

CDMA Power Control

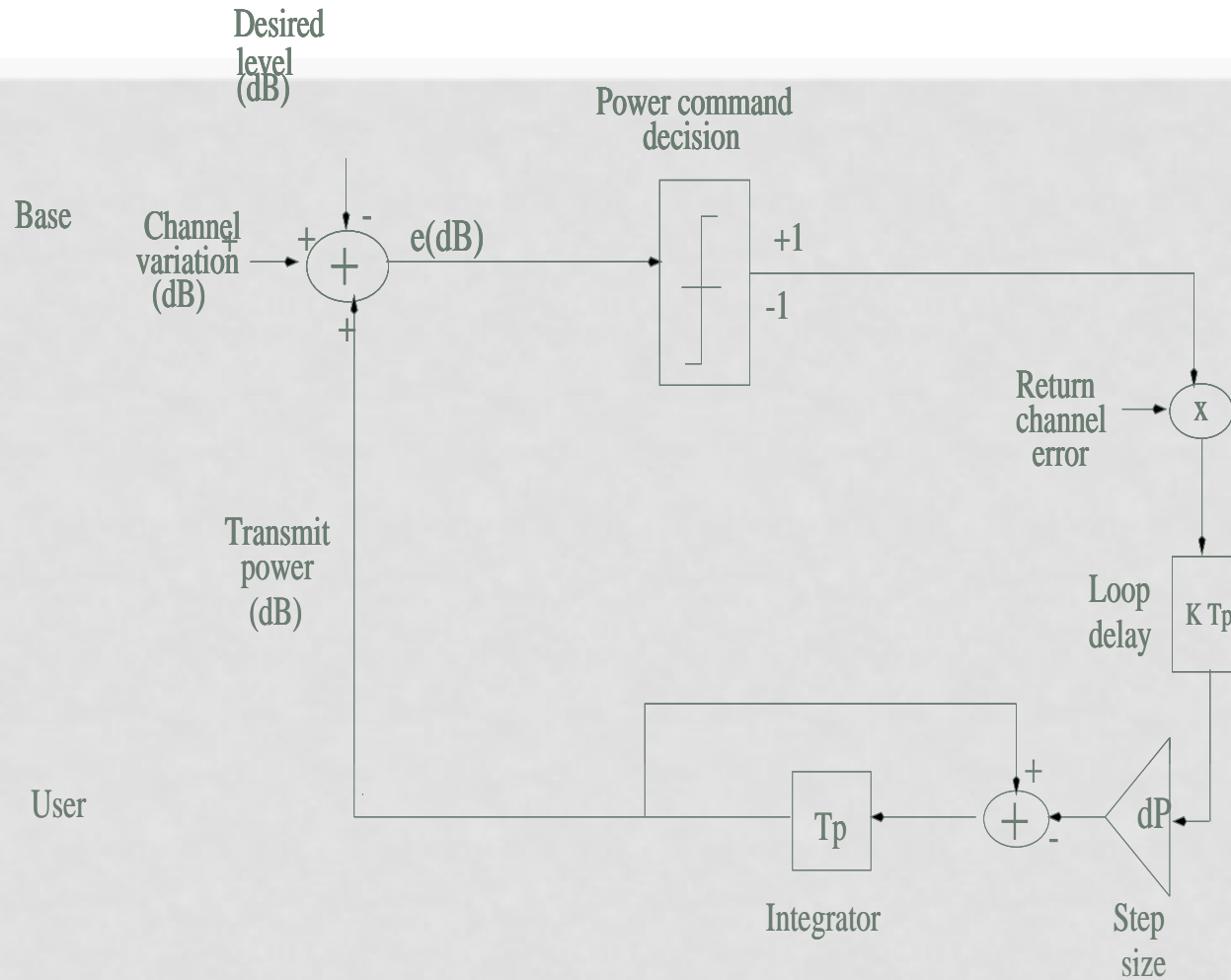
INTERFERENCE IN CDMA CELLULAR SYSTEMS

- -CDMA cellular systems are interference limited
- -Reducing the interference results in direct increase in system capacity.
- -Interference can be reduced by: Sectorization, voice activity monitoring, beam forming techniques, diversity techniques (SSTD), power control,...
- -Power control is needed in both FWL (3G) and RVL (near-far problem)
- -Power control compensates for: distance, shadowing and multipath fading. It can be based on signal strength or based on SIR $[E_b/(N_o+I_o)]$
- Power control has two loops: Inner loop (open,closed) and outer loop.

INNER LOOP POWER

- Distance and Shadowing: Reciprocal on both FW and Rev. links
- Mobile measure signal on the FW and adjusts its power accordingly (OLPC)
- Multipath fading: Frequency separation between FW and Rev. links \gg coherence BW of the channel. Hence, both links fade independently. Base station has to tell the mobile how to adjust its power (CLPC).
- The rate of change in the channel is function of: mobile speed, number of fading resolvable paths, carrier frequency, etc.
- CDMA2000: 800 commands/sec
- 3GPP: 1500 commands/sec

CLOSED LOOP POWER CONTROL

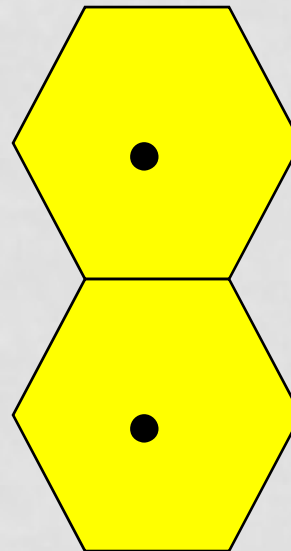


OUTER LOOP POWER CONTROL

- -Base station check if the frame is in error or not.
 - If frame is in error: $\text{target}=\text{target}+\Delta$
 - -If error free: $\text{target}=\text{target}-\delta$
- To achieve a given FER:
 - $\delta= \Delta/(1/\text{FER}-1)$.
- Example: $\Delta=1\text{dB}$ and $\text{FER}=1\%$: $\delta= 0.01$

VARIATIONS IN THE RECEIVED SIGNAL LEVEL

- The step size is in dB's
- The received power is modeled by a log-normal variable
- with a certain standard deviation.
- -This standard deviation is a function of which base station does the mobile communicate with.

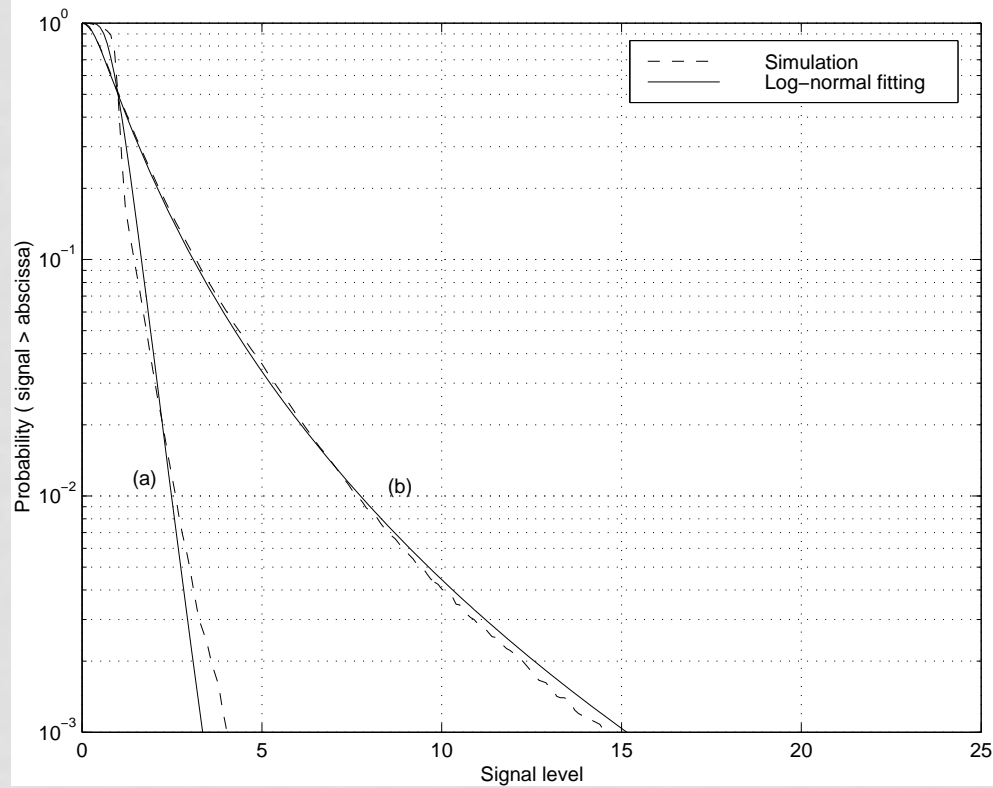


VARIATIONS IN THE RECEIVED SIGNAL (2)

Table 1: Standard deviation determined from logarithmic fitting of signal power versus carrier frequency for different laser intensities. The standard laser intensity used is 1000 W/cm².

VLaser/W	σ _{0.1dB}	σ _{0.2dB}	σ _{0.3dB}	σ _{0.4dB}	σ _{0.5dB}	σ _{0.6dB}	σ _{0.7dB}	σ _{0.8dB}	σ _{0.9dB}	σ _{1.0dB}
0	0.35	4.50	0.35	3.50	0.31	3.10	0.31	3.10	0.31	3.10
15	1.0	4.65	0.62	3.74	0.44	3.14	0.46	3.14	0.46	3.14
20	1.40	3.80	0.94	3.67	0.66	2.80	0.66	2.80	0.66	2.80
300	1.88	3.53	1.40	3.58	0.88	2.50	0.88	2.50	0.88	2.50
40	2.20	3.41	1.75	3.25	1.25	2.45	1.25	2.45	1.25	2.45

VARIATIONS IN THE RECEIVED SIGNAL (3)



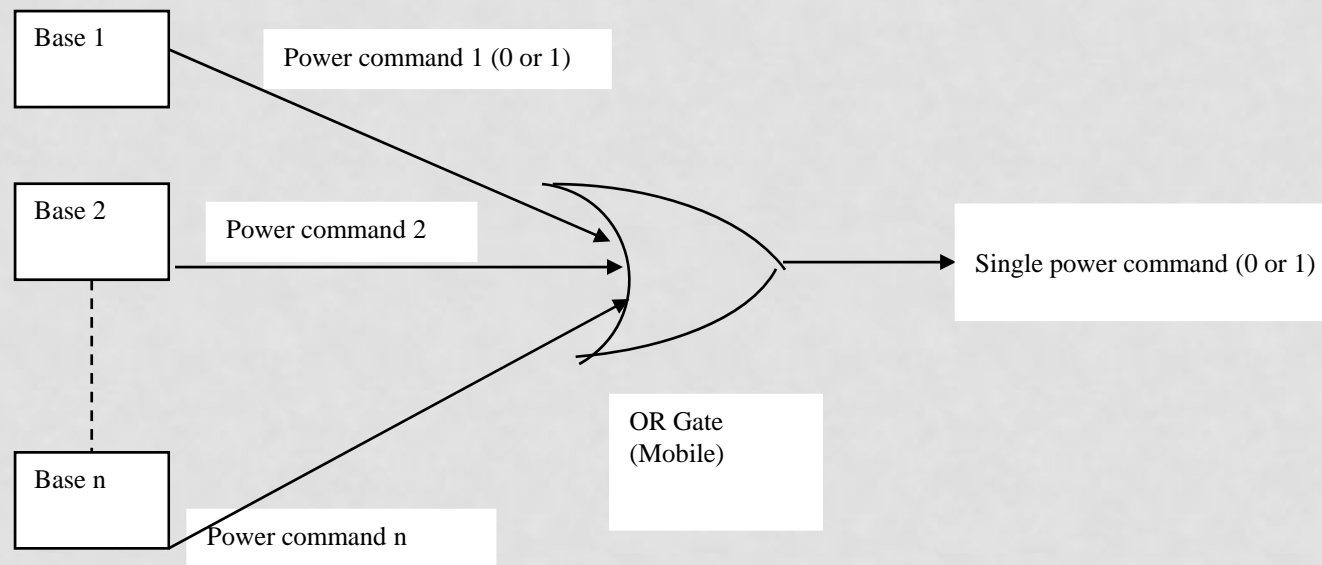
Perfect Power Control?!

COMBINED POWER/RATE CONTROL

- The objective is to achieve a given E_b/N_0 value.
- $E_b = S/R$, which means that a higher E_b can be achieved by either increasing the power or decreasing the rate.
- We can start decreasing the rate when the increase in power to compensate for multipath fading exceeds a certain value (P_1). This value can be dependent on the service type (delay tolerance). Or we can start decreasing the rate when the maximum power is reached.
- How can the receiver know what is the transmission rate?
 - -Blind rate detection (rate is one of few choices)
 - -Explicit rate information (TFICI in UMTS)

REVERSE LINK POWER CONTROL DURING SOFT HANDOFF

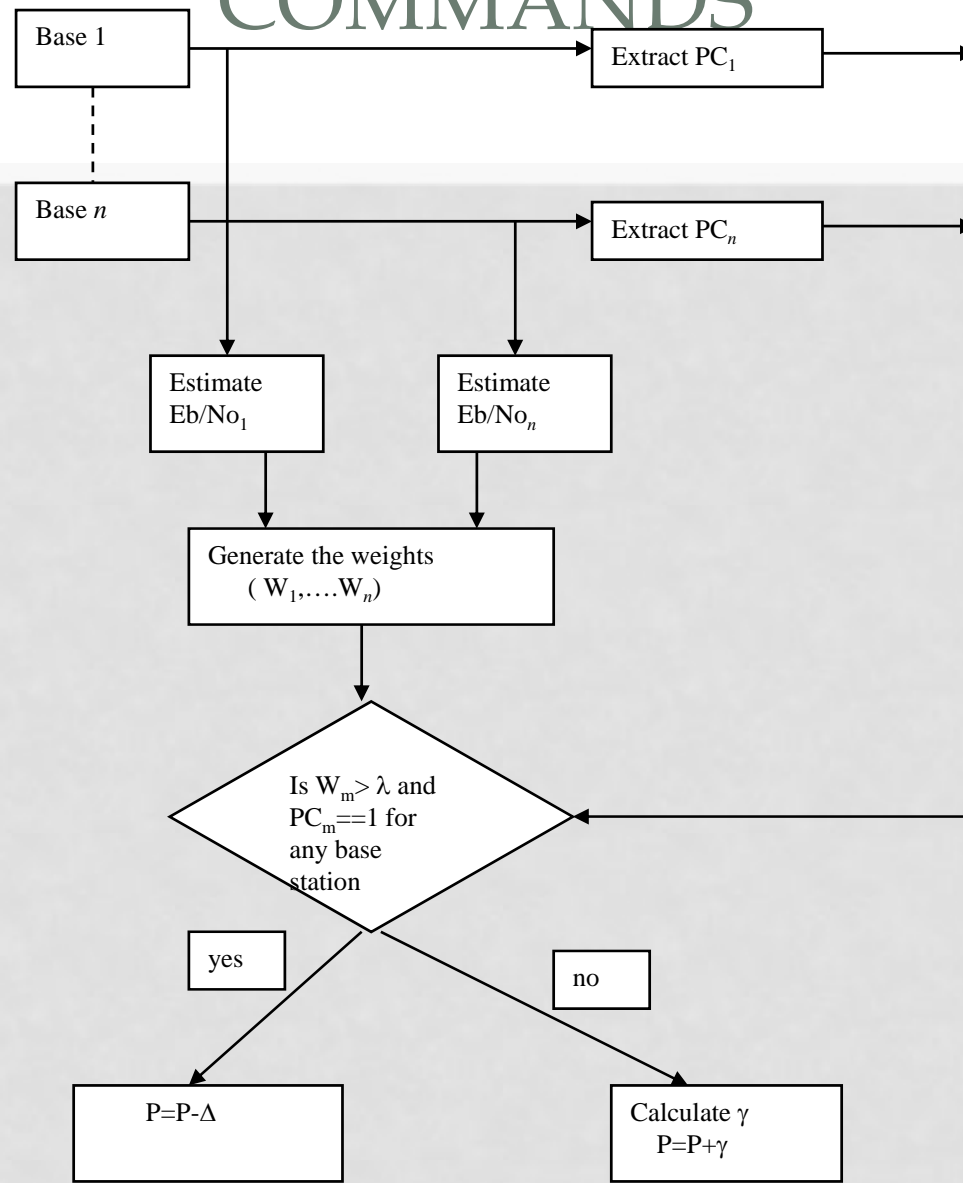
- The mobile receives different commands from the different base stations. How to adjust its power?
- The objective is to reduce interference. If any base station is receiving enough power and asks for a decrease in power, the mobile should reduce its transmitted power. This is called the "or of the downs", assume 1: down and 0 up



OR OF THE DOWNS

- The “or of the downs” assumes that the power control commands to be error free.
- The commands are sent uncoded to avoid the delay associated with coding.
- With a good link condition, the error rate of the power commands is about 5%.
- During soft handoff, we have one link which is weaker than the other which results in a higher error rate on the power commands.
- All base stations can be asking for an increase in power and if only one command is received in error, the mobile lowers its power.
- More frames will be received in error at the base stations which results in increasing the SIR target (outer loop). This results in the mobile transmitting extra power which increases the interference (reduces capacity)

RELIABILITY OF THE POWER CONTROL COMMANDS



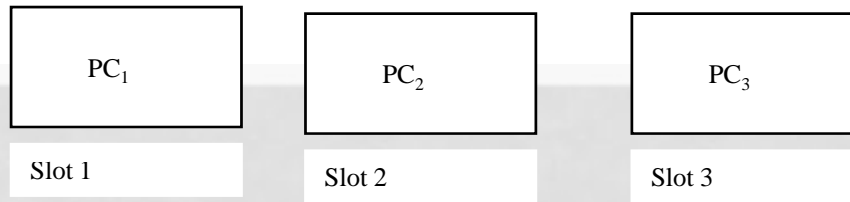
FORWARD LINK POWER CONTROL DURING SOFT HANDOFF

- The mobile enters in a soft handoff mode when the average received signal from the base stations is within a certain threshold (3dB, 6dB). The higher the threshold, the more mobiles in soft handoff.
- The mobile uses a Rake receiver to combine all signals from the different base stations and issues a single power command.
- The base stations can receive the command differently! And hence adjust their powers in opposite directions! If the step size is 1dB, 4 PC commands received differently result in 8 dB difference in transmitted powers. This obviously waste the diversity gain we get from soft handoff.
- Solution: synchronize the base stations transmitted powers. Give more error protection to the PC commands.
- The synchronization is done by higher layers ($> L1$) and thus is a slow process which is feasible only over many frames.

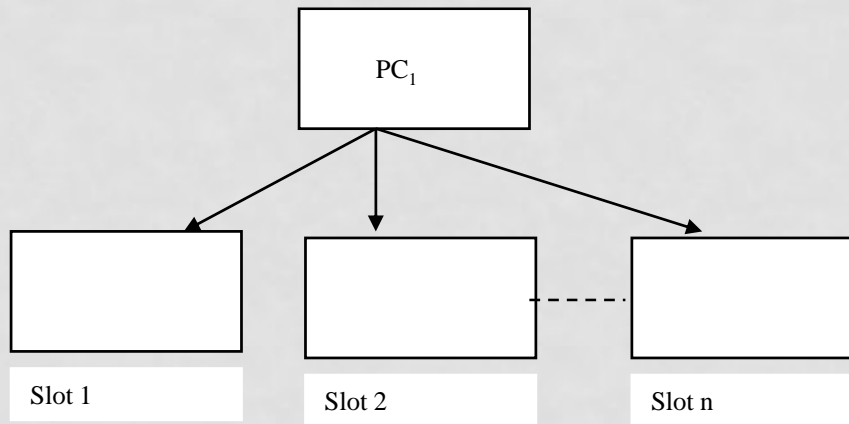
POWER CONTROL RATE REDUCTION

- The error rate of the PC commands can be reduced if the command is repeated over several PC groups (slots). This also results in the base stations adjusting their power less often.
- During soft handoff, the mobile receives the signal via more than one path and hence the channel is not expected to be changing rapidly.

POWER CONTROL RATE REDUCTION (2)



A: When the UE is not in soft handover



B: When the UE is in soft handover

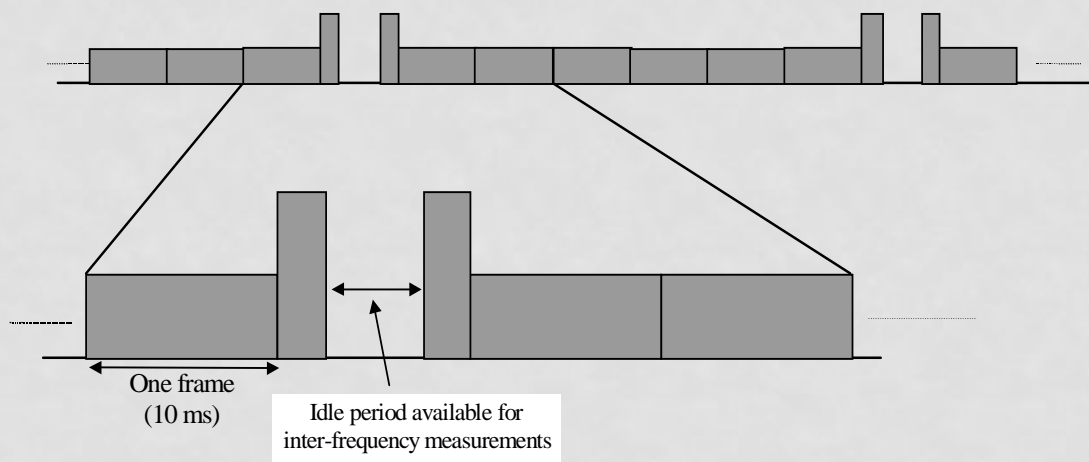
Proposed Scheme: A: when the UE is not in soft handover, B: when the UE is in soft handover

SITE SELECTION TRANSMIT DIVERSITY (SSDT)

- A form of downlink power control in soft or softer handover
- The UE selects one of the cells from its active set to be ‘primary’, all other cells are classed as ‘non primary’.
- The main objective is to transmit on the downlink from the best cell, thus reducing the interference caused by multiple transmissions in a soft handover mode.
- A second objective is to achieve fast site selection without network intervention, thus maintaining the advantage of the soft handover.
- In order to select a primary cell, each cell is assigned a temporary identification and UE periodically informs a primary cell identification (“ID”) to the connecting cells. The non-primary cells selected by UE switch off the transmission power. The primary cell identity code is delivered via uplink FBI field.

INNER LOOP POWER CONTROL IN COMPRESSED MODE

- Interruption of of downlink transmission (DI compressed mode) interrupts inner loop power control
- Modified PC algorithm at restart that applies on the end of the frame and possibly following frame
- Two modes of operation: same as in normal mode
 - different
 - PC step= $\min(2 \times \text{power step in normal mode}, 3\text{dB})$
 - Application duration : recovery period (RPL). RPL is fixed and equal to the minimum of (TGL, 7 slots)



CONCLUSION

- Power control is essential for CDMA cellular systems
- There is no optimum power control rate or step size
- Both the rate and the power can be adjusted to achieve a given QoS
- Power control during soft handoff should be implemented differently compared to normal mode case
- Any interruption in transmission degrades the PC algorithm performance