allowed in DR in serving accessed cell during the DR target cell selection. Provided that the queuing conditions are met. No queuing is allowed in the new target BTS after the directed retry procedure has been started. The BSC stars a clearing procedure if no TCH can be allocated in the target cell during the BSC internal directed retry handover.



Intelligent Directed Retry (IDR) can be used in call setup phase in service separation for handheld and car phones. This feature is based on DR except the target cell selection is done considering the classmark and the cell type (as explained just below) and not only a minimum threshold (that can be either **RxLevMinCell** or **drThreshold)**.

The MS classmark or the MS priority and the target cell type are taken into account when making the target cell selection. A parameter CELL_TYPE indicates the type of the cell and the ADJ_CELL_TYPE indicates the type of the adjacent cell. Possible values to both parameters are GSM and MCN. This feature is optional and it is controlled by the parameter **idrUsed (Yes / No)**.





IDR decision table is as follows:

Ch Req from MS
IMM ASS to DCCH of accessed cell
MS sends RXLEV measurements of adjacent cells

? Is TCH available on accessed cell

Yes -> Allocate TCH on accessed cell
No -> ? Classmark check or Priority check (it's checked if the MS belongs to MCN or GSM)

MCN -> ? Is IDR in use in this BTS

Yes -> IDR start, create new (target) cell list of MCN cells

No -> reject call

GSM -> ? Is DR in use in this BTS

Yes -> DR start, create new cell list of all adjacent cells

No -> reject call

Decision of subscriber type can be made based on the MS classmark

❐ classmark 1-4	= GSM subscriber
❐ classmark 5	= MCN subscriber

or based on the PIE

❐ priority level 4	= GSM subscriber
❐ priority level 9	= MCN subscriber

The PIE requires the MSC support, which determines the class of the subscriber. The PIE can be used in service separation.
So as a conclusion the IDR whenever is activated allows to select preferentially MCN cells as target cell for the retry if the call try is set up in MCN environment.

Note that the BSC internal DR handover procedure is always possible if allowed in the BSC and in the initial BTS parameterisation. In case we want BSC external directed retry handover to be performed, a special functionality in the MSC is required as well (available in M7B) and if the MSC doesn't support DR feature, the external DR handover must be denied.
The external DR attempt is controlled on a BSC basis with the parameter **disableExtDr** with two possible values: **Y**es/**N**o (S7).

The parameter allows when set to Yes, to use in DR only Internal Directed Retry HOs. Others are terminated. The parameter needs support from the MSC (MSC release supporting it M7B).

If all the BSSs in the network do not support DR feature, the parameter **disableExtDr** MUST be set in the BSC. When the parameter **disableExtDr** is set in the serving BSC and the first candidate cell belongs to another BSC, the BSC goes through the candidate cell list so that the cells belonging to the serving BSC are searched and the BSC internal DR is attempted according to this new list.

7.6 Queuing

In GSM, the queued radio resource is always a TCH, never a SDCCH. The queued seizure request can be either a call set-up (MOC set-up or MTC set-up) or a handover attempt (all GSM-specified handover types).

Queuing is used in order to give better service for Subscribers. Call attempts and handovers both can be queued and they are in the same queue. In queuing different priorizations can be used for both call attempts and for handovers (non-urgent handovers (S6) and urgent handovers) by parameters **queuingPriorityCall (1 ... 14), queuePriorityNonUrgentHo (1 ... 14)** and **queuingPriorityHandover (1 ... 14)**.

In S6 two different kind of handover are defined. One is Non-urgent HO which consists of power budget HO, umbrella HO, slow moving MS HO and traffic reason HO. Urgent HOs consist all other HOs, e.g. bad quality HO or weak field HO.

Use of priorities can be activated by parameters **queuePriorityUsed (Yes/No)** and **msPriorityUsedInQueuing (Yes/No)**.

If both priorities (**queuePriorityUsed** and **msPriorityUsedInQueuing**) are used at the same time, the queue type priority will be the dominating factor. Remember that the MS priority operates only inside one single queue type.

Example:
It is set that
queuingPriorityCall is 12,
queuePriorityNonUrgentHo is 14 and
queuingPriorityHandover is 9.

It is also defined that officers are the most important user group and then other users come.
Let’s assume that one officer is trying to setup a call, and two normal users are attempting handover, one of them a less urgent handover.

So what will happened?
Due to the fact that the three users are queued up into three different queues, it’s the queue type priority that will lead the decision about which user will be served first. The call attempt that the officer tries to do is placed after the handover attempt of the normal user waiting in the queue of urgent handover, because the handover queue type priority is set to 9 which is higher than the call queue type priority which is set to be 12. The second normal user will be served as last being his queue priority type value the lowest, that is 14.

NOTE! The lower the parameter, the higher the priority.

Queuing length is related to number of TRXs and to the parameter **maxQueueLength (0 ... 100 %)** and queuing time can be set individually both for call attempts by parameter **timeLimitCall (0 ... 15 s)** and for handovers by parameter **timeLimitHandover (0 ... 10 s)**. Queuing can be deactivated by setting queuing time to zero.

When the best candidate has been selected in RR Management (e.g. handover situation) and no free traffic channel can be found, the best candidate is queued. Handover timers (**hoPeriodPBGT**, **hoPeriodUmbrella**) are stopped during the queuing.

In combination with Directed Retry procedure the timers of each of the feature are set separately. The call attempt queuing goes on during the creation of the candidate cell list for DR, improving the possibility of obtaining the needed TCH quickly so that the call set up can be continued. If the queuing time is set smaller than the time set for the target cell selection and before the expiring of the queuing time no TCH in the serving cell is freed, the only chance to continue the call set-up is a successful identification of a target cell in the adj cell during the maximum period allowed by the parameter **MaxTimeLimitDR**.

What if the queuing time is longer than the time allowed for DR to be performed and the call cannot be handed over from the SDCCH of the serving cell to a target cell TCH during the DR period?

The BSC discontinues the call set up procedure: the possibly ongoing queuing is terminated and the call attempt is cleared (no matter if there is still some queuing time left to wait for a TCH to get free).

7.7 Drop Call Control

Some information is needed in order to know that the call is dropped before the same channel can be reused. **RadioLinkTimeout (4 ... 64)** is a parameter for the purpose of checking weather radio interface between Mobile Station and Base Station is still maintained. When Base Station gets the measurement results from the Mobile Station on SACCH it also counts a value, which decreases by 1 if SACCH is not received and increases by 2 every time when SACCH is received. If this value reaches 0 it means that radio connection between Base Station and Mobile Station has been lost.

Another parameter **call Reestablishment** can be used where the MSC will wait for some time before it disconnects the call and the mobile will try to re-establish the connection, it will use the best server which can also be one of the neighbouring cells.

7.8 Trunk Reservation Algorithm, optional

Trunk reservation (TR) is a stochastic algorithm employed in channel allocation from a cell. The initial purpose of the feature is to allow the shared use of traffic channel resources of a BTS by GSM and MCN users. The algorithm retains the tuning of the grade of service provided for the users of the two networks. The scheme ensures that the overload of the TCH resource in one network will not necessarily lead to congestion in the other network. The two networks can thus be dimensioned to offer different grades of service simultaneously.

Trunk reservation can be applied both to mobile originating and to mobile terminating calls. Handovers can also be treated as one traffic class, and the availability of a channel in a cell will thus be determined with the help of the stochastic algorithm.

After the access is granted to a subscriber in a specific BTS, a traffic channel is allocated for the MS by applying the BSC's internal algorithms that do not depend on trunk reservation.

The trunk reservation scheme is realised within a BSC, and is thus an entirely internal procedure.

The micro cellular network (MCN) service area is a subset of the GSM service area. GSM subscribers are allowed to camp on MCN cells, so the microcells must therefore provide traffic channel resources for both MCN and GSM use.

Each kind of access attempt to a cell made by an MS is considered to be one of the traffic types defined to the cell. The traffic types are determined by the services provided, plus the corresponding subscriber characteristics.

A decision threshold is defined as a function of the number of currently free radio resources, that is, idle traffic channels and service types.

When the trunk reservation algorithm is applied, a random variable R is compared with a threshold to find out whether a free traffic channel is available for a requester representing a specific traffic type.

The random value R is uniformly distributed between 0 and **randomValueLimit** and regenerated for each request. Possible values (Xij= **decisionThresholdValues**) of the threshold can be presented as a table:

IDLE TCHS	TRAFFIC TYPE		
	1	2	...
1	10	5	
2	20	10	
3	30	20	
.	.	.	
.	.	.	Xij
.	.	.	
Q	XQ1	XQ2	

Figure 1. The decision threshold table.

Access is granted only if R < Xij, with i and j corresponding to the number of free channels and traffic type respectively. Access can therefore be rejected even though there are idle channels left. If more than Q channels are free (**freeTchLimit**), all access attempts are granted.

Let's take an example: GSM user tries to make a call (assuming traffic type 2). We have three free TCHs in the cell. Due to the fact that only few TCHs are available (Q can be max 16) BSC will use the decision threshold table Xij. According to the above table in fig. 1 Xij = 20%. BSC will use the random value R to be compared with Xij = 20%. R value is random that's why we could have the following two alternative cases:

1. if R = 8 => R < Xij i.e. 8<20 is true=> call attempt will be successful

2. if R = 73 => R < Xij is NOT true i.e. 73 > 20 => call attempt will be terminated.

Note that the decision threshold table can be defined on cell basis, this will give a great opportunity to affect traffic distribution.

There are two exclusive methods of distinguishing between different subscriber's types. The distinction can be made according to the power capability class of the MS or according to the priority level of the service request given by the MSC. In this document the concept "priority level" means the priority level of the service request given by the MSC and received by the BSC in the Assignment or Handovers requests. The priority subscriber type is available only if the latter method is used in the BSC. The user can select the method with a BSC specific parameter.

The power capability class is indicated in the MS classmark. The possible values vary from 1 (the highest power level) to 5 (the lowest power level). The priority level can have several values between 1 (the highest priority) and 14 (the lowest priority).

Priority subscriber type

Employing new subscriber types means that the analogy between subscriber type and network is no longer explicit, that is, subscribers of different networks can represent the same subscriber type. The service separation is based on the priority level.

This kind of a subscriber type, where subscribers can belong to either a GSM or an MCN network, is the priority subscriber type. Priority subscriber type subscribers are the only subscribers who are able to access a certain amount of reserved priority channels (**nbrTCHForPrioritySubs)** in the cell.

When the number of priority channels is defined to zero then the "priority" traffic types are attached to decision threshold tables.

Trunk reservation gives the possibility to use two alternative reservation methods (**reservationMethod**) of traffic channels: static and dynamic. The reservation method is of significance only if the priority subscriber traffic type is employed in the BSC.

Static reservation method

In static reservation, once the priority channels have been allocated to priority subscribers, the remaining spare channels are available to other subscribers. Thus, in static reservation the number of channels reserved for priority subscribers is actually the number of simultaneous priority calls, which the BTS is able to transmit.

Dynamic reservation method

In dynamic reservation the number of channels reserved for priority subscribers means the number of channels that have to be left available to the priority subscribers only, no matter how many ongoing priority calls there are in the BTS.

The selection between static and dynamic reservation of traffic channels is made on a per cell basis. The reservation method can also be defined to apply only to call set-up, and in that case in an incoming handover the priority channels are available to all subscribers.

The queuing procedure is never applied to resource requests that have been rejected by the trunk reservation algorithm. In other words, although queuing would be allowed in a cell for call set-up or for handover, the resource request will not be put to queue if it represents a non-trivial traffic type and the trunk reservation algorithm has denied access to the requested resources. The access attempt is then rejected due to congestion in the BTS (no idle traffic channels) or by the stochastic algorithm.

If the access attempt has already been accepted by the trunk reservation algorithm or by some other procedure, but no TCHs meeting the extra requirements (interference band request, etc.) is available at that moment, the TCH request can be put to queue if that is allowed. The normal queuing procedures will then be followed.

Other Parameters

TrunkReservationUsed	Yes/No
priorityChUseIncomingHO	Yes/No

trunkTable-ID	1 .. 64

8 Measurements

The Base Station measures all the time slots in the uplink direction in every TRX all the time. Thus there is nothing special in the uplink measurements, because the Base Station knows the frequencies that it measures, and the measurement process is continuous. The Mobile Station, for its part, has to measure the downlink direction, and that is a little more complicated. In addition to the serving cell, the Mobile Station is also required to measure all the adjacent cells. The measurements carried out by the Mobile can be divided into two classes according to the status of the Mobile Station: Idle mode measurements and Dedicated mode measurements.

8.1 The Coding of the Measurements

All the measurements are coded as in the figure 20.

LEVEL

P (dBm)	FS (dBuV/m)	LEV
-110	27	0
-109	28	1
-108	29	2
.	.	.
.	.	.
.	.	.
-49	88	61
-48	89	62
-47	90	63

QUALITY

BER (%) RANGE	BER (%) MEAN	QUAL
< 0.2	0.14	0
0.2-0.4	0.28	1
0.4-0.8	0.57	2
0.8-1.6	1.13	3
1.6-3.2	2.26	4
3.2-6.4	4.53	5
6.4-12.8	9.05	6
> 12.8	18.1	7

Figure 20. Coding of Level and Quality.

8.2 Mobile Station Measurements in Idle Mode

In Idle mode, the Mobile receives information of the frequencies of the adjacent cells, which is sent on BCCH. The Mobile has to decode the BCCH of the serving cell every 30 s, and the BCCH of the adjacent cells every 5 min. The Mobile also has to pre-synchronise and decode the BSIC of the serving cell once in 30 s. The list of the Adjacent cells (six best adjacent cells) is updated every 60 s, and if a new cell appears in the list, the Mobile has to decode the BCCH of this new cell in 30 s.

In Idle mode, the Mobile has enough time to measure the adjacent cells, because there is no traffic between Mobile Station and Base Station. Actually, the Mobile measures the serving cell only when the Base Station sends paging messages to the paging group of Mobile Station.

8.3 Mobile Station Measurements in Dedicated Mode

In the Dedicated mode, the Mobile Station does not have so much time to make adjacent cell measurements, because the Mobile has to transmit and receive data to and from the serving Base Station, as shown in figure 21.

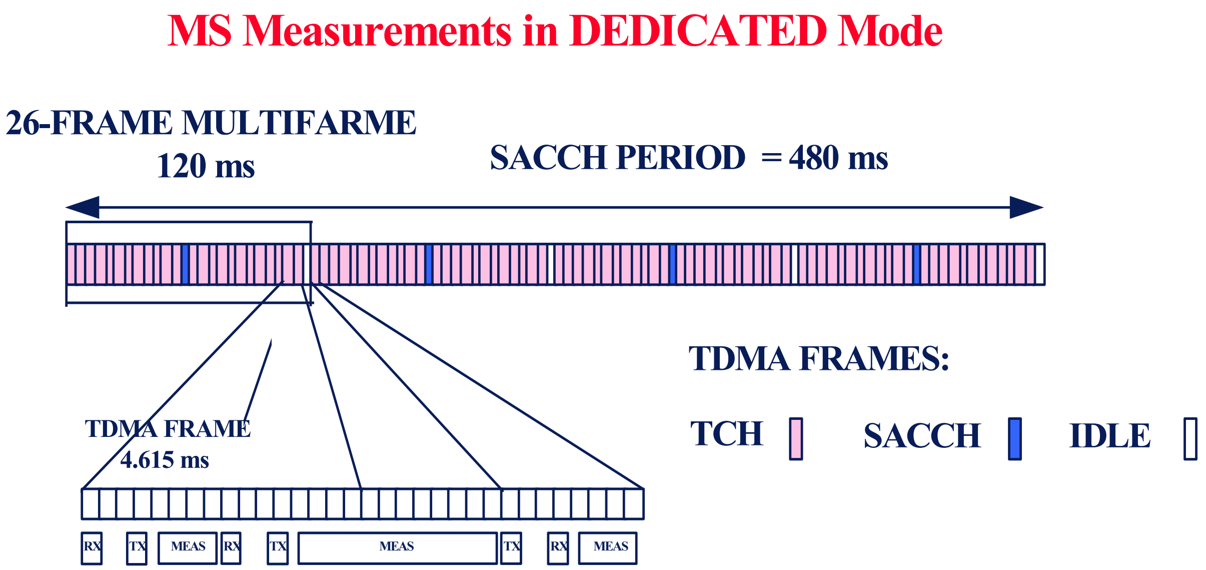


Figure 21. Mobile Station Measurements in Dedicated mode.

The Mobile Station measures the receiving level of the serving cell and receives data from serving cell simultaneously. When receiving the data from the serving Base Station, the Mobile also detects if DTX is used or not. After receiving the data, the Mobile in its turn transmits data to the serving Base Station. After transmitting and before receiving the next frame, the Mobile has a short time to measure the adjacent cell frequencies. The Mobile gets a list of them on System Info 5. During the Idle slot, the Mobile has a longer time to make the adjacent cell measurements, and during this time, the Mobile pre-synchronises itself to the frequency of the adjacent cell and tries to decode the BSIC of the adjacent cell.

In Dedicated mode the Mobile has to pre-synchronise and decode the BSIC of the adjacent cells once in 10 s. When a new adjacent cell is taken in the list, pre-synchronisation and BSIC decoding has to happen in 5 s. If it is not successful, the Mobile will use the old neighbour list and again try to decode the BSIC of the new adjacent cell.

The Mobiles sends a list of the six best adjacent cells every half second (exactly every SACCH period, i.e. 480 ms) to the Base Station, which pre-processes and sends the measurement results to the Base Station Controller (BSC).

9 Measurement Processing

The final measurement processing takes place in the BSC, but pre-processing to reduce signalling and processing the load in the BSC is carried out by each BTS.

9.1 Pre-processing in BTS

Pre-processing is the task of the BTS and means that the measurement results (both uplink and downlink) can be averaged over **1, 2, 3 or 4** SACCH period by the parameter **btsMeasAver**. This averaging is carried out to reduce the signalling load and the BSC processing load. Reducing the signalling load is necessary in the Abis interface where 16-kBit signalling is used.

Pre-processing also causes delay (**btsMeasAver**-1) x 480 ms in the final measurement processing in the BSC.

9.2 Averaging and Sampling in BSC

After the pre-processing, the results are sent to the BSC where the final processing is carried out. An important phase in the processing in the BSC is averaging and sampling. Averaging can be controlled by the parameters **ho/pcAveragingLev/QualDL/UL** (**msDistanceAveragingParam** for handover due to distance) including **windowSize (1 ... 32),** and **weighting (1 ... 3)**. Parameter **weighting** tells how samples are averaged and weighted due to the DTX. Averaging is done after each measurement result (after each SACCH period) so that the averaging window is sliding as shown in figure 22.

Averaging and Sampling

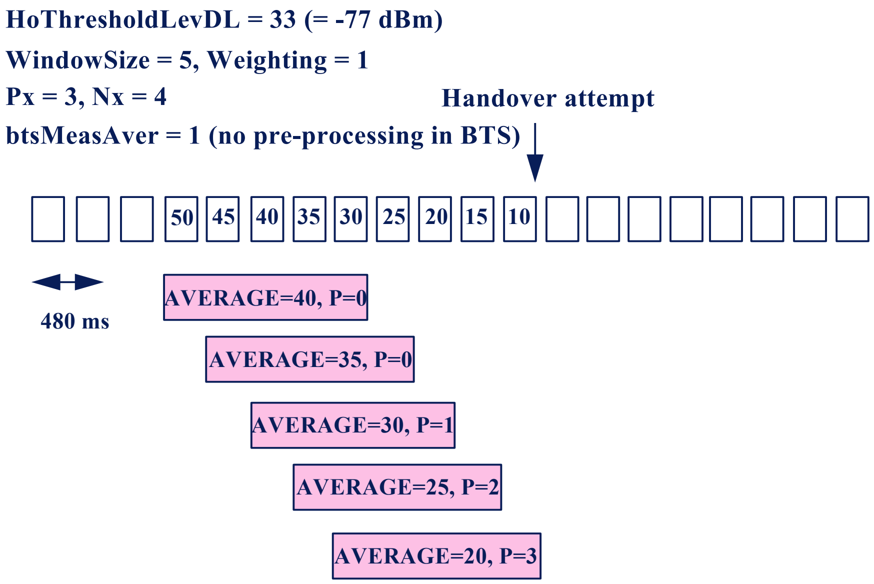


Figure 22. Averaging and Sampling.

9.2.1 Fast Handover Averaging Method (New feature available in S6)

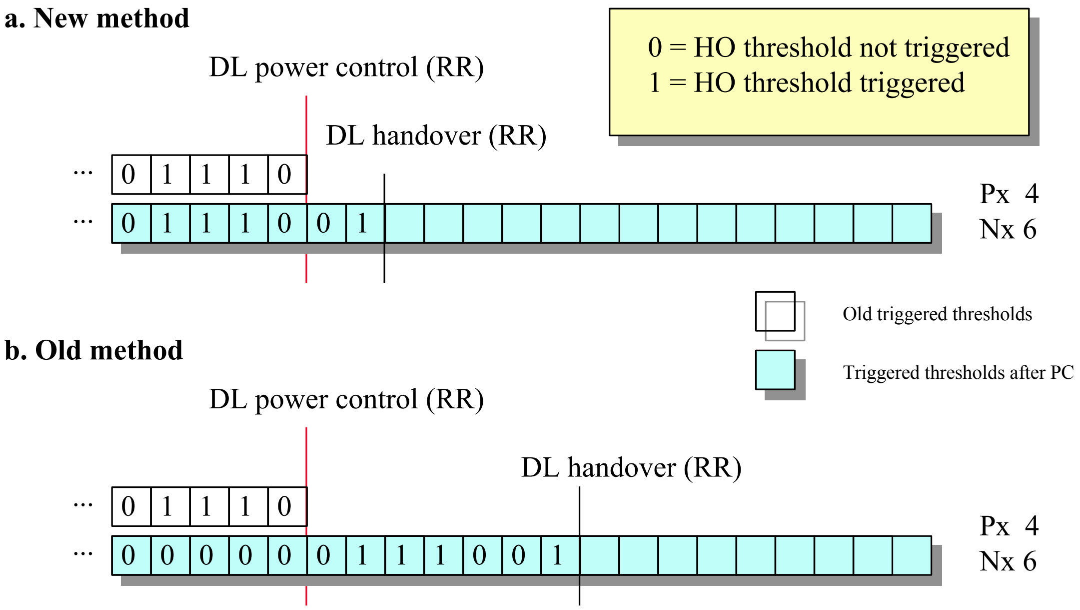
When the cells become smaller and smaller (micro cells) a faster handover algorithm is needed. A quick handover decision particularly in a handover between adjacent micro cells will be very feasible.

The following method allows faster handover decisions especially situations where the power control commands are normally being executed. The new method is alternative and it is based on the existing handover algorithm and the existing parameters and even the same values can be used.

The new handover measurement averaging method for serving cell can be used in call setup phase (SDCCH) by enabling the parameter **enaFastAveCallSetup (Yes / No)**, after power control command by enabling the parameter **enaFastAvePC (Yes / No)** and in the beginning of a new channel (TCH) by enabling the parameters **enaFastAveHO (Yes / No)**. The new handover measurement averaging method for neighboring cell measurements is always used (very feasible in IUO and DR).

After PC command the power control comparison is started again, but handover comparison is continued and only measurements before PC are initialized (the triggered thresholds are remained) and a new averaging method is used (see picture 1).

The following picture shows a difference between old and a new method.

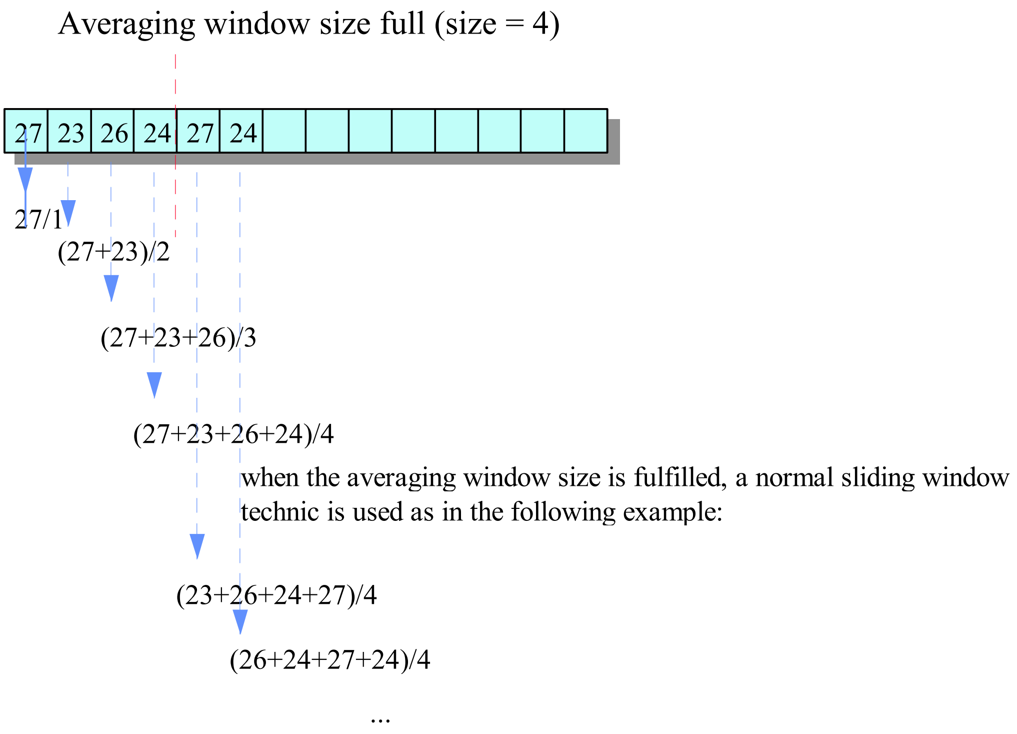


Picture 1. Initialisation of the triggered thresholds

The existing Handover & Power Control algorithm uses a sliding window technique in order to average the measurements. The sliding window technique takes into account the maximum of 32 most recent measurement samples. The averaging procedure can start as soon as possible as the required number of samples is available.

However, in some cases, it is reasonable to calculate averaging value before measurement averaging window is fulfilled.

The new technique potentiates Handover & Power Control algorithm to calculate averaging values beginning from the first measurement and enables reliable averaging values for handover algorithm (e.g. for Channel Allocation to Super-reuse Channel in IUO-feature (C/I calculation)). The following example (picture 2.) presents the new method.



Picture 2. New averaging method

The new averaging method averages new measurements before the averaging window size is fulfilled as an average value of new measurements. By using this method new measurements can be averaged although the averaging window size is not fulfilled The new method enables faster handover decisions and prevents consecutive PC commands where handover is needed. After the averaging window is fulfilled, the averaging algorithm works as before (average window is used).

9.3 DTX and Weighting

When DTX is used, only "SUB" measurement results are reported to the BSC, which means that averaging is done over 12 time slots (or 3 data blocks). This "SUB" measurement averaging process is controlled by the parameter **weighting (1 ... 3)** as in the following example.

Example

pcAveragingLevUL
WindowSize = 8
weighting = 2

Sample:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
DTX used:	**0**	**1**	**0**	**0**	**1**	**1**	**1**	**0**
uplinl level:	**35**	**42**	**33**	**36**	**39**	**40**	**39**	**35**

$$\mathrm{AV\_RXLEV\_UL\_PC} = \frac{2x35 + 1x42 + ... + 2x35}{2+1+2+2+1+1+1+2} = 36$$

9.4 Processing in BSC

The BSC gets all the results from the BTSs after the pre-processing and makes averaging calculations and comparisons to thresholds given e.g. in figure 22 by the parameter **hoThresholdsLevDL (-110- -47 dBm),** including **px (1 ... 32)** and **nx (1 ... 32)**. Threshold comparisons are always made in the BSC as a part of the BSC processing. All the handover and power control thresholds will be given in the chapters Handover Process and Power Control.

The capacity of the BSC is related to the number of the adjacent cells processed in the BSC simultaneously. The Nokia BSC can simultaneously maintain measurements from up to 32 samples of 32 different adjacent cells. All the adjacent cells can be averaged or just the six best ones controlled by the parameter **allAdjacentCellsAveraged (Yes/No)**.

The BTS sends only the six best measurement results to BSC, and the rest is being given a zero result (-110 dBm). Thus even some good adjacent cells can be given a zero result, as shown in the example below. These adjacent cells however can still be taken into account (up to 7 zero results) with the parameter **numberOfZeroResults (0 ... 7)**.

Example

allAdjacentCellsAveraged = No

numberOfZeroResults = 2

WindowSize = 8

Sample:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1.	**-65**	**-67**	**-71**	**-69**	**-72**	**-70**	**-73**	**-71**
2.	**-73**	**-75**	**-74**	**-75**	**-76**	**-77**	**-75**	**-77**
3.	**-77**	**0**	**-80**	**-79**	**-81**	**-79**	**0**	**-80**
4.	**-85**	**-83**	**-87**	**-88**	**-84**	**0**	**-86**	**-87**
5.	**-90**	**-94**	**-91**	**-90**	**-95**	**-93**	**-92**	**-90**
6.	**-97**	**-99**	**-98**	**-99**	**-96**	**-97**	**0**	**0**

Figure 23. Processing of measurements

Now, even if there are two zero results in the samples of the adjacent cell 3, the average of that cell can still be calculated, and the cell remains in the group of the six best adjacent cells.

10 Power Control

10.1 Reasons and Strategy

Power control is used in order to decrease the power consumption of the Mobile Station (in uplink direction) to reach a longer serving time to the Mobile Station. Another reason is to decrease interference in both directions (uplink and downlink) by using as low transmitting power as possible in the Mobile Station and in the BTS at all times.

Power control can be used in downlink direction in every TRX, except in a TRX with BCCH, because the BTS has to send data continuously on these frequencies without any Power Control (= full power in that cell. This is needed because the MS is continuously measuring the RX level of the adjacent cell BCCH's). The Mobile Station can use power control on each frequency continuously, if needed. In order to use BTS power control, the parameter **PowerCtrlEnabled** should be enabled on cell by cell basis.

When using power control, enough margin has to be reserved for Rayleigh fading and it has to be taken into account that handover has always higher priority than power control.

10.2 PC Threshold comparison and PC command

After every SACCH multiframe period, the BSC compares each of the processed measurement results (averages) with the relevant power control thresholds.

If the power control (PC) threshold comparison indicates that the MS or the BTS (a radio time slot on a carrier) needs an increase or decrease in RF power, the BSC sends a PC command to the MS/BTS including the new transmission power level of the MS/BTS. When the BSC defines the new transmission power level of the MS, it takes into account both the RF power capability and the revision level of the MS. The BSC may send the PC command simultaneously both to the MS and the BTS or to one of them, that is, the power control for the MS and BTS runs independently.

The minimum and maximum MS transmission powers are determined on cell-by-cell basis. The maximum transmission power that an MS may use in the serving cell is controlled by the parameter **MsTxPwrMax**. The minimum MS transmission power is controlled by the parameter **MsTxPwrMin.**

The maximum transmission power of the BTS is controlled by the parameter **BsTxPwrMax**. The parameter **BsTxPwrMin** indicates the minimum transmission power of the BTS. The range of the BTS transmission power is from 30 dB to 0 dB of attenuation from the maximum peak power of the base station transmitter. The parameter **PowerCtrlEnabled** indicates whether the BTS power control is enabled. When the power control is enabled, it concerns every transceiver of the BTS with the exception of the BCCH (broadcast control channel) transceiver which always transmits with the maximum power level (parameter **BsTxPwrMax)**.

In order to prevent repetitive power changes for the same MS/BTS, there is a timer for the minimum time interval between the changes in the RF output power level. The timer is controlled by the parameter **PowerControlInterval,** which is the minimum interval between the changes in the RF power level. The averaging and PC threshold comparison do not stop during this time but the PC commands are not possible.

The BSC observes the power changes from the measurement results it receives from the BTS (the measurement result includes the RF power level, which the MS and the BTS have used during the previous SACCH multiframe period). If the MS does not change its output power in time, the BSC sends the PC command once more. The power control of the MS does not stop even if the MS did not change its RF output power. If the BTS does not change its output power with the first PC command, the BSC does not send any further PC commands to the BTS.

The measurement results (uplink or downlink) preceding the MS/BTS power change are not valid after the power change. If the scaling of measurement results is disabled (selected by means of the parameter **EnaFastAvePC)**, the averaging and threshold comparison based on those measurement results (uplink/downlink) must start from the beginning after the power change (this concerns both Handover and Power control). When the scaling of measurement results is enabled, the BSC scales the relevant measurement results preceding the power change so that they correspond to the new transmission power level of the MS/BTS and thus the averaging and threshold comparison can continue without interruption, with the exception of the PC threshold comparison which always starts from the beginning after the power change.

10.3 Power Control Algorithms

Once the comparison of the averaged values with the corresponding thresholds has indicated the need for the MS or the BTS to increase or decrease their transmission power, the BSC has to determine the size of the increase/decrease.

This size is calculated by the Power Control algorithm, starting from a fixed power change step size, on the basis of the averaged values, of the relevant thresholds and in some cases of the current (non-averaged) measured values.

Fixed power change step size is selected by means of the parameter **powRedStepSize (2 or 4 dB)**, which impacts on the size of the step for the decrease of the MS/BTS transmission power, and the parameter **powIncrStepSize (2, 4 or 6 dB)**, which impacts on the size of the step for the increase of the MS/BTS transmission power.

In some cases the size of the increase / decrease corresponds to the fixed power change step size, while in other cases a variable power change step size is calculated from the fixed power change step size.

The BSC uses a variable power change step size for increasing and decreasing the MS transmission power and for <u>increasing</u> the BTS transmission power in such situations where the required power change is so large that the use of the fixed step size would require several power control commands and a lot of time.

By using the variable power change step size instead of the fixed step, it is possible to reach the required power level in one step. A detailed explanation of the variable power change step size can be found in the flowcharts below.

10.3.1 MS/BTS power increase due to signal level

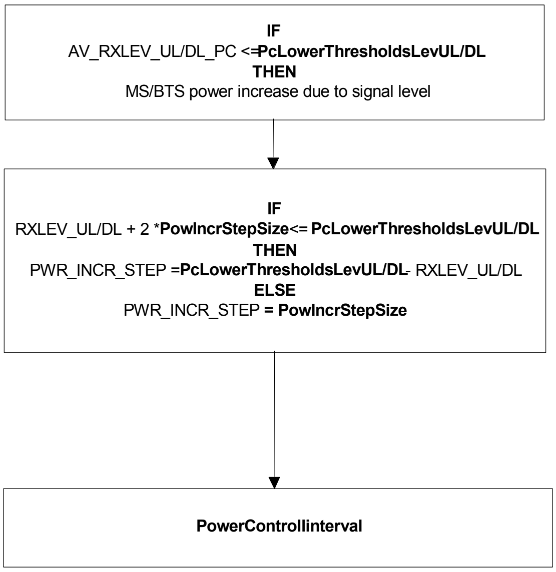


Figure 1 MS / BTS power control due to signal level

The parameter **powerCtrlEnabled** enables the BTS power increase.

The parameters **pcLowerThresholdsLevUL** and **pcLowerThresholdsLevDL** are used in comparison with the averaged values of uplink/downlink signal level to trigger the power control. Both thresholds are composed of three parts:

RxLev (-110 … -47 dBm) is the threshold level to be compared with the averaged level.

Nx (1 … 32) is the total number of averages to be taken into account before decision is possible.

Px (1 … 32) is the number of averages out of total averages that have to be lower than or equal to the threshold, before power increase is possible.

As described by Figure 1, the BSC compares the averaged measurement result AV_RXLEV_UL/DL_PC with **pcLowerThresholdsLevUL**/DL.

AV_RXLEV_UL/DL_PC <= PcLowerThresholdsLevUL/DL

If this condition is met for Px averaged values out of Nx, then the power control is triggered.

When the power control is triggered, the power increase step size is calculated based on the distance from the relevant threshold. The variable power change step size is used in the following signal strength conditions:

RXLEV_UL/DL + 2* PowIncrStepSize <= PcLowerThresholdsLevUL/DL

In such case the size of the variable power change step PWR_INCR_STEP is calculated in the following way:

PWR_INCR_STEP = PcLowerThresholdsLevUL/DL - RXLEV_UL/DL

In other cases the power increase step size is taken equal to the **powIncrStepSize (2, 4 or 6 dB)**.

In other words if two "regular" step are not enough to go above the lower thresholds then a variable step is used to increase the transmission power and bring the received level at the threshold.

It should be noted that RXLEV_UL/DL is the current uplink signal level measured by the BTS/MS and not the averaged value. This is due to the fact that the averaged values tend to follow the raw measurements with a certain delay that is longer when the averaging windows gets large.

10.3.2 MS/BTS power increase due to signal quality

The parameter **powerCtrlEnabled** enables the BTS power increase.

The parameters **pcLowerThresholdsQualUL** and **pcLowerThresholdsQualDL** are used in comparison with the averaged values of uplink/downlink signal quality to trigger the power control.

RxQual (0 … 7) is the threshold level for the MS/BTS power increase. The range is from 0 to 7

Nx (1 … 32) is the total number of averages to be taken into account before decision is possible.

Px (1 … 32) is the number of averages out of total averages that have to be lower than or equal to the threshold, before power increase is possible.

The BSC compares the averaged measurement result AV_RXQUAL_UL/DL_PC with PcLowerThresholdsQualUL/DL.

AV_RXQUAL_UL/DL_PC => PcLowerThresholdsQualUL/DL

If this condition is met Px times out of Nx then the power control is triggered.

NOTE: For 14.4 kbit/s data (see High Speed Circuit Switched Data and 14.4 kbit/s Data Services in BSC /13/), the BSC compares the averaged measurement result AV_RXQUAL_UL_PC with the power control threshold pcLowerThresholdsQual144 instead of the "standard" **pcLowerThresholdsQualUL**.

The BSC always uses a variable power change step size for increasing the MS/BTS transmission power due to signal quality.

The BSC is able to calculate the variable power change step size by means of two alternative algorithms, taking into account the cause of the bad signal quality. The cause in fact may be interference or low signal level; in order to cope with the most significant cause of bad quality, the BSC selects the largest step size.

The first way is based on the distance between the current quality and the relevant threshold:

PWR_INCR_STEP = (1+MAX (0,Qa)) * PowIncrStepSize

where Qa = RXQUAL_UL/DL – pcLowerThresholdsQualUL/DL

RXQUAL_UL/DL is the current signal quality measured by the BTS/MS and not the averaged value.

The second way is based on the distance between the current received level and the corresponding threshold. This possibility is taken into consideration only when this distance is meaningful, i.e. when

RXLEV_UL/DL + 2* PowIncrStepSize <= PcLowerThresholdsLevUL/DL

The size of the variable power change step PWR_INCR_STEP is calculated in the following way:

PWR_INCR_STEP = PcLowerThresholdsLevUL/DL - RXLEV_UL/DL

RXLEV_UL/DL is the current uplink signal level measured by the BTS/MS.

It should be noted that a low received level doesn't necessarily correlate to bad quality. In such a case the application of the fixed step in increasing the transmission power can be a reasonable possibility.

When the power control is triggered by quality, the situation is more critical as the radio connection is probably suffering from the transmission power being too low. Therefore a more aggressive action is taken by the BSC that always applies a variable step. This variable step is affected by the distance of the current quality from the threshold and by the distance of the current level from the relevant threshold.

10.3.3 BTS power decrease due to signal level (S9 improvement)

The parameter **powerCtrlEnabled** should be enabled for BTS power control.

The parameter **pcUpperThresholdsLevDL** and **pcUpperThresholdsQualDL** are used in comparison with the averaged values of downlink signal level and quality measurements to trigger the power control. They are composed of three elements as follows:

The decrease of the transmission power of the BTS due to level is triggered by

RxLev (-110 … -47 dBm) is the threshold level for the BTS power decrease.

Nx (1 … 32) is the total number of averages to be taken into account before decision is possible.

Px (1 … 32) is the number of averages out of total averages that have to be lower than or equal to the threshold, before power increase is possible.

The BSC compares the averaged measurement result AV_RXLEV_DL_PC with **PcUpperThresholdsLevDL**

AV_RXLEV _DL_PC >= **PcUpperThresholdsLevDL.**

If the condition is met for Px averaged values out of Nx then the power control due to level is triggered.

New BSC specific parameter, **VariableDLStepUse**, indicates if the variable step size is used, when downlink power is decreased. The parameter has two values, 'yes' and 'no'. The default value is 'no', in other words the variable step size is not in use.

New TRX specific parameter, **OptimumRxLevDL,** indicates the optimum downlink RF signal level which both ensures adequate speech/data quality and does not cause downlink interference. The parameter is used by the power control of the BTS.

The range is from -109 dBm to -47 dBm, the use of the parameter is disabled when the value is 'not used'. The default value is 'not used'.

The transmission power of the BTS is decreased of a quantity given by the fixed or variable power change step size, based on the distance between the threshold and the current received value uplink. In other words if

RXLEV_DL - 2* **PowRedStepSize** >= **PcUpperThresholdsLevDL**

the transmission power of the BTS is decreased by using the variable power change step size; otherwise the fixed power change step size is used.

The size of the variable power change step PWR_DECR_STEP is calculated in the following way:

PWR_DECR_STEP = MIN ((RXLEV_DL - PcUpperThresholdsLevDL), **10**[1])

RXLEV_DL is the current downlink signal level measured by the MS.

10.3.4 BTS power decrease due to quality (S9 improvement)

The parameter **powerCtrlEnabled** should be enabled for BTS power control.

The parameter **pcUpperThresholdsQualDL** is used in comparison with the averaged values of downlink quality measurements to trigger the power control. They are composed of three elements as follows:

---

[1] ***It must be noted that the power decrease step is limited to 10 dB at a time due to limitations in some mobile phones.***

The decrease of the transmission power of the BTS due to quality is triggered by

RxQual (0 … 7) is the threshold level for the BTS power decrease. The range is from 0 to 7

Nx (1 … 32) is the total number of averages to be taken into account before decision is possible.

Px (1 … 32) is the number of averages out of total averages that have to be lower than or equal to the threshold, before power increase is possible.

In the same way AV_QUAL_DL_PC and **PcUpperThresholdsQualDL** are compared by the BSC.

AV_RXQUAL_DL_PC =< **PcUpperThresholdsQualDL.**

If the condition is met for Px averaged values out of Nx then the power control due to quality is triggered.

The BSC will determine the power change step size by using two alternative algorithms. The algorithm is selected by means of the new parameter OptimumRxLevDL which is controlled on a transceiver-by-transceiver basis.

Calculation based on non-defined optimum downlink RF signal level

The transmission power of the BTS is decreased of a quantity given by the fixed or variable power change step size, based on the distance between the threshold and the current received value uplink.

If

RXLEV_DL – 2 * *PowRedStepSize* >= *PcUpperThresholdsLevD*L

the transmission power of the BTS is decreased by using the variable power change step size; otherwise the fixed power change step size is used.

The size of the variable power change step PWR_DECR_STEP is calculated in the following way:

PWR_DECR_STEP = MIN ((RXLEV_DL - PcUpperThresholdsLevDL*)*, 10[1])

RXLEV_DL is the current downlink signal level measured by the MS. The parameter PcUpperThresholdsLevDL is the threshold (signal strength) level for the BTS power decrease.

Calculation based on defined optimum downlink RF signal level

If the optimum downlink RF signal level has been defined for the transceiver by means of the parameter OptimumRxLevDL, the variable power change step size will be based on:

averaged downlink signal quality

quality threshold for BTS power decrease

the optimum downlink RF signal level

current downlink signal level.

---

[1] ***It must be noted that the power decrease step is limited to 10 dB at a time due to limitations in some mobile phones***

In this case the BSC uses merely a variable power change step size for decreasing the BTS transmission power. The size of the variable power change step PWR_DECR_STEP is calculated in the following way:

PWR_DECR_STEP = MIN ((

MIN (PwrDecrLimit, MAX (MAX (0, RXLEV_DL - OptimumRxLevDL),

(PwrDecrQualFactor + MAX (0,Qa)) * PowRedStepSize))), 10)

where Qa = **PcUpperThresholdsQualDL** - AV_RXQUAL_DL_PC

The parameter PwrDecrLimit/**Band0-2** is the maximum size of the variable power decrease step:

PwrDecrLimitBand0 indicates the maximum size of the power decrease step when the BTS power is decreased due to signal quality and the averaged signal quality (bit error rate) is better than 0.2% (quality band 0). The values range from 0 to 38 dB with a step size of 2 dB.

PwrDecrLimitBand1 indicates the maximum size of the power decrease step when the BTS power is decreased due to signal quality and the averaged signal quality (bit error rate) is between 0.2% and 0.4% (quality band 1). The values range from 0 to 38 dB with a step size of 2 dB.

PwrDecrLimitBand2 indicates the maximum size of the power decrease step when the BTS power is decreased due to signal quality and the averaged signal quality (bit error rate) is worse than 0.4 (quality bands from 2 to 7). The values range from 0 to 38 dB with a step size of 2 dB.

AV_RXQUAL_DL_PC is the averaged signal quality band for power control and the parameter PcUpperThresholdsQualDL indicates the quality band which corresponds to the quality threshold for the BTS power decrease

The parameter PwrDecrQualFactor indicates whether the power decrease takes place when the current downlink signal level (RXLEV_DL) is lower than the optimum downlink RF signal level (OptimumRxLevDL) and the averaged signal quality (AV_RXQUAL_DL_PC) equals to the quality threshold PcUpperThresholdsQualDL.

Additionally it should be noted that the power decrease due to quality does not take place if there is a possibility that it would trigger the threshold **pcLowerThresholdsLevDL**. A safety margin is used which is equal to 6 dB.

10.3.5 MS power decrease due to signal level

The parameter **pcUpperThresholdsLevUL** is used in comparison with the averaged values of uplink signal level measurements to trigger the power control. As usual the threshold is composed of three parts:

rxLev (-110 … -47 dBm) is the threshold level for the MS power decrease.

Nx (1 … 32) is the total number of averages to be taken into account before decision is possible.

Px (1 … 32) is the number of averages out of total averages that have to be greater than or equal to the threshold before power decrease is possible

The BSC compares the averaged measurement result AV_RXLEV_UL_PC with **pcUpperThresholdsLevUL**.

AV_RXLEV _UL_PC >= **PcUpperThresholdsLevUL.**

If at least Px averages out of Nx averages are greater than or equal to the threshold RxLev, the power control due to level is triggered.

The transmission power of the MS is decreased of a quantity given by the fixed or variable power change step size, based on the distance between the threshold and the current received value uplink. In other words if

RXLEV_UL - 2* **PowRedStepSize** >= **PcUpperThresholdsLevUL**

the transmission power of the MS is decreased by using the variable power change step size; otherwise the fixed power change step size is used.

The size of the variable power change step PWR_DECR_STEP is calculated in the following way:

PWR_DECR_STEP = RXLEV_UL - **PcUpperThresholdsLevUL**

where (again) the current uplink signal level RXLEV_UL is considered. The reason for using the current value of the uplink level measured by the BTS instead of the averaged value AV_RXLEV _UL_PC, is that the average is always delayed with respect to the raw values and consequently the power decrease might result too small when e.g. the MS is approaching the BTS.

10.3.6 MS power decrease due to signal quality

The parameter **pcUpperThresholdsQualUL** is used for comparing the averaged values of uplink signal quality measurements for triggering the power control. As all the other thresholds related with power control this parameter is composed of three parts:

RxQual (0 … 7) is the threshold level for the MS power increase. The range is from 0 to 7

Nx (1 … 32) is the total number of averages to be taken into account before decision is possible.

Px (1 … 32) is the number of averages out of total averages that have to be lower than or equal to the threshold, before power increase is possible.

The condition

AV_RXQUAL_UL_PC <= **PcUpperThresholdsQualUL.**

for at least **Px** averages out of **Nx** triggers the power control due to quality.

The BSC determines the variable power change step size by using two alternative algorithms. The algorithm is selected by means of the parameter **optimumRxLevUL (-109 dBm to -47 dBm)** which is controlled on a transceiver-by-transceiver basis. **OptimumRxLevUL (-109 dBm to -47 dBm)** indicates the optimum uplink RF signal level that is high enough to ensure adequate speech/data quality and low enough to avoid unnecessary uplink interference. The use of the parameter is disabled when the value is 'not used'.

Additionally it should be noted that the power decrease due to quality does not take place if there is a possibility that it would trigger the threshold **pcLowerThresholdsLevUL**. A safety margin is used which is equal to 6 dB.

OptimumRxLevUL = 'not used'

Fixed step is the default, but if the signal level is very high, besides the excessive signal quality, the variable power change step size is used. In other words if:

RXLEV_UL - 2* **PowRedStepSize** >= **PcUpperThresholdsLevUL**

then a variable step is used. The size of the variable power change step is calculated in the following way:

PWR_DECR_STEP = RXLEV_UL - **PcUpperThresholdsLevUL**

where RXLEV_UL is the current uplink signal level measured by the BTS and not the averaged value.

The philosophy behind this solution is that the condition of good quality doesn't necessarily correspond to a high received level and in such a case the application of the fixed step is a reasonable choice.

If the received level is above the threshold **pcUpperThresholdsLevUL,** then the step in the power decrease can be easily and safely determined. In this case the step size calculation is based on a different threshold than the one that triggered the power control.

OptimumRxLevUL <> 'not used'

If the optimum uplink RF signal level has been defined for the transceiver by means of the parameter **optimumRxLevUL** , the variable power change step size will be based on:

- the averaged uplink signal quality
- the quality threshold for the MS power decrease
- the optimum uplink RF signal level
- the current uplink signal level.

In this case the BSC always uses the variable power change step size for decreasing the MS transmission power. The variable step is calculated as follows:

PWR_DECR_STEP = MIN (PwrDecrLimit, MAX (MAX (0, RXLEV_UL - **OptimumRxLevUL)**, (PwrDecrQualFactor + MAX (0,Qa)) * **PowRedStepSize**))

The formula is quite complicated and can be simplified as follows:

PWR_DECR_STEP = MIN (PwrDecrLimit, MAX (A, B))

The parameter **pwrDecrLimit** indicates the maximum possible reduction to the power of the MS and in reality takes three different values depending on the value of the averaged quality that triggered the power control.

pwrDecrLimitBand0 (0, 2, … 38) maximum size of the power decrease, when the averaged signal quality (bit error rate) is better than 0.2% (quality band 0).

pwrDecrLimitBand1 (0, 2, … 38) maximum size of the power decrease, when the averaged signal quality (bit error rate) is between 0.2% and 0.4% (quality band 1).

pwrDecrLimitBand2 (0, 2, … 38) maximum size of the power decrease, when the averaged signal quality (bit error rate) is worse than 0.4% (quality bands 2-7)

The term

A = MAX (0, RXLEV_UL - **optimumRxLevUL**)

generates a decrease in the MS transmission power that would bring the received level Uplink (not the averaged level, but the current received level) to the optimum level as defined by the parameter **optimumRxLevUL (-109 dBm to -47 dBm).** It can be noted that A may be equal to 0.

The term

B = (**PwrDecrQualFactor** + MAX (0,Qa)) * **PowRedStepSize**

where

Qa = **pcUpperThresholdsQualUL** - AV_RXQUAL_UL_PC

takes into account the distance in quality between the averaged quality and the threshold that triggered the power control. This distance is multiplied by the **powerReductionStepSize (2 , 4)**.

The parameter **pwrDecrQualFactor (2 , 4)** is used to have always B > 0. In fact if Qa=0 and A=0, then the calculation of the variable step gives

PWR_DECR_STEP = **PwrDecrQualFactor * PowRedStepSize**

The parameter allows the operator to avoid that there is no reduction of transmission power in the MS when good quality uplink is encountered.

10.3.7 Conclusions

When trying to understand the power control algorithm, it should be kept in mind that the whole process is composed of three steps:

- Measurements done by the MS and by the BTS
- Measurement processing in the BSC
- Threshold comparison
- Calculation of the power change

The last step may appear complicated due to the large differentiation in the formulas used by the algorithm. The situation is different when the power control is triggered by quality (good or bad) or by level (high or low) and also depending on the transmission power being required for the MS or the BTS.

It is possible to get a more clear idea by noting that in all cases a range of good values is defined by an upper threshold and lower threshold. The power control works tries to keep the received level and the received quality into that range by changing the transmitter power "on the other side" of the radio connection.

In case of power control due to level, the averaged value is out of the range (or on its border) and the action is taken to bring it within the defined band. The variable step is calculated very easily in this case.

When the quality is out of range, then issue is more complicated because the reason for good (or bad) quality could be a very high (or too low) received power. Therefore the calculation of the power change step size involves both level and quality.

For the MS, in particular a dedicated parameter **optimumRxLevUL** is used to define what can be considered an optimum level to be received by the BTS. When used, this parameter affects the calculation of the step used in the power decrease.

Finally

The power decrease due to quality does not take place if there is a possibility that it would trigger the threshold **pcLowerThresholdsLevUL/DL**. A safety margin is used which is equal to 6 dB.

The power control of the BTS can be disabled by means of the parameter **powerCtrlEnabled**.

11 HANDOVER PROCESS

Handover decisions, made by RR Management in BSC, are based on the measurement results reported by the MS / BTS, parameter sets for each cell and algorithms. Target cell evaluation is also one part of the handover process. Handovers are triggered off by threshold comparison or by periodic comparison.

11.1 Handover Decision

The HO threshold comparison includes the evaluation of the uplink/downlink level, quality and interference, MS-BS distance evaluation, the evaluation of a rapid field drop, the detection of a fast/slow-moving MS, the detection of a turn-around-corner MS, power budget evaluation, and umbrella handover evaluation.

If two or more criteria for a handover are present simultaneously, the priority order is the following:

1. Interference (uplink or downlink)
2. Uplink quality
3. Downlink quality
4. Uplink level
5. Downlink level
6. MS-BS distance (maximum or minimum)
7. Turn-around-corner MS
8. Rapid field drop
9. Fast/Slow-moving MS
10. Better cell (Power budget or Umbrella)
11. PC due to Lower quality thresholds (uplink and downlink)
12. PC due to Lower level thresholds (uplink and downlink)
13. PC due to Upper quality thresholds (uplink and downlink)
14. PC due to Upper level thresholds (uplink and downlink).

When two or more of the above indicated criterias 1 - 9 are present simultaneously, for example Uplink quality and Uplink level, the BSC performs target cell evaluation only according to the criteria which has the highest priority, so of Uplink quality and Uplink level it would be Uplink quality. If no adjacent cell is good enough for the handover due to the criteria in question, the BSC proceeds to the following HO threshold comparison (Better cell) and the PC threshold comparisons.

11.2 Interval between Handovers and Handover Attempts

The BSC normally controls the intervals between handovers and handover attempts by parameters **MinIntBetweenHoReq (0 ... 30s)** and **MinIntBetweenUnsuccHoAttempt (0 ... 30s)**. The first parameter prevents repetitive handovers for the same MS with a timer that set the minimum interval between handovers related to the same connection. The latter parameter indicates the minimum time that MS must wait after handover attempt fails, before it can try a handover attempt again.

The averaging and HO Threshold comparison do not stop during these intervals although handovers are not possible.

11.3 Target Cell Evaluation

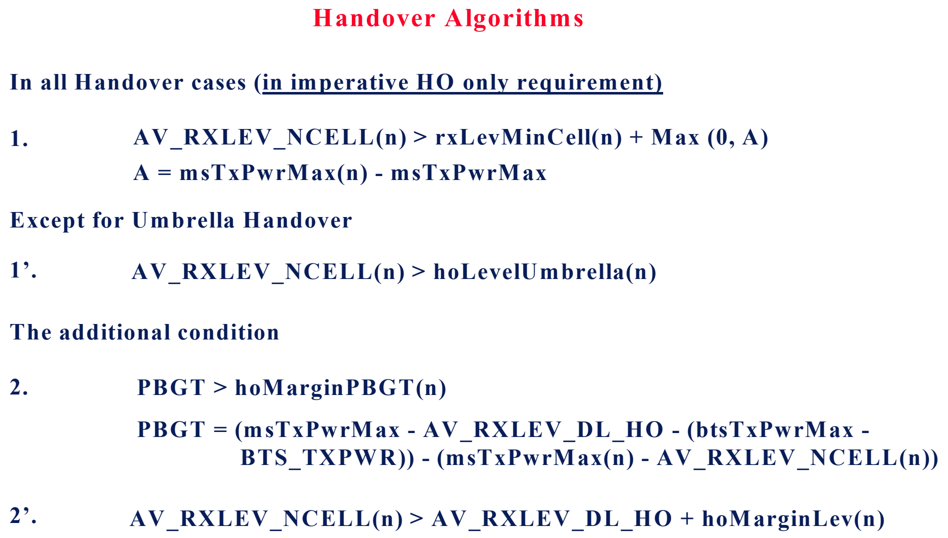
Target cell evaluation is made in RR Management in BSC and its purpose is to find the best cell for handover. The evaluation on the preferred list of the target cells is based on:

1. the radio link measurements
2. threshold comparison
3. the priority levels of the neighbouring cells
4. the load of the neighbouring cells which belong to the same BSC as the serving cell.
5. Rx level comparison – if it is needed

The BTS sends the list of best candidates to the BSC. First the BSC defines and selects those cells, which meet the requirements for the radio link properties. RR Management can handle up to 32 best candidates for target cell evaluation. The loads of these candidate cells are checked by the parameter **btsLoadThreshold (0 ... 100 %)**. If one of these candidate cells is already overloaded, the priority (given by parameter **holevPriority (0 ... 7)**) of that cell is decreased by the parameter **hoLoadFactor (0 ... 7)**. After the load check of each candidate, a comparison between priorities of each candidate cell is made**,** and the candidate with the highest priority will be selected as a target cell. If there are many cells with equally high priorities, the cell with the best receiving signal strength will be selected.

11.4 Algorithms

Handovers are made on the basis of algorithms, which are actually used, for comparisons. Different handovers make use of different algorithms to be successful in different situations. Reasons and priorities for different kinds of handovers have been presented in chapter **Handover Decisions**. Equations for different handovers can be seen in figure 27.



Handover Algorithms

In all Handover cases (in imperative HO only requirement)

1. AV_RXLEV_NCELL(n) > rxLevMinCell(n) + Max (0, A)
A = msTxPwrMax(n) - msTxPwrMax

Except for Umbrella Handover

1'. AV_RXLEV_NCELL(n) > hoLevelUmbrella(n)

The additional condition

2. PBGT > hoMarginPBGT(n)
PBGT = (msTxPwrMax - AV_RXLEV_DL_HO - (btsTxPwrMax - BTS_TXPWR)) - (msTxPwrMax(n) - AV_RXLEV_NCELL(n))

2'. AV_RXLEV_NCELL(n) > AV_RXLEV_DL_HO + hoMarginLev(n)

Figure 27. Handover Algorithms.

AV_RXLEV_NCELL (n) stands for averaged receiving levels of adjacent cells and AV_RXLEV_DL_HO stands for the averaged receiving level of the serving cell. So, small or capital n means always the Nth adjacent cell. BTS_TX_PWR stands for the transmitting power level of the serving cell.

The equations 1 and 2' are used in cases of handovers due to level, quality or distance. In the case of the Umbrella Handover, equations 1' and 2' are used. For the Power Budget Handover, equations 1 and 2 are used.

11.5 Radio Resource Handovers

The handover is considered radio resource if the cause is one of the following reasons:

1. Level (uplink / downlink)
2. Quality (uplink / downlink)
3. Interference (uplink / downlink)
4. Power budget
5. Umbrella

When the BSC receives measurement results from the BTS it always compares each of the processed results (averages) with the relevant thresholds:

- **hoThresholdsLevDL/UL**
- **hoThresholdsQualDL/UL**
- **hoThresholdsInterferenceDL/UL**
- **msSpeedThresholdNx/Px**

Each threshold is composed of three parts: the threshold itself, the total number of samples (Nx) to be taken into account before decision is possible, and the number of samples out of total samples (Px) that have to be lower/higher than, or equal to the threshold before any action is possible.

There are also other handover types for which the condition is checked periodically. These are Power Budget Handover, activated by **enablePwrBudgetHandover (Yes/No)** and Umbrella Handover, activated by **enableUmbrellaHandover (Yes/No)**. The checking periods for those handovers are controlled by parameters **hoPeriodicPBGT (0 ... 30 s)** and **hoPeriodicUmbrella (0 ... 30 s)**.

The BSC may perform either an intra-cell or inter-cell handover when the cause is interference. In that case the parameter **HoPreferenceOrderInterUL/DL (intra/inter)** determines which handover, intra-cell or inter-cell, is preferable. Those parameters are set for each BSC by means of the O&M. **EnableIntraHoInterfDL/UL (Yes/No)** indicates whether an intra-cell handover caused by interference is enabled.

11.5.1 Power Budget Handover

Power budget handover procedure ensures that the MS is always handed over to the cell with the minimum path loss, even though the quality and the level thresholds may not have been exceeded.

The parameter **EnablePowerBudgetHO** indicates whether the power budget is used as a criterion for a handover. The power budget handover is enabled when the value is 'yes'.

If the power budget handover is enabled, the BSC evaluates the radio link properties of the adjacent cells in order to find a target cell for the handover at every **HoPeriodPBGT (0…63 SACCH)** interval.

The BSC uses the power budget evaluation algorithm for target cell evaluation (equations 1 and 2 in chapter Algorithms).

Example (Power Budget HO)

Serving Cell:	**Best Adjacent Cell:**
AV_RXLEV_DL_HO = -90 dBm	**AV_RXLEV_NCELL(n) = -80 dBm**
msTxPwrMax = 33 dBm (= 2W)	**rxLevMinCell(n) = -99 dBm**
btsTxPwrMax = 42 dBm (= 16 W)	**msTxPwrMax(n) = 33 dBm (= 2W)**
BTS_TX_PWR = 42 dBm = (16 W)	**btsTxPwrMax = 42 dBm (= 16 W)**
hoMarginPBGT(n) = 6 dB	**BTS_TX_PWR = 42 dBm = (16 W)**

1. **-80 dBm > -99 dBm + (33 dBm - 33 dBm) = -99 dBm**

2. **PBGT = (33 dBm - -90 dBm - (42 dBm - 42 dBm)) - (33 dBm - -80 dBm)**
   = 10 dB

10 dB > 6 dB **OK !!!!**

Figure 28 Power Budget handover

As seen in figure 28, both requirements (equations) are fulfilled and the handover will be triggered off.

11.5.2 Umbrella Handover

If the umbrella handover is enabled, the BSC evaluates the radio link properties of the adjacent cells in order to find a target cell for the handover at every **HoPeriodUmbrella (0…63 SACCH)** interval.

The measurement results of the adjacent cell must satisfy the equation 1' (see chapter Algorithms) before the umbrella handover is possible.

Besides the radio link properties (equation 1'), the umbrella HO takes into account also the power class of the MS so that only those adjacent cells which fit the MS are selected to be the target cells, that is, the BSC selects macrocells for vehicle and portable MSs and microcells for handhelds. The BSC uses two thresholds in order to realise this property:

1. MACROCELL_THRESHOLD (parameters **gsmMacrocellThreshold** and **dcsMacrocellThreshold**)
2. MICROCELL_THRESHOLD (parameters **gsmMicrocellThreshold** and **dcsMicrocellThreshold**).

The maximum RF power (parameter **MsTxPwrMaxCell** (n)) an MS is permitted to use on a traffic channel in the adjacent cell (n) determines the size of the adjacent cell (n) by means of the thresholds MACROCELL_THRESHOLD and MICROCELL_THRESHOLD as follows:

- ⇨ If **MsTxPwrMaxCell (**n) is greater than or equal to MACROCELL_THRESHOLD, the adjacent cell is considered a macrocell.
- ⇨ If **MsTxPwrMaxCell** (n) is smaller than or equal to MICROCELL_THRESHOLD, the adjacent cell is considered a microcell.
- ⇨ If **MsTxPwrMaxCell** (n) is smaller than MACROCELL_THRESHOLD and greater than MICROCELL_THRESHOLD, the adjacent cell is considered a middle size cell.

When selecting the target cells, the BSC takes into account the following conditions in addition to the radio link properties (equation 1'):

- ⇨ If the maximum power capability of the MS is greater than or equal to MACROCELL_THRESHOLD, the adjacent cell must be considered a macrocell in order for the HO to be allowed.

- ⇨ If the maximum power capability of the MS is smaller than or equal to MICROCELL_THRESHOLD, the adjacent cell must be considered a microcell in order for the HO to be allowed.

- ⇨ If the maximum power capability of the MS is smaller than MACROCELL_THRESHOLD and greater than MICROCELL_THRESHOLD, the adjacent cell must be considered middle size cell in order for the HO to be allowed.

If the MACROCELL_THRESHOLD is selected so that it equals the lowest MS power level or the MICROCELL_THRESHOLD is selected so that it equals the highest MS power level, it is possible to pass this property and evaluate the target cells only according to radio link properties.

After the BSC has selected the target cells for the umbrella handover, the cells are ranked according to the priority levels.

11.5.3 Combined umbrella and power budget

The target cell evaluation for the power budget handover will be different from the standard procedure, described in section Power budget handover, if the umbrella handover and the power budget handover are active simultaneously in the same cell (parameters **EnableUmbrellaHO** and **EnablePowerBudgetHO**). In this case the power budget handover also takes into account the size/layer of the adjacent cell in addition to the radio link properties (equations 1 and 2).

The umbrella handover has priority over the power budget handover.

The size/layer of the adjacent cell must be equal to the size/layer of the serving cell in order for the handover to be allowed, that is, the BSC performs power budget handovers only between cells of the same size/layer (the power class of the MS does not affect the evaluation procedure) when the umbrella handover is employed. For example, if the serving cell is considered a microcell, the adjacent cell must also be considered a microcell in order for the power budget handover to be allowed.

The BSC is able to determine the size/layer of a cell by means of two alternative methods. The method is selected with the parameter **AdjCellLayer**. The BSC determines the size/layer of a cell as follows:

1. If the use of the parameter **AdjCellLayer** is disabled, that is, the layer of the adjacent cell has not been defined: The maximum RF power an MS is permitted to use on a traffic channel in the cell determines the size of the serving/adjacent cell as described before.

2. If the cell layer has been defined for the adjacent cell by means of the parameter **AdjCellLayer**: The parameter **AdjCellLayer** determines the layer of the adjacent cell from the point of view of the serving cell. The layer of an adjacent cell can be either:

    - ⇨ the same as the layer of the serving cell;

- ⇨ upper than the layer of the serving cell;
- ⇨ lower than the layer of the serving cell.

The adjacent cells which meet both of the required radio link properties and the required cell size/layer are ranked according to the priority levels as usual.

The parameter **AdjCellLayer** is related to the traffic control based on the MS speed, which is an optional feature in the BSC. If this option is not enabled, the use of the parameter **AdjCellLayer** is disabled as a default value.

The feature MS Speed consists in two different features: Fast moving MS in macro cell and MS Speed Detection. These features was introduced to increase the capacity of a cellular network, areas of high traffic density may be covered with a multi-layer network consisting of different sized cells. If a high speed mobile is located in such an area it should be located in a macrocell to decrease the amount of handovers. In other words a high speed mobile locating in a microcell would result in increased signalling load and potentially high amount of dropped calls in the network.

The "**Fast moving MS handling in macro cell**" (S5) feature uses the adjacent cell measurements to define the ms speed and the "**MS Speed Detection**" (S6) feature uses the crossing rate algorithm to define the ms speed. The S5 feature is handling MSs in macrocell (with RF hopping used) and the S6 feature is handling the MSs in microcells (no RF hopping). The handovers between cells at same layer are based on PBGT or radio reasons, and between cells at different layers are based on umbrella handovers.

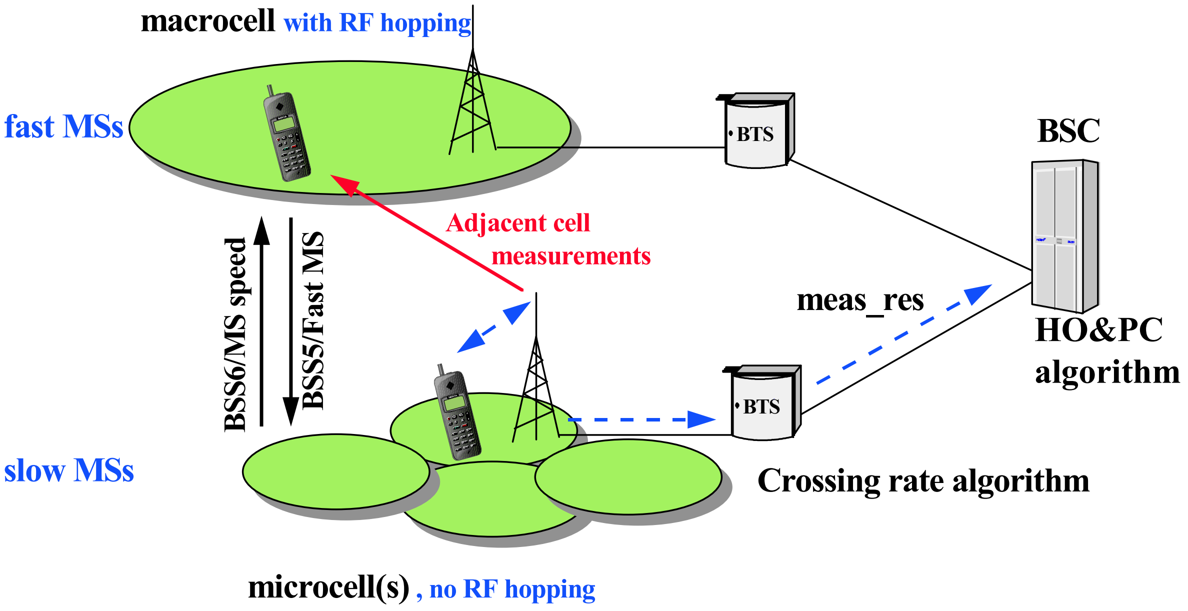


Figure 29. Fast / Slow Moving MS

11.5.3.1 Fast moving MS handling in macro cell

The feature estimates whether the mobile is moving fast or slow by checking the number of received measurements from adjacent microcells. This is done through a counter for each adjacent microcell at the BSC, and a threshold (**fastMovingThreshold 0 … 255**). The counter starts from zero if a measurement is received and the level exceeds the minimum for that cell (**rxLevMinCell**) the counter is increased by 2. Otherwise it is decreased by 1.

If the mobile is moving slow an umbrella handover to the lower layer (microcell) will be triggered, the cause being slow mobile. The feature is automatically used when there is at least one adjacent cell belonging to a lower layer than the serving cell.

11.5.3.2 MS Speed Detection and Various Window Size

The feature estimates whether the mobile is moving slow or fast by measuring MS speed. The MS speed can be verified by counting fading dips. The handover decision algorithm, called crossing rate algorithm, is based on comparison of signal strength values obtained from each burst and their averaged value (over one SACCH-frame). The averaged value is RXLEV in uplink direction, which BTS reports to BSC. The algorithm counts the rate with which the signal level crosses the averaged signal level due to fast fading.

If averaged MS speed indications (**msSpeedThresholdPx (1 ... 32)**) out of last averaged MS speed indications (**msSpeedThresholdNx (1 ... 32)**) exceeds the **upperSpeedLimit (0 ... 254)**, then the MS is considered as a fast moving MS and the call will be handed over (umbrella handover) to a suitable upper layer cell (macrocell) if any. If averaged MS speed indications out of last averaged MS speed indications is/are lower than the **lowerSpeedLimit (0 ... 254)**, then the MS is considered as a slow moving MS and the call will be handed over to a suitable lower layer cell (microcell) if any. The step size for **Upper/LowerSpeedLimit** parameter is 1, which correlates with a speed of 2 km/h.

If the RF hopping and the crossing rate algorithm are both set on in a BTS, then the MS speed detection indications to be sent to the BSC are all non-valid (255). The MS speed indication is set to non-valid also if the uplink DTX was used during the current and/or the previous SACCH multiframe. This means that the crossing rate algorithm can not determine the MS speed reliably and the HO&PC algorithm in the BSC will not take into account the speed indications and therefore no handovers will be made due to MS speed.

If the MS power control is in progress, the HO&PC algorithm will discard the MS speed indications until the power control is completed (i.e. the MS has received the requested power level). The MS speed estimations indicated before the power control start are valid for averaging and threshold comparison.

If the BTS sends the MS speed indication to the BSC, then the HO&PC algorithm will process the MS speed indications (averaging and threshold comparison).

The Various Window Size feature is introduced in S7 release because “Speed” itself has different interpretations in different locations. Therefore, it is reasonable to have various window size (i.e. Better Cell Trigger / Quality Trigger) according to the speed indication.

In principle, high-speed MS should use shorter average window size, and low-speed MS should use longer average window size. Therefore, all averaging-processes should have two sets of window parameters, one set for high speed MS and one set for low speed MS. By applying various window size, fast-moving MSs have shorter window size and they may handover to target cell faster. For a slow-moving MS, a longer window size is applied in order to prevent it from unnecessary oscillation.

The BSC may use the information on the speed of the mobile station either to control traffic between separate layers of the multi-layered cellular network or to scale the values of the averaging parameters. The function is selected with the parameter **MsSpeedDetectionState**. The alternative values are the following:

0	MS speed information is used to control traffic between separate layers of the multi-layered cellular network by means of the handover procedure.
1 – 100	MS speed information is used to scale the values of the averaging parameters. The range is from 1% to 100%. That is, if the value is, for example, 80% it means that the averaging window is 80% of the normal window size.

If Px averaged MS speed indications out of last Nx averaged MS speed indications exceeds the upper speed limit (USL), then the MS is considered as a fast moving MS and the scaled averaging windows are used. If Px averaged MS speed indications out of last Nx averaged MS speed indications is/are lower than the lower speed limit (LSL), then the MS is considered as a slow moving and the normal averaging windows are used.

The following averaging windows and number of zero result parameters are scaled after the MS is detected to fast moving:

- ⇨ UL signal level
- ⇨ DL signal level
- ⇨ DL signal levels of adjacent cells
- ⇨ Number of zero results
- ⇨ DL signal level of interfering cells in IUO
- ⇨ Number of zero results when averaging interfering cells in IUO

These parameters concern only handover, not power control.

The previous parameters are returned to originals when the mobile station is detected to slow moving one.

There is interaction with the existing feature MS Speed Detection. If the MS Speed Detection State is set to handover, the MS is always attempted to be directed to the correct cell according to the MS speed. If the MS Speed Detection State is set to various windows the algorithm only change the size of the averaging windows and number of zero results in the case of the fast or slow speed is detected.

The crossing rate algorithm gives reliable results only in non-hopping cells and when the uplink DTX was not used. The MS speed indications are received from the BTSs of B10 or DF3.0 and in later products and SW versions.

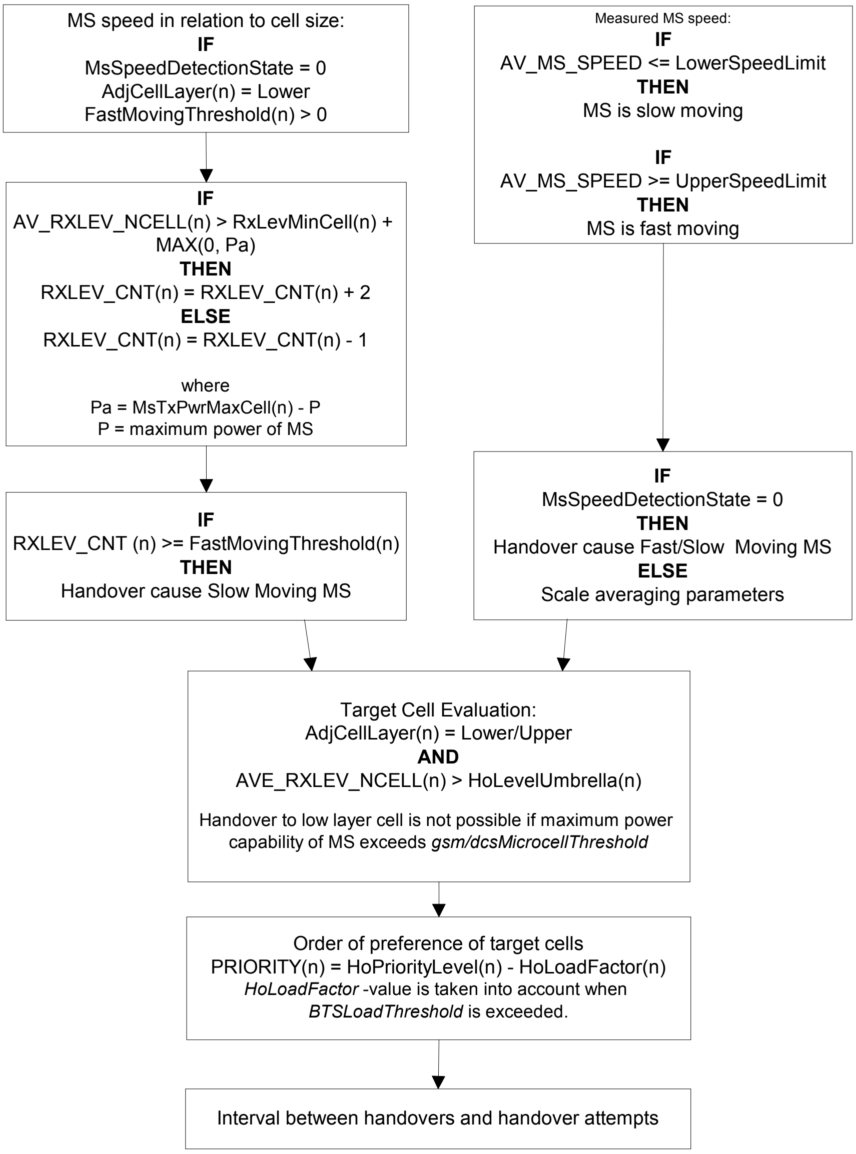


Figure 30. "Handover due to fast/slow-moving MS."

11.5.4 Handover due to Quality or Signal level

If the HO threshold comparison indicates that a handover due to uplink or downlink quality or level is required, the BSC evaluates the radio link properties of the adjacent cells in order to find a target cell for the handover. Equations 1 and 2' are used in case of uplink or downlink quality or level. (See chapter Algorithms)

The parameter **HoThresholdsQualUL/DL** is used for comparing the averaged values of uplink signal quality measurements for triggering the HO due to uplink quality.

- ⇨ RxQual is the threshold level for handover. The range is <0.2% - >12.8% (bit error rate).
- ⇨ Nx is the total number of averages to be taken into account before decision is possible. The range varies from 1 to 32.
- ⇨ Px is the number of averages out of total averages that have to be greater (of worse quality) than or equal to the threshold before a handover is possible. The range varies from 1 to 32.

The BSC compares the averaged measurement result AV_RXQUAL_UL/DL_HO with **HoThresholdsQualUL**. A handover whose cause is uplink quality might be required if at least Px averages out of Nx averages are greater (of worse quality) than or equal to the threshold RxQual.

The parameter **HoThresholdsLevUL/DL** is used for comparing the averaged values of uplink signal level measurements for triggering the HO due to uplink level.

- ⇨ RxLev is the threshold level for handover. The range is from -110 dBm to -47 dBm.
- ⇨ Nx is the total number of averages to be taken into account before decision is possible. The range varies from 1 to 32.
- ⇨ Px is the number of averages out of total averages that have to be lower than or equal to the threshold before a handover is possible. The range varies from 1 to 32.

The BSC compares the averaged measurement result AV_RXLEV_UL_HO with **HoThresholdsLevUL**. A handover whose cause is uplink level might be required if at least Px averages out of Nx averages are lower than or equal to the threshold RxLev.

11.6 Imperative Handovers

The handover is considered imperative if the cause is one of the following events:

1. MS - BTS distance
2. O&M order to empty the cell
3. Directed Retry
4. Chained cells in a rapid field drop (optional)

The target cells for imperative handovers are ranked only according to radio link properties; priority levels are not used.

11.6.1 MS – BTS Distance

In the case where distance is the reason for the handover request, the behaviour of the Mobile can be controlled by the parameter **msDistanceBehaviour (0 ... 60, 255)**. There are three alternatives in which the Mobile will act in the case of this Imperative Handover: it will release the call immediately, try a 1 ... 60 seconds Imperative Handover, or just try an Imperative Handover (255). As seen in chapter Handover Algorithms above, the Imperative Handover needs just one equation – equation 1.

11.6.2 Rapid Field Drop and Enhanced Rapid Field Drop

11.6.2.1 Chained adjacent cells in Rapid Field Drop

The BSC recognises the necessity to make a handover when the HO threshold comparison indicates that a handover whose cause is rapid field drop, might be required from the serving cell to a specified adjacent cell. The situation can take place, for example, when a MS moves so fast from the coverage area of an indoor cell to the coverage area of an outdoor cell that the uplink radio is lost. The parameter **HoThresholdsRapidLevUL** is used for comparing the *raw* results of uplink signal level measurements for triggering the HO due to rapid field drop. The parameter **hoThresholdsRapidUlN** defines how many successive rapid field drop thresholds have to be triggered before a call is handed over to a chained adjacent cell.

When the cause is rapid field drop, only those adjacent cells, which are defined as chained adjacent cells may be selected as target cells. The definition is made for each adjacent cell by the parameter **ChainedAdjacentCell (Yes / No)**. In this case it suffices that the radio link properties of the chained adjacent cells satisfy equation 1, (see chapter, Algorithms) i.e. the handover is considered imperative.

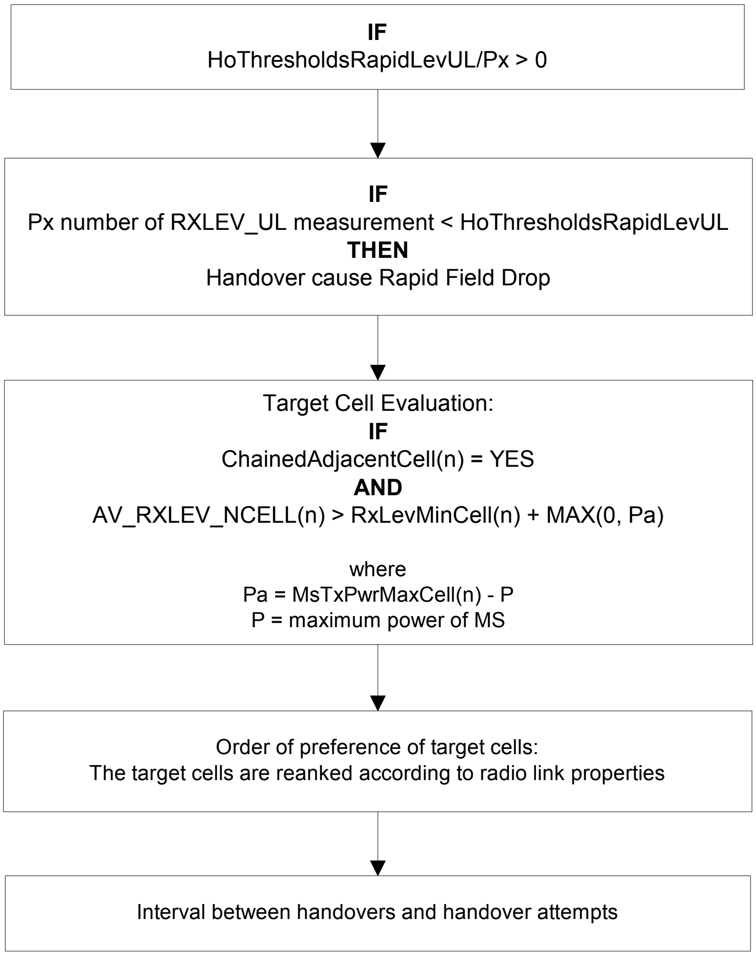


Figure 31. Handover due to Rapid Field Drop

11.6.2.2 Turn-Around-Corner MS

When a MS is turning a corner, the signal strength of micro-cell may drop by 30 dB due to the losing of line-of-sight effect. The existing feature rapid field drop in chained cells directs a MS from horizontal cell to the vertical one, but it may also cause ping-pong effect to the in-house slow-moving traffic, if the Rapid field drop threshold is set too high. Therefore, the new feature Enhanced Rapid Field Drop with Turn-Around-Corner handover is designed.

The basic idea of Enhanced Rapid Field Drop is to detect Deep Dropping Edge for serving cell signal and handover the call to the correct adjacent cell. The rapid field drop detection (**erfdEnabled**) can be done based on either uplink measurements or downlink measurements, or both uplink and downlink measurements.

The ERFD feature is particularly designed for micro cellular networks where the signal strength of MS can vary a lot. The DDE algorithm is based on monitoring continuous deep drops in the serving cell signal strength (both uplink and downlink) and the following new handover control parameters.

MS measures serving cell signal level all the time and reports the values to BSC in every SACCH frame. There is only one measurement result in one SACCH frame. The BSC calculates the dde_level value based on the raw measurement results coming from MS and defined **ddeWindow** –parameter value. The calculated dde_level value is then compared to the Deep Dropping Edge Threshold level (**ddeThresholdLev**), and if the dde_level value is above the threshold level n/p times then MS is considered to be as a Turn-Around-Corner MS

The basic idea of the ERFD target cell evaluation is to make the handover rapidly to the better adjacent cell by using smaller averaging windows (**modifiedAveWinNcell**). The shorter averaging windows and smaller amount of zero results (**modifiedNOZ**) are used to speed up the decision process. The new averaging windows are used after DDE is detected in the serving cell. The new averaging parameters are used as long as the timer **erfdOve**r expires. This is an improvement to existing optional feature Chained Cells in Rapid Field Drop.

The old Rapid Field Drop in Chained Cells can be used simultaneously, but the new algorithm has a higher priority.

For example, If the value of the parameter **ddeWindow** is 3 SACCH (1.5 sec), the BSC compares the most recent measurement sample 8 (multiframe k) with the measurement sample 1 (multiframe k-3).

Sample	1	2	3	4	5	6	7	8
Signal level	-71 dBm	-68 dBm	-70 dBm	-71 dBm	-69 dBm	-70 dBm	-75 dBm	-83 dBm

DDE_LEVEL = RXLEV (k- **ddeWindow**) – RXLEV (k) = -69 dBm – (-83 dBm) = 14 dB

Furthermore, if **ddeThresholdsLev** is 10 dB, px is 2 and nx 3, it is needed totally two DDE_LEVEL results bigger or equal than the defined threshold value before the MS is considered as a turn-around-corner MS. The minimum time for this decision will be 3 SACCH + 1 SACCH + 1 SACCH (**ddeWindow**) frames which is <u>about 2.5 sec</u>. After this the averaging window sizes can be changed and handover process can start.

If **modifiedAveWinNcell** is 2 and **modifiedNOZ** is 1, before the handover decision can be done the averaging window should be full. This will take <u>minimum 1 second.</u> So totally this process will take 3.5 seconds (2.5 sec + 1 sec.) before the handover is done.

The following figure presents the process leading to the handover

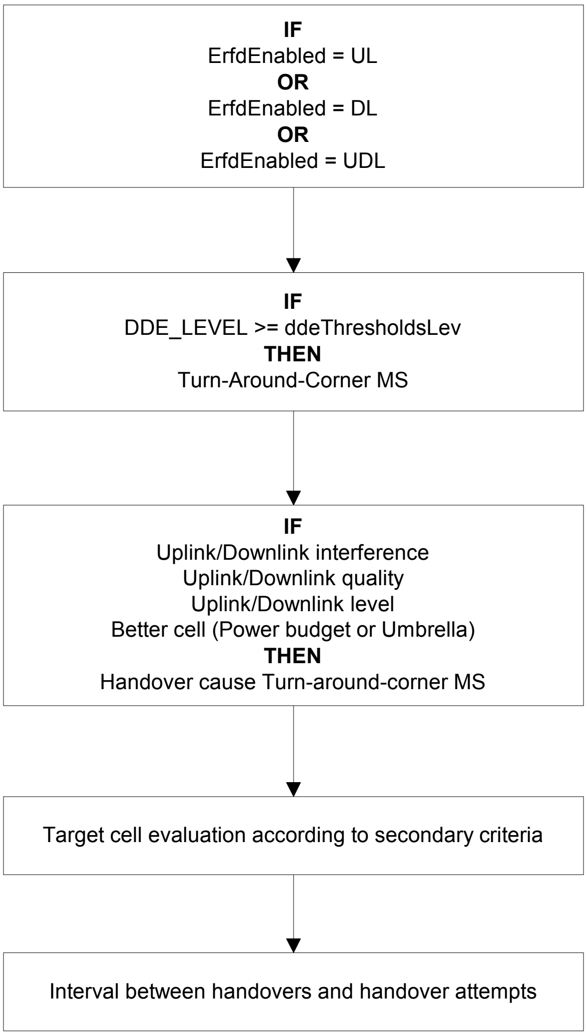


Figure 32. Handover due to Turn-Around-Corner MS

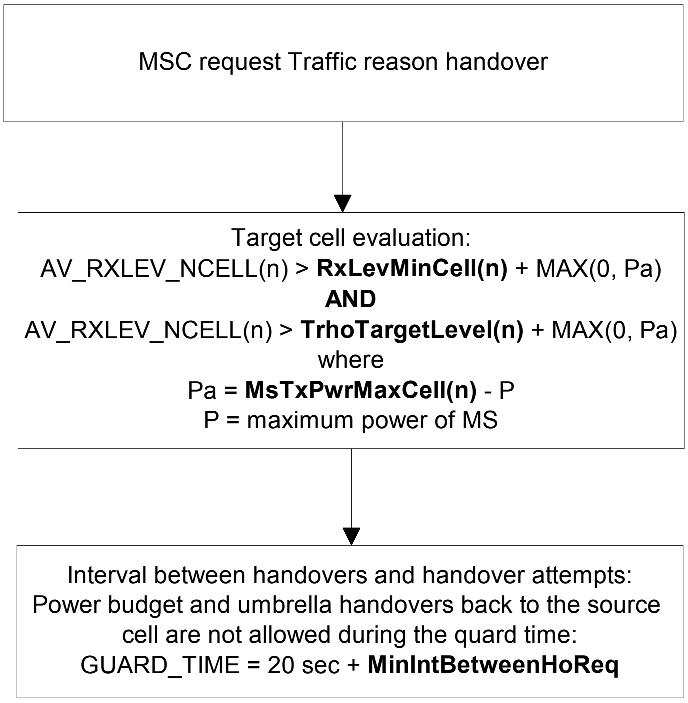
11.7 Traffic Reason Handover

11.7.1 11.7.1 MSC controlled traffic reason handover

In order to share the load between cells, the **MSC** may request the BSC to perform a specified number of handovers from one specified cell. In previous versions, it was possible to make only traffic reason handovers to cells with better or equal radiolink conditions.

Starting from S5, it is also possible to handover to ‘worse’ cells. The field strength in the adjacent cell has to be above the **rxLevMinCell** and also above the new parameter **trhoTargetLevel (-109 .. –**

47,N). Differences in mobile transmit power capabilities in source and target cells are also taken into account. The target cells are only ranked according to radiolink properties; priority levels are not used.



MSC request Traffic reason handover

Target cell evaluation:
AV_RXLEV_NCELL(n) > **RxLevMinCell(n)** + MAX(0, Pa)
AND
AV_RXLEV_NCELL(n) > **TrhoTargetLevel(n)** + MAX(0, Pa)
where
Pa = **MsTxPwrMaxCell(n)** - P
P = maximum power of MS

Interval between handovers and handover attempts:
Power budget and umbrella handovers back to the source cell are not allowed during the quard time:
GUARD_TIME = 20 sec + **MinIntBetweenHoReq**

Figure 33 Traffic reason handover

Traffic reason handover from the serving cell to the adjacent cell in question is disabled when the value of the parameter **TrhoTargetLevel** is 'not used'.

The target cells for traffic reason handover are ranked only according to radio link properties. Priority levels are not used.

11.7.2 BSC initiated Traffic reason handover (Advanced Multilayer Handling, S8)

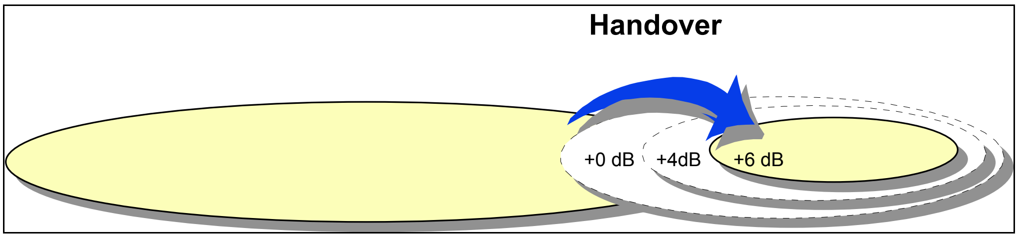


Fig 1. BSC initiated TRHO (Congestion relief)

The AMH concept provides the network operator with the tools needed to relieve the load of the congested cells and smooth out the load over the network. The overall traffic load of the network can be smoothed out using the BSC initiated TRHO feature. The basic idea of the feature is to dynamically change the power budget margins and thus, direct the MSs hanging around in the cell border to less loaded adjacent cells.

BSC initiated TRHO is based on the traffic load situation of the serving cell. If the traffic load of the serving cell exceeds the parameter **AmhUpperLoadThreshold**, **AmhTrhoPbgtMargin** is used for all adjacent cells in the power budget equation instead of the existing **HoMarginPBGT**.
The basic evaluation algorithm calculated according to radio link properties is based on the following strategy and order:

1. AV_RXLEV_NCELL (n) > *TRHO_TARGET_LEVEL (n)* + Max (0, (MS_TXPWR_MAX_CELL (n) - P))

2.PBGT (n) > **AmhTrhoPbgtMargin and PBGT** (n) < HOMarginPBGT

Note:
In the 1st equation of power budget HO the old parameter rxLevMin Cell (n) has been replaced by *TRHO_TARGET_LEVEL (n),* already seen in the MSC traffic reason HO.
Power Budget HO does not have to be enabled in order to make BSC initiated trho enabled.

If the PBGT value is between **AmhTrhoPbgtMargin** and **HoMarginPBGT**, the handover is triggered due to the BSC initiated TRHO handover.
If the PBGT value exceeds the **HoMarginPBGT**, the handover is triggered due to PBGT handover.

Furthermore, the TRHO candidate must have less than AmhMaxLoadOfTgtCell reserved traffic channels in order to become a target cell.
Note: Queueing is not used with the BSC initiated TRHO.

Sometimes, traffic must be directed to weaker cells. Therefore, a special mechanism for handling this kind of traffic, keeping the call in the new cell, is added to the concept. The parameter TrhoGuardTime determines the penalty time to handover back to the original cell because of PBGT handover. Therefore, consecutive handovers back to the original cell during the guard time are prevented.

Note 1: So that external AMH can be successful, the parameter "CAUSE FIELD IN HANDOVER REQUEST SUPPORTED" must have the value YES in the BSSAP version profile of the MSC. This parameter must be YES so that ho guard timers and queuing is not in use.

Note 2: Only calls from the regular layer can be redirected due to traffic reason handover.

Note 3: The new parameters are visible only when this new feature (AMH_USAGE) is in use: since it's an *OPTIONAL* feature it has to be configured in the BSC SW package.

Parameters involved:

AmhTrhoPbgtMargin	-24 dBm - +24 dBm, N

If the parameter is set to "N", the feature is turned off.
Power budget margin will be HoMarginPBGT.

AmhUpperLoadThreshold (serving cell parameter)	0 - 100%
AmhMaxLoadOfTgtCell (adj cell parameter)	0 - 100%
TrhoGuardTime	0 – 120 sec

11.7.2.1 Interactions with other features

MSC controlled TRHO

The AMH BSC initiated TRHO feature is not recommended to be used at the same time and in the same cell with the existing MSC controlled TRHO feature.

Meaning that the old parameter **trhoTargetLevel** would be set to "N", corresponding to the value –110 dBm according to the coding of level and quality done in the BSC for PC&HO algorithm.

Direct Access to Desired Layer/Band (S8)

The AMH multi layer load control has lower priority than the Direct Access to Desired Layer/Band (DADL/B) feature. It is possible to direct traffic to lower layer cells (underlaying micro cells or DCS cells) with DADL/B although AMH prevents mobiles from accessing to lower layer cells.

HSCSD (S7)

The BSC initiated TRHO is made only for single slot connections. The parameter UpperLimitCellLoadHSCSD should be set to a greater value than the parameter AmhUpperLoadThreshold. Through these actions unnecessary downgrades are avoided and radio resources are used efficiently.

11.8 Load control between layers : Advanced Multilayer Handling (S8)

The Nokia Advanced Multilayer Handling (AMH) concept consists also of other two features related to the network load.
We have already seen the feature related to same layer situation where the congestion can be regulated via a BSC traffic reason handover.
In case of network with more than one layer (GSM/DCS or/and IUO), the concept provides two more features.
The AMH concept is used to redistribute traffic to the appropriate layer/frequency band according to prevailing load of the network. Therefore, AMH can smooth out traffic over the network.

It provides operators with the tools necessary to use only the overlay network during low traffic periods, thus avoiding additional handovers between two layers. AMH is able to redistribute traffic from the congested regular layer to other cells, selecting the best mobile and cell combination which is most likely to survive and give good quality in the new cell.

11.8.1 IUO Load control

IUO is applied into the network to increase capacity. On the other hand, during periods when the capacity needs are not so high, the IUO functionality is still performing a lot of handovers. Therefore, by avoiding the additional handovers between different frequency layers, the quality of the network can be improved.

AMH can be used to prevent the use of IUO during very light traffic and thus, keep the mobiles only in the overlay network. The solution is based on the traffic load of the serving cell.

If the traffic load of the serving cell goes under ***AmhLowerLoadThreshold***, the IUO handover and the Direct Access to super-reuse TRX are not allowed. The functionality is controlled by parameter ***AmhTrafficControlIUO***.

11.8.2 Multilayer (Dual band/micro cellular) network load control

Many operators build capacity by using micro cells or a Dual Band solution. The increasing amount of different network layers also increases the number of handovers between layers. During very quiet traffic, i.e. during nights, the need for extra capacity is unactual and the underlay capacity is not necessarily needed. Therefore, adequate capacity can be achieved by using only overlay network.

On the other hand, during night time, most traffic is accomplished outside, particularly from fast moving vehicles. Furthermore, fast moving mobiles in the micro cell network generate a lot of handovers with relatively high speed. Therefore, it is more reasonable to keep the traffic in the overlay network instead of the underlay, in order to provide better quality to end users.

AMH can be used to prevent the use of the micro cell/DCS layer during very light traffic and, thus, keep the mobiles only in the macro/GSM network, once they have camped on it.
If the traffic load of the serving cell goes under ***AmhLowerLoadThreshold***, the FMMS (S5), MS Speed Detection (S6) and Umbrella handovers (AdjCellLayer enabled) are not allowed for lower layer cells. The functionality is controlled by the parameter ***AmhTrafficControlMCN.***

Note: The access to micro cells cannot be prevented, but C2 reselection can be used to keep the fast moving mobiles in the overlay network during idle mode.

11.8.3 11.8.3 Parameters involved

AmhTrafficControlIUO.	***N/Y***
AmhTrafficControlMCN	***N/Y***
AmhLowerLoadThreshold	***0-100%***

Also in this cases the parameters are visible only when the OPTIONAL feature is built in the BSC SW package being AMH_USAGE on.

11.9 Direct Access to Desired Layer/Band (S8)

The purpose of the Direct Access to Desired Layer/Band (DADL/B) feature is to direct traffic in the call setup phase from the SDCCH of macro cell / GSM900 cell to the TCH of micro cell / GSM1800 cell whenever possible.
Also the extended GSM900 band capability of the MS is taken into account. The functionality of this feature is similar to Directed Retry.

The difference is that the handover in DADL/B is triggered due to cell load and the target cell selection criteria are tighter.
Note: the functionality of this direct access feature is different from direct access in IUO.
The feature is *OPTIONAL*.

This feature makes it possible to reduce the number of unnecessary TCH reservations of dual band mobiles in GSM 900 cell and thus provides more trunking efficiency in the network. The DADL/B handover can also be made in another direction, from micro cell to macro cell or from GSM1800 cell to GSM 900 cell. The use of DADL/B is flexible with adjacent cell specific indications and DADL/B can be tailored to different environments and concepts.
Note also that this DADL/B feature is also applicable to phase 1 mobiles which do not support C2 cell re-selection.

The DADL/B will be applied if the DADL/B is enabled in BSC and if the load of the accessed cell is higher than the ***BTSLoadThreshold*** defined for the accessed cell.
There must also be are adjacent cells defined as DADL/B handover target cells with the ***dadlbTargetCell (n)*** parameter (the only new parameter added for this feature).
The adjacent cells are verified according to the MS capabilities (single band, dual band, and tri band) read from the classmark.

Directed Retry or Direct Access to Desired Layer/Band?

If there is real TCH congestion in the accessed cell, then a DR due to congestion with or without queuing will be made.
If there are TCHs available in accessed cell, then BSC will act according to the DADL/B usage determination and cell load. If DADL/B is applied and the TCH load in the accessed cell is higher than the ***BTSLoadThreshold****,* then DADL/B handover procedure will be started. If DADL/B is not applied or the TCH load is lower than the *BTSLoadThreshold,* a TCH will be allocated from the accessed cell. Note that pre-emption always has higher priority. The TCH will be allocated from the accessed cell and thus no DADL/B handover will be attempted.

The target cells for DADL/B handover are selected according to the following criteria:

Adjacent cells handled by the same BSC handling the accessed cell, considered as DADL/B target cells with signal level exceeding HOLevelUmbrella, will be sorted according to adjacent cell priority and load factor (HOPriorityLevel or HOPriorityLevel (n) – LoadFactor (n) if adjacent cell is loaded) to be used as target cells for DADL/B handover.

The DADL/B handover attempt can fail due to he following reasons:

- TCH could not be allocated from any cell included in the DADL/B list (TCH congestion in DADL/B target cells)

- DADL/B handover fails and MS returns to old channel (SDCCH).
- The timer monitoring DADL/B target cell list availability triggers. This timer is the same as this one used in Directed Retry (*MinTimeLimitDR*).

In these cases, the TCH is tried to allocate from the accessed cell. The DR and queuing are possible in the second TCH request if no TCHs are available in the accessed cell. The BSC will evaluate the target cells for DR. When at least one target cell for DR is found.

Note that the DADL/B handovers are possible only as intra BSC handovers.

11.9.1 Interactions with other features

Management of SDCCH-SDCCH handovers in ABIPRB
If an SDCCH-SDCCH handover is started and ABIPRB receives an abis_assignment_ s message, the SDCCH-SDCCH handover will be stopped and the assignment request will be handled.
If ABIPRB has received an abis_assignment_s message and is handling the assignment request, the SDCCH-SDCCH handover's and IUO DAC handover's starts will not be made.

DADL/B handover vs. IUO DAC and SDCCH-SDCCH handovers
The DADL/B handover case can not happen simultaneously with the IUO DAC handover and SDCCH-SDCCH handover, because DADL/B handover is triggered after ABIPRB has received the abis_assignment_s message (as stated above).

IUODR vs. DADL/B
In radio resource allocation (i.e. when allocating a TCH for a call) the IUODR has higher priority than the DADL/B.

Other interactions
Other interactions as in current DR. See the functional description of Directed Retry Procedure in BSC.

Parameters

Parameters	**Value Range**
1) BSC level HO parameters	
hoPreferenceOrderInterfDL	INTER / INTRA
hoPreferenceOrderInterfUL	INTER / INTRA
msDistanceBehaviour	0 ... 60, 255
genHandoverRequestMessage	1 ... 16

DisableIntHo	Yes	/	No	

2) HO Control Process

btsLoadThreshold	0	...	100	%
maxNumberOfRepetitions	5	...	35	

3) Averaging Adjacent Cells

AveragingWindowSizeAdjCell	1	...	32	SACCH
NumberOfZeroResults	0	...	7	
AllAdjacentCellsAveraged	Yes	/	No	

4) Ho Measurement Averaging Method

EnaFastAveCallSetup	Yes	/	No
EnaFastAveHo	Yes	/	No
EnaFastAvePC	Yes	/	No

5) Minimum Intervals between handovers

MinIntBetweenUnsuccHoAttempt	0	...	30
MinIntBetweenHoReq	0	...	30

6) HO types allowed

EnableIntraHoInterfUL	Yes	/	No
EnableIntraHoInterfDL	Yes	/	No
EnablePwrBudgetHandover	Yes	/	No
EnableUmbrellaHandover	Yes	/	No
EnableMSDistanceProcess	Yes	/	No
EnableSDCCHHandover	Yes	/	No

7) Periodic handovers

HoPeriodPBGT	0	...	63
HoPeriodUmbrella	0	...	63

8) Averaging windows and weighting values

HoAveragingLevDL	1	...	32
Weighting	1	...	3
HoAveragingLevUL	1	...	32

Weighting	1	...	3
HoAveragingQualDL	1	...	32
Weighting	1	...	3
HoAveragingQualUL	1	...	32
Weighting	1	...	3
MsDistanceAveragingParam	1	...	32
MsSpeedAveraging	1	...	32

9) Thresholds

HoThresholdsLevDL	-110	...	-47
Px	1	...	32
Nx	1	...	32
HoThresholdsLevUL	-110	...	-47
Px	1	...	32
Nx	1	...	32
HoThresholdsQualDL	0	...	7
Px	1	...	32
Nx	1	...	32
HoThresholdsQualUL	0	...	7
Px	1	...	32
Nx	1	...	32
HoThresholdsInterferenceDL	-110	...	-47
Px	1	...	32
Nx	1	...	32
HoThresholdsInterferenceUL	-110	...	-47
Px	1	...	32
Nx	1	...	32
MsDistanceHoThresholdParam	0	...	63
Px	1	...	32
Nx	1	...	32

10) Fast / Slow Moving Ms

LowerSpeedLimit	0	...	255
UpperSpeedLimit	0	...	255
MsSpeedThresholdNx	1	...	32
MsSpeedThresholdPx	1	...	32
MsSpeedDetectionState	0	…	100

11) Rapid Field Drop and Enhanced Rapid Field Drop

ErfdEnabled	DIS / UL / DL / UDL

ErfdOver	1	…	64
DdeWindow	1	…	32
ModifiedAveWinNcell	1	…	32
ModifiedNOZ	1	…	32
DdeThresholdsLev	0	…	63
Px	1	…	32
Nx	1	…	32
HOThresholdsRapidLevUl	-110	...	-47
HoThresholdsRapidLevUlN (px)	0	...	32

12) C/I Based Ho Candidate Evaluation

CiEstMethod	AVE /	MAX /	NONE
LowerCILimit	-128	...	127
L1	-128	...	127
L2	-128	...	127
L3	-128	...	127
L4	-128	...	127
L5	-128	...	127
L6	-128	...	127
PriorityAdjStep	-8	...	7
P1	-8	...	7
P2	-8	...	7
P3	-8	...	7
P4	-8	...	7
P5	-8	...	7
P6	-8	...	7
P7	-8	...	7

13) Directed Retry handover

drInUse	Yes	/	No
IdrUse	Yes	/	No
maxTimeLimitDirectedRetry	1	...	15
minTimeLimitDirectedRetry	0	...	14
disableExtDr	Yes	/	No
drMethod	0	…	1
drThreshold	-47	…	-110

14) Extended Cell Radius

maxMSDistanceHoThreshold	0	...	63

minMSDistanceHoThreshold	0	...	63

15) AMH

AmhUpperLoadThreshold	0	…	100 %
AmhLowerLoadThreshold	0	...	100 %
AmhMaxLoadOfTgtCell	0	...	100 %
AnhTrhoGuardTime	0	…	120 s
AmhTrhoPbgtMArgin	-24	…	24 dBm / N
AmhTrafficControlMCN	Y	/	N
AmhTrafficControlIUO	Y	/	N

16 Dynamic Hotspot

SoftBlockingStartReg	0	…	255
SoftBlockingStartSup	0	…	255
BadQualLimit	0	…	100 %
GoodQualLimit	0	…	100 %
SigQualLimit1	0	…	100 %
SigQualLimit2	0	…	100 %
TchProbability1	0	…	100 %
TchProbability2	0	…	100 %
TchProbability3	0	…	100 %

In the HO parameters list the parameter disableIntHo (read: disable internal handover) has been added in S7: it defines whether all handovers are controlled by the MSC or not.**Adjacent Cell Parameters**

The handover process always requires two cells: a serving cell and a target cell. The target cell has to be a defined adjacent cell to the serving cell because the Mobile Station measures only the serving cell and the defined adjacent cells. Some information is needed about the adjacent cells in order to know the conditions of these cells: their IDs, frequencies, cell priorities, minimum access levels, margins for handovers, etc. All the needed parameters for adjacent cells are presented below:

Parameter **Value**

1) Frequency

BCCHFrequency			
GSM	1	…	124
	975	…	1023
GSM1800	512	…	885

GSM1900	512	…	810	

2) Cell Accessing Parameters

msTxPwrMaxCell *GSM*	5	...	43	dBm
msTxPwrMaxCell *DCS*	0	...	36	dBm
msTxPwrMaxCell *DCS19*	0	...	33	dBm
RxLevMinCell	-110	...	-47	dBm

3)

Syncronised	Yes	/	No	
HoPriorityLevel	0	...	7	
HoLoadFactor	0	...	7	
MsPwrOptLev	-110	...	-47/ N	dBm

4) Handover Margins

EnableHoMarginLevQual	Yes	/	No	
HoMarginLev	-24	...	24	dB
HoMarginQual	-24	...	24	dB
HoMarginPBGT	-24	...	63	dB

5) Identity parameters for adjacent cell

AdjacentCellId			
Lac	0	…	65535
Ci	0	…	65535
BsIdentityCode			
Ncc	0	…	7
Bcc	0	…	7

6) Access Levels and Threshold

HoLevelUmbrella	-110	...	-47	dBm

7) DR and IDR

drThreshold	-110	…	-47	dBm
CellType	GSM	/	MCN	

8) Fast / Slow moving MS

AdjCellLayer	N / SAME / LOWER / UPPER			
FastMovingThreshold	0	...	255	

9) Rapid Field Drop

ChainedAdjacentCell	Yes	/	No

10) Traffic reason handover

TrhoTargetLevel	-109	...	-47/ N	dBm

11) Improved Solution for extended cell range

HoTargetArea	0	...	3

12) C/I based handover candidate evaluation

LAC1 … LAC5	0	…	65535	
ReferCell	0	…	65535	
CiEstWeight	0	...	10	
LevelAdjustment	-63	...	63	dB

13) Half Rate

TchRateInternalHO	1	..	5

14) DADL/B

DadlbTargetCell	Yes	/	No

15) Dynamic Hotspot

InterferedCell	0	…	3

Practical Examples of Handovers

Some practical examples will be given in figure 34. The first one is a quite normal case when the adjacent frequency is found in the adjacent cell. This is an example which shows that specifications are not tight enough concerning this matter. GSM specifications say that the adjacent channel can be 9 dB higher than the serving channel, and based on this fact, the **homarginLev** could be set at **6 dB**. In practice there is interference already when the adjacent channel is 4-5 dB higher than the serving channel, and this is the reason why the value of **hoMarginLev** has to be set lower than **6 dB**. This, however, easily causes the Ping-Pong effect.

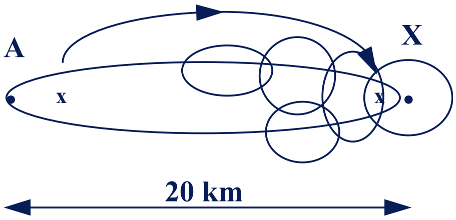
The second example is of some cells with very large coverage areas (high antenna mast or BTS in a hilly area with Line Of Site) in the network. This can be avoided sometimes with double adjacent cell list.

Practical Examples

1. Adjacent Channel in Adjacent Cell

- $C/I_a = -9$ dB
- **In practice after -6 dB -> interferencies + quality goes down to 4-5**
- **hoMarginLev < -6 dB -> Ping-Pong !!**

2. Cell with Very Large Coverage Area



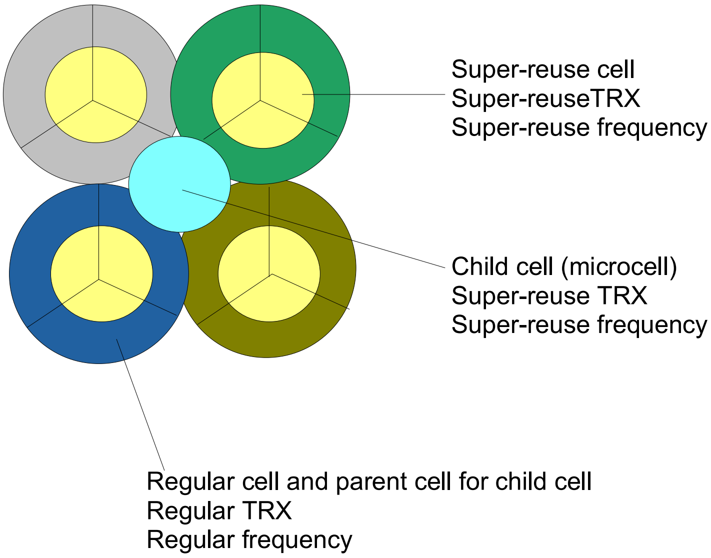
- **MS switched off in cell A and transferred to area of cell X**
- **MS switched on in new place**
  -> MS tries first old channel + neighbourgs
- **MS camped on cell A which is not in neighbourg list of cell X**
  -> do not listen BCCH of cell X -> no HOs to cell X !!!

Figure 34. Practical Examples about Handovers.

12 Intelligent Underlay Overlay (IUO)

12.1 Terminology

Super layer	A logical network layer consisting of TRXs with tight frequency reuse.
Regular layer	A logical network layer consisting of TRXs with normal frequency reuse.
Super-TRX	A TRX belonging to the super layer.
Regular-TRX	A TRX belonging to the regular layer.
Super-reuse factor	The average frequency reuse number for the super layer.
Good C/I probability	The percentage of the total cell traffic having C/I ratio above the defined threshold.
Absorption	Percentage of total cell traffic served by the super layer.



12.2 Functional Properties

12.2.1 Regular and super-reuse frequencies

In order to achieve a higher radio network capacity by means of the intelligent underlay-overlay procedure, the operating spectrum of the network is divided into regular and super-reuse frequencies.

Regular frequencies compose the overlay network, which provides the continuous coverage area of the radio network. The frequency planning of the underlay network is based on conventional planning criteria such as low co-channel and adjacent channel interference probability and overlapping cell areas required for handover control. The regular frequencies are intended to serve mobile stations mainly at cell boundary areas and other locations where the C/I (carrier/interference) ratio is the worst.

Super-reuse frequencies compose the underlay network where frequencies are reused very intensively to produce the extended capacity. In order to avoid the interference caused by the increased level of frequency reuse, the super-reuse frequencies are intended to serve mobile stations which are close to the BTS, inside buildings and other locations where the radio conditions are less vulnerable to the interference.

Division into regular and super-reuse frequencies is controlled by a parameter **TrxFrequencyType (FRT)** administered on transceiver-by-transceiver. All the transceivers (TRXs) of the BSC are identified as either a regular TRX or a super-reuse TRX:

the radio frequency of the transceiver belongs to regular frequencies (FRT=0)

the radio frequency of the transceiver belongs to super-reuse frequencies (FRT =1..16)

An ordinary cell (regular cell) is typically equipped with both types of TRXs.
The regular TRXs allocated to the cell belong to a regular frequency group.
A super-reuse TRX allocated to the cell belongs to a specified super-reuse frequency group. The super-reuse TRXs of the cell may belong to the same super-reuse frequency group or they may belong to different super-reuse frequency groups. The groups are selected with the parameter **TrxFrequencyType**. For example, the super-reuse TRXs allocated to the cell may be divided into super-reuse frequency groups according to the source of interference. Those super-reuseTRXs, which belong to the same super-reuse frequency group, have the same sources of interference.

The BSC uses radio resource allocation at call set-up and handover during the call to control traffic between regular and super-reuse frequencies.

Child cells and Parent cells

Micro cells may be equipped solely with the super-reuse frequencies. By establishing appropriate handover connections, a micro cell at a good location (traffic hot spot) can handle more traffic than the regular cells in its vicinity. With such an arrangement, the surrounding regular cells are called parent cells and the micro cell is called a child cell.

A child cell has only super-reuse TRXs (determined by means of the parameter **TrxFrequencyType**). The super-reuse TRXs of the child cell may belong to the same super-reuse frequency group or they may belong to different super-reuse frequency groups.

Since a child cell does not have any regular TRXs, the call set-up through the child cell is not possible; for that reason access to the child cell must be denied by means of a parameter **CellBarred**.

In case features like Direct Access (S7) are active, the call set-up is always started in the regular cell and then the access granted to the child cell. See more about Direct Access in the related chapter.

12.2.2 Downlink C/I ratio of the super-reuse TRX

The BSC calculates the downlink C/I ratio of the super-reuse TRX by means of various parameters and the measurement results reported by the MS via the BTS.

The principle of the C/I evaluation is simple. By comparing the downlink signal level of the serving cell (carrier) and the downlink signal level of those neighbouring cells which use the same super-reuse frequencies as the serving cell (and that therefor are seen as interferers), the BSC can calculate the C/I ratio on the super-reuse frequencies at the location of each active mobile station.

12.3 Traffic Channel Allocation in Call Setup and in Handovers

12.3.1 Traffic Channel Allocation in call setup

The radio resource management may allocate a traffic channel (TCH) for a call **from a regular TRX only**.

If no TCHs are available on regular TRXs when requested due to congestion or in case of queuing (if enabled) after the queuing timer has expired, the radio resource management rejects the TCH request because of lack of resources even though there might be free TCHs available on super-reuse TRXs.

If no TCHs are available on regular TRXs when requested, the BSC**, by means of DirectedRetryused** parameter **enabled**, may allow the MS to make a second attempt at gaining access in parallel with queuing (if that is employed as well) if the first one failed due to TCH congestion. That is:

- inter-cell handover from a dedicated control channel (SDCCH) of the serving cell to a TCH on a regular TRX of an adjacent (regular) cell.
- intra/inter-cell handover from a dedicated control channel (SDCCH) of the serving cell to a TCH on a super-reuse TRX of a serving/child cell

Directed Retry to a super-reuse TRX

In general the radio resource management may allocate a TCH for a call from a regular TRX only.

If no TCHs are available on regular TRXs when requested, the BSC starts the directed retry procedure being **DirectedRetryused** enabled. In this case the BSC may perform either:

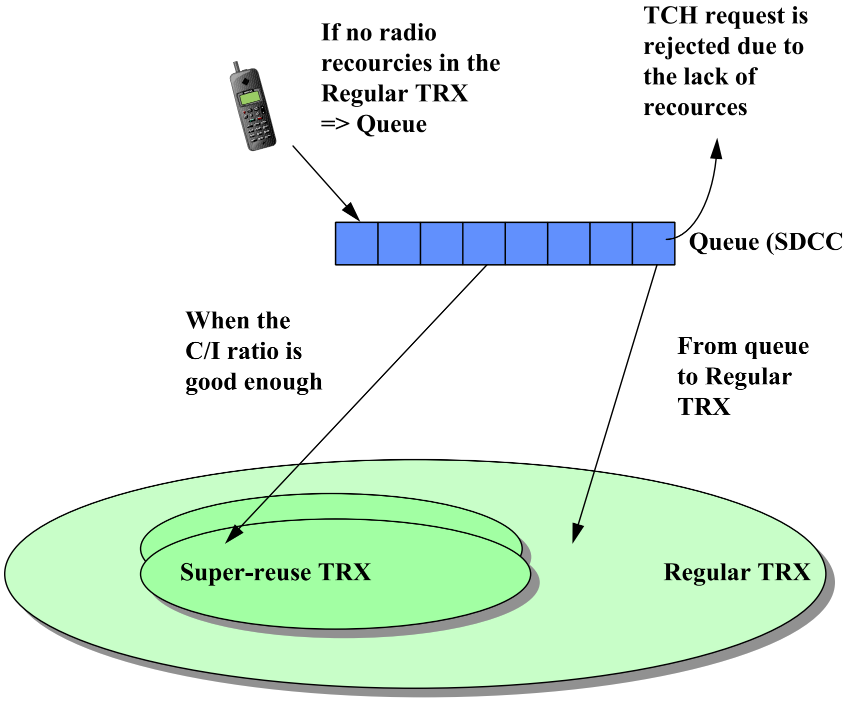
1. Inter-cell handover from a dedicated control channel of the serving cell to a TCH on a regular TRX of an adjacent (regular) cell when the signal level of the adjacent cell is good enough in comparison with the two thresholds: RxLevMinCell and drThreshold (S7).

The parameter **MinTimeLimitDR** determines the period starting from the assignment request during which the handover in question is not allowed. The period is allowed for the mobile station to decode the BSIC of the adjacent cells before the HO decision. The period also increases the possibility of allocating a TCH from the serving cell before the execution of handover to an adjacent cell. The BSC may perform the handover after the period has expired.

2. Intra/inter-cell handover from a dedicated control channel of the serving cell to a TCH on a super-reuse TRX of a serving/child cell when the downlink C/I ratio of the super-reuse TRX is good enough

The handover from a dedicated control channel to a super-reuse TRX is enabled by the parameter **EnaTchAssSuperIUO (S6)**. The parameter also determines the period starting form the assignment request during which the C/I evaluation is considered unreliable and the handover to a super-reuse TRX is not allowed. The period is allowed for the mobile station to decode the BSIC of the adjacent cells before the HO decision. The BSC may perform the handover to a super-reuse TRX after the period has expired.

The below picture clarifies batter what above said considering queuing enabled. Just remember that the S6 feature can perform only if DirectedRetryused is enable (it's using the algorithm of the DR).



If it is possible to perform a handover both to a regular TRX and to a super-reuse TRX simultaneously, the BSC prefers the super-reuse TRXs of the serving/child cell to regular TRXs of the adjacent cells.

The BSC may monitor the signal level of the adjacent cell and the C/I ratio of the super-reuse TRXs, and perform the handover from a dedicated control channel until the maximum period allowed for the directed retry procedure expires. The period starts from the assignment request and it is controlled by the parameter **MaxTimeLimitDR**. If the call cannot be handed over from the dedicated control channel during the period, the BSC discontinues the call setup procedure: **the possibly ongoing queuing is terminated and the call attempt is cleared**.

12.3.2 Traffic Channel Allocation for inter-cell and intra-cell handover to a regular TRX

A handover attempt to a regular TRX can be either an intra-BSC (inter-cell or intra-cell) or an inter-BSC handover. The call can be handed over to the regular TRX of the target cell either from a regular TRX or from a super-reuse TRX of another cell (regular or child cell), or an intra-cell handover can take place either from a super-reuse TRX to a regular TRX or within a regular frequency group.

Radio resource management may allocate a TCH for the handover attempt in question from a regular TRX. If no TCHs are available on regular TRXs when requested or in case of queuing after the queuing timer has expired, the radio resource management rejects the TCH request because of lack of resources even though there might be free TCHs available on super-reuse TRXs.

12.3.3 Traffic channel allocation for inter-cell and intra-cell handover to a super-reuse TRX

A handover attempt to a super-reuse TRX is always **an intra-BSC** handover (intra-cell or inter-cell). The handover candidate can be either a super-reuse TRX of the regular cell or a super-reuse TRX of the child cell.

The radio resource management allocates a TCH for the handover attempt in question according to the list of preferred super-reuse frequency groups within one target cell. The list is composed of the maximum of 16 super-reuse TRXs of the specified super-reuse frequency groups.

The TCH is allocated primarily from the super-reuse frequency group which has the most unallocated TCHs whose interference level is either within or better (of lower interference) than the recommended interference band (referring to the feature: Channel allocation criteria based on the minimum acceptable C/N ratio). If there are no such TCHs available, the TCH is allocated from that super-reuse frequency group which has the most unallocated TCHs within any interference band. If there are no unallocated TCHs available on the specified super-reuse frequency groups, radio resource management rejects the TCH request.

If there are two (or more) specified super-reuse frequency groups which have the same number of unallocated TCHs, the TCH is allocated from that frequency group which has priority over the other frequency groups according to the list of preferred super-reuse frequency groups.

In intra-cell handover within the super-reuse frequency group, the radio resource manager allocates the TCH primarily from a new TRX and secondly from the serving TRX.

12.4 Handover Strategy

When the BSC uses the intelligent underlay-overlay feature, the handover algorithm is able to perform handovers for the following reasons:

1. traffic control between regular and super-reuse frequencies during the call set-up phase in situations of congestion, that is, underlay - overlay assignment,
2. traffic control between regular and super-reuse frequencies during a call, that is, underlay - overlay handover
3. traffic control between regular and super-reuse frequencies without the C/I evaluation, that is, direct access procedure
4. conventional radio criteria such as power budget, low signal level and bad signal quality,
5. other reasons such as directed retry procedure, traffic reason handover, umbrella handover and an order from the channel administration to empty a cell by means of the handover procedure.

The BSC uses different handover decision algorithms for handover caused by:

- traffic control between regular and super-reuse frequencies
- handovers caused by conventional radio criteria and
- handovers caused by other reasons than radio criteria.

12.4.1 Underlay-overlay handover

The handover decision algorithm for the underlay-overlay handover consists of the following four stages:

1. processing of radio link measurements,
2. C/I evaluation procedure,
3. HO threshold comparison,
4. HO candidate selection.

The BSC monitors the downlink C/I ratio on the super-reuse frequencies continuously, determines the most appropriate frequency group, regular or super-reuse, to be assigned for the conversation and performs the underlay-overlay handover between frequency groups when necessary.

The possible types of the underlay-overlay HO are the following:

- intra-cell HO from a regular TRX to a super-reuse TRX
- intra-cell HO from a super-reuse TRX to a regular TRX
- intra-cell HO within a super-reuse frequency group
- inter-cell HO from a parent cell to a child cell
- inter-cell HO from a child cell to a parent cell
- intra-cell HO between super-reuse frequency groups
- inter-cell HO between super-reuse frequency groups.

When a call is on a regular TRX, the HO algorithm monitors every super reuse frequency group of the serving cell and those child cells which are adjacent to the serving cell. The BSC performs the HO from a regular TRX to a super-reuse TRX if the C/I ratio of the super-reuse TRX is greater than or equals a specified HO threshold (SuperReuseGoddCIThreshold).

If there are appropriate super-reuse freq. groups both in the serving cell and in the child cell, the last ones are preferred.

When a call is on a super-reuse TRX, the HO algorithm monitors exactly like in the above case. The BSC performs the HO from the super-reuse TRX to the regular TRX if the C/I ratio of the super-reuse TRX or the signal quality becomes worse than the relevant HO threshold. If a HO back to a regular TRX is not possible due to congestion (for example) the BSC may perform a HO from the serving super-reuse frequency group to another super –reuse frequency group which met the requirements for the C/I ratio.

The handover between super-reuse frequency groups is controlled by the parameter **EnableInterFrtIuoHo**. The parameter also determines which type of handover is preferable, a handover to another super-reuse frequency group or a handover to a regular TRX, when the downlink C/I ratio on the serving super-reuse frequency group becomes worse.

The BSC performs underlay-overlay handovers autonomously according to the list of preferred frequency groups within one target cell; that is, the underlay-overlay handover is always an intra-BSC handover.

NOTE: The BSC may perform underlay-overlay HOs between frequency groups WITHIN the serving cell although intra-cell HOs caused by conventional radio criteria are disabled. Nevertheless, the parameter **EnableIntraHoInterfUL** indicates whether an intra-cell HO within the frequency group caused by UL interference is enabled.

12.4.2 Direct access procedure: C/I evaluation by-passed! Extra capacity!

The basic procedure is that the traffic control between regular and super-reuse frequencies is based on the downlink C/I ratio, that is, a call is handed over to super-reuse TRX when the downlink C/I ratio of the super-reuse TRX is good enough to sustain a good radio link.

The BSC, however, may ignore the C/I evaluation procedure in situations when the downlink signal level of the super-reuse TRX exceeds a certain predetermined threshold. In this case the high downlink signal level (the carrier is well above the worst expected interference level) ensures that the downlink C/I ratio of the super-reuse TRX is good enough, and the BSC may perform a handover to the super-reuse TRX without the C/I evaluation, that is, direct access procedure.

The signal level which the downlink signal of the super-reuse TRX must exceed in order for the direct access to the super-reuse TRX (frequency group) to become possible, is controlled by the parameter **DirectAccessLevel** on a tranceiver-by-tranceiver basis.

The direct access procedure can be applied during the call set-up phase and in an inter-cell handover attempt to a regular cell. The BSC performs the direct access to a super-reuse TRX as a handover procedure.

The possible types of Direct Access are as follows:

intra-cell direct access from SDCCH (regular) to a super-reuse TRX
inter-cell direct access from SDCCH (regular) of a parent cell to a child cell
inter-cell direct access from a regular cell/child cell to a super-reuse TRX of a regular/parent cell.

If there are no free traffic channels available on super-reuse TRXs, the BSC allocates a TCH for the call or for the inter-cell handover attempt from a regular TRX.

NOTE: Direct Access procedure is not a normal IUO HO!!! The inter-cell direct access procedure might seem against the rule of inter-cell HO between super-reuse frequency groups, but it's a stand alone procedure based mainly on downlink signal level.

12.4.3 Handover caused by radio criteria or by other reasons than radio criteria

The IUO procedure does not affect the HO decision made by the BSC when the cause of the HO attempt is conventional radio criteria or when the HO attempt is caused by other reasons than radio criteria.

The possible HO types are the following:

- intra-cell HO within a regular frequency group
- inter-cell HO from a regular cell to another regular cell
- inter-cell HO from a child cell to a regular cell (regular TRX) .

12.5 Processing Radio Link Measurements

12.5.1 Bookkeeping and averaging of the RXLEV of the interfering cell

It is possible to define **up to 10 interfering cells (BSS7)** at most for each of the super-reuse TRXs (or for a super-reuse frequency group). This is possible when a super-reuse frequency group consists of two or more super-reuse TRXs.

The BSC is able to maintain a table of up to 32 interfering cells per each call and store the levels as they arrive, that is, the BSC is able to monitor several super-reuse TRXs simultaneously.

The interfering cells must be adjacent to the serving cell, otherwise the mobile station is not able to measure and report the signal levels of the interfering cells.

The MS is able to report the measurement results of the six strongest neighbouring cells it receives best, and the interfering cells are often weaker than the six strongest neighbouring cells, coupled with the possibility of BSIC decoding failure, the RXLEV of the interfering cell may be available intermittently.

12.5.2 Variable averaging window size

The **variable averaging window size** feature **(S7)** affects the averaging of the RXLEV of the interfering cell in the following way:

- if the MS is considered as a slow-moving MS or the MS speed cannot be determined, the BSC uses the normal values of the averaging parameters **IntfCellAveragingWindowSize** and **IntfCellNumberOfZeroResults**
- if the MS is considered as a fast-moving MS, the BSC uses the scaled values of the averaging parameters **IntfCellAveragingWindowSize** and **IntfCellNumberOfZeroResults**

The scaling of the averaging parameters is controlled by the parameter **MSSpeedDetectionState (0 ... 100%)**. The parameter indicates how much the values of the averaging parameters will be decreased if the MS is considered as a fast-moving MS.

12.6 C/I evaluation

When the intelligent underlay-overlay procedure is employed (parameter **SuperReuseEstMethod** is set for each cell), the BSC calculates the downlink C/I ratio on super-reuse TRXs whenever it receives measurement results from the BTS. The BSC receives measurement results after every SACCH multiframe or, if pre-processing is used in the BTS, every second, third or fourth SACCH multiframe.

The C/I evaluation concerns every super-reuse TRX of the serving cell and those child cells, which are adjacent to the serving (parent or child) cell.

The BSC calculates the downlink C/I ratio of the super-reuse TRX by means of the processed measurement results (averages) and the relevant parameters.

Processed measurement results are the following:

- downlink RXLEV of the serving cell,
- downlink RXLEV of the interfering cells,
- downlink RXLEV of the adjacent cell.

Parameters are the following:

- SuperReuseEstMethod,
- LevelAdjustment,
- CIEstWeight,
- CIEstType.

By comparing the downlink RXLEV of the super-reuse TRX and the downlink interference level, the BSC can calculate the C/I ratio of the super-reuse TRX.

12.6.1 RXLEV of the interfering cell

The parameter **CIEstType** indicates whether the signal level of the interfering cell is regarded as a directly-measured interference level or as a reference value which is used for calculating an interference level estimate (the interfering cell is actually a reference cell). The parameter is set separately for each of the **10** interfering cells.

If the averaging procedure has only been done for those interfering cells which are among the six best neighbouring cells according to the latest measurement sample (parameter **AllInterferingCellsAveraged**), the C/I evaluation procedure ignores those interfering cells of the TRX whose RXLEV has not been averaged. The BSC is not able to calculate the downlink C/I ratio of the super-reuse TRX if there is no averaged RXLEV available of any interfering cell. When the BSC calculates the downlink C/I ratio of the super-reuse TRX of the child cell for a handover attempt from a regular cell to a child cell, the average RXLEV of the child (adjacent) cell is also essential.

Directly-measured interference level

The most common situation is that the interfering cell is a regular cell which is adjacent to the serving cell and the interfering cell has the same set of super-reuse frequencies as the serving cell and also the location of the interfering cell is close enough to cause interference. In this situation the averaged downlink RXLEV of the interfering cell AV_RXLEV_INTFx (k) corresponds directly to the interference level on the super-reuse TRX caused by the interfering cell.

Estimated interference level

When the RF signal profile of a regular adjacent cell is similar to the interference profile within the coverage area of the serving cell, it is possible to define the regular adjacent cell as the interfering cell (reference cell) instead of the true source of interference. The RF signal profile is considered the same as the interference profile, when the ratio between the RF signal level and the interference level (for example 6 dB) remains relatively unchanged within the service area of the serving cell. The parameter **LevelAdjustment** represents the ratio set for each interfering/reference cell.

In order to increase the reliability of the estimation, several reference cells may be used for calculating the estimated downlink interference level AV_RXLEV_ESTM (k). AV_RXLEV_ESTM (k) and the downlink C/I ratio of the super-reuse TRX are calculated by using similar evaluation methods.

For those cells whose measurement values are used for calculating an interference level estimate and are missing from the measurement sample, a zero is entered as the measurement value.

In order to diminish the distortion of results of the averaging procedure caused by the zero values among the measurement results, the parameter **IntfCellNumberOfZeroResults** is used to indicate how many (maximum) zero values the BSC can ignore over the averaging interval.

The averaging procedure may be selected with the parameter **AllInterferingCellsAveraged** either for every interfering cell of the TRX or only for those interfering cells which are among the six best neighbouring cells as measured in the last sample.

The sliding window technique takes into account the maximum of 32 most recent measurement samples. The averaging window size is selected with the parameter **IntfCellAveragingWindowSize.** The averaging procedure can start as soon as the BSC receives the first measurement result from the BTS.

12.6.2 C/I calculation methods

The HO algorithm uses two alternative methods to calculate the downlink C/I ratio of the super-reuse TRX or the estimated downlink interference level:

1. average taking method,

2. maximum taking method.

The C/I estimation method is selected by the parameter **SuperReuseEstMethod**.

Average taking method

A weighted average of interfering neighbours represents the overall interference level. If there is only one interfering cell or all the interferers are equally strong, this method gives the same result as maximum taking method. If some of the interfering neighbours are weaker interferers than the others, the calculated C/I is always lower than in maximum taking method. Weighting factors can be used to rate the interferers by the parameter **CIEstWeight**.

Maximum taking method

Maximum taking method uses RX-level of the strongest interferer to represent the overall interference level.

12.7 Threshold comparison

12.7.1 Handover

The intelligent underlay-overlay feature introduces two special HO thresholds in addition to the basic HO thresholds:

1. SuperReuseGoodCiThreshold,
2. SuperReuseBadCiThreshold.

Both HO thresholds have three parts: the threshold itself (CiRatio), the total number of comparisons (Nx) to be taken into account before a decision is possible, the number of comparisons out of total comparisons (Px) where the downlink C/I ratio has to be lower/greater than or equal to the threshold before actions are possible.

When the call is on a regular TRX, the BSC performs the threshold comparison of good downlink C/I ratio (HO threshold **SuperReuseGoodCiThreshold**). The threshold comparison of good downlink C/I ratio concerns every super-reuse TRX of the serving cell and those child cells which are adjacent to the serving cell.

If the call has been handed over to a super-reuse TRX, the BSC performs both the threshold comparison of bad downlink C/I ratio (HO threshold **SuperReuseBadCiThreshold**) and the threshold comparison of good downlink C/I ratio (HO threshold **SuperReuseGoodCiThreshold**). The threshold comparison of bad downlink C/I ratio concerns only the super-reuse TRX itself. Whereas the threshold comparison of good downlink C/I ratio concerns every super-reuse frequency group of the serving cell, except the serving frequency group, and those child cells which are adjacent to the serving (parent or child) cell.

12.8 HO Decision algorithm

12.8.1 Underlay-overlay handover to a super-reuse TRX

That includes the following types:

- intra-cell HO from a regular TRX to a super-reuse TRX
- inter-cell HO from a parent cell to a child cell.

In the first type the BSC performs an intra-cell HO to a super-reuse TRX of the serving cell if no child cell is good enough for the HO (remember HO to child cell is always preferred when possible).

The BSC recognises the possibility of making the underlay-overlay handover when the comparison of Good C/I ratio indicates that a call can be handed over from a regular TRX to a specified super-reuse TRX of the serving/child cell. That is, the following conditions are fulfilled:

1. Downlink C/I ratio of the super-reuse TRX is good enough to sustain a good radio link;
2. Both uplink and downlink signal quality on the regular TRX are good;
3. MS-BS distance has not reached the HO threshold.

Time allowed for BSIC decoding

The parameter **MinBsicDecodeTime** determines the period starting from call setup or handover (inter-cell or intra-cell) during which the C/I evaluation is considered unreliable and the handover to a super-reuse TRX is not allowed. The BSC, however, performs the averaging, C/I evaluation and HO threshold comparison procedures normally during this period. This period allows MS to decode the BSIC of the interfering (adjacent) cells before the HO decision.

12.8.2 Underlay-overlay handover from a super-reuse TRX

The relevant types of the underlay-overlay HO are as follows:

- intra-cell HO from a super-reuse TRX to a regular TRX
- intra-cell HO within a super-reuse frequency group
- inter-cell HO from a child cell to a parent cell (regular TRX only)
- intra-cell HO between super-reuse frequency groups
- inter-cell HO between super-reuse frequency groups

The BSC recognises the need to make an underlay-overlay handover from the serving super-reuse frequency group when the HO threshold comparison indicates that some of the following criteria for a handover are fulfilled:

1. Downlink quality/interference,
2. Uplink interference,
3. Bad C/I ratio,
4. MS-BS distance has reached the HO threshold

Comments:

- inter-cell HO from a super-reuse to a regular TRX

If it is not possible to perform a handover back to a regular frequency group, or if a handover to a regular frequency group is not preferable in case of Bad C/I ratio, the BSC may perform a handover from a serving super-reuse frequency group to another super-reuse frequency group. The handover between super-reuse frequency groups is enabled by the parameter EnableInterFrtIuoHo**.**

If the handover between super-reuse frequency groups is disabled, there are no such super-reuse frequency groups available whose C/I is good enough, or the handover is not allowed as a result of a handover failure or bad quality experience. In that case the BSC may perform an imperative handover to a regular cell in order to maintain the call.

-inter-cell HO from a child to a parent cell

An inter-cell HO from a super-reuse TRX of the child cell to a REGULAR TRX of the parent cell is considered imperative.

-intra-cell HO within a super-reuse frequency group

The parameter **EnableIntraHOInterfUL** indicates whether an intra-cell HOI within a super-reuse frequency group caused by UL interference is enabled. When the HO is enabled, the BSC may perform an intra-cell HO within a super-reuse frequency group always when it's required.

If the intra-cell HO within a super-reuse frequency group is not possible due to TCH congestion or it's not allowed as a result of a HO failure or a bad quality experience, or the HO is not enabled, the BSC may perform a HO from super-reuse TRX to a regular TRX.

-inter-cell HO between super-reuse frequency groups

This type of HO between super-reuse frequency groups is enabled by the parameter **EnableInterFrtIuoHo** and means HO from super-reuse TRX of a parent cell to a child cell or even HO from a child cell to another. It's NOT possible to perform the HO from a child cell to a super-reuse frequency group of a parent cell.

12.8.3 Direct access to a super-reuse TRX

The direct access procedure can be applied during the call setup phase and in an inter-cell handover attempt to a regular cell. Remember again that Direct Access bypasses the C/I evaluation procedure of a normal IUO HO.

In call set-up the call starts on a regular TRX and it's then directed to a super-reuse TRX via this procedure.

Intra-cell direct access to a super-reuse TRX (call set-up)

During the call setup phase a TCH on a specified super-reuse TRX can be assigned for the call when the following radio link conditions are fulfilled:

1. Downlink signal level of the serving cell is high enough to ensure a good radio link on super-reuse TRX, that is:

   RXLEV_DL > **DirectAccessLevel (k)**

RXLEV_DL is the downlink signal level of the serving cell. The parameter **DirectAccessLevel (k)** is the signal level which the downlink signal on the super-reuse TRX (k) must exceed before the direct access to the super-reuse TRX (k) is possible.

2. Both uplink and downlink signal quality on the dedicated control channel are good.

3. MS-BS distance has not reached the HO threshold.

The radio link conditions are verified during the initial signalling period of call set-up after the BSC has received the first valid downlink measurement report from the MS via BTS.

If the value of the parameter **DirectAccessLevel** varies between the TRXs of the super-reuse frequency group, the BSC selects the greatest value for the equation. If the value of the parameter varies between the frequency groups, the handover algorithm ranks the groups according to the value of the parameter.

Inter-cell direct access to a child cell (call set-up)

During the call setup phase a TCH on a specified super-reuse TRX of the child cell can be assigned for the call when the following radio link conditions are fulfilled:

1. Downlink signal level of the child cell is high enough to ensure a good radio link on super-reuse TRX, that is:

   RXLEV_NCELL (n) > **DirectAccessLevel (k)**

RXLEV_NCELL is the downlink signal level of the child (adjacent) cell (n), measured by MS. The parameter **DirectAccessLevel (k)** is the signal level which the downlink signal on the super-reuse TRX (k) must exceed before the direct access to the super-reuse TRX (k) of the child cell (n) is possible.

2. Both uplink and downlink signal quality on the dedicated control channel are good.

3. MS-BS distance has not reached the HO threshold.

If there are appropriate super-reuse frequency groups in many child cells, the BSC ranks the child cells according to priority levels and the load of the child cells, and selects the best child cell as the target cell.

If there are several super-reuse TRXs in the target (child) cell which meet the requirements for the downlink signal level, the handover algorithm ranks the groups according to the value of the parameter **DirectAccessLevel**.

Inter-cell direct access to a regular cell (note! It's not a inter-cell IUO HO procedure)

The BSC may allocate a TCH on a super-reuse TRX for an inter-cell handover attempt to a regular cell when the cause of the handover attempts is either:

- turn around corner,
- Fast/Slow moving MS, or
- Better cell (PBGT or Umbrella)

The BSC may perform direct access only to the super-reuse TRX of the best target cell. The handover algorithm examines if there are any super-reuse TRXs in the best target cell that can be assigned for the handover attempt. The BSC may allocate a TCH on a super-reuse TRX for an inter-cell handover attempt to a regular cell when the following conditions are fulfilled

1. Downlink signal level of the best target cell is high enough to ensure a good radio link on super-reuse TRX, that is:

   RXLEV_DL > **DirectAccessLevel (k)**

   RXLEV_NCELL (n) > **DirectAccessLevel (k)**

RXLEV_NCELL is the downlink signal level of the target (adjacent) cell (n). The parameter **DirectAccessLevel (k)** is the signal level which the downlink signal on the super-reuse TRX (k) must exceed before the direct access to the super-reuse TRX (k) of the target cell (n) is possible.

2. Both uplink and downlink signal quality on the dedicated control channel are good.

The inter-cell direct access to a regular cell is not possible when:

- there are no super-reuse TRXs in the best target cell,
- direct access to the best target cell is disabled,
- downlink signal level is not high enough,
- direct access is not allowed as a result of either a handover failure or a direct access failure, or
- there are no TCHs available on the appropriate super-reuse TRXs.

Remember: inter-cell direct access from a regular/child cell to a super-reuse TRX of a regular/parent cell.

12.8.4 Interval between handovers and handover attempts

The BSC normally controls the intervals between handovers and handover attempts by means of the following two timers:

1. To prevent repetitive handovers for the same MS, there is a timer for the minimum interval between handovers related to the same connection. The minimum interval between handovers is defined by the parameter **MinIntBetweenHoReq**.

2. If handover attempt fails for some reason, there is a timer for the minimum interval between an unsuccessful handover attempt and the following handover attempt related to the same connection. The minimum interval between an unsuccessful handover attempt is defined by the parameter **MinIntBetweenUnsuccHoAttempt**.

The averaging and HO threshold comparison do not stop during these intervals although handovers are not possible.

The BSC may also determine extra guard timers for specified frequency groups as a result of handover, direct access failures and bad quality experience. The extra guard timers are controlled by the following two parameters:

1. The parameter **MinIntUnsuccIuoHo** determines the minimum interval between an unsuccessful handover attempt to a super-reuse TRX and the following handover attempt to the super-reuse frequency group in question.

2. The parameter **MinIntIuoHOReqBQ** determines the period during which a handover to one specified super-reuse frequency group is not allowed because of bad quality experience on the super-reuse frequency group in question.

12.9 Intelligent Frequency Hopping (S7)

With Intelligent Frequency Hopping we mean that IUO and FH can be used simultaneously in a cell though further improving the capacity of the radio network. Till S6 both features IUO and FH couldn't be used in the same cell.

When the IUO feature is employed in the BSC, the frequency hopping is controlled on a frequency group-by-group basis. The regular TRXs of the cell compose one hopping group and the super-reuse TRXs of the cell compose another hopping group, and frequency hopping can be used independently in both frequency/ hopping groups.

NOTE: It's not possible to use baseband hopping and radio frequency hopping in a base station at the same time.

For implementing IFH separate network plan for each layer (regular and super) is required and the feature is applicable for both Radio frequency and Base Band Hopping. Both layers of a sector can be set hopping separately by using regular hopping mode and super hopping mode. In RF Hopping BTS both layers, overlay and underlay, shall have their own mobile allocation (MA) attached.

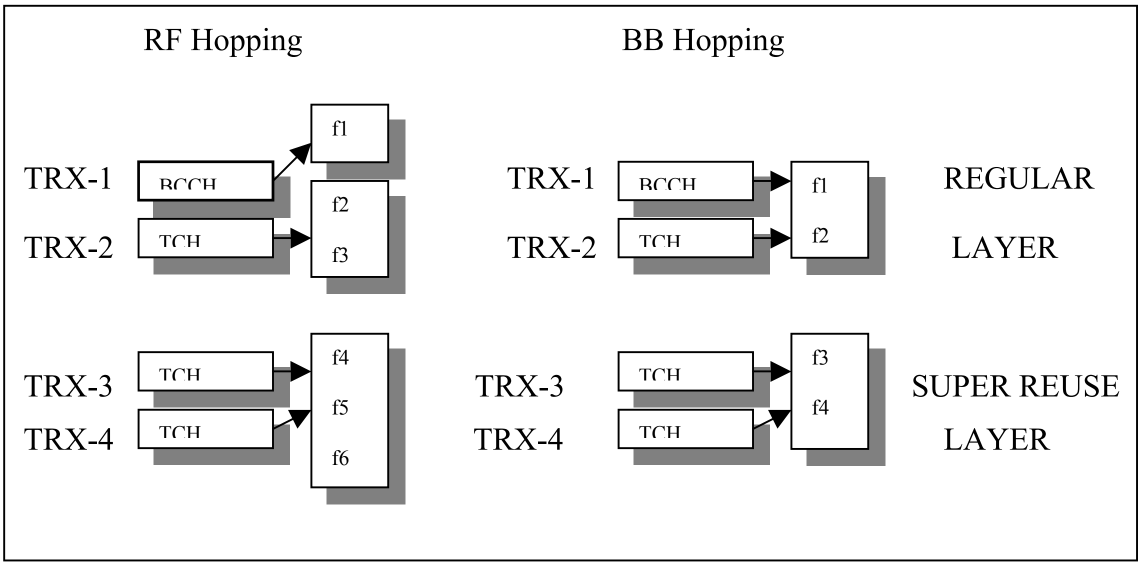


Figure 35 Hopping Modes in different layers

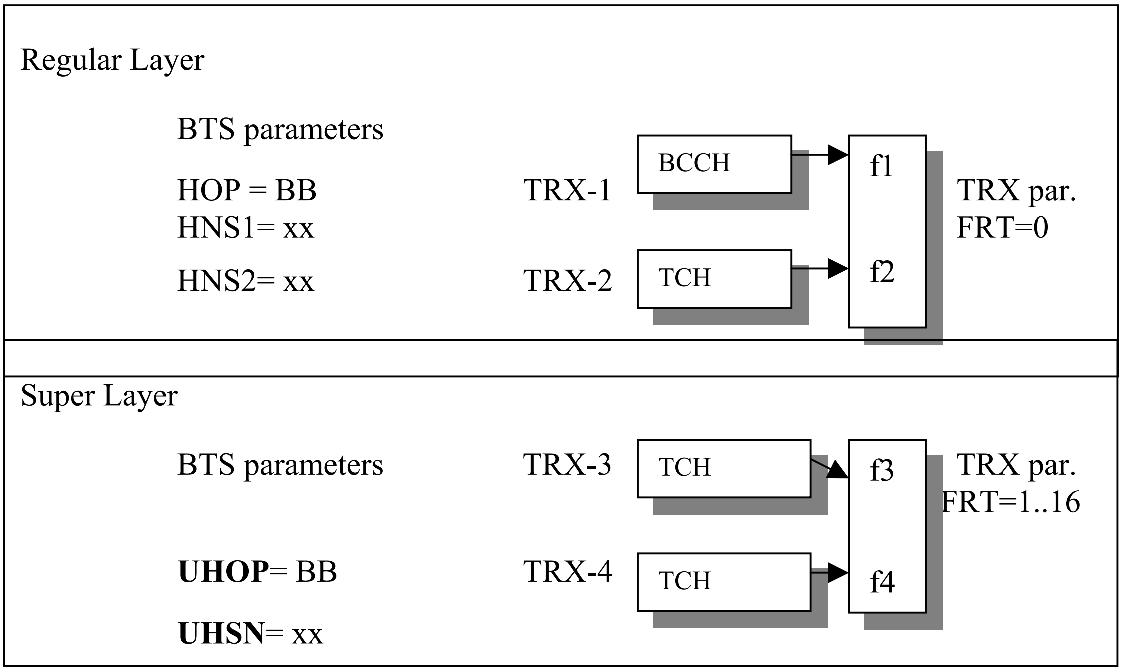


Figure 36: Base Band Freq. Hopping + IUO

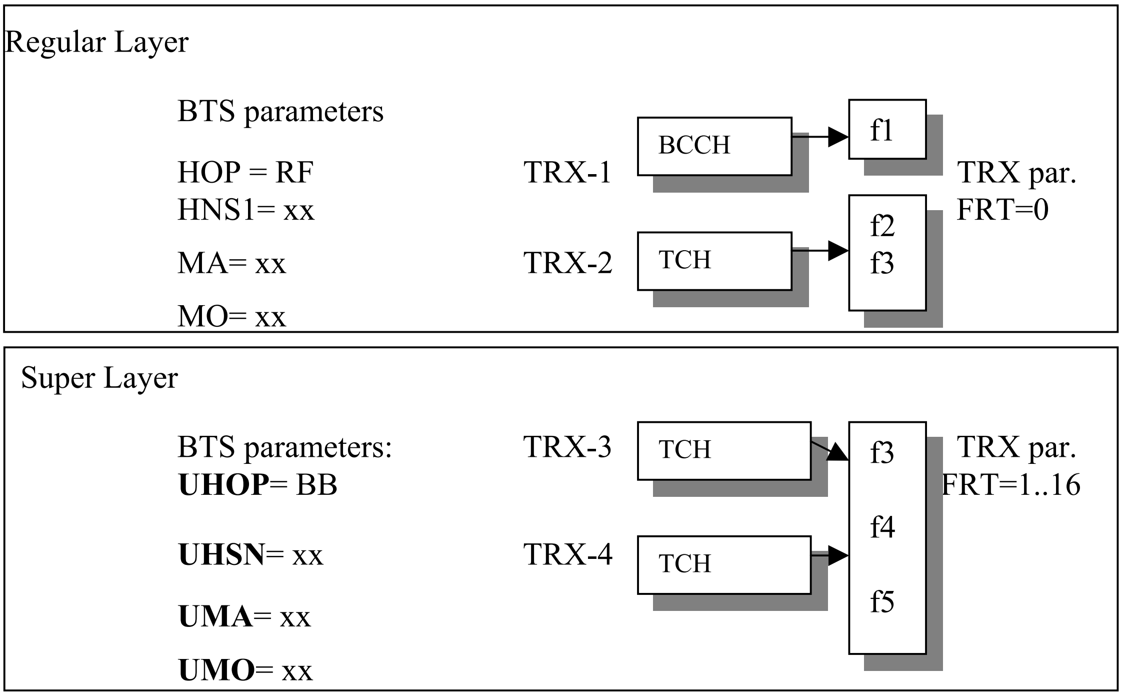


Figure 37: RF Freq. Hopping + IUO

In order to deal with FH separately in both layers a specific set of parameters has been created for the underlayer.

Four new parameters have been added for the underlay layer:

UnderlayHoppingMode (UHOP)	= BB, RF, N
UnderlayHSN (UHSN)	= 0,1-63
UnderlayMA (UMA)	= 0,1..128
Underlay MAIOOffset (UMO)	= 0..62

The introduction of FH and IUO feature at the same time in the same cell allows the introduction of a further parameter in order to get a flexible MAIO management when adopting RF Hopping.
A specific parameter has been added: **UnderlayMaioStep** (UMS) with a range from 1 to 62. For more detailed information of Flexible MAIO management see the chapter related to RF Hopping.

12.10 Parameters Related to IUO

1) Enable Inter FRT Handover

EnableInterFrtIuoHo	REG / SUP / DIS

2) Averaging

AllInterferingCellsAveraged	Yes	/	No	
intfCellAvgWindowSize	1	...	32	SACCH
intfCellNbrOfZeroResults	0	...	31	

3) Averaging Methods

EnaTchAssSuperIUO	0	...	32	SACCH
SuperReuseEstMethod	AVE /	MAX /	ICE /	NONE

4) Intervals

MinIntIuoHoReqBQ	0	...	255

MinIntUnsuccIuoHo	0	...	255	
MinBsicDecodeTime	0	...	128	

5) Thresholds

SuperReuseGoodCIThreshold	-127	...	127	
Px	0	...	32	
Nx	0	...	32	
SuperReuseBadCIThreslhold	-127	...	127	
Px	0	...	32	
Nx	0	...	32	
SuperReuseGoodRxLevThreshold	-47	...	-110	
px	1	...	32	
nx	1	...	32	
superReuseBadRxLevThreslhold	-47	...	-110	
px	1	...	32	
nx	1	...	32	

6) Intelligent Frequency Hopping

underlayHoppingMode	BB	RF	N	
underlayMAIOoffset	0	…	62	
underlayMaioStep	1	…	62	
underlayMA	0	…	128	
UnderlayHSN	0, 1	…	63	

7) TRX –level Parameters

C/I estimation type (T1 T10)	0 (meas)	/	1 (estim)	
C/I estimation weight (W1 –W10)	0	...	10	
Level adjustment (L1 L10)	-63	...	63	dB
DirectAccessLevel	-47	…	-109 / N	dBm
trxFrequencyType	0	...	16	

13 Handover Support for Coverage Enhancements (HSCE-S7)

The Handover Support for Coverage Enhancements feature is designed to support Nokia's **Intelligent Coverage Enhancement (ICE)** BTS solution to allow operators to use TRXs of different transmitting powers.

The basic idea of the feature is to provide handover support for the BTS's having TRXs of different transmitting power. Typically, the ICE cell is equipped with BCCH TRX having higher transmitting power than the other TRXs. Therefore, the cell is divided into two different areas, one larger area providing coverage and another with totally overlapping service area providing capacity.

Due to the different transmitting power of each TRXs of the cell a totally new HO mechanism is introduced. The new mechanism is based on the existing feature IUO.

The existing layer structure (regular/super-reuse) is utilised and the transceivers of BTS are divided into regular and super-reuse TRXs. We still continue to talk about super and regular layer.

The system structure when talking about Coverage Enhancements is a layer network: we have a coverage layer (provided by high-power transmitting TRXs, typically BCCH_TRX) and a capacity layer (provided by low-power transmitting TRXs, the others TRXs).

The feature is using some of the parameters related to IUO in order to regulate the Handover between the layer. Basically the call starts always in the coverage layer, but if the signal level exceed a predetermined threshold, the call can be handed over to the capacity layer. On the other hand, if the signal level falls below the threshold or the call suffers bad quality, the call is handed over to the coverage layer.

The analogy with the IUO type of HO mechanism is at the base of this HO mechanism.
SuperReuseEstMethod parameter is set to the new value **ICE** and defines the method with is used in the handover evaluation procedure when the HO algorithm calculates downlink signal level (if IUO is enabled we would have **AVE** or **MAX** value and the HO algorithm would calculate C/I for IUO, the fact that the parameter is set to ICE means automatically that Intelligent Coverage Enhancement feature is enabled and that layers are low-power and high-power layers).

The division into high-power and low-power TRXs is controlled with the parameter **TrxFrequencyType (FRT),** '0' value means high-power TRX (coverage TRX) and values from 1..16 means low-power TRX (capacity layer). If the transmitting power of low-power TRXs is the same, it is recommended to set the FRT=1 for each of the low-power TRXs.

When the above parameter is set to ICE value two new parameters are visible, those two parameters are thresholds and related Px and Nx needed for HO comparison:

superReuseGoodRxLevThreshold, (Px,Nx)
superReuseBadRxLevThreshold, (Px,Nx).

The first parameter is used for comparing the downlink signal level for triggering a handover to the super-reuse TRX (capacity TRXs). The second parameter is used for comparing the downlink level for triggering handover back to the regular TRX (coverage TRX).

The BSC allocates a traffic channel (TCH) for a call or for an inter-cell handover attempt between cells merely from the high-power TRX, that is, a high-power cell must have at least one high-power TRX, typically a BCCH TRX.

The basic procedure (for a call or for an inter-cell handover attempt between cells) is that the handover algorithm makes HSCE handover decisions based on the averaged downlink signal level of serving cell, that is, a call is handed over from a high-power TRX to a low-power TRX when the averaged downlink signal of the high-power cell is good enough to sustain a good radio link also in the low-power cell.

The possible types of handover for Handover Support for Coverage Enhancements are the following:
-intra-cell handover from a high-power TRX to a low-power TRX
-intra-cell handover from a low-power TRX to a high-power TRX
-intra-cell handover within a low-power frequency group.

However, the BSC may ignore the averaging procedure when the downlink signal (only one sample in the beginning of SDCCH channel) level on the high-power TRX exceeds a certain predetermined threshold. (It has to be taken into account that the handover decision is based on only one measurement and due to signal fading, the value is not so accurate than an averaged one, that is, direct access procedure.) The parameter DirectAccessLevel indicates whether a direct access to a low-power TRX is enabled. The parameter also determines the level which the downlink signal level on the high-power TRX must exceed in order to sustain a good radio link in the low-power TRX.

The BSC monitors the downlink signal level of serving cell during the call. The call is handed over from the high-power TRX to the low-power TRX always when the downlink RxLevel is good enough to sustain a good radio link. If the downlink RxLevel of the low-power TRX becomes worse, the call is handed over from the low-power TRX back to the high-power TRX.

The possible types of direct access are the following:
-intra-cell direct access from a dedicated control channel to a low-power TRX
-inter-cell direct access from a high-power cell to a low-power TRX of a high-power cell.

If there are no free traffic channels available on low-power TRXs, the BSC allocates a TCH for the call or for the inter-cell handover attempt from a high-power TRX.

14 Enhanced Coverage by Frequency Hopping or "Reversed ICE" (S8, *OPTIONAL*)

As seen before the coverage can be enhanced by using booster, but another way to do it is the use the gain provided by frequency hopping.
Frequency hopping is mainly used to improve capacity in the cellular network. However, it can be used to improve coverage as well. Due to the frequency diversity gain provided by frequency hopping, the coverage of the cell can be increased up to 7(2-4) dB for slow moving mobiles.

The gain that the frequency diversity potentially delivers depends mostly on the number of frequencies included in the hopping sequence and also on the environment. In a rural area, a line-of-sight condition often exists and the multipath effect is not very strong. Therefore, the gain produced by FH is clearly lower than in a city environment.

Because the frequency hopping gain depends on the number of hopping frequencies, RF hopping, is often the only way to achieve maximum gain. However, in RF hopping the BCCH transceiver can not hop or fully utilize the frequency diversity gain. Although the BCCH channel itself is robust enough to provide coverage in the edge of the cell, the BCCH TCH timeslots do not provide extended coverage.
In order to utilize the frequency hopping gain, the channel allocation and handover algorithm must be modified to support the proposed solution.
Therefore, Nokia is introducing a new solution for enhancing coverage.
The new solution provides the network operators with the tools to intelligently improve the coverage of their networks. Because the hopping transceivers provide more coverage than the BCCH one, the new solution must handle the channel allocation to the appropriate network layer. The new solution also provides seamless handovers between two layers according to the path loss or quality of the connection

14.1 Description of the feature

The basic idea of the new feature is to use RF frequency hopping gain, especially the frequency diversity gain, to build coverage for the radio network. Due to the RF hopping, the cell is composed of two different logical layers by means of coverage (stationary or slow moving mobile stations). The bigger area consists of hopping TRXs and it is serves mobile stations which are located on the edge of the cell. The smaller area consists of BCCH TRX, which serve mobiles, which are located close to the base station.

Because of the robustness of the BCCH and SDCCH channel, the call setups are provided on the edge of the cell, but the calls have to be assigned immediately to the hopping TRXs if the path loss of the connection is not good enough. The BSC handover algorithm takes care of the call setup and handover during the call (the functionality is already implemented to BSC (Handover Support for Coverage Enhancement) as explained in the previous chapter).

The BSC monitors the downlink signal level of the serving cell. The call is always handed over from the hopping TRX to BCCH TRX when the downlink RxLevel is good enough (more than an upper threshold **defined** by the parameter **SuperReuseGoodRxLevThreshold*)*** to sustain a good radio link. If the downlink RxLevel or quality of the BCCH TRX becomes worse (level less than a lower threshold defined by the parameter **SuperReuseBadRXLevThreshold**), the call is handed over from the BCCH TRX back to the hopping TRX.

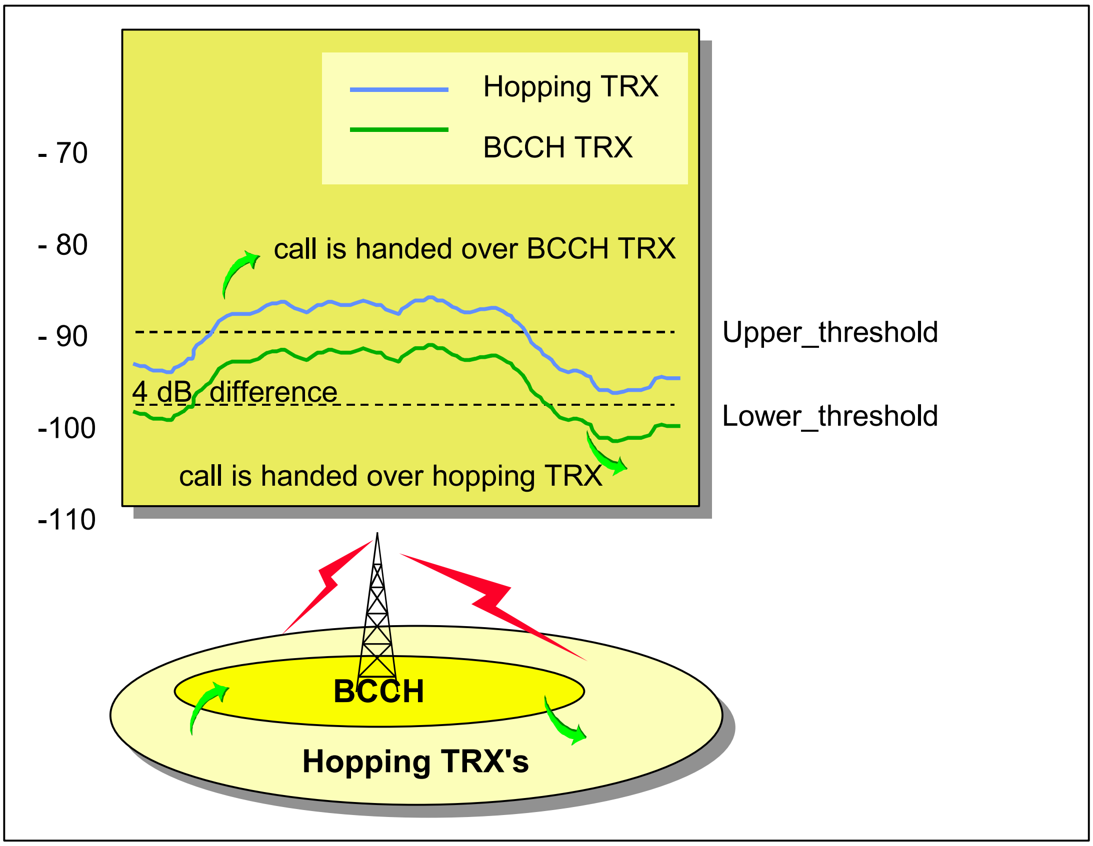


Fig. 1 Handover process in Reversed ICE

Once again we have a two layers network where the capacity layer (or low power layer) consists of the BCCH layer characterised this time by setting **trxFrequencyType** (or **FRT**) =1..16 and the coverage layer (or high power layer) consists of the hopping TCH TRXs characterised by FRT=0. Nothing prevent the use of more TRX in the capacity layer: meaning that in a (2+2)/cell configuration BCCH TRX 1, FRT=1 won't hop, TCH TRX2, FRT=2 can RF hop using in this case the hopping parameters specified for the underlay, TCH TRX3, FRT=0 and TCH TRX4, FRT=0 will form the overlay/coverage/high power layer and will RF hop using the parameter set for the regular layer.

The setting of the parameter FRT is opposite to the one used for ICE, and the concept itself can be seen as "Reversed" ICE.

Currently, Intelligent Underlay Overlay (IUO) can be used simultaneously with frequency hopping in the same cell (IFH feature).
The Handover Support for Coverage Enhancement uses the same TRX super reuse frequency group (**trxFrequencyType** (0..16)) parameters as the Intelligent Underlay Overlay to define different layers on the cell.
Enhanced Coverage by Frequency Hopping allows the BCCH TRXs to be set to the underlay layer and other TRXs to the overlay layer. The same layer allocation can be used on the Handover Support for Coverage Enhancement configuration to implement the radio frequency hopping for the cell layer. By combining these two features, the operator can enhance the coverage of the network.

NOTE: The Enhanced Coverage by Frequency Hopping is an *OPTIONAL* feature and is implemented only for RF hopping.

14.2 Parameters

Once set **SuperReuseEstMethod = ICE**, the IUO parameters plus the ICE parameters can be bent for this new functionality. Of course RF Hopping should be enabled in order to have the feature working.
The following BTS parameters, already defined in previous BSS version, have new optionality:

- Underlay BTS Hopping Mode (UHOP)
- Underlay Mobile Allocation Frequency List (UMAL)
- Underlay Hopping Sequence Number (UHSN)
- Underlay MAIO Offset (UMO)
- Background Underlay BTS Hopping Mode (BUHOP)
- Background Underlay Mobile Allocation Frequency List (BUMAL)
- Background Underlay Hopping Sequence Number (BUHSN)
- Background Underlay MAIO Offset (BUMO)

and for the following parameters the Flexible MAIO management option must also be set on:
- Underlay MAIO Step (UMS)
- Background Underlay MAIO Step (BUMS)

Note: The parameters are visible only when the Intelligent Frequency Hopping feature is activated either with the Intelligent Underlay Overlay feature or with the Handover Support for Coverage Enhancement feature. In S7 the parameters were visible when the Intelligent Frequency Hopping was activated with the Intelligent Underlay Overlay.

15 THE EXTENDED CELL

This feature enables the call to be handed over from an 'inner' cell to an 'outer' cell in extended cell environment. The handover decision is based on the measured and averaged timing advance values and the lower timing advance threshold defined for the 'outer' cell. The radius of extended cell can be defined by the parameter **radiusExtension (0 ... 67)**.

If the lower MS-BTS distance process is set **on** and the averaged timing advance value is smaller than or equal to the lower timing advance threshold, **minMSDistanceHOThreshold (0...63)**, the call will be handed over to an 'outer' cell. The target cell selection will be made according to the forced handover criteria. In both minimum and maximum distance handover cases the averaging window size and the threshold comparison parameters n and p are indicated by the same parameters: **msDistanceAveragingParam (1 ... 32)** and **msDistanceHoThresholdParam (ms max range (0 ... 63), Px/Nx (1 ... 32))**.

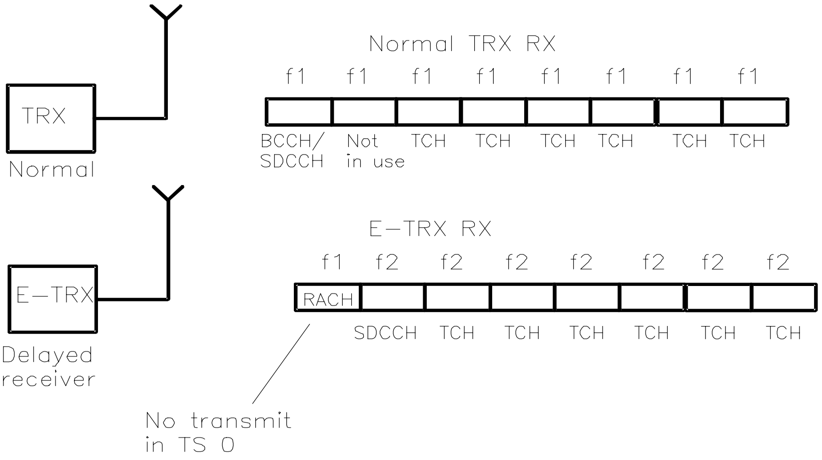
Note: The handover from an inner cell to an outer cell is made at least according to the existing handover distance criteria. A handover may also occur due to other criteria (power budget, RX level, RX quality) if required.

In idle mode the MS can be camped on either 'inner' or 'outer' cell. The camping to the 'outer' cell can happen even if the MS is in the 'inner' cell area, and vice versa. When the MS tries to make a call, it sends a RACH burst. If the MS has been camped on a wrong cell, it will change the cell. The cell change is based on the failure of the RACH burst and on the cell reselection based on path loss criterion C1.

15.1 IMPROVED SOLUTION FOR EXTENDED CELL (S6)

In GSM900 the cell radius of an ordinary cell is 35 km. In some case e.g. in large rural areas, a cell of that size may be too small compared to the coverage required in the area. This new feature in S6 increases the cell radius up to about 70 km which means that this kind of cell covers an area four times bigger than an ordinary cell.

The difference between the S5 extended cell solution and this new improved extended cell solution is that the S5 solution is based on two separate cells, which is not fully supported by some mobiles, and this new extended cell implementation is based on one-BCCH and two TRX solution. Thus, different TRXs serve normal area and extended area. The TRX which serves normal area is normally configured with BCCH/SDCCH and TCHs. The timing of the receiver of the TRX, which serves extended area (E-TRX), has been delayed so that it can serve the area beyond 35 kilometers. The time slot 0 of the E-TRX is tuned to the BCCH frequency in order to get RACH-bursts from extended area. The timing of transmitters is same in both TRX and E-TRX. See following picture. If more capacity is needed either in normal area or extended area more TRXs can be added as required to serve those areas. Only limitation for adding TRXs per cell is coming from BTS side.



The radius extension of an extended cell can be defined by the parameter **radiusExtension (0 ... 35, 0 ... 67)**. The transceiver can be selected to be either normal or extended transceiver by the parameter **eTRrxInd (E / N)** and an adjacent cell can be selected to be either normal or extended cell by the parameter **HOTargetArea (0 ... 3)**. The call is handed over to a normal area of an extended cell, when the threshold for the minimum value of the timing advance, **MSDistanceHOThresholdExtCellMin (0 ... 63)**, is reached, in case of DE34/DF34. In case of DE21, the call is handed over to an inner or another cell. The call is handed over to an extended area of an extended cell, when the threshold for the maximum value of the timing advance, **MSDistanceHOThresholdExtCellMax (0 ... 63)**, is reached, in case of DE34/DF34. In case of DE21, the call is handed over to an outer or another cell.

16 Dynamic HotSpot (S8, *OPTIONAL*)

16.1 Purpose of function class

Capacity of frequency hopping network is limited by the number of available traffic channels (hard blocking). However, capacity can be limited also by interference (soft blocking) if frequencies are reused tightly. Thus, when the load of an interference-limited network increases, the quality decreases respectively.
In a soft blocking limited network, the loading of the network has to be carefully controlled in order to guarantee the good quality and low dropped call rate. Without load control, the interference level is not verified but the BSC always tries to establish further calls if there are radio time slots available. If there is too much interference, the number of dropped calls or bad signal quality increases.

Note 1: The BSC monitors the level of interference by means of the measurement results reported by the MS/BTS

Note 2: The softblocking algorithm is based on the following criteria:
- traffic intensity in a cell
- radio connection quality in the interfered cells

Dynamic hotspot is a feature designed to control the traffic load of a frequency hopping radio network on the basis of interference and hence to achieve a higher radio network capacity in a network in which frequencies are reused tightly. Dynamic hotspot makes it possible to reuse hopping TRX frequencies very effectively without quality degradation. This is because the BSC can limit traffic intensity in areas in which the interference intends to increase above acceptable level. As a result, the quality of frequency hopping network is kept good and the number of dropped calls decreases.
Additionally, when the traffic of the network is unequally distributed, cells in high traffic concentration areas (hot spots) can dynamically and safely handle more traffic because the amount of interference is kept low when the dynamic hotspot is in use.

16.2 Dynamic Hotspot in TCH allocation

Dynamic Hotspot is applied to traffic channel allocation from frequency hopping (for more information, see Radio Frequency Hopping 7.4.2) BTS in the following situations:

-During a call
-During an internal inter-cell handover
-During an external handover
-During an underlay-overlay handover (for more information, see Intelligent Underlay-Overlay chapter 12).

Dynamic Hotspot is not normally applied during an intra-cell handover because intra-cell handover does not increase interference in the serving cell. However, in these two cases Dynamic Hotspot is applied during an intra-cell handover:

-Intra-cell handover is carried out from a super-reuse TRX to a regular TRX
-Intra-cell handover is carried out from a regular TRX to a super-reuse TRX.

Dynamic Hotspot is not applied when a TCH is allocated from a non-hopping TRX.
There are two cases when a TRX does not hop:
-Hopping is not used in the BTS at all
-BCCH TRX does not hop when the hopping mode is RF hopping.
Dynamic Hotspot is not applied when an internal inter-cell handover is performed because of bad signal quality in the source cell.

16.3 Dynamic Hotspot algorithm

Dynamic Hotspot application is a based on the following criteria:

-The traffic intensity in the serving cell
-The signal quality in the adjacent cells.

The BSC begins to apply the Dynamic Hotspot algorithm in radio channel allocation when the number of busy TSLs in the serving BTS exceeds a predetermined threshold.
This threshold is determined on a cell-by-cell basis by the parameter
softblocking_threshold_on_regular_frequencies (0..255) or, respectively,
softblocking_threshold_on_super_reuse_frequencies (0..255), depending on the type of the resource allocation request.
If the number of the busy TSLs in the serving BTS is smaller than the threshold, the radio resource management may always allocate a TCH according to the requirements included in the resource request, that is, Dynamic Hotspot is not used.
When the number of the busy TSLs in the serving BTS exceeds the threshold softblocking**_threshold_on_regular_frequencies** (or, if the resource request is a super-reuse request, the threshold is softblocking**_threshold_on_super_reuse_frequencies**), the signal quality is verified during TCH channel allocation.
This is done in those adjacent cells which use the same hopping frequencies as the serving BTS and which are close enough to be interfered with by the serving cell (therefore being characterised by the parameter **Interfered_Cell (0..3)**)
On the basis of this verification, the BSC calculates a probability which is used to determine whether a TCH can be allocated or not.
Adjacent cell signal quality is verified only in the following two ways:

-At the regular frequencies if regular TCH allocation is requested
-At the super-reuse frequencies if a super-reuse TCH is requested.

The signal quality is described as the proportion of bad samples to all samples in the adj. cell signal quality measurements, so it's calculated in % to be compared with quality thresholds.
The following cases determine if the request is accepted or not. Verification is based on the signal quality in adjacent cells:

-If the signal quality is good in every interfered cell, the probability of TCH allocation is 1 (100 per cent). Dynamic Hotspot does not limit the allocation of the TCH.

-If the signal quality is below the acceptable level on a single interfered cell, the probability of allocation is 0 (0 per cent). Dynamic Hotspot does not allow the allocation of a TCH.
-If the signal quality is at least acceptable (good signal quality or between good and bad signal quality) in every interfered cell (but not good in all interfered cells), an adjacent-cell specific probability of channel allocation is determined for each adjacent cell.

This is done by comparing the adjacent cell signal quality with the signal quality threshold table whose parameters are set on BSC level.
The operator defines the threshold table (see the example below).
The final probability is the product of multiplying all adjacent-cell specific probabilities together.
The probability is then compared to a fixed reference value (set to be *50*). The TCH request is accepted if the probability is higher than the reference value.

Example:

A super-reuse TCH is requested from a RF hopping BTS.
The number of the busy TSLs exceeds the threshold **softblocking_threshold_on_super_reuse_frequencies**, thus the Dynamic Hotspot algorithm is applied.
The serving BTS has two interfered adjacent cells, A and B, which use the same hopping frequencies as the serving BTS.
The signal quality in cell A is below BadQualLimit **but** above SigQualLimit1.
The signal quality in cell B is below SigQualLimit2 but above GoodQualLimit.
The operator has defined the probabilities of TCH allocation according to the following table:

Signal Quality %	Probability %
>= BadQualLimit	**0**
< BadQualLimit **>= SigQualLimit1**	**51 (TCHProb1)**
< SigQualLimit1 **>= SigQualLimit2**	**72 (TCHProb2)**
< SigQualLimit2 **>=QoodQualLimit**	**80 (TCHProb3)**

< QoodQualLimit	**100**

Fig .1 Signal Quality Threshold table

The probability of allocating a TCH in this example is 40 per cent (0.51*0.80 = 0.40).
The resource request is rejected because the probability is lower than the fixed reference value (50).
GoodQualLimit, BadQualLimit, SigQualLimits and TCHProbability are adjustable parameters.
In our generic examples let's give some possible values:
BadQualLimit (0..100) = 90%
SigQualLimit1 (0..100) = 30%
SigQualLimit2 (0..100) = 20%
GoodQualLimit (0..100) = 10%
The proportion given in % for signal quality for cell A results in 50%.
The proportion given in % for signal quality for cell B results in 15%.
According to the table above the probability to allocate TCH in cell A is 51% and in cell B is 80%. The average probability will be then 0.51*0.80 meaning 40%. Comparison with the fixed value 50% leads to rejection of the resource request.
TCHProbability1 (0..100), **TCHProbability2 (0..100)** and **TCHProbability3 (0..100)** are defined by the operator.
When Signal Quality % is bigger or equal to BadQualityLimit the probability to allocate a TCH is fixed to 0, when it is lower than GoodQualLimit the probability to allocate a TCH is fixed to 100%.

16.3.1 16.3.1 Adjacent cell signal quality calculation

The signal quality in the adjacent cell is the signal qualities of the regular or super-reuse TRXs on average. The average signal quality is counted from the last two 5 second measurement results.
The calculation of the signal quality depends on the interference type defined in the adjacent cell data with the parameter InterferedCell:

1.Regular TCH requested and interference type is 'regular'
-the signal quality in the adjacent cell is the average signal quality of the regular TRXs

2.Super-reuse TCH requested and interference type is 'regular'
-no interference = signal quality good = TCH probability '1'

3.Super-reuse TCH requested and interference type is 'super-reuse'
-the signal quality in the adjacent cell is the average signal quality of the super-reuse TRXs

4.Regular TCH requested and interference type is 'super-reuse'
-no interference = signal quality good = TCH probability '1'

5.Regular TCH requested and interference type is 'regular and super-reuse'
-the signal quality in the adjacent cell is the average signal quality of the regular TRXs

6.Super-reuse TCH requested and interference type is 'regular and super-reuse'
-the signal quality in the adjacent cell is the average signal quality of the super-reuse TRXs

7.Regular TCH requested and interference type is 'no interference'
-no interference = signal quality good = TCH probability '1'

8.Super-reuse TCH requested and interference type is 'no interference'
-no interference = signal quality good = TCH probability '1'

When the Dynamic Hotspot algorithm has accepted the TCH request, the channel allocation procedure continues normally.

16.4 Parameters

The parameters in the Dynamic Hotspot feature are listed below.
With the BTS-specific parameter softblocking**_threshold_on_regular_frequencies** the operator defines the threshold for the number of half (if half rate TSLs exist) or fully occupied TCH-TSLs on regular TRXs in a cell. If the traffic intensity on regular frequencies exceeds the threshold, the Dynamic Hotspot feature is activated in the BTS.
The values range from 0 to 255.
With the BTS-specific parameter softblocking**_threshold_on_super_reuse_frequencies** the operator defines the threshold for the number of half or fully occupied TCH-TSLs on super-reuse TRXs in a cell. If the traffic intensity on super-reuse frequencies exceeds the threshold, the softblocking procedure is activated in the BTS.
The values range from 0 to 255.
The BTS-specific parameter interfered_cell (defined on adj. cell basis) defines whether or not a BTS to which an adjacent cell is being defined is likely to cause interference in the adjacent cell. Interference type can have the following values:

0	No interference
1	Interference on regular frequencies
2	Interference on super-reuse frequencies
3	Interference on regular and super-reuse frequencies.

Signal quality threshold table is defined with the following parameters:

-bad_quality_limit	(0..100)
-good_quality_limit	(0..100)
-signal_quality_limit_1	(0..100)
-signal_quality_limit_2	(0..100)
-TCH_probability_1	(0..100)
-TCH_probability_2	(0..100)
-TCH_probability_3 .	(0..100)

The default value for the threshold table parameters is 100.
The quality limits in the threshold table are the threshold values for the adjacent cell signal quality (the signal quality is described as the proportion of bad samples to all samples in the signal quality measurement).
The smaller the value of the signal quality, the better the quality.
The probability values in the threshold table determine a TCH allocation probability.
The signal quality limits have the following dependence:
GQL <= SQL2 <= SQL1 <= BQL.
The TCH probabilities have the following dependence:
TCP1 <= TCP2 <= TCP3.

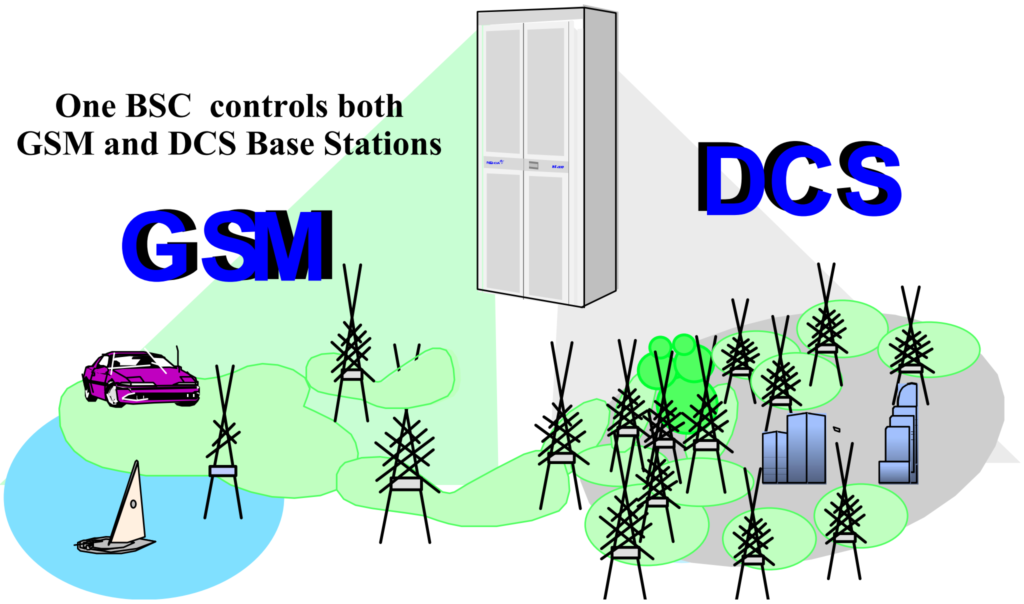
16.5 Adjacent cell signal quality measurements : know-how

The Radio Connection Supervision sends adjacent cell signal quality measurement results to the RRM. The Dynamic Hotspot algorithm needs the signal quality measurements, because on the basis of those, the resource request is either accepted or not accepted. The signal quality is presented as the number of bad uplink/downlink quality samples and the number of all samples on TRX level.
Note 1: Bad quality samples are not reported if measured signal level is equal or less than -100 dBm.
RCS sends the message (containing measurement results) at 5 second intervals (if the Dynamic Hotspot feature is activated in the BSC). One message contains the measurement results for all TRXs controlled by the same BCSU. The RRM stores the measurement results in its TCH data structures in both active and spare MCMU (the active RRM updates the spare RRM with a message). The last two measurement results for a specific TRX are kept in the memory of the RRM.
Signal quality in specific adjacent cell is counted either as the percentage of bad samples in all samples of regular TRXs or as the percentage of bad samples in all samples of super-reuse TRXs. The decision whether the signal quality is counted from the super-reuse or regular TRXs depends on the resource request and the interference type which the serving cell may cause to the adjacent cell.

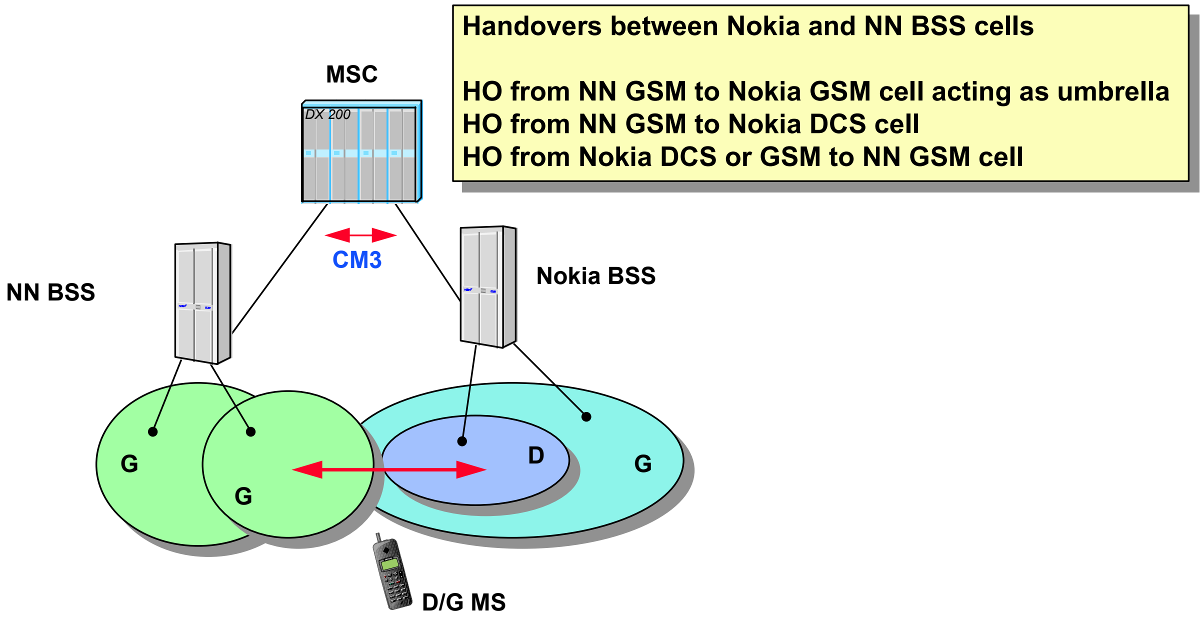
Note 2: The feature is activated setting dyn_hotspot_usage (ON, OFF) = ON and is an *OPTIONAL* feature.
Note 3: It is valid in a frequency hopping network (no matter if BB or RF hopping).

17 Dual Band GSM/DCS Network Operation in S5

The Dual Band GSM/DCS Network Operation feature allows the network operation to build a network with both GSM and DCS cells accessible for the MSs. It is important to remember that the Dual Band GSM/DCS requires multi band MS support. The principle of dual band operation is to provide the dual band MS the neighbour cell information concerning cells from both bands. The handover between the bands is based on the measurements sent from the MS and from the BTS.



The Dual Band GSM/DCS Network Operation can be used also in multivendor environment. A handover is possible for example from Nokia BSC / DCS cell to other users GSM cells as an external handover. The MSC / A interface support is needed to maintain the MS multi band capability after external handover (ClassMark 3 indication in A interface).



Handovers between Nokia and NN BSS cells

HO from NN GSM to Nokia GSM cell acting as umbrella
HO from NN GSM to Nokia DCS cell
HO from Nokia DCS or GSM to NN GSM cell

Traffic distribution measurements are introduced in S6. This measurement can be started from both the NMS2000 and the MML including all BTSs in one BSC.

The traffic distribution measurement is a BTS specific measurement. In the measurement the HO&PC algorithm measures the cumulative TCH holding time of single band subscribers and of dual band subscribers. It also counts the TCH reservations made by the single band and dual band subscribers. Here the TCH reservation means the starting of a HO&PC algorithm slave process in a TCH.

In S6 it is possible to control early classmark sending. The parameter **earlySendingIndication (Y/N)** is needed in indicating the early classmark sending in call setup phase by the MS. The parameter indicates whether the mobile will send the Classmark Change message after access to the network or not. The Classmark 3 defines the requirements for a mobile into the network.

Note: A dual band cell is a cell with adjacent cells allocated from both GSM and DCS frequency bands.

Parameters related to this feature

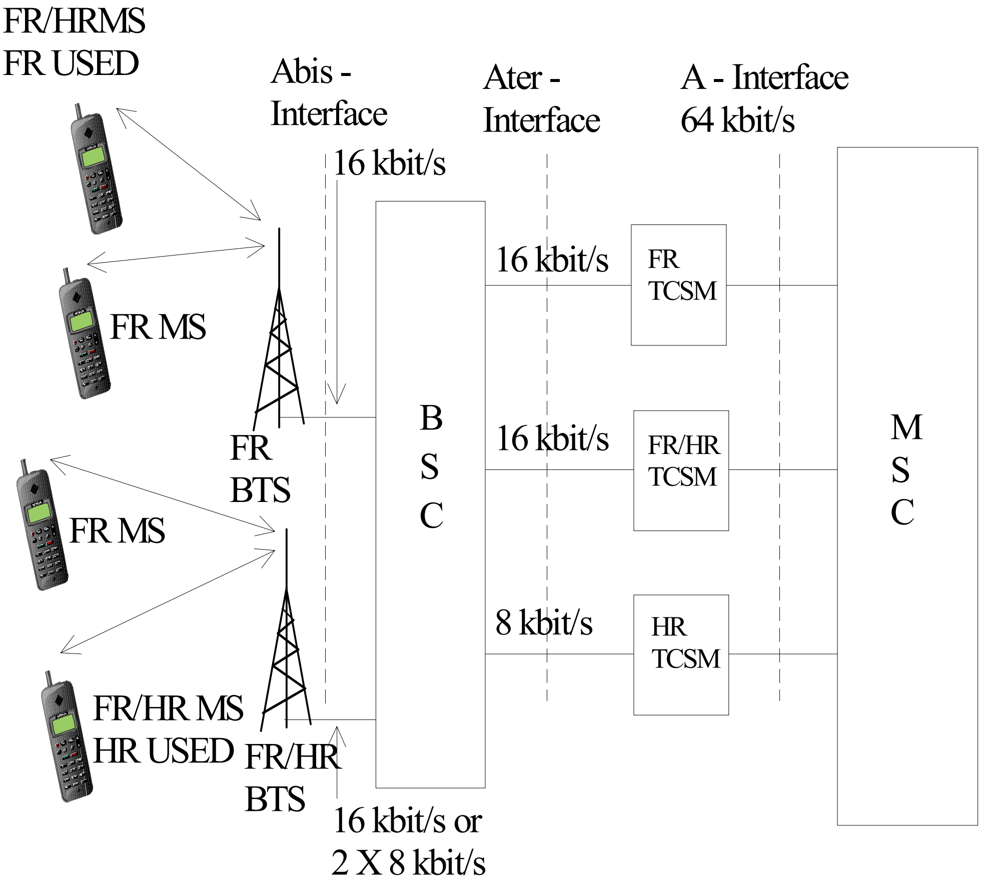
dual band cell	multiBandCell (Yes/No)
early sending indication	earlySendingIndication (Yes/No)
multiband cell reporting	multiBandCellReporting (0...3)

18 HALF RATE

Half Rate is a feature designed to maximize the spectrum efficiency by almost doubling the amount of radio resources as compared the use of the full rate traffic resources only.

Each radio time slot of the BTS TRX can be configured to be a full rate, half rate or dual rate TCH resource. In the last case the BSC will be able to allocate an idle radio time slot either for half rate or full rate coding dynamically on a call by call basis.

Full rate speech and data is coded and transferred by using 16 kbit/s channels in BSS. With the half rate coding 8 kbit/s transmission can be used on the Abis interface. The A- interface will support different types of transcoders capable of full rate coding or half rate coding or both. The utilization of a Half Rate (HR) and a Full Rate (FR) coding and corresponding transmission bit rates in Nokia system is introduced in the following picture:



It will be possible to introduce the half rate coding to existing full rate GSM/DCS network gradually. The BSS is able to co-operate with both old Full Rate mobiles and with new mobiles which support both Full and Half Rate.

Traffic channel allocation

In those cases where MSC does not uniquely determine the channel type, the BSC decides on the channel rate of the TCH to be allocated. The A interface circuit allocated by the MSC must enable the BSC to allocate a radio channel of requested type, the actual A interface circuit pool configuration determines how BSC should select the channel rate. In those cases when the A interface circuit which the MSC has allocated belongs to a pool which does not support the type of TCH, BSC wishes to allocate, then BSC can request the MSC to switch the circuit to the appropriate pool.

Type of traffic channel - half rate or full rate - to be allocated can be determined according to the actual traffic load of a cell. Full rate TCHs are allocated from the BTS until the number of free full rate resources are reduced below a particular lower limit, the half rate resources shall then be allocated. When the number of the free full rate resources of the cell increases above a particular upper limit, full rate TCHs can be allocated again.

The parameter consists of two threshold values, lower limit, **btsSpLoadDepTCHRate (0 ... 100)** and upper limit, **btsSpLoadDepTCHRate (0 ... 100)**. The former gives the limit value for the decreasing amount of free FR TCH resources from which HR TCHs shall be allocated; the latter determines the limit value for the increasing amount of free FR TCH resources when FR TCHs shall be allocated.

The limits shall be given as relative amount of free full rate TCH resources per working full rate TCH resources (%). The function can be deactivated by setting the lower limit higher than the upper limit (default value for the lower limit is 100% and for the upper limit 0%).

When the feature is activated and the lower limit is set to be higher than zero, last free full TCH resource will be split to two HR subchannels in TCH allocation. This makes it possible to determine the positive margin for the half rate TCH allocation in cells equipped only with one TRX without raising the lower limit value unnecessarily high.

While the value of the lower limit equals 0% then HR TCH resources are allocated for a speech or data call only if the MSC strictly requires a HR TCH regardless of the actual TCH configuration of the BTS.

Radio Resource Management of the BSC is able to optimize the allocation of the half rate traffic channel resources of the cell in such a way that they are primarily allocated from such radio timeslots where half rate call is already maintained.

Channel rate control in handovers

The channel rate can alter in handovers due to TCH resource reasons when only preferred channel rate without any channel rate change prohibition has initially been required in the radio resource request of MSC.

The operator will be provided with the means to determine at the BSC site extra constraints for the channel rate changes in internal inter-cell and intra-cell handovers; following different alternatives are possible:

- The source type of traffic channel shall be allocated primarily by the best candidate cell. If a suitable cell can not be found, then the other type of TCH can be allocated from the best possible cell.
- During the speech connection the source type of traffic channel shall be allocated primarily from the best cell. At the time of data connection the TCH shall be allocated from the best cell of the candidate list regardless of the call-maintaining TCH type.
- Channel rate changes are denied totally, i.e. the source type of channel is the only alternative in TCH allocation.
- The traffic channel of the channel rate which was determined to be preferred (initially in Assignment or Handover Request) by the MSC shall be allocated primarily.
- The TCH has to be allocated primarily from the best BTS of the handover candidate list regardless of the call-maintaining traffic channel type. This parameter value is not significant in intra-cell handovers; the same priority-setting method is applied for them as described in the first case above.

The interaction between cell load based radio channel allocation and the channel rate change control is:

- When the TCH is going to be allocated for internal handover and the channel rate changes are denied totally either by the MSC or by the BSC, then, neither of them will be allowed due to the cell-load-dependent resource conditions.

- When the TCH is going to be allocated for internal handovers and the source type of TCH is determined to be the preferred alternative, then a half rate channel shall be allocated for a call which already is going on a half rate channel regardless of the cell-load-dependent resource conditions.

Although the channel rate control is valid at BSS level for all internal handovers, they can be readjusted for intra-cell handovers in each BTS. In external handovers these parameters are not possible to apply because the source channel type and mode information is not transferred from the source BSS to the target BSS of the handover.

The parameter **tchRateInternalHo (1 ... 5)** which controls the channel rate in internal handovers at BSS level belongs to the BSC object class.

By default, the call-maintaining type of TCH shall be allocated in internal handovers.

The parameter **tchrateIntraCellHo** controlling the Intra-cell handovers is adjustable BTS-specifically when necessary.
The default value of the parameter is that the TCH channel rate shall be determined according to the BSS level parameter also in intra-cell handovers.

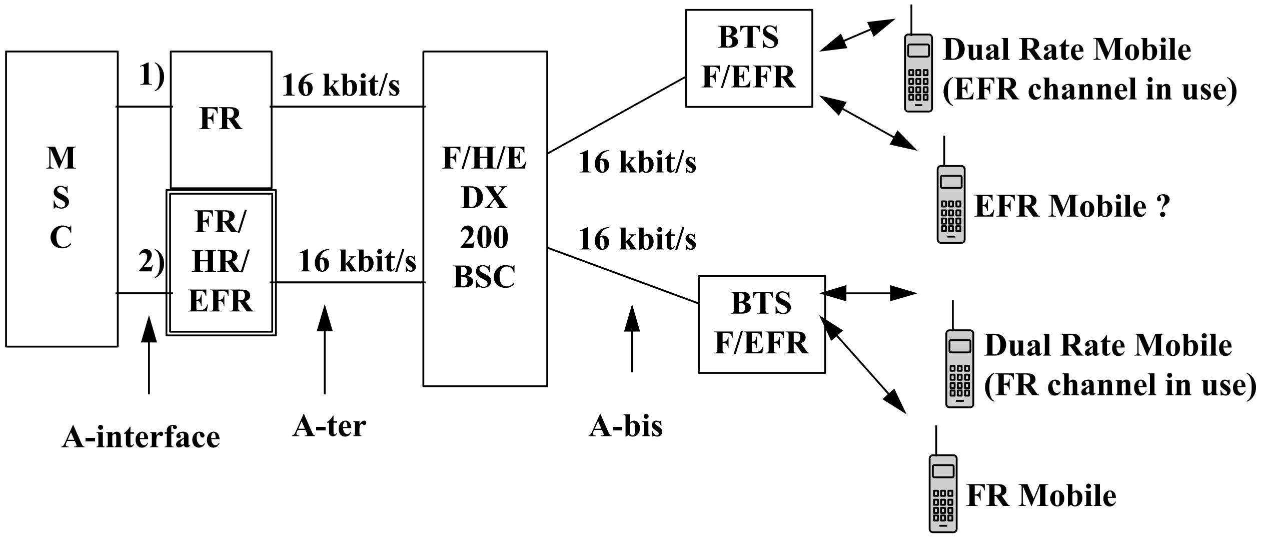
19 Enhanced Full Rate Codec (ETSI) (S6)

This feature introduces a new full rate speech coder to the BSS. Enhanced Full Rate (EFR) speech coder uses the existing GSM/DCS full rate channel coding but gives a considerably better performance in all channel conditions.

The tests indicate that in good channel conditions qualities better or comparable to ADPCM can be offered with this codec. TCSM2 will be SW upgradable to EFR.

From the Air interface dimensioning point of view no special attention has to be paid to EFR channels. A-interface and transcoders have to be dimensioned according to each type of pools.

EFR can coexists together with previous HR/FR ‘dual-codec’.



1) pool of old FR -TC's

2) dynamic triple-codec TC

Note: 1) & 2) can not co-exist if no support of pools by MSC

The basic information of a codec type comes from MSC. If MSC does not know anything about the types of codecs supported on per circuit group over A-interface then all A-interface channels must be equipped by TCSM2.

The BSC will make the final decision about the codec based upon input from the MSC, the BSS speech coder capabilities and possibly radio channel configurations and availability (FR/HR).

In the case of handover the BSC has the option to change the speech coder at the time of handover. For intra-BSC handover the BSC uses the previously stored information from the MSC/VLR about the speech coder preferences in the selection process.

BSC forwards the information of codec type to BTS in the channel activation message. BTS uses this information to configure activated RTSL to support either conventional full rate codec or EFR. Inband signaling between transcoder and BTS is used to control the transcoder codec selection on a call basis.

Parameters related to Half / Full Rate

BSC:	lower limit FR TCH resources	**btsLoadDepTCHRate (0...100)**
	upper limit FR TCH resources	**btsLoadDepTCHRate (0...100)**
BTS:	lower limit FR TCH resources	**btsLoadDepTCHRate (0...100)**
	upper limit FR TCH resources	**btsLoadDepTCHRate (0...100)**
	tch rate intra cell ho	**tchrateIntraCellHo (0...4)**

20 Background DATABASE

This feature enables the activation of several modified radio network parameters with one command. In previous releases the radio network objects had to be in LOCKED state before parameter modification. In S6 those parameters are modified to the background database and the whole database is activated by one command which causes the swapping of existing and background database. A restart to the Base Stations is needed for the changes to take effect.
The new background parameters (including S7) are the following:
BTS parameters:

- Background Network Color Code
- Background BTS Color Code
- Background BTS Hopping Mode
- Background Underlay BTS Hopping Mode
- Background Hopping Sequency Number 1
- Background Hopping Sequency Number 2
- Background Underlay Hopping Sequency Number
- Background MA Frequency list
- Background Underlay MA Frequency list
- Background MAIO Offset
- Background Underlay MAIO Offset
- Background MAIO Step
- Background Underlay MAIO Step

Adjacent Cell parameters:

- Background Network Color Code
- Background BTS Color Code
- Background Frequency Number of BCCH

TRX parameters:

- Background Frequency
- Background Optimum RX Level Uplink
- Background TRX Frequency Type
- Background Location Area Code of Interfering Cell 1 ... 10
- Background Cell Identification of Interfering Cell 1 ... 10
- Background Level Adjustment of Interfering Cell 1 ... 10
- Background C/I estimation weight parameter for Interfering Cell 1 ... 10
- Background C/I estimation type for Interfering Cell 1 ... 10
- Background direct access level (IUO) –109…-47 dBm

This new feature is created to help example for a new frequency plan and also for IUO parameter loading into network.

20.1 Background Loading of Radio Network Plan

A major part of frequency plan may require changing when new cells or channels are introduced to the network. Some times the entire plan is changed.
In an operation network, large changes are critical in regard to the time consumption and safety. The new plan must be taken into use overnight without remarkable degradation in the service.
If the new parameter set is downloaded from the OMC by the conventional way (i.e., first locking a TRX, then changing its frequency, and finally unlocking it), the whole operation for a large network may take too long.
This feature offers a better way to make large changes into the network: downloading into a background database. The following essential matters are covered:

- New data is loaded down as a background operation without disturbing traffic. The data may come either from the NMS2000 or from the BSC MML interface.
- Downloading errors are tolerated. Possible interrupted downloading may be repeated without disturbing traffic.
- New data can be quickly activated in the network independently from the downloading. Thus, disturbance in the network is remarkably shorter.
- Old data stays in the BSC as a back-up copy. It may be reactivated quickly.

21 High Speed Circuit Switched Data (HSCSD)

The high-speed circuit switched data feature provides accelerated data rates for end-user applications. Current trend is for increased demand for high data rate applications such as World Wide Web (WWW), file transfer and facsimile, which have so far been impractical to use in a mobile environment.

The Base Station System (BSS) implementation is to reserve a multiple set of basic (current) resources for one high speed data call. The data rate and number of reserved time slots varies between one and user application defined maximum. The variable rate is needed, for example, for handovers to a new cell if the requested data rate cannot be given right away. The BSS implementation of HSCSD supports simultaneous usage of four time slots per one HSCSD call. The following table (Table 1. Data rates achieved by HSCSD) presents corresponding maximum data rates with different channel codings:

RTSLs	9.6 kbit/s	14.4 kbit7s
1	9.6	14.4
2	19.2	28.8
3	28.8	43.2
4	38.4	57.6

Table 1. Data rates achieved by HSCSD

Both asynchronous and synchronous bearer services and transparent and non-transparent transfer modes are supported. Transparent HSCSD uses fixed data rate through the call but non-transparent HSCSD is flexible and the data rate can be changed during the call e.g. due to traffic situation. Radio interface is either symmetric or asymmetric according to MS capability. However, Abis interface and A interface are always symmetric. In A interface, HSCSD connection can be switched to one of the HSCSD supporting pools.

High Speed Circuit Switched Data is an optional feature in the BSC.

21.1.1 Description of the feature

In HSCSD, higher data rates are offered with several TCH/Fs for one connection. New functionality is needed in MS and Mobile Services Switched Centre (MSC) to split data to be carried in several radio interfaces TCH/Fs and to be combined in the other end. For cellular operations, HSCSD channels in the same connection are controlled as one radio link. For example, handover is made simultaneously for all channels in one HSCSD connection. On the A interface, HSCSD channels are multiplexed to one 64 kbit/s circuit.

The adaptation of the GSM transmission to other networks (for example, PSTN) is done by Interworking Functions (IWF) in MSC. On the MS side, the functional part which performs the adaptation between a terminal equipment and the GSM radio transmission part is called the Terminal Adaptation Function (TAF).

Transparent (T) service

In transparent data services, the radio interface transmission scheme provides only forward error correction. The throughput between IWF and TAF is constant. In HSCSD, this means that the requested data rate has to be fulfilled from the call setup to the release of the call, including possible handovers during the call. Radio interface user rates are requested in T service (e.g. 4.8, 9.6 or 14.4 kbit/s). In HSCSD, transparent service uses only bi-directional channels.

Non-transparent (NT) service and flexible channel allocation

In non-transparent data services the sent frames include redundancy bits to enable a receiver to detect remaining errors after forward error correction. With Radio Link Protocol (RLP), the receiver can test the correctness of the frame and if found not correct, send negative acknowledge to sender. The available throughput varies with the quality of basic transmission but the quality of the sent data is excellent.

NT service makes possible the use of flexible radio interface data rate. For HSCSD, this means that reserved radio resources can also vary during a call. Depending on the available resources, the HSCSD connection can occupy channels from one to user defined maximum number of channels. New procedures resource upgrade and resource downgrade are introduced in the BSC.

MS multislot capability

Currently used MSs (Type 1) can either receive, send or monitor neighbour cell field strengths at a time. MS needs time to adapt between different modes. Transmitting in the same time slot as the receiving is made possible by shifting the transmitting time slots.

Number of channels for a HSCSD connection depends on how many channels the MS is able to receive or transmit and how fast it can do the adaptations between its operation modes. With MS multislot capability, the BSC can determine the kind of HSCSD connections it can allocate for a certain MS.

The allocated channel may be from non-consecutive time slots as long as the MS multislot capability is taken into account. For type 1 MSs, it means that in practice almost always the consecutive time slots have to be allocated. Type 2 MSs can receive and transmit simultaneously, which makes radio channel allocation more flexible.

Radio interface

In a symmetric HSCSD connection, all the channels transfer data to both uplink and downlink directions. In order to enable greater data rates for type 1 MSs, it is possible to transmit to downlink direction with more channels than to uplink direction. Channels that transmit to both directions are called bi-directional channels and channels that transmit only to the downlink direction are called uni-directional channels.

At least one bi-directional channel is required for each HSCSD connection. In both symmetric and asymmetric HSCSD configurations one bi-directional channel, the main channel, carries a Fast Associated Control Channel (FACCH) used for all the signalling not carried on the Slow Associated Control Channels (SACCH).

Individual signal level and quality reporting is used for all the bi-directional channels. The quality measurements reported on the main channel are based on the worst downlink quality measured among the main and the uni-directional downlink time slots used.

Radio link timeout

Only the main SACCH is used for determining Base Station System (BSS) radio link failure.

21.1.2 Radio resource allocation

An HSCSD call uses a multislot configuration consisting of one or several TCH/F(s). HSCSD parameters for channel allocation are:

- required total radio interface data rate (NT service)
- requested radio interface user rate (T service)
- maximum number of sub-channels
- service (T/NT)
- MS multislot capability
- allowed radio interface rates per channel.

The BSC receives the parameters in either ASSIGNMENT REQUEST or HANDOVER REQUEST message. Exception is the MS multislot class, which is not a part of the ASSIGNMENT REQUEST message. In a call setup, the MS informs its multislot class in CLASSMARK CHANGE message before the assignment.

The BSC tries to allocate as many channels as needed to fulfil the required total data rate. The fastest appropriate data rate per channel is used. For example, when the required data rate for T service is 14.4 kbit/s, one 14.4 kbit/s channel is chosen. If only 9.6 kbit/s channel coding is supported, two 9.6

kbit/s channels are allocated, resulting in 19.2 kbit/s total data rate. In T service, extra data bits are padded with fill by TAF or IWF respectively in MS or MSC. If total data rate 9.6 or 19.2 kbit/s for T service is requested, 9.6 kbit/s channel coding is used.

Channels in a HSCSD connection must be allocated from the same transceiver (TRX). MS multislot capability determines how far the allocated time slots can be from each other. The number of channels for HSCSD connection at the first allocation after request or during the connection by downgrade procedure can be controlled with parameterisation (see chapter HSCSD load control). With downgrade procedure, part of the channels of the HSCSD connection are released for other use still maintaining the HSCSD connection with reduced total data rate.

The means to improve HSCSD service at the call setup or during the connection are directed retry and upgrade pending procedures. By upgrade procedure, new channels are activated and added to a current HSCSD connection, thus increasing the total data rate.

For transparent HSCSD connection, certain number of TCH/Fs must be allocated to meet the requested total data rate. In call setup, if there are not enough channels in a cell, directed retry (DR) procedure could be used. If target cell in handover cannot provide the requested total data rate, the DR attempt is terminated and the call is released.

A non-transparent HSCSD call can be started with less TCH/Fs than required. At least one channel is allocated for HSCSD connection if there are free resources available in a cell. Upgrade pending procedure is started if the required total radio interface data rate cannot be fulfilled at the initial channel allocation or if the number of channels is decreased during the connection. Pending is maintained until the required data rate is reached.

Channel allocation parameters may change during a non-transparent HSCSD call, for example the user may change the required total data rate. The MSC indicates the change by sending ASSIGNMENT REQUEST message to the BSC. If a contradiction between the new parameters and the used radio interface resources exists, the resource downgrade is needed.

21.1.3 Power Control and Handover algorithm

Power control

Power control is made individually for every bi-directional channel. The MS neglects power control information on a unidirectional channel. The BTS is commanded to use same power in uni-directional channels as in the main channel. Power control is not made during automatic link adaptation signalling.

Handover

Any bi-directional HSCSD channel can trigger a handover. ALA is prohibited during handover signalling. All existing handover reasons are supported.

21.1.4 Restrictions

HSCSD configurations up to four TCH/Fs are supported in BSS7 implementation.

HSCSD and 14.4 kbit/s data services can be employed only when the BSC is equipped with the Bit-oriented Group Switch (GSWB).

HSCSD and 14.4 kbit/s data services are supported only by the second generation transcoder submultiplexer (TCSM2).

ALA procedure is not used in T service.

4.8/6.0 kbit/s channel coding is not supported for HSCSD connections.

Resource upgrade and downgrade procedures are not used in T service.

Change of the main channel during the call is not supported.

Non-consecutive channel allocations are not allocated for T requests.

21.1.5 Interaction with other features

Frequency hopping

Same frequency hopping sequence is used for all the channels in the HSCSD configuration. When base band frequency hopping is in use, HSCSD channels in the same configuration must be allocated from the same hopping group.

Intelligent Underlay Overlay (IUO)

HSCSD radio resource allocation parameters are defined separately for regular layer. Resource upgrades are not done in regular frequency area.

In super-reuse layer, all the channels in HSCSD configuration must fulfil the interference band recommendation defined by BSC.

Trunk Reservation

When trunk reservation algorithm is applied:

- non-transparent connection is started with one channel and the connection is upgraded if possible. Trunk reservation algorithm is used for every channel allocation.

- for transparent connection, the number of free traffic channels (n) is modified: n = n - number of channels needed for T connection + 1

Queuing

Call setup or handover attempts in queue are preferred to upgrade pending HSCSD connections in channel allocation algorithm.

Transparent HSCSD connections cannot enter a cell through queueing. Non-transparent HSCSD connections can have the first channel through queuing.

Extended cell range

HSCSD load is controlled separately in extended and normal areas.

FACCH call setup

FACCH call setup is not made for transparent HSCSD connections requiring more than one channel. Non-transparent connection is started with one channel and the possibility to resource upgrade is checked after the assignment.

Traffic reason handover

Traffic reason handovers are made only to single slot connections and HSCSD connections requiring one channel.

Dual band network operation

System information messages Sys_Info_5, Sys_Info_5bis, Sys_Info_5ter and Sys_Info_6 are sent only in the main channel.

21.1.6 HSCSD load control

With parameter **minHSCSDcapacityCell (0..100%)**, a certain proportion of the cell capacity is offered for HSCSD use. In a low traffic load situation, the HSCSD calls can have more traffic channels (TCHs) than indicated by the parameter. Also minimum HSCSD capacity may not be reached due to single slot traffic congestion.

In a highly loaded cell, it is possible to restrict the allocation of multislot configurations by parameter **upperLimitCellLoadHSCSD (0..100%)**. When traffic load increases over the value of the parameter, each new HSCSD call is started with only one channel. Exceptions to this rule are:

- minimum HSCSD capacity of the cell is not completely in use

- service request is of transparent type.

Time resource upgrades are not made under multislot limitation. As long as the load of the cell is greater than upperLimitCellLoadHSCSD value and the minimum HSCSD capacity is in use, the HSCSD capacity is reduced by downgrading one of the HSCSD connections for every incoming call.

Channels for transparent HSCSD request are not reserved if it leads to a multislot limitation situation.

In the state where multislot allocation and HSCSD resource upgrades are allowed:

- if either the HSCSD load is more than minHSCSDcapacityCell or the total cell load is more than upperLimitCellLoadHSCSD, it causes no change in state;

- when the HSCSD load is more than minHSCSDcapacityCell and the total cell load is more than upperLimitCellLoadHSCSD, HSCSD resource upgrades and multislot allocations are denied and one resource downgrade is made for one of the HSCSD connection for every new channel allocation.

In the state where multislot allocation and resource upgrades are denied and downgrade for every new channel allocation is done:

- when the HSCSD load is less than minHSCSDcapacityCell or the total cell load is less than upperLimitCellLoadHSCSD, multislot allocation and resource upgrade are still denied but HSCSD resource downgrade for every new allocation is stopped.

- when the total cell load is less than **lowerLimitCellLoadHSCSD (0..100%)**, multislot allocation and resource upgrades are allowed.

Resource upgrades are denied in the Intelligent Underlay-Overlay (IUO) regular frequency area. The parameter **upperLimitRegularLoadHSCSD (0..100%)** determines the number of occupied TCHs in the IUO cell regular frequency area where single slot allocation is started. When the regular area load is under the threshold, multislot allocations are possible. When the threshold is exceeded, multislot allocations are denied and one resource downgrade is made for one of the HSCSD connection for every new channel allocation.

In super-reuse frequencies, the HSCSD load is controlled with parameters minHSCSDcapacityCell, upperLimitCellLoadHSCSD and lowerLimitCellLoadHSCSD as in normal cells. The number of TCHs defined by the parameters is counted from the whole cell resources.

Parameter **upgradeGuardTimeHSCSD (0..65535 s)** determines a guard time between two consecutive resource upgrades. However, if the data rate can be increased significantly, the resource upgrade procedure can be made before the end of the guard time. Parameter **upgradeGainHSCSD (0, 33, 55, 100%)** determines the needed gain of the increased number of used channels before upgrade during guard time can be made. For example, an upgrade from two to three channels gives a 50% gain in data rate and upgrade from one to two gives a 100% gain.

The number of timeslots to be released in the downgrade is defined by a parameter **minExhaustHSCSD (1..4)**.

Parameter **downgradeGuardTimeHSCSD (0..65535 s)** determines a guard time between two consecutive resource downgrades. When the downgrade guard timer expires and the cell is totally congested, the downgrade is done if there is a call in any of the queues.

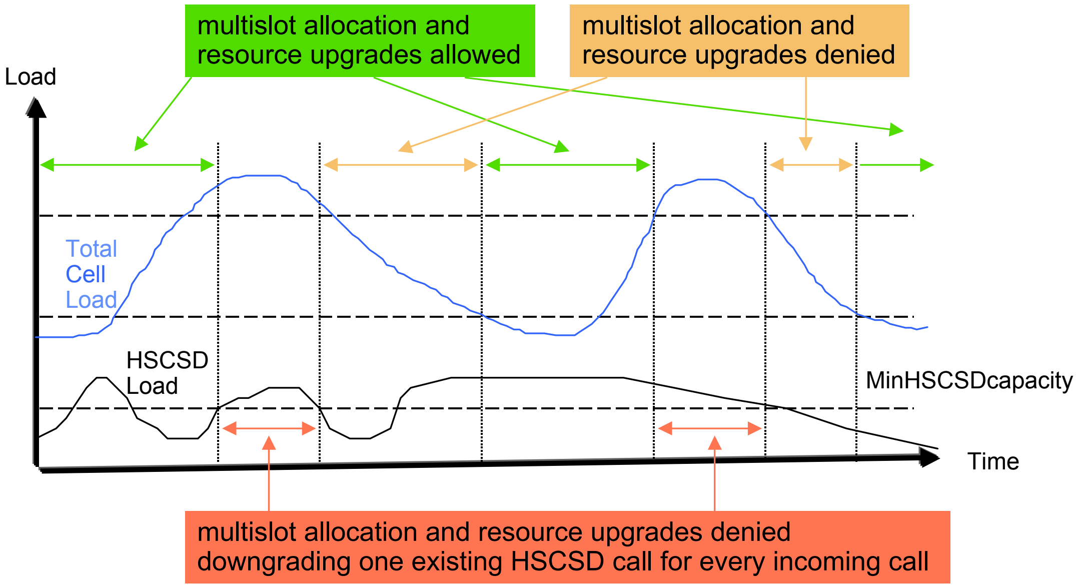


Figure 2. HSCSD Load Control

21.1.7 14.4/14.5 kbit/s connection power control and automatic link adaptation

RX_QUAL reported by the MS and the BTS tells the quality of the sent frame, not the performance of the user data. The current threshold for power control represents the predicted border of the acceptable user data performance for the speech for 9.6/12.0 kbit/s data. This is not adequate for 14.4/14.5 kbit/s user data because 14.4/14.5 kbit/s channel coding can stand less errors. To maintain 14.4/14.5 kbit/s performance adequate, the RX_QUAL needs to be kept better and so the power increase has to be started with better quality for 14.4/14.5 kbit/s calls +than other calls. A new threshold parameter pcLowerThresholdsQual144 is defined for triggering downlink and uplink power increase for 14.4/14.5 kbit/s connection. Its value should be set to better quality than the ordinary power increase lower thresholds. The parameter powerLimitALA determines the MS and BTS power levels where the channel coding is changed between 14.5 kbit/s and 12 kbit/s in NT service. The power level is identified as attenuation from the maximum allowed power of the MS/BTS. BTS power control is taken into account only if it is enabled. ALA is possible when:

- **enableALA (Y, N)** parameter enables ALA in the cell
- connection uses either 14.5 kbit/s or 12.0 kbit/s channel coding
- 14.5 kbit/s and 12.0 kbit/s channel codings are both allowed for the connection

- the A interface circuit pool used supports 14.5 kbit/s channel coding.

For the MS, the power limit for ALA is defined as:

MS_ALA_PWR_LIMIT = msTxPwrMax - powerLimitALA

The BTS power control range is defined by following existing parameters, bsTxPwrMax and bsTxPwrMin. The BTS power limit for ALA is defined as:

BTS_ALA_PWR_LIMIT = bsTxPwrMax - powerLimitALA

When pcLowerThresholdsQual144 triggers,

- if either BTS or MS power value is more than the power limit, channel coding is changed to 12.0 kbit/s. After that, RX_QUAL is not monitored to pcLowerThresholdsQual144.

- if BTS and MS power values are both below their ALA limit powers, the power of the triggered link is increased.

When pcUpperThresholdsQualDL or pcUpperThresholdsQualUL are triggered,

- the triggered link power is decreased

- if channel coding is 12.0 kbit/s and both BTS and MS power values are both below their ALA power limits, channel coding is changed to 14.5 kbit/s.

The parameter **minIntBetweenALA** defines an interval that has to be between two consecutive ALA procedures. The interval is, however, neglected if the power has been increased to its maximum value. If ALA from 14.5 kbit/s to 12.0 kbit/s is not made due to timer parameter, the triggered link power is increased.

21.1.8 Resource Upgrade

The radio resource upgrade procedure can be used for NT HSCSD calls to add more channels to the configuration in order to achieve better requested radio interface user rate. The resource upgrade can be done for a HSCSD call when the minimum HSCSD capacity for the cell is not achieved and when the traffic load of the cell does not exceed a particular level. Interference band to be used defined by the MSC and interference band recommendation defined by the BSC are followed as in initial channel allocation phase. Resource upgrade can be done until the user defined maximum number of channels is achieved or the required air interface user rate is achieved.

Resource upgrade is not done if

- HSCSD connection is allocated in IUO regular frequency area

- changes after first allocation are denied for the connection

- parameter upgradeGuardTimeHSCSD is set to value '0' for the cell

- the MS has rejected earlier upgrade or downgrade command with cause 'channel mode unacceptable'.

Resource upgrade procedure is initiated when

- a TCH/F is released from other connection

- resource upgrade timer expires for HSCSD connection or

- number of needed channels increases in ALA from 14.5 to 12.0 kbit/s.

Resource upgrade is not initialised when the upgrades become allowed after cell load goes under the lowerLimitCellLoadHSCSD parameter value. Upgrade timers are restarted when they expire under the upgrade denial time. This is done to avoid rapid signalling bursts.

When the TCH/F is released, queues are checked first for new allocation. If there are no calls in queue and there are HSCSD calls in the TRX, the released TSL location is checked if it is in the territory of an incompletely served HSCSD NT call.

- If the location is on the right area but the upgrade is currently denied by the cell load or the previous configuration allocation has not been acknowledged, the TSL is marked as to be in the HSCSD call territory. This means that the TSL is not allocated for single slot calls when there are other free TSLs.

- If the location is on the right area but the upgrade guard time is running, the number of free resources is counted from the HSCSD connection territory. Resource upgrade is made if the number of free channels permits the upgrade due to gain in data rate.

When the upgrade guard time expires, the HSCSD connection territory is checked for any free resources and as many channels are allocated as are needed and available.

21.1.9 Resource downgrade

Resource downgrade procedure is initiated:

- when the total cell traffic load exceeds a certain load and the minimum HSCSD capacity of the cell is offered. At this situation, HSCSD calls are downgraded for every incoming call.

- when target of pre-emption is an NT HSCSD connection with more than one channel.

- when number of needed channels change in the ALA from 12.0 kbit/s to 14.5 kbit/s.

- when the number of needed channels or user defined maximum number of channel changes in user initiated resource level change.

The target selection for the HSCSD connection to be downgraded is based on the following principles:

- The connection for which downgrade is allowed by the connection type and resource downgrade guard time can be selected.

- The connection of smallest priority is selected.

- The connection with most channels used is selected.

Resource downgrade is not done if

- changes after first allocation are denied for the connection
- parameter downgradeGuardTimeHSCSD is set to value '0' for the cell

the MS has rejected an earlier upgrade or downgrade command with cause 'channel mode unacceptable'.