UTRAN Radio Resource Management

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- Handover Control
  - Soft/Softer Handover
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- Power Control
  - Closed Loop Power Control
  - Open Loop Power Control
- Interference Management
- Load Control
  - Call Admission Control
  - Congestion Control
- Packet Data Transmission
  - Packet Data Control
  - Dynamic Scheduling
RRM – High-Level Requirements

- Efficient use of limited radio resources (spectrum, power, code space)
- Minimizing interference
- Flexibility regarding services (Quality of Service, user behaviour)
- Simple algorithms requiring small signalling overhead only
- Stability and overload protection
- Self adaptive in varying environments
- Allow interoperability in multi-vendor environments

Radio Resource Management algorithms control the efficient use of resources with respect to interdependent objectives:
- cell coverage
- cell capacity
- quality of service
RRM - Components

Core Network/ other RNCs

Radio Resource Management

Handover Control
Load Control
Packet Data Control

Power Control
Medium Access Control

Physical layer

typically in RNC

typically in NodeB
Handover Control: Basics

**General:** mechanism of changing a cell or base station during a call or session

**Handover in UMTS:**
- UE may have active radio links to more than one Node B
- Mobile-assisted & network-based handover in UMTS:
  - UE reports measurements to UTRAN if reporting criteria (which are set by the UTRAN) are met
  - UTRAN then decides to dynamically add or delete radio links depending on the measurement results

**Types of Handover:**
- Soft/Softer Handover (dedicated channels)
- Hard Handover (shared channels)
- Inter Frequency (Hard) Handover
- Inter System Handover (e.g. UMTS-GSM)
- Cell selection/re-selection (inactive or idle)

All handover types require heavy support from the UMTS network infrastructure!
Macro Diversity & Soft Handover (Wrap-Up)

Downlink: combining in the mobile station
Uplink: combining in the base station and/or radio network controller
Soft/ Softer Handover

- In soft/softer handover the UE maintains active radio links to more than one Node B
- Combination of the signals from multiple active radio links is necessary

**Soft Handover**

- The mobile is connected to (at least) two cells belonging to different NodeBs
- In uplink, the signals are combined in the RNC, e.g. by means of *selection combining* using CRC

**Softer Handover**

- The mobile is connected to two sectors within one NodeB
- More efficient combining in the uplink is possible like *maximum ratio combining* (MRC) in the NodeB instead of RNC

Note:

- In uplink no additional signal is transmitted, while in downlink each new link causes interference to other users, therefore:
  - Uplink: HO general increase performance
  - Downlink: Trade-off
Soft Handover Control

- Measurement quantity, e.g. $E_C/I_0$ on CPICH
- Relative thresholds $\delta_{add}$ & $\delta_{drop}$ for adding & dropping
- Preservation time $T_{link}$ to avoid “ping-pong” effects
- Event triggered measurement reporting to decrease signalling load

Diagram showing the soft handover area between NodeB 1 and NodeB 2 with measurement quantities such as $E_C/I_0$ on CPICH, thresholds $\delta_{add}$ and $\delta_{drop}$, and preservation time $T_{link}$. The diagram illustrates the transition from Link to 1, Link to 1 & 2, and Link to 2 over time.
Soft handover significantly improves the performance, but …
…the overhead due to simultaneous connections becomes higher!
Inter-Frequency Handover

Hierarchical cell structure (HCS)

- Hard handover
- Inter-frequency measurements of target cell needed in both scenarios
- Mobile-assisted handover (MAHO)
  - slotted (compressed) mode for inter-frequency measurements to find suitable target cell
  - also supports GSM system measurements
- Database assisted handover (DAHO)
  - no measurements performed on other frequencies or systems
  - use cell mapping information stored in data base to identify the target cell
Power Control: Basics

Controls the setting of the transmit power in order to:
- Keep the QoS within the required limits, e.g. data rate, delay and BER
- Minimise interference, i.e. the overall power consumption

Power control handles:
- Path Loss (Near-Far-Problem), Shadowing (Log-Normal-Fading) and Fast Fading (Rayleigh-, Ricean-Fading)
- Environment (delay spread, UE speed, ...) which implies different performance of the de-interleaver and decoder

Uplink: per mobile
Downlink: per physical channel

Three types of power control:
- Inner loop power control
- Outer loop power control (SIR-target adjustment)
- Open loop power control (power allocation)

Downlink power overload control to protect amplifier
- Gain Clipping (GC)
- Aggregated Overload Control (AOC)
Near-Far Problem:  
- Spreading sequences are not orthogonal (multi-user interference)  
- Near mobile dominate  
- Signal to interference ratio is lower for far mobiles and performance degrades

The problem can be resolved through dynamic power control to equalize all received power levels

**AND/OR**

By means of joint multi-user detection
Closed Loop Power Control

- Closed loop power control is used on channels, which are established in both directions, such as DCH.
- There are two parts:
  - Inner Loop Power Control (ILPC): receiver generates up/down commands to incrementally adjust the sender's transmit power.
  - Outer Loop Power Control (OLPC): readjusts the target settings of the ILPC to cope with different fading performance.

Example: Uplink Closed Loop Power Control

- Inner Loop (1500 Hz)
  - Control command: Up/Down
- SIR > SIR_{target}?
- Outer Loop (≤ 100Hz)
  - Target adjustment
  - BLER_{target}
- NodeB
- UE
- RNC
Impact of Power Control

Example: UMTS Closed Loop Power Control in the slow fading channel
SIR requirement strongly depends on the environment (due to different fast fading conditions – Jakes models)
⇒ outer loop power control needed to adapt SIR
Open Loop Power Control

- Open loop power control is used on channels that cannot apply closed loop power control, e.g. RACH, FACH
- The transmitter power is determined on the basis of a path loss estimate from the received power measure of the opposite direction
- To avoid excessive interference, probes with incremental power steps until a response is obtained: “power ramping”
CDMA Overload

- CDMA systems tend to become unstable
  - More traffic increases the interference
  - More interference requires higher power
  - More power increases the interference …

- Methods are required to limit the system load
  - Restrict the access to the system
  - Overcome overload situations
Cell Breathing

- CDMA systems: cell size depends on the actual loading
  - Additional traffic will cause more interference
  - If the interference becomes too strong, users at the cell edge can no more communicate with the basestation
- CDMA interference management
  - Restriction of the users access necessary
  - Cell breathing makes network planning difficult

Example: cell brething with increasing traffic
Cell Breathing (contd.)

Coverage depending on load: load causes interference, which reduces the area where a SIR sufficient for communication can be provided.

- **coverage low load**
- **coverage medium load**
- **coverage high load**

shadowed area: connection maybe lost
Load Control: Basics

- **Main objective:**
  - Avoid overload situations by controlling system load
  - Monitor and controls radio resources of users

- **Call Admission Control (CAC)**
  - Admit or deny new users, new radio access bearers or new radio links
  - Avoid overload situations, e.g. by means of blocking the request
  - Decisions are based on interference and resource measurements

- **Congestion Control (ConC)**
  - Monitor, detect and handle overload situations with the already connected users
  - Bring the system back to a stable state, e.g. by means of dropping an existing call
Resource Consumption

- Service/BLER-dependent resource consumption
- Uplink example:
  - Service I: Voice
    \[ R_b = 12.2 \text{kbps}, \frac{E_b}{N_t} = 5\text{dB} \]
    \[ \alpha_I = 0.99\% \]
  - Service II: Data
    \[ R_b = 144\text{kbps}, \frac{E_b}{N_t} = 3.1\text{dB} \]
    \[ \alpha_{II} = 7.11\% \]
- In downlink there is additional dependency on the location of the user
  - Cell center \(\rightarrow\) low consumption
  - Cell edge \(\rightarrow\) high consumption
Admission/ Congestion Control

Basic algorithm

- Admission control is triggered when load \( \geq \text{thr\_CAC} \)
  - New users are blocked
  - Existing users are not affected as long as load \( < \text{thr\_ConC} \)

- Congestion Control is triggered when load \( \geq \text{thr\_ConC} \)
  - Reduce consumption of one or several users
  - Simple action: drop the user
  - Repeat until load \( < \text{thr\_ConC} \)
**Tradeoff between blocking and dropping**

Example: 64k per user, urban
Cell load depending on CAC threshold

Example: 64k per user, urban
Packet Data Control: Channel Switching

- Flexibility of packet services
  - Asymmetrical data rates
  - Very low to very high data rates
  - Control information/user information

- Efficient transmission making good use of CDMA characteristics
  - Dedicated channel (DCH)
    - Minimise transmission power by closed-loop power control
    - Independence between uplink and downlink capacity
  - Common channel
    - Random access in the uplink (RACH)
    - Dynamic scheduling in the downlink (FACH)

- Adaptive channel usage depending on traffic characteristics
  - Infrequent or short packets \(\Rightarrow\) Common channel (Cell_FACH)
  - Frequent or large packets \(\Rightarrow\) Dedicated channel (Cell_DCH)
  - No packet transmission \(\Rightarrow\) UE “stand by” modus (URA_PCH)
Channel Switching – Example

- Example: Web service
- Chatty apps.: keep alive message, stock tickers, etc. (e.g. 100 bytes every 15 sec)
- Second stage: when no activity in CELL_FACH then switch to URA_PCH
Power Control vs. Rate Adaptation

- **Power Control:**
  - Balances user received quality (BLER, SIR)
  - Users at cell center get less share of BTS transmit power assigned than at cell edge
  - Occurrence of power overload

- **Rate Adaptation:**
  - Transmit power ~ data rate
  - Users at cell edge get lower data rate assigned than at cell center
  - Reduces also power overload

- **On DCH combination of power control and rate adaptation**
  - Rate assignment at begin of a transmission based on load and user location
  - Rate adaptation when ongoing transmission according to power consumption and overload
  - Based on RRC-signaling (time horizon: 100msec … 10sec)
Rate Adaptation Performance

Rate adaptation significantly improves the RRM performance on DCH.
Dynamic Scheduling

• “Statistical multiplexing” of data packets from different data flows on one shared medium, e.g. on DSCH or HSDPA
• Scheduling with time-horizon of 2msec … 1sec
• Optimised usage of radio resources
• Exploitation of the short-term variations on the radio channels (opportunistic scheduling)
• Can provide certain degree of QoS
References


3GPP standards:

- TS 25.214: “Physical Layer Procedures“ (esp. power control)
- TR 25.942: “RF System Scenarios“