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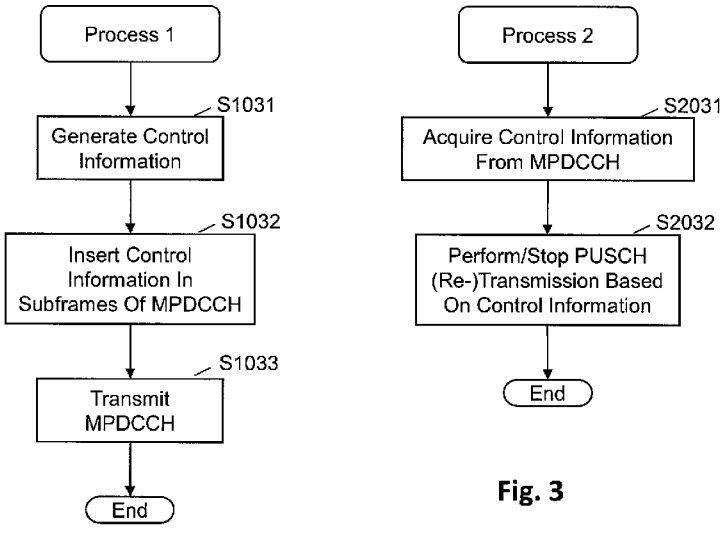

Fig. 3

(57) Abstract: A control channel transmitter generates (S1031) control information out of indications of HARQ-ACK for a plurality of user equipments, the indications of HARQ-ACK requesting retransmission on a PUSCH, inserts (S1032) the generated control information into subframes of a MPDCCH, which are included in a common search space of the MPDCCH, wherein the common search space is inserted into a period of a user-specific search space of the MPDCCH, and transmits (S1033) the MPDCCH. A user equipment of the plurality of user equipments acquires (S2031) the control information and performs (S2032) PUSCH retransmission or stops (S2032) PUSCH transmission based on the acquired control information.

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HARQ-ACK FEEDBACK FOR PUSCH TRANSMISSION FOR EMTC

BACKGROUND OF THE INVENTION

Field of the invention

The present invention relates to providing HARQ-ACK feedback for PUSCH transmission for eMTC.

Related background Art

In 3GPP, for accommodating machine type communication, eMTC has been developed.

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

3GPP	3rd Generation Partnership Project
AL	Aggregation Level
BL	Bandwidth reduced Low complexity
CE	Coverage Enhancement
DCI	Downlink Control Information
DL	DownLink
DRX	Discontinuous Reception
eMTC	enhanced Machine Type Communication
eNB	enhanced Node-B
FD	Full Duplex
FDD	Frequency Division Duplex
HARQ	Hybrid Automatic ReQuest
HD	Half Duplex
LTE	Long Term Evolution
MPDCCH	MTC Physical Downlink Control CHannel
PUSCH	Physical Uplink Sharing CHannel
PHICH	Physical Hybrid-ARQ Indicator CHannel
PBCH	Physical Broadcast Channel
PSS	Primary Synchronization Signal
RNTI	Radio Network Temporary Identity
RRC	Radio Resource Control

SSS	Secondary Synchronization Signal
TDD	Time Division Duplex
UE	User Equipment
UL	Uplink
USS	User-specific Search Space

SUMMARY OF THE INVENTION

At least some embodiments of the invention aim at saving UE power consumption and reducing signaling overhead in eMTC.

According to an aspect of the invention, this is achieved by a method for use by a control channel transmitter as set out in the appended claims.

According to another aspect of the invention, this is achieved by a method for use by a user equipment as set out in the appended claims.

According to a further aspect of the invention, the above aim is achieved by a control channel transmitter as set out in the appended claims.

According to a further aspect of the invention, the above aim is achieved by a user equipment as set out in the appended claims.

According to a further aspect of the invention, the above aim is achieved by a computer-readable storage medium as set out in the appended claims.

According to at least some embodiments of the invention, backward compatibility with legacy eMTC channels, such as MPDCCH, PBCH, PSS/SSS is provided, UE implementation complexity is kept low, for example by not increasing the UE blind decoding number for MPDCCH detection, and signaling overhead is minimized as much as possible.

In the following the invention will be described by way of embodiments thereof with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows a schematic block diagram illustrating a network device and UEs, in which examples of embodiments of the invention are implementable.

Fig. 2 shows a schematic block diagram illustrating a configuration of control units in which examples of embodiments of the invention are implementable.

Fig. 3 shows flowcharts illustrating processes of examples of embodiments of the invention.

Fig. 4 illustrates an example of a search space structure according to an embodiment of the invention.

DESCRIPTION OF THE EMBODIMENTS

Fig. 1 shows a schematic block diagram illustrating a network device 10 and UEs 20, in which examples of embodiments of the invention are implementable. The network device 10 comprises a control channel transmitter.

According to at least some embodiments of the invention, the network device 10 comprises an eNB of an LTE system.

The UEs 20 shown in Fig. 1 comprise UE_1, UE_2,..., UE_M, which form a group of eMTC UEs. The UEs 20 receive control information regarding PUSCH (re-)transmissions from the network device 10, which provides HARQ-ACK feedbacks on the PUSCH transmissions.

In this context, machine type communications (MTC) refer to direct communication between devices using any communications channel, including wired and wireless. MTC can include industrial instrumentation, enabling a sensor or meter to communicate the data it records (such as temperature, inventory level, etc.) to application software that can use it (for example, adjusting an industrial process based on temperature or placing orders to replenish inventory). MTC are characterized by fully automatic data generation, exchange, processing and actuation among intelligent machines, without or with low intervention of humans.

In this context, hybrid automatic repeat request (HARQ) is an acknowledged retransmission scheme, a combination of high-rate forward error-correcting coding and

automatic repeat request (ARQ) error-control. In standard ARQ, redundant bits are added to data to be transmitted using an error-detecting (ED) code such as a cyclic redundancy check (CRC). Receivers detecting a corrupted message will request a new message from the sender. In Hybrid ARQ, the original data is encoded with a forward error correction (FEC) code, and the parity bits are either immediately sent along with the message or only transmitted upon request when a receiver detects an erroneous message.

As a preliminary matter before exploring details of various implementations, reference is made to Fig. 2 for illustrating a simplified block diagram of various electronic devices that are suitable for use in practicing the exemplary embodiments of this invention.

Fig. 2 shows a control unit 1001 which is part of and/or is used by the network device 10, e.g. the control channel transmitter.

The control unit 1001 includes processing resources (processing circuitry) 11, memory resources (memory circuitry) 12 that store a program, and interfaces (interface circuitry) 13, which are coupled via a connection 14. The interfaces 13 include a suitable radio frequency (RF) transceiver (not shown) coupled to one or more antennas (not shown) for bidirectional wireless communications over one or more wireless links 1020 with the UEs 20.

Further, Fig. 2 shows a control unit 2001 which is part of and/or is used by any one of the UEs 20.

The control unit 2001 includes processing resources (processing circuitry) 21, memory resources (memory circuitry) 22 that store a program, and interfaces (interface circuitry) 23, which are coupled via a connection 24. The interfaces 23 include a suitable radio frequency (RF) transceiver (not shown) coupled to one or more antennas (not shown) for bidirectional wireless communications over one or more wireless links 1020 with the network device 10.

The terms "connected," "coupled," or any variant thereof, mean any connection or coupling, either direct or indirect, between two or more elements, and may encompass the presence of one or more intermediate elements between two elements that are "connected" or "coupled" together. The coupling or connection between the elements can be physical, logical, or a combination thereof. As employed herein, two elements may be considered to be "connected" or "coupled" together by the use of one or more wires,

cables and printed electrical connections, as well as by the use of electromagnetic energy, such as electromagnetic energy having wavelengths in the radio frequency region, the microwave region and the optical (both visible and invisible) region, as non-limiting examples.

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At least one of the programs stored in the memory resources 12, 22 is assumed to include program instructions that, when executed by the associated processing resources 11, 21, enable the electronic device to operate in accordance with the exemplary embodiments of this invention. Inherent in the processing resources 11, 21 is a clock to enable
10 synchronism among the various apparatus for transmissions and receptions within the appropriate time intervals and slots required, as the scheduling grants and the granted resources/subframes are time dependent. The transceivers of the interfaces 13, 23 include both transmitter and receiver, and inherent in each is a modulator/demodulator commonly known as a modem. The processing resources 11 also are assumed to include
15 a modem to facilitate communication over a (hardwire) link (not shown) between the network device 10 and other network devices (not shown).

In general, the exemplary embodiments of this invention may be implemented by computer software stored in the memory resources 12 and executable by the processing
20 resources 11 of the network device 10 and similar for the other memory resources 22 and processing resources 21 of the UE 20, or by hardware, or by a combination of software and/or firmware and hardware in any or all of the devices shown.

In general, the various embodiments of the UE 20 can include, but are not limited to,
25 mobile stations, cellular telephones, personal digital assistants (PDAs) having wireless communication capabilities, portable computers having wireless communication capabilities, image capture devices such as digital cameras having wireless communication capabilities, gaming devices having wireless communication capabilities, music storage and playback appliances having wireless communication capabilities,
30 Internet appliances permitting wireless Internet access and browsing, as well as portable units or terminals that incorporate combinations of such functions.

The memory resources 12, 22 may be of any type suitable to the local technical environment and may be implemented using any suitable data storage technology, such
35 as semiconductor based memory devices, magnetic memory devices and systems, optical memory devices and systems, fixed memory and removable memory. The processing resources 11, 21 may be of any type suitable to the local technical environment, and may

include one or more of general purpose computers, special purpose computers, microprocessors, digital signal processors (DSPs) and processors based on a multi core processor architecture, as non limiting examples.

Now reference is made to Fig. 3 illustrating flowcharts of processes performed by the network device 10 and the UE 20 according to at least some embodiments of the invention.

According to an embodiment of the invention, process 1 shown in Fig. 3 is performed by the control channel transmitter of the network device 10.

In step S1031, control information, such as DCI, is generated out of HARQ-ACK indications for the plurality of UEs 20 as illustrated in Fig. 1. The HARQ-ACK indications convey information regarding successful decoding of packets by the network device 10 and request PUSCH (re-)transmissions from the UEs to the network device 10 based on these indications.

In step S1032, the generated control information is inserted into subframes of an MPDCCH, e.g. into subframes configured for MPDCCH transmission. In particular, the subframes are included in a common search space of the MPDCCH, which is common to the UEs 20, and the common search space is inserted into a period of a user-specific search space of the MPDCCH, which is specific to each of the UEs 20.

In this context, an MPDCCH search space is a set of MPDCCH candidates for a UE to monitor. It is composed by the aggregation level and repetition level. Each MPDCCH candidate is repeated in a set of consecutive subframes in an aggregation level. In particular, an MPDCCH search space $MS_k^{(L',R)}$ at aggregation level $L' \in \{2,4,8,16,24\}$ and repetition level $R \in \{1,2,4,8,16,32,64,128,256\}$ is defined by a set of MPDCCH candidates where each candidate is repeated in a set of R consecutive BL/CE downlink subframes starting with subframe k.

In step S1033, the MPDCCH is transmitted. Thereafter, process 1 ends.

According to an embodiment of the invention, process 2 shown in Fig. 3 is performed by any one of the UEs 20.

In step S2031, control information (e.g. the control information generated in S1031) is acquired from a common search space of an MPDCCH (e.g. the MPDCCH transmitted in S1033). The control information comprises HARQ-ACK indications for a plurality of UEs (e.g. the UEs 20). As mentioned above, the HARQ-ACK indications request PUSCH retransmissions from the UEs. In particular, the control information is acquired in a period of a user-specific search space of the MPDCCH, which is specific to the plurality of UEs.

In step S2032, based on the acquired control information, e.g., HARQ-ACK indication, PUSCH retransmission is performed or PUSCH transmission is stopped. Thereafter, process 2 ends.

According to processes 1 and 2, which will be described in more detail below, signaling overhead for scheduling PUSCH retransmission is saved. In process 1, multiple HARQ-ACK feedbacks for different users are multiplexed on the eMTC downlink control channel, i.e., MPDCCH, and a common search space is introduced. Using this search space allows the network device to better fine-tune and utilize multiple HARQ-ACK feedbacks.

According to at least some embodiments of the invention, the introduced common search space is inserted in an existing MPCCH search space period, such as inserted in UE specific search space period. The UE (e.g. any one of the UEs 20) checks the introduced common search space before monitoring the next UE specific search space, which reduces the number of additional decoding attempts.

According to at least some embodiments of the invention, the introduced common search space shares the same narrowband as the UE specific search space for a category M1 UE.

According to at least some embodiments of the invention, for a category M2 UE, the introduced common search space is configured in a different narrowband from the UE specific search space, to take advantage of either or both of the 24-PRB wideband and faster frequency band retuning capabilities.

According to at least some embodiments of the invention, for a non-MTC UE category operating in coverage enhancement, the introduced common search space is configured in a different narrowband from the UE specific search space, to take advantage of either or both of the wideband and faster frequency band retuning capabilities.

In this context, narrowband refers to a channel in which the bandwidth of the message does not significantly exceed the channel's coherence bandwidth.

According to at least some embodiments of the invention, the configuration of the introduced search space is signaled to the UE via either broadcast channel or using dedicated Radio Resource Control (RRC) configuration. According to an implementation example, a G factor and r_max are signaled to the UE via System Information Block. The search space can also be enabled or disabled implicitly via the presence of such configuration parameters. According to another implementation example, multiple search space configurations may be defined, and UE is configured via higher layer signaling which configuration to use.

In this context, the G factor is a USS starting subframe adjustment factor in $T = r_{max} \cdot G$, where T is the USS periodicity.

Further, r_max is the maximum number of MPDCCH repetition for the USS.

According to at least some embodiments of the invention, a PUSCH transmission gap is configured to allow the UE check the MPDCCH for HARQ-ACK information. According to an implementation example, the gap is defined by a gap period and gap length. According to another implementation example, this transmission gap may coincide with uplink compensation gap configured for UE to perform time and frequency tracking. According to another implementation example, this transmission gap may coincide with the common search space.

According to at least some embodiments of the invention, UE monitors the common search space for HARQ-ACK only after PUSCH transmission or during PUSCH transmission gap. In addition, the UE continues to monitor the common search space for a period of time, for example given by number of search space occurrences. In case of collision between the common search space and another search space, the UE may drop monitoring the common search space.

According to at least some embodiments of the invention, the introduced common search space and the UE specific search space are distinguished in time domain. According to an implementation example, the same G factor and r_max are applied to both search spaces, and a subframe offset is introduced for the introduced common search space relative to the UE specific search space.

According to another implementation example, to provide some scheduling flexibility, a window is defined within which the UE checks the introduced common search space, and the G factor and r_max are configured independently for the introduced common search space.

By means of the above G factor and r_max setting, the introduced common search space can be exactly the same as the type-0 common search space, so the legacy search space can be re-used.

According to at least some embodiments of the invention, the UE decodes the common search space blindly, and the blind decoding number is four, which is the same as that of MPDCCH common search space.

According to at least some embodiments of the invention, a downlink control information format (e.g. DCI format) is introduced and scrambled with eMTC-HARQ-RNTI. The introduced DCI format is formed by multiple HARQ-ACK indications for different UEs, e.g. HARQ-ACK indication 1 for UE_1 of Fig. 1, HARQ-ACK indication 2 for UE_2, ..., HARQ-ACK indication M for UE_M. In other words, each user equipment that will receive its HARQ-ACK indication in control information format scrambled with eMTC-HARQ-RNTI is preconfigured with a unique HARQ-ACK indication field index. The network device may perform configuration of the user equipments with a HARQ-ACK indication field index using higher-layer signaling.

According to at least some embodiments of the invention, multiple eMTC-HARQ-RNTI values may be defined. Different UEs may be grouped together, for example based on required r_max, and assigned the same eMTC-HARQ-RNTI value.

According to at least some embodiments of the invention, the control information is composed by HARQ-ACK indication fields for each of the plurality of user equipments, and each HARQ-ACK indication field includes a HARQ-ACK indication, a HARQ process identification, a PUSCH re-transmission repetition number, or a starting subframe of PUSCH re-transmission. The PUSCH retransmission repetition number is determined for the HARQ process identification.

According to at least some embodiments of the invention, each of the HARQ-ACK indication fields is identified by the configured HARQ-ACK indication field index.

For example, according to at least some embodiments of the invention, for a UE in CE Mode A, the HARQ-ACK indication field of the control information has a size of 6 bits: 1 bit for HARQ-ACK feedback, e.g., indicating ACK or NACK, and other 3 bits for the corresponding HARQ process ID for a given UE in CE mode A, and 2 bits to indicate the repetition number for re-transmission if the feedback is NACK, otherwise, 00 is filled in the 2 bits.

For example, according to at least some embodiments of the invention, for a UE in CE Mode B, the HARQ-ACK indication field of the control information has a size of 4 bits: 1 bit for HARQ-ACK feedback, e.g., indicating ACK or NACK, and other 1 bit for corresponding HARQ process ID for a given UE in CE mode B, and 2 bits to indicate the repetition number for re-transmission if the feedback is NACK, otherwise, 00 is filled in for the 2 bits.

The number M of HARQ-ACK feedback indications which can be included into the control information is calculated as follows:
M= floor(size of introduced DCI format/number of bits of HARQ-ACK indication field)

According to at least some embodiments of the invention, the UE 20 starts PUSCH re-transmission at a subframe n+4, where n is the last subframe of MPDCCH in the introduced common search space.

Alternatively, according to at least some embodiments of the invention, the DCI contains information about when PUSCH retransmission is to be started. For example, four values are defined corresponding to {n+4, n+8, n+12, n+16} and one value is indicated in the DCI.

As described above, HARQ-ACK indications for different eMTC UEs are multiplexed in one MPDCCH.

An example of a search space structure according to an implementation of the present invention is shown in Fig. 4. The repetitions of the MPDCCH, which correspond to a maximum value of r_max, are contained at the beginning of each USS, and the introduced common search space (which is referred to as "new SS" in Fig. 4) is inserted after the MPDCCH repetitions in the period of the USS.

According to Fig. 4, the UE specific search space (USS) periodicity is configured with more subframes than UE specific search space, e.g., r_max. With this search space configuration, overlapping between two search spaces (the introduced common search space and the UE specific search space) due to invalid subframe existence is avoided. Further, by monitoring only part of subframes in one USS periodicity by the UE, the UE power consumption is reduced.

According to at least some embodiments of the invention as described above, UE blind decoding number is not increased, as the UE detects the introduced common search space in the specific subframes, and does not decode both the introduced common search space and the USS in the same subframe.

With the introduced common search space, PUSCH early termination is enabled. For example, as PUSCH repetition number cannot be estimated accurately by the network device 10 (e.g. eNB), PUSCH is likely to be configured with a larger repetition number than the number actually needed for decoding. The network device 10 may correctly decode a PUSCH transmission already before the introduced common search space starts, and in this case the network device 10 can send the ACK via the MPDCCH in the introduced common search space. The UE 20 stops the PUSCH transmission after receiving the ACK from the network device 10. Thus, UE transmission power can be saved. If the PUSCH transmission is not correctly decoded, NACK will be sent by the network device 10 with a newly set repetition number, which is beneficial to reduce the repetition for re-transmission.

As described above, according to at least some embodiments of the invention, signaling overhead for PUSCH retransmission is reduced, and the UE blind decoding number is reasonable.

Further, with the introduced common search space, PUSCH early termination can be achieved, and PUSCH retransmission triggered at the UE is more efficient with exact repetition number indication.

According to an aspect of the present invention, an apparatus is provided which comprises means for generating control information out of indications of hybrid automatic request-acknowledgment, HARQ-ACK, for a plurality of user equipments, the indications of HARQ-ACK requesting retransmission on a physical uplink sharing channel, PUSCH, means for inserting the generated control information into subframes of a physical

downlink control channel for machine type communication, MPDCCH, wherein the subframes are included in a common search space of the MPDCCH, which is common to the user equipments, wherein the common search space is inserted into a period of a user-specific search space of the MPDCCH, which is specific to each of the plurality of user equipments, and means for transmitting the MPDCCH.

According to an implementation example of the present invention, the apparatus comprises means for configuring each of the plurality of user equipments with a HARQ-ACK indication field index using higher-layer signaling.

According to an implementation example of the present invention, the apparatus comprises means for signaling the common search space to the plurality of user equipments via broadcast channel or using dedicated radio resource control configuration.

According to an implementation example of the present invention, the apparatus comprises means for signaling a G factor and r_max to the plurality of user equipments via system information block.

According to an implementation example of the present invention, the apparatus comprises means for defining multiple configurations of the common search space and means for configuring the plurality of user equipments via higher layer signaling which configuration to use.

According to an implementation example of the present invention, the apparatus comprises means for configuring a PUSCH transmission gap for the plurality of user equipments for allowing the plurality of user equipments check the MPDCCH for the control information.

According to an implementation example of the present invention, the apparatus comprises means for configuring the common search space to share the same narrowband as the user-specific search space.

According to an implementation example of the present invention, the apparatus comprises means for configuring the common search space on a narrowband different from that of the user-specific search space.

According to an implementation example of the present invention, the apparatus comprises means for configuring the common search space by applying the same G factor and the same r_max to the common search space and the user-specific search space, and means for configuring a subframe offset for the common search space relative to the user-specific search space.

According to an implementation example of the present invention, the apparatus comprises means for configuring the common search space by defining a time window for the common search space, and means for configuring a G factor and r_max for the common search space independently from those of the user-specific search space.

According to an implementation example of the present invention, the means for configuring the common search space comprises means for setting the G factor and r_max such that the common search space is type-0 common search space.

According to an implementation example of the present invention, the means for generating the control information comprises means for scrambling the control information with an evolved machine-type communication-hybrid automatic request-radio network temporary identity, eMTC-HARQ-RNTI.

According to an implementation example of the present invention, the apparatus comprises means for composing the control information by HARQ-ACK indication fields for each of the plurality of user equipments, wherein each HARQ-ACK indication field includes a HARQ-ACK indication, a HARQ process identification, a PUSCH retransmission repetition number, or a starting subframe of PUSCH retransmission, and wherein a number M of the plurality of user equipments is calculated by M=floor(bit size of control information/number of bits of the HARQ-ACK indication field).

According to an implementation example of the present invention, the apparatus comprises means for determining the PUSCH retransmission repetition number for the HARQ process identification.

According to an implementation example of the present invention, the above-described means of the apparatus are implemented by the processing resources (processing circuitry) 11, the memory resources (memory circuitry) 12 and the interfaces (interface circuitry) 13 of the control unit 10.

According to another aspect of the invention, a user equipment of a plurality of user equipments is provided, the user equipment comprising means for acquiring control information from a common search space of a physical downlink control channel for machine type communication, MPDCCH, in a period of a user-specific search space of the MPDCCH, which is specific to each of the plurality of user equipments, wherein the control information comprises indications of hybrid automatic request-acknowledgment, HARQ-ACK, and means for performing PUSCH retransmission or stopping PUSCH transmission based on the acquired control information.

According to an implementation example of the present invention, the user equipment comprises an evolved machine-type communication user equipment, and comprises means for decoding the common search space blindly, wherein the blind decoding number is four.

According to an implementation example of the present invention, the control information is composed by HARQ-ACK indication fields for each of the plurality of user equipments, and each of the plurality of user equipments is preconfigured with a unique HARQ-ACK indication field index, and the user equipment comprises means for identifying the user equipment's HARQ-ACK indication field by the user equipment's HARQ-ACK indication field index.

According to an implementation example of the present invention, the user equipment comprises means for starting the PUSCH retransmission at a subframe n+4, where n is the last subframe of MPDCCH in the common search space.

According to an implementation example of the present invention, the user equipment comprises means for acquiring retransmission information from the control information, and means for starting the PUSCH retransmission at a subframe indicated in the retransmission information.

According to an implementation example of the present invention, the user equipment comprises means for monitoring the user-specific search space in a period of the user-specific search space following the period of acquiring the control information from the common control channel.

According to an implementation example of the present invention, the user equipment comprises means for monitoring the common search space for the control information after PUSCH transmission or during PUSCH transmission gap.

According to an implementation example of the present invention, the user equipment comprises means for continuing monitoring the common search space for a period of time.

According to an implementation example of the present invention, the user equipment comprises means for dropping monitoring the common search space in case of collision between the common search space and another search space.

According to an implementation example of the present invention, the above-described means of the user equipment are implemented by the processing resources (processing circuitry) 21, the memory resources (memory circuitry) 22 and the interfaces (interface circuitry) 23 of the control unit 20.

It is to be understood that the above description is illustrative of the invention and is not to be construed as limiting the invention. Various modifications and applications may occur to those skilled in the art without departing from the true spirit and scope of the invention as defined by the appended claims.

WHAT IS CLAIMED IS:

1. A method for use by a control channel transmitter, the method comprising:

generating control information out of indications of hybrid automatic request-acknowledgment, HARQ-ACK, for a plurality of user equipments, the indications of HARQ-ACK requesting retransmission on a physical uplink sharing channel, PUSCH;

inserting the generated control information into subframes of a physical downlink control channel for machine type communication, MPDCCH,

wherein the subframes are included in a common search space of the MPDCCH, which is common to the user equipments, wherein the common search space is inserted into a period of a user-specific search space of the MPDCCH, which is specific to each of the plurality of user equipments; and

transmitting the MPDCCH.

2. The method of claim 1, wherein the common search space is configured to share the same narrowband as the user-specific search space.

3. The method of claim 1, wherein the common search space is configured on a narrowband different from that of the user-specific search space.

4. The method of any one of claims 1 to 3, wherein the same G factor and the same r_max are applied to the common search space and the user-specific search space, and a subframe offset is configured for the common search space relative to the user-specific search space.

5. The method of any one of claims 1 to 3, wherein a time window is defined for the common search space, and a G factor and r_max are configured for the common search space independently from those of the user-specific search space.

6. The method of claim 5, wherein the G factor and r_max are set such that the common search space is type-0 common search space.

7. The method of any one of claims 1 to 6, wherein the plurality of user equipments comprises evolved machine-type communication user equipments which decode the common search space blindly, and the blind decoding number is four.

8. The method of any one of claims 1 to 7, wherein generating the control information comprises scrambling the control information with an evolved machine-type communication-hybrid automatic request-radio network temporary identity, eMTC-HARQ-RNTI.

9. The method of any one of claims 1 to 8, wherein

the control information is composed by HARQ-ACK indication fields for each of the plurality of user equipments,

each of the plurality of user equipments is preconfigured with a unique HARQ-ACK indication field index,

each HARQ-ACK indication field includes a HARQ-ACK indication, a HARQ process identification, a PUSCH retransmission repetition number, or a starting subframe of PUSCH retransmission, and

a number M of the plurality of user equipments is calculated by M=floor(bit size of control information/number of bits of the HARQ-ACK indication field).

10. The method of claim 9, comprising:

determining the PUSCH retransmission repetition number for the HARQ process identification.

11. The method of any one of claims 1 to 10, comprising:

configuring each of the plurality of user equipments with a HARQ-ACK indication field index using higher-layer signaling, and/or

signaling the common search space to the plurality of user equipments via broadcast channel or using dedicated radio resource control configuration, and/or

signaling a G factor and r_max to the plurality of user equipments via system information block, and/or

defining multiple configurations of the common search space and configuring the plurality of user equipments via higher layer signaling which configuration to use.

12. The method of any one of claims 1 to 11, comprising:

configuring a PUSCH transmission gap for the plurality of user equipments for allowing the plurality of user equipments check the MPDCCH for the control information.

13. A method for use by a user equipment of a plurality of user equipments, the method comprising:

acquiring control information from a common search space of a physical downlink control channel for machine type communication, MPDCCH, in a period of a user-specific search space of the MPDCCH, which is specific to each of the plurality of user equipments, wherein the control information comprises indications of hybrid automatic request-acknowledgment, HARQ-ACK; and

based on the acquired control information, performing PUSCH retransmission or stopping PUSCH transmission.

14. The method of claim 13, wherein the control information is composed by HARQ-ACK indication fields for each of the plurality of user equipments, and each of the plurality of user equipments is preconfigured with a unique HARQ-ACK indication field index, the method comprising:

identifying the user equipment's HARQ-ACK indication field by the user equipment's HARQ-ACK indication field index.

15. The method of claim 13 or 14, wherein the PUSCH retransmission is started at a subframe n+4, where n is the last subframe of MPDCCH in the common search space.

16. The method of claim 13 or 14, further comprising:

acquiring retransmission information from the control information, the retransmission information indicating at which subframe the PUSCH retransmission is to be started.

17. The method of any one of claims 13 to 16, comprising:

monitoring the user-specific search space in a period of the user-specific search space following the period of acquiring the control information from the common control channel.

18. The method of any one of claims 13 to 17, comprising:

monitoring the common search space for the control information after PUSCH transmission or during PUSCH transmission gap, and/or

continuing monitoring the common search space for a period of time, and/or

in case of collision between the common search space and another search space, dropping monitoring the common search space.

19. A computer-readable storage medium storing a program for causing a computer to execute the following steps, when the program is run on the computer:

generating control information out of indications of hybrid automatic request-acknowledgment, HARQ-ACK, for a plurality of user equipments, the indications of HARQ-ACK requesting retransmission on a physical uplink sharing channel, PUSCH;

inserting the generated control information into subframes of a physical downlink control channel for machine type communication, MPDCCH,

wherein the subframes are included in a common search space of the MPDCCH, which is common to the user equipments, wherein the common search space is inserted into a period of a user-specific search space of the MPDCCH, which is specific to each of the plurality of user equipments; and

transmitting the MPDCCH.

20. A computer-readable storage medium storing a program for causing a computer to execute the following steps, when the program is run on the computer:

acquiring control information from a common search space of a physical downlink control channel for machine type communication, MPDCCH, in a period of a user-specific search space of the MPDCCH, which is specific to each of the plurality of user equipments, wherein the control information comprises indications of hybrid automatic request-acknowledgment, HARQ-ACK; and

based on the acquired control information, performing PUSCH retransmission or stopping PUSCH transmission.

21. A control channel transmitter comprising at least one processor and at least one memory including computer program code, the at least one memory and the computer program code configured to, with the at least one processor, cause the control channel transmitter at least to perform:

generating control information out of indications of hybrid automatic request-acknowledgment, HARQ-ACK, for a plurality of user equipments, the indications of HARQ-ACK requesting retransmission on a physical uplink sharing channel, PUSCH;

inserting the generated control information into subframes of a physical downlink control channel for machine type communication, MPDCCH,

wherein the subframes are included in a common search space of the MPDCCH, which is common to the user equipments, wherein the common search space is inserted into a period of a user-specific search space of the MPDCCH, which is specific to each of the plurality of user equipments; and

transmitting the MPDCCH.

22. The control channel transmitter of claim 21, wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the control channel transmitter at to further perform:

configuring each of the plurality of user equipments with a HARQ-ACK indication field index using higher-layer signaling, and/or

signaling the common search space to the plurality of user equipments via broadcast channel or using dedicated radio resource control configuration, and/or

signaling a G factor and r_max to the plurality of user equipments via system information block, and/or

defining multiple configurations of the common search space and configuring the plurality of user equipments via higher layer signaling which configuration to use.

23. The control channel transmitter of claim 21 or 22, wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the control channel transmitter to further perform:

configuring a PUSCH transmission gap for the plurality of user equipments for allowing the plurality of user equipments check the MPDCCH for the control information.

24. The control channel transmitter of any one of claims 21 to 23, wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the control channel transmitter to further perform:

configuring the common search space to share the same narrowband as the user-specific search space, and/or

configuring the common search space on a narrowband different from that of the user-specific search space, and/or

configuring the common search space by applying the same G factor and the same r_max to the common search space and the user-specific search space, and configuring a subframe offset for the common search space relative to the user-specific search space, and/or

configuring the common search space by defining a time window for the common search space, and configuring a G factor and r_max for the common search space independently from those of the user-specific search space.

25. The control channel transmitter of claim 24, the configuring of the common search space comprising setting the G factor and r_max such that the common search space is type-0 common search space.

26. The control channel transmitter of any one of claims 21 to 25, wherein generating the control information comprises scrambling the control information with an evolved machine-type communication-hybrid automatic request-radio network temporary identity, eMTC-HARQ-RNTI.

27. The control channel transmitter of any one of claims 21 to 26, wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the control channel transmitter to further perform:

composing the control information by HARQ-ACK indication fields for each of the plurality of user equipments,

wherein each HARQ-ACK indication field includes a HARQ-ACK indication, a HARQ process identification, a PUSCH retransmission repetition number, or a starting subframe of PUSCH retransmission, and

wherein a number M of the plurality of user equipments is calculated by M=floor(bit size of control information/number of bits of the HARQ-ACK indication field).

28. The control channel transmitter of claim 27, wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the control channel transmitter to further perform:

determining the PUSCH retransmission repetition number for the HARQ process identification.

29. A user equipment of a plurality of user equipments, the user equipment comprising at least one processor and at least one memory including computer program code, the at least one memory and the computer program code configured to, with the at least one processor, cause the user equipment at least to perform:

acquiring control information from a common search space of a physical downlink control channel for machine type communication, MPDCCH, in a period of a user-specific search space of the MPDCCH, which is specific to each of the plurality of user equipments, wherein the control information comprises indications of hybrid automatic request-acknowledgment, HARQ-ACK; and

based on the acquired control information, performing PUSCH retransmission or stopping PUSCH transmission.

30. The user equipment of claim 29, wherein the user equipment comprises an evolved machine-type communication user equipment, and the at least one memory and the

computer program code are configured to, with the at least one processor, cause the user equipment to further perform:

decoding the common search space blindly, wherein the blind decoding number is four.

31. The user equipment of claim 29 or 30, wherein the control information is composed by HARQ-ACK indication fields for each of the plurality of user equipments, and each of the plurality of user equipments is preconfigured with a unique HARQ-ACK indication field index, and the at least one memory and the computer program code are configured to, with the at least one processor, cause the user equipment to further perform:

identifying the user equipment's HARQ-ACK indication field by the user equipment's HARQ-ACK indication field index.

32. The user equipment of any one of claims 29 to 31, wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the user equipment to further perform:

starting the PUSCH retransmission at a subframe n+4, where n is the last subframe of MPDCCH in the common search space.

33. The user equipment of any one of claims 29 to 31, wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the user equipment to further perform:

acquiring retransmission information from the control information; and

starting the PUSCH retransmission at a subframe indicated in the retransmission information.

34. The user equipment of any one of claims 29 to 33, wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the user equipment to further perform:

monitoring the user-specific search space in a period of the user-specific search space following the period of acquiring the control information from the common control channel.

35. The user equipment of any one of claims 29 to 34, wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the user equipment to further perform:

monitoring the common search space for the control information after PUSCH transmission or during PUSCH transmission gap, and/or

continuing monitoring the common search space for a period of time, and/or

in case of collision between the common search space and another search space, dropping monitoring the common search space.

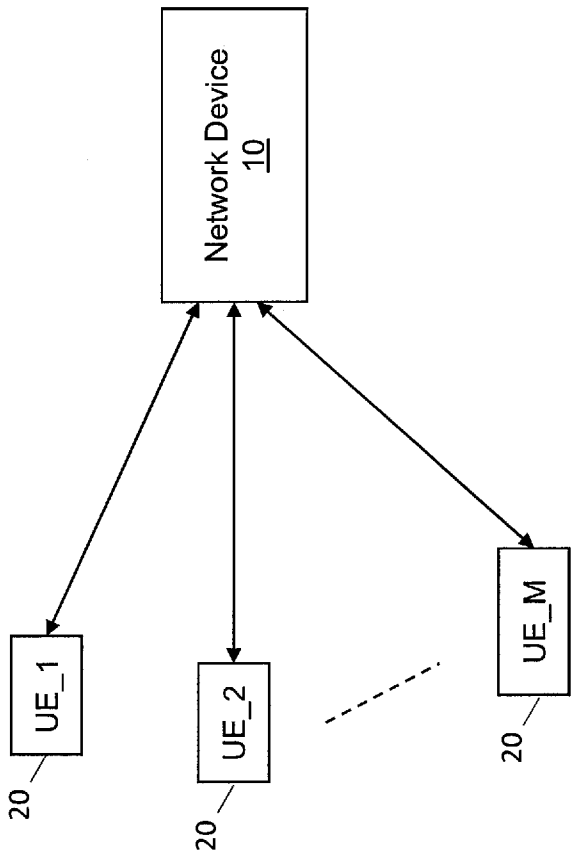

Fig. 1

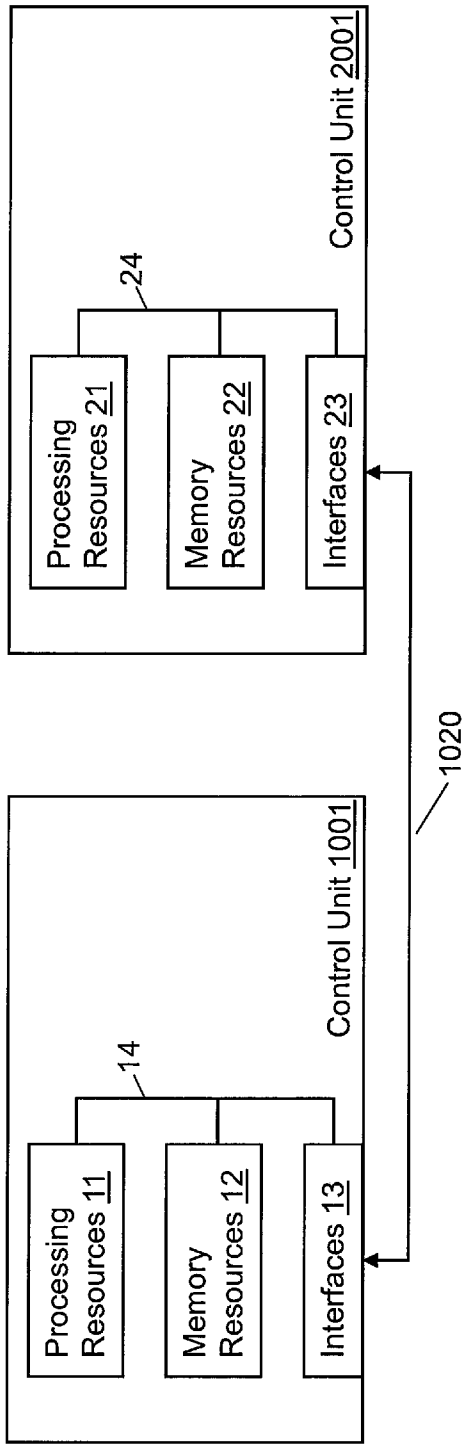
Control Unit 2001
24
Processing Resources 21
Memory Resources 22
Interfaces 23
1020
Control Unit 1001
14
Processing Resources 11
Memory Resources 12
Interfaces 13

Fig. 2

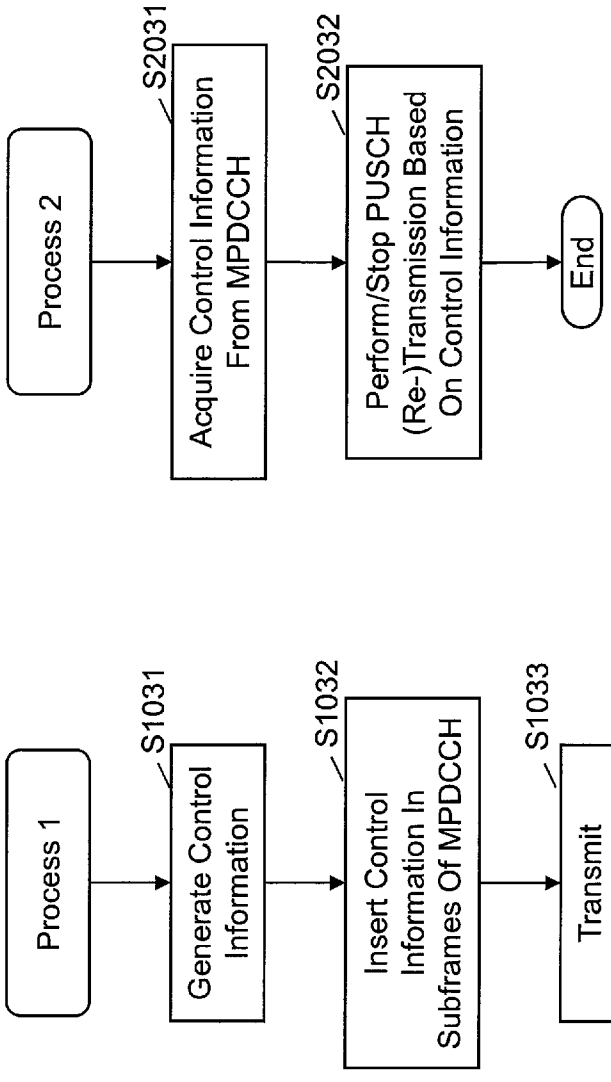
Process 2
S2031
Acquire Control Information From MPDCCH
S2032
Perform/Stop PUSCH (Re-)Transmission Based On Control Information
End
Process 1
S1031
Generate Control Information
S1032
Insert Control Information In Subframes Of MPDCCH
S1033
Transmit MPDCCH
End

Fig. 3

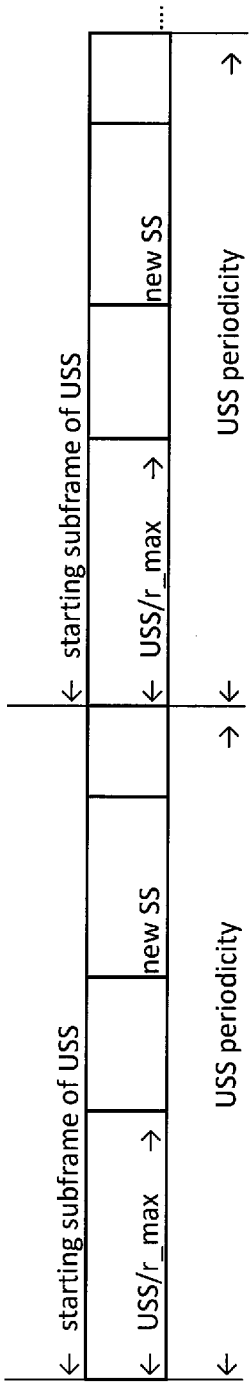
starting subframe of USS
USS/r_max
new SS
USS periodicity
starting subframe of USS
USS/r_max
new SS
USS periodicity

Fig. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2017/094642

A. CLASSIFICATION OF SUBJECT MATTER

H04W 72/12(2009.01)i; H04W 72/04(2009.01)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)

H04L H04W H04B

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)

CNPAT, CNKI, WPI, EPODOC,3GPP,GOOGLE: MTC, PUSCH, MPDCCH, M-PDCCH, HARQ, DCI, period, CSS, USS, machine type communication, ACK, NACK, indication, common search space, user specific space, band, blind, code, decode

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	SONY. "3GPP TSG RAN WG1 Meeting #83 R1-156699" *Considerations on PUSCH HARQ Feedbacks*, 22 November 2015 (2015-11-22), sections 2-3	1-35
A	CN 106717031 A (KT CORPORATION) 24 May 2017 (2017-05-24) the whole document	1-35
A	CN 106489246 A (INTEL IP CORPORATION) 08 March 2017 (2017-03-08) the whole document	1-35
A	CN 106559188 A (HUAWEI TECHNOLOG CO., LTD.) 05 April 2017 (2017-04-05) the whole document	1-35
A	US 2016270038 A1 (SAMSUNG ELECTRONICS CO., LTD.) 15 September 2016 (2016-09-15) the whole document	1-35
A	US 2017164407 A1 (LG ELECTRONICS INC.) 08 June 2017 (2017-06-08) the whole document	1-35
A	US 2017171842 A1 (LG ELECTRONICS INC.) 15 June 2017 (2017-06-15) the whole document	1-35

☐ 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
17 March 2018	**28 March 2018**

Name and mailing address of the ISA/CN	Authorized officer
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2017/094642

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
CN	106717031	A	24 May 2017	CN	107135473	A	05 September 2017
				US	2017272895	A1	21 September 2017
				US	2017303064	A1	19 October 2017
CN	106489246	A	08 March 2017	EP	3175574	A1	07 June 2017
				US	2017223725	A1	03 August 2017
				WO	2016018469	A1	04 February 2016
				KR	20170023101	A	02 March 2017
CN	106559188	A	05 April 2017		None		
US	2016270038	A1	15 September 2016	CN	107210903	A	26 September 2017
				EP	3269075	A1	17 January 2018
				KR	20170128209	A	22 November 2017
				WO	2016144140	A1	15 September 2016
US	2017164407	A1	08 June 2017	WO	2015199491	A1	30 December 2015
US	2017171842	A1	15 June 2017		None		