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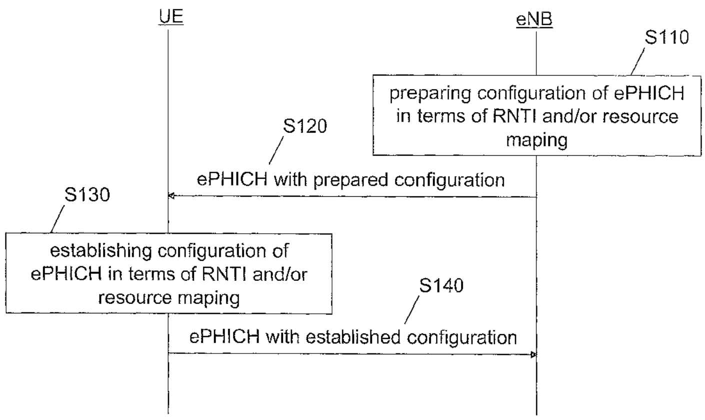

Figure 1

(57) Abstract: There are provided measures for realizing configuration of an enhanced physical hybrid automatic repeat request indicator channel (ePHICH). Such measures may exemplarily comprise preparing or establishing configuration of an enhanced physical hybrid automatic repeat request indicator channel (ePHICH) with downlink control information in a predetermined format in terms of at least one of radio network temporary identifier and resource mapping, and initiating signaling of the prepared or established configuration towards a terminal or network side.

WO 2013/149390 A1

CONFIGURATION OF ENHANCED PHYSICAL HYBRID AUTOMATIC REPEAT REQUEST INDICATOR CHANNEL

Field of the invention

The present invention relates to configuration of an enhanced physical hybrid automatic repeat request indicator channel. More specifically, the present invention relates to measures (including methods, apparatuses and computer program products) for realizing configuration of an enhanced physical hybrid automatic repeat request indicator channel.

Background

The present specification generally relates to an enhanced downlink control channel, especially an enhanced physical hybrid automatic repeat request indicator channel (ePHICH). Any such channel is generally applicable in any advanced communication system or network deployment, such as e.g. LTE Rel-11 onwards.

In this regard, attention is herein exemplarily drawn on an enhancement of a physical hybrid automatic repeat request indicator channel (PHICH) which is a downlink control channel to carry downlink HARQ feedback for UL (e.g. PUSCH) transmission.

An enhanced PHICH could be specifically effective in view of the following aspects. Firstly, in LTE Rel-11 carrier aggregation, there may exist an extension carrier which does not have a PDCCH (resource space) region, but only has ePDCCH (resource space) on it. In Rel-10, the PHICH is always sent on the component carrier where UL grant is sent. If PUSCH is granted by ePDCCH from the extension carrier, ePHICH has to be configured from the extension carrier as well. Secondly, the PHICH would benefit from ICIC point of view, as it is narrow band and adjustable in frequency resources. Thirdly, the ePHICH seems to be the preferable choice for MTC users with narrow band capability. Fourthly, a spatial reuse of PHICH may not always be possible e.g. in specified downlink CoMP scenario 4. Fifthly, the use of

UE-specific reference symbols (RS) may bring beamforming gain as well as the possibility of MU-MIMO transmission.

Thus, there is a desire to realize configuration of an enhanced physical hybrid automatic repeat request indicator channel.

Summary

Various exemplary embodiments of the present invention aim at addressing at least part of the above issues and/or problems and drawbacks.

Various aspects of exemplary embodiments of the present invention are set out in the appended claims.

According to an exemplary aspect of the present invention, there is provided a method comprising establishing configuration of an enhanced physical hybrid automatic repeat request indicator channel with downlink control information in a predetermined format in terms of at least one of radio network temporary identifier and resource mapping, and initiating signaling of said channel with the established configuration towards a network side.

According to an exemplary aspect of the present invention, there is provided a method comprising preparing configuration of an enhanced physical hybrid automatic repeat request indicator channel with downlink control information in a predetermined format in terms of at least one of radio network temporary identifier and resource mapping, and initiating signaling of said channel with the prepared configuration towards a terminal side.

According to an exemplary aspect of the present invention, there is provided an apparatus comprising at least one processor, at least one memory including computer program code, and at least one interface configured for communication with at least another apparatus, the at least one processor, with the at least one memory and the computer program code, being configured to cause the apparatus to perform: establishing configuration of an enhanced physical hybrid automatic repeat request indicator channel with downlink control information in a predetermined format in terms of at least one of radio network temporary identifier and resource mapping, and initiating signaling of said channel with the established configuration towards a network side.

According to an exemplary aspect of the present invention, there is provided an apparatus comprising at least one processor, at least one memory including computer program code, and at least one interface configured for communication with at least another apparatus, the at least one processor, with the at least one memory and the computer program code, being configured to cause the apparatus to perform: preparing configuration of an enhanced physical hybrid automatic repeat request indicator channel with downlink control information in a predetermined format in terms of at least one of radio network temporary identifier and resource mapping, and initiating signaling of said channel with the prepared configuration towards a terminal side.

According to an exemplary aspect of the present invention, there is provided a computer program product comprising a set of instructions (e.g. computer-executable computer program code) which, when executed on an apparatus or a computer of an apparatus (e.g. an apparatus according to any one of the aforementioned apparatus-related exemplary aspects of the present invention), is arranged to cause the computer or apparatus to carry out the method according to any one of the aforementioned method-related exemplary aspects of the present invention.

Such computer program product may comprise or be embodied as a (tangible) computer-readable (storage) medium or the like on which the computer-executable computer program code is stored, and/or the program may be directly loadable into an internal memory of the computer or a processor thereof.

Advantageous further developments or modifications of the aforementioned exemplary aspects of the present invention are set out in the following.

By virtue of any one of the aforementioned exemplary aspects of the present invention, configuration of an enhanced physical hybrid automatic repeat request indicator channel is realized, especially in terms of radio network temporary identifier and/or resource mapping.

Thus, enhancements are achieved by methods, apparatuses and computer program products realizing configuration of an enhanced physical hybrid automatic repeat request indicator channel is realized, especially in terms of radio network temporary identifier and/or resource mapping.

Brief description of drawings

For a more complete understanding of exemplary embodiments of the present invention, reference is now made to the following description taken in connection with the accompanying drawings in which:

Figure 1 shows a schematic diagram illustrating a first example of a procedure in the context of ePHICH configuration according to exemplary embodiments of the present invention,

Figure 2 shows a schematic diagram of an exemplary DCI format of an ePHICH according to exemplary embodiments of the present invention,

Figure 3 shows a schematic diagram illustrating a second example of a procedure in the context of ePHICH configuration according to exemplary embodiments of the present invention,

Figure 4 shows a schematic diagram of an exemplary format of a random access response according to exemplary embodiments of the present invention,

Figure 5 shows a schematic diagram of a resource space with multiple regions according to exemplary embodiments of the present invention,

Figure 6 shows a schematic diagram illustrating a third example of a procedure in the context of ePHICH configuration according to exemplary embodiments of the present invention,

Figure 7 shows a schematic diagram of a resource space with multiple regions and a concept of collision avoidance according to exemplary embodiments of the present invention, and

Figure 8 shows a schematic block diagram illustrating exemplary apparatuses according to exemplary embodiments of the present invention.

Description of exemplary embodiments

Exemplary aspects of the present invention will be described herein below. More specifically, exemplary aspects of the present are described hereinafter with reference to particular non-limiting examples and to what are presently considered to be conceivable embodiments of the present invention. A person skilled in the art will appreciate that the invention is by no means limited to these examples, and may be more broadly applied.

It is to be noted that the following description of the present invention and its embodiments mainly refers to specifications being used as non-limiting examples for certain exemplary network configurations and deployments. Namely, the present invention and its embodiments are mainly described in relation to 3GPP specifications being used as non-limiting examples for certain exemplary network configurations and deployments. In particular, a LTE/LTE-Advanced communication system is used as a non-limiting example for the applicability of thus described exemplary embodiments. As such, the description of exemplary embodiments given herein specifically refers to terminology which is directly related thereto. Such terminology is only used in the context of the presented non-limiting examples, and does naturally not limit the invention in any way. Rather, any other network configuration or system deployment, etc. may also be utilized as long as compliant with the features described herein.

It is noted that the present invention and its embodiments are not limited to the thus described example backgrounds, and may for example be applicable in any communication system or network deployment in which an enhanced downlink control channel is operable.

Hereinafter, various embodiments and implementations of the present invention and its aspects or embodiments are described using several alternatives. It is generally noted that, according to certain needs and constraints, all of the described alternatives may be provided alone or in any conceivable combination (also including combinations of individual features of the various alternatives).

According to exemplary embodiments of the present invention, in general terms, there are provided mechanisms, measures and means for realizing configuration of an enhanced physical hybrid automatic repeat request indicator channel (ePHICH).

In the following, exemplary embodiments of the present invention are described with reference to methods, procedures and functions, as well as with reference to structural arrangements and configurations.

Figure 1 shows a schematic diagram illustrating a first example of a procedure in the context of ePHICH configuration according to exemplary embodiments of the present invention.

The exemplary procedure according to Figure 1 is assumed to take place at or between a terminal entity (or modem thereof), such as a UE, and a network entity (or modem thereof), such as e eNB exemplifying a base station or access node.

As shown in Figure 1, a procedure according to exemplary embodiments of the present invention may comprise, at the network side, an operation

(S110) of preparing configuration of an ePHICH with downlink control information (DCI) in a predetermined format in terms of at least one of radio network temporary identifier and resource mapping, and an operation of initiating (i.e. causing or triggering) signaling (S120) of said channel with the prepared configuration towards the terminal side. Additionally or alternatively, a procedure according to exemplary embodiments of the present invention may comprise, at the terminal side, an operation (S130) of establishing configuration of an ePHICH with downlink control information (DCI) in a predetermined format in terms of at least one of radio network temporary identifier and resource mapping, and an operation of initiating (i.e. causing or triggering) signaling (S140) of said channel with the established configuration towards the network side.

According to exemplary embodiments of the present invention, the procedure at the network side and the procedure at the terminal side may be independent from each other or may cooperate with each other in terms of ePHICH configuration.

Figure 2 shows a schematic diagram of an exemplary DCI format of an ePHICH according to exemplary embodiments of the present invention.

As shown in Figure 2, an ePHICH configuration (200) according to exemplary embodiments of the present invention may be based on a predetermined DCI format. The thus illustrated example of an ePHICH design according to exemplary embodiments of the present invention is based on the use of a DCI structure similar to PDCCH format 3/3a to convey DL HARQ ACK/NACK information for a group of UEs (exemplified as a single 0/1 bit for each UE in question).

Such exemplary ePHICH (E-PHICH) design according to exemplary embodiments of the present invention is beneficial and/or effective in that it can reuse any specified ePDCCH (E-PDCCH) structure and/or resource mapping, as basically the ePHICH (E-PHICH) information is carried by a new DCI format.

Such exemplary ePHICH (E-PHICH) design according to exemplary embodiments of the present invention, for example in an ePHICH design with DCI format 3/3a, at least two parameters are needed to be known by UEs.

On the one hand, a RNTI such as ePHICH-RNTI, for example 16 bits similar to Rel-8 TPC-PUCCH-RNTI or TPC-PUSCH-RNTI, is required. For example, in Rel-8 TPC-PUCCH-RNTI or TPC-PUSCH-RNTI are configured in *PhysicalConfigDedicated*, which is only signaled after Msg3 in a random access procedure (e.g., can be included in Msg4 in a random access procedure as part of a *RRCConnectionSetup* message).

On the other hand, an ePHICH-Index (of N bits) to indicate the position of a certain UE's PHICH bits within the DCI format is required.

In the following, special consideration is made to a random access procedure, and the applicability of ePHICH configuration according to exemplary embodiments of the present invention in such scenario.

For an initial access UE, the earliest place to use ePHICH is for RACH Msg3 for contention-based RACH since RACH Msg3 supports HARQ functionality. This means that any UE needs to acquire ePHICH configuration (e.g. ePHICH-RNTI and ePHICH-Index) before Msg3 transmission. To obtain these parameters is especially important to new UEs that do not use legacy PHICH (e.g., MTC UEs or new UEs using a future proof extension carrier in future releases). Even if the eNB has already configured the ePHICH position for each UE, for other contention-based RA case, e.g. UL data arrival without UL synchronization, or RRC re-establishment, eNB and UE could still not have a same understanding of the UE position because eNB could not tell which UE is transmitting the preamble, for example. However, the conventional PHICH configuration in MIB or SIB nowadays can not solve the problem as it does not apply to ePHICH.

Currently, RACH Msg3 could also rely on adaptive retransmission, if there is no PHICH, i.e. Msg3 retransmission is also scheduled by one PDCCH. Such method does not need PHICH or ePHICH (and thus does not need to acquire ePHICH configuration), but with the cost of increased PDCCH/ePDCCH overhead. This may not be not applicable e.g. when the system already has heavy load or the accessed UE number is large e.g. for MTC UEs.

In 3GPP LTE Rel-8, a PHICH configuration is indicated in MIB, i.e. in *phich-Config*. Once a UE obtains *phich-Config*, the UE is able to derive the proper PHICH channel for itself based on PUSCH resources that are actually used (PRB index and UL DMRS CS).

With regard to ePHICH-Index configuration, it may be noted that the eNB may configure the UE with the needed (E-PDCCH and) E-PHICH parameters, such as the E-PDCCH / E-PHICH PRB allocation and the used E-PHICH-RNTI. The bit position(s) of the ACK/NACK(s) intended for a specific UE can be configured either explicitly via higher layer signaling, or implicitly by mapping the bit position e.g. to the information carried in the corresponding uplink grant. For example, similar implicit resource mapping mechanisms as in Release 8 PHICH can be used, i.e. mapping the bit position to the first PRB allocated in uplink for PUSCH and/or the DMRS cyclic shift allocated for the PUSCH transmission.

Referring to a random access procedure, the eNB's configuration of ePHICH-RNTI and ePHICH-Index could not be accomplished earlier than Msg4, which means that Msg3 still could not use ePHICH.

According to exemplary embodiments of the present invention, an initial configuration of ePHICH with DCI format is proposed, by way of which the above issues may be solved. Exemplary embodiments of the present invention, as outlined below, could provide solutions to solve the above issue, while minimizing any additional complexity or specification impact.

According to exemplary embodiments of the present invention, an initial configuration of ePHICH with new DCI format may be realized so as to have an explicitly/implicitly defined ePHICH-RNTI and/or a 1 bit signaling to inform the UE whether there will be corresponding ePHICH for it, so that ePHICH could also support RACH procedure.

In the following, it is assumed that the ePHICH-Index is implicitly mapped e.g. from first PRB allocated for PUSCH. Besides, it is assumed that an ePHICH reconfiguration could be done e.g. via RRC signalling.

Figure 3 shows a schematic diagram illustrating a second example of a procedure in the context of ePHICH configuration according to exemplary embodiments of the present invention.

In the exemplary illustration of Figure 3, two basically independent aspects of an initial ePHICH configuration according to exemplary embodiments of the present invention are shown, which are shown to be separated by a dashed line. According to various exemplary embodiments of the present invention, any one or both of these separated procedures may be realized.

As shown in Figure 3 (i.e. in the part above the dashed line), a procedure according to exemplary embodiments of the present invention may comprise an operation (S310) of setting a channel-specific radio network temporary identifier as an initial identifier configuration of the channel in question, i.e. setting an ePHICH-RNTI as an initial identifier configuration of the ePHICH, at the network side, and/or an operation (S320) of adopting a channel-specific radio network temporary identifier as an initial identifier configuration of the channel in question, i.e. adopting an ePHICH-RNTI as an initial identifier configuration of the ePHICH, at the terminal side.

According to exemplary embodiments of the present invention, the thus set/adopted ePHICH-RNTI may configure the ePHICH for transmission of a random access message (in PUSCH) in a random access procedure. Further, the ePHICH-RNTI may be a predefined ePHICH-RNTI and/or an ePHICH-RNTI being associated with at least one specific RNTI value.

In a first alternative, as indicated above, the ePHICH-RNTI value may be reserved/predefined (e.g. in a 3GPP specification), and both initial access

UE and normal UE which is using contention-based RACH could use this RNTI to acquire ePHICH for RACH Msg3.

In this alternative, for UE which is using contention-based RACH, ePHICH-RNTI is reserved to a fixed value *ePHICH_RNTIres*. This value is predefined, and UEs doing contention-based RACH could directly use this RNTI to acquire ePHICH for Msg3. After the UE successfully performed the RACH, the eNB could reconfigure ePHICH-RNTI for UE e.g. by RRC signaling.

In a second alternative, as indicated above, the ePHICH-RNTI may be implicitly linked to specific RNTI values, e.g. T-C-RNTI.

In this alternative, the ePHICH-RNTI could implicitly link to RNTI values. The advantage of this alternative is that eNB could allocate T-C-RNTI to initial access UE in order to allocate such UE and normal UE into the same group to save ePHICH overhead.

For example, if two ePHICH_RNTIs are reserved as ePHICH_RNTI1 and ePHICH-RNTI2, and a T-C-RNTI mapping to the reserved ePHICH_RNTI is defined, e.g. T-C-RNTI = i maps to *ePHICH-RNTIres* = ePHICH_RNTI1 and T-C-RNTI = j maps to *ePHICH-RNTIres* = ePHICH_RNTI2, then if the eNB would like to schedule group2 UEs in subframe n, it can allocate T-C-RNTI2 to Msg3 UE in same subframe, then this UE and other normal UE will both monitor ePHICH in DCI with ePHICH-RNTI2. Based on T-C-RNTI to ePHICH-RNTI mapping, it can get that *ePHICH-RNTIres* = ePHICH-RNTI2, then only one DCI is needed. This enables DCI reduction via T-C-RNTI allocation by eNB.

As shown in Figure 3 (i.e. in the part below the dashed line), a procedure according to exemplary embodiments of the present invention may comprise, at the network side, an operation (S330) of determining at least one of system load and load on a physical downlink control channel (PDCCH) or enhanced physical downlink control channel (ePDCCH), and an operation (S340) of issuing indication on a retransmission mode for a specific message (e.g. Msg3) transmitted on the channel in question (ePHICH) on the basis of the determined load. Additionally, or alternatively, a procedure according to exemplary embodiments of the present invention may comprise, at the terminal side, an operation (S350) of obtaining indication on a retransmission mode for a specific message (e.g. Msg3) transmitted on the channel in question (ePHICH), and an operation (S360) of applying the channel in question (ePHICH) in a non-adaptive mode or a physical downlink control channel (PDCCH) or enhanced physical downlink control channel (ePDCCH) in an adaptive mode as the retransmission mode for the specific message (e.g. Msg3) on the basis of the obtained indication.

According to exemplary embodiments of the present invention, the indication may be issued and/or obtained in at least one of a master information block (MIB), a system information block (SIB), and a random access response (RAR). Also, as indicated above, the specific message in question may comprise a terminal-specific random access message (such as Msg3) in a random access procedure.

Stated in other words, referring to a random access procedure, a new signalling (B1) may indicate if Msg3 retransmission is using non-adaptive mode with ePHICH or adaptive mode with PDCCH/ePDCCH. For example, one bit signaling B1=0 could mean that Msg3 retransmission uses non-adaptive mode based on ePHICH, while one bit signaling B1=1 could mean that Msg3 retransmission uses adaptive mode based on PDCCH/ePDCCH.

In a first alternative, as indicated above, this signaling (B1) could be indicated in system information e.g. MIB or SIB.

In this alternative, the indication value B1 could be transmitted in system information e.g. MIB or SIB, since UE need to read such information before doing any RACH procedure. Then, the UE could utilize the indication of B1 as a basis to determine which retransmission mode is used for RACH Msg3.

With such signaling as outlined above, it is possible that the eNB controls the UE ePHICH resources based on the actual load of the system. For example, if eNB decides that the PDCCH load is acceptable then it can set

B1=1, upon which UE shall assume that Msg3 retransmission uses adaptive retransmission mode based on PDCCH/ePDCCH.

In a second alternative, as indicated above, this signaling (B1) could be indicated in RAR for UEs.

In this alternative, the indication value B1 could be transmitted in RAR, e.g. with a modified reserved bit. For example, '0' is indicating that Msg3 is using adaptive retransmission mode based on PDCCH/ePDCCH scrambled with T-C-RNTI that is allocated in Msg2, and '1' is indicating that Msg3 is using non-adaptive retransmission mode based on ePHICH. Since '1' is an invalid value for legacy UEs, if legacy UEs accidently receive such RAR, they will abandon it. Accordingly, such technique according to exemplary embodiments of the present invention does not impact legacy UEs.

Figure 4 shows a schematic diagram of an exemplary format of a random access response (400) according to exemplary embodiments of the present invention. In the example according to Figure 4, the first bit in the first octet (410) is used for the B1 signaling according to exemplary embodiments of the present invention, which in the illustrated example is set to 1.

With such signaling as outlined above, it is possible that the eNB controls the UE EPHICH resources based on the actual load of the system. For example, if eNB decides that the PDCCH load is acceptable then it can set B1=1, upon which UE shall assume that Msg3 retransmission use adaptive mode based on PDCCH/ePDCCH.

Compared with the first alternative above the second alternative may ensure resource adjustment on a per UE basis and may thus be more flexible.

For a retransmission mode indication according to exemplary embodiments of the present invention, the eNB may need to know if the UE is using ePHICH, since for contention-based RACH the eNB could not identify the UE by preamble. According, the thus described technique is specifically effective for the following use cases. On the one hand, it is applicable for any future proof extension carrier, wherein such extension carrier could be used as Pcell for new UEs. On the other hand, it is applicable e.g. for low-cost MTC UEs. Namely, for low cost MTC UEs in a backward compatible carrier, in some cases eNB could know when low cost UE is accessing. For example, on the basis of some slot based RACH or dedicate RACH resource for MTC/low-cost MTC, it could be assumed that eNB could know when such UE access is made.

In summary of the above description, exemplary embodiments of the present invention are specifically beneficial and/or effective in the following points.

With minor cost and minor impact on specification and/or implementation, an initial configuration of ePHICH could be done, and also ePHICH could support RACH Msg3 retransmission. Such feature is beneficial especially when the PDCCH load in the system is high, e.g., due to large number of MTC users, for example. Further, retransmission mode indication could be done in a signaling design to allow more flexibility for eNB to adjust the ePHICH/PDCCH resources.

In the following, special consideration is made to resource mapping or resource indexing, and the applicability of ePHICH configuration according to exemplary embodiments of the present invention in such scenario.

Figure 5 shows a schematic diagram of a resource space with multiple regions according to exemplary embodiments of the present invention.

As shown in Figure 5, a resource space (500) given by system bandwidth within one subframe may be divided into multiple regions, i.e. resource space regions. In a first region (510), such as the one extending over the entire system bandwidth in the left part of the subframe, a PDCCH may be allocated and PHICH resources may be mapped. Such region could be referred to as a legacy region or region 1, and may be applicable for legacy

UEs such as non-MTC UEs. In a second region (520), such as the one extending through a part of the system bandwidth in the right part of the subframe, an ePDCCH (E-PDCCH) may be allocated and ePHICH (E-PHICH) resources may be mapped. Such region could be referred to as an enhancement region or region 2, and may be applicable for new UEs such as MTC UEs, especially low cost MTC UEs which only have narrow band capability. The corresponding PDSCH region for the first region (510) is located in the upper and lower parts in the right part of the subframe, and the corresponding PDSCH region for the second region (520) is located in upper and lower bands along the second region in the right part of the subframe.

Accordingly, for a cell with both MTC and non-MTC UEs, there can be multiple E-/PHICH regions in terms of resource space.

In view thereof, there can be applicable multiple PHICH regions for a system with co-existence of MTC UE and non-MTC UEs, e.g. legacy PHICH region can be utilized to support legacy UEs and non-MTC new UEs. Since these UEs can be scheduled in the whole UL bandwidth, then a mapping between each PUSCH PRB and PHICH index is needed. The E-PHICH region in the narrow bandwidth can be used to feedback ACK/NACK for PUSCH from MTC UEs. Since the low cost MTC UEs can have more UL traffic than DL, such low cost MTC UEs can support the whole UL bandwidth, while they can only access to narrow band in DL. In such a case, for E-PHICH, there still needs to be a mapping between each UL PRB and the E-PHICH index. That is to say, both the PHICH region and E-PHICH region need to reserve resource for the whole system UL bandwidth. This may result in significant PHICH resource over reservation.

In this regard, PHICH design in LTE Rel-8/9/10 could be considered. On the one hand, the UE can determine its PHICH resource(s) (for example subframe, PHICH group(s), PHICH sequence(s)) in a specified manner. On the other hand, PHICH resource(s) can be configured by the eNB, for example by configuring the number of PHICH groups, N_{PHICH}^{group}. With a small value of N_{PHICH}^{group}, there may be a multiple-to-one mapping between a resource allocation parameter, such as combination (UL PRB, DMRS), and the PHICH index. Thereby, the PHICH over-reservation can be reduced at the cost of PHICH index collision.

In case of multiple PHICH regions, it is still possible to configure a smaller N_{PHICH}^{group} to reduce the PHICH overhead to make the total PHICH overhead similar as that in case of a single PHICH region. However, the collision rate may increase. To avoid the collision, some scheduling restriction may be used, or the eNB may send UL grant instead of PHICH for some UEs which again cause PDCCH control overhead increase.

Moreover, it is to be noted that, in case of multiple PHICH regions, the PHICH load in each region can be unbalanced, i.e. there is PHICH collision in one PHICH region and at the same time many PHICH resources may be left unused in another PHICH region.

Further, conventional design of implicit mapping between DL grant to PUCCH format 1 resource could be considered, where the PUCCH format 1 to be used for feedback of ACK/NACK for DL PDSCH is derived according to the index of the first CCE used for sending the corresponding DL grant. However, this can hardly be applied directly to PHICH design, i.e. derive PHICH resource based on UL grant CCE, since there is non-adaptive retransmission in UL, i.e. the UE can retransmit based a NACK in PHICH channel without need for a UL retransmission grant. Then in this case, it would be infeasible to get PHICH for the retransmission. If the PHICH resource was still derived implicitly as PUCCH, i.e. derive PHICH resource based on previous UL grant CCE, then there would arise a potential collision, since that CCE can already been used for sending UL grant for another UE.

According to exemplary embodiments of the present invention, a resource mapping configuration of ePHICH with DCI format is proposed, by way of which the above issues may be solved. Exemplary embodiments of the present invention, as outlined below, could provide solutions to solve the above issue, while minimizing any additional complexity or specification impact, for example.

According to exemplary embodiments of the present invention, a configuration of ePHICH with new DCI format is realized for enabling the UE to get ePHICH resource(s) for ACK/ANCK detection, which reduces the PHICH collision rate and potentially reduce the PHICH resource reservation, for example.

In the following, it is assumed that, in case of multiple PHICH regions (such as according to Figure 5), the UE knows the PHICH configuration in each region, e.g. from system information or RRC signaling.

Figure 6 shows a schematic diagram illustrating a third example of a procedure in the context of ePHICH configuration according to exemplary embodiments of the present invention.

As shown in Figure 6, a procedure according to exemplary embodiments of the present invention may comprise, at the network side, an operation (S610) of instructing reservation of resources for the channel in question (i.e. ePHICH) out of at least one of a plurality of resource space regions in accordance with a resource configuration in each resource space region. An instruction in this regard may be an instruction for detecting resources in at least one resource space region for resource allocation, and for mapping of the detected resources. Additionally or alternatively, a procedure according to exemplary embodiments of the present invention may comprise, at the terminal side, an operation (S620) of reserving resources for the channel in question (i.e. ePHICH) out of at least one of a plurality of resource space regions in accordance with a resource configuration in each resource space region. A resource reservation in this regard may comprise detecting (S620a) resources in at least one resource space region for resource allocation, and mapping (S620b) of the detected resources.

Figure 7 shows a schematic diagram (Fig. 7(a)) of a resource space with multiple regions and a schematic diagram (Fig. 7(b)) of a concept of collision avoidance according to exemplary embodiments of the present invention.

As shown in Figure 7(a), it is assumed that there are two PHICH regions (710, 720) in the resource space (700). The first PHICH region (710) is legacy PHICH which is multiplexed with legacy PDCCH, while the second PHICH region (720) is aPHICH which is multiplexed with ePDCCH. For the following description of alternatives, it may be assumed that UE1 and UE2 are new non-MTC UEs, and UE3 is a low cost MTC UE. The configurations of both PHICH regions are assumed to be known to UE1 and UE2, while it is assumed that UE3 can be configured with PHICH region#2 only.

According to exemplary embodiments of the present invention, as indicated in Figure 7(b), various alternatives are applicable in terms of resource reservation in a resource reservation space (730). Any one of these alternatives may be accomplished on/by the network side (i.e. corresponding instruction(s)) and/or on/by the terminal side (i.e. corresponding execution(s)), respectively.

The alternatives described next correspond to techniques for achieving load balance in multiple PHICH regions and for reducing collision rate. These alternatives may be applied distinctively or in combination.

In a first alternative in this regard, resources may be detected in at least one resource space region for resource allocation on the basis of a channel-specific radio network temporary identifier of the channel in question (i.e. ePHICH), and every uplink physical resource may be mapped block to one of the detected resources.

Namely, in case there are multiple ePHICH/PHICH regions, one UE can be indicated implicitly (e.g. during initial access) in which PHICH region to detect HARQ-ACK feedback for its PUSCH transmission. For example, the PHICH region to detect can be derived implicitly (in sort of semi-static manner) from an allocated RNTI, e.g. ePHICH-RNTI.

The UE1 and UE2 can be configured to detect PHICH region#1 or PHICH region#2 for the PUSCH feedback, and such configuration may be implicit and UE can derive it e.g. from the allocated RNTI. Thereby, an implicit way of initial PHICH region allocation may be provided, which helps PHICH load balance to avoid that too many UEs need to detect PHICH in the same region and then cause collision. Since both MTC and non-MTC UEs are assumed to be scheduled in the whole UL bandwidth, rather than restricted to the narrow bandwidth as ePDCCH, then in both PHICH regions every UL PRB is mapped to one of the PHICH resources. Then, to reduce PHICH overhead, there can be multiple UL PRBs mapped to the same PHICH resource in each region. The more UEs are in one PHICH region, the higher the collision rate is. Such initial load balance is beneficial and effective.

In a second alternative in this regard, resources may be detected in at least one resource space region for resource allocation on the basis of an indication in an uplink grant corresponding to the channel in question (i.e. ePHICH), and every uplink physical resource block may be mapped to one of the detected resources.

Namely, in case there are multiple ePHICH/PHICH regions, one UE can be indicated dynamically (e.g. during contention-based access) in which (e)PHICH region to detect HARQ-ACK feedback for its PUSCH transmission. For example, a corresponding indication can be made in UL grant as additional bit(s) and/or by reinterpreting some original bit(s) thereof.

This alternative may improve load balance via enabling dynamic adjustment of PHICH region. The adjustment can be done e.g. via 1 additional bit in UL grant (which for example be a (reinterpreted) padding bit in UL grant as well) to indicate which PHICH region to detect the PUSCH feedback. For example, both UE1 and UE2 can be configured to detect PHICH region#1 (e.g. as initial setting and/or as a result of the aforementioned technique of implicit indication), then in the same subframe UE1 can be scheduled to send PUSCH in PRB i, while UE2 can be scheduled to send PUSCH in PRB j. As PRB i and j can map to the same PHICH resource in PHICH region#1, then there can be PHICH collision. In such a case, the eNB can indicate to UE1 or UE2 to detect PHICH in region#2, if the corresponding PHICH resource is unoccupied. Otherwise, the collision may be avoided via not scheduling UE1 or UE2, or via sending UL grant to UE1 or UE2 for the retransmission. Then, this may result in scheduling restriction or increase in control overhead.

The alternative described next corresponds to a technique for mapping PHICH resource based on a different parameter as in the above alternatives, i.e. other than the PUSCH PRB, which helps reducing PHICH resource reservation.

In this alternative, resources may be detected in at least one resource space region for resource allocation, and a plurality of uplink physical resource blocks may be mapped for every control channel element to one of the detected resources.

The ePHICH resource may for example be determined by a function of CCE index of UL grant. For example, the ePHICH resource may be determined by a function of one or more of CCE index of UL grant, CCE aggregation level for UL grant, retransmission number, and an explicit indicator of PHICH index for retransmission in over-reserved PHICH resource (wherein DMRS cyclic shift of PUSCH may be reused and/or new (e.g. 2) bits in DCI format 0 may be defined).

Namely, a new mapping rule is provided by the present alternative.

Conventionally, the PHICH resource is mapped by PUSCH PRB index and DMRS cyclic shift. Obviously, if reserving PHICH resource for each PRB and each DMRS cyclic shift, there is much over-reservation, since not all DMRS cyclic shift will be used and not all PRBs will be scheduled as first PRB of one UE's PUSCH.

Accordingly, to reduce the reservation, the technique according to the present alternative is to allow multiple-to-one mapping, e.g. a mapping of multiple (PRB, DMRS cyclic shift) combinations to the same PHICH resource. While resource over-reservation may be reduced thereby, collision rate may potentially increase.

The present alternative provides a new mapping rule which can reduce the PHICH resource reservation without or with very low (increase in) collision rate. This new mapping specifically applies to the ePHICH region, since in the narrow band ePDCCH region there are less CCEs reserved for control, e.g. there are only 8 CCEs reserved for scheduling MTC UEs in narrow band. According to the present alternative, the PHICH resource for each CCE is reserved and then compared with reserving PHICH for each UL PRB, thereby avoiding much PHICH reservation.

For example, for a UE with CCE aggregation level L for its UL grant, then the PHICH resource can be derived as follows.

According to a first rule, for a retransmission of a certain number, the resource is mapped by the control channel element of the same number of an uplink grant corresponding to the channel in question (i.e. ePHICH).

By the first rule:

For the ith retransmission, the E-PHICH will be mapped by the ith CCE of UL grant unless UL grant is detected.

According to this, the retransmission can get PHICH resource without collision by using other CCEs of its previous UL grant if the aggregation level is larger than 1.

Namely, as one DCI may occupy multiple CCEs, the ePHICH resource can be derived as a function of the ith CCE's index of the UL grant DCI.

According to a second rule, for a retransmission of a certain number equal to or smaller than the minimum between an aggregation level of control channel element and a predefined number, the resource is mapped by the control channel element of the same number of an uplink grant corresponding to the channel in question (i.e. ePHICH), or for a retransmission of a certain number larger than the minimum between an aggregation level of control channel element and a predefined number, the resource is mapped based on a demodulation reference signal cyclic shift on the basis of an indication in an uplink grant corresponding to the channel in question (i.e. ePHICH).

By the second rule:

For the ith retransmission (i<=min (L,M)), the E-PHICH will be mapped by the ith CCE of UL grant, where M is predefined or configured e.g. by eNB.

For the ith retransmission (i>min(L,M)), PHICH is mapped based on DMRS cyclic shift, e.g. for the ith retransmission (i> min (L, M)), the PHICH resource to be used can be derived as $N+I_{Cyclic\_shift}$, where N is the total number of CCEs in the subframe in question, and I_{cyclic_shift} is the cyclic shift indicated in a previous UL grant. This requires the system to reserve more PHICH resources than the number of CCEs in control region.

According to this, a certain explicit indicator in UL grant (e.g. by reusing DMRS cyclic shift and/or defining new bits in UL grant) is utilized to avoid the collision due to retransmission. For some retransmission with less collision rate, i.e. i< min(L,M), the PHICH resource is mapped by CCE index, while in high collision rate case, DMRS cyclic shift may be used to shift the PHICH detection to over-reservation PHICH region (i.e. to over-reserve a bit more than total CCE numbers).

It is to be noted that in any case UL grant can be sent by eNB when necessary to override the ACK/NACK feedback in PHICH, e.g. in case adaptive retransmission is needed, or to avoid a collision.

The following is noted with respect to collision rate considerations with respect to the second rule of the third alternative described above.

As a first exemplary use case scenario, MTC UEs operating with 1.4MHz are assumed.

Assuming ePDCCH for MTC has similar control region density as traditional Rel-8 PDCCH, there are a total of 6 CCEs within the 1.4MHz band. Besides, a typical case may be considered, which is to schedule 2 UEs with L=1 and

2 UEs with L=2 in one subframe. Therefore, it could be a maximum of 6 MTC UEs (4 new UEs + 2 retransmission UEs) that need PHICH. If 6 PHICH links are reserved to each CCE and 2 PHICH over-reserved resources, no high collision rate will arise.

For CCE aggregation level L=2 and above, retransmission PHICH can be almost well contained in PHICH resource linked to second CCE of previous grant, and will not use over-reserved resource. This assumes that eNB tried to keep all L=2 CCE in the same position.

For CCE aggregation level L=1, it will use over-reserved PHICH for first retransmission. Assume that there is assigned a different cyclic shift value in UL grants for L=1 UEs in initial grant, they could use different PHICH in over-reserved PHICH part. The only collision is in case any L=1 need a second retransmission and will collide with next L=1 UE's first retransmission. Assuming two independent UEs, UE A's first retransmission probability is 0.2 (BLER target is 20%), UE B's second retransmission probability is 0.05, the chance this happens simultaneously is 1%. That is, the collision rate is 1%. This is worst case, since the calculation assumes that 20% block error only happens to aggregation level L=1 UE.

As a second exemplary use case scenario, MTC UEs operating with 5MHz are assumed.

Similarly, there may be considered a total of 28 CCEs in one subframe, and there may be assumed a typical case of 4 UEs of L=1, 4 UEs of L=2, 2 UEs of L=4 in one subframe. Thus, there could be a maximum of 18 MTC UEs (10 new UEs + 8 retransmission UEs) that need PHICH. If 28 PHICH links are reserved to each CCE and 4 PHICHs are over-reserved, a proper handling is possible (32 PHICH in total).

For CCE aggregation level L=2 and above, considering 20% first transmission BLER, in average 1.2 UE will need to use PHICH resource linked to second CCE of previous grant for first retransmission. For L=4 UE, it will be well contained in 4 PHICH resource linked to 4 CCEs of initial grant.

For L=2 who get ACK in first retransmission, it will not need further PHICH. For L=2 who need go to second retransmission, it will go to over-reserved resource, the chance of this happening is 5%*(4/10)=2%.

For CCE aggregation level L=1, it will use over-reserved PHICH part for first retransmission. Assume that there is assigned different cyclic shift value for L=1 UEs, the over-reserved PHICH resource is enough. The collision might happen when second retransmission of L=1 is needed, the chance is 1%. On top of this, it might still collide with L=2 UE who need go to second retransmission.

Total worse case collision rate considering all aggregation level is 3%. This is worst case. Further, L=2's maximum transmission may be blocked to two to reduce the collision rate to 1%.

In summary of the above description, exemplary embodiments of the present invention are specifically beneficial and/or effective in the following points.

Specifically, load balancing between (load in) different resource space regions may be achieved. At the same time, a reduction in PHICH resource (over-) reservation and/or a reduction in collision rate may be potentially achieved.

Generally, the above-described procedures and functions may be implemented by respective functional elements, processors, or the like, as described below.

While in the foregoing exemplary embodiments of the present invention are described mainly with reference to methods, procedures and functions, corresponding exemplary embodiments of the present invention also cover respective apparatuses, network nodes and systems, including both software and/or hardware thereof.

Respective exemplary embodiments of the present invention are described below referring to Figure 8, while for the sake of brevity reference is made to the detailed description with regard to Figures 1 to 7.

In Figure 8 below, which is noted to represent a simplified block diagram, the solid line blocks are basically configured to perform respective operations as described above. The entirety of solid line blocks are basically configured to perform the methods and operations as described above, respectively. With respect to Figure 8, it is to be noted that the individual blocks are meant to illustrate respective functional blocks implementing a respective function, process or procedure, respectively. Such functional blocks are implementation-independent, i.e. may be implemented by means of any kind of hardware or software, respectively. The arrows and lines interconnecting individual blocks are meant to illustrate an operational coupling there-between, which may be a physical and/or logical coupling, which on the one hand is implementation-independent (e.g. wired or wireless) and on the other hand may also comprise an arbitrary number of intermediary functional entities not shown. The direction of arrow is meant to illustrate the direction in which certain operations are performed and/or the direction in which certain data is transferred.

Further, in Figure 8, only those functional blocks are illustrated, which relate to any one of the above-described methods, procedures and functions. A skilled person will acknowledge the presence of any other conventional functional blocks required for an operation of respective structural arrangements, such as e.g. a power supply, a central processing unit, respective memories or the like. Among others, memories are provided for storing programs or program instructions for controlling the individual functional entities to operate as described herein.

Figure 8 shows a schematic block diagram illustrating exemplary apparatuses according to exemplary embodiments of the present invention.

In view of the above, the thus illustrated apparatuses 10 and 20 are suitable for use in practicing the exemplary embodiments of the present invention, as described herein.

The thus illustrated apparatus 10 may represent a (part of a) terminal entity such as a terminal or user equipment, e.g. a non-/MTC UE, or a modem (which may be installed as part of a UE or the like, but may be also a separate module, which can be attached to various devices, as described above), and may be configured to perform a procedure and/or functionality as described in conjunction with any one of Figures 1 to 7. The thus illustrated apparatus 20 may represent a (part of a) network entity such as a base station or access node, e.g. an eNB, and may be configured to perform a procedure and/or functionality as described in conjunction with any one of Figures 1 to 7.

As indicated in Figure 8, according to exemplary embodiments of the present invention, each of the apparatuses comprises a processor 11/21, a memory 12/22 and an interface 13/23, which are connected by a bus 14/24 or the like, and the apparatuses may be connected via a link 30. The link 30 may be a physical and/or logical coupling, which is implementation-independent (e.g. wired or wireless).

The processor 11/21 and/or the interface 13/23 may be facilitated for communication over a (hardwire or wireless) link, respectively. The interface 13/23 may comprise a suitable receiver or a suitable transmitter-receiver combination or transceiver, which is coupled to one or more antennas or communication means for (hardwire or wireless) communications with the linked or connected device(s), respectively. The interface 13/23 is generally configured to communicate with another apparatus, i.e. the interface thereof.

The memory 12/22 may store respective programs assumed to include program instructions or computer program code that, when executed by the respective processor, enables the respective electronic device or apparatus to operate in accordance with the exemplary embodiments of the present invention.

In general terms, the respective devices/apparatuses (and/or parts thereof) may represent means for performing respective operations and/or exhibiting respective functionalities, and/or the respective devices (and/or parts thereof) may have functions for performing respective operations and/or exhibiting respective functionalities.

When in the subsequent description it is stated that the processor (or some other means) is configured to perform some function, this is to be construed to be equivalent to a description stating that at least one processor, potentially in cooperation with computer program code stored in the memory of the respective apparatus, is configured to cause the apparatus to perform at least the thus mentioned function. Also, such function is to be construed to be equivalently implementable by specifically configured means for performing the respective function (i.e. the expression "processor configured to [cause the apparatus to] perform xxx-ing" is construed to be equivalent to an expression such as "means for xxx-ing").

According to exemplary embodiments of the present invention, an apparatus representing the apparatus 10 comprises at least one processor 11, at least one memory 12 including computer program code, and at least one interface 13 configured for communication with at least another apparatus. The processor (i.e. the at least one processor 11, with the at least one memory 12 and the computer program code) is configured to perform establishing configuration of an enhanced physical hybrid automatic repeat request indicator channel with downlink control information in a predetermined format in terms of at least one of radio network temporary identifier and resource mapping, and initiating signaling of the established configuration towards a network side.

Stated in other words, the apparatus 10 may comprise means for establishing configuration of an enhanced physical hybrid automatic repeat request indicator channel with downlink control information in a predetermined format in terms of at least one of radio network temporary identifier and resource mapping, and means for initiating signaling of the established configuration towards a network side.

As outlined above, in various forms, the apparatus 10 may comprise one or more of respective functionalities or means for adopting a channel-specific radio network temporary identifier as an initial identifier configuration of said channel, obtaining indication on a retransmission mode for a specific message transmitted on said channel, applying said channel in a non-adaptive mode or a physical downlink control channel or enhanced physical downlink control channel in an adaptive mode, reserving resources for said channel out of at least one of a plurality of resource space regions in accordance with a resource configuration in each resource space region, detecting resources in at least one resource space region for resource allocation, and mapping to one of the detected resources.

According to exemplary embodiments of the present invention, an apparatus representing the network entity 20 comprises at least one processor 20, at least one memory 22 including computer program code, and at least one interface 23 configured for communication with at least another apparatus. The processor (i.e. the at least one processor 21, with the at least one memory 22 and the computer program code) is configured to perform preparing configuration of an enhanced physical hybrid automatic repeat request indicator channel with downlink control information in a predetermined format in terms of at least one of radio network temporary identifier and resource mapping, and initiating signaling of the prepared configuration towards a terminal side.

Stated in other words, the apparatus 20 may comprise means for preparing configuration of an enhanced physical hybrid automatic repeat request indicator channel with downlink control information in a predetermined format in terms of at least one of radio network temporary identifier and resource mapping, and means for initiating signaling of the prepared configuration towards a terminal side.

As outlined above, in various forms, the apparatus 20 may comprise one or more of respective functionalities or means for setting a channel-specific radio network temporary identifier as an initial identifier configuration of said channel, determining at least one of system load and load on a physical downlink control channel or enhanced physical downlink control channel, issuing indication on a retransmission mode for a specific message transmitted on said channel, instructing reservation of resources for said channel out of at least one of a plurality of resource space regions in accordance with a resource configuration in each resource space region, and instructing for detecting resources in at least one resource space region for resource allocation and for mapping to one of the detected resources.

For further details of specifics regarding functionalities according to exemplary embodiments of the present invention, reference is made to the foregoing description in conjunction with Figures 1 to 7.

According to exemplarily embodiments of the present invention, a system may comprise any conceivable combination of the thus depicted devices/apparatuses and other network elements, which are configured to cooperate as described above.

In general, it is to be noted that respective functional blocks or elements according to above-described aspects can be implemented by any known means, either in hardware and/or software, respectively, if it is only adapted to perform the described functions of the respective parts. The mentioned method steps can be realized in individual functional blocks or by individual devices, or one or more of the method steps can be realized in a single functional block or by a single device.

Generally, any structural means such as a processor or other circuitry may refer to one or more of the following: (a) hardware-only circuit implementations (such as implementations in only analog and/or digital circuitry) and (b) combinations of circuits and software (and/or firmware), such as (as applicable): (i) a combination of processor(s) or (ii) portions of processor(s)/software (including digital signal processor(s)), software, and memory(ies) that work together to cause an apparatus, such as a mobile phone or server, to perform various functions) and (c) circuits, such as a microprocessor(s) or a portion of a microprocessor(s), that require software or firmware for operation, even if the software or firmware is not physically present. Also, it may also cover an implementation of merely a processor (or multiple processors) or portion of a processor and its (or their) accompanying software and/or firmware, any integrated circuit, or the like.

Generally, any procedural step or functionality is suitable to be implemented as software or by hardware without changing the idea of the present invention. Such software may be software code independent and can be specified using any known or future developed programming language, such as e.g. Java, C++, C, and Assembler, as long as the functionality defined by the method steps is preserved. Such hardware may be hardware type 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. A device/apparatus may be represented by a semiconductor chip, a chipset, system in package, or a (hardware) module comprising such chip or chipset; this, however, does not exclude the possibility that a functionality of a device/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 a device/apparatus or as an assembly of more than one device/apparatus, whether functionally in cooperation with each other or functionally independently of each other but in a same device housing, for example.

Apparatuses and/or means or parts thereof can be implemented as individual devices, but this does not exclude that they may be implemented in a distributed fashion throughout the system, as long as the functionality of the device is preserved. Such and similar principles are to be considered as known to a skilled person.

Software in the sense of the present description comprises software code as such comprising code means or portions or a computer program or a computer program product for performing the respective functions, as well as software (or a computer program or a computer program product) embodied on a tangible medium such as a computer-readable (storage) medium having stored thereon a respective data structure or code means/portions or embodied in a signal or in a chip, potentially during processing thereof.

The present invention also covers any conceivable combination of method steps and operations described above, and any conceivable combination of nodes, apparatuses, modules or elements described above, as long as the above-described concepts of methodology and structural arrangement are applicable.

In view of the above, the present invention and/or exemplary embodiments thereof provide measures for realizing configuration of an enhanced physical hybrid automatic repeat request indicator channel (ePHICH). Such measures may exemplarily comprise preparing or establishing configuration of an enhanced physical hybrid automatic repeat request indicator channel (ePHICH) with downlink control information in a predetermined format in terms of at least one of radio network temporary identifier and resource mapping, and signaling the prepared or established configuration towards a terminal or network side.

Even though the present invention and/or exemplary embodiments are described above with reference to the examples according to the accompanying drawings, it is to be understood that they are not restricted thereto. Rather, it is apparent to those skilled in the art that the present invention can be modified in many ways without departing from the scope of the inventive idea as disclosed herein.

List of acronyms and abbreviations

3GPP	Third Generation Partnership Project
ARQ	Automatic Repeat Request
BLER	Block Error Rate
CCE	Control Channel Element
CoMP	Coordinated Multi-Point Communication
C-RNTI	Cell RNTI
CRC	Cyclic Redundancy Check
CS	Cyclic Shift
DCI	Downlink Control Information
DL	Downlink
DMRS	Demodulation Reference Signal
eNB	evolved Node B (E-UTRAN base station)
E-/ePDCCH	Enhanced Physical Downlink Control Channel
E-/ePHICH	Enhanced Physical Hybrid-ARQ Indicator Channel
HARQ	Hybrid ARQ
ICIC	Inter Cell Interference Cancellation
LTE	Long Term Evolution
LTE-A	Long Term Evolution Advanced
MIB	Master Information Block
MTC	Machine Type Communication
MU-MIMO	Multi User Multiple Input Multiple Output
PDCCH	Physical Downlink Control Channel
PDSCH	Physical Downlink Shared Channel
PHICH	Physical Hybrid-ARQ Indicator Channel
PRB	Physical Resource Block
PUCCH	Physical Uplink Control Channel
PUSCH	Physical Uplink Shared Channel
RACH	Random Access Channel
RAR	Random Access Response
RNTI	Radio Network Temporary Identifier
RRC	Radio Resource Control
SIB	System Information Block

TPC	Transmit Power Control
T-C-RNTI	Temporary C-RNTI
UE	User Equipment
UL	Uplink

What is claimed is:

1. A method comprising

establishing configuration of an enhanced physical hybrid automatic repeat request indicator channel with downlink control information in a predetermined format in terms of at least one of radio network temporary identifier and resource mapping, and

initiating signaling of said channel with the established configuration towards a network side.

2. The method according to claim 1, wherein establishing configuration comprises

adopting a predefined channel-specific radio network temporary identifier as an initial identifier configuration of said channel, and/or

adopting a channel-specific radio network temporary identifier, which is associated with at least one specific radio network temporary identifier value, as an initial identifier configuration of said channel.

3. The method according to claim 2, wherein the adopted channel-specific radio network temporary identifier configures said channel for transmission of a random access message in a random access procedure.

4. The method according to any one of claims 1 to 3, wherein establishing configuration comprises

obtaining indication on a retransmission mode for a specific message transmitted on said channel, and

applying said channel in a non-adaptive mode or a physical downlink control channel or enhanced physical downlink control channel in an adaptive mode as the retransmission mode for the specific message on the basis of the obtained indication.

5. The method according to claim 4, wherein

the indication is obtained in at least one of a master information block, a system information block, and a random access response, and/or the specific message comprises a terminal-specific random access message in a random access procedure.

6. The method according to any one of claims 1 to 5, wherein establishing configuration comprises

reserving resources for said channel out of at least one of a plurality of resource space regions in accordance with a resource configuration in each resource space region.

7. The method according to claim 6, wherein reserving comprises

detecting resources in at least one resource space region for resource allocation on the basis of a channel-specific radio network temporary identifier of said channel, and

mapping every uplink physical resource block to one of the detected resources.

8. The method according to claim 6 or 7, wherein reserving comprises

detecting resources in at least one resource space region for resource allocation on the basis of an indication in an uplink grant corresponding to said channel, and

mapping every uplink physical resource block to one of the detected resources.

9. The method according to claim 6, wherein reserving comprises

detecting resources in at least one resource space region for resource allocation, and

mapping a plurality of uplink physical resource blocks for every control channel element to one of the detected resources.

10. The method according to claim 9, wherein

for a retransmission of a certain number, the resource is mapped by the control channel element of the same number of an uplink grant corresponding to said channel.

11. The method according to claim 9 or 10, wherein

for a retransmission of a certain number equal to or smaller than the minimum between an aggregation level of control channel element and a predefined number, the resource is mapped by the control channel element of the same number of an uplink grant corresponding to said channel, or

for a retransmission of a certain number larger than the minimum between an aggregation level of control channel element and a predefined number, the resource is mapped based on a demodulation reference signal cyclic shift on the basis of an indication in an uplink grant corresponding to said channel.

12. A method comprising

preparing configuration of an enhanced physical hybrid automatic repeat request indicator channel with downlink control information in a predetermined format in terms of at least one of radio network temporary identifier and resource mapping, and

initiating signaling of said channel with the prepared configuration towards a terminal side.

13. The method according to claim 12, wherein preparing configuration comprises

setting a predefined channel-specific radio network temporary identifier as an initial identifier configuration of said channel, and/or

setting a channel-specific radio network temporary identifier, which is associated with at least one specific radio network temporary identifier value, as an initial identifier configuration of said channel.

14. The method according to claim 12 or 13, wherein preparing configuration comprises

determining at least one of system load and load on a physical downlink control channel or enhanced physical downlink control channel, and

issuing indication on a retransmission mode for a specific message transmitted on said channel on the basis of the determined load.

15. The method according to claim 14, wherein

the indication is issued in at least one of a master information block, a system information block, and a terminal-specific random access response, and/or

the specific message comprises a random access message in a random access procedure.

16. The method according to any one of claims 12 to 15, wherein preparing configuration comprises

instructing reservation of resources for said channel out of at least one of a plurality of resource space regions in accordance with a resource configuration in each resource space region.

17. The method according to claim 16, wherein instructing comprises an instruction for

detecting resources in at least one resource space region for resource allocation on the basis of a channel-specific radio network temporary identifier of said channel, and

mapping every uplink physical resource block to one of the detected resources.

18. The method according to claim 16 or 17, wherein instructing comprises an instruction for

detecting resources in at least one resource space region for resource allocation on the basis of an indication in an uplink grant corresponding to said channel, and

mapping every uplink physical resource block to one of the detected resources.

19. The method according to claim 16, wherein instructing comprises an instruction for

detecting resources in at least one resource space region for resource allocation, and

mapping a plurality of uplink physical resource blocks for every control channel element to one of the detected resources.

20. The method according to claim 19, wherein

for a retransmission of a certain number, the resource is to be mapped by the control channel element of the same number of an uplink grant corresponding to said channel.

21. The method according to claim 19 or 20, wherein

for a retransmission of a certain number equal to or smaller than the minimum between an aggregation level of control channel element and a predefined number, the resource is to be mapped by the control channel element of the same number of an uplink grant corresponding to said channel, or

for a retransmission of a certain number larger than the minimum between an aggregation level of control channel element and a predefined number, the resource is to be mapped based on a demodulation reference signal cyclic shift on the basis of an indication in an uplink grant corresponding to said channel.

22. An apparatus comprising

at least one processor,

at least one memory including computer program code, and

at least one interface configured for communication with at least another apparatus,

the at least one processor, with the at least one memory and the computer program code, being configured to cause the apparatus to perform:

establishing configuration of an enhanced physical hybrid automatic repeat request indicator channel with downlink control information in a predetermined format in terms of at least one of radio network temporary identifier and resource mapping, and

initiating signaling of said channel with the established configuration towards a network side.

23. The apparatus according to claim 22, wherein the at least one processor is configured to cause the apparatus to perform:

adopting a predefined channel-specific radio network temporary identifier as an initial identifier configuration of said channel, and/or

adopting a channel-specific radio network temporary identifier, which is associated with at least one specific radio network temporary identifier value, as an initial identifier configuration of said channel.

24. The apparatus according to claim 23, wherein the adopted channel-specific radio network temporary identifier configures said channel for transmission of a random access message in a random access procedure.

25. The apparatus according to any one of claims 22 to 24, wherein the at least one processor is configured to cause the apparatus to perform:

obtaining indication on a retransmission mode for a specific message transmitted on said channel, and

applying said channel in a non-adaptive mode or a physical downlink control channel or enhanced physical downlink control channel in an adaptive mode as the retransmission mode for the specific message on the basis of the obtained indication.

26. The apparatus according to claim 25, wherein the at least one processor is configured such that

the indication is obtained in at least one of a master information block, a system information block, and a random access response, and/or

the specific message comprises a terminal-specific random access message in a random access procedure.

27. The apparatus according to any one of claims 22 to 26, wherein the at least one processor is configured to cause the apparatus to perform:

reserving resources for said channel out of at least one of a plurality of resource space regions in accordance with a resource configuration in each resource space region.

28. The apparatus according to claim 27, wherein the at least one processor is configured to cause the apparatus to perform: detecting resources in at

least one resource space region for resource allocation on the basis of a channel-specific radio network temporary identifier of said channel, and

mapping every uplink physical resource block to one of the detected resources.

29. The apparatus according to claim 27 or 28, wherein the at least one processor is configured to cause the apparatus to perform:

detecting resources in at least one resource space region for resource allocation on the basis of an indication in an uplink grant corresponding to said channel, and

mapping every uplink physical resource block to one of the detected resources.

30. The apparatus according to claim 27, wherein the at least one processor is configured to cause the apparatus to perform: detecting resources in at least one resource space region for resource allocation, and

mapping a plurality of uplink physical resource blocks for every control channel element to one of the detected resources.

31. The apparatus according to claim 30, wherein the at least one processor is configured such that

for a retransmission of a certain number, the resource is mapped by the control channel element of the same number of an uplink grant corresponding to said channel.

32. The apparatus according to claim 30 or 31, wherein the at least one processor is configured such that

for a retransmission of a certain number equal to or smaller than the minimum between an aggregation level of control channel element and a predefined number, the resource is mapped by the control channel element of the same number of an uplink grant corresponding to said channel, or

for a retransmission of a certain number larger than the minimum between an aggregation level of control channel element and a predefined number, the resource is mapped based on a demodulation reference signal cyclic shift on the basis of an indication in an uplink grant corresponding to said channel.

33. The apparatus according to any one claims 22 to 32, wherein

the apparatus is operable as or at a terminal or user equipment or modem operable in a cellular communication system, and/or

the apparatus is operable in at least one of a LTE and a LTE-A cellular system.

34. An apparatus comprising

at least one processor,

at least one memory including computer program code, and

at least one interface configured for communication with at least another apparatus,

the at least one processor, with the at least one memory and the computer program code, being configured to cause the apparatus to perform:

preparing configuration of an enhanced physical hybrid automatic repeat request indicator channel with downlink control information in a predetermined format in terms of at least one of radio network temporary identifier and resource mapping, and

initiating signaling of said channel with the prepared configuration towards a terminal side.

35. The apparatus according to claim 34, wherein the at least one processor is configured to cause the apparatus to perform:

setting a predefined channel-specific radio network temporary identifier as an initial identifier configuration of said channel, and/or

setting a channel-specific radio network temporary identifier, which is associated with at least one specific radio network temporary identifier value, as an initial identifier configuration of said channel.

36. The apparatus according to claim 34 or 35, wherein the at least one processor is configured to cause the apparatus to perform:

determining at least one of system load and load on a physical downlink control channel or enhanced physical downlink control channel, and

issuing indication on a retransmission mode for a specific message transmitted on said channel on the basis of the determined load.

37. The apparatus according to claim 36, wherein the at least one processor is configured such that

the indication is issued in at least one of a master information block, a system information block, and a terminal-specific random access response, and/or

the specific message comprises a random access message in a random access procedure.

38. The apparatus according to any one of claims 34 to 37, wherein the at least one processor is configured to cause the apparatus to perform:

instructing reservation of resources for said channel out of at least one of a plurality of resource space regions in accordance with a resource configuration in each resource space region.

39. The apparatus according to claim 38, wherein the at least one processor is configured to cause the apparatus to perform instructing by an instruction for:

detecting resources in at least one resource space region for resource allocation on the basis of a channel-specific radio network temporary identifier of said channel, and

mapping every uplink physical resource block to one of the detected resources.

40. The apparatus according to claim 38 or 39, wherein the at least one processor is configured to cause the apparatus to perform instructing by an instruction for:

detecting resources in at least one resource space region for resource allocation on the basis of an indication in an uplink grant corresponding to said channel, and mapping every uplink physical resource block to one of the detected resources.

41. The apparatus according to claim 38, wherein the at least one processor is configured to cause the apparatus to perform instructing by an instruction for:

detecting resources in at least one resource space region for resource allocation, and

mapping a plurality of uplink physical resource blocks for every control channel element to one of the detected resources.

42. The apparatus according to claim 41, wherein the at least one processor is configured such that

for a retransmission of a certain number, the resource is to be mapped by the control channel element of the same number of an uplink grant corresponding to said channel.

43. The apparatus according to claim 41 or 42, wherein the at least one processor is configured such that

for a retransmission of a certain number equal to or smaller than the minimum between an aggregation level of control channel element and a predefined number, the resource is to be mapped by the control channel element of the same number of an uplink grant corresponding to said channel, or

for a retransmission of a certain number larger than the minimum between an aggregation level of control channel element and a predefined number, the resource is to be mapped based on a demodulation reference signal cyclic shift on the basis of an indication in an uplink grant corresponding to said channel.

44. The apparatus according to any one claims 34 to 43, wherein

the apparatus is operable as or at a base station or access node of a cellular communication system, and/or

the apparatus is operable in at least one of a LTE and a LTE-A cellular system.

45. A computer program product comprising computer-executable computer program code which, when the program is run on a computer, is configured to cause the computer to carry out the method according to any one of claims 1 to 11 or any one of claims 12 to 21.

46. The computer program product according to claim 45, embodied as a computer-readable storage medium.

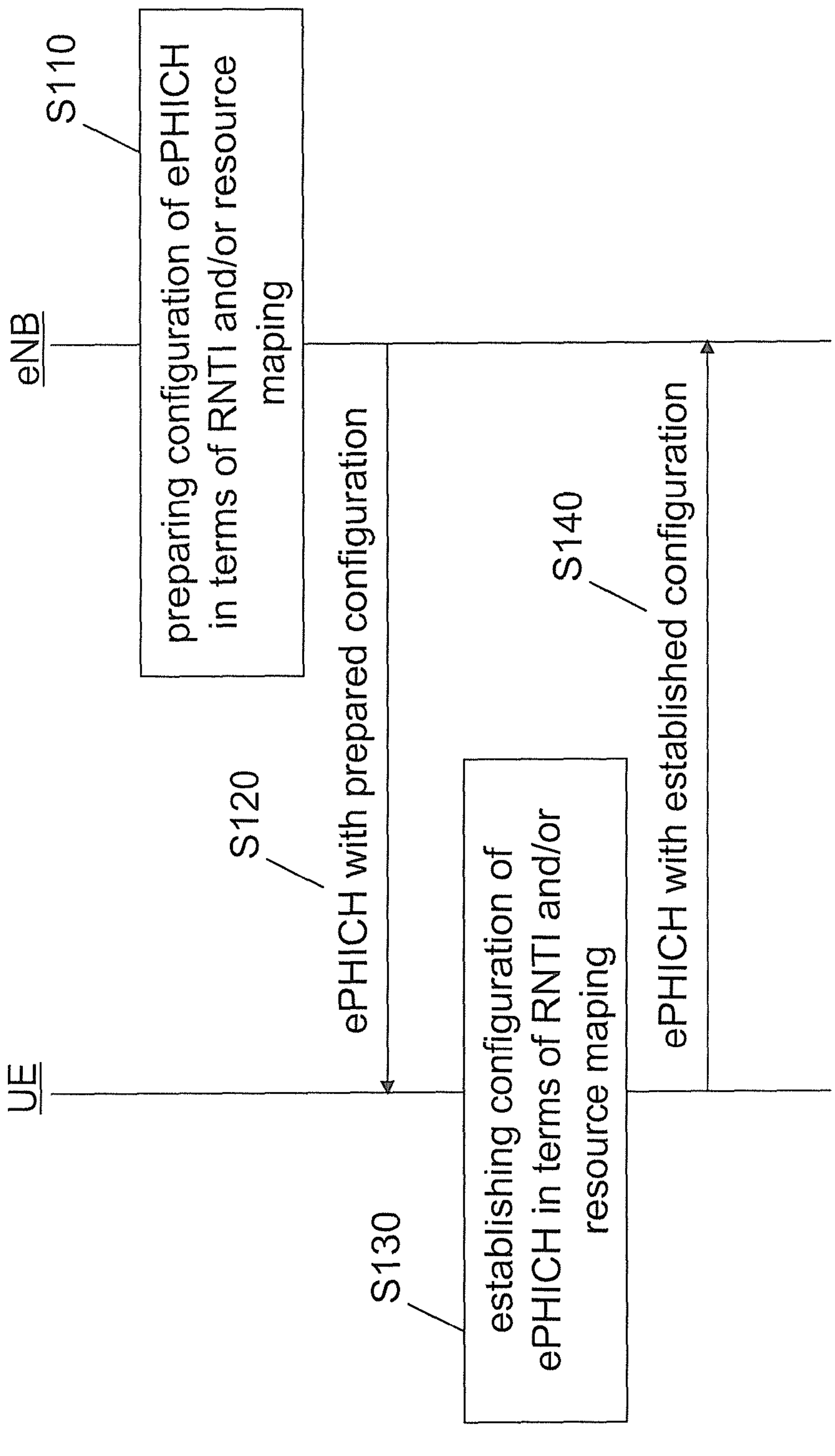
eNB
UE
S110
preparing configuration of ePHICH in terms of RNTI and/or resource maping
S120
ePHICH with prepared configuration
S130
establishing configuration of ePHICH in terms of RNTI and/or resource maping
S140
ePHICH with established configuration

Figure 1

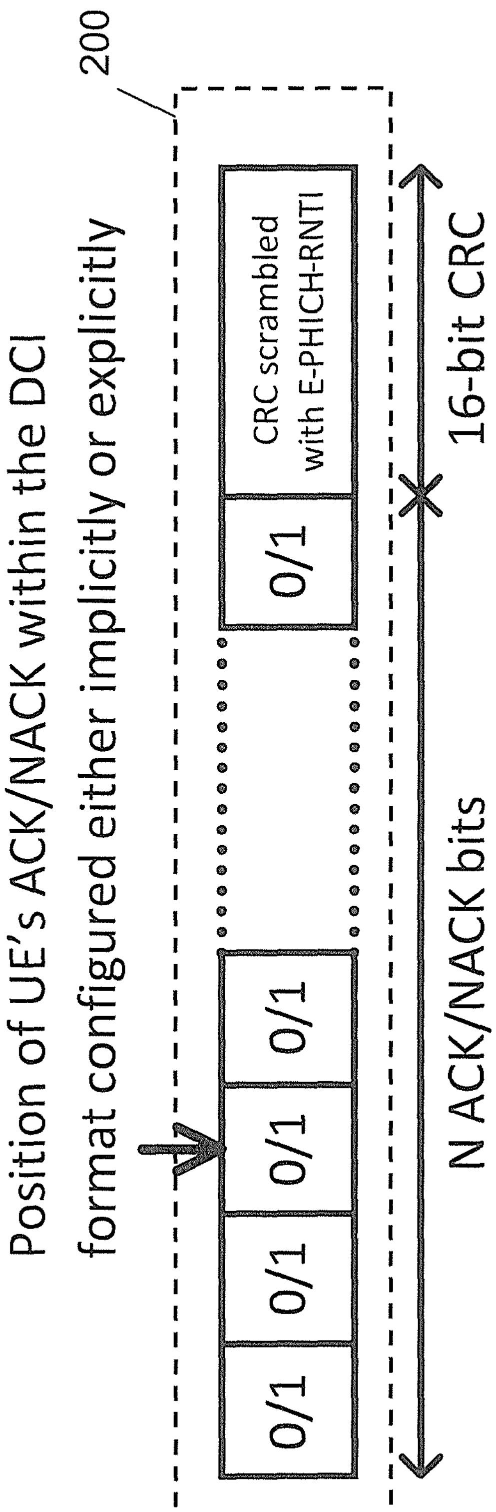
200
Position of UE's ACK/NACK within the DCI format configured either implicitly or explicitly
0/1
0/1
0/1
0/1
0/1
CRC scrambled with E-PHICH-RNTI
N ACK/NACK bits
16-bit CRC

Figure 2

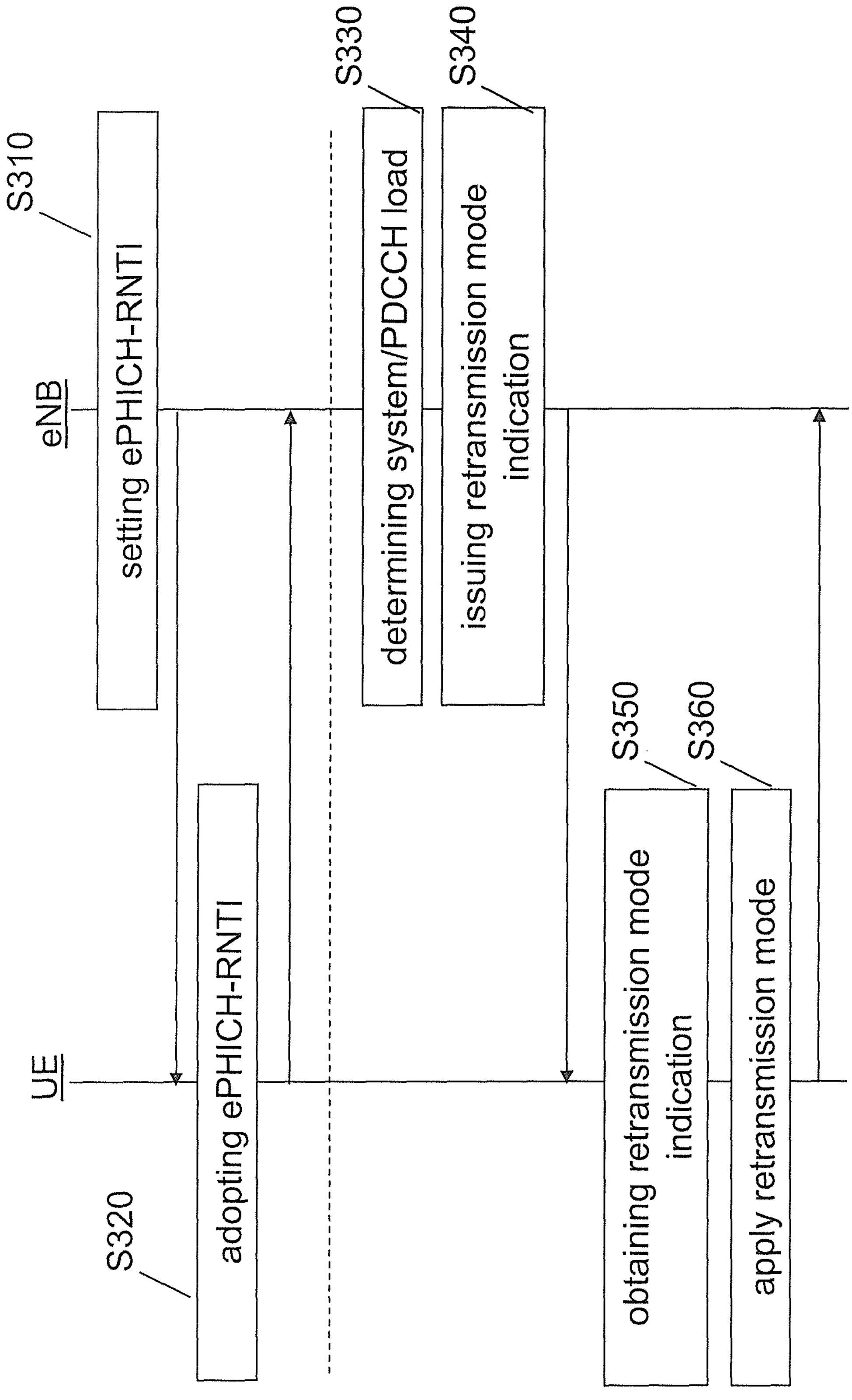
UE
eNB
S310
setting ePHICH-RNTI
S320
adopting ePHICH-RNTI
S330
determining system/PDCCH load
S340
issuing retransmission mode indication
S350
obtaining retransmission mode indication
S360
apply retransmission mode

Figure 3

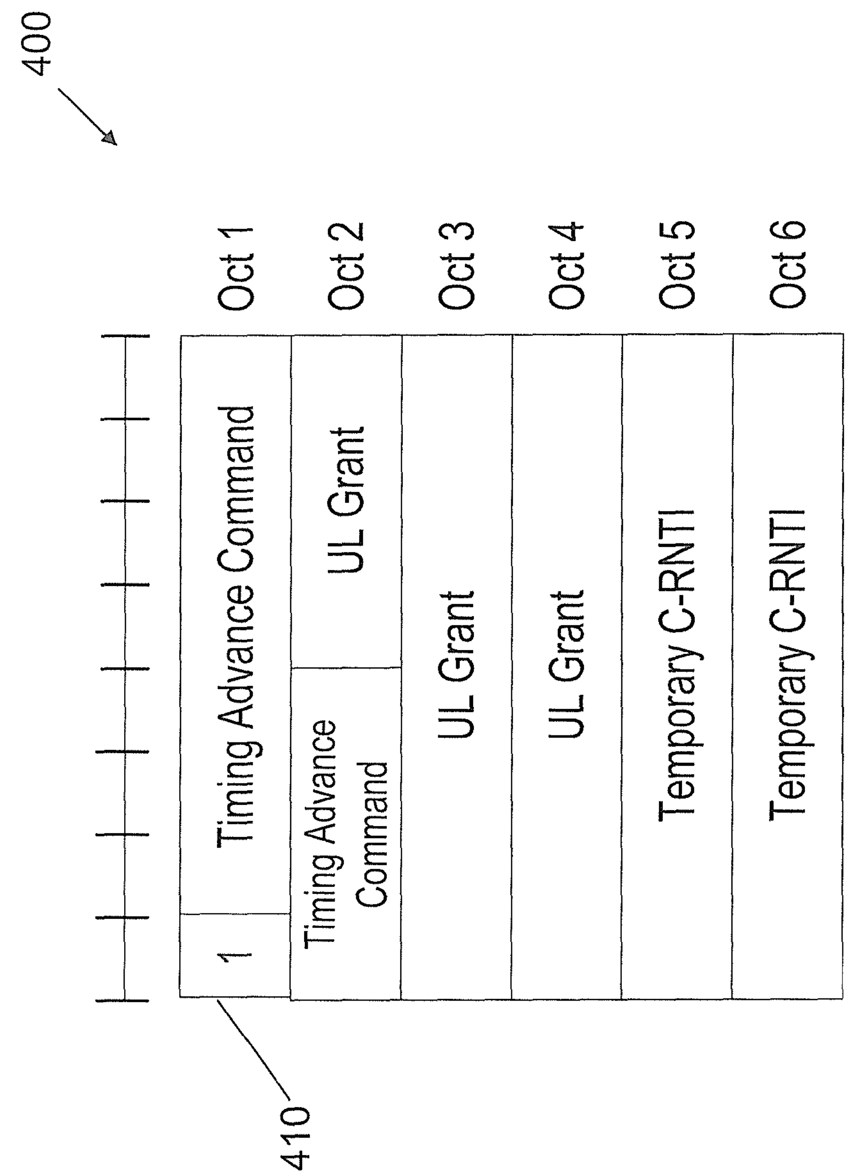
400
Oct 1
Oct 2
Oct 3
Oct 4
Oct 5
Oct 6
1
Timing Advance Command
Timing Advance Command
UL Grant
UL Grant
UL Grant
Temporary C-RNTI
Temporary C-RNTI
410

Figure 4

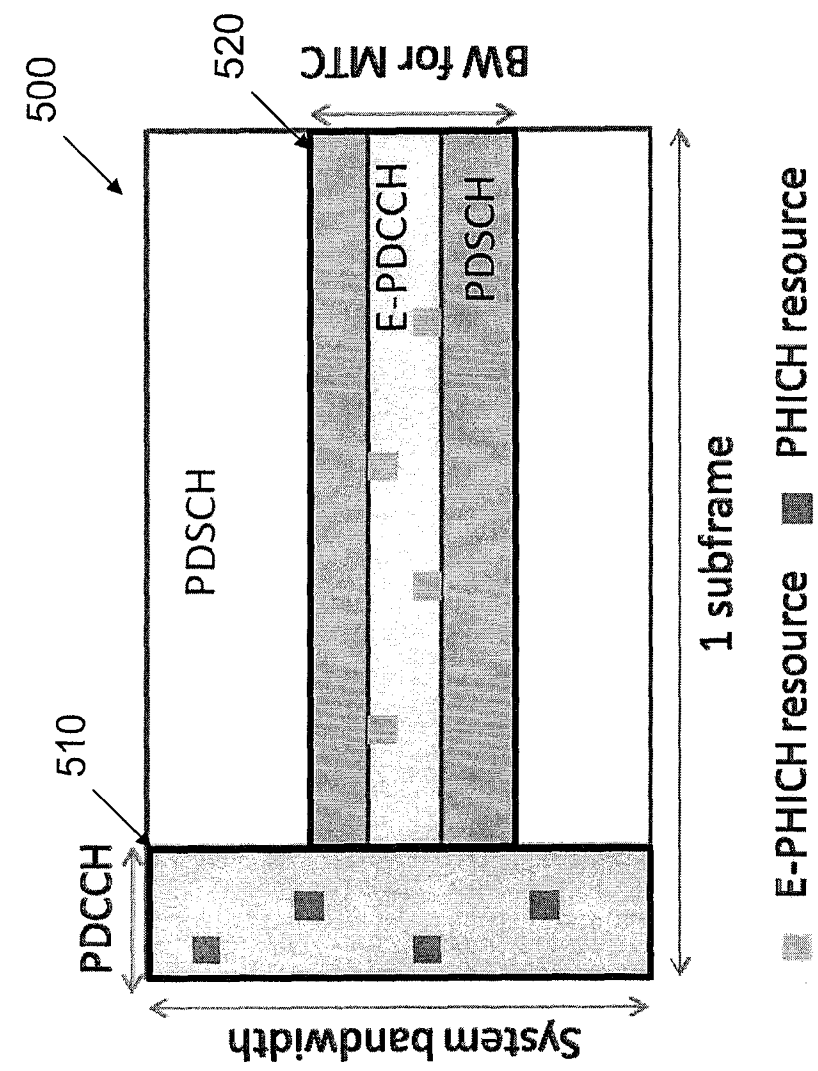
500
520
BW for MTC
510
PDCCH
PDSCH
E-PDCCH
PDSCH
System bandwidth
1 subframe
E-PHICH resource
PHICH resource

Figure 5

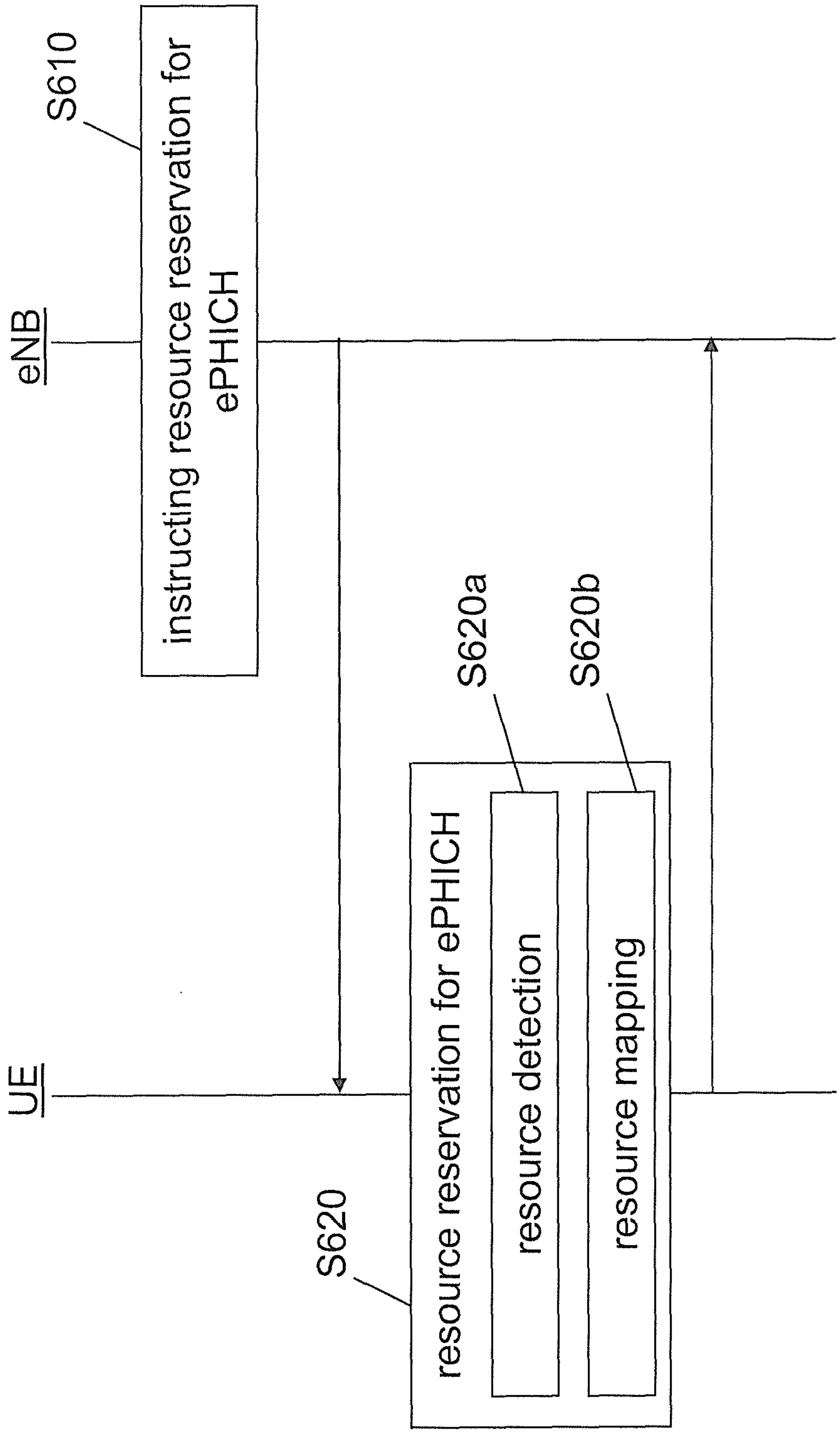
eNB
UE
S610
instructing resource reservation for ePHICH
S620
resource reservation for ePHICH
S620a
resource detection
S620b
resource mapping

Figure 6

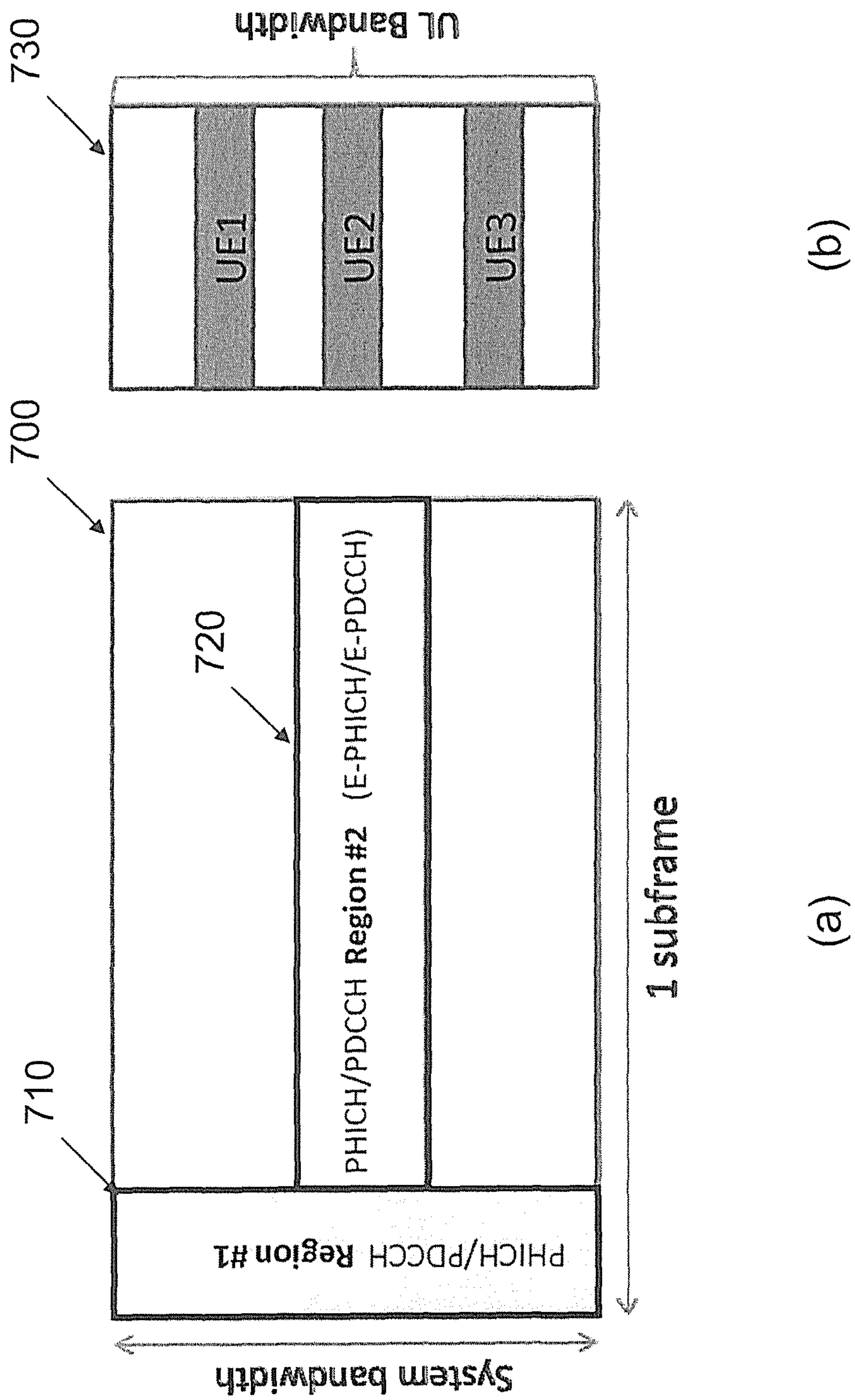
730
UL Bandwidth
UE1
UE2
UE3
(b)
700
720
PHICH/PDCCH Region #2 (E-PHICH/E-PDCCH)
710
PHICH/PDCCH Region #1
System bandwidth
1 subframe
(a)

Figure 7

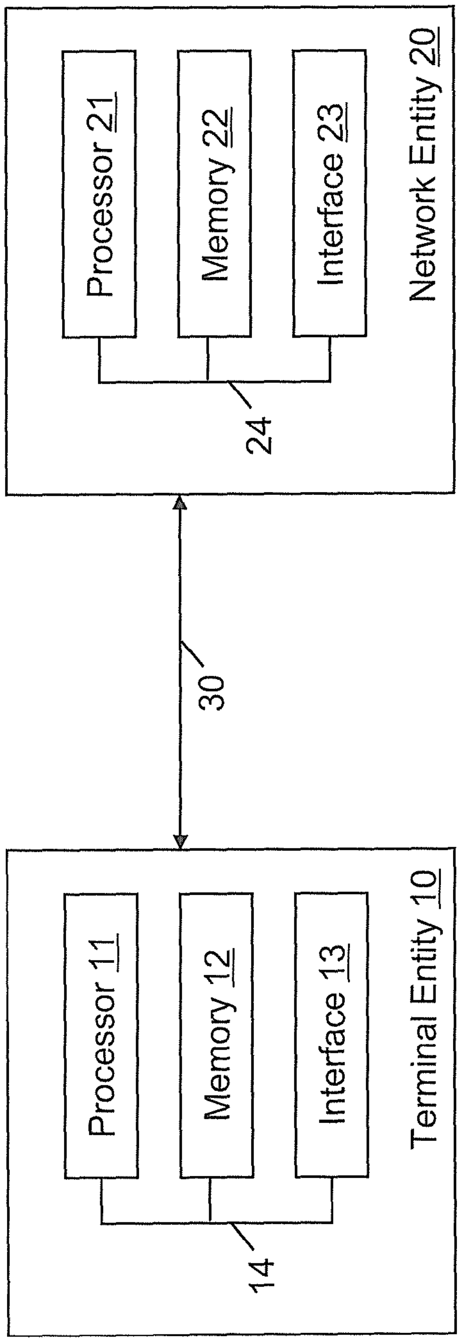
Processor 21
Memory 22
Interface 23
Network Entity 20
24
30
Processor 11
Memory 12
Interface 13
Terminal Entity 10
14

Figure 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2012/073554

A. CLASSIFICATION OF SUBJECT MATTER

H04L 1/18 (2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC:H04L H04Q G06F H04B H04W

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

VEN, CPRSABS, CNTXT, CNKI: physical hybrid automatic repeat request indicator, PHICH, enhanced, LTE, resource?, control information, map+, identifier, retransmit+, mode, manner, type, downlink, configur+

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN101631374A (ZTE CORP.) 20 Jan. 2010(20.01.2010) the whole document.	1-46
A	CN101702644A (ZTE CORP.) 05 May 2010(05.05.2010) the whole document	1-46
A	US2011292875A1 (QUALCOMM INC.) 01 Dec. 2011(01.12.2011) the whole document	1-46
A	Alcatel-Lucent et al, PHICH design for aggregated carriers in LTE-A, 3GPP TSG-RAN WG1, pages 1-3, October 12-16, 2009	1-46

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim (S) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"& "document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
24 Dec. 2012(24.12.2012)	**17 Jan. 2013 (17.01.2013)**

Name and mailing address of the ISA/CN
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100088
Facsimile No. 86-10-62019451

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Telephone No. (86-10)62411280

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2012/073554

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
CN101631374A	20.01.2010	WO2011015098A1	10.02.2011
CN101702644A	05.05.2010	WO2010145605A1	23.12.2010
US2011292875A1	01.12.2011	WO2011150382A1	01.12.2011