Radio Resource Management

RRM is needed to:

• Guarantee Quality of Service (QoS)
• Maintain the planned coverage area
• Offer high capacity
Location of RRM algorithms

MS:
- Power Control

BS:
- Power Control
- Load Control

RNC:
- Power Control
- Load Control
- Admission Control
- Handover Control
- Packet Scheduling

Power Control

- Slow power control - compensates for path loss and shadowing
- Fast power control - compensates for Rayleigh fading
- Errors arise from inaccurate SIR estimation, signalling errors, and delays in the power control loop

<table>
<thead>
<tr>
<th></th>
<th>Slow power control</th>
<th>Fast Power control</th>
<th>Gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pedestrian 3 kph</td>
<td>11.3 dB</td>
<td>5.5 dB</td>
<td>5.8 dB</td>
</tr>
<tr>
<td>Vehicular 3kph</td>
<td>8.5 dB</td>
<td>6.7 dB</td>
<td>1.8 dB</td>
</tr>
<tr>
<td>Vehicular 50 kph</td>
<td>6.8 dB</td>
<td>7.3 dB</td>
<td>-0.5 dB</td>
</tr>
</tbody>
</table>

Required $E_s/I_0$ for FER = 1% for 8 kbps speech
(Holma & Toskala Table 9.1)
Power Control in Soft Handover

Downlink power drifting
- MS sends a single command to control BS transmit powers
- MS command is received by all BSs in the active set
- A receive error by a BS can result in e.g. one BS reducing its power to the MS while other BSs increase power
  ⇒ Power Drifting
- Solution: RNC needs to be involved to stop this drifting.
  RNC maintains an average reference level over 500 ms, and sends that reference level to the BSs

Note: This is not an issue in IS95, as IS95 has only slow power control on the downlink.

Outer Loop Power Control

- Outer Loop control sets the target SIR for fast power control
  SIR too high ⇒ quality too high ⇒ wastes capacity

- Received quality better than required quality?
  - Yes: Decrease SIR target
  - No: Increase SIR target
Uplink Outer Loop Power Control

Signal Combining

Outer Loop Power Control

Received Data

SIR Target

BS1

BS2

PC targets for Multiservices

Air Interface: Common Fast PC for all services

One target for Fast PC

Speech service

Video service

Web browsing

Fast PC

BS

RNC

Estimate the quality for each service

Set target according to the service requiring the highest target

Received Data for all services

Set target for Fast PC
Intra-frequency Handover

- Use pilot channel $E_b/I_0$ for handover measurement quality
- Use dynamic thresholds
- **Parameters:**
  - `Reporting_Range` is the threshold for soft handover
  - `Addition_Hysteresis`
  - `Removal_Hysteresis`
  - `Replacement_Hysteresis`
  - $\Delta T$ is the time to trigger

Intra-frequency Handover...

**Soft Handover Algorithm**

If $(Pilot_E_b/I_0 > Best_Pilot_E_b/I_0 - Reporting_Range + Addition_Hysteresis)$ for a period $\Delta T$
and (the active set is not full),
then add the cell to the active set

If $(Pilot_E_b/I_0 < Best_Pilot_E_b/I_0 - Reporting_Range - Removal_Hysteresis)$ for a period $\Delta T$
then remove the cell from the active set

If (active set is full)
and $(Best_Candidate_Pilot_E_b/I_0 > Worst_Old_Pilot_E_b/I_0 + Replacement_Hysteresis)$ for a period $\Delta T$
then the weakest cell in the active set is replaced by the
strongest candidate cell.
Measuring the Air Interface Load

- Measurements needed for load control and admission control
- No method specified in the standards - it is up to an operator to decide
Uplink load - wideband received power

- \( I_{\text{total}} \) = total received wideband interference
- \( N_0 \) = background noise

\[
\eta_{UL} = 1 - \frac{N_0}{I_{\text{total}}}
\]

\( \eta_{UL} \) is used as the uplink load indicator

Uplink load - throughput

\[
\eta_{UL} = (1 + \kappa) \sum_{j=1}^{N} \left( \frac{1}{1 + \left( \frac{W}{(E_b/N_0)_{j} \alpha_j R_j} \right)} \right)
\]

- \( W \) = chip rate
- \( R_j \) = bit rate of the \( j \)th user
- \( W/R_j \) = processing gain of the \( j \)th user
- \( \alpha_j \) = activity factor of the \( j \)th user
Downlink load - wideband received power

\[ P_{\text{total}} = \text{total downlink transmission power} \]
\[ P_{\text{max}} = \text{maximum base station transmission power} \]

\[ \eta_{DL} = \frac{P_{\text{total}}}{P_{\text{max}}} \]

\( \eta_{DL} \) is used as the downlink load indicator

---

Downlink load - throughput

\[ \eta_{DL} = \sum_{j=1}^{N} \frac{R_j}{R_{\text{max}}} \]

\[ \eta_{DL} \approx (1 + \kappa) \sum_{j=1}^{N} R_j \frac{\alpha_j (E_b / N_0)_j}{W} \]

\( R_j \) = bit rate of the \( j \)th user
\( R_{\text{max}} \) = maximum allowed throughput of a cell
Admission Control

Principle:
• Calculate/estimate the interference that would be produced by the new connection
• Make sure that new connection will receive adequate quality
• Make sure that the new connection will not cause excessive interference to other connections

Load Control

Load control actions
• Deny downlink power-up commands
• Reduce uplink $E_b/I_0$ targets
• Reduce throughput of packet traffic
• Handover to another WCDMA carrier
• Handover to GSM
• Decrease bit rates of real-time users
• Drop calls as a last resort
References

H. Holma and A. Toskala (eds),