VARIED SIGNALING CHANNELS FOR A REVERSE LINK IN A WIRELESS COMMUNICATION SYSTEM

BACKGROUND

I. Field

[0001] The present disclosure relates generally to communication, and more specifically to transmission of signaling in a wireless communication system.

II. Background

[0002] Wireless communication systems are widely deployed to provide various communication services such as voice, packet data, broadcast, messaging, and so on. These systems may be multiple-access systems capable of supporting communication for multiple users by sharing the available system resources. Examples of such multiple-access systems include code division multiple access (CDMA) systems, time division multiple access (TDMA) systems, and frequency division multiple access (FDMA) systems.

[0003] A communication system typically utilizes various signaling channels to support data transmission on the forward and reverse links. The forward link (or downlink) refers to the communication link from the base stations to the terminals, and the reverse link (or uplink) refers to the communication link from the terminals to the base stations. For example, the terminals may send signaling on the reverse link to request for data transmission on one or both links, to report channel quality, to request for handoff to stronger base stations, and so on. The signaling sent by the terminals, although beneficial, represent overhead in the system.

[0004] There is therefore a need in the art for techniques to efficiently send signaling on the reverse link in a communication system.

SUMMARY

[0005] Techniques for efficiently sending signaling on a CDMA control segment on the reverse link of a wireless communication system are described herein. The CDMA control segment has various configurable features. In an embodiment, the size of the

CDMA control segment, the frames in which the CDMA control segment is sent, the signaling channels to be sent on the CDMA control segment, and so on, may be configurable. Signaling channels carrying various types of signaling may be sent on the CDMA control segment. A signaling channel may also be called a control channel, a feedback channel, a reporting channel, an overhead channel, and so on.

[0006] In an embodiment for transmitting signaling on the CDMA control segment by a terminal, transmission parameters for the CDMA control segment for a serving base station are determined. These parameters may indicate, e.g., the CDMA control segment size, the frames for sending the CDMA control segment, frequency hopping for the CDMA control segment, and so on. The enabled CDMA signaling channels for the terminal and the average transmission interval for each enabled CDMA signaling channel are also determined. For each frame in which the CDMA control segment is sent, the signaling channels to be sent on the CDMA control segment in the frame are determined. The signaling for each signaling channel is processed, e.g., encoded, channelized, scaled, and scrambled. The processed signaling for all signaling channels is combined and mapped to a time-frequency region used for the CDMA control segment in the frame.

[0007] Various aspects and embodiments of the invention are described in further detail below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] The features and nature of the present invention will become more apparent from the detailed description set forth below when taken in conjunction with the drawings in which like reference characters identify correspondingly throughout.

[0009] FIG. 1 shows a wireless communication system.

[0010] FIG. 2A shows superframe structures for the forward and reverse links.

[0011] FIG. 2B shows an interlace structure for the reverse link.

[0012] FIGS. 3A and 3B show a frequency hopping CDMA control segment with two different sizes for one carrier.

[0013] FIG. 3C shows a frequency hopping CDMA control segment for four carriers.

[0014] FIG. 4 shows H-ARQ transmission on the forward link.

[0015] FIG. 5 shows a block diagram of a base station and a terminal.

[0016] FIG. 6 shows a block diagram of a transmit data and signaling processor.

[0017] FIG. 7 shows a block diagram of a receive data and signaling processor.

[0018] FIGS. 8 and 9 show a process and an apparatus, respectively, for controlling signaling transmission on a CDMA control segment.

[0019] FIGS. 10 and 11 show a process and an apparatus, respectively, for sending signaling on the CDMA control segment.

[0020] FIGS. 12 and 13 show a process and an apparatus, respectively, for receiving signaling sent on the CDMA control segment.

DETAILED DESCRIPTION

[0021] The word "exemplary" is used herein to mean "serving as an example, instance, or illustration." Any embodiment or design described herein as "exemplary" is not necessarily to be construed as preferred or advantageous over other embodiments or designs.

[0022] **FIG. 1** shows a wireless communication system 100 with multiple base stations 110 and multiple terminals 120. A base station is a station that communicates with the terminals. A base station may also be called, and may contain some or all of the functionality of, an access point, a Node B, and/or some other network entity. Each base station 110 provides communication coverage for a particular geographic area 102a-c. The term "cell" can refer to a base station and/or its coverage area depending on the context in which the term is used. To improve system capacity, a base station coverage area may be partitioned into multiple smaller areas, e.g., three smaller areas 104a, 104b, and 104c. Each smaller area is served by a respective base transceiver subsystem (BTS). The term "sector" can refer to a BTS and/or its coverage area depending on the context in which the term is used. For a sectorized cell, the BTSs for all sectors of that cell are typically co-located within the base station for the cell.

[0023] Terminals 120 are typically dispersed throughout the system, and each terminal may be fixed or mobile. A terminal may also be called, and may contain some or all of the functionality of, a mobile station, a user equipment, and/or some other device. A terminal may be a wireless device, a cellular phone, a personal digital assistant (PDA), a wireless modem card, and so on. A terminal may communicate with zero, one, or multiple base stations on the forward and reverse links at any given moment.

[0024] For a centralized architecture, a system controller 130 couples to base stations 110 and provides coordination and control for these base stations. System controller 130 may be a single network entity or a collection of network entities. For a distributed architecture, the base stations may communicate with one another as needed.

[0025] The signaling transmission techniques described herein may be used for a system with sectorized cells as well as a system with un-sectorized cells. For clarity, the techniques are described below for a system with sectorized cells. In the following description, the term "base station" and 'sector" are used interchangeably.

[0026] The signaling transmission techniques described herein may also be used for various wireless communication systems such as a CDMA system, a TDMA system, an FDMA system, an orthogonal frequency division multiple access (OFDMA) system, a single-carrier FDMA (SC-FDMA) system, and so on. An OFDMA system utilizes orthogonal frequency division multiplexing (OFDM), which is a modulation technique that partitions the overall system bandwidth into multiple (K) orthogonal subcarriers. These subcarriers are also called tones, bins, and so on. With OFDM, each subcarrier may be independently modulated with data. An SC-FDMA system may utilize interleaved FDMA (IFDMA) to transmit on subcarriers that are distributed across the system bandwidth, localized FDMA (LFDMA) to transmit on a block of adjacent subcarriers, or enhanced FDMA (EFDMA) to transmit on multiple blocks of adjacent subcarriers. In general, modulation symbols are sent in the frequency domain with OFDM and in the time domain with SC-FDMA.

[0027] System 100 may use various subcarrier structures for the forward and reverse links. For a distributed subcarrier structure, the K total subcarriers are arranged into S non-overlapping sets such that each set contains N subcarriers that are uniformly distributed across the K total subcarriers. Consecutive subcarriers in each set are spaced apart by S subcarriers, where $K = S \cdot N$. Thus, set s contains subcarriers s, $S+s$, $2S+s$, ..., $(N-1)\cdot S+s$, for $s \in \{1,...,S\}$. For a block subcarrier structure, the K total subcarriers are arranged into S non-overlapping sets such that each set contains N consecutive subcarriers. Thus, set s contains subcarriers $(s-1)\cdot N+1$ through , for $s \in \{1,...,S\}$. In general, the subcarrier structure used for each link may include any number of sets, and each set may include any number of subcarriers that may be arranged in any manner. In an embodiment that is assumed for much of the description

below, the distributed or block subcarrier structure is used for the forward link, and the block subcarrier structure is used for the reverse link.

[0028] System 100 may support a single carrier or multiple carriers for each link. In an embodiment, multiple (C) subcarriers are available for each carrier supported by the system. Each carrier may also be partitioned into multiple (P) subbands. A subband is a range of frequency within the system bandwidth. In an embodiment, each carrier spans approximately 5 MHz, $C=512$, $P=4$, $S=32$, and $N=16$. For this embodiment, a single-carrier system has $K=512$ total subcarriers that are arranged into four subbands, and each subband includes 128 subcarriers. For this embodiment, the single-carrier system has 32 subcarrier sets, and each set includes 16 subcarriers. For this embodiment, a system with four carriers has $K=2048$ total subcarriers that are arranged into 16 subbands.

[0029] On the forward link, a base station may transmit data to one or multiple terminals on the S subcarrier sets using OFDMA or SC-FDMA. For example, the base station may simultaneously transmit data to S different terminals, one subcarrier set per terminal. On the reverse link, one or multiple terminals may transmit data to a base station on the S subcarrier sets using OFDMA or SC-FDMA. For example, each terminal may transmit data on one subcarrier to the base station. For each of the forward and reverse links, the transmissions on the S subcarrier sets are orthogonal to one another. The S subcarrier sets for each link may be allocated to the terminals in various manners, as described below. A base station may also transmit data to multiple terminals and/or receive data from multiple terminals on a given subcarrier set with spatial division multiple access (SDMA).

[0030] An OFDM symbol may be generated for one subcarrier set in one symbol period as follows. N modulation symbols are mapped to the N subcarriers in the set and zero symbols with signal value of zero are mapped to the remaining $K-N$ subcarriers. A K-point inverse fast Fourier transform (IFFT) or inverse discrete Fourier transform (IDFT) is performed on the K modulation symbols and zero symbols to obtain a sequence of K time-domain samples. The last C samples of the sequence are copied to the start of the sequence to form an OFDM symbol that contains $K+C$ samples. The C copied samples are often called a cyclic prefix or a guard interval, and C is the cyclic prefix length. The cyclic prefix is used to combat intersymbol interference (ISI) caused

by frequency selective fading, which is a frequency response that varies across the system bandwidth.

[0031] An SC-FDMA symbol may be generated for one subcarrier set in one symbol period as follows. N modulation symbols to be sent on the N subcarriers in the set are transformed to the frequency domain with an N-point fast Fourier transform (FFT) or discrete Fourier transform (DFT) to obtain N frequency-domain symbols. These N frequency-domain symbols are mapped to the N subcarriers in the set, and zero symbols are mapped to the remaining $K-N$ subcarriers. A K-point IFFT or IDFT is then performed on the K frequency-domain symbols and zero symbols to obtain a sequence of K time-domain samples. The last C samples of the sequence are copied to the start of the sequence to form an SC-FDMA symbol that contains $K+C$ samples.

[0032] In general, an OFDM symbol or an SC-FDMA symbol for any number of subcarriers and any combination of subcarriers may be generated in a similar manner by mapping symbols to the subcarriers used for transmission. The $K+C$ samples of an OFDM symbol or an SC-FDMA symbol are transmitted in $K+C$ sample/chip periods. A symbol period is the duration of one OFDM symbol or one SC-FDMA symbol and is equal to $K+C$ sample/chip periods.

[0033] **FIG. 2A** shows exemplary superframe structures 200 that may be used for the forward and reverse links. The transmission timeline for each link is partitioned into units of superframes. Each superframe spans a particular time duration, which may be fixed or configurable. For the forward link, each superframe includes a preamble followed by M frames, where $M>1$. A frame may refer to a time interval in a transmission timeline or a transmission sent during the time interval. The superframe preamble carries overhead information that enables the terminals to receive forward link control channels and subsequently access the system. Each subsequent frame may carry traffic data and/or signaling. For the reverse link, each superframe includes M frames, where the first frame may be extended by the length of the superframe preamble on the forward link. The superframes on the reverse link are time aligned with the superframes on the forward link.

[0034] FIG. 2A shows specific superframe structures for the forward and reverse links. In general, a superframe may span any time duration and may include any number of frames and other fields. The superframe structure for the reverse link may be the same or different from the superframe structure for the forward link.

[0035] **FIG. 2B** shows an interlace structure 210 for the reverse link. Referring back to FIG. 2A, for each link, the frames in each superframe may be arranged into groups, with each group including Q consecutive frames, where $Q > 1$. Q interlaces may be formed for each link with this grouping of frames. In an embodiment, which is shown in FIG. 2B, interlace 1 includes frames 1, $Q+1$, $2Q+1$, and so on, interlace 2 includes frames 2, $Q+2$, $2Q+2$, and so on, and interlace Q includes frames Q, 2Q, 3Q, and so on. The Q interlaces are offset from one another by one frame. In an embodiment that is assumed for much of the description below, $Q = 6$, six interlaces are formed and may be used to send six packets in an interlaced manner, one packet in each interlace, as described below.

[0036] System 100 may support frequency division duplexing (FDD) and/or time division duplexing (TDD). For FDD, the forward and reverse links are allocated separate frequency bands, and transmissions may be sent simultaneously on the two links, as shown in FIG. 2A. For TDD, the forward and reverse links share the same frequency band, and transmissions for the two links may be sent in different frames. For example, the forward link may be allocated odd-numbered frames, and the reverse link may be allocated even-numbered frames.

[0037] In an embodiment, a CDMA control segment is sent on the reverse link. The CDMA control segment carries various signaling channels for the reverse link. In an embodiment, the CDMA control segment is mapped to a fixed region of time and frequency in each CDMA frame. A CDMA frame is a frame in which the CDMA control segment is sent. In another embodiment, the CDMA control segment hops in a pseudo-random or deterministic manner from CDMA frame to CDMA frame to achieve frequency diversity.

[0038] **FIG. 3A** shows an embodiment of a CDMA control segment 300 for a single carrier. For this embodiment, $Q = 6$ and the CDMA control segment is sent on one interlace, or every 6^{th} frame. For this embodiment, the CDMA control segment spans an entire regular-size frame. If the CDMA control segment is sent on interlace 1, then for the extended RL frame 1, the CDMA control segment may be sent in the time interval corresponding to FL frame 1, as shown in FIG. 3A. If the CDMA control segment is sent on interlace 2, 3, 4, 5 or 6, then the CDMA control segment may be sent in the entire frame for each frame in that interlace.

[0039] **FIG. 3B** shows an embodiment of an extended CDMA control segment 310 for a single carrier. For this embodiment, $Q = 6$ and the CDMA control segment is sent on two adjacent interlaces in two regular-size frames. For the embodiment shown in FIG. 3B, the CDMA control segment is sent in the entire extended RL frame 1, RL frames 6 and 7, RL frames 12 and 13, and so on. The CDMA control segment may also be sent in other RF frames and/or on more than two adjacent interlaces.

[0040] Sending the CDMA control segment across an entire frame as shown in FIG. 3A or across multiple frames as shown in FIG. 3B, instead of across a portion of a frame, may improve link budget for terminals located at the edge of coverage. These terminals typically have an upper limit on transmit power. A longer CDMA control segment allows these terminals to transmit signaling with more energy spread over a longer period of time, which improves the likelihood of correctly receiving the signaling. In general, the CDMA control segment may be sent across an entire frame, across a portion of a frame, across multiple frames, across portions of multiple frames, and so on.

[0041] In an embodiment, the CDMA control segment occupies at least one subband in each CDMA frame. For the embodiment shown in FIG. 3A, $P = 4$ and the CDMA control segment is sent on at least one of the four subbands in each CDMA frame. In an embodiment that is assumed for much of the description below, the size of the CDMA control segment is scalable in frequency, e.g., in units of subbands. For this embodiment, the CDMA control segment may span one, two, or possibly more subbands in each CDMA frame. The subband(s) for the CDMA control segment may be contiguous or may spread across the system bandwidth. In other embodiment, the size of the CDMA control segment may be scalable in time or both time and frequency.

[0042] In general, the CDMA control segment may be mapped to a time-frequency region that covers F subcarriers and spans T symbol periods, where $F \geq 1$ and $T \geq 1$, as shown in the upper left corner of FIG. 3A. The CDMA control segment includes U transmission units, where $U = F \cdot T$. A transmission unit is one subcarrier in one symbol period. For clarity, much of the following description is for the embodiment in which the CDMA control segment occupies one or more subbands and spans an entire CDMA frame, except for RL frame 1. In an embodiment, $K = 512$, $P = 4$, and $T = 8$. For this embodiment, the CDMA control segment (1) covers an integer multiple of 128

subcarriers in 8 symbol periods of a CDMA frame and (2) includes an integer multiple of 1024 transmission units, e.g., 1024, 2048, 3072 or 4096 transmission units.

[0043] FIG. 3A also shows frequency hopping for the CDMA control segment. The CDMA control segment may hop across frequency in different CDMA frames, as shown in FIG. 3A. The frequency hopping may be pseudo-random or deterministic.

[0044] FIG. 3A further shows an exemplary frequency-hopping scheme for traffic channels. A traffic channel is a means for sending data from a transmitter to a receiver and may also be called a channel, a physical channel, a physical layer channel, a data channel, and so on. Each traffic channel may be mapped to a specific sequence of time-frequency blocks that hop across frequency in different frames to achieve frequency diversity, as shown in FIG. 3A. In an embodiment, a time-frequency block corresponds to one set of subcarriers in one frame. A frequency hopping (FH) pattern indicates the specific time-frequency block to use for each traffic channel in each frame. FIG. 3A shows a sequence of time-frequency blocks for one traffic channel y. The other traffic channels may be mapped to vertically and circularly shifted versions of the time-frequency block sequence for traffic channel y.

[0045] In an embodiment, the frequency hopping for the traffic channels avoids the CDMA control segment. In another embodiment, the frequency hopping for the traffic channels is pseudo-random with respect to the CDMA control segment. For this embodiment, a number of (e.g., eight) subcarrier sets may be allocated for the CDMA control segment in each CDMA frame. Each traffic channel that collides with the CDMA control segment is then mapped to a subcarrier set allocated to the CDMA control segment. For this embodiment, the traffic channels and the CDMA control segment swap subcarriers whenever a collision occurs.

[0046] **FIG. 3C** shows an embodiment of a frequency hopping CDMA control segment 320 for four carriers. For this embodiment, one instance of the CDMA control segment is provided for each carrier. In an embodiment, the CDMA control segment instance for each carrier carries reverse link signaling for that carrier and is independent of the CDMA control segment instances for the other carriers. The four CDMA control segment instances for the four carriers (1) may have the same or different sizes, (2) may hop together or independently of one another, and (3) may be sent on one interlace, e.g., every 6^{th} frame.

[0047] FIGS. 3A and 3B show some embodiments of the CDMA control segment. In another embodiment, the CDMA control segment may be sent in multiple interlaces. In yet another embodiment, the CDMA control segment may be selectively enabled or disabled in each frame in which the CDMA control segment might be sent.

[0048] System 100 may utilize various signaling channels to support data transmission on the forward and reverse links. The signaling channels typically carry small amounts of signaling for the physical layer. The specific signaling channels to use for each link may be dependent on various factors such as, e.g., the manner in which traffic data is transmitted, the manner in which signaling is transmitted, the design of the traffic channels and the signaling channels, and so on.

[0049] Table 1 lists exemplary signaling channels for the reverse link and a short description for each signaling channel. In an embodiment, which is described in detail below, all of the signaling channels shown in Table 1 except for the acknowledgment (ACK) channel are sent on the CDMA control segment. A signaling channel that is sent on the CDMA control segment is called a CDMA signaling channel. The ACK channel may be sent using time and/or frequency division multiplexing to achieve good performance for the ACK channel. In general, any signaling channel may be sent on the CDMA control segment.

Table 1

Signaling Channel	Notation	Description
ACK Channel	ACKCH	Carry ACKs for packets received from a base station.
CQI Channel	CQICH	Carry CQIs used for rate control on the forward link.
Request Channel	REQCH	Carry requests for resources on the reverse link.
Beamforming Feedback Channel	BFCH	Carry feedback for beamforming and spatial multiplexing on the forward link.
Subband Feedback Channel	SFCH	Carry feedback for adaptive subband scheduling on the forward link.
Pilot Channel	PICH	Carry a broadband pilot.
Access Channel	ACH	Carry access probes for accessing the system.

The use of some of the signaling channels in Table 1 for data transmission on the forward link is described below.

[0050] **FIG. 4** shows a hybrid automatic repeat request (H-ARQ) transmission on the forward link, which is also called an incremental redundancy (IR) transmission. A terminal initially sends access probes (AP) on the access channel to access the system. Thereafter, if a base station has data to send to the terminal, then the base station may request for the received signal quality at the terminal and/or other information that may be used for data transmission to the terminal. The terminal estimates the received signal quality for the forward link and sends a channel quality indicator (CQI) value on the CQI channel to the base station. The received signal quality may be quantified by a signal-to-interference-and-noise ratio (SINR) and/or some other signal quality metric. The terminal may also send other types of feedback (e.g., for beamforming and/or subband scheduling) on the feedback channels.

[0051] The base station receives the CQI value from the terminal and selects a packet format (e.g., data rate, packet size, and so on) to use for data transmission to the terminal. The base station then processes (e.g., encodes and modulates) a data packet (Packet 1) in accordance with the selected packet format and generates multiple (V) data blocks for the packet, where $V > 1$. A data packet may also be called a codeword and so on, and a data block may also be called a subpacket and so on. Each data block may contain sufficient information to allow the terminal to correctly decode the packet under favorable channel conditions. The V data blocks typically contain different redundancy information for the packet. The V data blocks may be sent one block at a time until the packet is terminated. The data blocks may be sent on one interlace, one data block in each frame, and the block transmissions would then be spaced apart by Q frames.

[0052] The base station transmits the first data block (Block 1) for Packet 1 in frame m. The terminal receives and processes (e.g., demodulates and decodes) Block 1, determines that Packet 1 is decoded in error, and sends a negative acknowledgment (NAK) on the ACK channel to the base station in frame $m+q$, where q is the ACK/NAK delay and $1 \le q < Q$. The base station receives the NAK and transmits the second data block (Block 2) for Packet 1 in frame $m+Q$. The terminal receives Block 2, processes Blocks 1 and 2, determines that Packet 1 is decoded correctly, and sends back an ACK in frame $m+Q+q$. The base station receives the ACK and terminates the transmission of Packet 1. The base station processes the next data packet (Packet 2) and transmits the data blocks for Packet 2 in similar manner.

[0053] For clarity, FIG. 4 shows transmission of both NAKs and ACKs. For an ACK-based scheme, an ACK is sent if a packet is decoded correctly, and NAKs are not sent and are presumed by the absence of ACKs.

[0054] In FIG. 4, a new data block is sent every Q frames on a given interlace. To improve channel utilization, the base station may transmit up to Q packets on the Q interlaces. The H-ARQ retransmission delay Q and the ACK/NAK delay q are typically selected to provide sufficient processing time for both the transmitter and receiver.

[0055] As shown in FIG. 4, the terminal may send CQI and other feedbacks periodically on the signaling channels. The terminal may also send a request (REQ) for resources on the reverse link to transmit data to the base station.

[0056] **FIG. 5** shows a block diagram of an embodiment of a base station 110 and a terminal 120 in FIG. 1. For this embodiment, base station 110 and terminal 120 are each equipped with multiple antennas.

[0057] At base station 110, a transmit (TX) data and signaling processor 510 receives traffic data for one or more terminals, processes (e.g., formats, encodes, interleaves, and symbol maps) the traffic data for each terminal in accordance with one or more packet formats selected for that terminal, and provides data symbols. Processor 510 also generates pilot symbols and signaling symbols. As used herein, a data symbol is a symbol for traffic data, a pilot symbol is a symbol for pilot, which is data that is known *a priori* by both the base station and the terminals, a signaling symbol is a symbol for signaling, and a symbol is typically a complex value. A TX spatial processor 512 performs transmitter spatial processing (e.g., adaptive beamforming) on the data symbols, pilot symbols, and/or signaling symbols and provides N_{bs} streams of transmit symbols to N_{bs} modulators (MOD) 514a through 514bs. Each modulator 514 performs OFDM modulation on its transmit symbol stream and provides a stream of OFDM symbols. If system 100 utilizes SC-FDMA, then each modulator 514 performs SC-FDMA modulation and provides a stream of SC-FDMA symbols. Each modulator 514 further conditions (e.g., converts to analog, filters, amplifies, and upconverts) its OFDM symbol stream and generates an FL modulated signal. Modulators 514a through 514bs provide N_{bs} FL modulated signals, which are transmitted from N_{bs} antennas 516a through 516bs, respectively.

[0058] At terminal 120, N_{at} antennas 552a through 552at receive the FL modulated signals from base station 110 and possibly other base stations and provides N_{at} received

signals to N_{at} demodulators (DEMOD) 554a through 554at, respectively. Each demodulator 554 processes (e.g., conditions and digitizes) its received signal and obtains input samples. Each demodulator 554 further performs OFDM demodulation on the input samples and provides frequency-domain received symbols for all subcarriers. A receive (RX) spatial processor 556 performs receiver spatial processing on the received symbols from all R demodulators 554a through 554at and provides data symbol estimates, which are estimates of the data symbols sent by base station 110 to terminal 120. An RX data processor 558 processes (e.g., symbol demaps, deinterleaves, and decodes) the data symbol estimates and provides decoded data for terminal 120.

[0059] A controller/processor 570 receives decoding results from RX data processor 558 and measurements for received signal quality and FL channel response from RX spatial processor 556. Controller/processor 570 generates various types of signaling for terminal 120. A TX data and signaling processor 560 generates signaling symbols for the signaling from controller/processor 570, data symbols for traffic data to be sent to base station 110, and pilot symbols. A TX spatial processor 562 performs transmitter spatial processing on the data symbols, pilot symbols, and/or signaling symbols and provides transmit symbols, which are further processed by modulators 554a through 554at and transmitted via antennas 552a through 552at.

[0060] At base stations 110, the RL modulated signals from terminal 120 and other terminals are received by antennas 516a through 516bs, conditioned, digitized, and OFDM demodulated by demodulators 514a through 514bs, spatially processed by an RX spatial processor 518, and further processed by an RX data and signaling processor 520 to recover the traffic data and signaling sent by terminal 120 and other terminals. A controller/processor 530 receives the signaling and controls data transmissions on the forward link to the terminals.

[0061] Controllers/processors 530 and 570 direct the operation of various processing units at base station 110 and terminal 120, respectively. Memories 532 and 572 store program codes and data for base station 110 and terminal 120, respectively.

[0062] **FIG. 6** shows a block diagram of an embodiment of TX data and signaling processor 560 at terminal 120 in FIG. 5. For this embodiment, processor 560 includes a TX data processor 610, a TX signaling processor 620, and a multiplexer (MUX) 660.

[0063] Within TX data processor 610, a unit 612 encodes, interleaves, and symbol maps traffic data and provides data symbols. A symbol-to-subcarrier mapper 614 maps the data symbols to time-frequency blocks for a traffic channel assigned to terminal 120.

[0064] FIG. 6 shows the embodiment in which all signaling channels except for the ACK channel are sent on the CDMA control segment. For this embodiment, TX signaling processor 620 includes a channel processor 630a for each CDMA signaling channel. Within a channel processor 630a, an encoder 632 encodes a CQI value and provides a coded message W_{CQICH}. A channelizer 634 multiplies the coded message with a channelization sequence S_{CQICH}. A multiplier 636 multiplies the output of channelizer 634 with a gain G_{CQICH} and provides an output sequence X_{CQICH} for the CQI channel. A channel processor 630b encodes a request message, multiplies the resultant coded message with a channelization sequence S_{REQCH}, scales the channelized sequence with a gain G_{REQCH}, and provides an output sequence X_{REQCH} for the request channel. A channel processor 630c encodes beamforming feedback, multiplies the resultant coded message with a channelization sequence S_{BFCH}, scales the channelized sequence with a gain G_{BFCH}, and provides an output sequence X_{BFCH} for the beamforming feedback channel. A channel processor 630d encodes subband feedback, multiplies the resultant coded message with a channelization sequence S_{SFCH}, scales the channelized sequence with a gain G_{SFCH}, and provides an output sequence X_{SFCH} for the subband feedback channel. A channel processor 630e encodes pilot data, multiplies the resultant coded message with a channelization sequence S_{PICH}, scales the channelized sequence with a gain G_{PICH}, and provides an output sequence X_{PICH} for the pilot channel. A channel processor 630f encodes an access probe, multiplies the resultant coded message with a channelization sequence S_{ACH}, scales the channelized sequence with a gain G_{ACH}, and provides an output sequence X_{ACH} for the access channel.

[0065] The transmit power for each signaling channel may be controlled by selecting an appropriate gain for that signaling channel. The transmit power may be selected to achieve a target level of performance, e.g., 50 % erasure rate or lower and 1% error rate.

[0066] A combiner 640 combines the output sequences from channel processors 630a through 630e and provides a composite sequence X_{SM}. A scrambler 642a scrambles the composite sequence X_{SM} with a scrambling sequence Y_{SM} provided by a scrambling sequence generator 644 and provides a first scrambled sequence Z_{SM}. A

scrambler 642b scrambles the output sequence X_{ACH} for the access channel with a scrambling sequence Y_{SS} provided by the scrambling sequence generator 644 and provides a second scrambled sequence Z_{SS}. A combiner 650 combines the first and second scrambled sequences and provides a time-domain output sequence Z_{OUT}. Combiner 650 also partitions the output sequence Z_{OUT} into T output sub-sequences Z_1 through Z_T for the T symbol periods of the CDMA control segment. Each output sub-sequence contains up to F time-domain samples.

[0067] In an embodiment, which is shown in FIG. 6, signaling is sent in the time domain. For this embodiment, a unit 652 transforms each output sub-sequence to the frequency domain with a DFT or FFT and provides F signaling symbols for the F subcarriers of the CDMA control segment. In another embodiment, which is not shown in FIG. 6, signaling is sent in the frequency domain. For this embodiment, combiner 650 provides the signaling symbols, and DFT/FFT unit 652 is omitted. For both embodiments, a symbol-to-subcarrier mapper 654 maps the F signaling symbols for each output sub-sequence to F subcarriers in one symbol period for the CDMA control segment.

[0068] A TX ACK channel processor 656 processes an ACK message, generates signaling symbols for the ACK message, and maps these signaling symbols to time and frequency segments allocated for the ACK channel. Multiplexer 660 receives and multiplexes the data symbols from TX data processor 610 and the signaling symbols from TX signaling processor 620 and provides multiplexed data and signaling symbols.

[0069] In an embodiment, a terminal may communicate with one or more sectors in one or more synchronous subsets. Each synchronous subset includes one or more sectors that are synchronous with one another. The sectors in different synchronous subsets may not be synchronous with one another. In an embodiment, a terminal may be assigned a different identifier or media access control identifier (MACID) for communication with each synchronous subset. The synchronous subsets are described in commonly assigned U.S. Patent Publication No. US2006/0223449 filed on the same day herewith, and incorporated herein by reference.

[0070] In an embodiment, a terminal may send the CQICH, REQCH, BFCH, SFCH and PICH to a target base station in a serving synchronous subset, which is a synchronous subset that contains a FL serving sector. A target base station is a base station to which the signaling is sent. A FL serving sector is a base station currently

transmitting data to the terminal. In an embodiment, a terminal may send the CQICH to a target base station in a non-serving synchronous subset, which is a synchronous subset that does not contain the FL serving sector. The terminal may send the CQICH to the serving synchronous subset and/or one or more non-serving synchronous subsets.

[0071] The signaling for the CDMA control segment may be processed in various manners. A specific embodiment is described below. For this embodiment, a B-bit signaling message M_c to be sent on signaling channel c, where c ∈ {CQICH, REQCH, BFCH, SFCH, PICH, and ACH}, may be processed as follows. Message M_c is first encoded by mapping this message to an L-bit coded message W_c, where $L = 2^B$.

[0072] In an embodiment, the coded message W_c is a Walsh sequence of length L. A 2×2 Hadamard matrix $\underline{\mathbf{W}}_{2\times 2}$ and a larger size Hadamard matrix $\underline{\mathbf{W}}_{2k\times 2k}$ may be expressed as:

$$\underline{\mathbf{W}}_{2\times 2} = \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} \quad \text{and} \quad \underline{\mathbf{W}}_{2k\times 2k} = \begin{bmatrix} \underline{\mathbf{W}}_{k\times k} & \underline{\mathbf{W}}_{k\times k} \\ \underline{\mathbf{W}}_{k\times k} & -\underline{\mathbf{W}}_{k\times k} \end{bmatrix}. \qquad \text{Eq (1)}$$

Hadamard matrices of square dimensions that are power of two (e.g., 2×2, 4×4, 8×8, and so on) may be formed as shown in equation (1). L different Walsh sequences of length L may be formed with L column of an $L\times L$ Hadamard matrix $\underline{\mathbf{W}}_{L\times L}$. The signaling message M_c has a B-bit binary value of i, where $0 \le i \le (L-1)$. The (i+1)-th column of the Hadamard matrix $\underline{\mathbf{W}}_{L\times L}$ is provided as the coded message W_c. In an embodiment, the signaling message M_c is 10 bits long, and the coded message W_c is a 1024-bit Walsh sequence that may be given as:

$$W_c = \{ w_1^i,\ w_2^i,\ w_3^i,\ ...,\ w_{1024}^i \}, \qquad \text{Eq (2)}$$

where each Walsh bit w_k^i, for $k = 1,...,1024$, can take on a value of +1 or –1, or $w_k^i \in \{+1, -1\}$. In an embodiment, the coded message W_{PICH} for the PICH is a sequence of all ones, which corresponds to Walsh code 0 from the first column of $\underline{\mathbf{W}}_{L\times L}$. A signaling message may also be encoded in other manners besides the Walsh code mapping described above.

[0073] The coded message W_c is channelized with a channelization sequence S_c for signaling channel c. In an embodiment, the channelization sequence S_c is generated as

follows. A 20-bit shift register generates a pseudo-random binary sequence F_c based on the following generator polynomial:

$$h(D) = D^{20} + D^{17} + D^{12} + D^{10} + 1 \ , \qquad \text{Eq (3)}$$

where D denotes a delay of one bit. The initial state of the 20-bit shift register is set to a 20-bit value $F_{c,int}$, which may be generated as follows:

$$F_{c,init} = [\ \text{Bit reverse}(A_c \cdot P_r)]\ \text{mod}\ 2^{20} \ , \qquad \text{Eq (4)}$$

where P_r is a large prime number, e.g., $P_r = 2{,}654{,}435{,}761$; and

A_c is a seed value for signaling channel c.

The same large prime number may be used for all signaling channels.

[0074] In an embodiment, the seed value for signaling channel c is given as:

$$A_c = [\ s_3\ s_2\ s_1\ m_5\ m_4\ m_3\ m_2\ m_1\ p_{12}\ p_{11}\ p_{10}\ p_9\ p_8\ p_7\ p_6\ p_5\ p_4\ p_3\ p_2\ p_1\ ] \ , \qquad \text{Eq (5)}$$

where $[c_3\ c_2\ c_1]$ is a 3-bit index for signaling channel c;

$[m_5\ m_4\ m_3\ m_2\ m_1]$ is a 5-bit index for the frame in which the signaling is sent; and

$[p_{12}\ p_{11}\ p_{10}\ p_9\ p_8\ p_7\ p_6\ p_5\ p_4\ p_3\ p_2\ p_1]$ is a 12-bit identifier for a target base station.

The signaling channels may be assigned different indices that may be used to generate different seed values, and hence different channelization sequences, for these signaling channels. In an embodiment, the CQICH is assigned an index of [000] (binary), the BFCH is assigned an index of [001], the SFCH is assigned an index of [010], the ACH is assigned an index of [100], the REQCH is assigned an index of [101], and the PICH is assigned an index of [110]. The target base station may be the FL serving sector in the serving synchronous subset, a designated sector in a non-serving synchronous subset, and so on.

[0075] The binary sequence F_c of length $L/2$ from the shift register may be given as:

$$F_c = \{f_c^1,\ f_c^2,\ f_c^3,\ ...,\ f_c^{L/2}\} \ . \qquad \text{Eq (6)}$$

The binary sequence F_c is repeated 2R times to form the channelization sequence S_c of length $L \cdot R$, as follows:

$$S_c = \{\underbrace{f_c^1, \ldots, f_c^1}_{\text{first } 2R \text{ bits}}, \underbrace{f_c^2, \ldots, f_c^2}_{\text{next } 2R \text{ bits}}, \ldots, \underbrace{f_c^{L/2}, \ldots, f_c^{L/2}}_{\text{last } 2R \text{ bits}}\}, \quad \text{Eq (7)}$$

where R is a repetition factor that is selected as described below.

[0076] As shown in equation (5), the seed value A_c and hence the channelization sequence S_c for each signaling channel is dependent on (1) an index for that signaling channel, which allows the target base station to distinguish the different CDMA signaling channels, (2) the frame in which the signaling is sent, and (3) the identifier of the target base station, which allows each base station to receive the signaling sent for that base station.

[0077] To channelize the coded message W_c, this message is first repeated R times to form a repeated sequence containing L·R bits. The repetition factor R is selected such that the total number of bits after the repetition is less than or equal to the total number of transmission units in the CDMA control segment, or $L \cdot R \leq U$. For simplicity, the following description assumes that $L \cdot R = U$. The repeated sequence is multiplied with the channelization sequence S_c to obtain an output sequence X_c for signaling channel c, as follows:

$$X_c = \{\underbrace{(-1)^{S_c^1} \cdot w_1^I, \ldots, (-1)^{S_c^R} \cdot w_1^I}_{\text{first } R \text{ bits}}, \ldots, \underbrace{(-1)^{S_c^{1023R+1}} \cdot w_{1024}^I, \ldots, (-1)^{S_c^{1024 \cdot R}} \cdot w_{1024}^I}_{\text{last } R \text{ bits}}\}. \quad \text{Eq (8)}$$

As shown in equation (8), each bit in the repeated sequence is either (1) inverted if the corresponding bit in the channelization sequence S_c is equal to 1 or (2) not inverted otherwise. The output sequence X_c for signaling channel c may be scaled based on the power allocated to that signaling channel, as shown in FIG. 6. The CDMA signaling channels may be allocated the same or different amounts of power. For simplicity, the power scaling is omitted in equation (8).

[0078] In an embodiment, the last R·F bits of the output sequence X_{ACH} for the ACH are set to zero, and the length of the output sequence X_{ACH} is effectively shortened to $(L-F) \cdot R$. In another embodiment, the coded message W_{ACH} or the repeated message for the ACH is formed such that it is shorter than L·R bits. The shorter repeated sequence is multiplied with a shorter channelization sequence to obtain a shorter output sequence X_{ACH}. In any case, the shorter output sequence X_{ACH} may be sent in a smaller

time duration. This provides some guard time to account for inaccurate timing at a terminal when sending an access probe to the system.

[0079] In an embodiment, the CDMA signaling channels may be individually enabled and disabled for each CDMA frame. A given CDMA signaling channel may be disabled by setting the output sequence X_c for that signaling channel to a sequence of all zeros.

[0080] In an embodiment, the output sequences for the CQICH, REQCH, BFCH, SFCH, and PICH may be combined by combiner 640 to obtain a composite sequence X_{SM}^{s} for the serving synchronous subset. In an embodiment, the output sequence for the CQICH may be provided as a composite sequence X_{SM}^{ns} for a non-serving synchronous subset. In an embodiment, the composite sequences X_{SM}^{s} and X_{SM}^{ns} may be given as follows:

$$X_{SM}^{s} = (X_{CQICH} + X_{SFCH} + X_{PICH}) + j(X_{REQCH} + X_{BFCH}) \text{ , and} \qquad \text{Eq (9a)}$$

$$X_{SM}^{ns} = X_{CQICH}. \qquad \text{Eq (9b)}$$

The composite sequences X_{SM}^{s} and X_{SM}^{ns} each contain U complex values. For the embodiment shown in equation (9a), the CQICH, SFCH, and PICH are sent in the inphase (I) component and the REQCH and BFCH are sent in the quadrature (Q) component of X_{SM}^{s}. The output sequences for the CQICH, REQCH, BFCH, SFCH, and PICH may also be combined in other manners for the serving synchronous subset. In the following description, the composite sequence X_{SM} may be equal to X_{SM}^{s} for the serving synchronous subset or X_{SM}^{ns} for the non-serving synchronous subset.

[0081] In an embodiment, the composite sequence X_{SM} is scrambled with a scrambling sequence Y_{SM} that is specific for both the target base station and the terminal. The scrambling sequence Y_{SM} is thus different for different synchronous subsets. The scrambling sequence Y_{SM} may be generated as follows. A 28-bit shift register generates a pseudo-random binary sequence F_{SM} based on the following generator polynomial:

$$h(D) = D^{28} + D^{25} + 1 . \qquad \text{Eq (10)}$$

The initial state of the 28-bit shift register is set to a 28-bit value $F_{SM,init}$, which may be generated as follows:

$$F_{SM,init} = [\text{Bit reverse}(A_{SM} \cdot P_c)] \bmod 2^{28}, \quad \text{Eq (11)}$$

where $A_{SM} = [m_5\ m_4\ m_3\ m_2\ m_1\ t_{11}\ t_{10}\ t_9\ t_8\ t_7\ t_6\ t_5\ t_4\ t_3\ t_2\ t_1\ p_{12}\ p_{11}\ p_{10}\ p_9\ p_8\ p_7\ p_6\ p_5\ p_4\ p_3\ p_2\ p_1]$, and $[t_{11}\ t_{10}\ t_9\ t_8\ t_7\ t_6\ t_5\ t_4\ t_3\ t_2\ t_1]$ is an 11-bit identifier or MACID for the terminal, which may be different for different synchronous subsets.

[0082] The scrambling sequence Y_{SM} may then be generated as follows:

$$Y_{SM} = \{y_{SM}^1, y_{SM}^2, y_{SM}^3, \ldots, y_{SM}^U\}, \quad \text{Eq (12)}$$

$$y_{SM}^{k+1} = y_{SM}^k \cdot e^{j(\pi/2)\cdot(2\cdot f_{SM}^k - 1)}, \quad \text{for } k = 1, \ldots, (U-1), \quad \text{with } y_{SS}^1 = 1, \quad \text{Eq (13)}$$

where $f_{SM}^k \in \{0, 1\}$ is the k-th bit of the binary sequence F_{SM}; and

$y_{SM}^k \in \{-1, +1\}$ is the k-th bit of the scrambling sequence Y_{SM}.

The scrambling sequence Y_{SM} rotates +90° or –90° in a pseudo-random manner from bit to bit based on the pseudo-random binary sequence F_{SM}.

[0083] The composite sequence X_{SM} may be scrambled with the scrambling sequence Y_{SM} to generate a scrambled sequence Z_{SM}, as follows:

$$Z_{SM} = \{y_{SM}^1 \cdot x_{SM}^1, y_{SM}^2 \cdot x_{SM}^2, y_{SM}^3 \cdot x_{SM}^3, \ldots, y_{SM}^U \cdot x_{SM}^U\}, \quad \text{Eq (14)}$$

where $x_{SM}^k \in \{-1, +1\}$ is the k-th bit of the composite sequence X_{SM}.

[0084] In an embodiment, the output sequence X_{ACH} for the ACH is scrambled with a scrambling sequence Y_{SS} that is specific for the target base station. The reason for using a sector-specific scrambling sequence Y_{SS} for the ACH is because (1) a terminal that is attempting to access the system may not have a valid MACID and (2) the target base station is typically not aware of which terminals are attempting to access that base station. The scrambling sequence Y_{SS} may be generated as follows. A pseudo-random binary sequence F_{SS} of length U may be generated as described above with a seed value of $A_{SS} = [1\ 1\ 1\ m_5\ m_4\ m_3\ m_2\ m_1\ p_{12}\ p_{11}\ p_{10}\ p_9\ p_8\ p_7\ p_6\ p_5\ p_4\ p_3\ p_2\ p_1]$. The scrambling sequence Y_{SS} may then be formed as:

$$Y_{SS} = \{ y_{SS}^{1}, y_{SS}^{2}, y_{SS}^{3}, \ldots, y_{SS}^{U} \} , \quad \text{Eq (15)}$$

$$y_{SS}^{k+1} = y_{SS}^{k} \cdot e^{j(\pi/2)(2 \cdot f_{SS}^{k} - 1)} , \text{ for } k = 1, \ldots, (U-1), \text{ with } y_{SS}^{1} = 1, \quad \text{Eq (16)}$$

where $f_{SS}^{k} \in \{0, 1\}$ is the k-th bit of the binary sequence F_{SS}; and

$y_{SS}^{k} \in \{-1, +1\}$ is the k-th bit of the scrambling sequence Y_{SS}.

[0085] The output sequence X_{ACH} may be scrambled with the scrambling sequence Y_{SS} to generate a scrambled sequence Z_{SS}, as follows:

$$Z_{SS} = \{ y_{SS}^{1} \cdot x_{ACH}^{1}, y_{SS}^{2} \cdot x_{ACH}^{2}, y_{SM}^{3} \cdot x_{ACH}^{3}, \ldots, y_{SS}^{U} \cdot x_{ACH}^{U} \} , \quad \text{Eq (17)}$$

where $x_{ACH}^{k} \in \{-1, +1\}$ is the k-th bit of the output sequence X_{ACH}. As noted above, some of the bits at the end of the output sequence X_{ACH} may be set to zero.

[0086] In an embodiment, the scrambled sequences Z_{SM} and Z_{SS} are combined by combiner 650 to generate the output sequence Z_{OUT}, as follows:

$$Z_{OUT} = \{ z_{SM}^{1} + z_{SS}^{1}, z_{SM}^{2} + z_{SS}^{2}, z_{SM}^{3} + z_{SS}^{3}, \ldots, z_{SM}^{U} + z_{SS}^{U} \} , \quad \text{Eq (18)}$$

where z_{SM}^{k} and z_{SS}^{k} are the k-th bits of the output sequences Z_{SM} and Z_{SS}, respectively. The output sequence Z_{OUT} is further processed and sent on the CDMA control segment.

[0087] For the embodiment described above, the messages for the CDMA signaling channels have a fixed length of B bits. This allows the messages to be mapped to Walsh sequences of length L, where $L = 2^{B}$. For this embodiment, a message with more than B bits may be partitioned and sent (1) on one instance of the signaling channel in multiple CDMA frames or (2) on multiple instances of the signaling channel in one CDMA frame. Multiple instances of a given signaling channel may be obtained, e.g., by sending multiple Walsh sequences on the signaling channel. In another embodiment, the messages for the CDMA signaling channels may have different lengths.

[0088] **FIG. 7** shows a block diagram of an embodiment of RX data and signaling processor 520 at base station 110 in FIG. 5. Processor 520 includes a demultiplexer (DEMUX) 710, an RX data processor 720, and an RX signaling processor 730. For clarity, the processing to recover traffic data and signaling from one terminal (e.g., terminal 120 in FIG. 5) is described below.

[0089] Within RX data processor 720, a symbol-to-subcarrier demapper 722 extracts received symbols from the time-frequency blocks for the traffic channel assigned to terminal 120. A unit 724 symbol demaps, deinterleaves, and decodes the extracted received symbols and provides decoded data for terminal 120.

[0090] Within RX signaling processor 730, a symbol-to-subcarrier demapper 732 extracts received symbols from the time-frequency region used for the CDMA control segment in each CDMA frame. For each symbol period in which the CDMA control segment is sent, an IDFT/IFFT unit 734 transforms the received symbols for that symbol period to the time domain and provides received samples. A descrambler 736a descrambles the received samples with the scrambling sequence Y_{SM} provided by a scrambling sequence generator 738 and provides descrambles samples D_{SM} to channel processors 740a through 740e for the CQICH, REQCH, BFCH, SFCH, and PICH. Within channel processor 740a for the CQICH, a de-channelizer 742 multiplies the descrambled samples D_{SM} with the channelization sequence S_{CQICH}. A decoder 744 decodes the channelized samples and provides a recovered message for the CQICH. Each of channel processors 740b through 740e similarly multiplies the descrambled samples D_{SM} with the channelization sequence for the associated signaling channel, decodes the channelized samples, and provides a recovered message for that signaling channel. Pilot channel processor 740e may provide a broadband channel estimate that covers all of the subcarriers used for the CDMA control segment. The broadband channel estimate may be used for data detection, scheduling, and so on. A descrambler 736b descrambles the received samples with the scrambling sequence Y_{SS} provided by the scrambling sequence generator 738 and provides descrambles samples D_{SS} for the ACH. A channel processors 740f multiplies the descrambled samples D_{SS} with the channelization sequence for the ACH, decodes the channelized samples, and provides a recovered message for the ACH. An RX ACK channel processor 750 processes received symbols for the ACKCH and provides a detected ACK message.

[0091] The pilot channel (PICH) carries a sequence of all ones that is used by the base station estimate the RL channel response. The RL channel response estimate may be used (1) for adaptive subband scheduling on the reverse link and (2) as an FL channel response estimate in a TDD system in which the FL channel response may be assumed to be reciprocal of the RL channel response.

[0092] The access channel (ACH) carries messages or access probes sent by the terminal for system access. The available Walsh sequences for the ACH may be divided into multiple groups. Each group may be associated with specific parameters such as, e.g., buffer level, measured FL signal strength, and so on. A terminal may randomly select a Walsh sequence from a group associated with the desired parameters and may send the selected Walsh sequence to a base station. The terminal may thus communicate the desired parameters to the base station via the selected Walsh sequence.

[0093] The ACH may be sent with an extended guard band and guard time in order to prevent intra-sector interference caused by misalignment of the access probe with the CDM control segment boundaries. This timing misalignment may result from the fact that the terminal in the access phase may not have accurate RL timing information.

[0094] **FIG. 8** shows a process 800 to control signaling transmission on the CDMA control segment. In an embodiment, the CDMA control segment and the CDMA signaling channels are configurable for each sector in the system. Process 800 may be performed by a base station for its sector or by a network entity for a base station. The following description is for one sector.

[0095] Transmission parameters for the CDMA control segment for the sector are determined (block 812). These transmission parameters may indicate the size of the CDMA control segment (e.g., the number of subbands or subcarriers for the CDMA control segment), the frames or interlace to use for the CDMA control segment, the frequency hopping for the CDMA control segment, and so on. CDMA signaling channels that are enabled for the sector are also determined (block 814). Which CDMA signaling channels to enable may be dependent on how traffic data is transmitted on the forward and/or reverse link and/or other factors. For example, the SFCH may be disabled if adaptive subband scheduling is not performed for the forward link, and the BFCH may be disabled if beamforming and spatial multiplexing is not performed in an FDD system.

[0096] The average transmission interval for each enabled CDMA signaling channel is selected (block 816). The average transmission interval is the average time between successive transmissions of a given signaling channel. The use of an average transmission interval, instead of a fixed transmission interval, provides a terminal with

flexibility in determining when to send signaling and further allows for finer granularity in setting the transmission interval.

[0097] CDMA signaling channels that are enabled for each terminal are determined and selected from among the enabled CDMA signaling channels for the sector (block 818). The reporting mode to use for each CDMA signaling channel with multiple reporting modes is also determined for each terminal, e.g., based on the transmission scheme (e.g., SISO or MIMO) used for the terminal and/or other factors (also block 818). Control information indicative of various parameters for the CDMA control segment and the enabled CDMA signaling channels is sent to the terminals (block 820). For example, control information that is applicable to all terminals may be broadcast in the FL superframe preamble, and control information that is specific for each terminal may be sent directly to that terminal.

[0098] FIG. 8 shows a specific embodiment for controlling the operation of the CDMA control segment. In another embodiment, the average transmission interval is individually selected for each enabled CDMA signaling channel for each terminal. In yet another embodiment, the transmission rate for each enabled CDMA signaling channel is configurable and given by a fixed rate instead of an average rate. The operation of the CDMA control segment may also be controlled in other manners.

[0099] **FIG. 9** shows an apparatus 900 for controlling signaling transmission on the CDMA control segment. Apparatus 900 includes means for determining transmission parameters (e.g., the size, interlace, and frequency hopping) for the CDMA control segment for a sector (block 912), means for determining CDMA signaling channels that are enabled for the sector (block 914), means for selecting the average transmission interval for each enabled CDMA signaling channel (block 916), means for determining CDMA signaling channels that are enabled for each terminal (block 918), means for sending control information indicative of various parameters for the CDMA control segment and the enabled CDMA signaling channels to the terminals (block 920).

[00100] **FIG. 10** shows a process 1000 performed by a terminal for sending signaling on the CDMA control segment. Initially, transmission parameters (e.g., the size, interlace, and frequency hopping) for the CDMA control segment for a serving sector are determined (block 1012). The enabled CDMA signaling channels for the terminal and the average transmission interval for each enabled CDMA signaling channel are determined (block 1014).

[00101] For each frame, a determination is made whether the CDMA control segment is being sent in that frame (block 1016). If the answer is 'Yes', then all CDMA signaling channels to be sent in the current frame are determined (block 1018). This determination may be made based on the average transmission intervals for the enabled CDMA signaling channels, whether there is signaling to send for each enabled CDMA signaling channel, and so on. The signaling for each CDMA signaling channel to be sent in the current frame is processed (e.g., encoded, channelized, scaled, and scrambled) (block 1020). The processed signaling for all CDMA signaling channels is combined (block 1022) and the combined signaling is mapped to a time-frequency region used for the CDMA control segment in the current frame (block 1024).

[00102] **FIG. 11** shows an apparatus 1100 for sending signaling on the CDMA control segment. Apparatus 1100 includes means for determining transmission parameters (e.g., the size, interlace, and frequency hopping) for the CDMA control segment for a serving sector (block 1112) and means for determining the enabled CDMA signaling channels for a terminal and the average transmission interval for each enabled CDMA signaling channel (block 1114).

[00103] Apparatus 1100 further includes means for processing each frame in which the CDMA control segment is sent, which includes means for determining CDMA signaling channels to be sent in a current frame (block 1118), means for processing (e.g., encoding, channelizing, scaling, and scrambling) the signaling for each CDMA signaling channel to be sent in the current frame (block 1120), means for combining the processed signaling for all CDMA signaling channels (block 1122), and means for mapping the combined signaling to a time-frequency region used for the CDMA control segment in the current frame (block 1124).

[00104] **FIG. 12** shows a process 1200 performed by a base station for receiving signaling sent on the CDMA control segment. For each frame, a determination is made whether the CDMA control segment is being sent in that frame (block 1212). If the answer is 'Yes', then received symbols are extracted from a time-frequency region used for the CDMA control segment in the current frame (block 1214).

[00105] For each active terminal, which is a terminal that may send signaling using the sector-specific and user-specific scrambling sequence Y_{SM}, all CDMA signaling channels that might be sent by the active terminal in the current frame are determined (block 1216). The received symbols are processed (e.g., descrambled, dechannelized,

and decoded) for each CDMA signaling channel that might be sent by each active terminal to recover signaling, if any, from that CDMA signaling channel (block 1218). The received symbols are also processed (e.g., descrambled, dechannelized, and decoded) for the access channel to recover any access probes sent by terminals attempting to access the system (block 1220).

[00106] **FIG. 13** shows an apparatus 1300 for receiving signaling sent on the CDMA control segment. Apparatus 1300 includes means for processing each frame in which the CDMA control segment is sent, which includes means for extracting received symbols from a time-frequency region used for the CDMA control segment in a current frame (block 1314), means for determining CDMA signaling channels that might be sent by each active terminal in the current frame (block 1316), means for processing (e.g., descrambling, dechannelizing, and decoding) the received symbols for each CDMA signaling channel that might be sent by each active terminal to recover signaling, if any, from that CDMA signaling channel (block 1318), and means for processing (e.g., descrambling, dechannelizing, and decoding) the received symbols for the access channel to recover any access probes sent by terminals attempting to access the system (block 1320).

[00107] The signaling transmission techniques described herein may be implemented by various means. For example, these techniques may be implemented in hardware, firmware, software, or a combination thereof. For a hardware implementation, the processing units at a terminal may be implemented within one or more application specific integrated circuits (ASICs), digital signal processors (DSPs), digital signal processing devices (DSPDs), programmable logic devices (PLDs), field programmable gate arrays (FPGAs), processors, controllers, micro-controllers, microprocessors, electronic devices, other electronic units designed to perform the functions described herein, or a combination thereof. The processing units at a base station may also be implemented within one or more ASIC, DSPs, processors, and so on. Processor 530 may implement process 800 in FIG. 8, processor 560 may implement process 1000 in FIG. 10, and processor 520 may implement process 1200 in FIG. 12.

[00108] For a firmware and/or software implementation, the techniques may be implemented with modules (e.g., procedures, functions, and so on) that perform the functions described herein. The software codes may be stored in a memory (e.g.,

memory 532 or 572 in FIG. 5) and executed by a processor (e.g., processor 530 or 570). The memory may be implemented within the processor or external to the processor.

[00109] The previous description of the disclosed embodiments is provided to enable any person skilled in the art to make or use the present invention. Various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments without departing from the spirit or scope of the invention. Thus, the present invention is not intended to be limited to the embodiments shown herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

WHAT IS CLAIMED IS:

CLAIMS

1. An apparatus comprising:

at least one processor configured to determine frames in which a control segment is sent and, for each frame in which the control segment is sent, to process signaling for signaling channels, if any, to be sent on the control segment in the frame, and to map the processed signaling to a time-frequency region used for the control segment in the frame, wherein signaling from multiple terminals are sent on the control segment with code division multiple access (CDMA) and wherein the time-frequency region comprises OFDM symbols; and

a memory coupled to the at least one processor.

2. The apparatus of claim 1, wherein the control segment is sent in every Q frames, where Q is an integer greater than one.

3. The apparatus of claim 1, wherein the control segment spans an entire frame for each frame in which the control segment is sent.

4. The apparatus of claim 1, wherein each frame covers multiple subbands, and wherein the control segment has a configurable size and is sent in an integer number of subbands.

5. The apparatus of claim 1, wherein for each of the signaling channels the at least one processor is configured to encode a message for the signaling channel to obtain a coded message, and to channelize the coded message with a channelization code for the signaling channel.

6. The apparatus of claim 5, wherein for each of the signaling channels the at least one processor is configured to encode the message for the signaling channel by mapping the message to one of a plurality of Walsh sequences.

7. The apparatus of claim 5, wherein for each of the signaling channels the at least one processor is configured to generate the channelization code for the signaling channel based on an index for the signaling channel and an identifier for a base station intended to receive the signaling channel.

8. The apparatus of claim 1, wherein messages for the signaling channels have equal length.

9. The apparatus of claim 1, wherein the at least one processor is configured to scramble the signaling for the signaling channels with at least one scrambling sequence.

10. The apparatus of claim 9, wherein the at least one processor is configured to generate one of the at least one scrambling sequence based on an identifier for a base station intended to receive the signaling channels.

11. The apparatus of claim 9, wherein the at least one processor is configured to generate one of the at least one scrambling sequence based on an identifier for a terminal sending the signaling channels and an identifier for a base station intended to receive the signaling channels.

12. The apparatus of claim 1, wherein the at least one processor is configured to combine the signaling for the signaling channels, to transform the combined signaling to frequency domain to obtain signaling symbols, and to map the signaling symbols on the time-frequency region used for the control segment in the frame.

13. The apparatus of claim 1, wherein the signaling channels includes a signaling channel carrying channel quality indicator (CQI).

14. The apparatus of claim 13, wherein the at least one processor is configured to sent the signaling channel carrying CQI to multiple base stations.

15. The apparatus of claim 1, wherein the signaling channels includes a signaling channel carrying beamforming feedback information.

16. The apparatus of claim 1, wherein the signaling channels includes a signaling channel carrying feedback information indicative of channel quality for at least one subband among multiple subbands.

17. The apparatus of claim 1, wherein the signaling channels includes a signaling channel carrying feedback information for multiple spatial channels of a multiple-input multiple-output (MIMO) channel.

18. The apparatus of claim 1, wherein the at least one processor is configured to determine the signaling channels to be sent on the control segment in the frame based on an average transmission interval for each signaling channel.

19. The apparatus of claim 1, wherein the control segment hops across frequency from frame to frame.

20. The apparatus of claim 1, wherein the at least one processor is configured to determine subcarriers used for a traffic channel, to determine subcarriers allocated for the control segment, and to map the traffic channel to the subcarriers allocated for the control segment if the traffic channel collides with the control segment.

21. A method comprising:

determining frames in which a control segment is sent; and

for each frame in which the control segment is sent,

processing signaling for signaling channels to be sent on the control segment in the frame, wherein the processing the signaling for the signaling channels comprises mapping a message for each of the signaling channels to a Walsh sequence among a

plurality of Walsh sequences, and channelizing the Walsh sequence for each signaling channel with a channelization code for the signaling channel, and

mapping the processed signaling to a time-frequency region used for the control segment in the frame, wherein the time-frequency region comprises OFDM symbols.

22. The method of claim 21, wherein the processing the signaling for the signaling channels comprises

generating the channelization code for each signaling channel based on an index for the signaling channel and an identifier for a base station intended to receive the signaling channel.

23. The method of claim 21, wherein the processing the signaling for the signaling channels comprises

scrambling the signaling for the signaling channels with at least one scrambling sequence.

24. The method of claim 23, wherein the processing the signaling for the signaling channels comprises

generating one of the at least one scrambling sequence based on an identifier for a terminal sending the signaling channels and an identifier for a base station intended to receive the signaling channels.

25. The method of claim 21, wherein the processing the signaling for the signaling channels comprises

combining the signaling for the signaling channels,

transforming the combined signaling to frequency domain to obtain signaling symbols, and

mapping the signaling symbols to the time-frequency region used for the control segment in the frame.

26. An apparatus comprising:

means for determining frames in which a control segment is sent; and

means for processing each frame in which the control segment is sent, comprising

means for processing signaling for signaling channels to be sent on the control segment in the frame, wherein the means for processing the signaling for the signaling channels comprises means for mapping a message for each of the signaling channels to a Walsh sequence among a plurality of Walsh sequences, and means for channelizing the Walsh sequence for each signaling channel with a channelization code for the signaling channel, and

means for mapping the processed signaling to a time-frequency region used for the control segment in the frame, wherein the time-frequency region comprises OFDM symbols.

27. The apparatus of claim 26, wherein the means for processing the signaling for the signaling channels comprises

means for generating the channelization code for each signaling channel based on an index for the signaling channel and an identifier for a base station intended to receive the signaling channel.

28. The apparatus of claim 26, wherein the means for processing the signaling for the signaling channels comprises

means for scrambling the signaling for the signaling channels with at least one scrambling sequence.

29. The apparatus of claim 28, wherein the means for processing the signaling for the signaling channels comprises

means for generating one of the at least one scrambling sequence based on an identifier for a terminal sending the signaling channels and an identifier for a base station intended to receive the signaling channels.

30. An apparatus comprising:

at least one processor configured to channelize messages for multiple signaling channels with multiple channelization codes, to scramble the channelized messages with at least one scrambling code, and to map the scrambled messages to a time-frequency region used for a control segment, wherein the time-frequency region comprises OFDM symbols; and

a memory coupled to the at least one processor.

31. The apparatus of claim 30, wherein the at least one processor is configured to generate the multiple channelization codes for the multiple signaling channels based on a pseudo-random number (PN) generator and different seed values for the multiple signaling channels.

32. The apparatus of claim 30, wherein the at least one processor is configured to generate one of the at least one scrambling sequence based on an identifier for a terminal sending the multiple signaling channels and an identifier for a base station intended to receive the multiple signaling channels.

33. The apparatus of claim 30, wherein the at least one processor is configured to map the messages for the multiple signaling channels to Walsh sequences, and to channelize the Walsh sequences with the multiple channelization codes.

34. The apparatus of claim 30, wherein the multiple signaling channels carry different types of feedback information, and wherein the messages for the multiple signaling channels carry channel quality indicator (CQI), beamforming feedback information, subband feedback information, or a combination thereof.

35. An apparatus comprising:

at least one processor configured to determine frames in which a control segment is sent and, for each frame in which the control segment is sent, to extract received symbols from a time-frequency region used for the control segment in the frame, wherein the time-frequency region comprises OFDM symbols, to determine signaling channels

potentially sent by a terminal on the control segment in the frame, wherein signaling from multiple terminals are sent on the control segment with code division multiple access (CDMA), and to process the received symbols for the potentially sent signaling channels to recover signaling sent by the terminal; and

a memory coupled to the at least one processor.

36. The apparatus of claim 35, wherein the control segment is sent in every Q frames, where Q is an integer greater than one.

37. The apparatus of claim 35, wherein the control segment spans an entire frame for each frame in which the control segment is sent.

38. The apparatus of claim 35, wherein the at least one processor is configured to transform the received symbols to time domain to obtain received samples, and to descramble the received samples with at least one scrambling sequence.

39. The apparatus of claim 38, wherein the at least one processor is configured to generate one of the at least one scrambling sequence based on an identifier for the terminal and an identifier for a base station receiving the control segment.

40. The apparatus of claim 35, wherein for each of the potentially sent signaling channels the at least one processor is configured to perform channelization with a channelization code for the signaling channel to obtain channelized samples, and to decode the channelized samples to recover a message for the signaling channel.

41. The apparatus of claim 40, wherein for each potentially sent signaling channel the at least one processor is configured to map the channelized samples to a Walsh sequence among a plurality of Walsh sequences, and to provide a message associated with the Walsh sequence as a recovered message for the signaling channel.

42. The apparatus of claim 40, wherein for each potentially sent signaling channel the at least one processor is configured to generate the channelization code for the signaling channel based on an index for the signaling channel and an identifier for a base station intended to receive the signaling channel.

43. A method comprising:

determining frames in which a control segment is sent; and

for each frame in which the control segment is sent,

extracting received symbols from a time-frequency region used for the control segment in the frame, wherein the time-frequency region comprises OFDM symbols,

determining signaling channels potentially sent by a terminal on the control segment in the frame, and

processing the received symbols for the potentially sent signaling channels to recover signaling sent by the terminal, wherein the processing the received symbols for the potentially sent signaling channels comprises transforming the received symbols to time domain to obtain received samples, and descrambling the received samples with at least one scrambling sequence.

44. The method of claim 43, wherein the processing the received symbols for the potentially sent signaling channels comprises, for each potentially sent signaling channel,

performing channelization with a channelization code for the signaling channel to obtain channelized samples,

mapping the channelized samples to a Walsh sequence among a plurality of Walsh sequences, and

providing a message associated with the Walsh sequence as a recovered message for the signaling channel.

45. An apparatus comprising:

means for determining frames in which a control segment is sent; and

means for processing each frame in which the control segment is sent, comprising

means for extracting received symbols from a time-frequency region used for the control segment in the frame, wherein the time-frequency region comprises OFDM symbols,

means for determining signaling channels potentially sent by a terminal on the control segment in the frame, and

means for processing the received symbols for the potentially sent signaling channels to recover signaling sent by the terminal, wherein the means for processing the received symbols for the potentially sent signaling channels comprises means for transforming the received symbols to time domain to obtain received samples, and means for descrambling the received samples with at least one scrambling sequence.

46. The apparatus of claim 45, wherein the means for processing the received symbols for the potentially sent signaling channels comprises, for each potentially sent signaling channel,

means for performing channelization with a channelization code for the signaling channel,

means for mapping channelized samples to a Walsh sequence among a plurality of Walsh sequences, and

means for providing a message associated with the Walsh sequence as a recovered message for the signaling channel.

47. An apparatus comprising:

at least one processor configured to determine transmission parameters for a control segment, to determine signaling channels that are enabled for the control segment, and to send control information indicative of the transmission parameters for the control segment and the enabled signaling channels for the control segment, wherein signaling from multiple terminals are sent on the control segment with code division multiple access (CDMA) SCHEME, wherein the transmission parameters for the control segment indicate size of the control segment and frames in which the control segment is sent, wherein the size of the control segment comprises at least 8 OFDM symbols and 128 sub-carriers; and

a memory coupled to the at least one processor.

48. The apparatus of claim 47, wherein the at least one processor is configured to determine an average transmission interval for each of the enabled signaling channels for the control segment.

49. The apparatus of claim 47, wherein the at least one processor is configured to determine signaling channels that are enabled for each of at least one terminal.

50. The apparatus of claim 1, wherein the time-frequency region comprises at least 8 OFDM symbols and at least 128 sub-carriers.

51. The method of claim 21, wherein the time-frequency region comprises at least 8 OFDM symbols and at least 128 sub-carriers.

52. The apparatus of claim 26, wherein the time-frequency region comprises at least 8 OFDM symbols and at least 128 sub-carriers.

53. The apparatus of claim 30, wherein the time-frequency region comprises at least 8 OFDM symbols and at least 128 sub-carriers.

54. The apparatus of claim 35, wherein the time-frequency region comprises at least 8 OFDM symbols and at least 128 sub-carriers.

55. The method of claim 43, wherein the time-frequency region comprises at least 8 OFDM symbols and at least 128 sub-carriers.

56. The apparatus of claim 45, wherein the time-frequency region comprises at least 8 OFDM symbols and at least 128 sub-carriers.

57. A computer-readable medium, with code stored thereon, the code comprising:

code for causing a computer to determine frames in which a control segment is sent; and

for each frame in which the control segment is sent,

code for causing a computer to process signaling for signaling channels to be sent on the control segment in the frame, wherein the processing the signaling for the signaling channels comprises code for causing a computer to map a message for each of the signaling channels to a Walsh sequence among a plurality of Walsh sequences, and channelize the Walsh sequence for each signaling channel with a channelization code for the signaling channel, and

code for causing a computer to map the processed signaling to a time-frequency region used for the control segment in the frame, wherein the time-frequency region comprises OFDM symbols.

58. A computer-readable medium, with code stored thereon, the code comprising:

code for causing a computer to determine frames in which a control segment is sent; and

for each frame in which the control segment is sent,

code for causing a computer to extract received symbols from a time-frequency region used for the control segment in the frame, wherein the time-frequency region comprises OFDM symbols,

code for causing a computer to determine signaling channels potentially sent by a terminal on the control segment in the frame, and

code for causing a computer to process the received symbols for the potentially sent signaling channels to recover signaling sent by the terminal, wherein the processing the received symbols for the potentially sent signaling channels comprises code for causing a computer to transform the received symbols to time domain to obtain received samples, and descramble the received samples with at least one scrambling sequence.