# ACKNOWLEDGEMENT OF CONTROL MESSAGES IN A WIRELESS COMMUNICATION SYSTEM

**[0001]** The present application claims priority to provisional U.S. Application Serial No. 60/868,464, filed December 4, 2006, entitled "ASSIGNMENT ACKNOWLEDGEMENT FOR A WIRELESS COMMUNICATION SYSTEM," both assigned to the assignee hereof and incorporated herein by reference in their entirety .

## BACKGROUND

### I. Field

**[0002]** The present disclosure relates generally to communication, and more specifically to techniques for sending control messages.

### II. Background

**[0003]** Wireless communication systems are widely deployed to provide various communication services such as voice, video, packet data, messaging, broadcast, etc. These wireless 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, Frequency Division Multiple Access (FDMA) systems, Orthogonal FDMA (OFDMA) systems, Single-Carrier FDMA (SC-FDMA) systems, etc.

**[0004]** A multiple-access system typically employs a method of assigning system resources to individual users of the system. It is desirable to send assignments of resources as efficiently as possible in order to reduce the amount of overhead for sending the assignments. Furthermore, it is desirable to send the assignments in a reliable manner so that the assigned resources are properly used for data transmission. Reliability may be particularly important for persistent assignments that extend over time rather than have a deterministic expiration time.

**[0005]** There is therefore a need in the art for techniques to efficiently and reliably send assignment of resources.

## SUMMARY

**[0006]** Techniques for efficiently and reliably sending control messages such as those for assignment of resources are described herein. In an aspect, assignment messages may be acknowledged based on either linked or dedicated acknowledgement (ACK) resources. In one design, a terminal may receive an assignment message from a base station and may determine whether to acknowledge the assignment message. For example, the assignment message may be acknowledged if it is received on a control block to be acknowledged. A control block may be logical resources that may be mapped to physical resources. If the assignment message is to be acknowledged, then the terminal may determine ACK resources to use to acknowledge the assignment message. The ACK resources may be linked to the control block on which the assignment message was received or linked to resources assigned by the assignment message. The ACK resources may also be dedicated ACK resources previously assigned to the terminal. The terminal may send the acknowledgement on the linked or dedicated ACK resources.

**[0007]** In another aspect, a control message may be acknowledged based on ACK resources determined based on the control message or a control block on which the control message is sent. In one design, a number of control blocks may be available for sending control messages. Certain control blocks may be linked to ACK resources, which may be used to send acknowledgements for control messages sent on these control blocks. The terminal may determine ACK resources based on the control message or the control block. The ACK resources may be linked to the control block or linked to resources assigned by the control message. The terminal may send an acknowledgement for the control message on the ACK resources.

**[0008]** Various aspects and features of the disclosure are described in further detail below.

## BRIEF DESCRIPTION OF THE DRAWINGS

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

**[0010]** FIGS. 2A to 2C show linked and dedicated ACK resources.

**[0011]** FIG. 3 shows a design of ACK resources.

[0012] FIG. 4 shows a design of an ACK channel.

[0013] FIG. 5 shows a design of a binary channel tree.

[0014] FIG. 6 shows a process for acknowledging assignment messages.

[0015] FIG. 7 shows an apparatus for acknowledging assignment messages.

[0016] FIG. 8 shows a process for sending assignment messages.

[0017] FIG. 9 shows an apparatus for sending assignment messages.

[0018] FIG. 10 shows a process for acknowledging control messages.

[0019] FIG. 11 shows an apparatus for acknowledging control messages.

[0020] FIG. 12 shows a process for sending control messages.

[0021] FIG. 13 shows an apparatus for sending control messages.

[0022] FIG. 14 shows a block diagram of a base station and a terminal.

## DETAILED DESCRIPTION

[0023] **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 referred to as an access point, a Node B, an evolved Node B, etc. Each base station 110 provides communication coverage for a particular geographic area 102. 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 may be served by a respective base station subsystem. The term "sector" can refer to the smallest coverage area of a base station and/or a base station subsystem serving this coverage area. The techniques described herein may be used for a system with sectorized cells as well as a system with un-sectorized cells. For simplicity, in the following description, the term "base station" is used generically for a station that serves a sector as well as a station that serves a cell.

[0024] Terminals 120 may be dispersed throughout the system, and each terminal may be stationary or mobile. A terminal may also be referred to as an access terminal, a mobile station, a user equipment, a subscriber unit, a station, etc. A terminal may be a cellular phone, a personal digital assistant (PDA), a wireless communication device, a wireless modem card, a handheld device, a laptop computer, a cordless phone, etc. A

terminal may communicate with zero, one, or multiple base stations on the forward and reverse links at any given moment. 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.

**[0025]** For a centralized architecture, a system controller 130 may couple to base stations 110 and provide 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.

**[0026]** The techniques described herein may be used for various wireless communication systems such as CDMA, TDMA, FDMA, OFDMA and SC-FDMA systems. The terms "system" and "network" are often used interchangeably. A CDMA system may implement a radio technology such as cdma2000, Universal Terrestrial Radio Access (UTRA), etc. An OFDMA system may implement a radio technology such as Ultra Mobile Broadband (UMB), Evolved UTRA (E-UTRA), IEEE 802.16, IEEE 802.20, Flash-OFDM®, etc. UTRA and E-UTRA are described in documents from an organization named "3rd Generation Partnership Project" (3GPP). cdma2000 and UMB are described in documents from an organization named "3rd Generation Partnership Project 2" (3GPP2). These various radio technologies and standards are known in the art. For clarity, certain aspects of the techniques are described below for UMB, and UMB terminology is used in much of the description below. UMB is described in 3GPP2 C.S0084-001, entitled "Physical Layer for Ultra Mobile Broadband (UMB) Air Interface Specification," and 3GPP2 C.S0084-002, entitled "Medium Access Control Layer For Ultra Mobile Broadband (UMB) Air Interface Specification," both dated August 2007 and publicly available.

**[0027]** System 100 may use various channels for transmission of traffic data and control information on the forward and reverse links. Table 1 lists some channels in UMB and provides a short for each channel. UMB also support various other channels on the forward and reverse links, which are not given in Table 1 for simplicity.

Table 1

| Symbol | Channel | Description |
|---|---|---|
| F-SCCH | Forward Shared Control Channel | Carry access grants, assignment messages, and other messages related to resource management and/or other functions. |
| F-DCH | Forward Data Channel | Carry traffic data on the forward link. |
| R-ACKCH | Reverse Acknowledgement Channel | Carry acknowledgements for data sent on the F-DCH and possibly messages sent on the F-SCCH. |

**[0028]** A base station may send control messages to terminals for various purposes. For example, the base station may send control messages containing assignments of resources for the forward and/or reverse links, control information for data transmission on the forward and/or reverse links, etc. It is desirable to send the control messages as efficiently and reliably as possible.

**[0029]** In an aspect, control messages may be sent on control blocks that are linked to ACK resources that may be used to acknowledge these control messages. A control message may also be referred to as a message, a packet, signaling, etc. A control block may be logical resources used to send a control message and may also be referred to as a control channel block, an F-SCCH block, etc. Control messages may be processed (e.g., encoded, interleaved, and modulated) and sent on the control blocks. The control blocks may be mapped to physical resources, which may be given by time, frequency, code, etc. The ACK resources linked to the control blocks may correspond to certain physical resources reserved for sending acknowledgements for the control messages sent on the control blocks.

**[0030]** **FIG. 2A** shows a design of sending acknowledgements for control messages using linked ACK resources. In this design, multiple (T) control messages may be processed and sent on T control blocks on the forward link. T may be selected based on various factors such as the expected number of control messages to send, the amount of resources to reserve for the control blocks, etc. All or a subset of the T control blocks may be linked to ACK resources. In the design shown in FIG. 2A, the first L control blocks 1 through L are linked to ACK resources 1 through L, respectively, and the

remaining $T - L$ control blocks are not linked to ACK resources, where in general $L \leq T$. For a control message sent on control block $\ell$, where $\ell \in \{1, ..., L\}$, an acknowledgement may be sent for the message on ACK resources $\ell$, which are linked to control block $\ell$. Control messages sent on the first L control blocks are acknowledgeable via their linked ACK resources. Messages sent on the remaining $T - L$ control blocks are not acknowledgeable via linked ACK resources.

**[0031]** In one design, the T available control blocks may be partitioned into common control blocks and shared/multicast control blocks. The common control blocks may be monitored by all terminals. The shared control blocks may be further divided into groups, and multiple terminals may be assigned to each group. Each terminal may be assigned a specific group of control blocks and may then monitor the shared control blocks in that group as well as the common control blocks. This design may reduce the number of control blocks that each terminal monitors while improving utilization of the available control blocks via statistical multiplexing gains. In one design, the common control blocks may be linked to ACK resources whereas the shared control blocks are not linked to ACK resources. In another design, only a subset of the common control blocks may be linked to ACK resources. These designs allow the linked ACK resources to be shared by all terminals since the common control blocks are monitored by all terminals. In general, any number of control blocks and any of the available control blocks may be linked to ACK resources. The identities of the control blocks that are linked to ACK resources may be conveyed to the terminals via broadcast information and/or by other means.

**[0032]** In general, a control block may be used to send a unicast message to a specific terminal, a multicast message to a group of terminals, or a broadcast message to all terminals. The first L control blocks may be used to send messages deemed to be important and for which acknowledgements are desired. The remaining control blocks may be used to send messages for which acknowledgements may be forego. L may be selected based on various factors such as the expected number of messages for which acknowledgements are desired, the amount of ACK resources to reserve, etc. Various types of messages such as assignment messages, access grants, and messages related to resource management and/or other functions may be sent on the control blocks.

**[0033]** Table 2 lists some assignment messages that may be sent on the control blocks and provides a short description for each assignment message. In general, an assignment message may be for (i) assignment of forward link resources and/or reverse link resources, (ii) new assignment of resources, incremental/supplemental assignment of additional resources, or decremental assignment (de-assignment) of resources previously assigned, etc. In one design, an assignment message may include a supplemental bit that may be set to '0' to indicate that the message is for a new assignment or to '1' to indicate that the message is for an incremental or decremental assignment. A terminal can determine that an assignment message is for an incremental assignment if the resources assigned by the message are more than the resources currently assigned to the terminal. The terminal can determine that the assignment message is for a decremental assignment if the resources assigned by the message are less than the currently assigned resources.

Table 2

| Message Type | Description |
|---|---|
| Access Grant | Sent in response to an access sequence from a terminal and carry a MACID for the terminal. |
| Forward link assignment | Inform a terminal of modifications of forward link resources, e.g., for assignment of base nodes, subzones, packet format, precoding scheme, rank, etc. |
| Reverse link assignment | Inform a terminal of modifications of reverse link resources, e.g., for assignment of hop ports, packet format, etc. |

**[0034]** **FIG. 2B** shows a design of sending acknowledgements for assignment messages using ACK resources linked to the assigned resources. In this design, an assignment message for a terminal may be sent on a control block. The assignment message may convey forward link resources assigned to the terminal. The assigned forward link resources may be linked to ACK resources. The terminal may receive the assignment message, determine the assigned forward link resources, and send an acknowledgement for the assignment message on the ACK resources linked to the assigned forward link resources. The design shown in FIG. 2B may be used for any type of assignment message, e.g., for all or a subset of the assignment messages shown in Table 2.

**[0035]** **FIG. 2C** shows a design of sending acknowledgements for assignment messages using dedicated ACK resources. In this design, an assignment message for a terminal may be sent on a control block. The assignment message may convey forward link resources assigned to the terminal. The terminal may receive the assignment message, determine the assigned forward link resources, and send an acknowledgement for the assignment message on ACK resources previously assigned to the terminal. For example, the terminal may be assigned certain ACK resources for acknowledging traffic data sent on the forward link and may use the assigned ACK resources to send the acknowledgement for the assignment message. The design shown in FIG. 2C may be used for any type of assignment message, e.g., for all or a subset of the assignment messages shown in Table 2.

**[0036]** FIGS. 2A through 2C show three designs of sending acknowledgements for assignment messages. It may be desirable to acknowledge assignment messages in order to increase assignment reliability, improve scheduling, reduce lost or not decoded packets, and/or obtain other benefits. Furthermore, by acknowledging assignment messages, the number of assignments to send may be reduced, and the resources and/or power budget available for other transmissions on the forward link may be increased.

**[0037]** The designs in FIGS. 2A through 2C may allow for efficient allocation and use of ACK resources for acknowledging assignment messages sent by base stations. The ACK resources may be linked to the control blocks used to send assignment messages (e.g., as shown in FIG. 2A) or linked to the assigned forward link resources (e.g., as shown in FIG. 2B). The ACK resources may also be dedicated ACK resources for a terminal (e.g., as shown in FIG. 2C).

**[0038]** A terminal may use its dedicated ACK resources to send acknowledgements for forward link data (or data ACKs), acknowledgements for assignment messages (or assignment ACKs), and/or acknowledgements for other messages or transmissions sent to the terminal. The use of dedicated ACK resources for data ACKs and/or assignment ACKs may be controlled by various factors such as the amount of dedicated ACK resources for the terminal, the type of assignment message received, whether data is received on the forward link data, etc. For example, if both forward link data and an assignment message are received, then acknowledgement may be sent only for the

forward link data, or only for the assignment message, or both the forward link data and the assignment message.

**[0039]** The system may utilize orthogonal frequency division multiplexing (OFDM), single-carrier frequency division multiplexing (SC-FDM), and/or some other multiplexing scheme for each of the forward and reverse links. OFDM and SC-FDM partition the overall system bandwidth into multiple (K) orthogonal subcarriers, which are also referred to as tones, bins, etc. Each subcarrier may be modulated with data. In general, modulation symbols are sent in the frequency domain with OFDM and in the time domain with SC-FDM.

**[0040]** In one design, the time frequency resources on each link may be partitioned into tiles. Each tile may be a time frequency block of a predetermined dimension. On the forward link, certain tiles may be used for control blocks, and control messages may be processed and sent on these tiles. On the reverse link, ACK resources may occupy all or a portion of certain tiles, and acknowledgements may be sent on the ACK portion of these tiles.

**[0041]** Control messages (e.g., assignment messages) may be sent in various manners. In one design, control messages may be processed as individual packets. A control message may be appended with a cyclic redundancy check (CRC), encoded, interleaved, repeated as necessary, and mapped to modulation symbols. The modulation symbols may be mapped to a control block, which may then be mapped to one or more tiles. The processing for control messages is described in detail in the aforementioned 3GPP2 C.S0084 documents. The control messages may also be processed and sent in other manners.

**[0042]** Acknowledgements for control messages (e.g., assignment messages) may also be sent in various manners. For the designs shown in FIGS. 2A and 2B, the linked ACK resources may correspond to time frequency resources or symbols that are not used for acknowledging traffic data by the terminals. The linked ACK resources may be dynamically allocated and conveyed, e.g., by broadcast messages sent on the forward link, by system parameters, by signaling exchanged during call setup, etc. For the design shown in FIG. 2C, the dedicated ACK resources may be assigned to a terminal or may be associated with forward link resources assigned to the terminal.

**[0043]** In one design, the R-ACKCH includes all ACK resources available on the reverse link. Some of the available ACK resources may be used as linked ACK resources for the L control blocks, and the remaining ACK resources may be assigned to terminals.

**[0044]** **FIG. 3** shows a design of ACK resources. In one design, a tile may cover 16 subcarriers in 8 symbol periods and may include 128 transmission units. A transmission unit may be one subcarrier in one symbol period and may be used to send one symbol, which may be a real or complex value. Pilot symbols may be sent on some of the transmission units in the tile, and other symbols may be sent on the remaining transmission units in the tile. As used herein, a data symbol is a symbol for traffic data, a signaling symbol is a symbol for signaling or control information, a pilot symbol is a symbol for pilot, and pilot is data that is known *a priori* by both the base station and the terminals.

**[0045]** The ACK resources for the R-ACKCH may be taken from specific tiles on the reverse link. In general, all or a portion of a tile may be used for ACK resources. In the design shown in FIG. 3, a half-tile may be used for ACK resources and may be partitioned into four subtiles. A half-tile may also be referred to as an ACK segment, and a subtile may also be referred to as an ACK cluster. The half-tile used for ACK resources may occupy the lower half of a tile and may cover 8 subcarriers in 8 symbol periods. Each subtile may cover 8 subcarriers in 2 consecutive symbol periods and may include 16 transmission units. The ACK resources may also be defined in other manners.

**[0046]** **FIG. 4** shows a design of the R-ACKCH. The timeline for the reverse link may be partitioned into frames, and each frame may span a predetermined time duration, e.g., 8 symbol periods. The available subcarriers may be arranged into S non-overlapping sets. S tiles may be defined in each frame with the S subcarrier sets. The R-ACKCH may be mapped to one or more ACK tiles in each ACK frame. An ACK tile is a tile to which the R-ACKCH is mapped, and an ACK frame is a frame in which the R-ACKCH is sent. The R-ACKCH may puncture a portion of each ACK tile.

**[0047]** The number of ACK tiles and the number of ACK frames for the R-ACKCH may be dependent on various factors such as the system bandwidth, the number of data channels, the amount of forward link data to acknowledge, the expected number of

control messages to be acknowledged, etc. In one design, the number of ACK tiles is dependent on the system bandwidth. For example, each ACK frame may include four ACK tiles for a system bandwidth of 5 MHz or lower, eight ACK tiles for a system bandwidth of 10 MHz, 16 ACK tiles for a system bandwidth of 20 MHz, etc. Fewer or more ACK tiles may also be used for the R-ACKCH in each ACK frame.

**[0048]** In one design, multiple (Q) ACK indices are defined for the R-ACKCH. Each ACK index may be associated with certain ACK resources that may be used to send acknowledgement. Forward link resources assigned to the terminals may be associated with ACK indices, as described below. Acknowledgeable control blocks may also be associated with ACK indices. In general, the forward link resources assigned to the terminals and the acknowledgeable control blocks may be mapped to ACK resources based on any known mapping.

**[0049]** The ACK resources for the R-ACKCH may occupy certain tiles on the reverse link, and these ACK tiles may be determined based on a predetermined mapping. In general, the ACK tiles may vary across time in a pseudo-random manner or a deterministic manner. The R-ACKCH may be mapped to different subcarrier sets to achieve frequency and interference diversity. The R-ACKCH may also be pseudo-random with respect to data channels on the reverse link and may equally puncture these data channels. This may be achieved by hopping the R-ACKCH, hopping the data channels, or hopping both the R-ACKCH and the data channels. A frequency hopping pattern may indicate specific tile(s) to use for the R-ACKCH in each ACK frame. The frequency hopping pattern may be sent to the terminals or may be known *a priori* by the terminals. In any case, the terminals have knowledge of the reverse link resources used for the R-ACKCH.

**[0050]** Multiple terminals may send acknowledgements using code division multiplexing (CDM), time division multiplexing (TDM), frequency division multiplexing (FDM), some other multiplexing scheme, or a combination thereof. Multiple terminals may send their acknowledgements in the same subtile using any multiplexing scheme.

**[0051]** In one design, acknowledgements are sent using CDM. In this design, acknowledgements from different terminals may be spread with different spreading codes, and the spread acknowledgements from these terminals may be orthogonal to one

another in the code domain. The spreading codes may be Walsh codes, orthogonal codes formed with columns of a Fourier matrix, etc. A 1-bit acknowledgement from a terminal may be spread with an N-chip spreading code by replicating the acknowledgement bit N times and multiplying the N replicated bits with the N chips of the spreading code to obtain N spread chips for the acknowledgement. In one design, a 1-bit acknowledgement may be spread with a 16-chip spreading code to obtain 16 spread chips. The 16 spread chips may be mapped to 16 transmission units in one subtile. In another design, the 16 spread chips may be transformed with a 16-point fast Fourier transform (FFT) to obtain 16 symbols, which may then be mapped to 16 transmission units in one subtile. In any case, up to 16 different terminals may send their acknowledgements in the same subtile using different spreading codes, and up to 64 different terminals may send their acknowledgements in the four subtiles of one half-tile.

**[0052]** In one design, a subset of the available spreading codes is used for sending acknowledgements, and the remaining spreading codes are used for interference estimation. For example, eight spreading codes may be used to send acknowledgements in each subtile, and the remaining eight spreading codes may be used for interference estimation.

**[0053]** In one design, an acknowledgement may be sent on different subtiles in different tiles to achieve time and frequency diversity. For example, the acknowledgement may be sent on subtile 1 in a first tile, on subtile 2 in a second tile, on subtile 3 in a third tile, and on subtile 4 in a fourth tile. The four tiles may be in the same frame covering 8 symbol periods. Sending the acknowledgement on four different tiles occupying different sets of subcarriers may improve frequency diversity. Sending the acknowledgement on four different subtiles may improve time diversity as well as link budget for a terminal located at the edge of coverage. The terminal may have an upper limit on transmit power and may be able to transmit the acknowledgement with more energy spread over a longer period of time, which may improve reception of the acknowledgement. In general, an acknowledgement may be sent on C subtiles in C different tiles to achieve C-th order diversity, where $C \geq 1$.

**[0054]** A base station may perform the complementary despreading to recover the acknowledgements sent by the terminals. To recover an acknowledgement sent by a

terminal on C different subtiles, the base station may despread the received symbols for each of the C subtiles with the spreading code used by the terminal to obtain C despread symbols for the C subtiles. For each of the C subtiles, the base station may also despread the received symbols with each of the spreading codes not used for sending acknowledgements to obtain an interference estimate for that subtile. The base station may scale and combine the C despread symbols with the interference estimates for the C subtiles to obtain a detected acknowledgement for the terminal.

**[0055]** In the design described above, a half-tile is partitioned into four subtiles, and an acknowledgement is sent on a set of subtiles using CDM. A half-tile may also be partitioned in other manners. In another design, each subtile may cover two subcarriers and span all 8 symbol periods. In yet another design, each subtile may include different subcarriers in different symbol periods of the half-tile. In general, acknowledgements may be sent on subtiles using CDM, TDM, FDM, etc.

**[0056]** Multiple terminals may receive individual assignment messages from a base station and may send acknowledgements for these messages on ACK resources in a single half-tile. A group of terminals may also receive a group assignment message that may be applicable to all terminals in the group. These terminals may also send acknowledgements for this group assignment message on a single half-tile.

**[0057]** In one design, a channel tree may be used to assign resources to terminals. The channel tree may constrain assignments of resources to a subset of all possible permutations of the available resources. This may reduce the amount of overhead to send assignment messages.

**[0058]** **FIG. 5** shows a design of a binary channel tree 500 for a case in which 32 subcarrier sets are available for use. A set of data channels may be defined with the 32 subcarrier sets. Each data channel may be assigned a unique channel ID and may be mapped to one or more subcarrier sets in each time interval. In one design, a data channel may be defined for each node in channel tree 500. The data channels may be sequentially numbered from top to bottom and from left to right for each tier, as shown in FIG. 5. The largest data channel corresponding to the topmost node is assigned a channel ID of 0 and is mapped to all 32 subcarrier sets. The 32 data channels in the lowest tier 1 have channel IDs of 31 through 62 and are called base channels or base nodes. Each base channel is mapped to one subcarrier set.

**[0059]** The tree structure shown in FIG. 5 places certain restrictions on the use of the data channels. For each data channel that is assigned, all data channels that are subsets (or descendants) of the assigned channel and all data channels for which the assigned channel is a subset are restricted. The restricted channels are not used concurrently with the assigned channel so that no two data channels use the same subcarrier set at the same time.

**[0060]** In one design, ACK resources may be assigned for each data channel that is assigned for use and may be conveyed to the terminal. The ACK resources may include pertinent resources (e.g., spreading code and subtiles) used to send an acknowledgement in each ACK frame. In this design, acknowledgements for each data channel may be sent on the ACK resources associated with that data channel.

**[0061]** In another design, ACK resources may be associated with each base channel/ node in the channel tree. A larger data channel may use (i) the ACK resources for all base channels under the larger data channel, (ii) the ACK resources for one of the base channels, e.g., the base channel with the lowest channel ID, or (iii) the ACK resources for a subset of the base channels. For options (i) and (iii) above, an acknowledgement for the larger data channel may be sent using more ACK resources to improve reliability.

**[0062]** In yet another design, ACK resources may be assigned for each data packet to be acknowledged. If multiple data packets are sent in parallel, e.g., in a multiple-input multiple-output (MIMO) transmission, then a larger data channel with multiple base channels may be assigned for the transmission. The number of base channels may be equal to or greater than the number of data packets, and each data packet may be mapped to a different base channel. The acknowledgement for each data packet may then be sent using the ACK resources for the associated base channel.

**[0063]** In one design, an acknowledgement for an assignment message may be sent using ACK resources for a designed channel ID (e.g., the highest channel ID of an unused channel) if the acknowledgement is sent as part of a data transmission on the reverse link. For example, if the assignment message assigns channel ID 15 (which includes channel IDs 31 and 32) to a terminal, then an acknowledgement for the assignment message may be sent using the ACK resources for channel ID 32. This

design may allow the base station to determine what is being acknowledged based on the channel ID on which the acknowledgement is received.

**[0064]** In one design, an acknowledgement for an assignment message may be sent if sufficient ACK resources associated with the assigned forward link resources are available to send the acknowledgement. For example, ACK resources may be associated with each base node in the channel tree. ACK resources may not be available to acknowledge control messages if a terminal is assigned only one base node and may be available if the terminal is assigned more than one base node.

**[0065]** A terminal may receive an assignment message and one or more data packets at or near the same time. The terminal may send acknowledgement only for the data packet(s) if no ACK resources are available to acknowledge the assignment message. This may be the case, e.g., if there is no unused channel, if the number of data packets to be acknowledged is equal to the number of available ACK resources for the terminal, etc. If the data packet(s) are sent on the forward link resources assigned by the assignment message and are decoded correctly, then the terminal may send acknowledgement only for the data packet(s). A base station may infer that the assignment message is received correctly by the terminal based on the acknowledgement received for the data packet(s). The terminal may also send acknowledgement for only the data packets if the terminal is link budget limited or power limited.

**[0066]** **FIG. 6** shows a design of a process 600 for acknowledging assignment messages by a terminal. An assignment message for the terminal may be received from a base station (block 612). Whether to acknowledge the assignment message may be determined (block 614). The determination in block 614 may be based on various factors such as a control block on which the assignment message was received, the type of assignment message, whether at least one data packet is to be acknowledged, the amount of ACK resources available to the terminal for sending acknowledgements, etc. For example, acknowledgement may be sent if the assignment message is received on a control block in a group of control blocks for which acknowledgements are to be sent. As another example, acknowledgement may be sent if the assignment message is of certain types (e.g., new assignment) but not of other types (e.g., incremental or decremental). As yet another example, acknowledgement may be sent if sufficient

ACK resources are available, which may be dependent on the amount of resources assigned by the assignment message.

**[0067]** If the assignment message is to be acknowledged ('Yes' for block 614), then ACK resources to use to acknowledge the assignment message may be determined (block 616). In one design, the ACK resources are linked to the control block on which the assignment message was received, e.g., as shown in FIG. 2A. In another design, the ACK resources are linked to resources assigned by the assignment message, e.g., as shown in FIG. 2B. In yet another design, the ACK resources are assigned to the terminal, e.g., as shown in FIG. 2C. In any case, an acknowledgment for the assignment message may be sent on the ACK resources (block 618). The acknowledgement may be sent across time and/or frequency to achieve diversity.

**[0068]** **FIG. 7** shows a design of an apparatus 700 for acknowledging assignment messages. Apparatus 700 includes means for receiving an assignment message for a terminal from a base station (module 712), means for determining whether to acknowledge the assignment message (module 714), means for determining ACK resources to use to acknowledge the assignment message if the assignment message is to be acknowledged (module 716), and means for sending an acknowledgment for the assignment message on the ACK resources (module 718).

**[0069]** **FIG. 8** shows a design of a process 800 for sending assignment messages by a base station. An assignment message may be sent to a terminal (block 812). An acknowledgement for the assignment message may be received on ACK resources designated for sending the acknowledgement (block 814). The ACK resources may be linked to a control block used to send the assignment message, linked to resources assigned by the assignment message, or assigned to the terminal.

**[0070]** **FIG. 9** shows a design of an apparatus 900 for sending assignment messages. Apparatus 900 includes means for sending an assignment message to a terminal (module 912), and means for receiving an acknowledgement for the assignment message on ACK resources designated for sending the acknowledgement (module 914).

**[0071]** **FIG. 10** shows a design of a process 1000 for acknowledging control messages by a terminal. A control message may be received on a control block (block 1012). ACK resources may be determined based on the control message or the control

block (block 1014). In one design, the ACK resources may be linked to the control block. In another design, the control message may be an assignment message that assigns resources to the terminal, and the ACK resources may be linked to the assigned resources. The ACK resources may also be determined in other manners. An acknowledgement for the control message may be sent on the ACK resources (block 1016).

**[0072]** Acknowledgements may be sent based on various criteria. In one design, acknowledgements may be sent for certain control blocks, e.g., control blocks linked to ACK resources. For example, the terminal may monitor at least one first (e.g., common) control block used by a base station to send control messages to be acknowledged. The terminal may send acknowledgements for control messages received on the at least one first control block. The terminal may monitor at least one second (e.g., shared) control block used by the base station to send control messages not to be acknowledged. The terminal may send no acknowledgements for control messages received on the at least one second control block. In another design, the terminal may send acknowledgements for (i) certain type of control messages, e.g., for assignment messages but not for access grant messages, or (ii) certain types of assignment messages. The terminal may also send acknowledgements based on other criteria.

**[0073]** **FIG. 11** shows a design of an apparatus 1100 for acknowledging control messages. Apparatus 1100 includes means for receiving a control message on a control block (module 1112), means for determining ACK resources based on the control message or the control block (module 1114), and means for sending an acknowledgement for the control message on the ACK resources (module 1116).

**[0074]** **FIG. 12** shows a design of a process 1200 for sending control messages by a base station. A control message may be sent on a control block (block 1212). An acknowledgement for the control message may be received on ACK resources determined based on the control message or the control block (block 1214).

**[0075]** **FIG. 13** shows a design of an apparatus 1300 for sending control messages. Apparatus 1300 includes means for sending a control message on a control block (module 1312), and means for receiving an acknowledgement for the control message

on ACK resources determined based on the control message or the control block (module 1314).

**[0076]** The modules in FIGS. 7, 9, 11 and 13 may comprise processors, electronics devices, hardware devices, electronics components, logical circuits, memories, etc., or any combination thereof.

**[0077]** **FIG. 14** shows a block diagram of a design of a base station 110 and a terminal 120, which may be one of the base stations and one of the terminals in FIG. 1. In this design, base station 110 and terminal 120 are each equipped with a single antenna.

**[0078]** At base station 110, a transmit (TX) data and signaling processor 1410 may receive traffic data for one or more terminals, process (e.g., encode, interleave, and symbol map) the traffic data for each terminal based on one or more packet formats selected for that terminal, and provide data symbols. Processor 1410 may also process control messages (e.g., assignment messages) and provide signaling symbols. Processor 1410 may also generate pilot symbols. A modulator 1412 may perform modulation on the data symbols, signaling symbols, and pilot symbols (e.g., for OFDM, CDM, SC-FDM, etc.) and provide output chips. A transmitter (TMTR) 1414 may condition (e.g., convert to analog, filter, amplify, and upconvert) the output chips and generate a forward link signal, which may be transmitted via an antenna 1416.

**[0079]** At terminal 120, an antenna 1452 may receive the forward link signals from base station 110 and possibly other base stations and may provide a received signal to a receiver (RCVR) 1454. Receiver 1454 may condition and digitize the received signal and provide received samples. A demodulator (Demod) 1456 may perform demodulation on the received samples (e.g., for OFDM, CDM, SC-FDM, etc.) and provide received symbols. A receive (RX) data and signaling processor 1458 may process (e.g., symbol demap, deinterleave, and decode) the received symbols and provide decoded data and control messages for terminal 120.

**[0080]** A controller/processor 1470 may receive decoding results from processor 1458 and generate acknowledgements for data packets, control messages, etc. A TX data and signaling processor 1460 may process traffic data to send to base station 110 to obtain data symbols, process acknowledgements and/or other control information to obtain signaling symbols, and generate pilot symbols. A modulator 1462 may perform

modulation on the data symbols, signaling symbols, and pilot symbols and provide output chips. A transmitter 1464 may condition the output chips and generate a reverse link signal, which may be transmitted via antenna 1452.

**[0081]** At base station 110, reverse link signals from terminal 120 and other terminals may be received by antenna 1416, conditioned and digitized by a receiver 1420, demodulated by a demodulator 1422, and processed by an RX data and signaling processor 1424 to recover the traffic data, acknowledgements, and/or other control information sent by terminal 120 and other terminals. A controller/processor 1430 may receive the acknowledgements and control the data transmission on the forward link to the terminals.

**[0082]** Controllers/processors 1430 and 1470 may direct the operation at base station 110 and terminal 120, respectively. Memories 1432 and 1472 may store program codes and data for base station 110 and terminal 120, respectively.

**[0083]** The concept of channels described herein may refer to information or transmission types that may be transmitted by a terminal or a base station. It does not require or utilize fixed or predetermined sets of subcarriers, time periods, or other resources dedicated to such transmissions. Furthermore, time frequency resources are exemplary resources that may be assigned and/or used for sending data and messages/ signaling. The time frequency resources may also comprise frequency subcarriers, transmission symbols, and/or other resources in addition to time frequency resources.

**[0084]** The 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 an entity (e.g., a terminal or a base station) 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, a computer, or a combination thereof.

**[0085]** For a firmware and/or software implementation, the techniques may be implemented with code (e.g., procedures, functions, modules, instructions, etc.) that performs the functions described herein. In general, any computer/processor-readable

medium tangibly embodying firmware and/or software code may be used in implementing the techniques described herein. For example, the firmware and/or software code may be stored in a memory (e.g., memory 1432 or 1472 in FIG. 14) and executed by a processor (e.g., processor 1430 or 1470). The memory may be implemented within the processor or external to the processor. The firmware and/or software code may also be stored in a computer/processor-readable medium such as random access memory (RAM), read-only memory (ROM), non-volatile random access memory (NVRAM), programmable read-only memory (PROM), electrically erasable PROM (EEPROM), FLASH memory, floppy disk, compact disc (CD), digital versatile disc (DVD), magnetic or optical data storage device, etc. The code may be executable by one or more computers/processors and may cause the computer/processor(s) to perform certain aspects of the functionality described herein.

**[0086]** The previous description of the disclosure is provided to enable any person skilled in the art to make or use the disclosure. Various modifications to the disclosure will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other variations without departing from the spirit or scope of the disclosure. Thus, the disclosure is not intended to be limited to the examples and designs described herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

**[0087] WHAT IS CLAIMED IS:**

# CLAIMS

1. An apparatus for wireless communication, comprising:

at least one processor configured to receive an assignment message for a terminal from a base station, to determine whether to acknowledge the assignment message, and if the assignment message is to be acknowledged, to determine acknowledgement (ACK) resources to use to acknowledge the assignment message; and

a memory coupled to the at least one processor.

2. The apparatus of claim 1, wherein the at least one processor is configured to determine whether to acknowledge the assignment message based on a control block on which the assignment message was received.

3. The apparatus of claim 1, wherein the at least one processor is configured to determine whether to acknowledge the assignment message based on a type of the assignment message.

4. The apparatus of claim 1, wherein the at least one processor is configured to determine whether to acknowledge the assignment message based on whether at least one data packet is to be acknowledged and amount of ACK resources available for sending acknowledgements.

5. The apparatus of claim 1, wherein the at least one processor is configured to determine whether to acknowledge the assignment message based on amount of resources assigned by the assignment message.

6. The apparatus of claim 1, wherein the at least one processor is configured to send an acknowledgment for the assignment message on ACK resources linked to a control block on which the assignment message was received.

7. The apparatus of claim 1, wherein the at least one processor is configured to send an acknowledgment for the assignment message on ACK resources linked to resources assigned by the assignment message.

8. The apparatus of claim 1, wherein the at least one processor is configured to send an acknowledgment on ACK resources assigned to the terminal.

9. A method for wireless communication, comprising:

receiving an assignment message for a terminal from a base station;

determining whether to acknowledge the assignment message; and

determining acknowledgement (ACK) resources to use to acknowledge the assignment message if the assignment message is to be acknowledged.

10. The method of claim 9, wherein the determining whether to acknowledge the assignment message comprises determining whether to acknowledge the assignment message based on a control block on which the assignment message was received.

11. The method of claim 9, further comprising:

sending an acknowledgment for the assignment message on ACK resources linked to a control block on which the assignment message was received.

12. An apparatus for wireless communication, comprising:

means for receiving an assignment message for a terminal from a base station;

means for determining whether to acknowledge the assignment message; and

means for determining acknowledgement (ACK) resources to use to acknowledge the assignment message if the assignment message is to be acknowledged.

13. The apparatus of claim 12, wherein the means for determining whether to acknowledge the assignment message comprises means for determining whether to acknowledge the assignment message based on a control block on which the assignment message was received.

14. The apparatus of claim 12, further comprising:

means for sending an acknowledgment for the assignment message on ACK resources linked to a control block on which the assignment message was received.

15. A computer program product, comprising:

a computer-readable medium comprising:

code for causing at least one computer to receive an assignment message for a terminal from a base station;

code for causing the at least one computer to determine whether to acknowledge the assignment message; and

code for causing the at least one computer to determine acknowledgement (ACK) resources to use to acknowledge the assignment message if the assignment message is to be acknowledged.

16. An apparatus for wireless communication, comprising:

at least one processor configured to send an assignment message to a terminal, and to receive an acknowledgement for the assignment message on acknowledgement (ACK) resources designated for sending the acknowledgement; and

a memory coupled to the at least one processor.

17. The apparatus of claim 16, wherein the at least one processor is configured to send the assignment message on a control block to the terminal, and to receive the acknowledgment on ACK resources linked to the control block.

18. The apparatus of claim 16, wherein the at least one processor is configured to receive the acknowledgment on ACK resources linked to resources assigned by the assignment message.

19. The apparatus of claim 16, wherein the at least one processor is configured to receive the acknowledgment on ACK resources assigned to the terminal.

20. An apparatus for wireless communication, comprising:

at least one processor configured to receive a control message on a control block, to determine acknowledgement (ACK) resources based on the control message or the control block, and to send an acknowledgement for the control message on the ACK resources; and

a memory coupled to the at least one processor.

21. The apparatus of claim 20, wherein the at least one processor is configured to determine the ACK resources based on the control block, the ACK resources being linked to the control block.

22. The apparatus of claim 20, wherein the control message is an assignment message, and wherein the at least one processor is configured to determine resources assigned by the assignment message, and to determine the ACK resources based on the assigned resources, the ACK resources being linked to the assigned resources.

23. The apparatus of claim 20, wherein the at least one processor is configured to send the acknowledgement if the control block is one of a group of control blocks for which acknowledgements are to be sent.

24. The apparatus of claim 20, wherein the at least one processor is configured to send the acknowledgement if the control message is an assignment message.

25. The apparatus of claim 20, wherein the at least one processor is configured to send the acknowledgement if the control message is of a type for which acknowledgement is to be sent.

26. The apparatus of claim 20, wherein the at least one processor is configured to monitor at least one first control block used by a base station to send control messages to be acknowledged, and to send the acknowledgement for the control message if the control block is one of the at least one first control block.

27. The apparatus of claim 26, wherein the at least one processor is configured to monitor at least one second control block used by the base station to send control messages not to be acknowledged, and to send no acknowledgement for the control message if the control block is one of the at least one second control block.

28. A method for wireless communication, comprising:

receiving a control message on a control block,

determining acknowledgement (ACK) resources based on the control message or the control block; and

sending an acknowledgement for the control message on the ACK resources.

29. The method of claim 28, wherein the determining the ACK resources comprises determining the ACK resources based on the control block, the ACK resources being linked to the control block.

30. The method of claim 28, wherein the sending the acknowledgement comprises sending the acknowledgement if the control block is one of a group of control blocks for which acknowledgements are to be sent.

31. The method of claim 28, further comprising:

monitoring at least one first control block used by a base station to send control messages to be acknowledged; and

sending the acknowledgement for the control message if the control block is one of the at least one first control block.

32. The method of claim 31, further comprising:

monitoring at least one second control block used by the base station to send control messages not to be acknowledged, and

sending no acknowledgement for the control message if the control block is one of the at least one second control block.

33. An apparatus for wireless communication, comprising:

means for receiving a control message on a control block,

means for determining acknowledgement (ACK) resources based on the control message or the control block; and

means for sending an acknowledgement for the control message on the ACK resources.

34. The apparatus of claim 33, wherein the means for determining the ACK resources comprises means for determining the ACK resources based on the control block, the ACK resources being linked to the control block.

35. The apparatus of claim 33, wherein the means for sending the acknowledgement comprises means for sending the acknowledgement if the control block is one of a group of control blocks for which acknowledgements are to be sent.

36. The apparatus of claim 33, further comprising:

means for monitoring at least one first control block used by a base station to send control messages to be acknowledged; and

means for sending the acknowledgement for the control message if the control block is one of the at least one first control block.

37. The apparatus of claim 36, further comprising:

means for monitoring at least one second control block used by the base station to send control messages not to be acknowledged, and

means for sending no acknowledgement for the control message if the control block is one of the at least one second control block.

38. A computer program product, comprising:

a computer-readable medium comprising:

code for causing at least one computer to receive a control message on a control block;

code for causing the at least one computer to determine acknowledgement (ACK) resources based on the control message or the control block; and

code for causing the at least one computer send an acknowledgement for the control message on the ACK resources.

39. An apparatus for wireless communication, comprising:

at least one processor configured to send a control message on a control block, and to receive an acknowledgement for the control message on acknowledgement (ACK) resources determined based on the control message or the control block; and

a memory coupled to the at least one processor.

40. The apparatus of claim 39, wherein the at least one processor is configured to send control messages on at least one first control block linked to ACK resources, and to receive acknowledgements for the control messages sent on the at least one first control blocks via the linked ACK resources.

41. The apparatus of claim 40, wherein the at least one processor is configured to send control messages on at least one second control block not linked to ACK resources, and to receive no acknowledgements for the control messages sent on the at least one second control blocks.