Radio Resource Management
Content of the lecture

• Changing capacity.
• Admission control.
• Packet scheduling.
• Load Control.
• Resource management.
• Power control.
• Handover control.
Changing Capacity

RRM purpose.
- Ensure planned coverage for each service.
- Ensure required connection quality.
- Ensure planned (low) blocking.
- Optimise the system usage in run time.

Real time RRM and Optimisation functions.
- Interference measurements.
- Soft capacity utilisation.
- Scheduling in radio interface.
- Actions to load change.
- Real time interference minimisation:
  - Handover control.
  - Service prioritisation.
  - Connection parameter settings.
  - Admission control.
WCDMA radio network control

In WCDMA QoS will be controlled by:

- Radio Network Planning. (Network Parameters.)
- Real time RRM (Radio Resource Management) operations in RNC BS.
- Real time power control.


RRM functionality is a set of algorithms used for optimal utilisation of air interface and HW resources.

- RRM is operating on connection and cell bases.
- System load is measured in run time.
RRM methods

Network based functions.

• Admission control (AC).
  – Handles all new incoming traffic. Check whether new connection can be admitted to the system and generates parameters for it.
  – Occurs when new connection is set up as well during handovers and bearer modification.

• Load control (LC).
  – Manages situation when system load exceeds the threshold and some counter measures have to be taken to get system back to a feasible load.

• Packet scheduler (PS).
  – Handles all non real time traffic, (packet data users). It decides when a packet transmission is initiated and the bit rate to be used.

• Resource Manager (RM).
  – Controller over logical resources in BTS and RNC and reserves resources in terrestrial network.

Connection based functions.

• Handover Control (HC).
  – Handles and makes the handover decisions.
  – Controls the active set of BS of MS.

• Power Control (PC).
  – Maintains radio link quality.
  – Minimise and control the power used in radio interface.
Interworking actions of AC, PS, and LC

![Diagram showing interworking actions of AC, PS, and LC]

- **PrxTarget**, the optimal average $PrxTotal$.
- **PrxOffset**, the maximum margin by which $PrxTarget$ can be exceeded.

In downlink.
- **PtxTarget**, the optimal average for $PtxTotal$.
- **PtxOffset**, the maximum margin by which $PtxTarget$ can be exceeded.
Air Interface Load: Uplink

Wideband power based uplink loading.
- The BS measures the total received power
- The Uplink loading can be described by
  - Load factor \( \eta_{UL} = \frac{I_{own} + I_{oth}}{P_{rxTotal}} \)
  - Noise rise \( \text{Noise\_Rise}_{UL} = \frac{P_{rxTotal}}{P_N} = \frac{1}{1 - \eta_{UL}} \)

Throughput based uplink loading
- The UL loading is calculated based on the individual load factor of each individual user.
  \[
  \eta_{UL} = \sum_k \frac{1}{1 + \frac{W}{\rho_k \cdot R_k \cdot v_k} \cdot (1 + i)}
  \]
Air Interface Load: Downlink

Wideband power-based downlink loading.
- The load can be estimated by dividing the total currently allocated transmit power at the BS by the maximum transmitted power capability of the cell:

\[ \eta_{DL} = \frac{P_{txTotal}}{P_{txmax}} \]

Throughput based downlink loading.
- The loading is the sum of the bit rates of all currently active connections divided by the maximum throughput of the cell:

\[ \eta_{DL} = \frac{\sum_{k=1}^{N} R_k}{R_{max}} \]

- Alternatively. Loading is calculated by using concepts of orthogonality other-to-own cell interference:

\[ \eta_{DL} = \left[ (1 - \alpha) + i_{DL} \right] \sum_{k=1}^{N} \left( \frac{W}{\rho_k \cdot R_k \cdot \nu_k} \right) \]
Admission control

- Decides whether new RAB is admitted or not.
  - Real-Time traffic admission to the network is decided.
  - Non-Real-Time traffic after RAB has been admitted the optimum scheduling is determined.
    Co-operation with PC.
- Used when the bearer is
  - Set up.
  - Modified
  - During the handover.
    - Only downlink is considered in UL the BS is already measuring a MS as and other to own cell interference.
      - In new branch the AC is needed for initial power allocation.
    - In inter-frequency handovers the UL is also considered.
- Estimates the load and fills the system up to the limit.
- Used to guarantee the stability of the network and to achieve high network capacity.
- Separate admission for UL and DL.
  - Load change estimation is done in the own and neighbouring cells.
  - RAB admitted if the resources in both links can be guaranteed.
  - In decision procedure AC will use thresholds set during radio network planning.
- The functionality located in the RRM of the RNC.
Power based admission control

Uplink

- The bearer is admitted if RT load fulfils: $P_{rxNC} + \Delta I \leq P_{rxTarget}$ and total received wideband power fulfils $P_{rxTotal} \leq P_{rxTarget} + P_{rxOffset}$.
- For NRT only the latter condition is applied.
- The increase of wideband power is estimated as

  \[- \Delta I \approx \frac{P_{rxTotal}}{1 - \eta} \Delta L - \frac{P_{rxTotal}}{1 - \eta - \Delta L} \Delta L.\]

- The fractional load for the new user can be calculated $\Delta L = \frac{1}{W} \cdot \frac{1}{1 + \rho \cdot R \cdot v}$.

Downlink

- RT bearer will be admitted if non-controllable downlink load fulfils equation $P_{txNC} + \Delta P \leq P_{txTarget}$ and total transmitted power fulfils $P_{txTotal} \leq P_{txTarget} + P_{txOffset}$. 
Throughput based admission control

- A new bearer is admitted only if the load after admittance stays below the threshold defined by RNP.

Uplink

$$\eta_{oldUL} + \Delta L \leq \eta_{thresholdUL}$$

Downlink

$$\eta_{oldDL} + \Delta L \leq \eta_{thresholdDL}$$
Admission control

- In the decision procedure AC will use threshold form network planning and from interference measurements.
- The new connection should not impact the planned coverage and quality of existing connections. (During the whole connection time.)
- AC estimates the UL and DL load increase which new connection would produce. AC uses load information from LC and PC.
- Load change depends on attributes of RAB: traffic and quality parameters.
- If UL or DL limit threshold is exceeded the RAB is not admitted.
- AC derives the transmitted bit rate, processing gain, Radio link initial quality parameters, target BER, BLER, Eb/No, SIR target.
- AC manages the bearer mapping
  - The L1 parameters to be used during the call.
- AC initiates the forced call release, forced inter-frequency or intersystem handover.
Logical dependencies of AC

- **RM**
  - Radio Resource Info
  - Codes
  - Transport resources

- **AC**
  - Load change estimation
  - RAB admission
  - L2 parameters
  - Transport Format Combination
  - DL Power allocation

- **PS**
  - Load Info

- **LC**
  - Load Info

- **PC**
  - Target BER/BLER/SIR

- **HC**
  - Active set Info

**lub**
- Bearer set up request

**Iub**
-Bearer set up request
Packet scheduling

- To determine the available radio interface resources for non real time radio bearer.
- To share the available radio interface resources between non real time radio bearers.
- to monitor the allocations for non real time radio bearers.
- To initiate transport channel type switching between common, shared and dedicated channels when necessary.
- To monitor the system loading.
- To perform load control actions for the non-real-time radio bearers when necessary.
Properties of WCDMA transport channels applicable for packet data transfer

<table>
<thead>
<tr>
<th>TrCh</th>
<th>DCH</th>
<th>RACH</th>
<th>FACH</th>
<th>CPCH</th>
<th>DSCH</th>
</tr>
</thead>
<tbody>
<tr>
<td>TrCH type</td>
<td>Dedicated</td>
<td>Common</td>
<td>Common</td>
<td>Common</td>
<td>Shared</td>
</tr>
<tr>
<td>Applicable UE state</td>
<td>CELL_DCH</td>
<td>CELL_FACH</td>
<td>CELL_FACH</td>
<td>CELL_FACH</td>
<td>CELL_FACH</td>
</tr>
<tr>
<td>Direction</td>
<td>Both</td>
<td>Uplink</td>
<td>Downlink</td>
<td>Uplink</td>
<td>Downlink</td>
</tr>
<tr>
<td>Code Usage</td>
<td>According to maximum bit rate</td>
<td>Fixed code allocations in a cell</td>
<td>Fixed code allocations in a cell</td>
<td>Fixed code allocations in a cell</td>
<td>Fixed code allocations in a cell</td>
</tr>
<tr>
<td>Power control</td>
<td>Fast closed-loop</td>
<td>Open-loop</td>
<td>Fast closed-loop</td>
<td>Open-loop</td>
<td>Fast closed-loop</td>
</tr>
<tr>
<td>SHO support</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Target data traffic volume</td>
<td>Medium or high</td>
<td>Small</td>
<td>Small</td>
<td>Small or medium</td>
<td>Medium or high</td>
</tr>
<tr>
<td>Suitability for bursty data</td>
<td>Poor</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Setup time</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Relative radio performance</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>Medium</td>
<td>Medium or high</td>
</tr>
</tbody>
</table>
Configurations for transport channel

- AC determines the Transport Channel parameters (RNC, BS, MS).
- Transport format (RNC, BS, MS).
- AC/PS determine a Transport Format Combination in DCN multiplexing (RNC, BS, MS).
- Service multiplexing and rate matching are controlled (RNC)
- AC/PS determine a Gain factor for the uplink DPCCH/DPDCH power difference. (MS RNC)
Load Control

Purpose: optimise the capacity of a cell and prevent overload

– The interference main resource criteria.
– LC measures continuously UL and DL interference.
– RRM acts based on the measurements and parameters from planning

Preventive load control.

– In normal conditions LC takes care that the network is not overloaded and remains stable.

Overload condition.

– LC is responsible for reducing the load and bringing the network back into operating area.

• Fast LC actions in BTS:
  – deny (DL) or overwrite (uplink) TPC ‘up’ commands.
  – Lower SIR target for the uplink inner-loop PC.

• LC actions located in the RNC.
  – Interact with PS and throttle back packet data traffic.
  – Lower bit rates of RT users (speech service or CS data).
  – WCDMA interfrequency or GSM intersystem handover.
  – Drop single calls in a controlled manner.
Traffic types and load

- **Non controllable traffic**
  - Real-time (RT) users (traffic).
  - Users in other cells.
  - Noise.
  - NRT users with minimum bit rate.
- **Controllable traffic.**
  - Non-real-time users (traffic).

- **Uplink received power.**
  \[
  P_{rxTotal} = P_{rxOwn} + P_{rxOth} + P_n = P_{rxNc} + P_{rxNRT}
  \]

- **Downlink received power.**
  \[
  P_{txTotal} = P_{txNc} + P_{txNRT}
  \]

Some slice of capacity must be allocated to the non controllable traffic for mobility purposes all the time. The proportion between controllable and non-controllable traffic varies all the time.
Description of LC

LC consists of AC, PS algorithms and LC, updating load status based on the measurements and estimations from AC and PS.

**LC algorithm**

- BTS measures the total received power.
- BTS reports measurements to the Controlling-RNC. (periodically).
- RRM in RNC updates cell load status for each controlled cell.
- AC and PS work based on the current load status in the cell.

- The load is estimated based on received noise power. PrxNoise.
  - Overestimation -> under estimation of cell load, can lead to overload situation.
  - Underestimation -> overestimation of the cell load, causes low system utilisation (unnecessary call blocking).
Resource management

- Purpose: to allocate physical radio resources when requested by the RRC layer.
- Knows radio network configuration and state data.
- Sees only logical radio resources.
  - Allocation is a reservation of proportion of the available radio resources according to the channel request from RRC layer for each radio connection.
- Input comes from AC/PS.
- RM informs PS about network conditions.
- Allocates scrambling codes in UL.
- Allocates the spreading codes in downlink direction.
  - Able to switch codes and code types
    - During soft handover.
    - defragmentation of code tree.
Power control

- Uplink open loop power control.
- Downlink open loop power control.
- Power in downlink common channels.
- Uplink inner (closed) loop power control.
- Downlink inner (closed) loop power control.
- Outer loop power control.
- Power control in compressed mode.
Uplink open loop PC

- Setting the initial transmission power.
- The terminal sets the initial power for the first PRACH preamble and for the DPCCH before starting inner loop PC.

\[ \text{Preamble	extunderscore Initial	extunderscore Power} = \text{CPICH	extunderscore Tx	extunderscore Power} - \text{CPICH	extunderscore RSCP} + \text{UL	extunderscore interference} + \text{UL	extunderscore required	extunderscore CI} \]

*UL	extunderscore interference* is measured at the BS and broadcast on the BCH.

- First DPCCH power level for the uplink inner-loop PC is started as.

\[ \text{DPCCH	extunderscore Initial	extunderscore Power} = \text{DPCCH	extunderscore Power	extunderscore Offset} - \text{CPICH	extunderscore RSCP} \]

*CPICH	extunderscore RSCP* is measured by the terminal.

\[ \text{DPCCH	extunderscore Power	extunderscore Offset} = \text{CPICH	extunderscore Tx	extunderscore Power} + \text{UL	extunderscore interference} + SIR_{DPCCH} - 10 \cdot \log_{10} \left( SF_{DPDCH} \right) \]

*SIR_{DPCCH}* is the initial target SIR produced by the AC for the particular connection. 

*SF_{DPDCH}* is the spreading factor of the corresponding DPDCH.
Downlink Open loop PC

- The open loop PC is used to the the initial power of the downlink channels based on downlink measurement reports.
- The function is in UTRAN and MS.
- A possible algorithm for initial power calculations is

\[
P_{\text{Tx}}^{\text{Initial}} = \frac{R \cdot (E_b/N_0)_{DL}}{W} \left( \frac{CPICH_{\text{Tx power}}}{(E_b/N_0)_{CPICH}} - \alpha \cdot P_{\text{TxTotal}} \right)
\]

- \( R \): user bit rate
- \( (E_b/N_0)_{DL} \): downlink planned Eb/No set by RNP for particular bearer service.
- \( W \): the chip rate.
- \( (E_b/N_0)_{CPICH} \): reported by MS.
- \( \alpha \): the downlink orthogonality factor.
- \( P_{\text{TxTotal}} \): carrier power measured at the BS an reported to the RNC.
### PC in downlink common channels

- Determined by the network.
- The ratio of the transmit powers between different downlink common channels not specified in recommendations.

<table>
<thead>
<tr>
<th>DL common channels</th>
<th>Typical power level</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>P-CPICH</td>
<td>30-33 dBm</td>
<td>5-10% of maximum cell Tx power (20 W). Set during Network planning.</td>
</tr>
<tr>
<td>P-SCH, S-SCH, P-CCPCH</td>
<td>-3 dB</td>
<td>Relative to P-CPICH power.</td>
</tr>
<tr>
<td>PICH</td>
<td>-8 dB</td>
<td>Relative to P-CPICH power and Number of paging indicators per frame Np = 72.</td>
</tr>
<tr>
<td>AICH</td>
<td>-8 dB</td>
<td>Power of one Acquisition Indicator (AI) compared to P-CPICH power.</td>
</tr>
<tr>
<td>S-CCPCH</td>
<td>-5 dB</td>
<td>Relative to P-CPICH and SF=256 (15 kbps). The configuration covers FACH power, max FACH power, PCH power. FACH slow PC can be applied.</td>
</tr>
<tr>
<td>PDSCH</td>
<td>Inner loop PC</td>
<td>TPC commands from user. A proprietary protocol for slow PC can be used.</td>
</tr>
</tbody>
</table>
UL/DL inner and Outer loop PC

- Inner loop PC relies on the feedback information at Layer 1.
- The fast PC is used in UMTS for the dedicated channels in uplink and downlink.
- PC commands update rate 1500 Hz
Uplink closed loop PC

- Received signal power is compared to the CIRtarget and depending on the result transmission power is asked to increase to decrease.
  - CIRtarget is got from uplink outer loop PC.
- Performance depends on users speed
  - $v < 30$ km/h step size 1 dB. (Algorithm 1).
  - $30 < v < 80$ km/h step size 2 dB. (Algorithm 1).
  - $80 < v$ PC can not follow the channel changes and generates only noise (Algorithm 2).
- Before starting the communication a DPCCH PC preamble could be send.
  - For convergence of the uplink Tr power. 0-7 frames (the number set during RNP).

Fast PC algorithm: 1

- The PC command is received and that can be +1 or -1 dB

PC during handover

- Commands know to be same are combined into one command that is combined further with other TPC commands
- commands not known to be the same
  - soft symbol decision on each of the PC commands TPCi where $i=1 \ldots N$
  - to each symbol is assigned a realiability figure $W_i$
  - The TPC commands are combined as function of $\gamma$ of all $N$ power control commands TPCi and reliability estimates $W_i$: $\text{TPC}_\text{cmd}=\gamma(W_1,W_2,\ldots,W_N,\text{TPC}_1,\text{TPC}_2,\ldots,\text{TPC}_N)$, where $\text{TPC}_\text{cmd} \in -1,1$
Fast PC algorithm: 2

- Allows:
  - To emulate smaller step sizes for PC.
  - To turn off uplink PC.

- PC commands processed in non overlap 5 slot cycle.

- TPC_cmd
  - for the first 4 slots of a set TPC_cmd = 0
  - for the fifth slot is used hard decision
    - all hard decisions 1 TPC_cmd = 1.
    - all hard decisions 0 TPC_cmd = 0.
    - Otherwise TPC_cmd = 0.

Algorithm 2 during handover.

- Combining TPC_cmd known to be same. The commands are combined into one command

- Combining TPC_cmd not known to be same
  - MS makes PC decision over 3 slots
  - sums all the decisions that are not known to be same in a slot
  - the TPC_cmd for two first slots is 0 and for the third slot it is either - 1, 0, + 1 depending on the value of the normalised sum of PC bits

- Example: TPC_cmd set accordingly
  - +1 if \( \frac{1}{N} \sum_{i} TPC_{cmdi} > 0.5 \)
  - -1 if \( \frac{1}{N} \sum_{i} TPC_{cmdi} < 0.5 \)
  - otherwise 0
DL fast closed loop PC

- MS estimates the received SIR and compares it with required SIR target.
  - SIR is estimated from the pilot symbols of the DL-DPCH
- MS transmits the TPC command in first available TPC field.
- Two downlink PC modes:
  - DPC_MODE = 0: power command in every slot.
  - DPC_MODE = 0: power command once in every third slot.
- Power difference for different channels is estimated from given power offset values.
- Changes of power are multiplies of the minimum step size
  - it is mandatory for BS to support 0.5 and 1 dB step size
DL power during handover

Softer handover (diversity transmission).
- Only one TPC is send.
- Signals from different antennas are combined in the symbol level.

Soft handover.
- The signals are combined in MS.
- Power drifting?
- In Soft handover mode only one single TPC is send in uplink.
- Each cell detects TPC command independently.
  - Possible errors. Some BS may lower the Tx power when others increase -> the Tx powers are drifting apart.
- The transmission code power levels of the connections from the cell in SHO are forwarded, after averaging, to RNC.
  - Averaging for example 750 TPC commands (500 ms).
- RNC derives a reference power values and send to the cells.
Outer loop PC

- Outer loop power control produces an adequate target CIR for inner loop PC.
- Done for each DCH belonging to the same RRC connection.
- Frequency typically 10-100 Hz.
- During Soft HO.
  - The UL quality is observed after the MDC. The SIR target is generated for all cells in SHO.
    - The reliability of the blocks is provided to RNC. The quality is estimated based on CRC codes.

- DL the outer loop PC implemented in MS.
  - In CPCH a quality target is DPCCH BER.
  - DPCCH BLER quality target otherwise.

- The value of the DL outer loop PC is controlled by the AC in RNC.
  - The value of the target is sent to MS in a RRC message.
PC in compressed mode

- Aim to recover a SIR close to the target SIR after each transmission gap
- In downlink compressed mode no PC is applied during transmission gap
- In simultaneous DL/UL compressed mode transmission is stopped
- The initial tr power of each UL after the tr gap is equal to the power before the gap, but with an offset $\Delta$resume
- $\Delta$resume may be
  - 0
  - $\Delta$resume = Int[$\sigma_{last} / \Delta$TPCmin] $\Delta$TPCmin
    $\sigma_{last} = 0.9375 \sigma_{last-1} - 0.96875$ TPCcmdlast $\Delta$TPC
- PC modes are fixed and signalled with the other parameters during the downlink compressed mode
  - ordinary PC is applied
  - ordinary PC is applied with step size $\Delta$RP-TPC during RPL slots after transmission gap.
- $\Delta$RP-TPC is recovery PC step size in dB
  - if algorithm 1 used is is equal to the minimum value of 3 dB and 2 $\Delta$TPC
  - if algorithm 2 is used $\Delta$RP-TPC is equal to 1 dB
- RPL is recovery period length and is expressed in number of slots
Handovers

- Intrasytem HO.
  - Intrafrequency HO.
  - Interfrequency HO.
- Intersystem HO.

- Hard HO (HHO).
  - All the old radio links of an MS are released before the new radio links are established.
    - Real time bearers: short disconnection in transmission.
    - Non real time bearers HHO is lossless.
- Soft HO (SHO).
  - MS always keeps at least one radio link to UTRAN.
  - Soft HO: MS is simultaneously controlled by two or more cells belonging to different BTS of the same RNC or to different RNC.
  - Softer HO. MS is controlled by at least two cells under one BTS.
- Mobile evaluated handover (MEHO).
  - The UE mainly prepares the handover decision. The final decision is made by SRNC.
- Network evaluated handover (NEHO).
  - The SRNC makes the handover decision.
Intrasystem intra-frequency HO

Objectives of *soft*/*softer* HO.

- Optimum fast closed loop PC as the terminal is always linked with the strongest cells.
- Seamless handover with no disconnection of the radio access bearer.
- Diversity gain by combining the received signals from different cells. Better coverage. Less transmission power.

- MEHO: MS continuously measures serving and neighbouring cells on the current carrier.
- The RAN can perform *soft* and *softer* HO simultaneously.

General HO activities.

- Reporting of the MS measurements.
  - Compares measurement results with the HO threshold.
  - MS sends reports to BTS when the criteria is met.
    - Threshold is provided by the RNC.
    - Comparison result is transmitted to RNC.

- HO decision.
  - SRNC orders MS to add or remove cells from/to Active set.

- Measurement reporting criteria.
  - Definition of event that triggers the measurement report.
  - Parameters are defined on cell bases.
RRM functions in HO process

RRM functions
HC: processes the measurements made by terminal and makes decisions. Updates reference transmission powers.
AC: DL admission decision: acceptance and queuing. DL power allocation. May initiate a forced call release of IF-HO IS-HO.
LC: Updates DL load information when new HO link is admitted.
PS: Releases codes for HO branches of NRT. Schedules HO additions requests for NRT

- DL channelisation codes are allocated separately for each soft(er) HO branch.
- UL channelisation code is the same for each soft(er) HO branch.
Measurements reporting

- The measurements based on Eb/Io.
- The MS constantly monitors the CPICH Eb/Io of the cells defined by the neighbouring list.
- If the reporting criteria is fulfilled MS sends an event triggered measurement report.
- The CPICH Eb/Io is the received energy per chip divided by the power density in the band.
- The accuracy of pilot Eb/Io important for HO performance.
  - The accuracy depends on the filtering length and mobile speed.

HO measurements reporting can be divided as:
- Neighbouring cell definitions.
- Measurement reporting criteria.
- Reporting of measurement results.
Neighbouring cells

For each cell in the radio network configuration database are defined a list of neighbouring cells.

- Intrafrequency neighbouring list. The UE must be able to monitor at least 32 cells on the same WCDMA carrier frequency as the serving cell.
- Interfrequency neighbouring list. The UE must be able to monitor at least 32 cells on the two other WCDMA carrier frequencies compared to the serving cell.
- Intersystem neighbouring list. For each neighbouring PLMN a separate list is maintained.

Measurement reporting criteria

Depending on the handover type (MEHO, NEHO) different measurement reporting criteria can be used.

- Intrafrequency measurements.(MEHO).
  - HO measurements. The RAN broadcast the measurements reporting criteria (measurements parameters on the BCCH).
- Interfrequency and Intersystem measurements.
  - Made only when requested by RNC.
  - When once initiated MS periodically reports the measurement results to RNC
- UE internal measurements.
  - Controlled cell by cell bases. Info transmitted to MS in DCCH.
Reporting Intrafrequency measurements

Can be either event-triggered or periodic.

Reporting criteria for intrafrequency measurements are:

- Event 1a: A p-CPICH enters the reporting range.
- Event 1b: A P-CPICH leaves the reporting range.
- Event 1c: A non-active P-CPICH becomes better than an active one.
- Event 1d: Change of best cell. Reporting event is triggered when any P-CPICH in the reporting range becomes better than the current best one plus an optional hysteresis value.
- Event 1e: A P-CPICH becomes better than an absolute threshold plus an optional hysteresis value.
- Event 1f: A P-CPICH becomes worse than an absolute minus an optional hysteresis value.
Intrafrequency measurements (2)

- Event 1a. \(10 \cdot \log_{10} (M_{new}) \geq W \cdot 10 \cdot \log_{10} \left( \sum_{i=1}^{N_A} M_i \right) + (1-W) \cdot M_{Best} - (R_{1a} - H_{1a}/2)\)
- Event 1b. \(10 \cdot \log_{10} (M_{Old}) \leq W \cdot 10 \cdot \log_{10} \left( \sum_{i=1}^{N_A} M_i \right) + (1-W) \cdot M_{Best} - (R_{1b} + H_{1b}/2)\)

- \(M_{new}\) the measurement result of the cell entering the reporting range.
- \(M_i\) a measurement result of a cell in the active set.
- \(N_A\) the number of cells in the current active set.
- \(M_{Best}\) the measurement result of the strongest cell in the active set.
- \(W\) a weighting parameter sent from RNC to UE.
- \(R_{1a}\) the reporting range for Event 1a sent from RNC to UE.
- \(H_{1a}\) the hysteresis parameter for Event 1a.
- \(R_{1b}\) the reporting range constant for Event 1b sent from RNC.
- \(M_{Old}\) the measurement result of the cell leaving the reporting range.
- \(H_{1b}\) the hysteresis parameter for Event 1B.

**Time to trigger mechanism.**
- To protect the network from excessive signalling in case of frequent reports.
  - The reporting events could have a timer.
    - If the measuring criteria is fulfilled during the whole period the event is reported.

**Periodic Reporting.**
- If the operation (AS update) can not occur because lack of HW the MS continues to send periodic reports.