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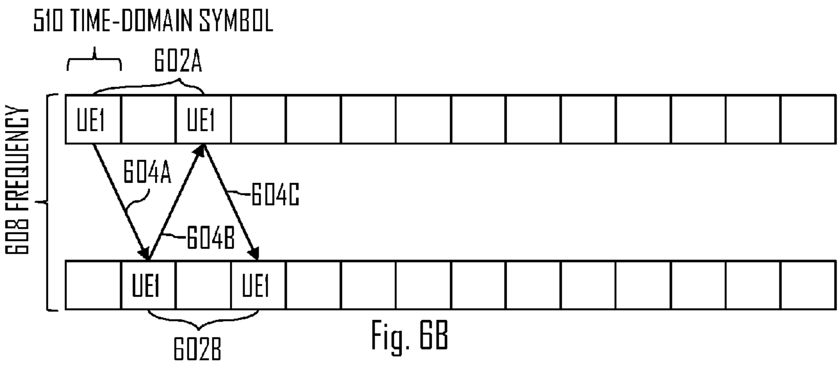

Fig. 6B

(57) Abstract: There is provided a method comprising: receiving, by a terminal device, one or more data blocks from a network element; determining an acknowledgement message related to the one or more data blocks; determining radio resources for transmission of the acknowledgement message, wherein the radio resources comprise a subset of first radio resources and a subset of second radio resources, the first and second radio resources being associated with a first logical channel and a second logical channel, wherein the subsets of the first and second radio resources are situated on different frequency areas of a radio band, and wherein combined duration of said subsets is less than duration of one subframe; and transmitting the acknowledgement message to the network element using said radio resources comprising the subsets of the first and second radio resources such that during the transmission at least one frequency hop between said subsets is performed.

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METHOD AND APPARATUS FOR DETERMINING ACK/NACK RESOURCES

TECHNICAL FIELD

The invention relates to communications.

BACKGROUND

In a communication network, data may be transferred between network elements and terminal devices. It may be beneficial to provide solutions to enhance transfer of acknowledgement information related to the transmitted data.

BRIEF DESCRIPTION

According to an aspect, there is provided the subject matter of the independent claims. Some embodiments are defined in the dependent claims.

One or more examples of implementations are set forth in more detail in the accompanying drawings and the description below. Other features will be apparent from the description and drawings, and from the claims.

BRIEF DESCRIPTION OF DRAWINGS

In the following embodiments will be described in greater detail with reference to the attached drawings, in which

Figure 1 illustrates an example a radio system to which embodiments of the invention may be applied;

Figure 2 illustrates a flow diagram according to an embodiment of the invention;

Figure 3 illustrates a flow diagram according to an embodiment of the invention;

Figures 4A to 4B illustrate some embodiments;

Figures 5A to 5B illustrate some embodiments;

Figures 6A to 6F illustrate some embodiments;

Figures 7A to 7B illustrate some embodiments;

Figures 8 to 10B illustrate some embodiments of the invention;

Figures 11 to 12 illustrate block diagrams of apparatuses according to some embodiments of the invention; and

Figure 13 illustrates an embodiment.

DETAILED DESCRIPTION OF SOME EMBODIMENTS

The following embodiments are exemplifying. Although the specification may refer to “an”, “one”, or “some” embodiment(s) in several locations of the text, this does not necessarily mean that each reference is made to the same embodiment(s), or that a particular feature only applies to a single embodiment. Single features of different embodiments may also be combined to provide other embodiments.

Embodiments described may be implemented in a radio system, such as in at least one of the following: Worldwide Interoperability for Micro-wave Access (WiMAX), Global System for Mobile communications (GSM, 2G), GSM EDGE radio access Network (GERAN), General Packet Radio Service (GRPS), Universal Mobile Telecommunication System (UMTS, 3G) based on basic wideband-code division multiple access (W-CDMA), high-speed packet access (HSPA), Long Term Evolution (LTE), and/or LTE-Advanced.

The embodiments are not, however, restricted to the system given as an example but a person skilled in the art may apply the solution to other communication systems provided with necessary properties. Another example of a suitable communications system is the 5G concept. 5G is likely to use multiple input – multiple output (MIMO) techniques, many more base stations or nodes than the LTE (a so-called small cell concept), including macro sites operating in co-operation with smaller stations and perhaps also employing a variety of radio technologies for better coverage and enhanced data rates. 5G will likely be comprised of more than one radio access technology (RAT), each optimized for certain use cases and/or spectrum. 5G mobile communications will have a wider range of use cases and related applications including video streaming, augmented reality, different ways of data sharing and various forms of machine type applications, including vehicular safety, different sensors and real-time control. 5G is expected to have multiple radio interfaces, namely below 6GHz, cmWave and mmWave, and also being integradable with existing legacy radio access technologies, such as the LTE. Integration with the LTE may be implemented, at least in the early phase, as a system, where macro coverage is provided by the LTE and 5G radio interface access comes from small cells by aggregation to the LTE. In other words, 5G is planned to support both inter-RAT operability (such as LTE-5G) and inter-RI operability (inter-radio interface operability, such as below 6GHz – cmWave, below 6GHz – cmWave – mmWave). One of the concepts considered to be used in 5G networks is network slicing in which multiple independent and dedicated virtual sub-networks (network instances) may be created within the same infrastructure to run services that have different requirements on latency, reliability, throughput and mobility.

Figure 1 shows an example of a radio system to which embodiments of the invention may be applied. Radio communication networks, such as the Long Term Evolution (LTE) or the LTE-Advanced (LTE-A) of the 3rd Generation Partnership Project (3GPP), are typically composed of at least one network element, such as a network element 102, providing a cell 104. As explained above, the radio system of Figure 1 may be an example and thus the embodiments of the invention may be applied in 5G system, for example. Each cell may be, e.g., a macro cell, a micro cell, or a pico-cell, for example. Thus, the communication network may be a heterogeneous network (HetNet). The network element 102 may be a network node, an evolved node B (eNB) as in the LTE and LTE-A, a radio network controller (RNC) as in the UMTS, a base station controller (BSC) as in the GSM/GERAN, or any other apparatus capable of controlling radio communication and managing radio resources within a cell. The network element 102 may be a base station or a small base station, for example. In the case of multiple eNBs in the communication network, the eNBs may be connected to each other with an X2 interface as specified in the LTE. Other communication methods between the network elements may be possible. Such may be the case, for example, with the 5G system.

The network element 102 may control one or more cellular radio communication links 116, 126, 136 established between the network element 102 and at least one terminal device 110, 120, 130 located within or comprised in the cell 104. The one or more cellular radio communication links 116, 126, 136 may be referred to as conventional communication link for end-to-end communication, where the source device transmits data to the destination device via the network element 102 and/or core network. Thus, the one or more cellular radio communication links 116, 126, 136 may be used to transmit data blocks to uplink and/or downlink direction. Further, control information may also be transmitted using said communication links.

The radio system may comprise more than one network element, similar to the network element 102. For example, a second network element may be used to increase performance of the communication network within the cell 104. For example, the second network element may be a local area access node or a small base station. Thus, a cell provided by the second network element may be, e.g., a macro cell, a micro cell, or a pico-cell, for example. Said cell may be referred to as a sub-cell, for example. Said sub-cell may at least partly be within and/or comprised in the cell 104. The second network element and the network element 102 may be connected, for example, over the X2 interface providing communication link between network elements. The second network element may control a cellular radio communication link(s) established between the second network element and at least one terminal device 110, 120, 130.

The network element 102 and the second network element may further be connected via an S1 interface to an evolved packet core (EPC) 130, more specifically to a mobility management entity (MME) and to a system architecture evolution gateway (SAE-GW).

The at least one terminal device 110, 120, 130 may be simultaneously within multiple cells provided by network element(s). The serving network element may be selected by various criteria, such as received power, signal to noise ratio (SNR) and path loss, to name a few. The at least one terminal device 110, 120, 130 may be a terminal device of a cellular communication system, e.g. a computer (PC), a laptop, a palm computer, a mobile phone, a tablet, a phablet or any other user terminal or user equipment capable of communicating with the cellular communication network.

In an embodiment, the at least one terminal device 110, 120, 130 is able to communicate with other similar devices via the network element 102. The other devices may be within the cell 104 and/or may be within other cells provided by other network elements. The at least one terminal device 110, 120, 130 may be stationary or on the move. In an embodiment, the at least one terminal device 110, 120, 130 may communicate directly with other terminal devices using, for example, Device-to-Device (D2D) communication.

The radio system may support Carrier Aggregation (CA). CA may enable increasing usable bandwidth between the terminal devices and network elements of the radio system. For example, in the 3GPP, CA may be used for LTE-A in order to support wider transmission bandwidths enhancing increased potential peak data rates to meet LTE-A requirements. For example, more than one component carriers may be aggregated contiguously and/or non-contiguously to provide a wider bandwidth. In uplink carrier aggregation, multiple uplink component carriers may be aggregated and can be allocated in a subframe to a terminal device.

The radio system may support Dual Connectivity (DC). This may be enabled by the network element 102 and the second network element, for example. Naturally, in order to use DC, the at least one terminal device 110, 120, 130 may also need to support DC. The DC may be a radio system feature, wherein the at least one terminal device 110, 120, 130 may simultaneously receive and/or may simultaneously transmit to at least two network points. Similarly, the radio system of Figure 1 may support Multiple-Input and Multiple-Output (MIMO) techniques. Thus, the network elements and/or the terminal devices of the radio system may comprise more than one antenna for data transfer.

It may be possible that the radio system shown in Figure 1 supports Licensed-Assisted Access (LAA) which relates to using unlicensed radio band(s) for data transfer. For example, the network element 102 and/or the second network element may provide one or more cells on an unlicensed radio band in order to increase data transfer capability on the radio system. For example, the network element 102 may allocate radio resources of the one or more cell on an unlicensed radio band for the at least one terminal device 110, 120, 130 through CA, thus increasing the data transfer between the at least one terminal device 110, 120, 130 and the network element(s).

When data blocks are transmitted from the network element(s), such as from the network element 102, to the at least one terminal device 110, 120, 130, the receiving terminal device may respond to the transmitter with acknowledgement message. The acknowledgement message may comprise Hybrid Automatic Repeat ReQuest Acknowledgement/Non-Acknowledgement (HARQ-ACK) information. The HARQ-ACK may be used to indicate to the transmitter whether a specific data block has been successfully received by the receiver. For example, a terminal device 110 may receive one or more data blocks from the network element 102, and transmit the HARQ-ACK to the network element 102 indicating that the one or more data blocks were successfully received. Generally speaking, HARQ-ACK can contain one or more HARQ-ACK bits corresponding to one or more transport blocks (per subframe and component carrier). In the case of Time Division Duplex (TDD) mode, HARQ-ACK corresponding to multiple Downlink (DL) subframes/HARQ processes may be transmitted via one UL subframe. The same principle may apply to carrier aggregation where HARQ-ACK corresponding to multiple component carriers/HARQ processes may be transmitted via one UL component carrier. The HARQ-ACK may also be used to indicate to the transmitter whether a specific set of data blocks has been successfully received by the receiver. For example, a terminal device 110 may receive one or more data blocks from the network element 102, and transmit the HARQ-ACK to the network element 102 indicating that all data blocks within a pre-determined set, e.g. all data blocks within a pre-determined set of subframes, were successfully received.

To increase the performance of the radio system, it may be beneficial to support shorter Transmission Time Interval (TTI) and TTI processing time in the radio system. TTI processing time is the time that UE and/or eNB requires to perform TTI related processing, for example such as, but not limited to, channel estimation, received signal detection, demodulation and decoding, HARQ related processing, determination of control signals, determination of transmission parameters, including scheduling and link adaptation in case of eNB, encoding, interleaving, multiplexing, and modulating. It may also be beneficial to preserve backwards compatibility of the radio system and thus support larger TTI values and TTI processing time which may be used, for example, with the LTE system. Support for shorter TTI value(s) and TTI processing time may be required in order to reduce latency of the radio system. However, as the TTI of the transmitted data blocks decreases, acknowledgement messages, such as HARQ-ACK, may need to be configured to support the reduced TTI lengths and TTI processing time.

For example, Physical Uplink Control Channel (PUCCH) may be used to transmit HARQ-ACK related to one or more data blocks in the LTE system. As discussed above, the LTE system may be understood as an example, and thus similar systems may be used in which, for example, an equivalent of the PUCCH may be utilized.

From a terminal device perspective PUCCH consists of frequency resources of one Physical Resource Block (PRB) (i.e. reaching over 12 subcarriers) and time resource of one subframe (e.g. 1 millisecond for a LTE subframe). To handle coverage-limited situations, transmission of HARQ-ACK may span the full 1 ms subframe. With PUCCH, slot-based frequency hopping between the band edges symmetrically over the center frequency may be applied. The frequency hopping may provide frequency diversity, and thus increase the control signaling robustness, for example. For example, there may be three different PUCCH formats in the LTE system:

- Format 1/1a/1b may be used to convey Scheduling Request (SR) and/or HARQ-ACK. Said format may be based on the combination of Constant Amplitude Zero AutoCorrelation waveform (CAZAC) sequence modulation and block-wise spreading, and can carry one information symbol (e.g. 1 or 2 bits) per subframe.
- Format 2/2a/2b may be used to convey periodic Channel State Information (CSI) (with (2a, 2b) or without (2) HARQ-ACK). Said format may utilize CAZAC sequence modulation, and is capable of conveying 5 symbols per slot (e.g. 10 coded bits + 1 or 2 Acknowledgement/Non-Acknowledgement (ACK/NACK) bits per subframe).

- Format 3 introduced in Rel-10 of LTE specifications may be used to convey CA HARQ-ACK (with and without CQI/SR). Said format may be based on the combination of Discrete Fourier Transform-spread- Orthogonal Frequency-Division Multiplexing (DFT-S-OFDMA) and block-wise spreading, and may convey 12 information symbols (e.g. 24 bits with QPSK) per slot.

For example, TTI lengths from one symbol (e.g. OFDM symbol or SC-FDMA symbol) to 0.5 ms may be supported by the future LTE systems. Therefore, the current HARQ-ACK process or similar acknowledgement process may need to be enhanced in order to tackle the future requirements for radio interface latency. Further, as explained, there may a need to support the existing solutions and/or coexist, for example, with the current LTE features and/or channels (e.g. Sounding Reference Signal (SRS)).

Therefore, there is provided a solution to enhance the acknowledgement message (e.g. HARQ-ACK) transfer. The solution may enable support for shorter TTI lengths in the radio system, thus enabling the system latency to be reduced.

Figure 2 illustrates a flow diagram of an embodiment of the invention. Referring to Figure 2, in step 210, a terminal device may receive one or more data blocks from a network element. In step 220, said terminal device may determine an acknowledgement message related to the one or more data blocks. In step 230, said terminal device may determine radio resources for transmission of the acknowledgement message, wherein the radio resources comprise a subset of first radio resources and a subset of second radio resources, the first and second radio resources being associated with a first logical channel and a second logical channel, wherein the subsets of the first and second radio resources are situated on different frequency areas of a radio band, and wherein combined duration of said subsets is less than duration of one subframe. In step 240, said terminal device may transmit the acknowledgement message to the network element using said radio resources comprising the subsets of the first and second radio resources such that during the transmission at least one frequency hop between said subsets is performed.

The terminal device performing the steps 210-240 of Figure 2 may be and/or be comprised in the at least one terminal device 110, 120, 130, for example. Further, an apparatus (e.g. circuitry) integrated with a terminal device may perform the steps of Figure 2. The network element related to Figure 2 may be and/or be comprised in the network element 102 and/or the second network element.

Figure 3 illustrates a flow diagram according to an embodiment of the invention. Referring to Figure 3, in step 310, a network element may transmit one or more data blocks to a terminal device. In step 320, said network element may receive an acknowledgement message from the terminal device, the acknowledgement message related to the transmission of the one or more data blocks, wherein the acknowledgement message is received on radio resources comprising a subset of first radio resources and a subset of second radio resources, the first and second radio resources being associated with a first logical channel and a second logical channel, wherein the subsets of the first and second radio resources are situated on different frequency areas of a radio band, wherein combined duration of said subsets is less than duration of one subframe, and wherein the acknowledgement message is received on the subsets of the first and second radio resources such that at least one frequency hop between said subsets is performed.

The network element performing the steps 310-320 of Figure 3 may be and/or be comprised in network element 102, for example. Further, an apparatus (e.g. circuitry) integrated with a network element may perform the steps of Figure 3. The terminal device related to Figure 3 may be and/or be comprised in the at least one terminal device 110, 120, 130. Let us now examine closer on some embodiments of the invention. Some of the following embodiments are introduced as being performed by a terminal device 110 (i.e. comprised in the at least one terminal device 110, 120, 130) and/or the network element 102. This is done for simplicity reasons, and thus there may be different device(s) and/or network element(s) performing said embodiment and/or functions.

Figures 4A to 4B illustrate some embodiments. Referring to Figures 4A to 4B, the network element 102 may transmit configuration information to the terminal device 110, wherein the configuration information indicates the first and second radio resources to the terminal device 110. This may mean that the terminal device 110, based on the configuration information, may become aware how to use the radio resources. E.g. the configuration information from the network element 102 may cause the terminal device 110 to enter into a reduced latency mode, wherein the first and second radio resources are used the way described in Figure 2. Similarly, the terminal device 110 may acquire configuration information from the network element 102, wherein the determining the radio resources (i.e. subsets of the first and second radio resources) for the transmission of the acknowledgement message (e.g. transmitted in step 240 of Figure 2) is at least partly based on the received configuration information.

The transferred configuration information may be understood as higher-layer configuration information. Thus, the network element 102 and/or some other network element may configure the terminal devices (or at least some of the terminal devices) within the cell 104 or a larger area to use the described acknowledgement message transmission. For example, the network element 102 may configure the terminal device 110 to use the described method when the terminal device 110 enters the cell 104. Thus, the terminal device 110 may be aware of the configuration when downlink data is received from the network element 102, and may therefore act accordingly with the acknowledgement message (e.g. HARQ ACK).

Two examples of the configuration information signaling may be shown in Figure 4A. The network element 102 may, for example, use dedicated signaling 402 to indicate to the terminal device 110 about the acknowledgement message configuration. This may not necessarily mean that the resources for the acknowledgement message transmission are given, but that the terminal device 110 becomes aware about how to interpret and/or use allocated resources for the acknowledgement message transmission. Another example may be the use of common signaling 404 (e.g. broadcasting). Thus, the network element 102 may configure one or more terminal devices 110, 120, 130 to use the reduced latency mode, i.e. transmitting the acknowledgement message on the first and second radio resources as explained in relation to Figures 2 and 3.

The configuration information may indicate to the one or more terminal devices 110, 120, 130 acknowledgement message resource pool (e.g. HARQ ACK resource pool) for transmitting the acknowledgement message related to the received one or more data blocks. Thus for example, the terminal device 110 may become aware of the acknowledgement message resource pool, and select and/or use the subsets of the first and second resources to transmit the acknowledgement message, wherein the first and second radio resources are comprised in the acknowledgement message resource pool.

Referring to Figure 4B, the terminal device 110 may determine the configuration of the reduced latency mode (block 412). That is, the terminal device 110 may determine the configuration of the acknowledgement message resource pool, for example. This may simply mean that the terminal device 110 may receive the configuration from the network element 102 as shown in Figure 4A, for example.

At some point, the network element 102 may transmit downlink data to the terminal device 110 (block 414). The downlink data may comprise one or more data blocks for example. Each data block may comprise, for example, one or more transport blocks. In block 416, the terminal device 110 may determine the acknowledgement message related to the received one or more transport blocks. For example, if one data block out of two transmitted transport blocks are received, the terminal device 110 may generate the acknowledgement message such that said message indicates which data blocks were received (ACK) and which were not (NACK).

In block 418, the terminal device 110 may determine radio resources for transmitting said acknowledgement message. The determination of the radio resources may be based on the received configuration of the reduced latency mode from the network element 102. This may mean that the terminal device 110 determines the subsets of the first and second radio resources from the acknowledgement message resource pool indicated by the network element 102. In block 420, the terminal device 110 may transmit the acknowledgement message to the network element 102 using the subsets of the first and second radio resources, as described in relation to Figure 2.

The configuration of the terminal device(s) 110, 120, 130 in Figure 4A (and consequently the determination of the configuration in step 412 of Figure 4B) may be performed such that the configuration signaling comprises needed parameters to enable, for example, the terminal device 110 to transmit the HARQ-ACK (or similar acknowledgement message) via the resources pool defined for the reduced latency mode. The needed parameters may comprise HARQ-ACK resource index or alternatively the parameters used to derive it, Tx format, and/or power control –related parameters.

Figures 5A to 5B illustrate some embodiments. Referring to Figure 5A, the radio resources used for transmitting the acknowledgement message may be comprised in a radio frame 502, and more precisely in one or more subframes 506 of the radio frame 502. Using LTE system as an example, one LTE radio frame (i.e. LTE frame) may comprise ten subframes each having length of 1 ms, and thus the LTE frame may be 10 ms long.

Referring to Figure 5B, the subframe 506 may comprise two slots 508, wherein each slot 508 comprises one or more time-domain symbols 510. One slot may be, for example, 0.5 ms long. The time-domain symbols 510 may comprise, for example, OFDM and/or SC-FDMA symbols. In an embodiment, the slot 508 comprises 6 or 7 time-domain symbols 510. Therefore, the subframe 506 may comprise, for example, 14 SC-FDMA symbols (i.e. the SC-FDMA symbols being time-domain symbols).

The time-domain symbol(s) 510 may be, for example, OFDM or SC-FDMA symbol(s). However, time-domain symbol(s) 510 are not limited to these, and thus, for example, they may also comprise future time-domain symbol(s) of 5G system. The use of different time-domain symbol(s) may depend on the modulation scheme used in the particular system. For example, one Physical Resource Block (PRB) may comprise 12 frequency bins extending over 7 consecutive time-domain symbols 510 (e.g. SC-FDMA symbols). In an embodiment, the subsets of the first and second radio resources each comprise at least one time-domain symbol. The at least one time-domain symbol may be, for example, similar to the time-domain symbol 510 shown in Figure 5B. Therefore, for example, the first radio resources may comprise one or more time-domain symbols 510 and the second radio resources may comprise one or more time-domain symbols 510. In an embodiment, the subsets of the first and second radio resources each comprise maximum of seven time-domain symbols.

Figures 6A to 6F illustrate some embodiments of the invention. Referring to Figure 6A, the situation of Figure 5B may be illustrated such that the frequency dimension is also shown. As described above, the subsets of the first and second radio resources may be located in different frequency areas. This may be shown in Figure 6A, for example, wherein the radio resources for the acknowledgement message transmission comprise radio resources from a first frequency area and from a second frequency area. For example, the subset of the first radio resources may comprise radio resources 602A, and the subset of the second radio resources may comprise radio resources 602B. Thus, for example, each subset may comprise two time-domain symbols 510.

In an embodiment, the at least one frequency hop, between the subsets of the first and second radio resources, comprises only one frequency hop between the subsets of the first and second radio resources. Example of this may be shown in Figure 6A, wherein a frequency hop 604 may be performed from one subset (e.g. comprising the radio resources 602A) to another subset (comprising the radio resources 602B). The frequency hop 604 may be performed from the subset of the first radio resources to the subset of the second radio resources.

In an embodiment, the frequency hop is performed in the middle of the radio resources for the acknowledgement message transmission. For example, if the subsets of the first and second radio resources each comprise two time-domain symbols, the frequency hop 604 may be performed after two time-domain symbols.

It may also be possible that the number of time-domain symbols in the subsets is different, and thus the frequency hop 604 may be performed more than once and/or not in the middle in respect to the radio resources for the acknowledgement message transmission. For example, if one subset comprises one time-domain symbol and the other comprise three time-domain symbols, the frequency hop 604 may performed after one or three time-domain symbols. One example of uneven number of time-domain symbols in the different subsets may be seen in Figure 9, wherein one of the subsets may be have less time-domain symbols because of Sounding Reference Signal (SRS). SRS may prevent transmission, by the terminal device 110, on one or more time-domain symbols if the SRS is simultaneous with said one or more time-domain symbols. Thus, for example, if the subsets each comprise two time-domain symbols, and SRS would collide with one time-domain symbol of one of the subsets, therefore the terminal device 110 may utilize radio resources comprising one time-domain symbol in one subset and two time-domain in the other subset. Another example may be that shortened PUCCH transmission (e.g. on top of twoPUCCH format 2/2a/2b resources) comprises an odd number of time-domain symbols. Therefore, one of the subsets may consequently comprise an odd number of time-domain symbols.

In an embodiment, the at least one frequency hop between the subsets of the first and second radio resources is performed after each time-domain symbol comprised in said subsets. Example of this may be show in Figure 6B, wherein frequency hops 604A-604B may be performed between the subsets of the first and second radio resources. For example, the subset of the first radio resources may comprise the radio resources 602A, and the subset of the second radio resources may comprise the radio resources 602B. It may also be possible that the at least one frequency hop is performed after, for example, two time domain symbols.

The frequency hopping may increase the frequency diversity of the transmission, and thus may enhance the robustness of the acknowledgement message transfer. Therefore, it may be beneficial to perform at least one frequency change, i.e. use resources from both subsets which are located in different frequency areas.

To increase the frequency diversity, the subsets of the first and second radio resources may be situated on different side areas of the radio band. For example, referring to 6B frequency 608 may be illustrated, wherein the frequency 608 may illustrate the frequency area of the radio band. That is, the frequency of the radio band. Thus for example, the subset 602A of the first radio resources may be situated on one side area of the frequency 608, and the subset 602B of the second radio resources may be situated on other side area of the frequency 608. In other words, the subsets 602A, 602B may situated on the radio band edge areas and/or edges.

Referring to Figure 6A, the transmitting the acknowledgement message in step 240 of Figure 2 may comprise: transmitting, by the terminal device 110, using the subset 602A of the first radio resources; after transmitting using the subset 602A of the first radio resources, performing the frequency hop 604; and transmitting using the subset 602B of the second radio resources. Similarly, the receiving the acknowledgement message in step 320 of Figure 3 may comprise: receiving, by the network element 102, on the subset 602A of the first radio resources; after receiving on the subset 602A of the first radio resources, determining that the frequency hop 604 is performed; and receiving on the subset 602B of the second radio resources.

In an embodiment, the subsets of the first and second radio resources are situated such that the radio resources of said subsets are not simultaneous to each other. Let us again look at the example of Figure 6A, wherein the radio resources 602A, 602B of the subsets may be situated such that they are not simultaneous to each other. Another example of this may be shown in Figure 6B. This may mean that when radio resources of one subset are utilized, the radio resources of the other subset are not, and vice versa. Therefore, time and frequency diversity to the acknowledgement message transfer may both be achieved if necessary.

Referring to Figure 6C, one example of the subset of the first and second radio resources may be shown. The subframe 506 may be shown, wherein the subframe 506 comprises the slots 508A, 508B. As described in relation to Figures 6A and 6B, the subsets 602A, 602B (i.e. radio resources 602A, 602B of the subsets) may be comprised in one slot of a subframe. However, as shown in Figure 6C, the subsets 602A, 602B may be fully or partially comprised in different slots 508A, 508B of the subframe 506.

In an embodiment, the subsets 602A, 602B are at least partially comprised in different subframes. For example, the subsets 602A, 602B may be partially comprised in different subframes of the radio frame 502.

Looking closer on Figure 6C, the slot boundary between slots 508A, 508B may also indicate boundary for the first and second radio resources. For example, the first radio resources within the subframe 506 may be comprised in a first frequency area 692 for the duration of the first slot 508A and in a second frequency area 694 for the duration of the second slot 508A. Similarly, the second radio resources within the subframe 506 may be comprised in the second frequency area 694 for the duration of the first slot 508A and in the first frequency area 694 for the duration of the second slot 508A. Therefore, with the first radio resources a frequency hop from the first frequency area 692 to the second frequency area 694 may need to be performed, and similarly with the second radio resources a frequency hop from the first frequency area 692 to the second frequency area 694 may need to be performed. This may mean that, for example, the subset 602B is partially comprised in the second radio resources and partially comprised in the first radio resources.

In an embodiment, the first radio resources are comprised in one frequency area of the first slot 508A and the second radio resources are comprised in another frequency area of the second slot 508B, and wherein the subsets of the first and second radio resources are one time-domain symbol 510 long. Thus, the subsets may be situated at the slot boundary.

Referring to Figure 6D, further subsets 696A, 696B of the first and second radio resources may be used by other terminal devices. For example, the subsets 696A, 696B may be used by a third terminal device similar to the terminal device 110. The subsets 696A, 696B may be determined similarly as the subsets 602A, 602B, for example.

In an embodiment, the network element 102 transmits at least one data block to the third terminal device; receives a third acknowledgement message from the third terminal device, the third acknowledgement message related to the transmitted at least one data block, wherein the third acknowledgement message is received on subsets 696A, 696B of the first and second radio resources.

In an embodiment, the subsets 696A, 696B are simultaneous with the subsets 602A, 602B. This may be shown in Figure 6D, wherein the subset 602A may be simultaneous with the subset 696A, and the subset 602B may be simultaneous with the subset 696B.

In an embodiment, the radio resources of the subset 696A are situated on same frequency area compared with the radio resources of the subset 602A, and the radio resources of the subset 696B are situated on same frequency area compared with the radio resources of the subset 602B.

Let us now take a closer look on the how the acknowledgement message channel structure may be built with reference to Figure 8. There may be different ways to structure and/or control the usage of the first and second radio resources, and more precisely the subsets of the first and second radio resources. The resources may be arranged either in the logical channel domain by means of a parameter n (i.e. $n_{\mathrm{PUCCH}}^{(2,\tilde{p})}$), or in the physical resource domain (such as PRB indexes and CAZAC sequence cyclic shifts).

The two different basic principles to define the acknowledgement message channel structure (e.g. HARQ-ACK channel structure) on top of PUCCH Format 2/2a/2b resources pair (i.e. the first and second radio resources may form said resource pair). Referring to Figure 8, the physical resource domain example may be shown with sub-slots 810, 820, the two sub-slots extending over one HARQ-ACK TTI 804. For example, the first resources 810 may comprise, during the HARQ-ACK TTI, two time-domain symbols 806 on the PRB #0 (e.g. on the frequency edge area). Further, the first resources 810 may comprise, during the HARQ-ACK TTI, two time-domain symbols 806 on the PRB #N+1 (e.g. on the frequency edge area). Same may apply for the second radio resources 820. Therefore, the frequency hopping may take place at the sub-slot boundary between the two PRBs defined, for example, by the PUCCH format 2/2a/2b resources.

The logical channel example may be shown with the radio resources 830, 840. The terminal device 110 may obtain, for example, a predefined SC-FDMA symbol based hopping pattern over two PRBs (e.g. #1 and #N). The hopping may thus take place after every SC-FDMA symbol between the PRBs, for example.

It needs to be noted that the #N+1 PRB may mean the outermost PRB on the frequency 802 and/or the radio band. Similarly, the #N may be the outermost PRB if defined such. Same applies for the PRB #1.

Let us now look closer on the first and second radio resources with reference to Figures 6E and 6F. The first and second radio resources 610 (610A, 610B), 620 (620A, 620B) may be illustrated. In an embodiment, the first radio resources 610 or the second radio resources 620 are used to transmit the acknowledgement message. Therefore, not necessarily both of the radio resources 610, 620 are utilized by a terminal device. In an embodiment, the first radio resources are first PUCCH format 2/2a/2b resources, and the second radio resources are second PUCCH format 2/2a/2b resources.

In Figure 6F, it may be shown that the subsets used by the terminal device 110 (e.g. UE1) may be comprised in the first and second radio resources 610, 620. Further, the network element 102 may receive acknowledgement message from the terminal device 110 on the subsets of the first and second radio resources, and also receive an acknowledgement message from another terminal device on the first and/or second radio resources 610, 620. This may be because the subsets may only utilize partly the first and second radio resources. Therefore, it is possible that the network element 102 receives one or more acknowledgement messages from one or more terminal devices on subsets of the first and second radio resources (e.g. two messages from two terminal devices, i.e. total of four subsets), and PUCCH format 2/2a/2b HARQ-ACK message from another terminal device on the first and/or the second radio resources.

It needs to be understood that the length of the one or more acknowledgement messages (e.g. number of time-domain symbols in different subsets) may vary between parallel and consecutive resources. For example, an acknowledgement message transmitted by a first terminal device may comprise 3 time-domain symbols (e.g. 1 and 2 time-domain symbols in different subsets). Further, an acknowledgement message transmitted by a second terminal device may comprise 4 time-domain symbols (e.g. 2 time-domain symbols in different subsets). As described above, these two acknowledgement messages may be comprised in the same first and second radio resources (i.e. be subsets of the first and second radio resources). It further needs to be understood that the one or more acknowledgement messages may be received and/or transmitted via different parallel resources (i.e. within one PRB but separated by different sequence cyclic shift and/or resources located on different PRBs), and/or via consecutive subframes.

In an embodiment, the terminal device 110 may determine whether the one or more data blocks are related to a first latency mode or to a second latency mode, wherein a transmission time interval of the one or more data blocks related to the first latency mode is shorter compared with the transmission time interval of the one or more data blocks related to the second latency mode; and if the one or more data blocks are related to the first latency mode, transmit the acknowledgement message using the subsets of the first and second radio resources 610, 620, or if the one or more data blocks are related to the second latency mode, transmitting the acknowledgement message using the first radio resources 610 or the second radio resources 620. This may mean that the terminal device 110 may determine, before step 230 of Figure 2, whether it should transmit the acknowledgement message using the subsets, the first radio resources, or the second radio resources.

For example, if the network element 102 is transmitting data related to the second latency mode (i.e. normal latency mode), wherein the TTI of the data blocks may be at least 1 ms, the terminal device 110 may respond using the first or the second radio resources. For example, it may respond with periodic CSI and HARQ-ACK transmission using PUCCH format 2a/2b resources. If however, the network element 102 is transmitting data related to the first latency mode (i.e. reduced latency mode), wherein the TTI of the data blocks may be less than 1 ms (e.g. from one symbol to one slot), the terminal device 110 may respond using the subsets of the first and the second radio resources.

As described above, the radio resources used by the terminal device(s) may be comprised in radio resource pool(s). The radio resource pool(s) may be indicated by the network element 102 to the terminal device(s), for example. The first and second latency modes may each have a dedicated radio resources pool and/or they may be related to the same radio resource pool. The one or more (e.g. 1 to 2) radio resource pools may comprise a number of PUCCH format 2/2a/2b resources with dedicated cyclic shift and PRB allocation.

In one example, the network element 102 may transmit configuration information to the terminal device 110, wherein the configuration information causes the terminal device 110 to transmit the acknowledgement message in wanted latency mode.

In an embodiment, the transmitted data blocks, by the network element 102 to the terminal device 110, are related to the first latency mode or to the second latency mode, wherein transmission time interval of the transmitted data blocks related to the first latency mode is shorter compared with the transmission time interval of the transmitted data blocks related to the second latency mode, wherein if the transmitted data blocks are related to the first latency mode, receiving the acknowledgement message on the subsets of the first and second radio resources, or if the transmitted data blocks are related to the second latency mode, receiving the acknowledgement message on the first radio resources or the second radio resources. In the latter case, it may also be possible that, for example, CSI is transmitted with the acknowledgement information.

In an embodiment, each of the first and second radio resources 610, 620 comprise two consecutive slots having length of 0.5 milliseconds, and wherein the two consecutive slots are situated on different frequency areas of the radio band. Example of this may be shown in Figure 6F, for example.

Figures 7A to 7B illustrate some embodiments of the invention. Referring to Figure 7A, the resource mapping of the first and second radio resources to the PRB-domain may be illustrated. The mapping may be illustrated for duration of one subframe 704. For example, the system bandwidth 702 may comprise a plurality PRBs.

The first radio resources may be comprised in the sections indicated with m=0, for example. In such case, the second radio resources may be comprised in the sections indicated with m=1. In another example, the first radio resources are comprised in the sections indicated with m=2. In such case the second radio resources may be comprised in the sections indicated with m=3.

In an embodiment, the m=0, m=1, m=2, and m=3 indicate PUCCH format 2/2a/2b resources of the system bandwidth 702. The system bandwidth 702 may comprise the radio band or equal to the radio band described in relation to Figure 2, for example.

In an embodiment, the first PUCCH format 2/2a/2b resources are characterized by a first resource index and the second PUCCH format 2/2a/2b resources are characterized by a second resource index, and wherein the difference between the first resource index and the second resource index is 12. Example of this may be shown in Figure 7B, wherein the resource indexes related to m=0 may range from 0 to 11, for example. Thus, for example, if the first resource index equals to 2, the second resource index may equal to 14. Therefore, for example, $n_{\mathrm{PUCCH}}^{(2,\tilde{p},2)} = n_{\mathrm{PUCCH}}^{(2,\tilde{p},1)}$ +12, wherein $n_{\mathrm{PUCCH}}^{(2,\tilde{p},2)}$ equals to the second resource index and $n_{\mathrm{PUCCH}}^{(2,\tilde{p},1)}$ equals to the first resources index. The resource indexes may be shown in Figure 7B.

Another way to express the above-mentioned frequency diversity acquiring is to select the PRB resources such that

- for the first radio resources, $n_{\mathrm{PUCCH}}^{(2,\tilde{p},1)}$ is selected such that $m_1 = \left\lfloor n_{\mathrm{PUCCH}}^{(2,\tilde{p},1)} / 12 \right\rfloor$ is an even integer and;
- for the second resource, $n_{\mathrm{PUCCH}}^{(2,\tilde{p},2)}$ is selected such that $m_2 = \left\lfloor n_{\mathrm{PUCCH}}^{(2,\tilde{p},2)} / 12 \right\rfloor$ is an odd integer.

If we take a look at Figure 7A, we may see that the when, for example, m_1 equals to zero for the first resource, m_2 may equal to 1 for the second resource. This may mean that two resources occupy exactly the same PRB resources over the subframe, which in turn can improve the receiver performance e.g. by means of improved channel estimation.

Let us consider now the PUCCH 2/2a/2b resource used as an example for the embodiments of the invention. A PUCCH Format 2/2a/2b resource may be understood to determine a PRB, a base sequence and a sequence cyclic shift used for transmission by the terminal device 110, for example. At least some of them may change between SC-FDMA symbols according to frequency hopping, cyclic shift randomization and/or base sequence (group) hopping patterns.

Referring to Figure 6B, for example, a SC-FDMA symbol based hopping pattern may be shown. In case that SC-FDMA symbol based hopping pattern over two PUCCH format 2/2a/2b resources is applied, block-wise spreading may be applied over SC-FDMA symbols transmitted on the same PRB, e.g. over every second SC-FDMA symbol. Thus, for example, for the symbols comprising the subsets 602A same block-wise spreading may be applied. The block-wise spreading may be applied when, for example, the HARQ-ACK TTI expands over more than three SC-FDMA symbols. In Figure 6B, the HARQ-ACK TTI may expand over four SC-FDMA symbols (i.e. radio symbols 510 may be SC-FDMA symbols). The block-wise spreading may increase the multiplexing capacity of given radio resources by a factor of spreading factor (SF) used. For example, spreading factor of two may be applied for both a reference signal part and a data part within each sub-slot. This may mean that the length of each sub-slot would be 4 time-domain symbols 806, such as SC-FDMA symbols, and the control TTI would become 8 time-domain symbols long.

The low latency PUCCH may involve a specific arrangement for HARQ-ACK transmission, for example non-coherent transmission without reference signal (RS). This approach may be beneficial especially when the duration of a HARQ-ACK TTI is only a few SC-FDMA symbols (e.g. 2). One example would be to apply on-off keying (similar to current scheduling request transmission) combined with HARQ-ACK bundling when transmitting HARQ-ACK

o Bundled NACK may correspond to DTX

o Bundled ACK may correspond transmission.

Figure 9 illustrates an embodiment. Referring to Figure 9, an arrangement for multiplexing between HARQ-ACK and Sounding Reference Signal (SRS) may be shown. In the example of Figure 9, the length of HARQ-ACK TTI may be an odd number. For example, for the first three HARQ-ACK TTI length may be three time-domain symbols (e.g. SC-FDMA symbols) and for the last HARQ-ACK TTI length may be five time-domain symbols. Therefore, for example, for the HARQ-ACK TTI 904 the length of the part 912A may be one symbol shorter compared to the part 912B, wherein the parts 912 may be comprised in the subsets of the first and/or second radio resources. For example, part 912A may form one subset and the part 912B may form another subset. The corresponding parts may be shown with same filling color Figure 9.

When a system-specific SRS symbol 918 collides with a part (e.g. radio resources of a subset of the first and/or second radio resources) comprised in the HARQ-ACK TTI (e.g. HARQ-ACK TTI 906), puncturing 916 may be applied for the part having one symbol more. Thus, for example, the parts 914B and/or 912B may be shorter during the HARQ-ACK TTI 906 compared with the HARQ-ACK TTI 904. If the SRS symbol 918 collides with a part having less time-domain symbols, the parts may need to be rearranged. For example, if the SRS symbol 918 collides with the part 912A, the part 914B may need to be shortened to one time-domain symbol and the excess time-domain symbol allocated to the part 912A. Similar reasoning may apply for the part 914A.

In an embodiment, the radio resources for the acknowledgement message transmission follow an interference randomization base sequence of the PUCCH format 2/2a/2b resources. The cell specific base sequence may be a function of the Physical layer Cell Identity. If sequence group hopping is enabled by higher layer signaling, the base sequence may change between time slots. Thus, cyclic shift may be changed between time slots and SC-FDMA symbols according to rules defined for the two PUCCH Format 2/2a/2b resources (e.g. the first and second radio resources).

In an embodiment, the radio resources used for the transmitting the acknowledgement message determine time-domain symbols and discrete Fourier transformation frequency bins used for the transmission. For example, a PRB may comprise 12 frequency bins during 7 time-domain symbols. Thus, radio resources (e.g. the subsets of the first and second radio resources) may determine the resource elements used for the transmission.

Figure 10A illustrates an embodiment of the invention. Referring to Figure 10A, an example of a resource pool with a number of implicit HARQ-ACK resources 1004 may be shown. The HARQ-ACK resources 1004 may refer to the radio resources used to transmit the acknowledgement message comprising the subsets of the first and second radio resources. The resource pool may have a higher-layer -configured starting point 1020 with given resource index $n_{\mathrm{PUCCH}}^{(2,\tilde{p},1)}$ for the first PUCCH format 2/2a/2b resources. The corresponding resource (i.e. the second PUCCH 2/2a/2b resources) may be derived implicitly by $n_{\mathrm{PUCCH}}^{(2,\tilde{p},2)}=n_{\mathrm{PUCCH}}^{(2,\tilde{p},1)}+12$. The following resource pairs may be derived with a predetermined cyclic shift with respect to the previous resources. For example, Δ2 may be set to, for example, 1, 2, or 3, wherein, for the following resource pairs Δ2 may be added to the first and second radio resources respectively. For example, in the example of Figure 10A, Δ2 may equal to 2. This may indicate that for the HARQ-ACK resources 1004 there is a difference of two (e.g. 12 to 14) between consecutive two first PUCCH format 2/2a/2b resource 1002 portions. Similarly, between two consecutive second PUCCH format 2/2a/2b resource 1002 portions, there may be a difference of Δ2 (e.g. 24 to 26).

Further, after a certain number of cyclic shifts (e.g. 12 cyclic shifts in Figure 10A) have been occupied (i.e. 12/Δ2 resource pairs have been assigned), there may need to be an additional offset value (e.g. +12 in Figure 10A) to take into account that each pair occupies two resources in the consecutive PRBs: $n_{\mathrm{PUCCH}}^{(2,\tilde{p},\frac{12}{\Delta_2})}$ = ($n_{\mathrm{PUCCH}}^{(2,\tilde{p},1)}+24$) and ($n_{\mathrm{PUCCH}}^{(2,\tilde{p},1)}+36$). This may be shown in Figure 10A.

The given set of PUCCH Format 2/2a/2b resources may provide a set of predetermined HARQ-ACK resources with a predefined length for “HARQ-ACK TTI”.

For example, there may be two resources for each resource pair (e.g. if block spreading is not defined). The HARQ-ACK resource indexes may increase with the resources pair indexes as shown in Figure 10A. If block spreading is applied, then SF value applied may define the number of parallel resources per implicitly determined resource. For example, if SF=2, then there may be four resources corresponding to each pair or PUCCH Format 2/2a/2b resources.

There may be a one-to-one mapping between HARQ-ACK resources and control channel element (CCE/eCCE) indexes, or short-TTI DL control channel element indexes, carrying short-TTI Physical Downlink Shared Channel (PDSCH) scheduling assignment. Alternatively, the terminal device(s) may be configured with a set of HARQ-ACK resources, and a specific field on short-TTI PDSCH scheduling assignment indicates a resource to be used from the set of configured HARQ-ACK resources.

The starting SC-FDMA symbol for HARQ-ACK TTI may be determined based on a predetermined offset and the timing of short-PDSCH scheduling assignment. In other words, HARQ-ACK TTI occurs k TTIs after the DL TTI containing short-PDSCH scheduling assignment. The predetermined offset k may be a fixed value, e.g. 4, or it may depend on other parameters, e.g. on the radio frame configuration, and variables, e.g. on the subframe number.

The above-described resource pool may apply implicit resource allocation. This may mean that, for example, the network element 102 may not need to explicitly configure radio resources to the terminal device(s). Instead the terminal device(s) may derive the resources, for example, based on the CCE/eCCE index together with predefined configuration parameters (e.g. starting resource index and offset between consecutive resources). Thus, for example, the network element 102 may transmit configuration information to the terminal device 110, wherein the configuration information indicates the implicit resource pool for the HARQ-ACK transmission. The terminal device 110 may then derive the necessary resources based on the configuration information.

Figure 10B illustrates an embodiment showing how the HARQ-ACK resources may be mapped to the physical PRBs. As described also in relation to Figure 7B, the resources may be mapped to different sides of the channel bandwidth. Referring to Figure 10B, the paired resources 1010 are now shown to be located in different frequency areas (e.g. different sides) of the channel bandwidth. For example, resource portions 1002 from 12 to 23 may be located in a physical PRB m = 1, and the resource portions 1002 from 24 to 35 may be located in a physical PRB m = 2.

Thus, the resource pool of Figure 10A may be understood as a way to map the different HARQ-ACK resources 1004 to the physical PRB domain as shown in Figure 10B. Although not shown in Figure 10B, the mapping for m equaling 0 or 3 may be similar as shown with m equaling 1 and 2.

The above-described solution may bring some additional benefits. For example, frequency diversity may be enhanced, and in some examples case maximized. This may allow to increase the performance in considered operation scenarios. Secondly, the solution may be performed with small amount of additional signaling. Thirdly, backwards compatibility may be maintained: the solution may operate on top of existing PUCCH format 2/2a/2b resources, and coexist with legacy PUCCH Format 2/2a/2b transmission on the same PRB. Fourth the solution may be scalable in terms of supported TTI length: it may support TTI lengths between 0.5 ms and one OFDM symbol, for example. Fifth, the solution may support coexistence with other LTE features/channels, such as SRS. Lastly, the solution may provide enablers for minimized receiver complexity.

Figures 11 to 12 provide apparatuses 1100, 1200 comprising a control circuitry (CTRL) 1110, 1210, such as at least one processor, and at least one memory 1130, 1230 including a computer program code (software) 1132, 1232, wherein the at least one memory and the computer program code (software) 1132, 1232, are configured, with the at least one processor, to cause the respective apparatus 1100, 1200 to carry out any one of the embodiments of Figures 1 to 10, or operations thereof.

Referring to Figures 11 to 12, the memory 1130, 1230, may be implemented using any suitable data storage technology, such as semiconductor based memory devices, flash memory, magnetic memory devices and systems, optical memory devices and systems, fixed memory and removable memory. The memory 1130, 1230 may comprise a database 1134, 1234 for storing data.

The apparatuses 1100, 1200 may further comprise radio interface (TRX) 1120, 1220 comprising hardware and/or software for realizing communication connectivity according to one or more communication protocols. The TRX may provide the apparatus with communication capabilities to access the radio access network, for example. The TRX may comprise standard well-known components such as an amplifier, filter, frequency-converter, (de)modulator, and encoder/decoder circuitries and one or more antennas. For example, the TRX may enable communication between the terminal device 110 and the network element 102. Further, the TRX may provide access to X2-interface by the network element 102, for example.

The apparatuses 1100, 1200 may comprise user interface 1140, 1240 comprising, for example, at least one keypad, a microphone, a touch display, a display, a speaker, etc. The user interface 1140, 1240 may be used to control the respective apparatus by a user of the apparatus 1100, 1200. For example, a network element may be configured using the user interface 1140 comprised in said network element. Naturally, a terminal device may comprise a user interface.

In an embodiment, the apparatus 1100 may be or be comprised in a terminal device, such as a mobile phone or cellular phone, for example. The apparatus 1100 may be the at least one terminal device 110, 120, 130, for example. In an embodiment, the apparatus 1100 is the terminal device performing the steps of Figure 2. In an embodiment, the apparatus 1100 is comprised in one of the terminal device(s) 110, 120, 130.

Referring to Figure 11, the control circuitry 1110 may comprise a data receiving circuitry 1112 configured to receive one or more data blocks from a network element; an acknowledgement (ACK) determining circuitry 1114 configured to determine an acknowledgement message (e.g ACK/NACK) related to the one or more data blocks; a radio resource determining circuitry 1116 configured to determine radio resources for transmission of the acknowledgement message, wherein the radio resources comprise a subset of first radio resources and a subset of second radio resources, the first and second radio resources being associated with a first logical channel and a second logical channel, wherein the subsets of the first and second radio resources are situated on different frequency areas of a radio band, and wherein combined duration of said subsets is less than duration of one subframe; and an acknowledgement (ACK) transmitting circuitry 1118 configured to transmit the acknowledgement message to the network element using said radio resources comprising the subsets of the first and second radio resources such that during the transmission at least one frequency hop between said subsets is performed.

In an embodiment, the apparatus 1200 may be or be comprised in a base station (also called a base transceiver station, a Node B, a radio network controller, or an evolved Node B, for example). The apparatus 1200 may be the network element 102, for example. Further, the apparatus 1200 may be the network element performing the steps of Figure 3. In an embodiment, the apparatus 1200 is comprised in the network element 102.

Referring to Figure 12, the control circuitry 1210 may comprise a data transmitter circuitry 1212 configured to transmit one or more data blocks to a terminal device; and an acknowledgement (ACK) receiving circuitry 1214 configured to receive an acknowledgement message from the terminal device, the acknowledgement message related to the transmission of the one or more data blocks, wherein the acknowledgement message is received on radio resources comprising a subset of first radio resources and a subset of second radio resources, the first and second radio resources being associated with a first logical channel and a second logical channel, wherein the subsets of the first and second radio resources are situated on different frequency areas of a radio band, wherein combined duration of said subsets is less than duration of one subframe, and wherein the acknowledgement message is received on the subsets of the first and second radio resources such that at least one frequency hop between said subsets is performed.

In an embodiment, as shown in Figure 13, at least some of the functionalities of the apparatus 1200 may be shared between two physically separate devices, forming one operational entity. Therefore, the apparatus 1200 may be seen to depict the operational entity comprising one or more physically separate devices for executing at least some of the described processes. Thus, the apparatus 1200 utilizing such shared architecture (e.g. as shown in Figure 13), may comprise a remote control unit (RCU) 1352, such as a host computer or a server computer, operatively coupled (e.g. via a wireless or wired network) to a remote radio head (RRH) 1354 located in the base station. In an embodiment, at least some of the described processes may be performed by the RCU 1352. In an embodiment, the execution of at least some of the described processes may be shared among the RRH 1354 and the RCU 1352.

In an embodiment, the RCU 1352 may generate a virtual network through which the RCU 1352 communicates with the RRH 1354. In general, virtual networking may involve a process of combining hardware and software network resources and network functionality into a single, software-based administrative entity, a virtual network. Network virtualization may involve platform virtualization, often combined with resource virtualization. Network virtualization may be categorized as external virtual networking which combines many networks, or parts of networks, into the server computer or the host computer (i.e. to the RCU). External network virtualization is targeted to optimized network sharing. Another category is internal virtual networking which provides network-like functionality to the software containers on a single system. Virtual networking may also be used for testing the terminal device.

In an embodiment, the virtual network may provide flexible distribution of operations between the RRH and the RCU. In practice, any digital signal processing task may be performed in either the RRH or the RCU and the boundary where the responsibility is shifted between the RRH and the RCU may be selected according to implementation.

As used in this application, the term ‘circuitry’ refers to all of the following: (a) hardware-only circuit implementations, such as implementations in only analog and/or digital circuitry, and (b) combinations of circuits and soft-ware (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 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. This definition of ‘circuitry’ applies to all uses of this term in this application. As a further example, as used in this application, the term ‘circuitry’ would also cover an implementation of merely a processor (or multiple processors) or a portion of a processor and its (or their) accompanying software and/or firmware. The term ‘circuitry’ would also cover, for example and if applicable to the particular element, a baseband integrated circuit or applications processor integrated circuit for a mobile phone or a similar integrated circuit in a server, a cellular network device, or another network device.

In an embodiment, at least some of the processes described in connection with Figures 1 to 10B may be carried out by an apparatus comprising corresponding means for carrying out at least some of the described processes. Some example means for carrying out the processes may include at least one of the following: detector, processor (including dual-core and multiple-core processors), digital signal processor, controller, receiver, transmitter, encoder, decoder, memory, RAM, ROM, software, firmware, display, user interface, display circuitry, user interface circuitry, user interface software, display software, circuit, antenna, antenna circuitry, and circuitry. In an embodiment, the at least one processor, the memory, and the computer program code form processing means or comprises one or more computer program code portions for carrying out one or more operations according to any one of the embodiments of Figures 1 to 10B or operations thereof.

According to yet another embodiment, the apparatus carrying out the embodiments comprises a circuitry including at least one processor and at least one memory including computer program code. When activated, the circuitry causes the apparatus to perform at least some of the functionalities according to any one of the embodiments of Figures 1 to 10B, or operations thereof.

The techniques and methods described herein may be implemented by various means. For example, these techniques may be implemented in hardware (one or more devices), firmware (one or more devices), software (one or more modules), or combinations thereof. For a hardware implementation, the apparatus(es) of embodiments may be implemented within one or more application-specific integrated circuits (ASICs), digital signal processors (DSPs), digital signal processing devices (DSPDs), programmable logic devices (PLDs), field programmable gate arrays (FPGAs), processors, controllers, micro-controllers, microprocessors, other electronic units designed to perform the functions described herein, or a combination thereof. For firmware or software, the implementation can be carried out through modules of at least one chip set (e.g. procedures, functions, and so on) that perform the functions described herein. The software codes may be stored in a memory unit and executed by processors. The memory unit may be implemented within the processor or externally to the processor. In the latter case, it can be communicatively coupled to the processor via various means, as is known in the art. Additionally, the components of the systems described herein may be rearranged and/or complemented by additional components in order to facilitate the achievements of the various aspects, etc., described with regard thereto, and they are not limited to the precise configurations set forth in the given figures, as will be appreciated by one skilled in the art.

Embodiments as described may also be carried out in the form of a computer process defined by a computer program or portions thereof. Embodiments of the methods described in connection with Figures 1 to 10B may be carried out by executing at least one portion of a computer program comprising corresponding instructions. The computer program may be in source code form, object code form, or in some intermediate form, and it may be stored in some sort of carrier, which may be any entity or device capable of carrying the program. For example, the computer program may be stored on a computer program distribution medium readable by a computer or a processor. The computer program medium may be, for example but not limited to, a record medium, computer memory, read-only memory, electrical carrier signal, telecommunications signal, and software distribution package, for example. The computer program medium may be a non-transitory medium. Coding of software for carrying out the embodiments as shown and described is well within the scope of a person of ordinary skill in the art.

Even though the invention has been described above with reference to an example according to the accompanying drawings, it is clear that the invention is not restricted thereto but can be modified in several ways within the scope of the appended claims. Therefore, all words and expressions should be interpreted broadly and they are intended to illustrate, not to restrict, the embodiment. It will be obvious to a person skilled in the art that, as technology advances, the inventive concept can be implemented in various ways. Further, it is clear to a person skilled in the art that the described embodiments may, but are not required to, be combined with other embodiments in various ways.

CLAIMS

1. A method comprising:

receiving, by a terminal device, one or more data blocks from a network element;

determining an acknowledgement message related to the one or more data blocks;

determining radio resources for transmission of the acknowledgement message, wherein the radio resources comprise a subset of first radio resources and a subset of second radio resources, the first and second radio resources being associated with a first logical channel and a second logical channel, wherein the subsets of the first and second radio resources are situated on different frequency areas of a radio band, and wherein combined duration of said subsets is less than duration of one subframe; and

transmitting the acknowledgement message to the network element using said radio resources comprising the subsets of the first and second radio resources such that during the transmission at least one frequency hop between said subsets is performed.

2. The method of claim 1, further comprising:

acquiring configuration information from the network element, wherein the determining the radio resources for the transmission of the acknowledgement message is at least partly based on the received configuration information.

3. The method of any preceding claim, wherein the at least one frequency hop between the subsets of the first and second radio resources is performed after each time-domain symbol comprised in said subsets.

4. The method of any preceding claim, wherein the at least one frequency hop comprises only one frequency hop between the subsets of the first and second radio resources.

5. The method of any preceding claim, wherein the transmitting the acknowledgement message comprises:

transmitting using the subset of the first radio resources;

after transmitting using the subset of the first radio resources, performing the frequency hop; and

transmitting using the subset of the second radio resources.

6. The method of any preceding claim, wherein the subsets of the first and second radio resources are situated on different side areas of the radio band.

7. The method of any preceding claim, wherein the subsets of the first and second radio resources are situated such that the radio resources of said subsets are not simultaneous to each other.

8. The method of any preceding claim, wherein the first radio resources are first PUCCH format 2/2a/2b resources and the second radio resources are second PUCCH format 2/2a/2b resources.

9 The method of claim 8, wherein the first PUCCH format 2/2a/2b resources are characterized by a first resource index and the second PUCCH format 2/2a/2b resources are characterized by a second resource index, and wherein the difference between the first resource index and the second resource index is 12.

10. The method of any preceding claim wherein the radio resources used for the transmitting the acknowledgement message determine time-domain symbols and discrete Fourier transformation frequency bins used for the transmission.

11. The method of any preceding claim, further comprising:

determining whether the one or more data blocks are related to a first latency mode or to a second latency mode, wherein a transmission time interval of the one or more data blocks related to the first latency mode is shorter compared with the transmission time interval of the one or more data blocks related to the second latency mode; and

if the one or more data blocks are related to the first latency mode, transmitting the acknowledgement message using the subsets of the first and second radio resources, or

if the one or more data blocks are related to the second latency mode, transmitting the acknowledgement message using the first radio resources or the second radio resources.

12. The method of any preceding claim, wherein each of the first and second radio resources comprise two consecutive slots having length of 0.5 milliseconds, and wherein the two consecutive slots are situated on different frequency areas of the radio band.

13. A method comprising:

transmitting, by a network element, one or more data blocks to a terminal device; and

receiving an acknowledgement message from the terminal device, the acknowledgement message related to the transmission of the one or more data blocks, wherein the acknowledgement message is received on radio resources comprising a subset of first radio resources and a subset of second radio resources, the first and second radio resources being associated with a first logical channel and a second logical channel, wherein the subsets of the first and second radio resources are situated on different frequency areas of a radio band, wherein combined duration of said subsets is less than duration of one subframe, and wherein the acknowledgement message is received on the subsets of the first and second radio resources such that at least one frequency hop between said subsets is performed.

14. The method of claim 13, further comprising:

transmitting configuration information to the terminal device, wherein the configuration information relates to the radio resources for the acknowledgement information transmission.

15. The method of any of claims 13 to 14, wherein the at least one frequency hop between the subsets of first and second radio resources is performed after each time-domain symbol comprised in said subsets.

16. The method of any of claims 13 to 15, wherein the at least one frequency hop comprises only one frequency hop between the subsets of the first and second radio resources.

17. The method of any of claims 13 to 16, wherein the receiving the acknowledgement message comprises:

receiving on the subset of the first radio resources;

after receiving on the subset of the first radio resources, determining that the frequency hop is performed; and

receiving on the subset of the second radio resources.

18. The method of any of claims 13 to 17, wherein the subsets of the first and second radio resources are situated on different side areas of the radio band.

19. The method of any of claims 13 to 18, wherein the subsets of the first and second radio resources are situated such that radio resources of said subsets are not simultaneous to each other.

20. The method of any of claims 13 to 19, wherein the first radio resources are first PUCCH format 2/2a/2b resources and the second radio resources are second PUCCH format 2/2a/2b resources.

21. The method of claim 20, wherein the first PUCCH format 2/2a/2b resources are characterized by a first resource index and the second PUCCH format 2/2a/2b resources are characterized by a second resource index, and wherein the difference between the first resource index and the second resource index is 12.

22. The method of any of claims 13 to 21, wherein the radio resources used for the transmitting the acknowledgement message, by the terminal device, determine time-domain symbols and discrete Fourier transformation frequency bins used for the transmission.

23. The method of any of claims 13 to 22, further comprising:

transmitting at least one data block to a second terminal device;

receiving a second acknowledgement message from the second terminal device, wherein the second acknowledgement message is related to the transmitted at least one data block, and wherein the second acknowledgement message is received on the first radio resources or the second radio resource.

24. The method of any of claims 13 to 23, wherein each of the first and second radio resources comprise two consecutive slots having length of 0.5 milliseconds, and wherein the two consecutive slots are situated on different frequency areas of the radio band.

25. The method of any of claims 13 to 24, wherein the transmitted data blocks are related to a first latency mode or to a second latency mode, wherein transmission time interval of the transmitted data blocks related to the first latency mode is shorter compared with the transmission time interval of the transmitted data blocks related to the second latency mode, the method further comprising:

if the transmitted data blocks are related to the first latency mode, receiving the acknowledgement message on the subsets of the first and second radio resources, or

if the transmitted data blocks are related to the second latency mode, receiving the acknowledgement message on the first radio resources or second radio resources.

26. An apparatus comprising at least one processor and at least one memory including a computer program code, wherein the at least one memory and the computer program code are configured, with the at least one processor, to cause a terminal device to perform operations comprising:

receiving one or more data blocks from a network element;

determining an acknowledgement message related to the one or more data blocks;

determining radio resources for transmission of the acknowledgement message, wherein the radio resources comprise a subset of first radio resources and a subset of second radio resources, the first and second radio resources being associated with a first logical channel and a second logical channel, wherein the subsets of the first and second radio resources are situated on different frequency areas of a radio band, and wherein combined duration of said subsets is less than duration of one subframe; and

transmitting the acknowledgement message to the network element using said radio resources comprising the subsets of the first and second radio resources such that during the transmission at least one frequency hop between said subsets is performed.

27. The apparatus of claim 26, wherein the at least one memory and the computer program code are configured, with the at least one processor, to cause the terminal device further to perform operations comprising:

acquiring configuration information from the network element, wherein the determining the radio resources for the transmission of the acknowledgement message is at least partly based on the received configuration information.

28. The apparatus of any of claims 26 to 27, wherein the at least one frequency hop between the subsets of the first and second radio resources is performed after each time-domain symbol comprised in said subsets.

29. The apparatus of any of claims 26 to 28, wherein the at least one frequency hop comprises only one frequency hop between the subsets of the first and second radio resources.

30. The apparatus of any of claims 26 to 29, wherein the transmitting the acknowledgement message comprises:

transmitting using the subset of the first radio resources;

after transmitting using the subset of the first radio resources, performing the frequency hop; and

transmitting using the subset of the second radio resources.

31. The apparatus of any of claims 26 to 30, wherein the subsets of the first and second radio resources are situated on different side areas of the radio band.

32. The apparatus of any of claims 26 to 31, wherein the subsets of the first and second radio resources are situated such that the radio resources of said subsets are not simultaneous to each other.

33. The apparatus of any of claims 26 to 32, wherein the first radio resources are first PUCCH format 2/2a/2b resources and the second radio resources are second PUCCH format 2/2a/2b resources.

34. The apparatus of claim 33, wherein the first PUCCH format 2/2a/2b resources are characterized by a first resource index and the second PUCCH format 2/2a/2b resources are characterized by a second resource index, and wherein the difference between the first resource index and the second resource index is 12.

35. The apparatus of any of claims 26 to 34, wherein the radio resources used for the transmitting the acknowledgement message determine time-domain symbols and discrete Fourier transformation frequency bins used for the transmission.

36. The apparatus of any of claims 26 to 35, wherein the at least one memory and the computer program code are configured, with the at least one processor, to cause the terminal device further to perform operations comprising:

determining whether the one or more data blocks are related to a first latency mode or to a second latency mode, wherein a transmission time interval of the one or more data blocks related to the first latency mode is shorter compared with the transmission time interval of the one or more data blocks related to the second latency mode; and

if the one or more data blocks are related to the first latency mode, transmitting the acknowledgement message using the subsets of the first and second radio resources, or

if the one or more data blocks are related to the second latency mode, transmitting the acknowledgement message using the first radio resources or the second radio resources.

37. The apparatus of any of claims 26 to 36, wherein each of the first and second radio resources comprise two consecutive slots having length of 0.5 milliseconds, and wherein the two consecutive slots are situated on different frequency areas of the radio band.

38. An apparatus comprising at least one processor and at least one memory including a computer program code, wherein the at least one memory and the computer program code are configured, with the at least one processor, to cause a network element to perform operations comprising:

transmitting one or more data blocks to a terminal device; and

receiving an acknowledgement message from the terminal device, the acknowledgement message related to the transmission of the one or more data blocks, wherein the acknowledgement message is received on radio resources comprising a subset of first radio resources and a subset of second radio resources, the first and second radio resources being associated with a first logical channel and a second logical channel, wherein the subsets of the first and second radio resources are situated on different frequency areas of a radio band, wherein combined duration of said subsets is less than duration of one subframe, and wherein the acknowledgement message is received on the subsets of the first and second radio resources such that at least one frequency hop between said subsets is performed.

39. The apparatus of claim 38, wherein the at least one memory and the computer program code are configured, with the at least one processor, to cause the network element further to perform operations comprising:

transmitting configuration information to the terminal device, wherein the configuration information relates to the radio resources for the acknowledgement information transmission.

40. The apparatus of any of claims 38 to 39, wherein the at least one frequency hop between the subsets of first and second radio resources is performed after each time-domain symbol comprised in said subsets.

41. The apparatus of any of claims 38 to 40, wherein the at least one frequency hop comprises only one frequency hop between the subsets of the first and second radio resources.

42. The apparatus of any of claims 38 to 41, wherein the receiving the acknowledgement message comprises:

receiving on the subset of the first radio resources;

after receiving on the subset of the first radio resources, determining that the frequency hop is performed; and

receiving on the subset of the second radio resources.

43. The apparatus of any of claims 38 to 42, wherein the subsets of the first and second radio resources are situated on different side areas of the radio band.

44. The apparatus of any of claims 38 to 43, wherein the subsets of the first and second radio resources are situated such that radio resources of said subsets are not simultaneous to each other.

45. The apparatus of any of claims 38 to 44, wherein the first radio resources are first PUCCH format 2/2a/2b resources and the second radio resources are second PUCCH format 2/2a/2b resources.

46. The apparatus of claim 45, wherein the first PUCCH format 2/2a/2b resources are characterized by a first resource index and the second PUCCH format

2/2a/2b resources are characterized by a second resource index, and wherein the difference between the first resource index and the second resource index is 12.

47. The apparatus of any of claims 38 to 46, wherein the radio resources used for the transmitting the acknowledgement message, by the terminal device, determine time-domain symbols and discrete Fourier transformation frequency bins used for the transmission.

48. The apparatus of any of claims 38 to 47, wherein the at least one memory and the computer program code are configured, with the at least one processor, to cause the network element further to perform operations comprising:

transmitting at least one data block to a second terminal device;

receiving a second acknowledgement message from the second terminal device, wherein the second acknowledgement message is related to the transmitted at least one data block, and wherein the second acknowledgement message is received on the first radio resources or the second radio resource.

49. The apparatus of any of claims 38 to 48, wherein each of the first and second radio resources comprise two consecutive slots having length of 0.5 milliseconds, and wherein the two consecutive slots are situated on different frequency areas of the radio band.

50. The apparatus of any of claims 38 to 49, wherein the transmitted data blocks are related to a first latency mode or to a second latency mode, wherein transmission time interval of the transmitted data blocks related to the first latency mode is shorter compared with the transmission time interval of the transmitted data blocks related to the second latency mode, the method further comprising:

if the transmitted data blocks are related to the first latency mode, receiving the acknowledgement message on the subsets of the first and second radio resources, or

if the transmitted data blocks are related to the second latency mode, receiving the acknowledgement message on the first radio resources or second radio resources.

51. A computer program product embodied on a distribution medium readable by a computer and comprising program instructions which, when loaded into

an apparatus, execute the method according to any of claims 1 to 25.

52. A computer program product comprising program instructions which, when loaded into an apparatus, execute the method according to any of claims 1 to 25.

53. An apparatus, comprising means for performing the method according to any of claims 1 to 25.

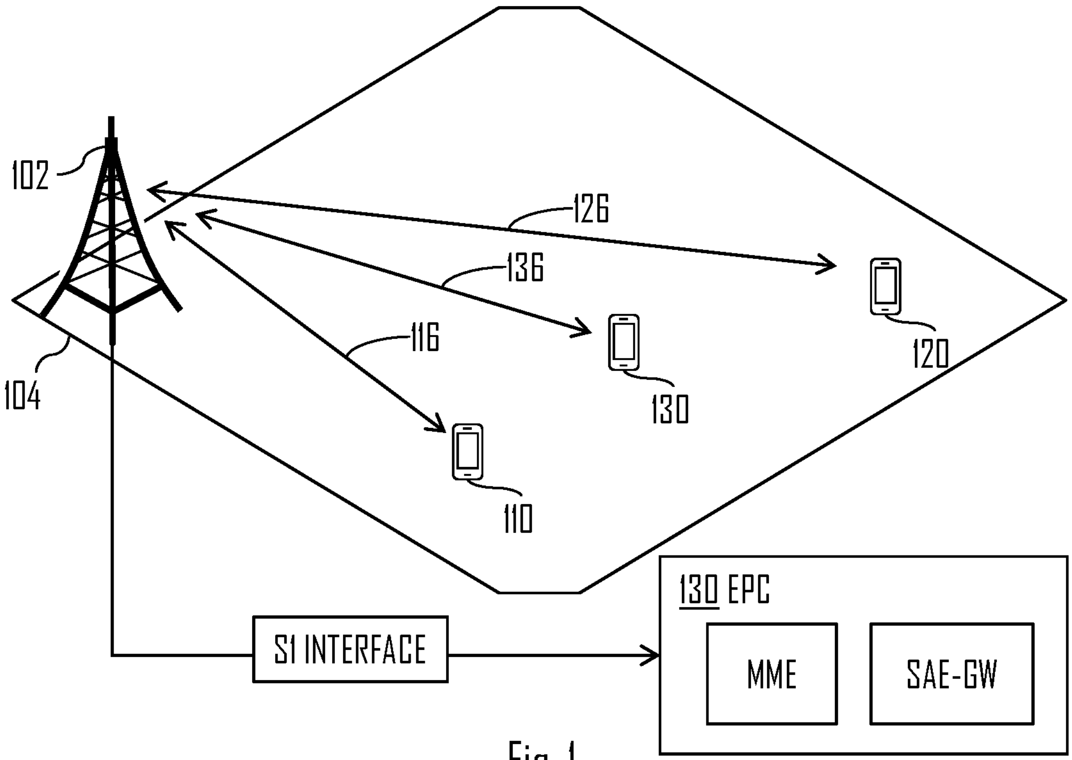
102
104
126
136
116
120
130
110
S1 INTERFACE
130 EPC
MME
SAE-GW

Fig. 1

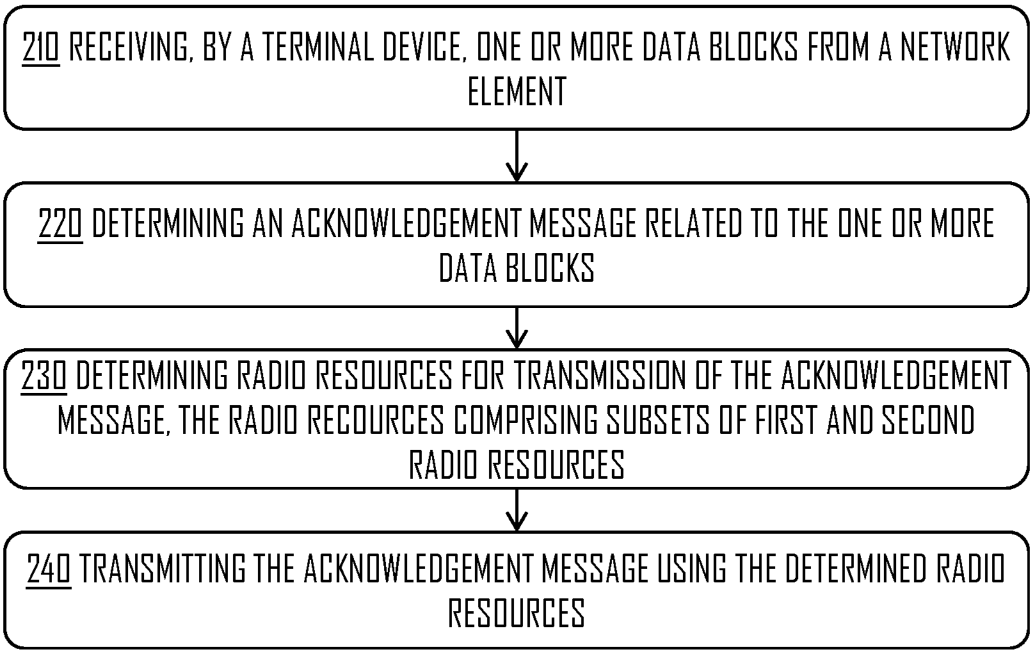
210 RECEIVING, BY A TERMINAL DEVICE, ONE OR MORE DATA BLOCKS FROM A NETWORK ELEMENT
220 DETERMINING AN ACKNOWLEDGEMENT MESSAGE RELATED TO THE ONE OR MORE DATA BLOCKS
230 DETERMINING RADIO RESOURCES FOR TRANSMISSION OF THE ACKNOWLEDGEMENT MESSAGE, THE RADIO RECOURCES COMPRISING SUBSETS OF FIRST AND SECOND RADIO RESOURCES
240 TRANSMITTING THE ACKNOWLEDGEMENT MESSAGE USING THE DETERMINED RADIO RESOURCES

Fig. 2

310 TRANSMITTING, BY A NETWORK ELEMENT, ONE OR MORE DATA BLOCKS TO A TERMINAL DEVICE

↓

320 RECEIVING AN ACKNOWLEDGMENT MESSAGE FROM THE TERMINAL DEVICE ON A SUBSETS OF FIRST AND SECOND RADIO RRESOURCES

Fig. 3

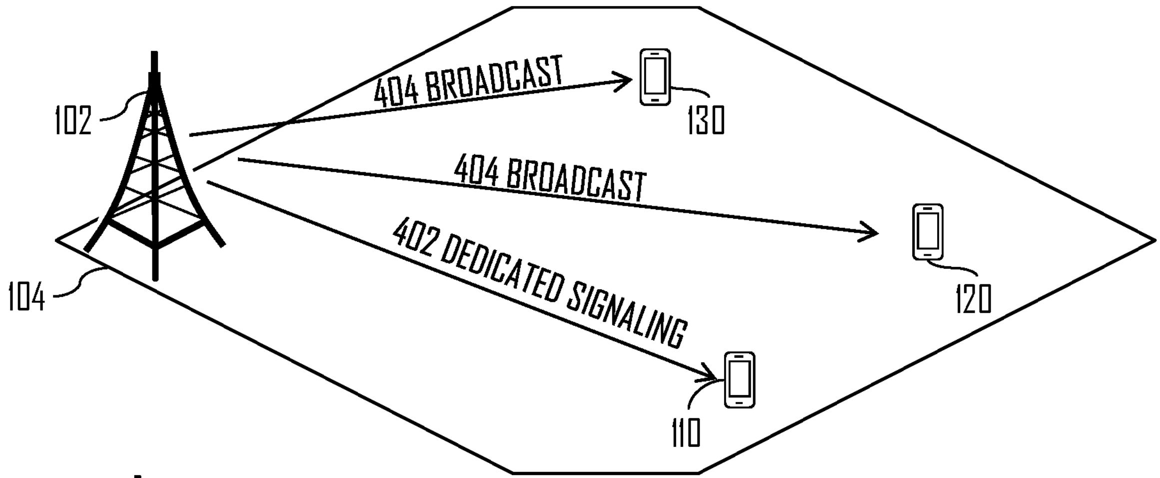

Fig. 4A

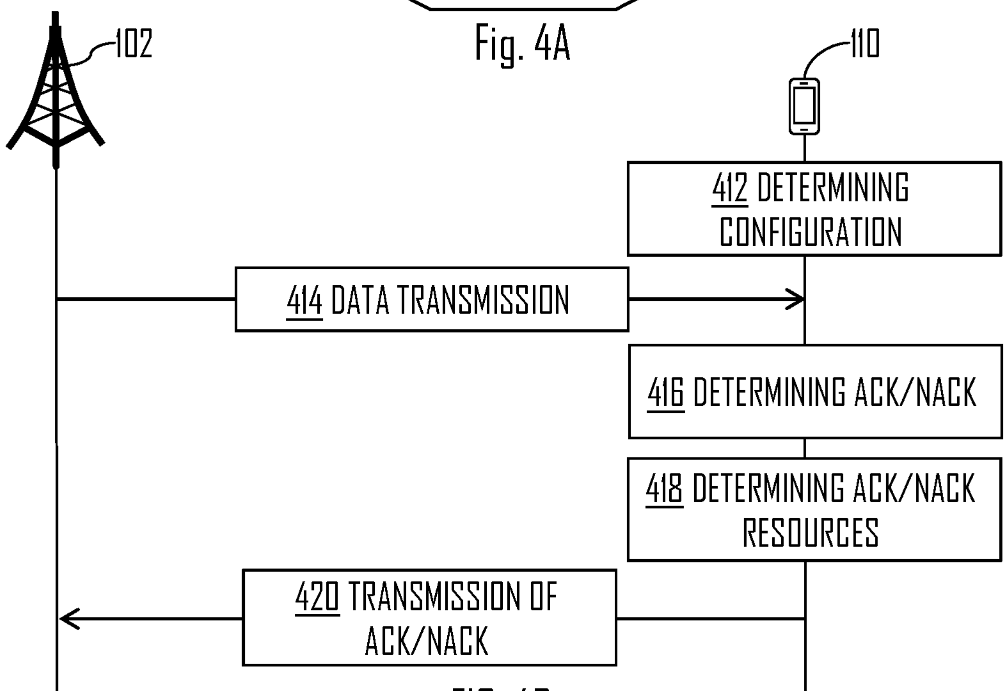

FIG. 4B

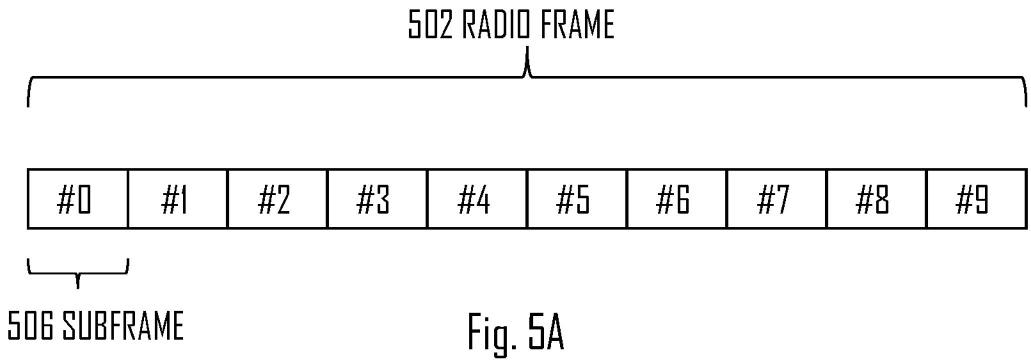

Fig. 5A

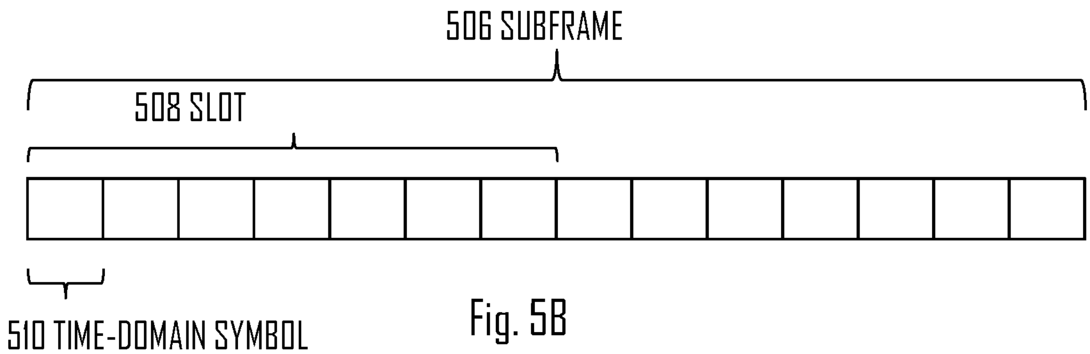

Fig. 5B

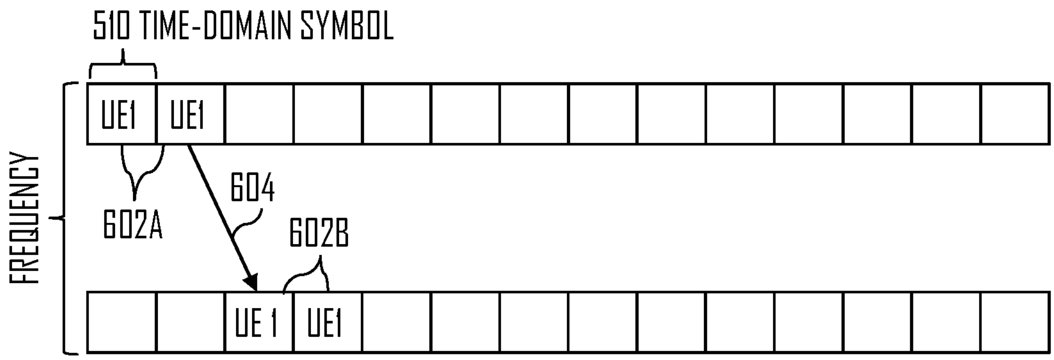

Fig. 6A

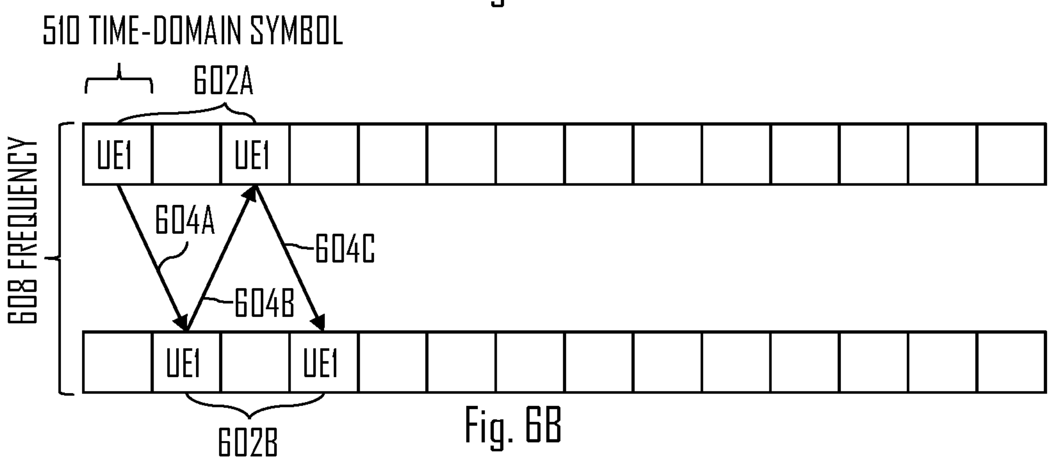

Fig. 6B

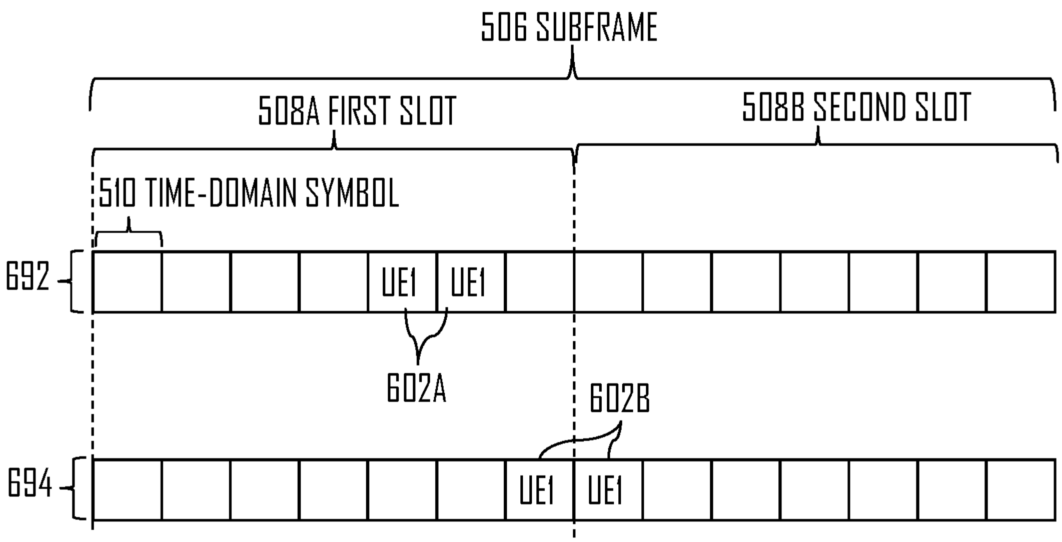
506 SUBFRAME
508A FIRST SLOT
508B SECOND SLOT
510 TIME-DOMAIN SYMBOL
692
UE1
UE1
602A
602B
694
UE1
UE1

Fig. 6C

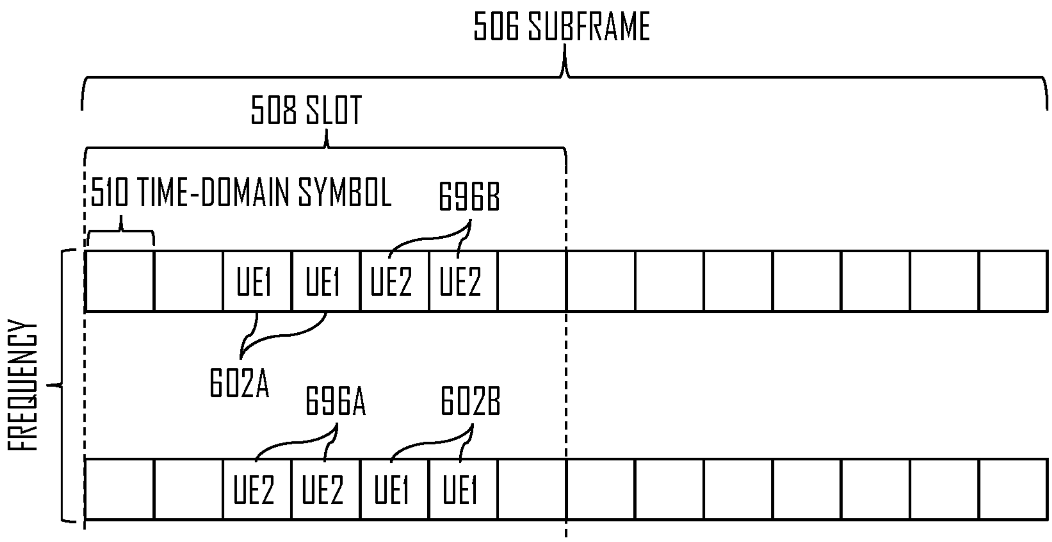
506 SUBFRAME
508 SLOT
510 TIME-DOMAIN SYMBOL
696B
UE1
UE1
UE2
UE2
FREQUENCY
602A
696A
602B
UE2
UE2
UE1
UE1

Fig. 6D

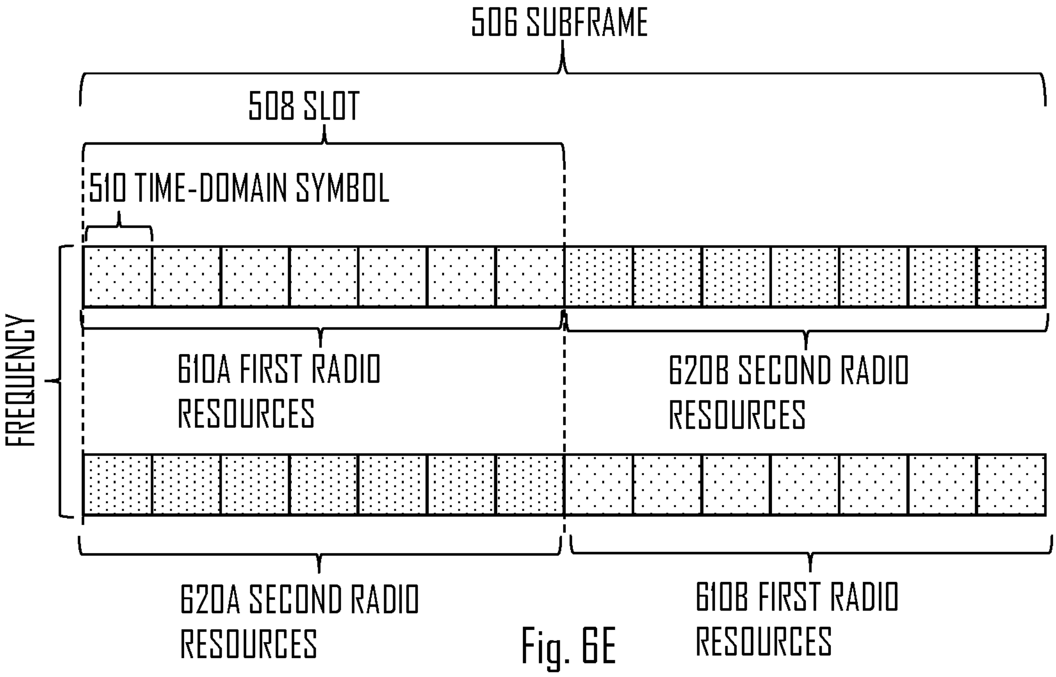
506 SUBFRAME
508 SLOT
510 TIME-DOMAIN SYMBOL
FREQUENCY
610A FIRST RADIO RESOURCES
620B SECOND RADIO RESOURCES
620A SECOND RADIO RESOURCES
610B FIRST RADIO RESOURCES

Fig. 6E

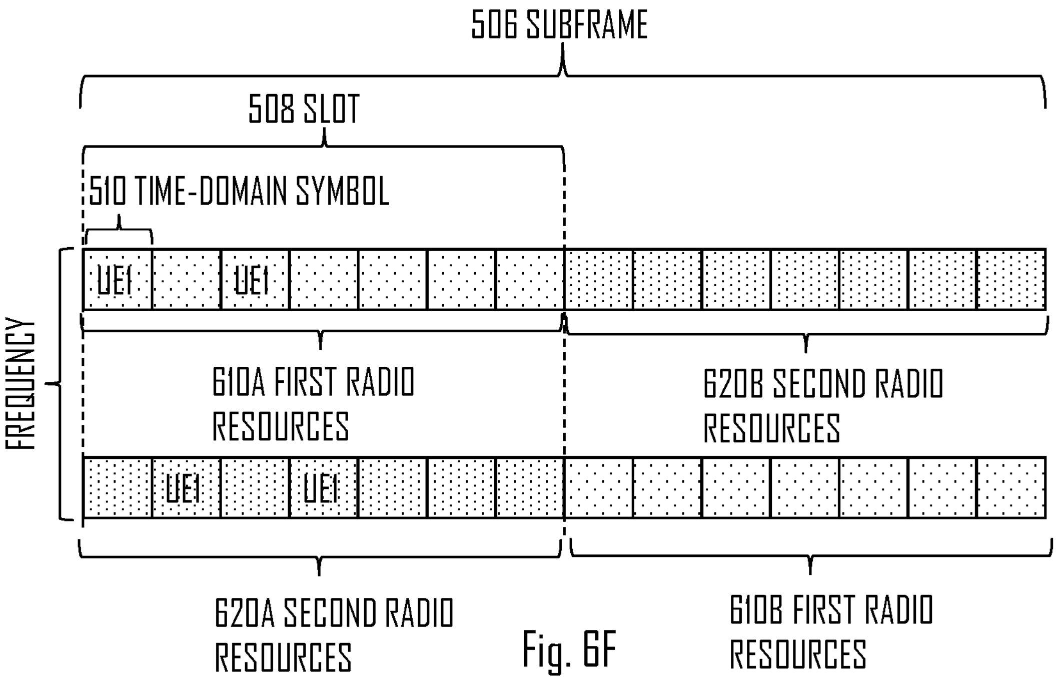
506 SUBFRAME
508 SLOT
510 TIME-DOMAIN SYMBOL
FREQUENCY
UE1
UE1
610A FIRST RADIO RESOURCES
620B SECOND RADIO RESOURCES
UE1
UE1
620A SECOND RADIO RESOURCES
610B FIRST RADIO RESOURCES

Fig. 6F

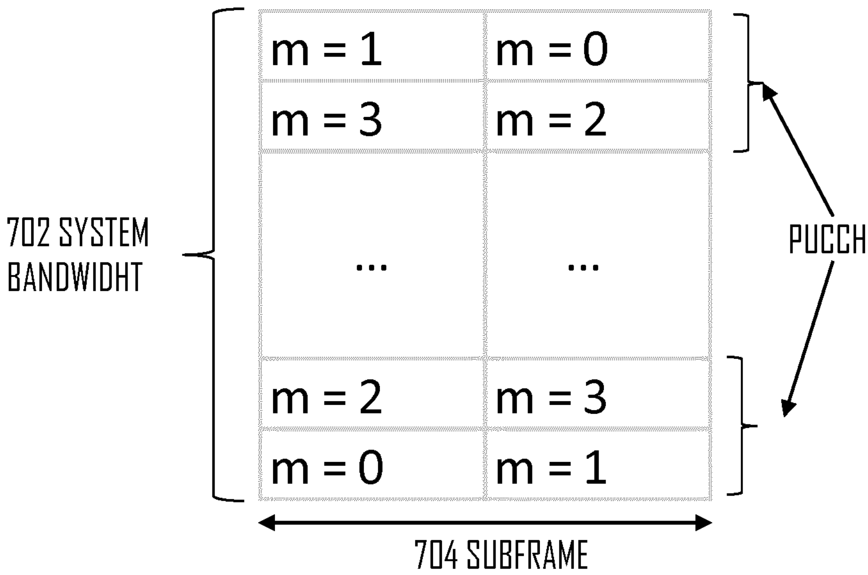
m = 1
m = 0
m = 3
m = 2
...
...
m = 2
m = 3
m = 0
m = 1
702 SYSTEM BANDWIDHT
PUCCH
704 SUBFRAME

Fig. 7A

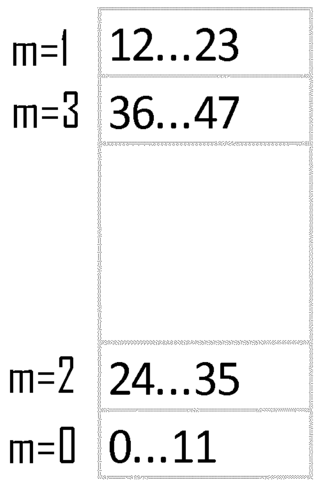
m=1
12...23
m=3
36...47
m=2
24...35
m=0
0...11

Fig. 7B

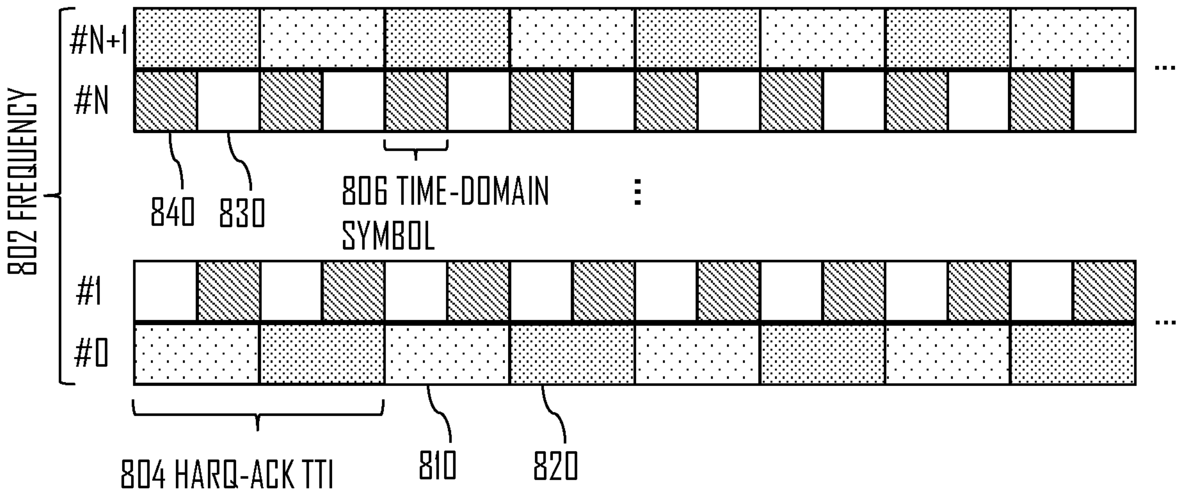
802 FREQUENCY
#N+1
#N
#1
#0
840
830
806 TIME-DOMAIN SYMBOL
804 HARQ-ACK TTI
810
820

Fig. 8

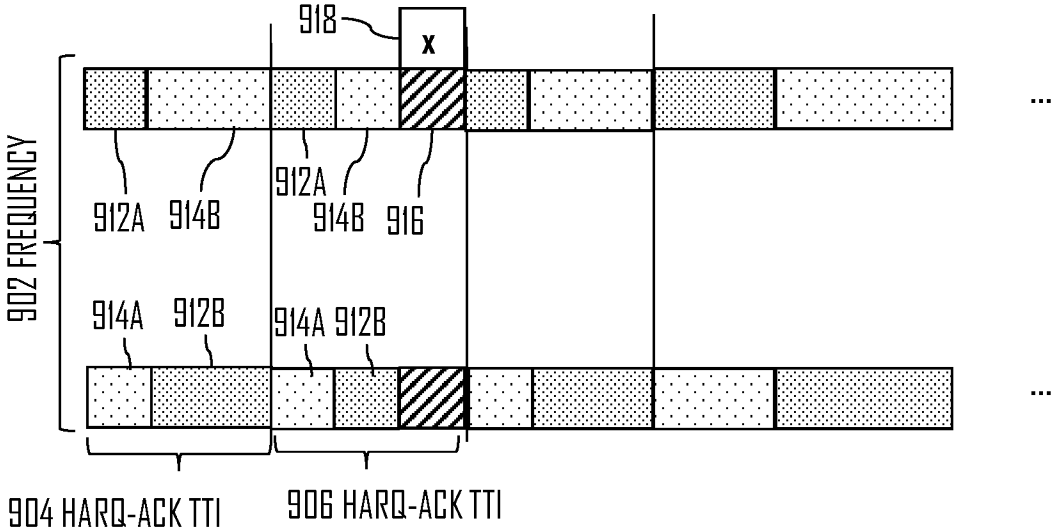
918
x
902 FREQUENCY
912A
914B
912A
914B
916
914A
912B
914A
912B
904 HARQ-ACK TTI
906 HARQ-ACK TTI

Fig. 9

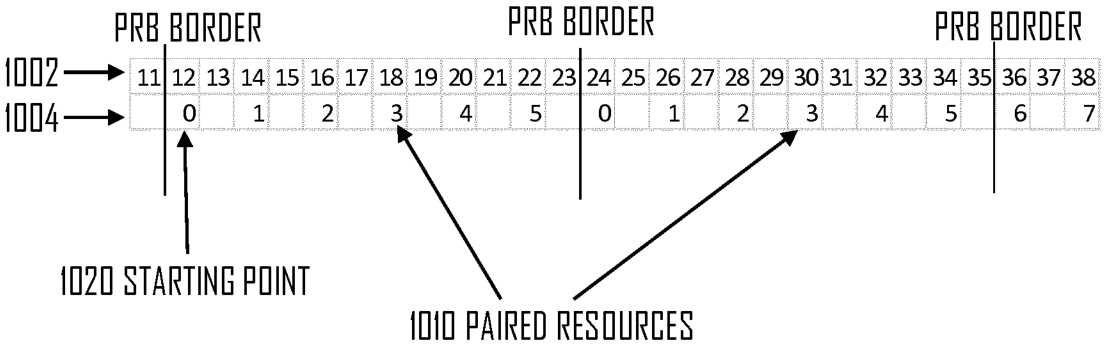

Fig. 10A

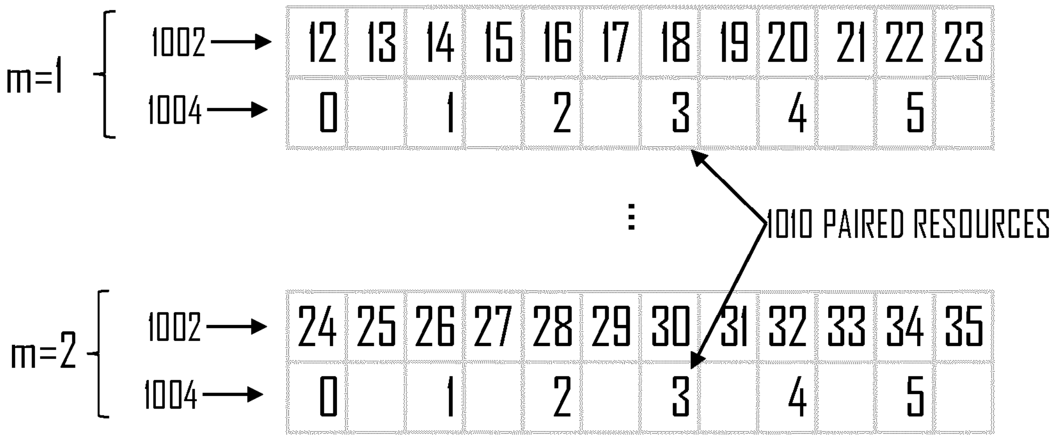

Fig. 10B

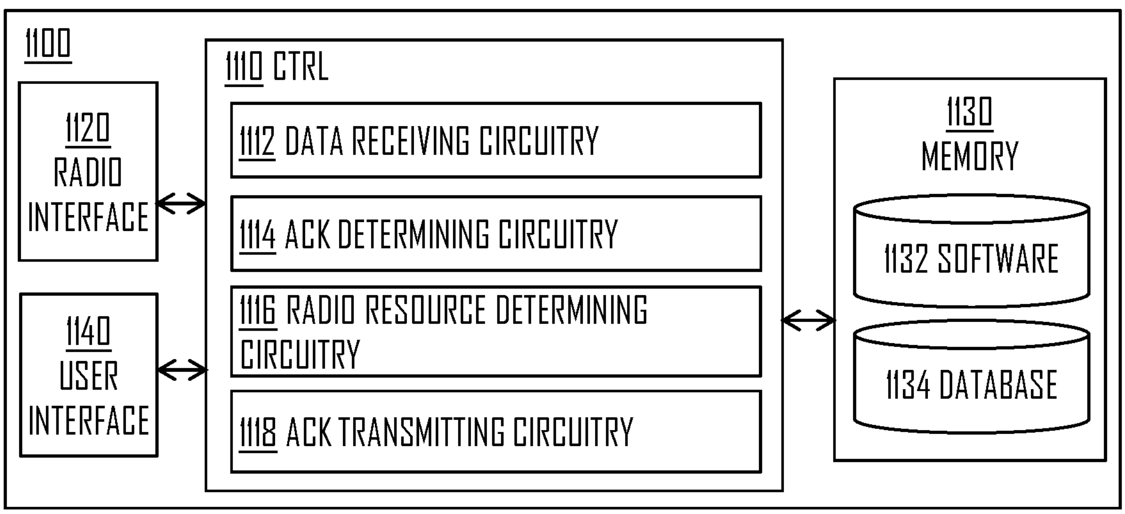

Fig. 11

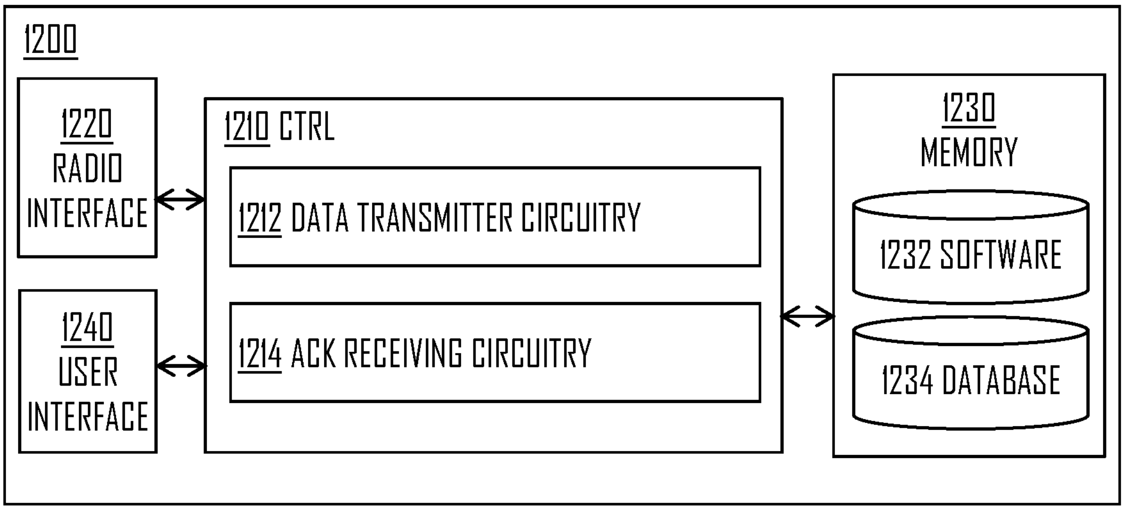
1200
1220
RADIO
INTERFACE
1210 CTRL
1212 DATA TRANSMITTER CIRCUITRY
1214 ACK RECEIVING CIRCUITRY
1240
USER
INTERFACE
1230
MEMORY
1232 SOFTWARE
1234 DATABASE

Fig. 12

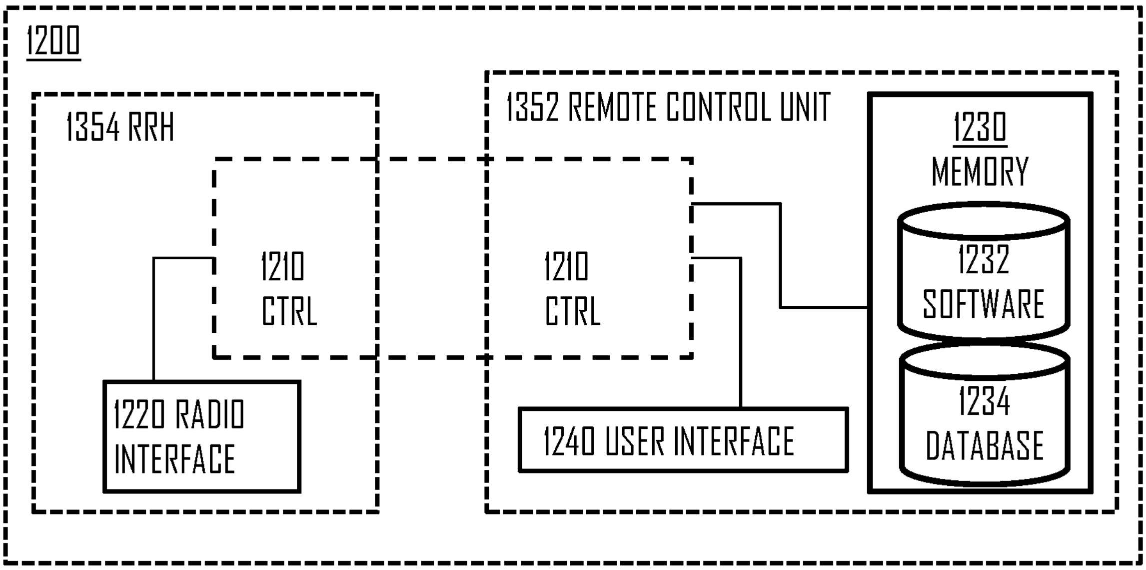
1200
1354 RRH
1352 REMOTE CONTROL UNIT
1210
CTRL
1210
CTRL
1220 RADIO
INTERFACE
1240 USER INTERFACE
1230
MEMORY
1232
SOFTWARE
1234
DATABASE

Fig. 13

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2015/072699

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04L1/18 H04L5/00 H04L1/04
ADD.

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

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)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2015/078223 A1 (YANG SUCKCHEL [KR] ET AL) 19 March 2015 (2015-03-19)	1,2,4-7, 10-14, 16-19, 22, 24-27, 29-32, 35-39, 41-44, 47,49-53
Y	paragraph [0061] - paragraph [0071] figures 4, 5	8,9,20, 21,23, 33,34, 45,46,48
A		3,15,28, 40

	-/--	

[X] Further documents are listed in the continuation of Box C.

[X] 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
7 June 2016	14/06/2016

Name and mailing address of the ISA/	Authorized officer
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