Abstract Title: Separate ACK/NACK channel from a control channel

Uplink and downlink scheduling information transmitted on a control channel to a mobile device requires varying content depending on the current state of the device. For instance an ACK/NACK message may or may not be required, resulting in different control channel sizes. The invention relates to fixing control channel sizes by transmitting ACK/NACK messages on a separate channel that is different from the control channel. A direct mapping function is preferably used to determine the sub-carriers to be used for the ACK/NACK messages from the uplink sub-carriers. This has particular relevance to an orthogonal frequency division multiple access (OFDMA) communication system.
8 subcarriers per ACK/NACK

Figure 3

Figure 4
Figure 7
Communication System

The present invention relates to the signalling of ACK/NACK messages in a communications method and apparatus. The invention has particular, although not exclusive relevance to the signalling ACK/NACK messages in an orthogonal frequency division multiple access (OFDMA) communication system.

OFDMA and single carrier FDMA have been selected as the downlink and uplink multiple access schemes for the E-UTRA air interface currently been studied in 3GPP (which is a standard based collaboration looking at the future evolution of third generation mobile telecommunication systems). Under the E-UTRA system, a base station which communicates with a number of user devices allocates the total amount of time/frequency resource (depending on bandwidth) among as many simultaneous users as possible, in order to enable efficient and fast link adaptation and to attain maximum multi-user diversity gain. The resource allocated to each user device is based on the instantaneous channel conditions between the user device and the base station and is informed through a control channel monitored by the user device.

When data is transmitted from the user device to the base station, an acknowledgment (ACK) or a non-acknowledgment (NACK) is typically signalled back from the base station to the user device. Under the current proposals for E-UTRA, these ACK/NACK messages are to be sent in the downlink control channel for the user device. However, the inventor has realised that this leads to a problem that the size of the control channel will vary depending on the situation of the user device.

According to one aspect, the present invention provides a communication method, typically performed in a base station which communicates with a plurality of user devices using a plurality of sub-carriers, the method comprising: receiving uplink data from a user device and generating a corresponding
ACK/NACK message for the received data; forming control data defining an allocation of said sub-carriers for the user devices; transmitting said control data to the user devices; and transmitting said ACK/NACK message to the corresponding user devices; wherein said control data is transmitted over a control channel using a first subset of said sub-carriers and said ACK/NACK message is transmitted on an ACK/NACK channel that is separate from said control channel using a second different subset of said sub-carriers.

Preferably the sub-carriers are grouped into a sequence of chunks and the control data allocates one or more chunks of sub-carriers to each of the plurality of user devices. In one embodiment, an ACK/NACK message is generated for the data received on each chunk of sub-carriers.

Preferably the sub-carriers to be used to transmit an ACK/NACK message to a user device are determined in dependence upon the sub-carriers allocated to that user device for transmitting the uplink data that is being acknowledged. This avoids the need for the base station to separately signal data to each user device identifying the sub-carriers that will carry the ACK/NACK messages for that user device. The dependence between the sub-carriers used for the uplink data and the sub-carriers used for the ACK/NACK messages is preferably defined by a direct mapping function.

In one embodiment, the sub-carriers to be used to transmit each ACK/NACK message are determined using the following mapping function:

\[ \text{Position}[0] = L \cdot (i \div M) + (i \mod M) + \Delta \]

where \(0 \leq \Delta < L\)

For \(j > 0\)

\[ \text{Position}[j] = \text{Position}[j-1] + L \cdot \frac{N}{M} \]

where \(L\) is the number of sub-carriers in a chunk; \(i\) is the chunk number allocated
to the user device to which the ACK/NACK message is to be transmitted; \( M \) is the number of sub-carriers allocated per ACK/NACK channel; \( \Delta \) is the ACK/NACK sub-carrier position offset within a chunk; and \( N \) is the total number of chunks within the allocated bandwidth.

In an alternative embodiment, the sub-carriers to be used to transmit each ACK/NACK message are determined using the following mapping function:

\[
\text{Position}[0] = L \times i + \Delta
\]

where \( 0 \leq \Delta < L \)

For \( j > 0 \) and \( j < M \)

\[
\text{Position}[j] = \left( \left( \text{Position}[j-1] + L \times N / M \right) \mod L \times N \right) \text{ in symbol } j \times N_{\text{sym}} / M
\]

where \( L \) is the number of sub-carriers in a chunk; \( i \) is the chunk number allocated to the user device to which the ACK/NACK message is to be transmitted; \( M \) is the number of sub-carriers allocated per ACK/NACK channel; \( \Delta \) is the ACK/NACK sub-carrier position offset within a chunk; \( N \) is the total number of chunks within the allocated bandwidth; and \( N_{\text{sym}} \) is the number of available symbols in which the sub-carriers can be allocated.

The invention also provides a communication method (that is typically performed in a user device) which uses a plurality of sub-carriers, the method comprising: receiving control data defining an allocation of said sub-carriers; transmitting uplink data using the allocated sub-carriers; and receiving ACK/NACK messages for the transmitted uplink data; wherein said control data is received over a control channel using a first subset of said sub-carriers and said ACK/NACK messages are received on an ACK/NACK channel that is separate from said control channel using a second different subset of said sub-carriers.

In one embodiment the receiving step receives an ACK/NACK message for the uplink data transmitted on each chunk of sub-carriers.
In a preferred embodiment the sub-carriers on which an ACK/NACK message is to be received are determined in dependence upon the sub-carriers allocated to the user device for transmitting said uplink data. This removes the need for the station transmitting the ACK/NACK messages to inform the user device of the sub-carriers that it will use to carry the ACK/NACK messages for that user device. The dependence between the sub-carriers used for the uplink data and the sub-carriers used for the ACK/NACK messages is preferably defined by a direct mapping function.

In one embodiment the user device determines the sub-carriers on which each ACK/NACK message is to be received using the following mapping function:

\[ \text{Position}[0] = L \cdot (i \mod M) + \Delta \]

where \( 0 \leq \Delta < L \)

For \( j > 0 \)

\[ \text{Position}[j] = \text{Position}[j - 1] + L \cdot N / M \]

where \( L \) is the number of sub-carriers in a chunk; \( i \) is the chunk number allocated to the user device to which the ACK/NACK message is to be transmitted; \( M \) is the number of sub-carriers allocated per ACK/NACK channel; \( \Delta \) is the ACK/NACK sub-carrier position offset within a chunk; and \( N \) is the total number of chunks within the allocated bandwidth.

In another embodiment the user device determines the sub-carriers on which each ACK/NACK message is to be received using the following mapping function:

\[ \text{Position}[0] = L \cdot i + \Delta \]

where \( 0 \leq \Delta < L \)

For \( j > 0 \) and \( j < M \)

\[ \text{Position}[j] = ( ( \text{Position}[j - 1] + L \cdot N / M ) \mod L \cdot N ) \text{ in symbol } j \cdot N \text{ sym} / M \]

where \( L \) is the number of sub-carriers in a chunk; \( i \) is the chunk number allocated
to the user device to which the ACK/NACK message is to be transmitted; \( M \) is the number of sub-carriers allocated per ACK/NACK channel; \( \Delta \) is the ACK/NACK sub-carrier position offset within a chunk; \( N \) is the total number of chunks within the allocated bandwidth; and \( N_{\text{sym}} \) is the number of available symbols in which the sub-carriers can be allocated.

The present invention also provides a communication node and a user device operable to perform the methods discussed above.

According to another aspect, the invention provides a communication method which uses a plurality of sub-carriers, the method comprising: forming control data defining an allocation of said sub-carriers for each of a plurality of user devices; transmitting said control data to said user devices; receiving uplink data from a user device; generating an ACK/NACK message for the user device; determining one or more sub-carriers to be used to transmit the ACK/NACK message to the user device, in dependence upon the sub-carriers allocated to that user device; and transmitting said ACK/NACK message to user device on the determined one or more sub-carriers.

In one embodiment the determining step used a predetermined mapping between the allocated sub-carriers and the sub-carriers used for the ACK/NACK message. In one embodiment the following mapping is used:

\[
\text{Position}[0] = L^*(i \div M) + (i \mod M) + \Delta
\]

where \( 0 \leq \Delta < L \)

For \( j > 0 \)

\[
\text{Position}[j] = \text{Position}[j - 1] + L^*\frac{N}{M}
\]

where \( L \) is the number of sub-carriers in a chunk; \( i \) is the chunk number allocated to the user device to which the ACK/NACK message is to be transmitted; \( M \) is the number of sub-carriers allocated per ACK/NACK channel; \( \Delta \) is the
ACK/NACK sub-carrier position offset within a chunk; and $N$ is the total number of chunks within the allocated bandwidth.

In another embodiment the following mapping can be used:

$$\text{Position}[0] = L \times i + \Delta$$
where $0 \leq \Delta < L$

For $j > 0$ and $j < M$

$$\text{Position}[j] = ((\text{Position}[j-1] + L \times N/M) \mod L \times N) \text{ in symbol } j \times N_{sym}/M$$

where $L$ is the number of sub-carriers in a chunk; $i$ is the chunk number allocated to the user device to which the ACK/NACK message is to be transmitted; $M$ is the number of sub-carriers allocated per ACK/NACK channel; $\Delta$ is the ACK/NACK sub-carrier position offset within a chunk; $N$ is the total number of chunks within the allocated bandwidth; and $N_{sym}$ is the number of available symbols in which the sub-carriers can be allocated.

This aspect of the invention also provides a communication method which uses a plurality of sub-carriers, the method comprising: receiving control data defining an allocation of said sub-carriers on which uplink data can be transmitted; transmitting said uplink data; determining one or more sub-carriers to be used to receive an ACK/NACK message for the transmitted uplink data, in dependence upon the sub-carriers allocated for transmitting said uplink data; and receiving an ACK/NACK message for the transmitted uplink data on the determined sub-carriers. Typically the sub-carriers on which the ACK/NACK message is to be received will be different from the sub-carriers used to transmit the uplink data and are related to them through a mapping function, such as the ones discussed above.

These and various other aspects of the invention will become apparent, from the following detailed description of embodiments which are given by way of example only and which are described with reference to the accompanying
Figures in which:

Figure 1 schematically illustrates a communication system comprising a number of user mobile (cellular) telephones which communicate with a base station connected to the telephone network;

Figure 2 illustrates the way in which a communication bandwidth of the base station shown in Figure 1 can be allocated to a number of different mobile telephones having different supported bandwidths;

Figure 3 illustrates the way in which sub-carriers in the downlink can be reserved for carrying the ACK/NACK information;

Figure 4 illustrates an alternative way in which sub-carriers in the downlink can be reserved for carrying the ACK/NACK information;

Figure 5 illustrates a proposed control channel mapping that uses two types of downlink control channels of the same size;

Figure 6 is a block diagram illustrating the main components of the base station shown in Figure 1; and

Figure 7 is a block diagram illustrating the main components of one of the mobile telephones shown in Figure 1.

Overview

Figure 1 schematically illustrates a mobile (cellular) telecommunication system in which users of mobile telephones (MT) 3-0, 3-1, and 3-2 can communicate with other users (not shown) via a base station 5 and a telephone network 7. In this embodiment, the base station 5 uses an orthogonal frequency division multiple access (OFDMA) technique in which the data to be transmitted to the
mobile telephones 3 is modulated onto a plurality of sub-carriers. Different sub-
carriers are allocated to each mobile telephone 3 depending on the supported
bandwidth of the mobile telephone 3 and the amount of data to be sent to the
mobile telephone 3. In this embodiment the base station 5 also allocates the sub-
carriers used to carry the data to the respective mobile telephones 3 in order to try
to maintain a uniform distribution of the mobile telephones 3 operating across the
base station's bandwidth. To achieve these goals, the base station 5 dynamically
allocates sub-carriers for each mobile telephone 3 and signals the allocations for
each sub-frame to each of the scheduled mobile telephones 3. In the proposed E-
UTRA air interface, each downlink sub-frame comprises a sequence of seven
OFDM symbols. The first two symbols typically carry the scheduling and
resource allocation control data as well as other general control data whilst the
remaining five symbols contain the user data for the downlink.

Figure 2 illustrates an example of the way in which the base station 5 can allocate
sub-carriers within its supported bandwidth to different mobile telephones 3
having different supported bandwidths. In this embodiment, the base station 5
has a supported bandwidth of 20MHz of which 18MHz is used for data
transmission. Typically each mobile telephone 3 is allocated one or more chunks
of sub-carriers on which to transmit their uplink data.

In order that each of the mobile telephones 3 can be informed about the
scheduling decision within each sub-band, each mobile telephone 3 requires a
shared control channel within its camped frequency band. The current proposal
for the E-UTRA air interface specifies that this control channel will include:

i)  resource block allocation information (for both downlink (DL)
    communications and uplink (UL) communications);

ii) resource block demodulation information for the downlink;

iii) resource block demodulation information for the uplink;

iv) ACK/NACK for uplink transmissions; and

v) timing control bits.
Therefore, given the different types of information that the control channel must carry, the size of the control channel will depend on the individual mobile telephone’s situation. Examples of situations that lead to different control channel sizes are given in the following table:

<table>
<thead>
<tr>
<th>Case</th>
<th>DL Scheduling Information</th>
<th>UL Scheduling Information</th>
<th>ACK/NACK</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>MT scheduled on UL and DL, and awaiting ACK/NACK</td>
<td>Required</td>
<td>Required</td>
</tr>
<tr>
<td>2</td>
<td>MT scheduled on DL only, and awaiting ACK/NACK</td>
<td>Required</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>MT scheduled on UL only, and awaiting ACK/NACK</td>
<td></td>
<td>Required</td>
</tr>
<tr>
<td>4</td>
<td>MT not scheduled on UL or DL, and awaiting ACK/NACK</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>MT scheduled on UL and DL, not awaiting ACK/NACK</td>
<td>Required</td>
<td>Required</td>
</tr>
<tr>
<td>6</td>
<td>MT scheduled on DL only, not awaiting ACK/NACK</td>
<td>Required</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>MT scheduled on UL only, not awaiting ACK/NACK</td>
<td></td>
<td>Required</td>
</tr>
</tbody>
</table>

The inventor has realised that having control channels of different sizes will create
problems, as either the sizes of the control channels will have to be signalled to the mobile telephones 3 or the receiving mobile telephones 3 will have to consider all possible sizes to try to recover the control channel data.

The inventor has realised that this problem can be avoided or at least mitigated by removing the ACK/NACK field from the control channel itself into a dedicated (semi-static) time/frequency resource. In addition, if a mobile telephone 3 is scheduled on both UL and DL then the UL scheduling information can be contained within the allocated DL resource block. This leaves two cases for the DL control channel size:

Type 1: DL Scheduling Information (used in cases 1, 2, 5 and 6 above)
Type 2: UL Scheduling Information (used in cases 3 and 7 above)

Proposed ACK/NACK Channel Mapping in Downlink

The inventor proposes that one or more sub-carriers in the downlink be reserved for carrying ACK/NACK information for mobile telephones 3 expecting such information in the downlink. The number of resources reserved for such usage and their locations in the time/frequency plane can be intimated to the mobile telephones through common signalling. In this embodiment, to reduce the signalling required to inform the mobile telephones of which sub-carriers carry their ACK/NACK information, the mobile telephones are programmed to work out on which sub-carriers their ACK/NACK information will be transmitted using the UL chunk allocation for the data being acknowledged and information obtained from the common signalling channel. There are various techniques that can be used to perform the actual mapping between the allocated chunks for uplink transmissions and the sub-carriers allocated for the corresponding ACK/NACK messages.

First example mapping

In this example, the mobile telephones 3 are informed by the base station 5 over the common signalling channel the number (M) of sub-carriers allocated by the base station 5 to each ACK/NACK channel, with one ACK/NACK channel being used to acknowledge the data transmitted on one chunk of sub-carriers by a mobile
telephone 3. Therefore, if a mobile telephone 3 is allocated two chunks for uplink transmissions, then two ACK/NACK channels will be used to transmit the ACK/NACK commands (messages) for that mobile telephone 3. In this example, the base station 5 also informs the mobile telephones 3 what the ACK/NACK sub-carrier position offset ($\Delta$) is within a chunk. Each mobile telephone 3 then determines the mapping between each uplink transmitted chunk number ($i$) on which it transmits data and the sub-carriers of the corresponding ACK/NACK channel as below –

$$\text{Position}[0] = L^*(i \text{ div } M) + (i \text{ mod } M) + \Delta$$

where $0 \leq \Delta < L$

For $j > 0$

$$\text{Position}[j] = \text{Position}[j - 1] + L^*N/M$$

where $L$ is the number of sub-carriers in each chunk and $N$ is the total number of chunks in the allocated bandwidth, both of which will typically (although not necessarily) be static for the system design and programmed into the mobile telephone 3 and the base station 5.

Figure 3 demonstrates the case for $N = 12$, $L = 25$, $M = 6$ and $\Delta = 0$, where all the ACK/NACK's are multiplexed within the second OFDM symbol of a downlink sub-frame. As shown, the multiplexing illustrated in Figure 3 is designed to support a maximum of 12 simultaneous users within the 5 MHz band (in which each user is allocated one chunk) with each chunk being acknowledged by a six sub-carrier ACK/NACK channel. The use of these sub-carriers will obviously reduce the number of sub-carriers available in the second OFDM symbol for the downlink control channel. However, this structure also allows support of a micro-sleep mode at the mobile telephones 3, since a mobile telephone 3 expecting an ACK/NACK (and not scheduled to receive other downlink data) need monitor only the first two OFDM symbols and then enter the micro-sleep mode.

Preferably the transmitted power of each ACK/NACK command is inversely
proportional to the number of chunks allocated the mobile telephone 3 in the uplink, so that the total energy per ACK/NACK command is independent of the number of chunks being acknowledged.

As those skilled in the art will appreciate, $M$ needs to be a factor of $N$ in order to exploit the full frequency diversity with an equally spaced ACK/NACK sub-carrier distribution.

Another mechanism of the TDM mapping scheme illustrated in Figure 3 is to spread the $N*M$ ACK/NACK sub-carriers uniformly over the entire band within the second OFDM symbol. However, if $M$ is not a factor of $L$, the ACK/NACK spacing will be non-uniform in this case.

**Second example mapping**

Instead of allocating the sub-carriers for the ACK/NACK channels in one OFDM symbol, in an alternative allocation, they are allocated across multiple symbols. For example, the ACK/NACK resources can be scattered over the remaining (all but the first OFDM symbol which contains the pilot and control channels only) OFDM symbols.

In this example, the base station 5 will inform the mobile telephones 3 of the number ($M$) of sub-carriers per ACK/NACK channel, an ACK/NACK sub-carrier position offset ($\Delta$) within a chunk and the number ($N_{sym}$) of available OFDM symbols, and the mobile telephones 3 will determine the mapping between the uplink transmitted chunk number $i$ and the corresponding downlink ACK/NACK sub-carriers as below:

\[
\text{Position}[0] = L*i + \Delta \\
\text{where } 0 \leq \Delta < L \\
\text{For } j > 0 \text{ and } j < M \\
\text{Position}[j] = (\text{Position}[j - 1] + L*N/M) \mod L*N) \text{ in symbol } j*N_{sym}/M
\]
Figure 4 illustrates the case for \( N = 12, \ L = 25, \ M = 6, \ \Delta = 0 \) and \( N_{sym} = 6 \). As those skilled in the art will appreciate, with this type of mapping, the chunk bandwidth for user data is only reduced by a single sub-carrier within each symbol, however, the micro-sleep mode possibility is reduced. Further, in order to enable a uniform spacing of the ACK/NACK commands in the time domain, \( M \) needs to be a factor of \( N_{sym} \).

**Downlink Control Channel Size**

Assuming one of the above structures for the ACK/NACK channels, the number of bits needed in the downlink control channel for a 5 MHz bandwidth mobile telephone 3 can be derived as follows –

<table>
<thead>
<tr>
<th>Information bits</th>
<th>Type 1</th>
<th>Type 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Type Indicator</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>- DL Resource Allocation (bit mask)</td>
<td>12</td>
<td>(bit mask)</td>
</tr>
<tr>
<td>- DL Resource Duration</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>- DL TFCI</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>- UL Scheduling Info is present in DL resource block</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>- UL Resource Allocation</td>
<td></td>
<td>7 (tree method)</td>
</tr>
<tr>
<td>- UL Resource Duration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- UL Category 2 Information</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Padding bits</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>CRC (Masked with UE ID)</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Total information + CRC bits</td>
<td>33</td>
<td>33</td>
</tr>
<tr>
<td>Encoded bits (1/3 tail biting)</td>
<td>99</td>
<td>99</td>
</tr>
<tr>
<td>After rate matching</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Number of sub-carriers (QPSK)</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Number of chunks</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

Padding bits are used in this embodiment to make the number of encoded bits the
same for Type 1 and Type 2 so that the mobile telephones 3 only need to perform one decoding attempt. Slightly modified structures without any padding bits can also be envisaged if required by the design.

An example of the proposed control channel mapping is shown in Figure 5. In this figure we assume that control channels are individually coded in order to allow efficient power control and possible beam-forming techniques. Control channel positions are shown in the first OFDM symbol only while the second symbol is assumed to carry pilot and additional control information. Each scheduled mobile telephone 3 is assumed to have been allocated one control channel within 5 MHz with higher bandwidth capable mobile telephones 3 decoding multiple such channels. When possible, the frequency position of the control channel should be chosen to span the resources (sub-carriers) on which the user data is scheduled in order to exploit the superior channel characteristics at these frequency positions. Figure 5 shows a case when a maximum of twelve possible users are scheduled within 10 MHz. In case the number of users is less, some of the control channel resources can be freed and occupied by user data. The absence of a control channel in a specific position can be indicated using a single bit field in the preceding control channel.

As shown in Figure 5, Type 1 and Type 2 control channels are each assumed to span 2 chunks. The total number of control channels possible depends on the mapping adopted for the ACK/NACK channels which has not been shown in the figure.

The structure of the ACK/NACK resource allocation can be further simplified by allocating only mobile telephones 3 without a downlink resource allocation within the same sub-frame. A mobile telephone 3 with a downlink scheduling message in the same sub-frame can be intimated about ACK/NACK's within the downlink resource block (user data). In such a case, a single bit ACK/NACK will suffice since the control information within the downlink resource block will have its own error coding protection. However, an error in the control channel detection in this case will also lead to the inability of the mobile telephone 3 from being able to retrieve
ACK/NACK information which may, in turn, put tighter performance requirements on the downlink control channel.

**Base Station**

Figure 6 is a block diagram illustrating the main components of the base station 5 used in this embodiment. As shown, the base station 5 includes a transceiver circuit 21 which is operable to transmit signals to and to receive signals from the mobile telephones 3 via one or more antennae 23 (using the above described sub-carriers) and which is operable to transmit signals to and to receive signals from the telephone network 7 via a network interface 25. The operation of the transceiver circuit 21 is controlled by a controller 27 in accordance with software stored in memory 29. The software includes, among other things, an operating system 31 and a resource allocation module 33. The resource allocation module 33 is operable for allocating the sub-carriers used by the transceiver circuit 21 in its communications with the mobile telephones 3. The software also includes an ACK/NACK module 35, which is operable for informing the mobile telephones 3 of the information needed to map between the allocated chunk numbers for their uplink transmission to the ACK/NACK channels used for the acknowledgments of that data. The ACK/NACK module 35 is also operable to transmit the ACK/NACK commands for the received data on the corresponding ACK/NACK channels for reception by the mobile telephones 3.

**Mobile Telephone**

Figure 7 schematically illustrates the main components of each of the mobile telephones 3 shown in Figure 1. As shown, the mobile telephones 3 include a transceiver circuit 71 that is operable to transmit signals to and to receive signals from the base station 5 via one or more antennae 73. As shown, the mobile telephone 3 also includes a controller 75 which controls the operation of the mobile telephone 3 and which is connected to the transceiver circuit 71 and to a loudspeaker 77, a microphone 79, a display 81, and a keypad 83. The controller 75 operates in accordance with software instructions stored within memory 85.
As shown, these software instructions include, among other things, an operating system 87 and a communications module 89. In this embodiment, the communications module 89 includes an ACK/NACK module 91 that is operable to perform the appropriate mapping to identify the sub-carriers that carry the ACK/NACK commands for the data that the mobile telephone 3 has transmitted. The mobile telephones 3 may be programmed to be able to perform only one of the mappings discussed above (with reference to figures 3 and 4) or if the base station 5 varies the mapping that it uses, then the mobile telephones 3 will have to be informed of the mapping to be used for a given sub-frame.

**Modifications and Alternatives**

A number of detailed embodiments have been described above. As those skilled in the art will appreciate, a number of modifications and alternatives can be made to the above embodiments whilst still benefiting from the inventions embodied therein. By way of illustration only a number of these alternatives and modifications will now be described.

In the above embodiments, a mobile telephone based telecommunication system was described in which the above described ACK/NACK resource signalling techniques were employed. As those skilled in the art will appreciate, the signalling of such ACK/NACK resources can be employed in any communication system that uses a plurality of sub-carriers. In particular, the signalling techniques described above can be used in wire or wireless based communications either using electromagnetic signals or acoustic signals to carry the data. In the general case, the base station would be replaced by a communication node which communicates with a number of different user devices. User devices may include, for example, personal digital assistants, laptop computers, web browsers, etc.

In the above embodiments, the base station was assumed to have an operating bandwidth of 20MHz (which was divided into a number of sub-bands) and the
chunks of carrier frequencies were defined to comprise 25 sub-carriers each. As those skilled in the art will appreciate, the invention is not limited to this particular size of bandwidth or chunk size or to the size of the sub-bands described.

In the above embodiments, a number of software modules were described. As those skilled will appreciate, the software modules may be provided in compiled or un-compiled form and may be supplied to the base station or to the mobile telephone as a signal over a computer network, or on a recording medium. Further, the functionality performed by part or all of this software may be performed using one or more dedicated hardware circuits. However, the use of software modules is preferred as it facilitates the updating of the base station 5 and the mobile telephones 3 in order to update their functionalities.
Claims

1. A communication method which uses a plurality of sub-carriers, the method comprising:
   receiving uplink data from one or more user devices and generating corresponding ACK/NACK messages for the received data;
   forming control data defining an allocation of said sub-carriers for each of a plurality of user devices;
   transmitting said control data to said user devices; and
   transmitting said ACK/NACK messages to the corresponding user devices;
   wherein said control data is transmitted over a control channel using a first subset of said sub-carriers and said ACK/NACK messages are transmitted on an ACK/NACK channel that is separate from said control channel using a second different subset of said sub-carriers.

2. A method according to claim 1, comprising grouping the sub-carriers into a sequence of chunks and wherein said control data is operable to allocate one or more chunks of sub-carriers to each of said plurality of user devices.

3. A method according to claim 2, wherein said forming step forms control data that allocates said one or more chunks of sub-carriers to each of said user devices for use in transmitting uplink data.

4. A method according to claim 3, wherein said generating step generates an ACK/NACK message for the data received on each chunk of sub-carriers.

5. A method according to claim 4, wherein said transmitting step transmits each ACK/NACK message in a respective ACK/NACK channel, each formed using a respective one or more sub-carriers from said second subset.
6. A method according to any preceding claim, comprising determining the sub-carriers to be used to transmit an ACK/NACK message to a user device in dependence upon the sub-carriers allocated to the user device for transmitting uplink data.

7. A method according to claim 6, comprising determining the sub-carriers to be used to transmit each ACK/NACK message using the following expression:

\[ \text{Position}[0] = L \times (i \text{ div } M) + (i \text{ mod } M) + \Delta \]

where \( 0 \leq \Delta < L \)

For \( j > 0 \)

\[ \text{Position}[j] = \text{Position}[j - 1] + L \times N / M \]

where \( L \) is the number of sub-carriers in a chunk; \( i \) is the chunk number allocated to the user device to which the ACK/NACK message is to be transmitted; \( M \) is the number of sub-carriers allocated per ACK/NACK channel; \( \Delta \) is the ACK/NACK sub-carrier position offset within a chunk; and \( N \) is the total number of chunks within the allocated bandwidth.

8. A method according to claim 6, comprising determining the sub-carriers to be used to transmit each ACK/NACK message using the following expression:

\[ \text{Position}[0] = L \times i + \Delta \]

where \( 0 \leq \Delta < L \)

For \( j > 0 \) and \( j < M \)

\[ \text{Position}[j] = \left( (\text{Position}[j - 1] + L \times N / M ) \mod L \times N \right) \text{ in symbol } j \times N_{sym} / M \]

where \( L \) is the number of sub-carriers in a chunk; \( i \) is the chunk number allocated to the user device to which the ACK/NACK message is to be transmitted; \( M \) is the number of sub-carriers allocated per ACK/NACK channel; \( \Delta \) is the ACK/NACK sub-carrier position offset within a chunk; \( N \) is the total number of
chunks within the allocated bandwidth; and \( N_{\text{sym}} \) is the number of available symbols in which the sub-carriers can be allocated.

9. A method according to any preceding claim, wherein said forming step forms two types of control data, one for user devices that are scheduled to receive downlink data and one for user devices that are scheduled to transmit uplink data.

10. A method according to claim 9, wherein at least one of said first and second types of control data includes padding data so that each type of control channel is of the same size.

11. A method according to claim 10, wherein each type of control data corresponds in size to two chunks of sub-carriers.

12. A method according to any preceding claim, comprising forming respective control data for each user device scheduled to transmit and/or receive data in a current sub-frame and transmitting the respective control data to the corresponding user device over a channel that is dedicated to the user device.

13. A method according to any preceding claim, wherein said communication system uses a plurality of sub-bands, each of which comprises sub-carriers arranged in a sequence of chunks, and wherein the method generates respective control data for sub-carrier allocation in each sub-band.

14. A method according to claim 13, wherein the control data for a sub-band is signalled within that sub-band.

15. A method according to any preceding claim, wherein a separate control channel is provided for each user device scheduled in a current sub-frame and wherein a maximum number of user devices can be scheduled within the current sub-frame.
16. A method according to claim 15, wherein when the number of user devices to be scheduled in a current sub-frame is less than said maximum, some of the control channel resources are freed and occupied by user data.

17. A method according to claim 16, wherein the absence of a control channel is indicated using a single bit field in a preceding control channel.

18. A communication method which uses a plurality of sub-carriers, the method comprising:

- receiving control data defining an allocation of said sub-carriers;
- transmitting uplink data using the allocated sub-carriers; and
- receiving ACK/NACK messages for the transmitted uplink data;

wherein said control data is received over a control channel using a first subset of said sub-carriers and said ACK/NACK messages are received on an ACK/NACK channel that is separate from said control channel using a second different subset of said sub-carriers.

19. A method according to claim 18, wherein said received control data identifies one or more chunks of sub-carriers to be used for transmitting said uplink data.

20. A method according to claim 19, wherein said receiving step receives an ACK/NACK message for the uplink data transmitted on each chunk of sub-carriers.

21. A method according to claim 20, wherein said receiving step receives each ACK/NACK message in a respective ACK/NACK channel, each formed using a respective one or more sub-carriers from said second subset.

22. A method according to any of claims 18 to 21, comprising determining the sub-carriers on which an ACK/NACK message is to be received in
dependence upon the sub-carriers allocated to the user device for transmitting said uplink data.

23. A method according to claim 22, comprising determining the sub-carriers on which each ACK/NACK message is to be received using the following expression:

\[ \text{Position}[0] = L \cdot (i \text{ div } M) + (i \text{ mod } M) + \Delta \]

where \( 0 \leq \Delta < L \)

For \( j > 0 \)

\[ \text{Position}[j] = \text{Position}[j - 1] + L \cdot N/M \]

where \( L \) is the number of sub-carriers in a chunk; \( i \) is the chunk number allocated to the user device to which the ACK/NACK message is to be transmitted; \( M \) is the number of sub-carriers allocated per ACK/NACK channel; \( \Delta \) is the ACK/NACK sub-carrier position offset within a chunk; and \( N \) is the total number of chunks within the allocated bandwidth.

24. A method according to claim 22, comprising determining the sub-carriers on which each ACK/NACK message is to be received using the following expression:

\[ \text{Position}[0] = L \cdot i + \Delta \]

where \( 0 \leq \Delta < L \)

For \( j > 0 \) and \( j < M \)

\[ \text{Position}[j] = ((\text{Position}[j - 1] + L \cdot N/M) \text{ mod } L \cdot N) \text{ in symbol } j \cdot N_{sym}/M \]

where \( L \) is the number of sub-carriers in a chunk; \( i \) is the chunk number allocated to the user device to which the ACK/NACK message is to be transmitted; \( M \) is the number of sub-carriers allocated per ACK/NACK channel; \( \Delta \) is the ACK/NACK sub-carrier position offset within a chunk; \( N \) is the total number of chunks within the allocated bandwidth; and \( N_{sym} \) is the number of available symbols.
in which the sub-carriers can be allocated.

25. A method according to any of claims 18 to 24, wherein said receiving step receives said control data over a channel that is dedicated to the user device.

26. A method according to any of claims 18 to 25, wherein said communication system uses a plurality of sub-bands, each of which comprises sub-carriers arranged in a sequence of chunks, and wherein the method receives respective control data for sub-carrier allocation in each sub-band.

27. A method according to claim 26, wherein the control data for a sub-band is signalled within that sub-band.

28. A communication method which uses a plurality of sub-carriers, the method comprising:
   forming control data defining an allocation of said sub-carriers for each of a plurality of user devices;
   transmitting said control data to said user devices;
   receiving uplink data from a user device;
   generating an ACK/NACK message for the user device;
   determining one or more sub-carriers to be used to transmit the ACK/NACK message to the user device, in dependence upon the sub-carriers allocated to that user device; and
   transmitting said ACK/NACK message to the user device on the determined one or more sub-carriers.

29. A method according to claim 28, wherein said determining step uses a predetermined mapping between the allocated sub-carriers and the sub-carriers used for the ACK/NACK message.

30. A communication method which uses a plurality of sub-carriers, the
method comprising:

receiving control data defining an allocation of said sub-carriers on which uplink data can be transmitted;

transmitting said uplink data using the allocated sub-carriers;

determining one or more sub-carriers to be used to receive an ACK/NACK message for the transmitted uplink data, in dependence upon the sub-carriers allocated for transmitting said uplink data; and

receiving an ACK/NACK message for the transmitted uplink data on the determined sub-carriers.

A method according to claim 30, wherein said determining step uses a predetermined mapping between the allocated sub-carriers for the uplink and the sub-carriers used for the ACK/NACK message.

Computer implementable instructions for causing a programmable computer device to perform the method of any of claims 1 to 31.

The computer implementable instructions of claim 32 when recorded on a computer readable medium.

A communications node which is operable to communicate with a plurality of user devices using a plurality of sub-carriers, the communications node comprising:

a receiver operable to receive uplink data from one or more user devices and operable to generate corresponding ACK/NACK messages for the received data;

a controller operable to form control data defining an allocation of said sub-carriers for each of a plurality of user devices;

a transmitter operable to transmit said control data to said user devices and to transmit said ACK/NACK messages to the corresponding user devices;

wherein said transmitter is operable to transmit said control data over a
control channel using a first subset of said sub-carriers and to transmit said ACK/NACK messages on an ACK/NACK channel that is separate from said control channel using a second different subset of said sub-carriers.

35. A user device which is operable to communicate with a communication node which is operable to communicate with a plurality of user devices using a plurality of sub-carriers, the user device comprising:

   a receiver operable to receive control data defining an allocation of said sub-carriers; and

   a transmitter operable to transmit uplink data using the allocated sub-carriers;

   wherein said receiver is also operable to receive ACK/NACK messages for the transmitted uplink data;

   wherein said receiver is operable to receive said control data over a control channel using a first subset of said sub-carriers and to receive said ACK/NACK messages on an ACK/NACK channel that is separate from said control channel using a second different subset of said sub-carriers.

36. A communication method or apparatus substantially as described herein with reference to or as shown in the accompanying figures.
**Application No:** GB0612228.7  
**Examiner:** Steve Evans  
**Claims searched:** All  
**Date of search:** 11 October 2006

**Patents Act 1977: Search Report under Section 17**

**Documents considered to be relevant:**

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<tr>
<th>Category</th>
<th>Relevant to claims</th>
<th>Identity of document and passage or figure of particular relevance</th>
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| A        | -                 | WO 92/09148 A  
(COGNITO GROUP) - Whole document |

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Search of GB, EP, WO & US patent documents classified in the following areas of the UKC:

- **H4L**

Worldwide search of patent documents classified in the following areas of the IPC

- **H04L; H04Q**

The following online and other databases have been used in the preparation of this search report

- **Online: WPI, EPODOC**
**Patents Act 1977**
**Further Search Report under Section 17**

Documents considered to be relevant:

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<td>A</td>
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<td>US 2005/0232135 A1 (MUKAI et al) - Whole document</td>
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