S-72.333 Postgraduate Course in Radiocommunications

WCDMA Radio Link Performance Indicators
Seminar 21.01.2003

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Content

- **Definitions of WCDMA Radio Link Performance Indicators**
- **Multipath Channel Conditions and Services**
- **Link-level Simulation Principles**
- **Physical Layer Measurements (3GPP)**

Note:
- covers chapter 2.5. of course material “Radio Network Planning and Optimisation for UMTS”

General

- Link performance indicators are used in radio network dimensioning and planning ➔ realistic values needed
- Typically produced by link level simulations/in lab. measurements, optimally measured in a live network
- Difficult to obtain from real cases, standards needed
- Link performance indicators depend on:
- direction of transmission (UL, DL)
- mobile station speed
- service, bit rate (speech 8kbps, 12.2 kbps, packet data, circuit switched data)
- multipath channel (ITU models, 3GPP models)
- environment (dense urban, urban, suburban, rural)
- cell deployment (macro, micro, pico)
- diversity solution (1Rx, 2Rx, 4Rx, no Tx diversity, with Tx diversity)

Radio Link Performance Indicators: Definitions (X)

Radio link

- means the **physical layer connection** between one transmitter and one receiver (transmitted bit to received bit)
- Radio link model
  typically includes:
  - channel coding/decoding, interleaving, rate matching
  - spreading/despreading
  - power control
  - radio channel (fading channel, gaussian noise modeling)
  - RAKE receiver, channel estimation, SIR-estimation
  - detection

  but typically does not include:
  - handovers
  - multiple users, multiple services
  - RF (carrier frequency, automatic gain control (AGC), etc.)
  - code acquisition and tracking
- All these items can be modeled but typically this is not the case

Radio Link Performance Indicators: Definitions (1)

Radio link

- means the **physical layer connection** between one transmitter and one receiver (transmitted bit to received bit)

Block Error Rate, BLER

- Long term average BLER calculated for the transport blocks (TB). The TB is considered erroneous if it has at least one bit error. The system knows the correctness of the blocks with very high reliability through the CRC.

Bit Error Rate, BER

- Bit Error Rate after decoding.

Bit Rate, R

- Rate of user information bits = bit rate before L1 processing (CRC, coding and DPCCH control bits)

Radio Link Performance Indicators: Definitions (2)

Eb/N0 and Orthogonality, α

- Originally 'bit-energy divided by noise spectral density'
- Eb/N0 relates to respective quality target (e.g. BLER,BER)
- *Eb/N0* in uplink:

  $Eb/N0=(prx/R)/(I/W)=W/R \cdot prx/I$, where
  prx received constant power, I received interference power, R user bit-rate, W bandwidth
- Target of the power control is to keep Eb/N0 constant
- *Eb/N0* in downlink:

  $Eb/N0=W/R \cdot prx/(Iown \cdot (1-\alpha) + Ioth + PN)$, where
  Iown total power received from the serving cell, Ioth total power received from the surrounding cells, PN noise power (thermal and equipment), α orthogonality factor (depends on multipath conditions)

Radio Link Performance Indicators: Definitions (3)

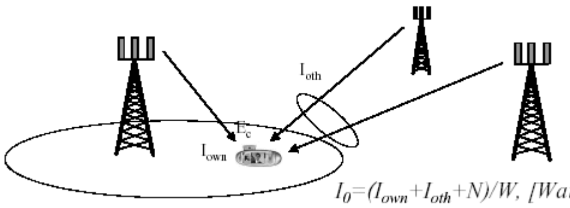
Orthogonality, α

- In the case of a single path channel the interference from the serving cell is cancelled and α=1 (i.e. interference from the own BS is small) $I_{own}=P_{rx}(1-\alpha)=0$, $\alpha=1$
- In the case of a multipath channel the interference from the own BS is $I_{own}=P_{rx}(1-\alpha)$, where α is the orthogonality of the channel α<1
- If there are instantaneously two equally strong propagation paths, then only ½ of the interference is cancelled from the receiver point of view
  ➔ α=*0.5*
- The orthogonality is highly varying and only mean value is used in the radio network planning

Radio Link Performance Indicators: Definitions (4)

Ec/I0

- Received chip energy relative to total power spectral density. In uplink *Ec/I0= Eb/N0/(W/R).* In downlink *I0* is the total received power spectral density (wideband power) without any effects of orthogonality.
- *Ec/I0* is used as a link performance indicator for signals which have no information e.g. CPICH, AICH, PICH. CPICH Ec/I0 is used for example when comparing different link strengths in handover algorithm.



$I_0=(I_{own}+I_{oth}+N)/W$, [Watts/Hz]

$E_c=P_{rx}/W$, [Watts/Hz]

Radio Link Performance Indicators: Definitions (5)

Ec/Ior

- transmitted energy per chip (on a chosen channel) relative to the total transmitted power spectral density at the BS. This is the same as the received energy per chip relative to the total (wideband) received power spectral density
- fraction of the power allocated to the channel from the total BS transmitted power used
- often utilized in DL performance requirements, used together with the geometry factor
- e.g. *Ec/Ior =(Ptx,channel /W)/(Ptx /W)= Ptx,channel /Ptx*

Radio Link Performance Indicators: Definitions (6)

Average Power Rise

- When the MS speed is low, the fast power control is able to compensate the fast fading (low *Eb/N0* values for a certain BLER)
- This increases the average transmitted power!
- measured from link-level simulations as the difference between the average transmitted power and the average received power, condition that the average channel gain is 1
- Increases the average interference to adjacent cells, has to be taken into account in dimensioning
- In downlink the average power rise is effecting the total increase in BS transmission power and is taken into account in downlink *Eb/N0* values

Radio Link Performance Indicators: Definitions (7)

Power control headroom

- In the cell border the fast power control starts to hit the maximum Tx power (21 dBm / 24 dBm). This means that the BLER starts to increase. A margin is required in order to ensure good enough link quality at the cell border, as well. This margin is called power control headroom

Macro Diversity Combining Gain (MDC gain)

- the reduction of Eb/N0 per link in soft(er) handover compared to the one radio link case.
- Uplink
  - The gain in received Eb/N0 values is relatively small (good TPC)
  - The gain in transmitted powers is significant (cell edge)
- Downlink
  - Decreases the needed Tx power per BS. However, more BSs needed. The net-effect can be quite small
- SHO gain ≠ MDC gain
  - In SHO gain the link is connected to the best cell and can, in principle, be obtained with very fast hard handover

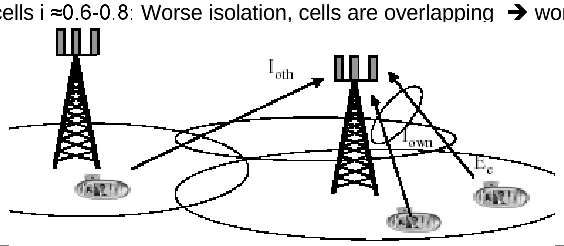
Radio Link Performance Indicators: Definitions (8)

Little i

- Other-to-own cell received power ratio: little i = total power received from surrounding cells per total power received from the owncell

i = Iother/Iown

- Gives the isolation of the cell; i.e. how well the radio cell is isolated from its adjacent cells
- In microcells i≈0.2: Good isolation because of surrounding buildings ➔ good spectral efficiency = good capacity
- In macrocells i ≈0.6-0.8: Worse isolation, cells are overlapping ➔ worse spectral density



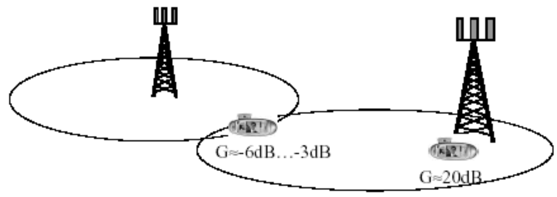
Radio Link Performance Indicators: Definitions (9)

Geometry Factor, G

- Used in downlink performance evaluation
- Definition: G = Iown/(Ioth+PN)

Ratio of the received power from the serving cell/
(received power from the surrounding cells +thermal noise)

- When the network is interference limited in DL (PN<<*Iother*): *G ≈1/i*
- Reflects the distance of the MS from the BS antenna. Typically –3 dB for the cell edge and 20 dB close to the BS



Multichannel Channel Conditions and Services

3GPP Multipath Channel Models

- MS and BS performance tests defined in specifications
- The main performance indicators (like Eb/N0) are dependent on the propagation¨channel conditions
- Well defined radio channel models
- Example of one 3GPP model:
  - MS speed 3 km/h,
  - tap1: relative delay 0 ns and average tap power 0 dB
  - tap2: relative delay 976 ns and average tap power –10 dB

ITU Multipath Models

- Similar models like 3GPP
- Models:
  - IndoorA, IndoorB
  - 'Outdoor-to-indoor and pedestrian'A, 'Outdoor-to-indoor and pedestrian'B
  - VehicularA, VehicularB

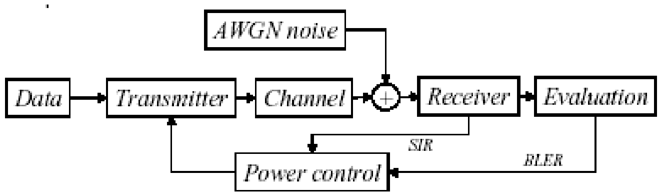
Multichannel Channel Conditions and Services

Reference Measurement Channels and the Link Performance Requirements in the Standard

- Reference services:
  - Speech: 12.2 kbps
  - Data: 64 kbps, 144 kbps, 384 kbps and 2048 kbps
- Uplink (UL) and downlink (DL)
- Link performance of above shown channels are in standard
- In UL average Eb/N0 performance with fixed BLER without PC
- In DL average required Ec/Ior for fixed BLER at selected G
  - Common channels not defined in 3GPP rel 99

Link Level Simulation Principles

Uplink simulations

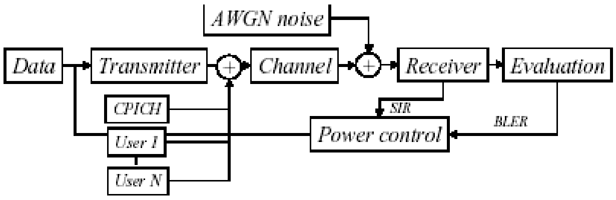


Outputs

- Transmitted power *ptx* in each slot
- Received power *prx* in each slot ➔ Eb/N0=(prx/R)/(I/W) at accepted BLER
- BER and BLER statistics

Link Level Simulation Principles

Downlink Simulations



- In DL interference from the own cell has to be taken into account
- CPICH used for the channel estimation in DL
- In DL the geometry factor is needed
- In uplink other users interference can be modelled with AWGN which is independent on the MS location
- In DL the own cell users can cause interference which is dependent on the MS location

$$\frac{W}{R}\cdot\frac{ptx}{Iown}\cdot\frac{1}{(1-\alpha)+\frac{1}{G}}=\rho \Rightarrow \frac{ptx}{Iown}=\frac{\rho R}{W}((1-\alpha)+\frac{1}{G})$$

Link Level Simulation Principles

Simulator features
(for reliability of the results):

- **High time resolution (at least chip resolution)**
- **Realistic channel estimation which uses as input only the received signal, not the known channel coefficients**
- **Power control, including closed-loop and outer-loop**
- **Realistic SIR estimation**
- **Delay in the power control feedback loop**
- **Power control bit errors**

Physical Layer Measurements

- The typical measurements defined in the standardization characterizing the link performance in live network
- UE measurements
  - CPICH RSCP – Received Signal Code Power
    - Received power of the CPICH channel measured by the UE (path loss estimation)
  - UTRA carrier RSSI – Received Signal Strength Indicator
    - Total wideband power
  - CPICH Ec/N0 – Received energy per chip divided by the power density in the band
    - theoretically equal to CPICH RSCP/ RSSI
  - Transport Channel BLER – estimate for the block error rate
  - UE Transmitted power

Physical Layer Measurements

UTRAN measurements

- RSSI - received total wideband power
- SIR - Signal to interference ratio
  - Definition: (RSCP/ISCP)*SF, where
    - RSCP = Received Signal Code Power on the DPCCH channel in question
    - ISCP = Interference Signal Code Power on the DPCCH i.e. Received total power (=interference) of the uplink quadrature channel
    - SF is the spreading factor on the DPCCH (=256)
- SIRerror
  - Difference between SIR and SIR target in the closed loop PC
- Transmitted carrier power
  - Ratio between the total transmitted power and the maximum transmission power of the base station
- Transmitted code power
  - Transmitted power (BS) of one code channel
- Transport Channel BER
- Physical Channer BER (=Raw BER)