Power Control in Cellular System

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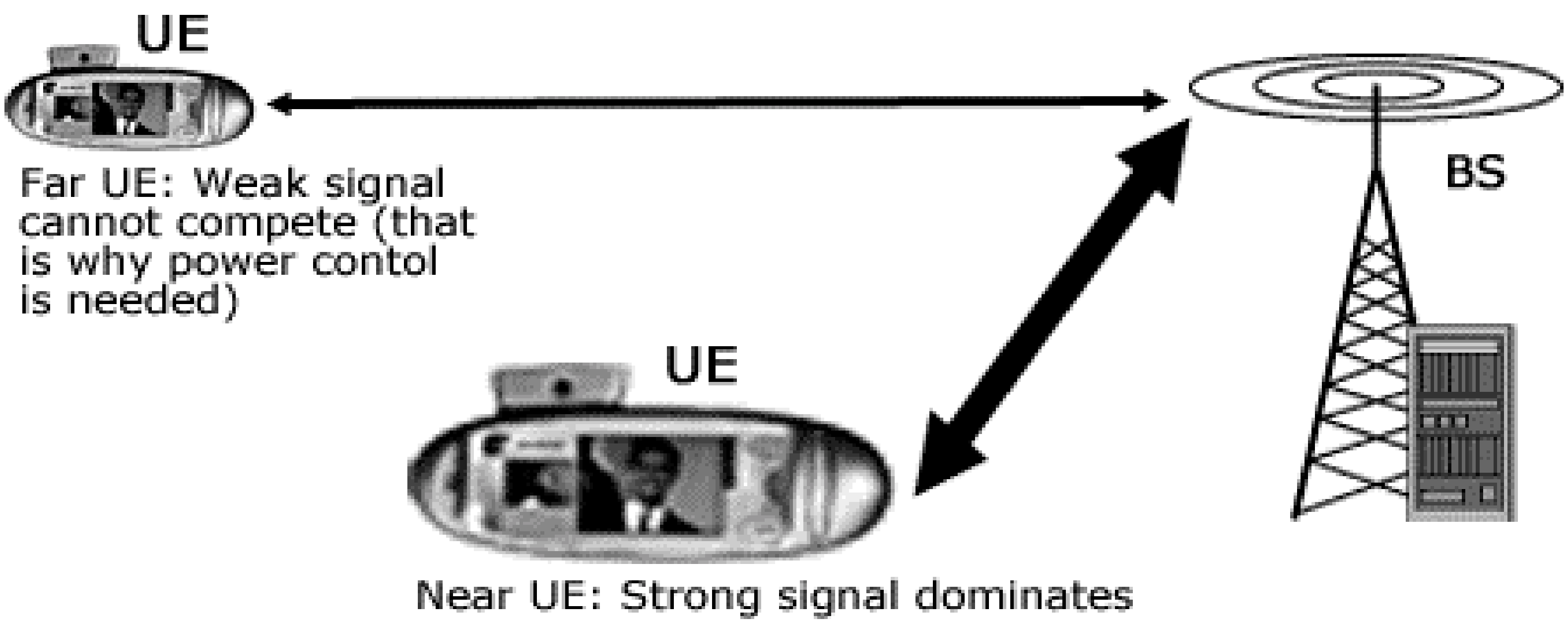
Power Control in WCDMA (General)

- Maintain the link quality in uplink and downlink by adjusting the powers
- Mitigate the near far effect by providing minimum required power level for each connection
- Power control provides protection against shadowing and fast fading
- Minimisies the interference in the network, thus improves capacity and quality
- The battery life of the MS can be extended

Near-Far Problem

Near-far problem

This problem arises in the uplink when all teminals use the same transmit power:



Power Control Loops in WCDMA

- **Open loop power control**
    - for *initial* power setting
- **Closed loop power control**
    - **Inner (Fast) power control (1500 Hz)**
        - makes Eb/N0 requirements lower
        - equalizes received powers at BS in reverse link (avoid near-far)
        - introduces peaks in the transmit power
    - **Outer power control loop**
        - at a much slower rate, across the Iub interface in reverse link
        - Adjusts the SIR target to achieve a target FER/BER

Open Loop Power Control (1)

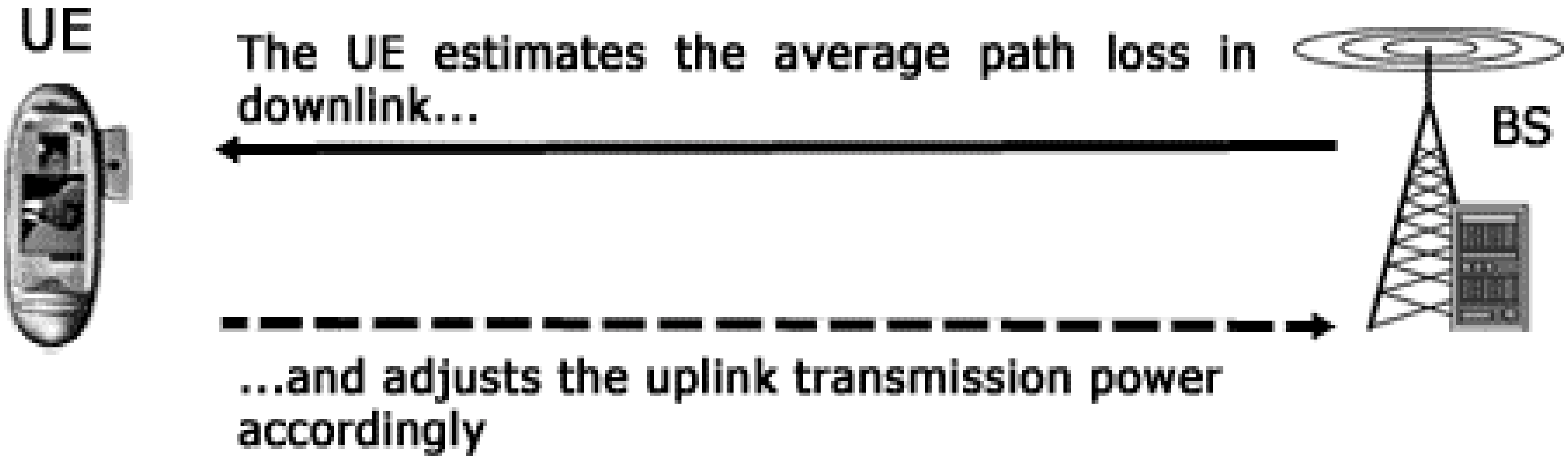
This form of power control is used in WCDMA to provide a coarse initial power setting of the mobile station at the beginning of a connection (i.E. During the random access procedure).

The problem with this scheme is that fast fading cannot be tracked and compensated by power control, since fast fading is different in uplink and downlink when different frequencies are used.

In UTRA TDD, open loop power control is much more effective, since uplink and downlink use the same frequency and the fast fading is the same in both directions.

Open Loop Power Control (2)

This simple and inaccurate power control scheme must be used during the random access process at the begining of a connection until more accurate control information is available



Open Loop Power Control (3)

- Open loop power control relies on the assumption that the power-loss in the uplink and downlink channel is identical.

- The MS Tx power is adjusted as follows:

  - ✧Measure the received power from the BS (after RAKE finger comb.)
  - ✧The power-loss in the downlink channel is determined based on knowledge of the BS Tx power.
  - ✧Adjust the MS Tx power according to the estimated power-loss.

Open Loop Power Control (4)

- Purpose: to set the initial transmitted power of PRACH in the UL and FACH in the DL
- UE determines the uplink preamble power of PRACH

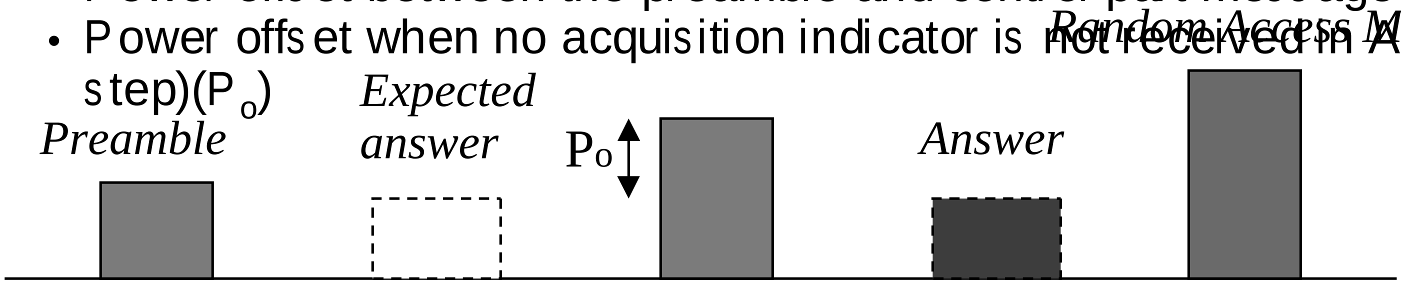
  UE PRACH first preamble power =
  Transmission power of CPICH (broadcast on BCH) -
  Downlink Ec/Io measurement of active cell on CPICH (measured by UE) +
  Total received wideband interference power at WCDMA BTS (broadcast on BCH) +
  Required received SIR at the WCDMA BTS (broadcast on BCH)

- BTS of downlink FACH is fixed and set on a per-cell basis (RAN1)
- Open loop PC is a part of random access procedure for PRACH channel

Open Loop Power control (5)

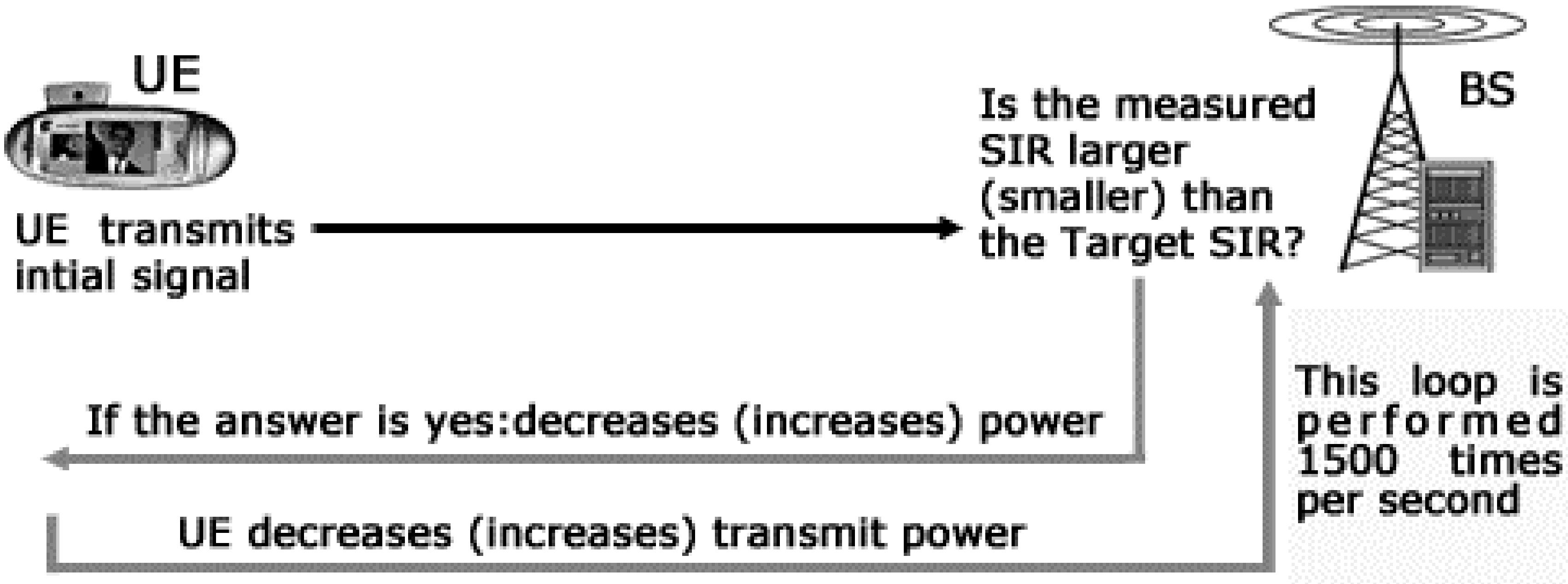
Random Access Procedure

- UE transmits the first preamble with the power determined by UL open loop PC
- If the UE does not detect any acquisition indicator in AICH, it increases the preamble Tx power by a specified offset P_o
- If the UE detects the positive indicator in AICH, it transmits the random access message, 3 or 4 access slots after the UL access slot of the last transmitted preamble
- The Tx power of the control part of random access message should be $p_{p\text{-}m}$ higher than the last transmitted preamble power
- The required power offset values for random access procedure
  - Power offset between the preamble and control part message in PRACH($p_{p\text{-}m}$)
  - Power offset when no acquisition indicator is not received in AICH (power ramp step)(P_o)



Inner Loop (closed) Power Control (1)

Inner loop power control (also called fast power control) is used both in uplink (shown in this figure) and downlink



Inner Loop (Closed) Power Control (2)

When using the inner loop (closed) power control scheme, the following three steps are performed once every slot (equal to 1500 times per second):

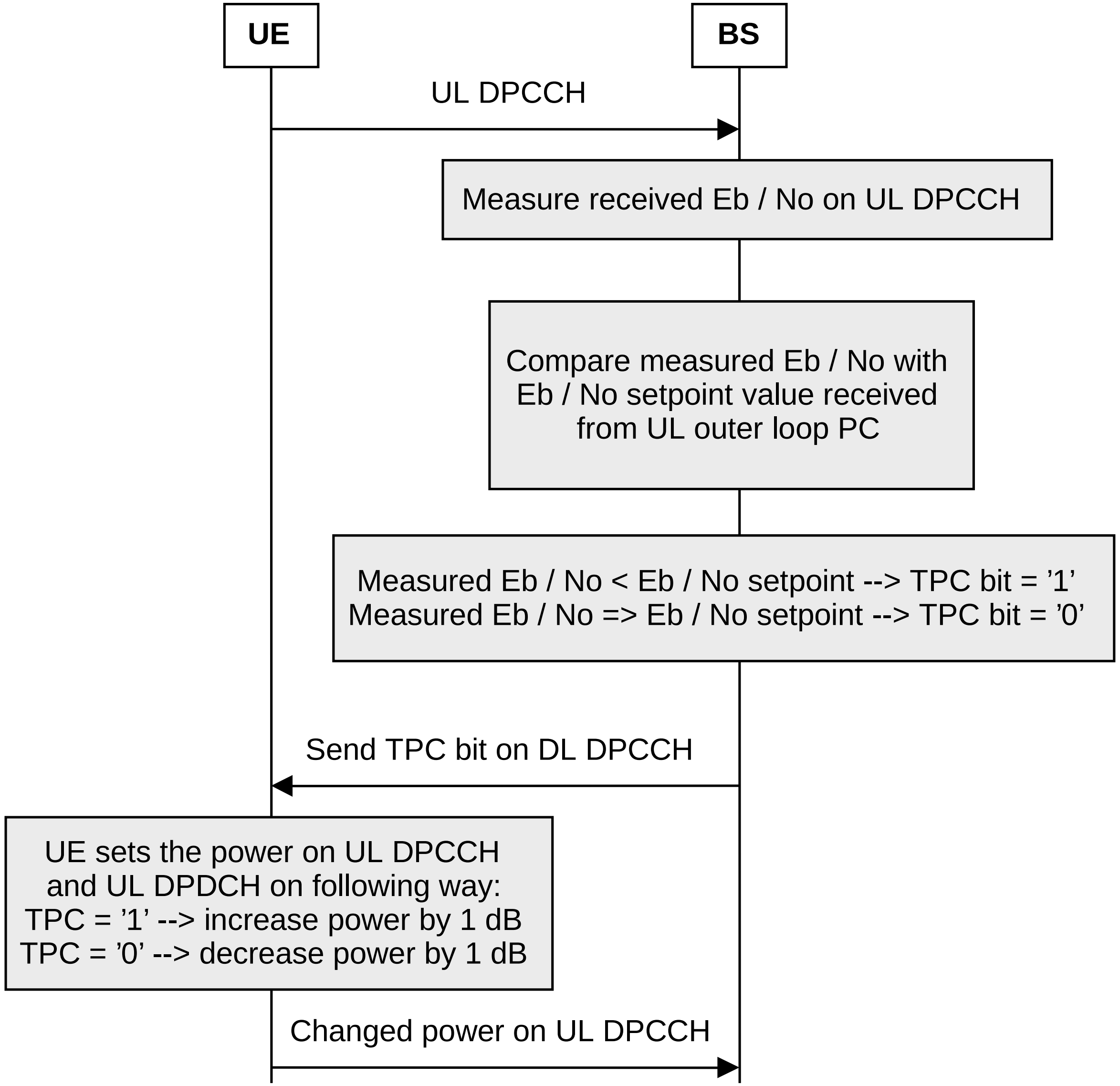
1. The receiving end of the connection compares the SIR value of the received signal to the target SIR value which is typically 3 ... 7 db depending on the QoS requirements and bit rate of the received signal.

2. Control bits are sent back to the transmitting end indicating that the transmit power should either be increased (received SIR < target SIR) or decreased (received SIR > target SIR) by a certain amount (typically 1 db).

3. The transmitter power is increased or decreased by the amount specified.

UpLink Inner Loop (Closed) Power Control (3)

- PC frequency 1500 Hz
- PC step 1dB (0.5 … 2 dB)
- PC delay approx. one slot



DownLink Inner Loop Power Control (4)

- UE measures the SIR on DL DPCCH during the pilot period (in SHO after MRC)
- Before generating TPC commands UE checks DPC_MODE (downlink power control mode)
  - DPC_MODE parameter is a UE specific parameter controlled by the network
  - If DPC_MODE is ’0’, UE sends unique TPC command in each slot in the first available TPC field in the UL DPCCH
  - If DPC_MODE is ’1’, repeats the same TPC commands over 3 slot but a new TPC command is sent at the beginning of the frame
  - DPC_MODE is set to ’0’ in RAN1, RNC sends it to UE in RRC
- Upon receiving the TPC commands BS adjusts its downlink DPCCH/DPDCH power accordingly

Gain of Inner Power Control (5)

- Speech performance FER=1% (8kbps 10ms interleaving) with 2 branch receiver antenna diversity in uplink
- Slow power control = no power control in simulations = correct average power

Received power

	Slow power control	*Fast 1.5kHz power control*	*Gain from fast power control*
ITU Pedestrian A 3 km/h	11.3dB	5.5dB	5.8dB
ITU Vehicular A 3 km/h	8.5dB	6.7dB	1.8dB
ITU Vehicular A 50 km/h	6.8dB	7.3dB	-0.5dB

Transmitted power

	Slow power control	*Fast 1.5kHz power control*	*Gain from fast power control*
ITU Pedestrian A 3 km/h	11.3dB	7.7dB	3.6dB
ITU Vehicular A 3 km/h	8.5dB	7.5dB	1.0dB
ITU Vehicular A 50 km/h	6.8dB	7.6dB	-0.8dB

- The gain from the fast power control is larger for low mobile speeds than for high mobile speeds in received powers than in transmitted powers if only little multipath diversity is available

Inner Loop Power Control (6)
- Consideration

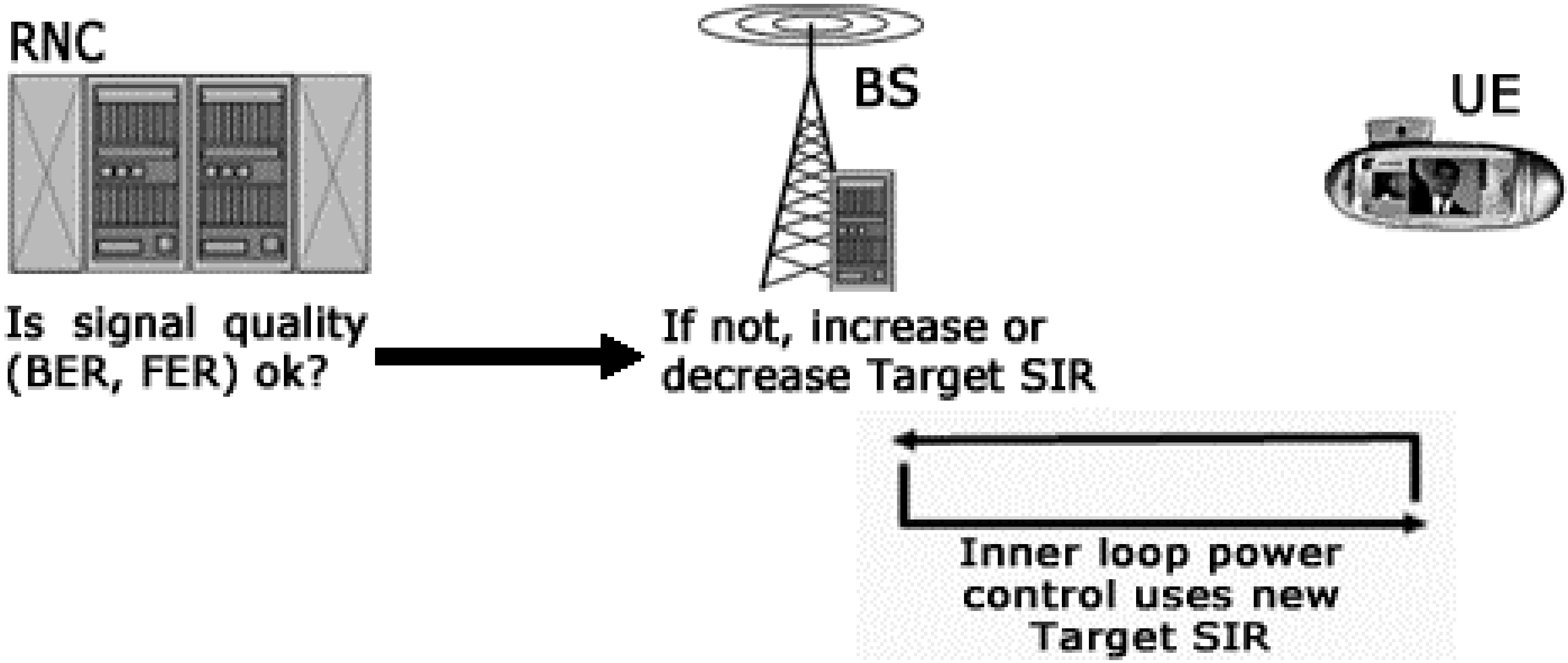
- Note that the feedback control bits may contain errors. Also, the soft handover procedure adds additional complexity to power control in uplink, since some base stations may send an ”increase power” and others a ”decrease power” command. Obviously, a strategy could be used where one ”decrease power” command overrides any number of ”increase power” commands, since there is strong indication that at least one radio link provides sufficient signal quality.

Outer Loop Power Control (1)

- Measures such as bit error ratio (BER) or frame error ratio (FER), rather than Target SIR, reflect how a user perceives service quality.
- Outer loop power control strives to keep the BER or FER value at a certain level, and accordingly adjusts (within certain limits) the Target SIR value utilized by the inner loop power control scheme.

Outer Loop Power Control (2)

Outer loop power control is used both in uplink (shown in this figure) and downlink



Outer Loop Power Control

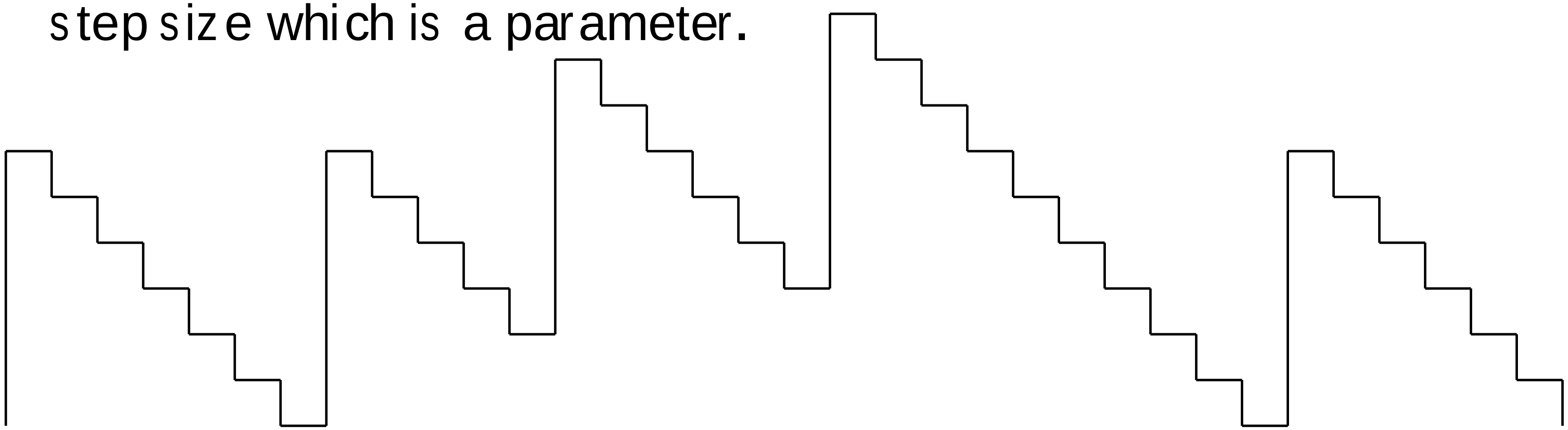
- Basic function

$$EbNoSetpoint(n+1) = EbNoSetpoint(n) + \Delta\,[dB]$$

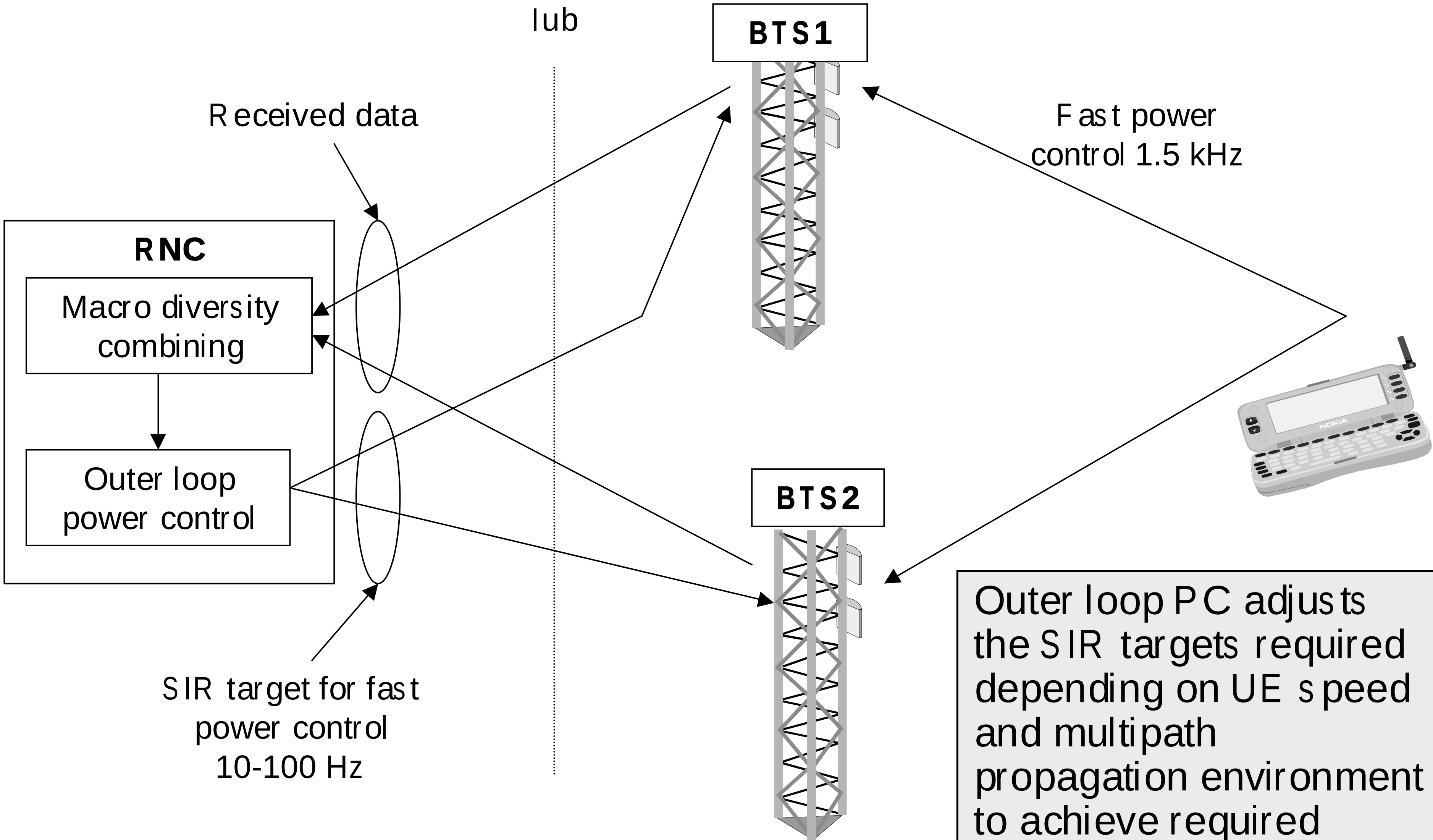
where

$$\Delta = \hat{f}\,s - F_{th}s$$

where $\hat{f}$ is 1 if there is a frame error according to CRC and $\hat{f}$ is 0 if the frame was correct. Fth is the wanted FER and s is the step size which is a parameter.



UpLink Outer Loop Power Control (3)



Outer loop PC adjusts the SIR targets required depending on UE speed and multipath propagation environment to achieve required quality with min. power

UpLink Outer Loop Power Control (4)

- The outer loop is responsible of controlling the E_b/N_0 set point so that the required quality is achieved with minimum power. The quality requirement of the link is usually given in long term average FER or BER.

- Uplink
  - located in RNC
  - The initial Eb/No set-point and changes to that are sent from RNC to BS.
  - outer loop must be prevented to run to abnormally high or low Eb/No setpoints

DownLink Outer Loop Power Control (5)

- Implemented in UE to set SIR target on each CCTrCH (one in RAN1) used for the DL closed loop PC
- Quality target: BLER of each transport channel as set by RNC
- Admission Control (AC) determines the value of DL BLER target for each DCH mapped on DPCH

Comparison of PC in WCDMA vs. CDMA

- The closed loop power control (i.e. fast power control) is that it works better in the WCDMA as the signal is spread to wider bandwidth.
- CDMA traditionally has fast power control only in the uplink and not in the downlink, whereas WCDMA has fast power control for both the uplink and downlink.
- The outer loop (quality) loop power control is much more critical in the WCDMA as it contains radio bearers of very diverse types and very different requirements. Traditional CDMA algorithms are developed for the speech bearers mainly, although recent development allows other bearers as well.

Abbreviation

- AICH: acquisition indicator channel;
- BER: bit error ratio;
- BLER: block error ratio; block error rate;
- PRACH:packet random access channel; physical random access channel;
- FACH; forward access channel;
- SIR: signal-to-interference ratio;
- FER: frame error rate;
- CCTrCH: coded composite transport channel;
- DPCCH:Dedicated Physical Control Channel
- TFCI: transport format combination indicator;
- TDD: time division duplex ;
- SHO: soft handover ; soft handoff /US/ ;

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