

Support of UL ACK/NACK Feedback for Carrier Aggregation During  
Timing Uncertainty Component Carrier (Re-) Configura-  
tion/Activation/De-activation Period

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### Field of the Invention

The present invention relates to an apparatus, method and  
computer program product for providing support of UL ACK/NACK  
10 feedback for carrier aggregation during a timing uncertainty  
component carrier (re-) configuration/activation/de-activation  
period.

### Related background Art

15

The following meanings for the abbreviations used in this  
specification apply:

|    |       |                                                |
|----|-------|------------------------------------------------|
|    | 3GPP  | 3 <sup>rd</sup> generation partnership project |
| 20 | ACK   | Acknowledgement                                |
|    | BW    | Bandwidth                                      |
|    | CA    | Carrier Aggregation                            |
|    | CC    | Component carrier                              |
|    | DL    | Downlink                                       |
| 25 | eNB   | Enhanced Node B, name for Node B in LTE        |
|    | FB    | Feedback                                       |
|    | FDD   | Frequency Division Duplex                      |
|    | LTE   | Long term evolution                            |
|    | LTE-A | LTE-Advanced                                   |
| 30 | MAC   | Media Access Control                           |
|    | MIMO  | Multiple Input Multiple Output                 |
|    | NAK   | Negative Acknowledgement                       |
|    | PDCCH | Physical Downlink Control Channel              |
|    | PUCCH | Physical Uplink Control Channel                |
| 35 | PUSCH | Physical Uplink Shared Channel                 |
|    | RRC   | Radio Resource Control                         |

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|         |                                            |
|---------|--------------------------------------------|
| SU-MIMO | Single User Multiple Input Multiple Output |
| TDD     | Time Division Duplex                       |
| UE      | User equipment                             |
| UL      | Uplink                                     |

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Embodiments of the present invention relate to LTE-Advanced system, which will be part of 3GPP LTE Rel-10. More specifically, some embodiments are focussed on UL ACK/NAK feedback design for component carrier (CC) aggregation to deal with the issues related to timing uncertainty CC re-configuration period.

In the following, carrier aggregation (CA) in LTE-Advanced is described in some more detail. In particular, 3GPP is currently studying a new system called LTE-Advanced which fulfils the IMT-Advanced requirements set by the ITU-R. Topics include e.g. bandwidth extensions beyond 20 MHz, relays, MIMO (multiple input multiple output) enhancements such as advanced multi-user MIMO (MU-MIMO) and introduction of SU-MIMO in uplink.

The bandwidth extension beyond 20 MHz in LTE-Advanced has been decided to be done via component carrier aggregation (CA), in which several Release 8 compatible carriers are aggregated together to form a larger bandwidth.

Fig. 3 shows an example for carrier aggregation, in which five carriers (carrier 1 to carrier 5), each corresponding to a Release 8 bandwidth (BW), can be aggregated to form the maximum bandwidth for LTE-Advanced (100 MHz).

The idea is that each Rel'8 terminal can receive/transmit on one of the CCs, whereas LTE-Advanced terminals supporting CA can receive/transmit on multiple CCs at the same time, thus having support for large bandwidth. It has been agreed that up to 5 CCs could be aggregated in LTE-Advanced in both FDD and TDD systems (Rel-10). This number can be increased in coming releases.

In the case eNB wants to enable transmission/reception via multiple DL CCs for a certain UE, it needs to configure the corresponding CCs via radio resource control (RRC) signaling (→ configured but de-activated component carriers). In addition to RRC-level CC- configuration it has been agreed to support MAC-level CC activation/deactivation mechanism in LTE-Advanced. An UE needs to be prepared to receive PDCCH and PDSCH (and transmit PUSCH) via activated component carriers. For deactivated CC(s), UE is prepared to receive neither PDCCH nor PDSCH.

In the following, uplink acknowledgement/negative acknowledgement (UL ACK/NAK) feedback for carrier aggregation is described.

For carrier aggregation, it has been agreed that:

- Independent transport block is sent via each CC
- One ACK/NAK for each transport block is supported.

Based on above agreements, multiple ACK/NAKs will be sent during one UL subframe. Furthermore, in typical configuration there is asymmetry between the number of DL and UL component carrier supported by the UE. This needs to be taken into account in the ACK/NAK feedback design as well. To support UL ACK/NAK feedback for CA, the following methods are considered to be promising:

- Channel selection (e.g., as defined in TS 36.213) to support up to 4 bits on PUCCH format 1b.
- ACK/NAK multiplexing method to support more than 4 bits on PUCCH format 2/2a/2b or other new structure (e.g. multi-sequence modulation).

Channel selection is a mature method to support up to 4 bits, which is used to support the asymmetry of the UL/DL subframe configuration in Rel'8 TDD. Hence, it is natural to support channel selection in carrier aggregation case as well (limited feedback (FB), up-to four bits). For the case with more than 4 ACK/NAK bits, PUCCH format 2 or some other physical channel needs to be

considered. It is also possible to extend channel selection to support more than 4 bits.

5 In the case of CA, the number of ACK/NAK bits that need to be sent during one UL subframe depends on the number of configured DL CCs (this signaled via RRC signaling) or activated DL CCs (signaled via MAC signaling). However, it is noted that there will be a time period when the eNB cannot be sure about the existing number of DL CCs configured and/or activated by the UE. Such misalignment  
10 may happen due to UE processing delays related to RRC signaling. Another source of misalignment is potential signaling errors (PDCCH, ACK, NAK) related to activation/deactivation commands. It is noted that during such uncertainty period the existing UL ACK/NAK signaling methods will face severe problems because of  
15 the ambiguity on the ACK/NAK codebook size between eNB and UE. These problems include severe scheduler restrictions and also a very high probability for higher layer errors.

Therefore new mechanisms are needed to support reliable ACK/NAK  
20 feedback in all cases.

For related design to support UL ACK/NAK feedback for CA during uncertainty higher layer signaling period, in the following, the existing mechanism is described:

25 For channel selection on PUCCH format 1b, the channel selection table depends on the number of configured/activated DL CCs, and UE will select one PUCCH resource and QPSK point for transmission based on ACK/NAK status. However, in case the ambiguity about the  
30 number of configured/activated DL CCs exists, eNB will have no idea which channel selection table is adopted at UE side. In such case, eNB can not be sure about the ACK/NAK status based on the detected PUCCH resource and QPSK constellation point.

For ACK/NAK multiplexing on PUCCH format 2, similar ambiguity exists if the number of ACK/NAK feedback depends on the configured or activated DL CCs.

5 So, existing mechanism could not handle such an issue.

#### Summary of the Invention

10 Thus, it is an object of the present invention to overcome the above problems of the prior art.

According to several embodiments of the present invention, an apparatus and a method are provided by which a component carrier  
15 configuration, re-configuration, activation or de-activation is performed, wherein a signaling format used for acknowledgment/negative acknowledgement messages on an uplink control channel is detected, and a codebook size of the acknowledgment/negative acknowledgement messages is decided based on the  
20 detected signaling format.

#### Brief Description of the Drawings

25 These and other objects, features, details and advantages will become more fully apparent from the following detailed description of embodiments of the present invention which is to be taken in conjunction with the appended drawings, in which:

30 Fig. 1 shows a structure of an apparatus, e.g. a user equipment (UE) or an eNB according to some embodiments of the present invention;

Fig. 2 shows a process according to some embodiments of the  
35 present invention; and

Fig. 3 shows an example of carrier aggregation.

#### Detailed Description of embodiments

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In the following, description will be made to embodiments of the present invention. It is to be understood, however, that the description is given by way of example only, and that the described embodiments are by no means to be understood as limiting the present invention thereto.

10

As described in the introductory part, some embodiments aim to provide new mechanisms for supporting reliable ACK/NAK feedback in all cases.

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In particular, according to embodiments, an arrangement is described which is capable to solve timing uncertainty related to ACK/NAK signaling during the component carrier re-configuration. According to more concrete examples, the arrangement contains the following parts:

20

- UE/eNB procedure to convey multi-ACK/NAK in the UL (standard-related)
- Signalling solution to implement the proposed arrangement (standard-related)
- eNB procedures to avoid potential error cases (implementation-related)

25

It is assumed that at least two multi-ACK/NAK signaling formats are applicable to convey ACK/NAK feedback corresponding to multiple DL CCs on the uplink (PUCCH and PUSCH)

30

- one is designed for limited ACK/NAK feedback and based on PUCCH format 1b and channel selection
- another is designed for full ACK/NAK feedback and based on joint coding on top of PUCCH Format 2, PUSCH or some other channel type.

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According to the scheme according to embodiments, the ACK/NAK codebook size depends on the signaling format used to convey ACK/NAK feedback on the PUCCH:

- ACK/NAK codebook size (i.e., channel selection table) is based on the maximum number of DL CCs in the case when PUCCH channel selection is applied on the PUCCH
- ACK/NAK codebook size is based on the number of configured (or activated) DL CCs in the case when PUCCH channel selection is not applied.

In the following, a more general embodiment applying the above scheme is described by referring to Fig. 1:

Fig. 1 shows an apparatus according to a general embodiment of the invention. This apparatus may be an eNB, a UE, or a part of an eNB or a UE, for example.

In particular, the apparatus comprises a processor (1) configured to perform a component carrier configuration, re-configuration, activation or de-activation. The processor comprises a detector 11 configured to detect a signaling format used for acknowledgment/negative acknowledgement messages on an uplink control channel (e.g., PUCCH), and a deciding unit 12 configured to decide a codebook size of the acknowledgment/negative acknowledgement messages based on the detected signaling format.

It is noted that the processor 1 can be part of a central processor of an eNB or an UE, and/or can be configured to carry out further functions. Moreover, the detector and the deciding unit can be implemented by software carried out by the processor, for example.

In the following, a method according to a general embodiment of the invention is described. Similar as described above, the method may be carried out by an eNB, a UE, or a part of an eNB or a UE, for example.

In particular, in the method, a component carrier configuration, re-configuration, activation or de-activation is performed, wherein the performing further comprises detecting a signaling  
5 format used for acknowledgment/negative acknowledgement messages on an uplink control channel (e.g., PUCCH), and deciding a codebook size of the acknowledgment/negative acknowledgement messages based on the detected signaling format.

10 Hence, in this way the ACK/NAK codebook size is decided based on the signalling format used to convey ACK/NAK feedback on an uplink control signal such as a PUCCH.

Thus, according to embodiments of the present invention, a  
15 solution is provided by which acknowledge/non-acknowledge (ACK/NAK) feedback error cases due to different component carrier (CC) configuration/activation between, e.g., UE and eNB are avoided.

20 The decided ACK/NAK codebook size may be applied in at least one of the following cases: when signaling ACK/NAK on PUCCH, when signaling ACK/NAK on PUSCH, or when signaling ACK/NAK on PUCCH and PUSCH.

25 As described above, ACK/NAK codebook size is based on maximum number of DL CCs (in the following also referred to as M) in the case of PUCCH channel selection. In the following, this maximum number of DL CCs is described in more detail.

30 There are few options to define the maximum number of DL CCs:

1. M is based on the UE category, i.e., how many DL CCs are supported by the UE
2. M is a value pre-defined in the specification. One approach  
35 is to define M based on the maximum number of DL CCs supported by the channel selection (e.g., M=4)

3. M can be a semi-statically configured parameter defined by the eNB (in UE-specific manner or in cell-specific manner).

After CC (re-)configuration/activation/de-activation the UE starts using pre-defined PUCCH channel selection table according to M. It is noted that the eNB can improve the detection performance of PUCCH channel selection by ignoring the states corresponding to non-activated CCs (i.e., it is known in advance that those CCs are in DTX state in any case).

In the following, the PUCCH resource allocation for PUCCH channel selection is described. In particular, there is no need to reserve PUCCH resources according to maximum number of configured/activated CCs. Instead, according to the present embodiment PUCCH Format 1a/1b resources are reserved using one of the following methods:

1. Implicit resource allocation based on number of scheduled CCs
2. Explicit resource allocation based on number of configured CCs
3. Hybrid resource allocation in which PUCCH resources corresponding to DL CCs scheduled via primary DL CC are reserved implicitly whereas PUCCH resources corresponding to DL CCs scheduled via secondary DL CC(s) are reserved explicitly.

According to the present embodiment, PUCCH resources other than those reserved using implicit RA are signaled as part of CC (re-)configuration/activation/de-activation.

In the following, procedures to avoid ACK/NAK error cases due to CC (re-)configuration are described:

There are various cases which may result in error case for multi-A/N signaling:

1. Number of DL CCs can change (→ payload of multi-ACK/NAK varies accordingly). This is not a problem with PUCCH channel

selection following the scheme according to the embodiment described above.

2. Multi-ACK/NAK format can change (PUCCH channel selection  $\leftrightarrow$  joint coding).

5 3. Both can change at the same time

In the following, three alternative procedures are described, by which the above problems 2 and 3 can also be overcome.

10 According to a first procedure, which is implementation related, the eNB changes the multi-ACK/NAK PUCCH resource in case CC (re-)configuration (or in activation/deactivation if applicable). This allows performing blind detection at the eNB side to decide which PUCCH resource is applied at UE side (old resource  
15 or new resource). The first procedure is applicable in particular for joint coding, more specifically when signaling multi-A/N on PUCCH. However, the first procedure may also be applied for channel selection, although this would not be necessary when applying the scheme according to the embodiment described above.

20

According to a second procedure, which is also implementation related, the eNB avoids concurrent transmission of PUSCH and multi-ACK/NAK using scheduler restrictions. This allows eNB to apply the first procedure described above. The second procedure  
25 is applicable to both cases, i.e., joint coding and channel selection.

In the following, a third procedure is described, which is standard-related: It is possible to include data-associated  
30 control signaling in multi-ACK/NAK FB to signal the status of CC re-configuration/activation/de-activation. One approach is to include this information in RS modulation (PUCCH format 2a/2b). Another approach is to signal the codebook size as part of multi-ACK/NAK message. This scheme is applicable in both PUCCH  
35 and PUSCH.

The third procedure is applicable in particular to joint coding. However, in the case ACK/NAK is multiplexed with UL data, then also the third procedure can be applied for both schemes, i.e., joint coding and channel selection.

5

In the following, examples for technical implementations are described.

The principle of the UE/eNB procedure is shown in Figure 2. It assumes that RRC-level CC (re-)configuration is used to configure the number of DL CCs, multi-ACK/NAK format and PUCCH resource allocation.

According to Figure 2, the following information may be potentially signaled accompanied with RRC CC (re-) configuration, as indicated in step S1:

1. Number of configured DL CCs (and also configured CC index).
2. PUCCH ACK/NAK container format (i.e. channel selection on PUCCH format 1b, or joint coding on PUCCH format 2/2a/2b, or other channel type).
3. Explicit resource allocation for multi ACK/NAK resource (per DL CC for PUCCH channel selection)

It is noted that in Fig. 2, the PUCCH ACK/NAK container format or multi ACK/NAK format is abbreviated as A/N format.

In step S2, it is detected which kind of multi-A/N format is used.

In case channel selection on PUCCH format 1b is used to convey multi-ACK/NAK, the ACK/NAK codebook size (i.e. channel selection table) depends on maximum number of DL CCs (as shown in step S2). It is noted that the defined codebook can be applied only in the case when signalling ACK/NAK on PUCCH. The other choice is to apply the selected codebook size also when multiplexing ACK/NAK with PUSCH data.

In case joint coding on PUCCH format 2/2a/2b, or PUSCH, or other channel type is used to convey multi-ACK/NAK, the ACK/NAK codebook size depends on the number of configured DL CCs (as shown in step S3). Again, it is possible to apply the defined codebook size only in the case when signaling ACK/NAK on PUCCH. The other choice is to apply the selected codebook size also when multiplexing ACK/NAK with PUSCH data.

Furthermore the first to third procedures described above can be used to handle potential ambiguity/error case.

After performing step S3 or step S4, the new CC configuration is taken into use (at the UE).

It is noted that step S2 corresponds to the detecting of a signaling format as described in the method according to the more general embodiment, and steps S3 and S4 correspond to deciding a codebook size as described in the method according to the more general embodiment.

Furthermore, the following implementations are available for PUCCH channel selection:

- Implementation 1: for one UE, if the possible maximum number of configured/activated DL CCs is not bigger than 4, channel selection table as defined in Table 10.1-4 (TS36.213 v8.8.0) is utilized at UE side for channel selection, no matter how many DL CCs are really configured/activated.

- Implementation 2: for one UE, if the possible maximum number of configured/activated DL CCs is not bigger than 4, a unified channel selection table is defined at UE side for channel selection, no matter how many DL CCs are really configured/activated. A unified channel selection table is a single

channel selection table applicable to all channel selection cases.

• Implementation 3: for one UE, if the possible maximum number of configured/activated DL CCs is 5 and UE detects one pre-defined DL CC is not scheduled, UE will perform channel selection (with unified channel selection table) on PUCCH format 1b. Otherwise, UE will perform ACK/NAK multiplexing on PUCCH format 2/2a/2b. For such an implementation, eNB performs blind detection to distinguish which container is utilized at UE side.

• Implementation 4: for ACK/NAK multiplexing on PUCCH format 2/2a/2b or other new structure, one bit is sent via RS modulation. In case ACK/NAK codebook size is changed, the bit will be toggled. Otherwise, the bit will not be changed. In such a way, eNB could know exactly which ACK/NAK codebook size is utilized at UE side.

Thus, by the embodiments described above, the following advantages are achieved:

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The proposed scheme is capable to handle all the error cases related to ACK/NAK codebook ambiguity during CC re-configuration/activation/deactivation. Also, the PUCCH resource consumption can be minimized with PUCCH channel selection. Embodiments can support for flexible scheduling during CC (re-) configuration. Furthermore, standardization effort is small.

Generally, the solutions described above are simple and efficient without permanent losses on signalling efficiency.

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It is noted that some embodiments as described above are directed to LTE-A. However, LTE-A is only an example, and embodiments of the present invention may be applied on any radio access technology in which a system bandwidth is divided in sub-bands

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and component carriers are used, and acknowledgement/negative acknowledgement messages are to be sent which may vary in size.

According to a first aspect of several embodiments of the invention, an apparatus is provided which comprises

a processor configured to perform a component carrier configuration, re-configuration, activation or de-activation, the processor comprising

a detector configured to detect a signaling format used for acknowledgement/negative acknowledgement messages on an uplink control channel, and

a deciding unit configured to decide a codebook size of the acknowledgement/negative acknowledgement messages based on the detected signaling format.

The first aspect may be modified as follows:

The deciding unit may be configured to decide the codebook size based on the maximum number of downlink component carriers in case as a signaling format for the acknowledgement/negative acknowledgement messages on the uplink control channel a channel selection is applied.

The maximum number of downlink component carriers

may be defined based on how many downlink component carriers are supported by a network element,

may be a predefined value,

may be defined based on a maximum number of downlink component carriers supported by the channel selection, or

may be a semi-statically configured parameter defined by a network control element.

The deciding unit may be configured to decide the codebook size based on the number of configured or activated downlink component carriers in case as a signaling format for the acknowledgement/negative acknowledgement messages on the uplink control

channel a channel selection is not applied. For example, in this case joint coding may be applied.

5 The processor may be configured to use a predefined uplink control channel selection table according to the maximum number of downlink component carriers.

The processor may be configured

10 to reserve uplink control channel resources based on a number of scheduled component carriers or a number of configured component carriers, and/or

15 to reserve uplink control channel resources corresponding to downlink component carriers scheduled via a primary downlink component carrier based on the number of scheduled component carriers, and to reserve uplink control channel resources corresponding to downlink component carriers scheduled via secondary downlink control channels based on the number of configured component carriers.

20 The processor may be configured to change an uplink control channel resource for multiple acknowledgment/negative acknowledgment messages on performing a component carrier configuration, re-configuration, activation or de-activation.

25 The processor may be configured to avoid concurrent transmission of a PUSCH and multiple acknowledgment/negative acknowledgment messages at predetermined time periods with time uncertainty related to component carrier configuration.

30 The processor may be configured to include data-associated control signaling in a multiple acknowledgment/negative acknowledgment message for signaling the status of a component carrier configuration, re-configuration, activation or de-activation.

The processor may be configured to use a unified channel selection table in case a possible maximum number of configured and/or activated downlink component carriers is not bigger than a predetermined number.

5

The processor may be configured to apply the decided codebook size of the acknowledgment/negative acknowledgement messages in at least one of the following cases:

when signaling acknowledgment/negative acknowledgement  
10 messages on an uplink control channel,

when signaling acknowledgment/negative acknowledgement  
messages on an uplink shared channel, and/or

when signaling acknowledgment/negative acknowledgement  
15 messages on an uplink control channel and an uplink shared  
channel.

The apparatus may be a user equipment or may be part of a user equipment, or may be a network control element such as an eNB, or may be a part thereof.

20

According to a second aspect of several embodiments of the invention, a method is provided which comprises

performing a component carrier configuration,  
re-configuration, activation or de-activation, the performing  
25 further comprising

detecting a signaling format used for acknowledgment/  
negative acknowledgement messages on an uplink control  
channel, and

30 deciding a codebook size of the acknowledgment/negative  
acknowledgement messages based on the detected signaling format.

The performing, detecting and deciding may be performed by a processor or a similar processing means, for example.

35 The second aspect may be modified as follows:

In case as a signaling format for the acknowledgment/negative acknowledgement messages on the uplink control channel a channel selection is applied, the codebook size may be decided based on the maximum number of downlink component carriers.

5

The maximum number of downlink component carriers  
may be defined based on how many downlink component carriers  
are supported by a network element,

may be a predefined value,

10

may be defined based on a maximum number of downlink  
component carriers supported by the channel selection, or  
may be a semi-statically configured parameter defined by a  
network control element.

15

In case as a signaling format for the acknowledgment/negative  
acknowledgement messages on the uplink control channel a channel  
selection is not applied, the codebook size may be decided based  
on the number of configured or activated downlink component  
carriers.

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The method may further comprise  
using a predefined uplink control channel selection table  
according to the maximum number of downlink component carriers.

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The method may further comprise  
reserving uplink control channel resources based on a number  
of scheduled component carriers or a number of configured  
component carriers, and/or

reserving uplink control channel resources corresponding to  
downlink component carriers scheduled via a primary downlink  
component carrier based on the number of scheduled component  
carriers, and reserving uplink control channel resources  
corresponding to downlink component carriers scheduled via  
secondary downlink control channels based on the number of  
configured component carriers.

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The method may further comprise

changing an uplink control channel resource for multiple  
acknowledgment/negative acknowledgement messages on performing  
a component carrier configuration, re-configuration, activation  
5 or de-activation.

The method may further comprise avoiding concurrent transmission  
of a PUSCH and multiple acknowledgment/negative acknowledgement  
messages at predetermined time periods with time uncertainty  
10 related to component carrier configuration.

The method may further comprise including data-associated  
control signaling in a multiple acknowledgment/negative ac-  
knowledge message for signaling the status of a component  
15 carrier configuration, re-configuration, activation or  
de-activation.

The method may further comprise using a unified channel selection  
table in case a possible maximum number of configured and/or  
20 activated downlink component carriers is not bigger than a  
predetermined number.

The decided codebook size of the acknowledgment/negative ac-  
knowledge messages may be applied in at least one of the  
25 following cases:

when signaling acknowledgment/negative acknowledgement  
messages on an uplink control channel,

when signaling acknowledgment/negative acknowledgement  
messages on an uplink shared channel, and/or

30 when signaling acknowledgment/negative acknowledgement  
messages on an uplink control channel and an uplink shared  
channel.

According to a third aspect of several embodiments of the present  
35 invention, a computer program product is provided which comprises

code means for performing a method according to any one of the second aspect and its modifications when run on a computer.

5 The computer program product is embodied on a computer-readable medium.

The computer program product may be directly loadable into an internal memory of the computer.

10 According to a fourth aspect of several embodiments of the invention, an apparatus is provided which comprises  
means for performing a component carrier configuration,  
re-configuration, activation or de-activation,  
means for detecting a signaling format used for ac-  
15 knowledgment/negative acknowledgement messages on an uplink control channel, and  
means for a deciding a codebook size of the acknowledg-  
ment/negative acknowledgement messages based on the detected signaling format.

20

The fourth aspect may be modified as follows:

The apparatus may further comprise means for deciding the codebook size based on the maximum number of downlink component  
25 carriers in case as a signaling format for the acknowledg-  
ment/negative acknowledgement messages on the uplink control channel a channel selection is applied.

The maximum number of downlink component carriers  
30 may be defined based on how many downlink component carriers are supported by a network element,  
may be a predefined value,  
may be defined based on a maximum number of downlink component carriers supported by the channel selection, or  
35 may be a semi-statically configured parameter defined by a network control element.

The apparatus may further comprise means for deciding codebook size based on the number of configured or activated downlink component carriers in case as a signaling format for the acknowledgment/negative acknowledgement messages on the uplink control channel a channel selection is not applied. For example, in this case joint coding may be applied.

The apparatus may further comprise means for using a predefined uplink control channel selection table according to the maximum number of downlink component carriers.

The apparatus may further comprise means for  
reserving uplink control channel resources based on a number  
of scheduled component carriers or a number of configured  
component carriers, and/or  
reserving uplink control channel resources corresponding to  
downlink component carriers scheduled via a primary downlink  
component carrier based on the number of scheduled component  
carriers, and reserving uplink control channel resources  
corresponding to downlink component carriers scheduled via  
secondary downlink control channels based on the number of  
configured component carriers.

The apparatus may further comprise means for changing an uplink control channel resource for multiple acknowledgment/negative acknowledgement messages on performing a component carrier configuration, re-configuration, activation or de-activation.

The apparatus may further comprise means for avoiding concurrent transmission of a PUSCH and multiple acknowledgment/negative acknowledgement messages at predetermined time periods with time uncertainty related to component carrier configuration.

The apparatus may further comprise means for including data-associated control signaling in a multiple acknowledg-

ment/negative acknowledgement message for signaling the status of a component carrier configuration, re-configuration, activation or de-activation.

- 5 The apparatus may further comprise means for using a unified channel selection table in case a possible maximum number of configured and/or activated downlink component carriers is not bigger than a predetermined number.
- 10 The apparatus may further comprise means for applying the decided codebook size of the acknowledgment/negative acknowledgement messages in at least one of the following cases:
- when signaling acknowledgment/negative acknowledgement messages on an uplink control channel,
  - 15 when signaling acknowledgment/negative acknowledgement messages on an uplink shared channel, and/or
  - when signaling acknowledgment/negative acknowledgement messages on an uplink control channel and an uplink shared channel.
- 20 The apparatus may be a user equipment or may be part of a user equipment, or may be a network control element such as an eNB, or may be a part thereof.
- 25 It is to be understood that any of the above modifications can be applied singly or in combination to the respective aspects and/or embodiments to which they refer, unless they are explicitly stated as excluding alternatives.
- 30 For the purpose of the present invention as described herein above, it should be noted that
- method steps likely to be implemented as software code portions and being run using a processor at a network element or terminal (as examples of devices, apparatuses and/or modules thereof, or
  - 35 as examples of entities including apparatuses and/or modules therefore), are software code independent and can be specified

using any known or future developed programming language as long as the functionality defined by the method steps is preserved;

- generally, any method step is suitable to be implemented as software or by hardware without changing the idea of the invention in terms of the functionality implemented;

- method steps and/or devices, units or means likely to be implemented as hardware components at the above-defined apparatuses, or any module(s) thereof, (e.g., devices carrying out the functions of the apparatuses according to the embodiments as described above, UE, eNB etc. as described above) are hardware independent and can be implemented using any known or future developed hardware technology or any hybrids of these, such as MOS (Metal Oxide Semiconductor), CMOS (Complementary MOS), BiMOS (Bipolar MOS), BiCMOS (Bipolar CMOS), ECL (Emitter Coupled Logic), TTL (Transistor-Transistor Logic), etc., using for example ASIC (Application Specific IC (Integrated Circuit)) components, FPGA (Field-programmable Gate Arrays) components, CPLD (Complex Programmable Logic Device) components or DSP (Digital Signal Processor) components;

- devices, units or means (e.g. the above-defined apparatuses, or any one of their respective means) can be implemented as individual devices, units or means, but this does not exclude that they are implemented in a distributed fashion throughout the system, as long as the functionality of the device, unit or means is preserved;

- an apparatus may be represented by a semiconductor chip, a chipset, or a (hardware) module comprising such chip or chipset; this, however, does not exclude the possibility that a functionality of an apparatus or module, instead of being hardware implemented, be implemented as software in a (software) module such as a computer program or a computer program product comprising executable software code portions for execution/being run on a processor;

- a device may be regarded as an apparatus or as an assembly of more than one apparatus, whether functionally in cooperation with

each other or functionally independently of each other but in a same device housing, for example.

5 It is noted that the embodiments and examples described above are provided for illustrative purposes only and are in no way intended that the present invention is restricted thereto. Rather, it is the intention that all variations and modifications be included which fall within the spirit and scope of the appended claims.

## CLAIMS

1. An apparatus comprising

5 a processor configured to perform a component carrier configuration, re-configuration, activation or de-activation, the processor comprising

a detector configured to detect a signaling format used for acknowledgment/negative acknowledgement messages on an uplink control channel, and

10 a deciding unit configured to decide a codebook size of the acknowledgment/negative acknowledgement messages based on the detected signaling format.

2. The apparatus according to claim 1, wherein the deciding  
15 unit is configured to decide the codebook size based on the maximum number of downlink component carriers in case as a signaling format for the acknowledgment/negative acknowledgement messages on the uplink control channel a channel selection is applied.

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3. The apparatus according to claim 2, wherein the maximum number of downlink component carriers

is defined based on how many downlink component carriers are supported by a network element,

25 is a predefined value,

is defined based on a maximum number of downlink component carriers supported by the channel selection, or

is a semi-statically configured parameter defined by a network control element.

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4. The apparatus according to any of the claims 1 to 3, wherein the deciding unit is configured to decide the codebook size based on the number of configured or activated downlink component carriers in case as a signaling format for the acknowledgment/negative acknowledgement messages on the uplink control  
35 channel a channel selection is not applied.

5. The apparatus according to any of the claims 2 to 4, wherein the processor is configured to use a predefined uplink control channel selection table according to the maximum number of downlink component carriers.

6. The apparatus according to any of the claims 1 to 5, wherein the processor is configured to reserve uplink control channel resources based on a number of scheduled component carriers or a number of configured component carriers, and/or to reserve uplink control channel resources corresponding to downlink component carriers scheduled via a primary downlink component carrier based on the number of scheduled component carriers, and to reserve uplink control channel resources corresponding to downlink component carriers scheduled via secondary downlink control channels based on the number of configured component carriers.

7. The apparatus according to any of the claims 1 to 6, wherein the processor is configured to change an uplink control channel resource for multiple acknowledgment/negative acknowledgment messages on performing a component carrier configuration, re-configuration, activation or de-activation.

8. The apparatus according to any of the claims 1 to 7, wherein the processor is configured to avoid concurrent transmission of a PUSCH and multiple acknowledgment/negative acknowledgment messages at predetermined time periods with time uncertainty related to component carrier configuration.

9. The apparatus according to any of the claims 1 to 8, wherein the processor is configured to include data-associated control signaling in a multiple acknowledgment/negative acknowledgment message for signaling the status of a component carrier configuration, re-configuration, activation or de-activation.

10. The apparatus according to any of the claims 1 to 9, wherein the processor is configured to use a unified channel selection table in case a possible maximum number of configured and/or  
5 activated downlink component carriers is not bigger than a predetermined number.

11. The apparatus according to any of the claims 1 to 10, wherein the processor is configured to apply the decided codebook size  
10 of the acknowledgment/negative acknowledgement messages in at least one of the following cases:

when signaling acknowledgment/negative acknowledgement messages on an uplink control channel,

when signaling acknowledgment/negative acknowledgement  
15 messages on an uplink shared channel, and/or

when signaling acknowledgment/negative acknowledgement messages on an uplink control channel and an uplink shared channel.

20 12. A method comprising  
performing a component carrier configuration,  
re-configuration, activation or de-activation, the performing further comprising

detecting a signaling format used for acknowledg-  
25 ment/negative acknowledgement messages on an uplink control channel, and

deciding a codebook size of the acknowledgment/negative acknowledgement messages based on the detected signaling format.

30 13. The method according to claim 12, wherein in case as a signaling format for the acknowledgment/negative acknowledgement messages on the uplink control channel a channel selection is applied, the codebook size is decided based on the maximum number of downlink component carriers.

14. The method according to claim 13, wherein the maximum number of downlink component carriers

is defined based on how many downlink component carriers are supported by a network element,

5 is a predefined value,

is defined based on a maximum number of downlink component carriers supported by the channel selection, or

is a semi-statically configured parameter defined by a network control element.

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15. The method according to any of the claims 12 to 14, wherein in case as a signaling format for the acknowledgment/negative acknowledgment messages on the uplink control channel a channel selection is not applied, the codebook size is decided based on the number of configured or activated downlink component carriers.

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16. The method according to any of the claims 13 to 15, further comprising

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using a predefined uplink control channel selection table according to the maximum number of downlink component carriers.

17. The method according to any of the claims 12 to 16, further comprising

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reserving uplink control channel resources based on a number of scheduled component carriers or a number of configured component carriers, and/or

reserving uplink control channel resources corresponding to downlink component carriers scheduled via a primary downlink component carrier based on the number of scheduled component carriers, and reserving uplink control channel resources corresponding to downlink component carriers scheduled via secondary downlink control channels based on the number of configured component carriers.

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18. The method according to any of the claims 12 to 17, further comprising

changing an uplink control channel resource for multiple acknowledgment/negative acknowledgement messages on performing  
5 a component carrier configuration, re-configuration, activation or de-activation.

19. The method according to any of the claims 12 to 18, further comprising avoiding concurrent transmission of a PUSCH and  
10 multiple acknowledgment/negative acknowledgement messages at predetermined time periods with time uncertainty related to component carrier configuration.

20. The method according to any of the claims 12 to 19, further  
15 comprising including data-associated control signaling in a multiple acknowledgment/negative acknowledgement message for signaling the status of a component carrier configuration, re-configuration, activation or de-activation.

20 21. The method according to any of the claims 12 to 20, further comprising using a unified channel selection table in case a possible maximum number of configured and/or activated downlink component carriers is not bigger than a predetermined number.

25 22. The method according to any of the claims 12 to 21, wherein the decided codebook size of the acknowledgment/negative acknowledgement messages is applied in at least one of the following cases:

when signaling acknowledgment/negative acknowledgement  
30 messages on an uplink control channel,

when signaling acknowledgment/negative acknowledgement messages on an uplink shared channel, and/or

when signaling acknowledgment/negative acknowledgement messages on an uplink control channel and an uplink shared  
35 channel.

23. A computer program product comprising code means for performing a method according to any one of claims 12 to 22 when run on a processing means or module.

- 5 24. The computer program product according to claim 23, wherein the computer program product is embodied on a computer-readable medium.