channel signal strength, control information regarding handoff operations, and ongoing frame error rate (FER) statistics. More detail about these topics will be forthcoming shortly.

CDMA Frame Format

Now that the logical CDMA channels in the forward and reverse direction have been introduced, it is time to examine the format of a basic CDMA frame and its role in the operation of the system. Similar to GSM system operation, CDMA systems take 20-ms segments of digital samples of a voice signal and encode them through the use of a speech coder (vocoder) into variable rate frames. Thus the basic system frame size is 20 ms. The first IS-95 systems employed the 8-kbps Qualcomm-coded excited linear prediction (QCELP) speech coder that produced 20-ms frame outputs of either 9600, 4800, 2400, or 1200 bps (Rate Set 1), with the addition of overhead (error detection) bits. The actual net bit rates are 8.6, 4.0, 2.0, or 0.8 kbps. A second encoder, the 13-kbps QCELP13 encoder, was introduced in 1995 and produced outputs of 14.4, 7.2, 3.6, and 1.8 kbps (Rate Set 2), with a net maximum bit rate of 13.35 kbps. In each case, the speech encoder makes use of pauses and gaps in the user's speech to reduce its output from a nominal 9.6 or 14.4 kbps to lower bit rates and 1.2 or 1.8 kbps during periods of silence.

The basic 20-ms speech encoder frame size is used in various configurations by several of the logical channels to facilitate CDMA system operation, increase system capacity, and improve mobile battery life. The next several sections will detail these operations.

Forward Channel Frame Formats

Of the four forward logical channels, only the pilot channel does not employ a frame format. It consists of a continuous transmission of the system RF signal (refer back to Figure 6–14). The forward traffic channel frames are 20 ms in duration and contain a varying number of information bits, frame error control check

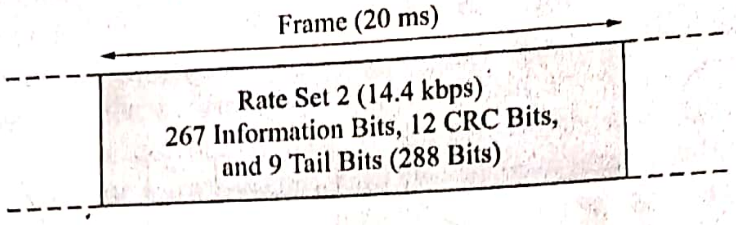

Figure 6–20 Rate Set 2 traffic channel structure.

bits, and tail bits depending upon the rate set and the data rate. Figure 6–20 depicts a forward traffic frame for Rate Set 2 at 14.4 kbps. The forward traffic channel frames are further logically subdivided into sixteen 1.25-ms power control groups. Power control bits transmitted over the forward traffic channels are randomly inserted into the data stream of each 1.25-ms power control group yielding a power control signal rate of 800 bps. More detail about the power control operation will be forthcoming later in this chapter.

The CDMA forward synchronization (sync) channel provides the mobile or subscriber device with system configuration and timing information. A sync channel message can be long and therefore the message is typically broken up into sync channel frames of 32 bits each. The sync channel frame consists of a start of message (SOM) bit and 31 data bits. The start of a sync message is indicated by a SOM bit set to 1 in the first frame and 0 in subsequent frames of the same message. At a data rate of 1200 bps, a sync channel frame is 26.666 ms in duration (the same repetition period employed by the short PN codes). Three sync channel frames of 96 bits form a sync channel superframe of 80-ms duration (equal to four basic 20-ms frames). The sync message itself consists of a field that indicates the message length in bits, the message data bits, error checking code bits, and additional padding bits (zeros) as needed.

The forward paging channels are used by the CDMA base station to transmit system overhead information and mobile station-specific messages. In IS-95A, the paging channel data rate can be either 4800 or 9600 bps. The paging channel is formatted into 80-ms paging slots of eight half frames of 10-ms duration. Each half frame starts with a synchronized capsule indicator (SCI) bit that is functionally similar to the SOM bit. A synchronized paging channel message capsule begins immediately after an SCI bit set to 1. To accommodate varying-length paging messages and to prevent inefficient operation of the paging channel, additional message capsules may be appended to the end of the first message capsule if space is available within the half frame or subsequent half frames. A paging message must be contained in at most two successive slots.

Furthermore, the paging channel structure is formatted into paging slot cycles to provide for increased mobile station battery life. A CDMA mobile may operate in either a slotted or unslotted mode. In the unslotted mode the mobile reads all the page slots while in the *mobile station idle state*. In the slotted mode, the mobile wakes up periodically to check for paging messages directed to it in specific preassigned slots (again, in the *mobile station idle state*). Therefore, slotted mode operation permits the mobile station to power down energy-consumptive RF electronic circuitry until its specific paging slot arrives. The mobile station will wake up for one or two paging slots (if required) of the paging slot cycle. The length of the paging cycle can vary from a minimum of sixteen slots (1.28 s) to a maximum of 2048 slots (163.84 s) (see Figure 6–21 for a diagram of the paging channel structure) as established by the system. Typically, minimal length cycles are employed; otherwise, significant delays in call termination could result. The CDMA system uses the mobile station's ESN to determine the correct slot to use for paging of the mobile. Further power savings are realized while in slotted mode by the transmission of a _DONE message by the base station after the end of the paging message scheduled for the particular mobile. In the case of a short message that uses only several half frames of a slot, the mobile can power down before the end of the slot to save even more battery power.

Reverse Channel Frame Formats

station will ...

The mobile station ... length of the paging cycle can vary from a minimum of sixteen slots (1.28 s) to a maximum of 2048 slots (163.84 s) (see Figure 6–21 for a diagram of the paging channel structure) as established by the system. Typically, minimal length cycles are employed; otherwise, significant delays in call termination could result. The CDMA system uses the mobile station's ESN to determine the correct slot to use for paging of the mobile. Further power savings are realized while in slotted mode by the transmission of a _DONE message by the base station after the end of the paging message scheduled for the particular mobile. In the case of a short message that uses only several half frames of a slot, the mobile can power down before the end of the slot to save even more battery power.

Reverse Channel Frame Formats

The reverse traffic channel, like the forward traffic channel, is also divided into 20-ms traffic channel frames. The reverse traffic channel frame is also further logically subdivided into sixteen 1.25-ms power control groups. As was the case for the forward traffic channel, variable rate reverse traffic channel. The coded bits from the convolutional encoder used in the reverse traffic channel are repeated before interleaving when the speech characteristics are such that the encoded data rate is less than the maximum. When the mobile transmit data rate is maximum, all sixteen power control groups are transmitted. If the transmitted data rate is one half of the maximum rate, then only eight power control groups are transmitted. Similarly, for a transmitted data rate of one-quarter or one-eighth, only four or two power control groups are transmitted per frame, respectively. As mentioned, this process, termed *burst transmission*, is made possible by the fact that reduced data rates have built-in redundancy that has been generated by the code repetition process. A data burst randomizer ensures that every repeated code symbol is only transmitted one time and that the transmitter is turned off at other times. This process reduces interference to other mobile stations operating on the same reverse CDMA channel by lowering the average transmitting power of the mobile and hence the overall background noise floor. The data burst randomizer generates a random masking pattern for the gating pattern that is tied to the mobile station's ESN. Figure 6–22 shows this process in more detail.

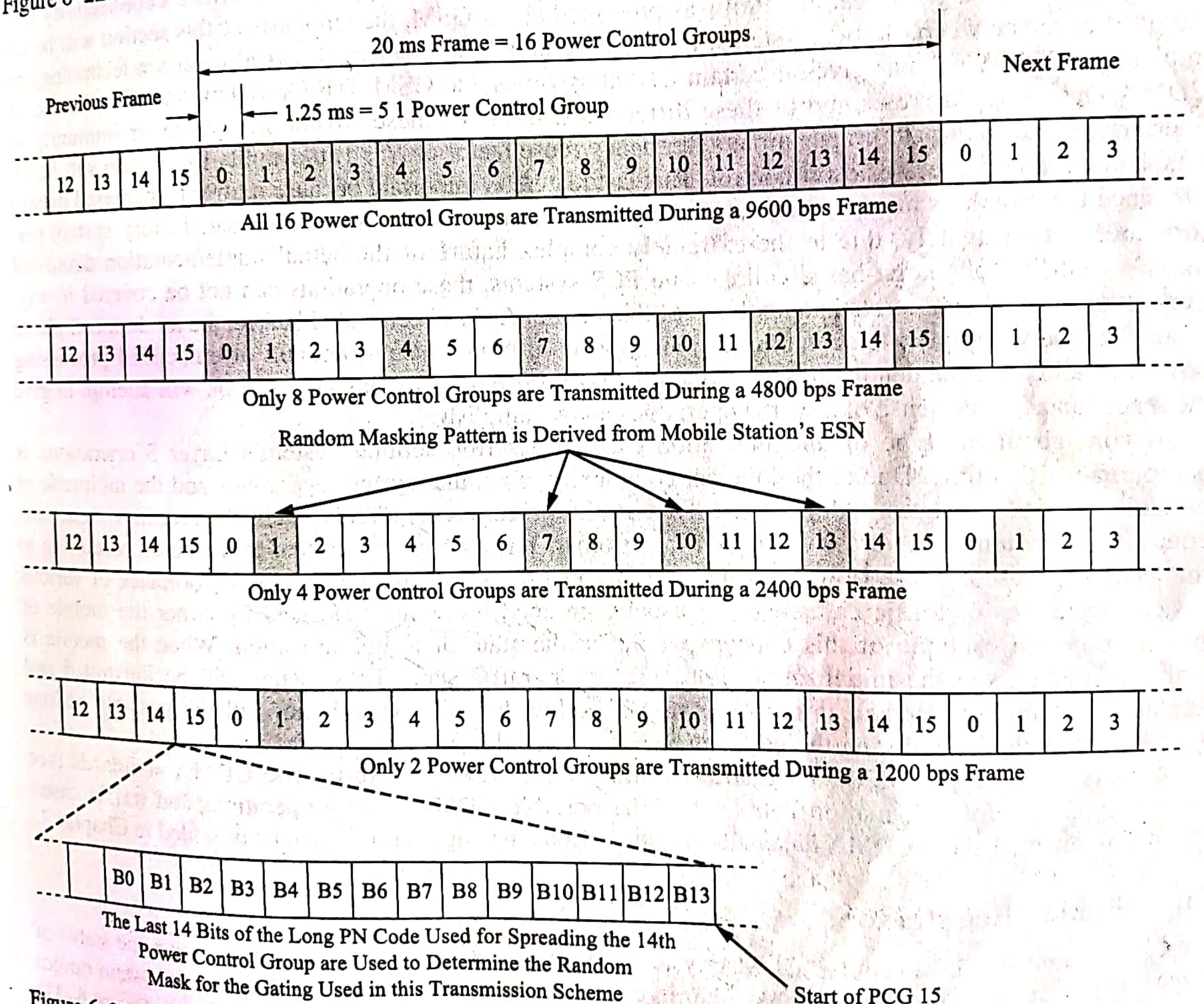

Figure 6–22 CDMA reverse channel variable data rate transmission.

The reverse access channel is used by the mobile station to communicate with the base station. The access channel is used for short message exchanges, such as responses to commands from the base station, for system registrations, and for call origination requests. The access channel data rate is 4.8 kbps using a

20-ms frame that contains 96 information bits. Each access channel message is typically composed of several access channel frames.

Since multiple mobile stations associated with the same paging channel may try to simultaneously access the same access channel, a random access protocol has been developed to avoid signal/data collisions. This topic will be discussed further in the next section about CDMA System Operations.

6.4 CDMA SYSTEM (LAYER 3) OPERATIONS

Initialization/Registration

As is the case with GSM cellular, CDMA system registration procedures are dependent upon the status of the mobile station. The mobile may be either in a detached condition (powered off or out of system range) or in an attached condition. When first turned on, the mobile goes through a power-up state (see Figure 6–23) during which it selects a CDMA system and then acquires the pilot and sync channels, which allows it to synchronize its timing to the CDMA system. When attached, the mobile may be in one of three states: the mobile station idle state, the system access state, or the mobile station control on the traffic channel state (see Figure 6–24).

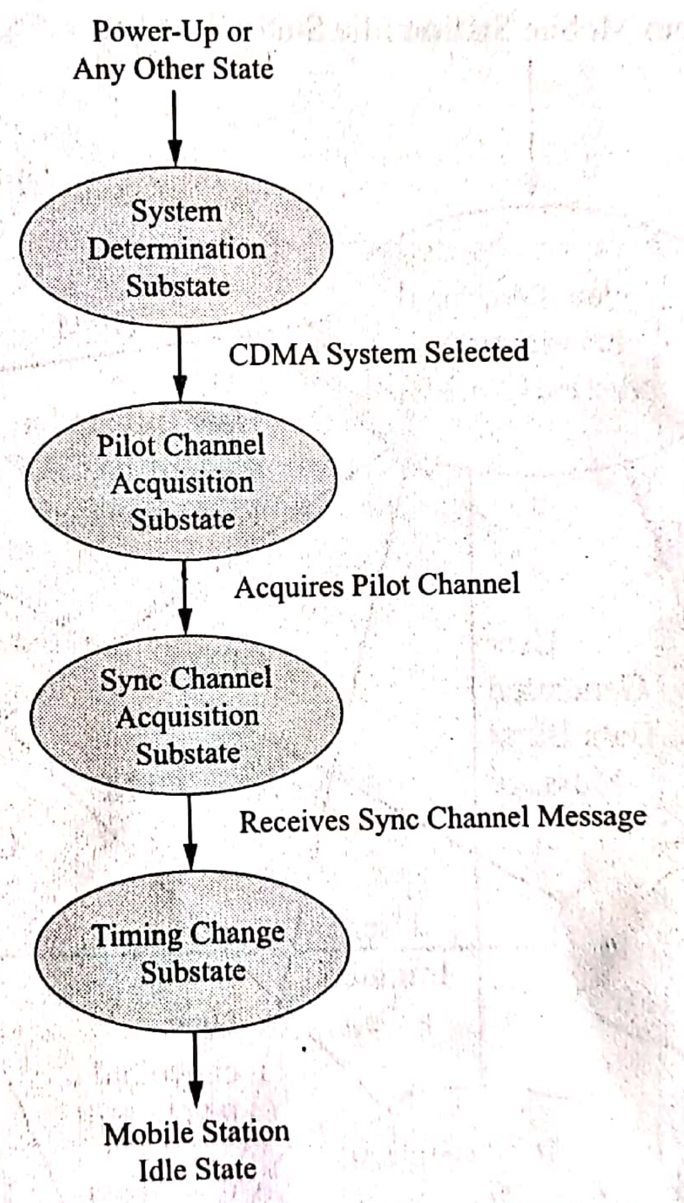

Figure 6–23 CDMA mobile station initialization state (Courtesy of 3GPP2).