Power Control

Objectives

- Understand the purpose of Power Control in CDMA.
- Identify the different types of Power Control mechanisms used in CDMA
  - » Reverse Open Loop Power Control
  - » Reverse Closed Loop Power Control
  - » Reverse Outer Loop Power Control
  - » Forward Traffic Channel Power Control
- Identify the Access Parameters Message parameters that participate in Reverse Power Control.
- Identify the Access Parameters Message parameters that participate in Forward Traffic Channel Power Control.
- Review the concepts of “power control groups”.

CDMA Power Control

- CDMA is an interference-limited system based on the number of users
- Unlike AMPS/TDMA, CDMA has a *soft* capacity limit
  - Each user is a noise source on the shared channel
  - The noise contributed by users is cumulative
  - This creates a practical limit to how many users a system will sustain
- Precise power control of the mobile stations is critical if we want to
  - Maximize system capacity
  - Increase battery life of the mobile stations
- The goal is to keep each mobile station at the absolute minimum power level necessary to ensure acceptable service quality
  - *Ideally* the power received at the base station from each mobile station should be the same (minimum signal to interference)
  - Mobile stations which transmit excessive power increase interference to other mobile stations

Reverse Loop Power Control

Reverse Open Loop Power Control

- The mobile station makes a coarse initial estimation of the required transmit power, based upon the total received power.
- Problems with Reverse Open Loop Power Control:
  - Assumes same exact path loss in both directions; therefore, cannot account for asymmetrical path loss
  - Estimates are based on total power received; therefore the power received from other cell sites by mobile station introduces inaccuracies

Estimated Reverse Open Loop Output Power

Power output level for the initial probe during open loop probing on the Access Channel (with closed loop correction inactive):

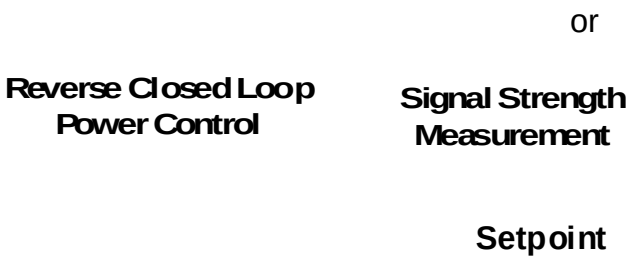
mean output power (dBm) = - mean power input (dBm)
+ K
+ NOM_PWR - 16 x NOM_PWR_EXT
+ INIT_PWR

Subsequent probes in the sequence are sent at increased power levels (each probe is incremented by a value equal to the parameter PWR_STEP)

Power output level for the initial transmission on the Reverse Traffic Channel:

mean output power (dBm) = - mean power input (dBm)
+ K
+ NOM_PWR - 16 x NOM_PWR_EXT
+ INIT_PWR
+ the sum of all access probe corrections (dB)

Reverse Close Loop Power Control



- Compensates for asymmetries between the forward and reverse paths
- Consists of power up (0) and power down (1) commands sent to the mobile stations, based upon their signal strength, measured at the Base Station and compared to a specified threshold *(setpoint)*
- Each command requests a 1dB increment or decrement of the mobile station transmit power
- Transmitted 800 times per second, always at full power
- Allows to compensate for the effects of fast fading

Reverse Close Loop Power Control

- The Reverse Closed Loop Power Control mechanism provides a correction on the Reverse Traffic Channel mean output power level with respect to the Open Loop estimate. 800 times per second (or once every 1.25 milliseconds) the base station overwrites one (13 kb vocoder) or two (8 kb vocoder) code symbols with a “power up” or “power down” command based on the strength of the signal received from the mobile during the preceding 1.25 ms interval. These power control bits are always transmitted at full power.
- As during some 1.25 ms intervals the mobile station’s transmitter is “gated on”, and during some other 1.25 ms intervals it is “gated off”, not every “power up” command received from the base station is meaningful. A power control bit is considered *valid* (and acted upon) only if it is received in the second 1.25 interval following an interval during which the mobile station transmitted. The mobile station “locks” on the accumulation of valid level changes and ignores received power control bits related to gated-off periods when the transmitter is disabled.
- Following the reception of a valid power control bit, the mean output power of the mobile station must be within ±0.3 dB of the final value in less than 500 μs. The change in mean output power level per single valid power control bit is ±1 dB nominal, and the total change in mean output power is the accumulation of all these individual changes. The *actual* change must be within ±0.5 dB of the nominal value, and the change in mean output power level per 10 valid power control bits of the same sign must be within ±20% of 10 times the nominal change.

Reverse Closed Loop Output Power Correction

Once the first power control bit has been received after initializing Reverse Traffic Channel transmissions, the mean output power is defined as follows:

mean output power (dBm) = - mean power input (dBm)
+ K
+ NOM_PWR - 16 x NOM_PWR_EXT
+ INIT_PWR
+ the sum of all access probe corrections (dB)
+ the sum of all closed loop power control corrections (dB)

The ‘turn around constant” K is calculated assuming a nominal cell Effective Radiation Power (ERP) of 5 W and a nominal cell loading of 50%.

Its value is -73 for cellular systems and -76 for PCS systems

Power Output Estimations (Summary)

Open Loop Probing on the Access Channel

Based on:

1. **mean input power** measured at mobile station
2. **access parameters** provided by the base station

(Subsequent probes are adjusted by access parameters provided by the base station)

Reverse Traffic Channel Initial transmission

Based on:

1. **mean input power** measured at mobile station
2. **access parameters** provided by the base station
3. **sum of all the access probe adjustments**

After First Power Control Bit Has Been Received

Based on:

1. **mean input power** measured at mobile station
2. **access parameters** provided by the base station
3. **sum of all the access probe adjustments**
4. **sum of all the power control bits received**

- The mean input power is defined as the power received at the mobile station for the 1.25 MHz RF channel bandwidth being used
- The access parameter values can vary between base stations
  - They accommodate differing forward power levels and antenna gains
  - They are specified in the *Access Parameters Message*, sent over the Paging channel

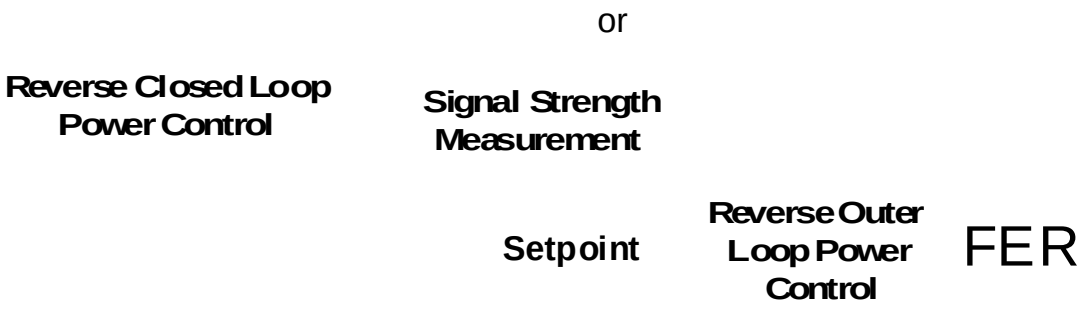
Access Parameters Message(Paging Channel)

Field	Length (bits)		
MSG_TYPE (‘00000010’)	8		
PILOT_PN	9	PSIST(14)	3
ACC_MSG_SEQ	6	PSIST(15)	3
ACC_CHAN	5	MSG_PSIST	3
NOM_PWR	**4**	REG_PSIST	3
INIT_PWR	**5**	PROBE_PN_RAN	4
PWR_STEP	**3**	ACC_TMO	4
NUM_STEP	4	PROBE_BKOFF	4
MAX_CAP_SZ	3	BKOFF	4
PAM_SZ	4	MAX_REQ_SEQ	4
PSIST(0-9)	6	MAX_RSP_SEQ	4
PSIST(10)	3	AUTH	2
PSIST(11)	3	RAND	0 or 32
PSIST(12)	3	**NOM_PWR_EXT**	**1**
PSIST(13)	3	RESERVED (‘000000’)	6

Access Parameters Message (Paging Channel)

- **INIT_PWR** – Initial Power. This is the correction factor to be used by the mobile stations in the open-loop power estimation for initial transmission on an Access Channel, expressed as a two's complement value in units of 1 dB.
- **NOM_PWR** – Nominal Transmit Power Offset. If the correction factor to be used by the mobile stations in the open-loop power estimation is between -24 dB and -9 dB, the NOM_PWR parameter must be set to 16 dB plus the correction factor. Otherwise (the correction factor is in the range -8 dB to 7 dB inclusive), the NOM_PWR parameter must be set to the correction factor. The NOM_PWR is expressed as a two's complement value in units of 1 dB.
- **NOM_PWR_EXT** – Extended Nominal Transmit Power. If the correction factor to be used by the mobile stations in the open-loop power estimation is between -24 dB and -9 dB, this parameter must be set to '1'. Otherwise (the correction factor is in the range -8 dB to 7 dB inclusive), this parameter must be set to '0'.
- PWR_STEP - Power increment. This is the value, in units of 1 dB, by which a mobile station is to increase its transmit power between successive probes in an access probe.

Reverse Outer Loop Power Control



- Not part of IS-95A or J-STD-008.
- Most gradual form of reverse link error control
  - *Setpoint* is varied according to the FER on the Reverse Traffic Channel (determined at the Base Station Controller)
  - Sampled at a rate of 50 frames per second (20 ms / frame)
  - Setpoint adjusted every 1-2 seconds

Forward Traffic Channel Power Control



- The base station slowly decreases power to each mobile station
- As the FER (determined at the mobile station) increases, the mobile station “requests” a Forward Traffic Channel power increase

Forward Traffic Channel Power Control

- The following applies only to the **8 kb vocoder**:
- To support Forward Traffic Channel power control, the mobile station reports FER statistics to the base station. If the base station enables **periodic reporting**, the mobile station reports FER statistics at specified intervals. If the base station enables **threshold reporting**, the mobile station reports FER statistics when the frame error rate exceeds a specified threshold.
- Either, or both types of reporting can be enabled or disabled at any given time by the base station. Periodic reporting is controlled by PWR_PERIOD_ENABLE and PWR_REP_FRAMES. Threshold reporting is controlled by PWR_THRESH_ENABLE and PWR_REP_THRESH.
- The mobile station maintains a counter of the total number of **received frames** and a counter for the number of **received bad frames**. At the end of the specified period or when the threshold is exceeded, depending on what has been enabled, the mobile station sends a “Power Measurement Report Message” to the base station. Then it resets both counters to zero and freezes them for PWR_REP_DELAY x 4 frames following the first transmission of the message.
- These parameters are delivered to the mobile station in the System Parameters Message.
- **BAD FRAMES** are either (a) 9600 bps primary-traffic-only frames, with bit errors, or (b) frames with “insufficient frame quality”
- A frame has **INSUFFICIENT FRAME QUALITY** if the mobile station cannot figure out its rate or if errors (other than bit errors in a 9600 bps traffic only frame) are detected.
- When a **13 kb vocoder** is used, the mechanism just described is automatically disabled, and the mobile station reports the quality of the received frames on a frame-by-frame basis through the “erasure” bit at the beginning of each frame transmitted on a reverse traffic channel.

System Parameters Message (Paging Channels)

MSG_TYPE ('00000001')	8	HOME_REG	1		**PWR_REP_THRESH**	**5**	
PILOT_PN	9	FOR_SID_REG	1	bad	**PWR_REP_FRAMES**	**4**	
CONFIG_MSG_SEQ	6	FOR_NID_REG	1		**PWR_THRESH_ENABLE**	**1**	total
SID	15	POWER_UP_REG	1		**PWR_PERIOD_ENABLE**	**1**	
NID	16	POWER_DOWN_REG	1		**PWR_REP_DELAY**	**5**	
REG_ZONE	12	PARAMETER_REG	1		RESCAN	1	
TOTAL_ZONES	3	REG_PRD	7		T_ADD	6	
ZONE_TIMER	3	BASE_LAT	22		T_DROP	6	
MULT_SIDS	1	BASE_LONG	23		T_COMP	4	
MULT_NIDS	1	REG_DIST	11		T_TDROP	4	
BASE_ID	16	SRCH_WIN_A	4		EXT_SYS_PARAMETER	1	
BASE_CLASS	4	SRCH_WIN_N	4		EXT_NGHBR_LIST	1	
PAGE_CHAN	3	SRCH_WIN_R	4		GLOBAL_REDIRECT	1	
MAX_SLOT_CYCLE_INDEX	3	NGHBR_MAX_AGE	4		RESERVED ('0')	1	

System Parameters Message (Paging Channels)

- **PWR_PERIOD_ENABLE** – Periodic report mode indicator. This field is set to ‘1’ if the mobile stations are to generate a Power Measurement Report Message after the number of frames determined by the value of PWR_REP_FRAMES has been received. Otherwise, it is set to ‘0’.
- **PWR_REP_FRAMES** – Power control reporting frame count. If PWR_PERIOD_ENABLE is set to ‘1’, the number of frames over which errors are to be count is given by the following expression (otherwise, this field is set to ‘0000’):
- 2(PWR_REP_FRAMES/2) x 5
- **PWR_THRESH_ENABLE** – Threshold report mode indicator. This field is set to ‘1’ if the mobile station is to generate a Power Measurement Report Message or if the number of bad frames received exceeds threshold determined by the value of PWR_REP_FRAMES. Otherwise, it is set to ‘0’.
- **PWR_REP_THRESH** – If PWR_THRESH_ENABLE is set to ‘1’, this field contains the number of bad frames that a mobile station must receive in a measurement period before it sends a Power Measurement Report Message (in this case, this field cannot be set to ‘00000’).
- **PWR_REP_DELAY** – Power report delay. The period that mobile stations wait following a Power Measurement Report Message before restarting frame counting for power control purposes.

Power Control Parameters Message (Forward Traffic Channels)

Field	Length (bits)
MSG_TYPE (‘00001010’)	8
ACK_SEQ	3
MSG_SEQ	3
ACK_REQ	1
ENCRYPTION	2
PWR_REP_THRESH	**5**
PWR_REP_FRAMES	**4**
PWR_THRESH_ENABLE	**1**
PWR_PERIOD_ENABLE	**1**
PWR_REP_DELAY	**5**
RESERVED (‘0’s)	7

The same parameters can also be sent by the base station in a

Power Control Parameters Message over the Forward Traffic Channel.

Power Measurement Report Message (Reverse Traffic Channels)

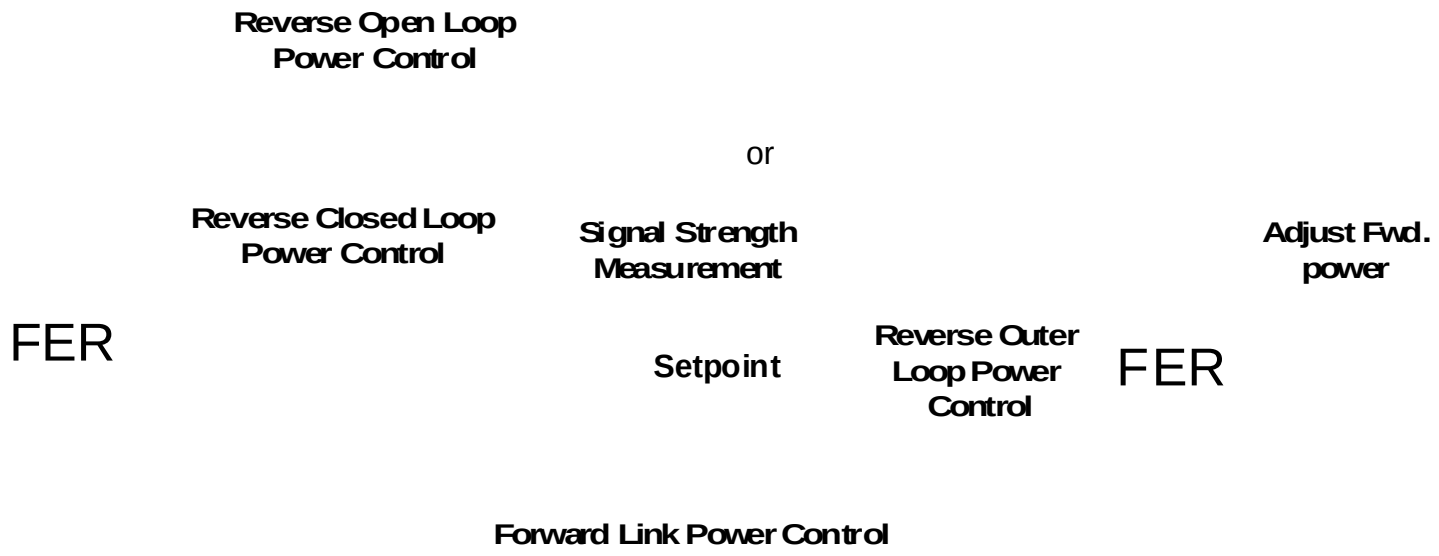
Field	Length (bits)	
MSG_TYPE (‘00000110’)	8	
ACK_SEQ	3	
MSG_SEQ	3	
ACK_REQ	1	
ENCRYPTION	2	
ERRORS_DETECTED	**5**	
POWER_MEAS_FRAMES	**10**	
LAST_HDM_SEQ	2	
NUM_PILOTS	4	
NUM_PILOTS occurrences of the following field:		HANDOFF-related fields
PILOT_STRENGTH	6	
RESERVED (‘0’s)	0-7 (as needed)	

Power Measurement Report Message (Reverse Traffic Channels)

- ENCRYPT_MODE field (binary) Encryption Mode Used

- 00 Encryption disabled
- 01 Encrypt call control messages
- All other values are reserved
- **ERRORS_DETECTED** – Number of frame errors detected. If the number of bad frames received in the measurement period is less than or equal to 31, the mobile station sets this field to the number of bad frames. If that number exceeds 31, this field is set to ‘11111’.
- **PWR_MEAS_FRAMES** – Number of Forward Traffic Channel frames in the measurement period.

Summary of All Power Control Mechanisms



- All types of power control work together to minimize transmit power

Functional Anatomy of a CDMA Handset

