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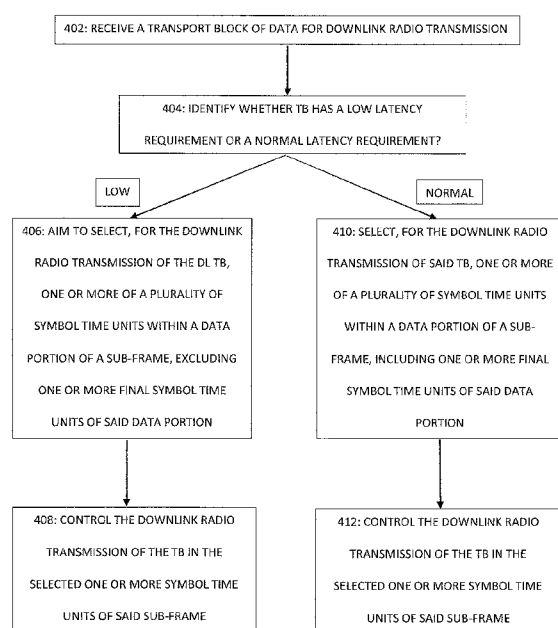


Figure 4

(57) Abstract: A technique comprising: controlling the scheduling of radio transmissions of data in sub-frames each including a sub-frame portion allocated to radio transmission of downlink control information and/or a sub-frame portion allocated to radio transmission of uplink control information, and a sub-frame portion allocated to radio transmission of data; wherein said technique comprises selecting, for radio transmission of a transport block of data, a location for a radio transmission time period within said sub-frame portion allocated to transmission of data, at least partly on the basis of a latency requirement for said transport block of data.

MIXED LATENCY COMMUNICATIONS

There are increasingly some types of radio communications for which successful delivery within a very short period of time (e.g. 1ms or less) may be critical, such as communications that control the operation
5 of an autonomous driverless vehicle.

The inventors for the present application have identified the challenge of facilitating such low latency communications in radio systems also involving other types of communications for which there are less stringent requirements for reliability and latency.

There is hereby provided a method comprising: controlling the scheduling of radio transmissions of
10 data in sub-frames each including a sub-frame portion allocated to radio transmission of downlink control information and/or a sub-frame portion allocated to radio transmission of uplink control information, and a sub-frame portion allocated to radio transmission of data; wherein said method comprises selecting, for radio transmission of a transport block of data, a location for a radio transmission time period within said sub-frame portion allocated to transmission of data, at least partly
15 on the basis of a latency requirement for said transport block of data.

According to one embodiment, said sub-frame portion allocated to the radio transmission of data comprises a plurality of symbol time units, and said method comprises: selecting, for radio transmission of a first transport block of data having a low latency requirement, one or more of said plurality of symbol time units excluding one or more final symbol time units of said plurality of symbol time units.

20 According to one embodiment, the method comprises: selecting for radio transmission of a second transport block of data having less of a low latency requirement than said first transport block of data, one or more or all of said plurality of symbol time units including a final symbol time unit of said plurality of symbol time units.

According to one embodiment, the method comprises: controlling the scheduling of radio transmissions
25 of said first and second transport blocks of data in the same sub-frame, and selecting for the radio

transmission of said second transport block of data all of said plurality of symbol time units not selected for the radio transmission of said first transport block of data.

According to one embodiment, the method comprises: controlling the radio transmission, in a single sub-frame, of information indicating both a radio resource allocated to a first radio transmission of the first transport block of data, and a radio resource allocated to a second radio transmission of the first transport block of data.

According to one embodiment, the method comprises: controlling the radio transmission of control information, for a communication device, indicating the number of said plurality of symbol time units selected for a radio transmission of a transport block of data to or from said communication device.

According to one embodiment, said control information indicates one of two latency modes about which information is pre-stored at the communication device: said two modes comprising a first latency mode involving radio transmission of a transport block of data in a predetermined front portion of said plurality of symbol time units, and a second latency mode involving the radio transmission of a transport block of data in all of said plurality of symbol time units.

According to one embodiment, the method comprises: controlling radio transmission of said transport block of data at said selected radio transmission time period.

According to one embodiment, the method comprises: controlling radio transmission of a scheduling grant for a communication device, indicating the radio transmission time period selected within the sub-frame for said transport block of data by said communication device.

There is also hereby provided a method comprising: controlling the radio transmission, in a control portion of a single sub-frame, of information indicating both a radio resource allocated to a first radio transmission of a first transport block of data in the sub-frame, and a radio resource allocated to a second radio transmission of the first transport block of data in a subsequent sub-frame.

There is also hereby provided a method, comprising: recovering, from radio transmissions by a network node, a scheduling grant indicating scheduling of a radio transmission to or from said network node of

a transport block of data in a sub-frame comprising a sub-frame portion allocated to radio transmission of data and comprising a plurality of symbol time units; further recovering, from said radio transmissions by said network node, control information indicating the number of said plurality of symbol time units selected for the radio transmission of said transport block of data; and controlling the
5 radio transmission of said transport block of data in the one or more symbol time units indicated in said control information.

According to one embodiment, said control information indicates one of two modes about which information is pre-stored at the communication device, said two modes comprising: a first latency mode involving radio transmission of said transport block of data in a predetermined sub-portion of said
10 plurality of symbol time units excluding at least a final one of said plurality of symbol time units; and a second latency mode involving the radio transmission of said transport block in all of said plurality of symbol time units.

There is also hereby provided an apparatus comprising: a processor and memory including computer program code, wherein the memory and computer program code are configured to, with the processor,
15 cause the apparatus to: control the scheduling of radio transmissions of data in sub-frames each including a sub-frame portion allocated to radio transmission of downlink control information and/or a sub-frame portion allocated to radio transmission of uplink control information, and a sub-frame portion allocated to radio transmission of data; wherein the memory and computer program code are further configured to, with the processor, cause the apparatus to select, for radio transmission of a transport
20 block of data, a location for a radio transmission time period within said sub-frame portion allocated to transmission of data, at least partly on the basis of a latency requirement for said transport block of data.

According to one embodiment, said sub-frame portion allocated to the radio transmission of data comprises a plurality of symbol time units; and the memory and computer program code are further configured to, with the processor, cause the apparatus to: select for radio transmission of a first transport
25 block of data having a low latency requirement, one or more of said plurality of symbol time units excluding one or more final symbol time units of said plurality of symbol time units.

According to one embodiment, the memory and computer program code are further configured to, with the processor, cause the apparatus to: select for radio transmission of a second transport block of data having less of a low latency requirement than said first transport block of data, one or more or all of said plurality of symbol time units including a final symbol time unit of said plurality of symbol time units.

According to one embodiment, the memory and computer program code are further configured to, with the processor, cause the apparatus to: control the scheduling of radio transmissions of said first and second transport blocks of data in the same sub-frame, and select for the radio transmission of said second transport block of data all of said plurality of symbol time units not selected for the radio transmission of said first transport block of data.

According to one embodiment, the memory and computer program code are further configured to, with the processor, cause the apparatus to: control the radio transmission, in a single sub-frame, of information indicating both a radio resource allocated to a first radio transmission of the first transport block of data, and a radio resource allocated to a second radio transmission of the first transport block of data.

According to one embodiment, the memory and computer program code are further configured to, with the processor, cause the apparatus to: control the radio transmission of control information, for a communication device, indicating the number of said plurality of symbol time units selected for a radio transmission of a transport block of data to or from said communication device.

According to one embodiment, said control information indicates one of two latency modes about which information is pre-stored at the communication device: said two modes comprising a first latency mode involving radio transmission of a transport block of data in a predetermined front portion of said plurality of symbol time units, and a second latency mode involving the radio transmission of a transport block of data in all of said plurality of symbol time units.

According to one embodiment, the memory and computer program code are further configured to, with the processor, cause the apparatus to: control radio transmission of said transport block of data at said selected radio transmission time period.

According to one embodiment, the memory and computer program code are further configured to, with the processor, cause the apparatus to: control radio transmission of a scheduling grant for a communication device, indicating the radio transmission time period selected within the sub-frame for said transport block of data by said communication device.

There is also hereby provided an apparatus comprising: a processor and memory including computer program code, wherein the memory and computer program code are configured to, with the processor, cause the apparatus to: control the radio transmission, in a control portion of a single sub-frame, of information indicating both a radio resource allocated to a first radio transmission of a first transport block of data in the sub-frame, and a radio resource allocated to a second radio transmission of the first transport block of data in a subsequent sub-frame.

There is also hereby provided an apparatus comprising: a processor and memory including computer program code, wherein the memory and computer program code are configured to, with the processor, cause the apparatus to: recover, from radio transmissions by a network node, a scheduling grant indicating scheduling of a radio transmission to or from said network node of a transport block of data in a sub-frame comprising a sub-frame portion allocated to radio transmission of data and comprising a plurality of symbol time units; further recover, from said radio transmissions by said network node, control information indicating the number of said plurality of symbol time units selected for the radio transmission of said transport block of data; and control the radio transmission of said transport block of data in the one or more symbol time units indicated in said control information.

According to one embodiment, said control information indicates one of two modes about which information is pre-stored at the communication device, said two modes comprising: a first latency mode involving radio transmission of said transport block of data in a predetermined sub-portion of said plurality of symbol time units excluding at least a final one of said plurality of symbol time units; and

a second latency mode involving the radio transmission of said transport block in all of said plurality of symbol time units.

There is also hereby provided an apparatus, comprising: means for controlling the scheduling of radio transmissions of data in sub-frames each including a sub-frame portion allocated to radio transmission of downlink control information and/or a sub-frame portion allocated to radio transmission of uplink control information, and a sub-frame portion allocated to radio transmission of data; wherein said controlling comprises selecting, for radio transmission of a transport block of data, a location for a radio transmission time period within said sub-frame portion allocated to transmission of data, at least partly on the basis of a latency requirement for said transport block of data.

10 There is also hereby provided an apparatus comprising: means for controlling the radio transmission, in a control portion of a single sub-frame, of information indicating both a radio resource allocated to a first radio transmission of a first transport block of data in the sub-frame, and a radio resource allocated to a second radio transmission of the first transport block of data in a subsequent sub-frame.

There is also hereby provided an apparatus comprising: means for recovering, from radio transmissions by a network node, a scheduling grant indicating scheduling of a radio transmission to or from said network node of a transport block of data in a sub-frame comprising a sub-frame portion allocated to radio transmission of data and comprising a plurality of symbol time units; means for recovering, from said radio transmissions by said network node, control information indicating the number of said plurality of symbol time units selected for the radio transmission of said transport block of data; and means for controlling the radio transmission of said transport block of data in the one or more symbol time units indicated in said control information.

There is also hereby provided a computer program product comprising program code means which when loaded into a computer controls the computer to: control the scheduling of radio transmissions of data in sub-frames each including a sub-frame portion allocated to radio transmission of downlink control information and/or a sub-frame portion allocated to radio transmission of uplink control information, and a sub-frame portion allocated to radio transmission of data; wherein said program code

means further controls the computer to select, for radio transmission of a transport block of data, a location for a radio transmission time period within said sub-frame portion allocated to transmission of data, at least partly on the basis of a latency requirement for said transport block of data.

There is also hereby provided a computer program product comprising program code means which
5 when loaded into a computer controls the computer to: control the radio transmission, in a control portion of a single sub-frame, of information indicating both a radio resource allocated to a first radio transmission of a first transport block of data in the sub-frame, and a radio resource allocated to a second radio transmission of the first transport block of data in a subsequent sub-frame.

There is also hereby provided a computer program product comprising program code means which
10 when loaded into a computer controls the computer to: recover, from radio transmissions by a network node, a scheduling grant indicating scheduling of a radio transmission to or from said network node of a transport block of data in a sub-frame comprising a sub-frame portion allocated to radio transmission of data and comprising a plurality of symbol time units; further recover, from said radio transmissions by said network node, control information indicating the number of said plurality of symbol time units
15 selected for the radio transmission of said transport block of data; and control the radio transmission of said transport block of data in the one or more symbol time units indicated in said control information.

Examples of techniques according to embodiments of the invention are described hereunder in detail, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 illustrates one example of an environment in which embodiments of the present invention may
20 be implemented;

Figure 2 illustrates one example of apparatus for use at the UEs of Figure 1;

Figure 3 illustrates one example of apparatus for use at the eNB of Figure 1;

Figures 4 and 5 illustrate one example of operations at a baseband processor of a network node for downlink (DL) and uplink (UL) data transmissions, respectively, according to an embodiment of the
25 present invention;

Figures 6 and 7 illustrate one example of operations at a UE baseband processor for downlink and uplink data transmissions, respectively, according to an embodiment of the present invention;

Figures 8 to 10 illustrate one example of selecting symbol time units for radio transmission of a low latency transport block in one example of a sub-frame structure; and

- 5 Figures 11 and 12 illustrate one example of selecting symbol time units for radio transmission of a normal latency transport block in the same example of a sub-frame structure.

Techniques according to embodiments of the present invention are described in detail below, by way of example only, for one example of a time division duplex (TDD) communication system based on the division of radio resources into short sub-frames each having a length of 0.125ms and comprising 7
10 OFDM or SC-FDMA symbol time units, each sub-frame comprising a first symbol time unit allocated to downlink radio transmission, a final symbol time unit allocated to uplink radio transmission, and the remaining symbol time units allocated to uplink or downlink transmissions with a guard time between a switch from DL to UL radio transmission within a sub-frame. However, the same technique is also applicable to other radio communication systems including frequency division duplex (FDD) systems
15 and TDD systems using other sub-frame structures.

Figure 1 schematically shows an example of four user equipments (UEs) (for example, high complexity devices such as smartphones etc., low complexity devices such as MTC devices or any other type of wireless communication device) 8 located within the coverage area of a cell operated by a wireless network infrastructure node, which is generally referred to below as a base station (BS). Figure 1 only
20 shows a small number of base stations, but a radio access network typically comprises a large number of base stations each operating one or more cells.

Each BS 2 of a radio access network is typically connected to one or more core network entities and/or a mobile management entity etc., but these other entities are omitted from Figure 1 for conciseness.

Figure 2 shows a schematic view of an example of apparatus for each UE 8. The UE 8 may be used
25 for various tasks such as making and receiving phone calls, receiving and sending data from and to a data network, and experiencing, for example, multimedia or other content. The UE 8 may be any device

at least capable of both recovering data/information from radio transmissions made by the BS 2, and making radio transmissions from which data/information is recoverable by the BS 2. Non-limiting examples of user equipment (UE) 8 include smartphones, tablets, personal computers, and devices without any user interface, such as devices that are designed for machine type communications (MTC).

5 With reference to Figure 2, a baseband processor 34, operating in accordance with program code stored at memory 32, controls the generation and transmission of radio signals via radio-frequency (RF) front end 36 and antenna 38. The RF front end 36 may include an analogue transceiver, filters, a duplexer, and antenna switch. Also, the combination of antenna 38, RF front end 36 and baseband processor 34 recovers data/information from radio signals reaching UE 8 from e.g. BS 2. The UE 8 may also
10 comprise an application processor (not shown) that generates user data for transmission via radio signals, and processes user data recovered from radio signals by baseband processor 34 and stored at memory 32.

The application processor and the baseband processor 34 may be implemented as separate chips or combined into a single chip. The memory 32 may be implemented as one or more chips. The memory
15 32 may include both read-only memory and random-access memory. The above elements may be provided on one or more circuit boards.

The UE may include additional other elements not shown in Figure 2. For example, the UE 8 may include a user interface such as a key pad, voice command recognition device, touch sensitive screen
20 or pad, combinations thereof or the like, via which a user may control operation of the UE 8. The UE 8 may also include a display, a speaker and a microphone. Furthermore, the UE 8 may comprise appropriate connectors (either wired or wireless) to other devices and/or for connecting external accessories (e.g. hands-free equipment) thereto.

Figure 3 shows an example of apparatus for use at the BS 2 of Figure 1. A baseband processor 20,
25 operating in accordance with program code stored at memory 22, (a) controls the generation and transmission of radio signals via the combination of RF front end 24 and antenna 26; and (b) recovers

control information/data from radio transmissions reaching the BS from e.g. UEs 8. The RF front end may include an analogue transceiver, filters, a duplexer, and antenna switch. Both the processor 20 and the memory 22 may be implemented as one or more chips. The memory 22 may include both read-only memory and random-access memory. The above elements may be provided on one or more circuit boards. The apparatus also comprises an interface 28 for transferring data to and from one or more other entities such as e.g. core network entities, mobile management entities, and other base stations in the same access network.

It should be appreciated that the apparatus shown in each of figures 2 and 3 described above may comprise further elements which are not directly involved with the embodiments of the invention described hereafter.

Figure 4 illustrates an example of operations at the baseband processor 20 of a base station for the example of downlink data transmission (downlink user plane transmission), according to one embodiment. All operations carried out by the BS processor 20 follow program code stored at BS memory 22.

The BS baseband processor 20 receives a transport block (TB) of data for downlink radio transmission to a UE 8 served by the BS 2 (STEP 402). The BS processor 20 identifies whether the DL TB has a low latency requirement or a normal latency requirement (STEP 404). As illustrated in Figure 8, each sub-frame has a data portion (e.g. OFDM symbols #2 to #5 in the sub-frame structure example of Figure 8) allocated to downlink data transmissions or uplink data/control transmissions.

If the DL TB has a low latency requirement (and the UE and BS 2 have sufficient processing power), the BS processor 20 aims to select, for radio transmission of the DL TB, one or more OFDM symbols of the DL data portion of the sub-frame that maximise the time for error checking at the UE processor 34 in time to transmit HARQ feedback in the UL control portion of the same sub-frame. Where possible, the BS processor 20 selects one or more (e.g. two) symbols of the DL data portion excluding at least the final OFDM symbol of the data portion (OFDM symbol #4 in the sub-frame structure example of Figure 8) (STEP 406). Even if it is not possible to select one or more OFDM symbols excluding at least

the final OFDM symbol in the data portion, the UE processor still has the guard time (OFDM symbol #5) in which to perform error checking and prepare for transmission of HARQ feedback in the UL control portion (OFDM symbol #6) of the same sub-frame.

In the example of Figure 8, the BS processor 20 selects a contiguous set of OFDM symbols at the start of the DL data portion of the sub-frame. The BS processor 20 controls the radio transmission via RF front end 24 and antenna 26 of the DL TB in the selected OFDM symbols (e.g. OFDM symbols #1 and #2 in the example of Figure 8) (STEP 408). This selection of OFDM symbols for the low latency DL TB facilitates error checking by the UE processor 34 in time to control the radio transmission of e.g. HARQ feedback in the same sub-frame (e.g. final OFDM symbol #6 of the same sub-frame in the example of Figure 8). If the UE processor 34 determines that it has not recovered the DL TB correctly and the HARQ feedback is negative, the BS processor 20 schedules and controls the radio transmission of a second transmission (re-transmission) of the same DL TB in the first two OFDM symbols of the DL data portion of the very next sub-frame, as shown in Figure 8.

Regarding the remaining OFDM symbols of the DL data portion of the same sub-frame (OFDM symbols #3 and #4 in the example of Figure 8), the BS processor 20 may schedule and control the radio transmission of another DL transport block without a low latency requirement.

On the other hand, if the DL TB has a normal latency requirement (or if the DL TB has a low latency requirement but the UE 8 and/or BS 2 does not have sufficient processing power), the BS processor 20 does not aim to restrict radio transmission of the TB to a portion of the DL data portion of the sub-frame excluding the final OFDM symbol of the data portion of the sub-frame. In the example illustrated in Figure 11, the BS processor 20 selects the whole of the DL data portion of the sub-frame (OFDM symbols #1 to #4), i.e. including the final OFDM symbol #4 of the DL data portion of the sub-frame (STEP 410). The BS processor 20 controls the radio transmission (via RF front end 24 and antenna 26) of a scheduling grant indicating the OFDM symbols selected for radio transmission of the DL TB, and controls the radio transmission of the DL TB in the selected OFDM symbols (e.g. OFDM symbols #1 to #4 in the example of Figure 11) (STEP 412). The UE baseband processor 34 recovers the DL TB from radio transmissions in the OFDM symbols identified in the scheduling grant recovered from radio

transmissions in the DL control portion of the subframe, and controls the radio transmission of HARQ feedback in the next sub-frame. Any second DL transmission (re-transmission) of the same DL TB happens in the 3rd sub-frame after the sub-frame in which the first transmission of the TB occurred.

Figure 5 illustrates an example of operations at the baseband processor 20 of a network node for the example of uplink data transmission (uplink user plane transmission), according to one embodiment. Again, all operations carried out by the BS processor 20 follow program code stored at BS memory 22.

In response to detecting a scheduling request from a UE served by the BS, the BS processor 20 identifies whether the scheduling request is for an uplink TB having a low latency requirement or for an UL TB having a normal latency requirement (STEP 502).

For uplink data transmissions, each sub-frame has a portion allocated to uplink data/control transmissions (OFDM symbols #2 to #6 in the sub-frame structure example of Figure 9).

If the scheduling request made by the UE is for an uplink TB having a low latency requirement (and the UE 8 and BS 2 have sufficient processing power), the BS processor 20 aims to select, for radio transmission of the UL TB, one or more OFDM symbols of the UL data/control portion of the sub-frame that maximise the time for error checking at the BS processor 20 in time to transmit HARQ feedback in the DL control portion (OFDM symbol #0) of the very next sub-frame. Where possible, the BS processor 20 selects one or more (e.g. two) symbols of the UL data portion excluding at least the final OFDM symbol of the UL data/control portion (OFDM symbol #6 in the sub-frame structure example of Figure 9) (STEP 504). In the example of Figure 9, the BS processor 20 selects a contiguous set of OFDM symbols at the start of the UL data/control portion of the sub-frame (symbols #2 and #3 in the example of Figure 9). The BS processor 20 controls the radio transmission via RF front end 24 and antenna 26 of a scheduling grant for the UE 8 in the DL control portion of the sub-frame (OFDM symbol #0 in the example of Figure 9) (STEP 506). The scheduling grant indicates the portion (selected OFDM symbols) of the UL data/control portion of the same sub-frame selected for the uplink radio transmission of the TB (e.g. OFDM symbols #2 and #3 in the example of Figure 9).

This selection of OFDM symbols for the UL transmission of the low latency UL TB facilitates early scheduling of any re-transmission of the same UL TB. For example, it may facilitate the DL transmission of a scheduling grant for a second UL transmission (re-transmission) of the same UL TB in the DL control portion of the very next sub-frame (as in the example of Figure 9) or the subsequent
5 sub-frame (as in the example of Figure 10). In the example of Figure 9, the BS processor 20 performs error checking in time to control the radio transmission of HARQ feedback in the DL control portion of the very next sub-frame (e.g. symbol time unit #0 of the very next sub-frame). If the BS processor 20 determines that it was not able to recover the uplink TB correctly, the BS processor 20 controls the radio transmission, in the DL control portion of the very next sub-frame, of a scheduling grant indicating
10 resources for the second radio transmission (re-transmission) of the same uplink TB in the very next sub-frame (symbols #2 and #3 of the very next sub-frame in the example of Figure 9). Accordingly, there may be only a one-sub-frame interval (e.g. 0.125ms interval) between the first UL transmission and second UL transmission of the uplink TB.

According to one variation, the BS processor 20 controls the radio transmission, in the DL control
15 portion (e.g. symbol #0 in the example of Figure 9) of the sub-frame including the first transmission of the uplink TB, of both a scheduling grant for the first transmission of the UL TB and a scheduling grant for a second transmission of the uplink TB in the very next sub-frame (e.g. symbols #2 and #3 of the very next sub-frame), i.e. in advance of knowing whether a second transmission of the UL TB is necessary (SECOND HALF OF STEP 506). This facilitates early re-transmission of the uplink TB
20 even when the BS processor 20 is not capable of performing error checking in time to control (if necessary) the transmission of a re-transmission scheduling grant in the DL control portion of the very next sub-frame (e.g. symbol #0 of the very next sub-frame in the example of Figure 9).

Regarding the remaining OFDM symbols of the UL data/control portion of the same sub-frame (OFDM symbols #3 to #6 in the example of Figure 9), the BS processor 20 may schedule the radio transmission
25 of another UL transport block without a low latency requirement.

Returning to Figure 5: if the UL TB has a normal latency requirement (or if the UL TB has a low latency requirement but the BS 2 and/or UE 8 does not have sufficient processing power), the BS processor 20

does not aim to restrict the radio transmission of the UL TB to a portion of the UL data/control portion of the sub-frame excluding at least the final symbol of the UL data/control portion of the sub-frame. In the example illustrated in Figure 12, the BS processor 20 selects the whole of the UL data/control portion of the sub-frame (symbols #2 to #6), i.e. including the final symbol #6 of the UL data/control portion of the sub-frame (STEP 508); and the BS processor 20 controls the radio transmission (via RF front end 24 and antenna 26) of a scheduling grant (in the DL control portion of the sub-frame) indicating the sub-frame symbols (e.g. symbols #2 to #6 in the example of Figure 12) selected for UL transmission of the UL TB (STEP 412).

The BS baseband processor 20 recovers the UL TB from radio transmissions in these OFDM symbols, and controls the radio transmission of HARQ feedback (and a scheduling grant for a re-transmission of the same UL TB, if necessary) in the DL control portion of the 2nd sub-frame after the sub-frame including the first UL transmission of the UL TB, as shown in Figure 12.

Figures 6 and 7 illustrate operations at BS and UE processors 20, 34 for DL and UL data transmissions respectively, according to an embodiment of the invention.

In the embodiment of Figures 6 and 7, the scheduling grant indicating the sub-frame symbols selected for a transmission comprises a latency mode indicator indicating one of a plurality of predetermined latency modes, which the UE processor 34 can map to a respective predetermined set of OFDM symbols within the sub-frame. In the example of Figures 6 and 7, there are only two pre-determined latency modes, and the latency mode indicator has one of two values: (i) a first, normal latency mode for which the predetermined set of sub-frame symbols is the whole of the DL data portion of the sub-frame (e.g. OFDM symbols #1 to #4 in the sub-frame structure example of Figure 8) in the case of a DL data transmission, or the whole of the UL data/control portion of the sub-frame (e.g. symbols #2 to #6 in the subframe structure example of Figure 9), in the case of UL data transmission; and (ii) a low latency mode for which the predetermined set of symbols is a predetermined sub-portion of the DL data portion of the sub-frame (e.g. first two OFDM symbols of the DL data portion, or e.g. other predetermined sub-portion of the DL data portion excluding at least the final OFDM symbol of the subframe) in the case of DL data transmission, or a predetermined sub-portion of the UL data/control portion of the sub-

frame (e.g. first two symbols of the UL data/control portion, or e.g. other predetermined sub-portion of the UL data/control portion excluding at least the final OFDM symbol of the subframe) in the case of UL data transmission.

The BS processor 20 controls the radio transmission (in the DL control portion of the sub-frame) of a scheduling grant indicating a latency mode indicator value (STEP 602 of Figure 6 for DL and STEP 5 702 of Figure 7 for UL). The UE processor 34 recovers the scheduling grant and latency mode indicator value, and retrieves from memory the predetermined set of subframe symbols corresponding to the latency mode indicator value indicated in the scheduling grant (STEP 604 of Figure 6 for DL and STEP 704 of Figure 7 for UL). In the case of DL data transmission, the UE processor 34 recovers the DL TB 10 from radio transmissions in the corresponding predetermined set of sub-frame symbols (STEP 606 of Figure 6); and in the case of UL data transmission, the UE processor 34 controls the radio transmission of the UL TB in the corresponding predetermined set of sub-frame symbols (STEP 706 of Figure 7).

All the above-described techniques facilitate the flexible allocation of symbol time units within a sub-frame to data packets having different latency requirements. These techniques may be used, for 15 example, to facilitate the ultra-reliable and low-latency communications (URLLC) envisaged for the coming 5G cellular system; and may involve, for example, imposing more restrictions (of the kind described above) on the allocation of sub-frame symbols to URLLC than on the allocation of subframe symbols to e.g. extreme mobile broadband (eMBB) communications.

Appropriately adapted computer program code product may be used for implementing the embodiments, 20 when loaded to a computer. The program code product for providing the operation may be stored on and provided by means of a carrier medium such as a carrier disc, card or tape. A possibility is to download the program code product via a data network. Implementation may be provided with appropriate software in a server.

Embodiments of the invention may be practiced in various components such as integrated circuit 25 modules. The design of integrated circuits is by and large a highly automated process. Complex and

powerful software tools are available for converting a logic level design into a semiconductor circuit design ready to be etched and formed on a semiconductor substrate.

Programs, such as those provided by Synopsys, Inc. of Mountain View, California and Cadence Design, of San Jose, California automatically route conductors and locate components on a semiconductor chip
5 using well established rules of design as well as libraries of pre stored design modules. Once the design for a semiconductor circuit has been completed, the resultant design, in a standardized electronic format (e.g., Opus, GDSII, or the like) may be transmitted to a semiconductor fabrication facility or "fab" for fabrication.

In addition to the modifications explicitly mentioned above, it will be evident to a person skilled in the
10 art that various other modifications of the described embodiment may be made within the scope of the invention.

CLAIMS

1. A method comprising: controlling the scheduling of radio transmissions of data in sub-frames each including a sub-frame portion allocated to radio transmission of downlink control information and/or a sub-frame portion allocated to radio transmission of uplink control information, and a sub-frame portion allocated to radio transmission of data; wherein said method comprises selecting, for radio transmission of a transport block of data, a location for a radio transmission time period within said sub-frame portion allocated to transmission of data, at least partly on the basis of a latency requirement for said transport block of data.
2. A method according to claim 1, wherein said sub-frame portion allocated to the radio transmission of data comprises a plurality of symbol time units, and wherein said method comprises: selecting, for radio transmission of a first transport block of data having a low latency requirement, one or more of said plurality of symbol time units excluding one or more final symbol time units of said plurality of symbol time units.
3. A method according to claim 2, comprising: selecting for radio transmission of a second transport block of data having less of a low latency requirement than said first transport block of data, one or more or all of said plurality of symbol time units including a final symbol time unit of said plurality of symbol time units.
4. A method according to claim 3, comprising controlling the scheduling of radio transmissions of said first and second transport blocks of data in the same sub-frame, and selecting for the radio transmission of said second transport block of data all of said plurality of symbol time units not selected for the radio transmission of said first transport block of data.
5. A method according to any of claims 2 to 4, further comprising controlling the radio transmission, in a single sub-frame, of information indicating both a radio resource allocated to a first radio transmission of the first transport block of data, and a radio resource allocated to a second radio transmission of the first transport block of data.

6. A method according to claim 1, comprising: controlling the radio transmission of control information, for a communication device, indicating the number of said plurality of symbol time units selected for a radio transmission of a transport block of data to or from said communication device.
7. A method according to claim 6, wherein said control information indicates one of two latency modes about which information is pre-stored at the communication device: said two modes comprising a first latency mode involving radio transmission of a transport block of data in a predetermined front portion of said plurality of symbol time units, and a second latency mode involving the radio transmission of a transport block of data in all of said plurality of symbol time units.
8. A method according to claim 1, further comprising controlling radio transmission of said transport block of data at said selected radio transmission time period.
9. A method according to claim 1, further comprising: controlling radio transmission of a scheduling grant for a communication device, indicating the radio transmission time period selected within the sub-frame for said transport block of data by said communication device.
10. A method comprising: controlling the radio transmission, in a control portion of a single sub-frame, of information indicating both a radio resource allocated to a first radio transmission of a first transport block of data in the sub-frame, and a radio resource allocated to a second radio transmission of the first transport block of data in a subsequent sub-frame.
11. A method comprising: recovering, from radio transmissions by a network node, a scheduling grant indicating scheduling of a radio transmission to or from said network node of a transport block of data in a sub-frame comprising a sub-frame portion allocated to radio transmission of data and comprising a plurality of symbol time units; further recovering, from said radio transmissions by said network node, control information indicating the number of said plurality of symbol time units selected for the radio transmission of said transport block of data; and controlling the radio transmission of said transport block of data in the one or more symbol time units indicated in said control information.

12. A method according to claim 11, wherein said control information indicates one of two modes about which information is pre-stored at the communication device, said two modes comprising: a first latency mode involving radio transmission of said transport block of data in a predetermined sub-portion of said plurality of symbol time units excluding at least a final one of said plurality of symbol time units; and a second latency mode involving the radio transmission of said transport block in all of said plurality of symbol time units.

13. An apparatus comprising: a processor and memory including computer program code, wherein the memory and computer program code are configured to, with the processor, cause the apparatus to: control the scheduling of radio transmissions of data in sub-frames each including a sub-frame portion allocated to radio transmission of downlink control information and/or a sub-frame portion allocated to radio transmission of uplink control information, and a sub-frame portion allocated to radio transmission of data; wherein the memory and computer program code are further configured to, with the processor, cause the apparatus to select for radio transmission of a transport block of data, a location for a radio transmission time period within said sub-frame portion allocated to transmission of data, at least partly on the basis of a latency requirement for said transport block of data.

14. An apparatus according to claim 13, wherein said sub-frame portion allocated to the radio transmission of data comprises a plurality of symbol time units, and wherein the memory and computer program code are further configured to, with the processor, cause the apparatus to: select for radio transmission of a first transport block of data having a low latency requirement, one or more of said plurality of symbol time units excluding one or more final symbol time units of said plurality of symbol time units.

15. An apparatus according to claim 14, wherein the memory and computer program code are further configured to, with the processor, cause the apparatus to: select for radio transmission of a second transport block of data having less of a low latency requirement than said first transport block of data, one or more or all of said plurality of symbol time units including a final symbol time unit of said plurality of symbol time units.

16. An apparatus according to claim 15, wherein the memory and computer program code are further configured to, with the processor, cause the apparatus to: control the scheduling of radio transmissions of said first and second transport blocks of data in the same sub-frame, and select for the radio transmission of said second transport block of data all of said plurality of symbol time units not selected for the radio transmission of said first transport block of data.

17. An apparatus according to any of claims 14 to 16, wherein the memory and computer program code are further configured to, with the processor, cause the apparatus to: control the radio transmission, in a single sub-frame, of information indicating both a radio resource allocated to a first radio transmission of the first transport block of data, and a radio resource allocated to a second radio transmission of the first transport block of data.

18. An apparatus according to claim 13, wherein the memory and computer program code are further configured to, with the processor, cause the apparatus to: control the radio transmission of control information, for a communication device, indicating the number of said plurality of symbol time units selected for a radio transmission of a transport block of data to or from said communication device.

19. An apparatus according to claim 18, wherein said control information indicates one of two latency modes about which information is pre-stored at the communication device: said two modes comprising a first latency mode involving radio transmission of a transport block of data in a predetermined front portion of said plurality of symbol time units, and a second latency mode involving the radio transmission of a transport block of data in all of said plurality of symbol time units.

20. An apparatus according to claim 13, wherein the memory and computer program code are further configured to, with the processor, cause the apparatus to: control radio transmission of said transport block of data at said selected radio transmission time period.

21. An apparatus according to claim 13, wherein the memory and computer program code are further configured to, with the processor, cause the apparatus to: control radio transmission of a

scheduling grant for a communication device, indicating the radio transmission time period selected within the sub-frame for said transport block of data by said communication device.

22. An apparatus comprising: a processor and memory including computer program code, wherein the memory and computer program code are configured to, with the processor, cause the apparatus to: control the radio transmission, in a control portion of a single sub-frame, of information indicating both a radio resource allocated to a first radio transmission of a first transport block of data in the sub-frame, and a radio resource allocated to a second radio transmission of the first transport block of data in a subsequent sub-frame.

23. An apparatus comprising: a processor and memory including computer program code, wherein the memory and computer program code are configured to, with the processor, cause the apparatus to: recover, from radio transmissions by a network node, a scheduling grant indicating scheduling of a radio transmission to or from said network node of a transport block of data in a sub-frame comprising a sub-frame portion allocated to radio transmission of data and comprising a plurality of symbol time units; further recover, from said radio transmissions by said network node, control information indicating the number of said plurality of symbol time units selected for the radio transmission of said transport block of data; and control the radio transmission of said transport block of data in the one or more symbol time units indicated in said control information.

24. An apparatus according to claim 23, wherein said control information indicates one of two modes about which information is pre-stored at the communication device, said two modes comprising: a first latency mode involving radio transmission of said transport block of data in a predetermined sub-portion of said plurality of symbol time units excluding at least a final one of said plurality of symbol time units; and a second latency mode involving the radio transmission of said transport block in all of said plurality of symbol time units.

25. An apparatus comprising: means for controlling the scheduling of radio transmissions of data in sub-frames each including a sub-frame portion allocated to radio transmission of downlink control information and/or a sub-frame portion allocated to radio transmission of uplink control information,

and a sub-frame portion allocated to radio transmission of data; wherein said controlling comprises selecting, for radio transmission of a transport block of data, a location for a radio transmission time period within said sub-frame portion allocated to transmission of data, at least partly on the basis of a latency requirement for said transport block of data.

26. An apparatus comprising: means for controlling the radio transmission, in a control portion of a single sub-frame, of information indicating both a radio resource allocated to a first radio transmission of a first transport block of data in the sub-frame, and a radio resource allocated to a second radio transmission of the first transport block of data in a subsequent sub-frame.

27. An apparatus comprising: means for recovering, from radio transmissions by a network node, a scheduling grant indicating scheduling of a radio transmission to or from said network node of a transport block of data in a sub-frame comprising a sub-frame portion allocated to radio transmission of data and comprising a plurality of symbol time units; means for recovering, from said radio transmissions by said network node, control information indicating the number of said plurality of symbol time units selected for the radio transmission of said transport block of data; and means for controlling the radio transmission of said transport block of data in the one or more symbol time units indicated in said control information.

28. A computer program product comprising program code means which when loaded into a computer controls the computer to: control the scheduling of radio transmissions of data in sub-frames each including a sub-frame portion allocated to radio transmission of downlink control information and/or a sub-frame portion allocated to radio transmission of uplink control information, and a sub-frame portion allocated to radio transmission of data; wherein said program code means further controls the computer to select, for radio transmission of a transport block of data, a location for a radio transmission time period within said sub-frame portion allocated to transmission of data, at least partly on the basis of a latency requirement for said transport block of data.

29. A computer program product comprising program code means which when loaded into a computer controls the computer to: control the radio transmission, in a control portion of a single sub-

frame, of information indicating both a radio resource allocated to a first radio transmission of a first transport block of data in the sub-frame, and a radio resource allocated to a second radio transmission of the first transport block of data in a subsequent sub-frame.

30. A computer program product comprising program code means which when loaded into a computer controls the computer to: recover, from radio transmissions by a network node, a scheduling grant indicating scheduling of a radio transmission to or from said network node of a transport block of data in a sub-frame comprising a sub-frame portion allocated to radio transmission of data and comprising a plurality of symbol time units; further recover, from said radio transmissions by said network node, control information indicating the number of said plurality of symbol time units selected for the radio transmission of said transport block of data; and control the radio transmission of said transport block of data in the one or more symbol time units indicated in said control information.

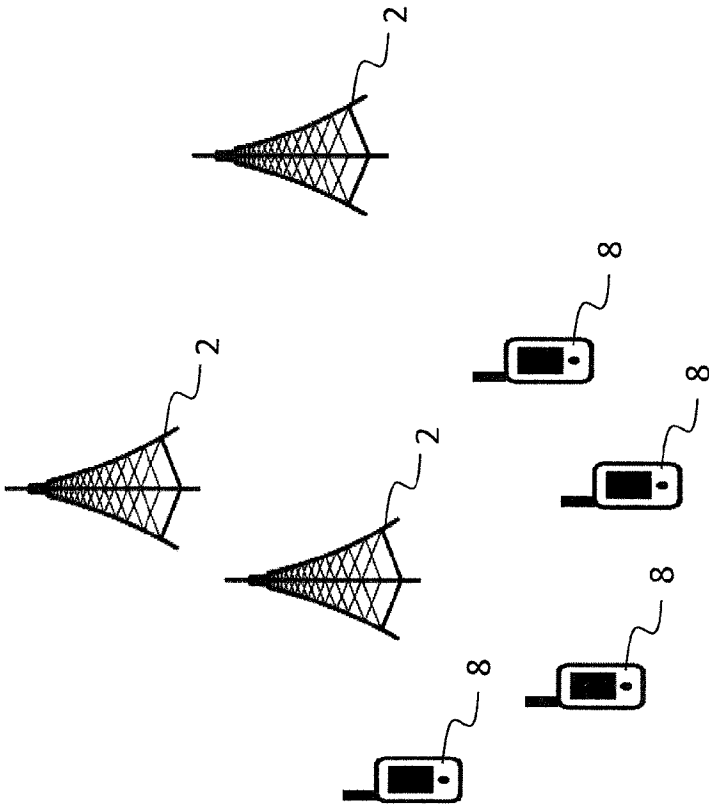


Figure 1

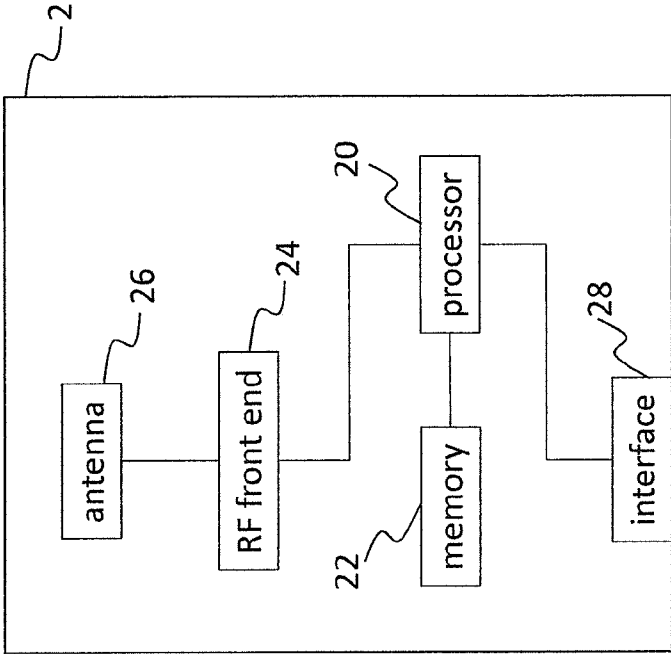


Figure 3

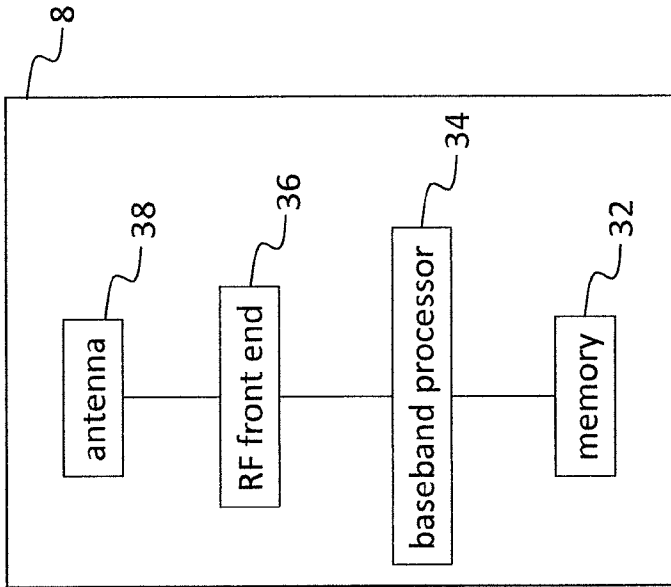


Figure 2

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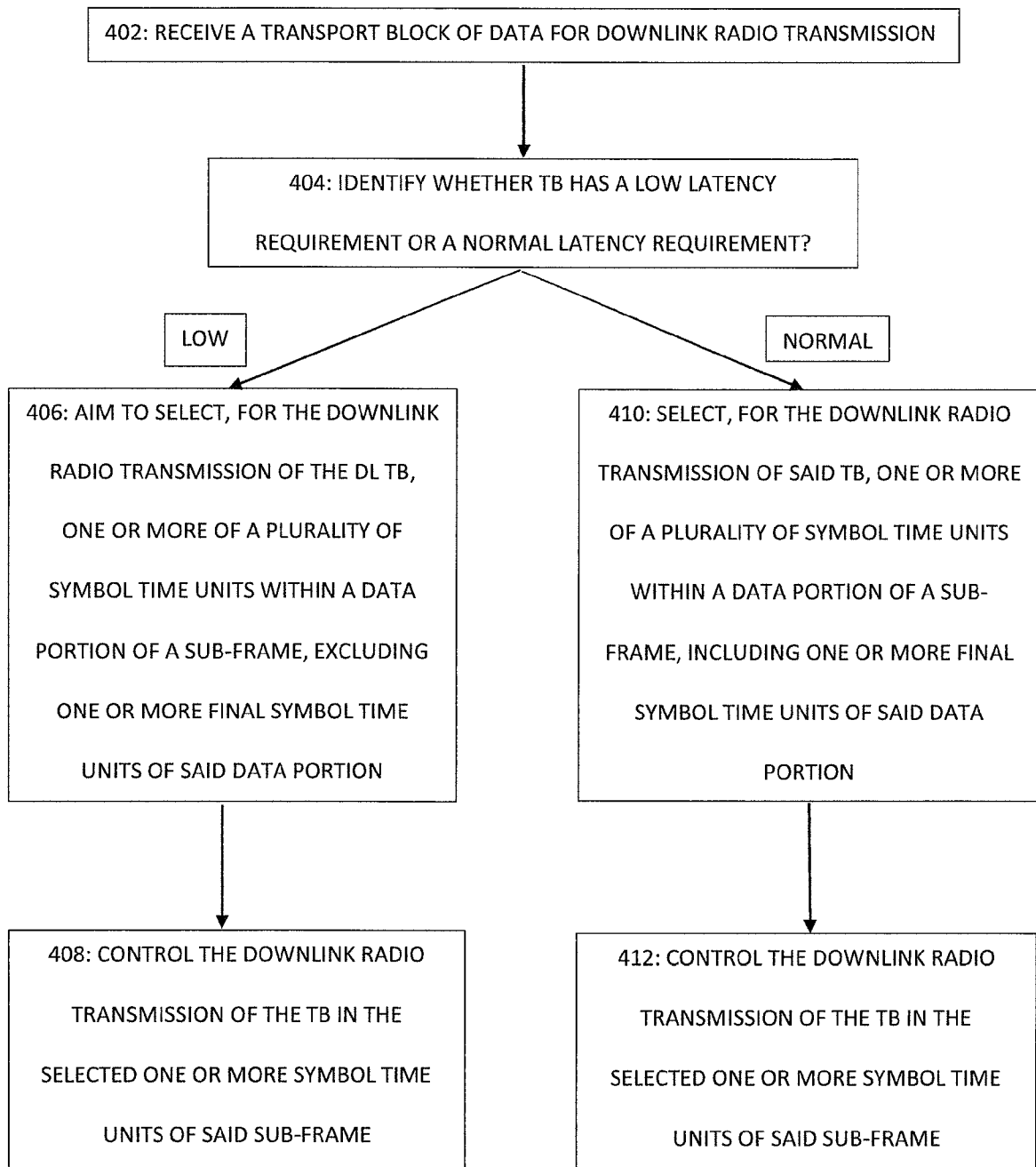


Figure 4

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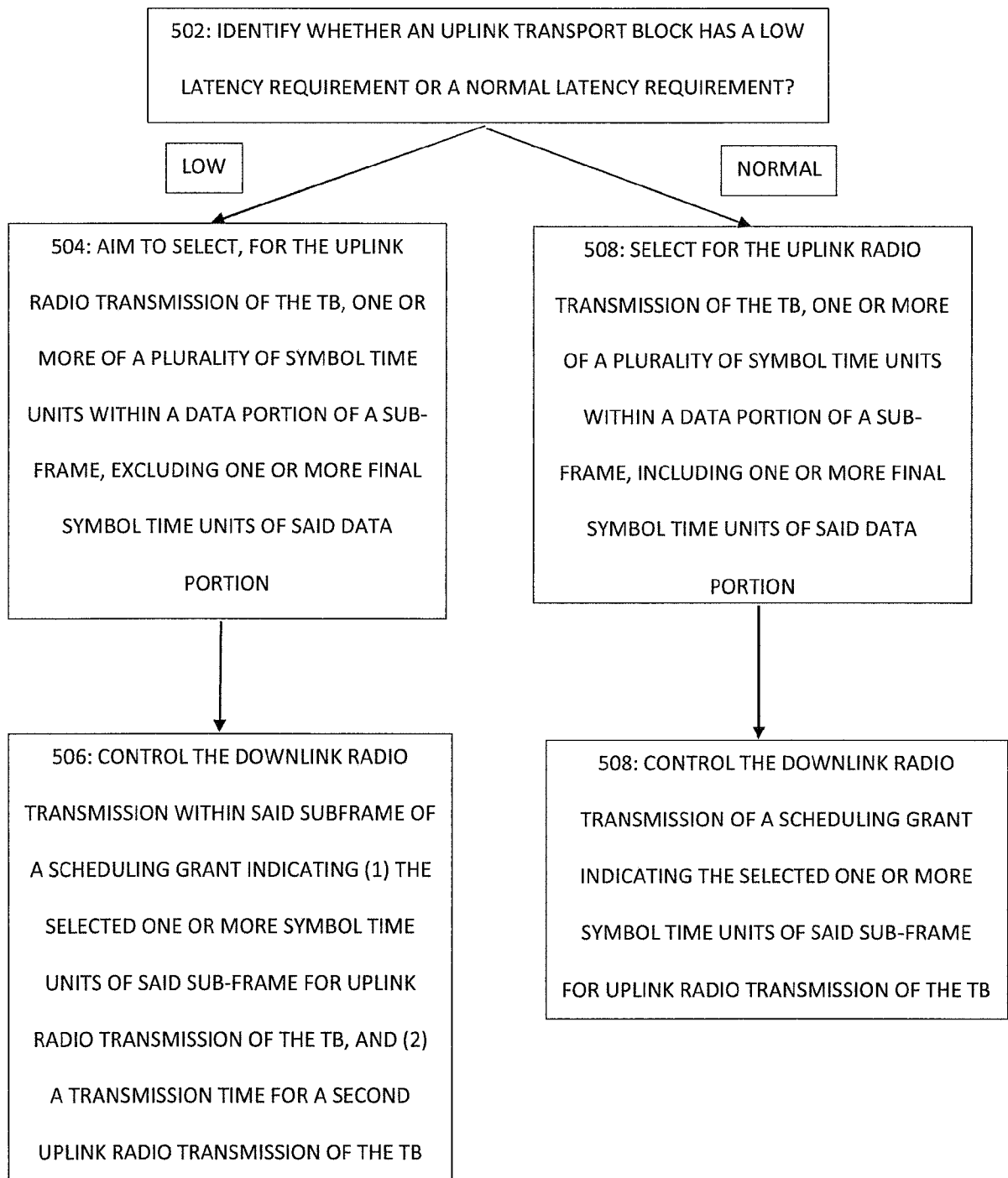


Figure 5

5/11

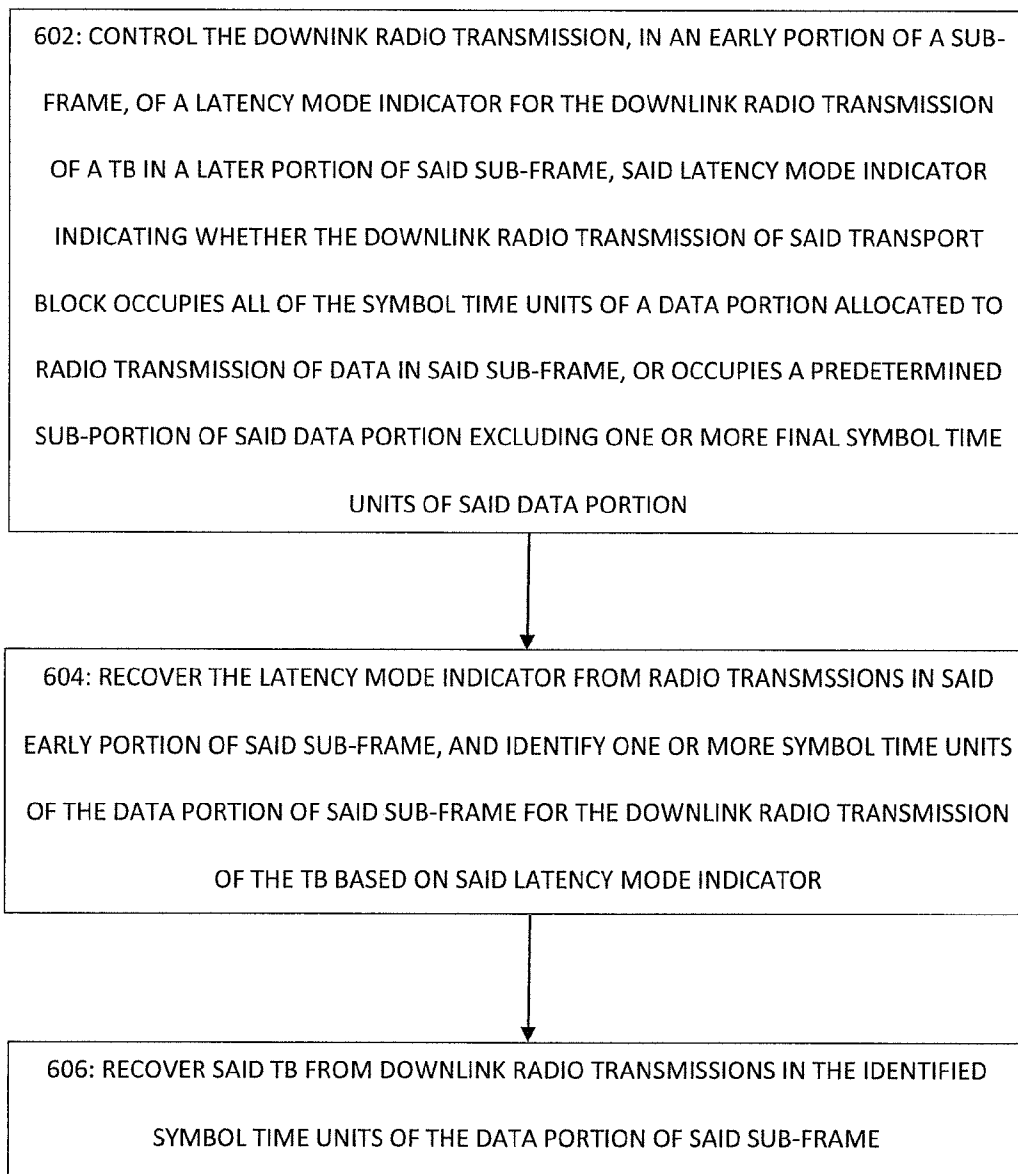


Figure 6

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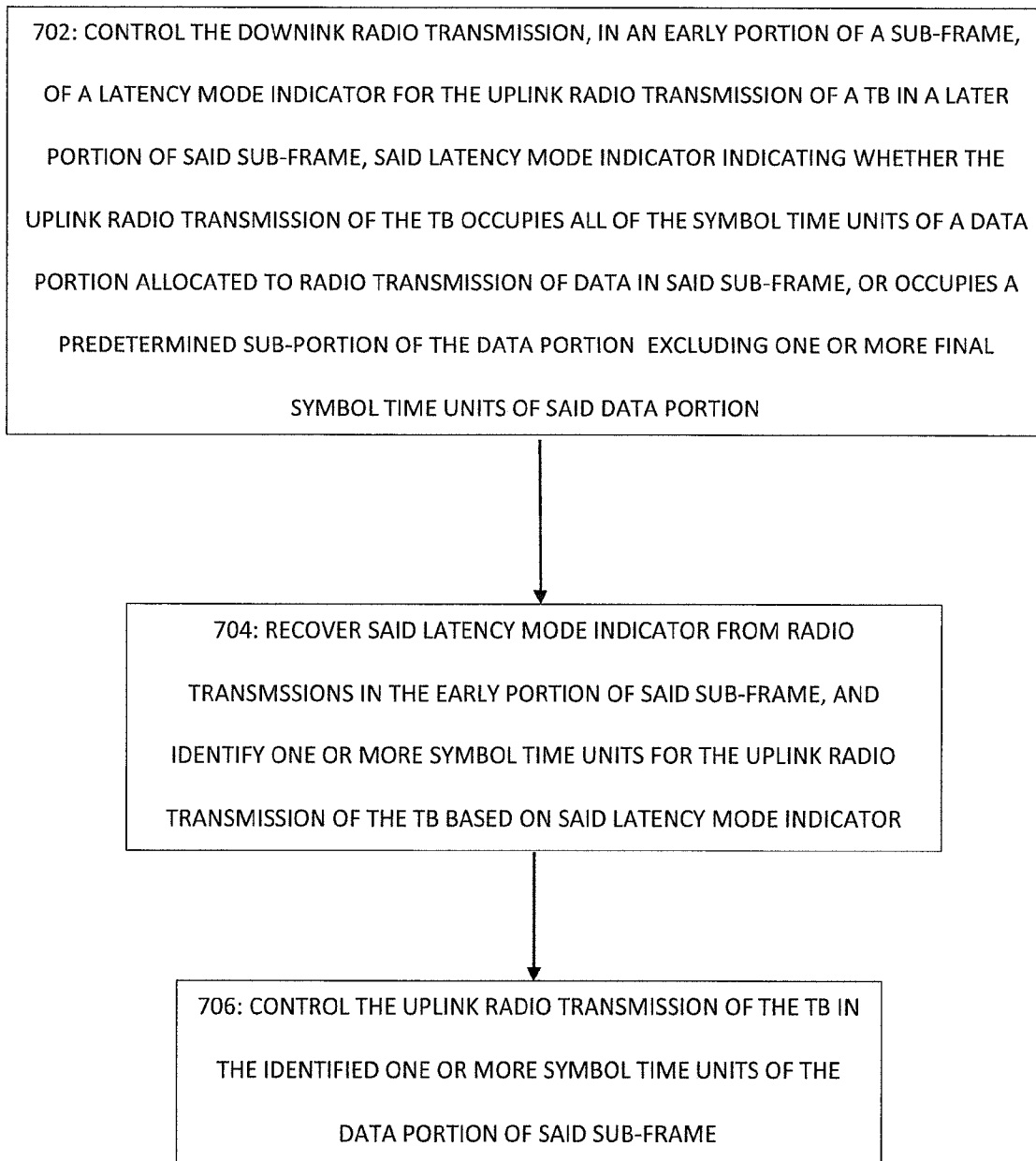


Figure 7

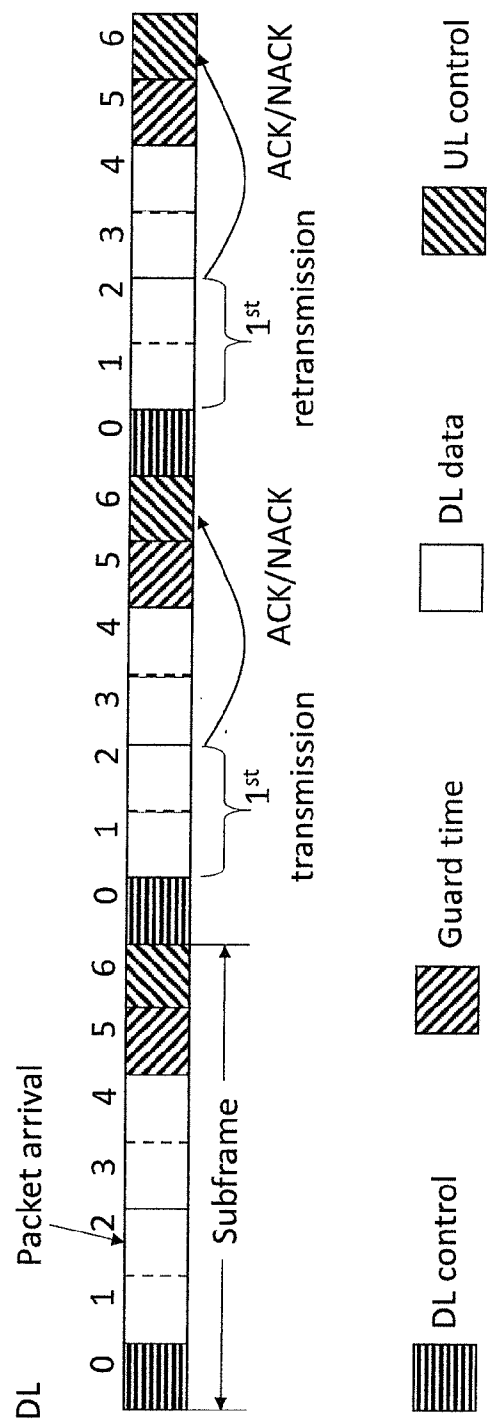


Figure 8

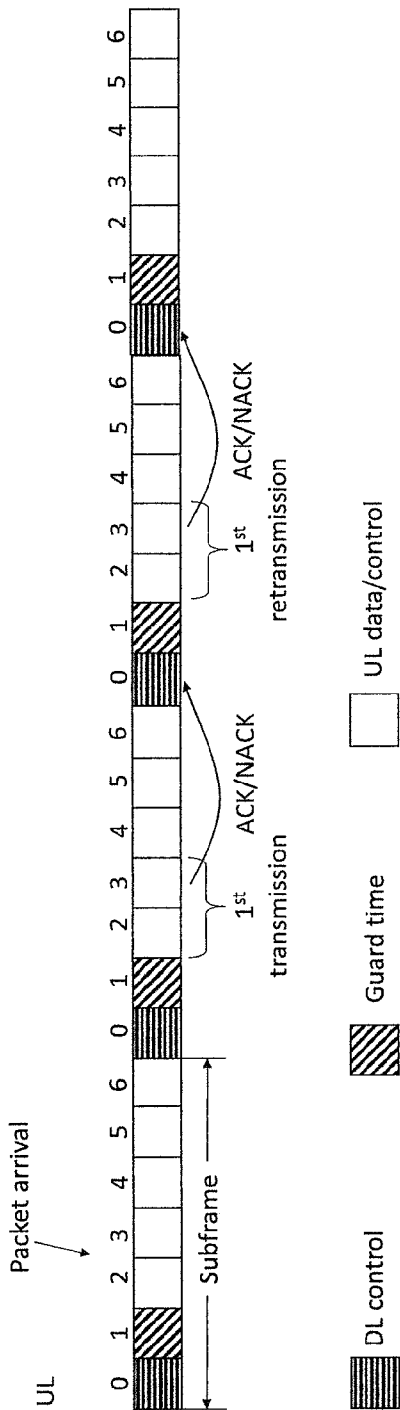


Figure 9

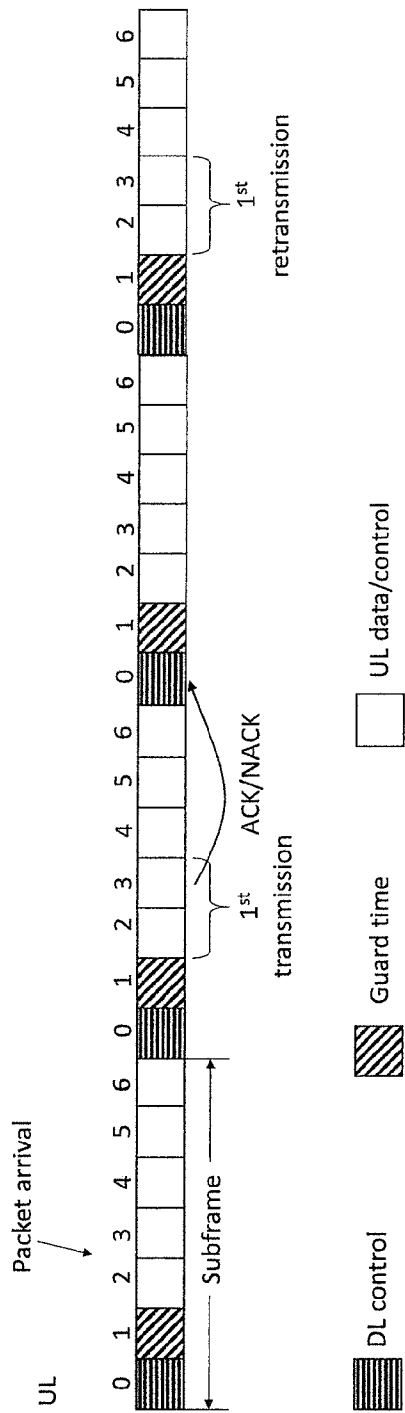


Figure 10

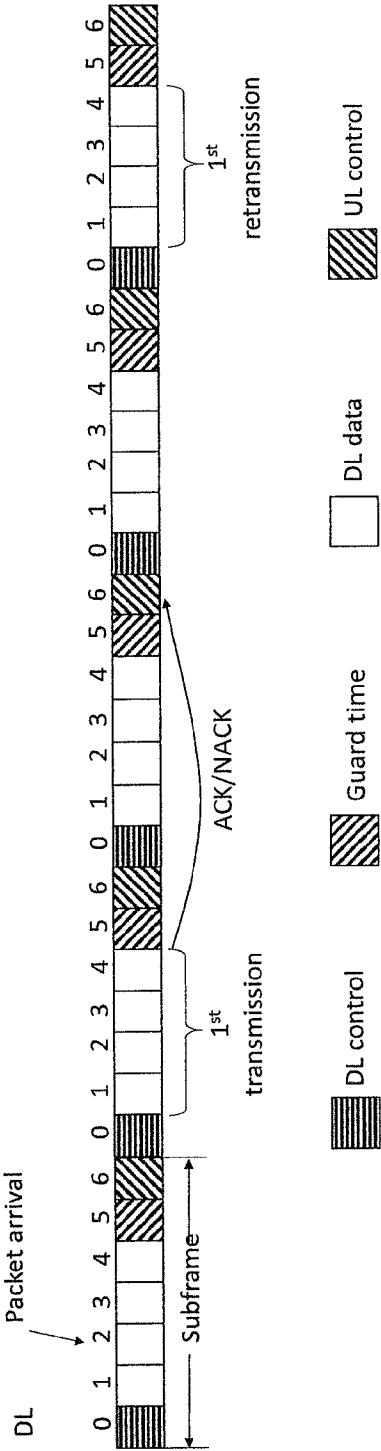


Figure 11

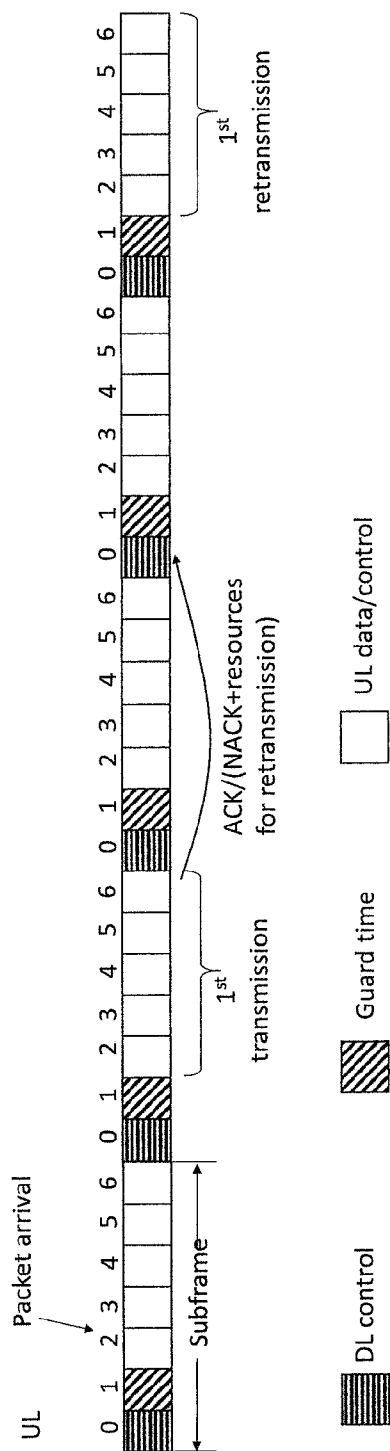


Figure 12

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2016/056826

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: H04L, H04W

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

SE, DK, FI, NO classes as above

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

EPO-Internal, PAJ, WPI data, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2016064049 A1 (LG ELECTRONICS INC), 28 April 2016 (2016-04-28); abstract; paragraphs [0074], [0244]-[0246], [0367]-[0368], [0384]; figure 12 --	1-30
A	US 20160128039 A1 (LIM KWANG JAE ET AL), 5 May 2016 (2016-05-05); abstract; paragraph [0011]; figure 3 -- -----	1-30

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

* Special categories of cited documents:	"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
"A" document defining the general state of the art which is not considered to be of particular relevance	"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
"E" earlier application or patent but published on or after the international filing date	"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
"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)	"&" document member of the same patent family
"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	

Date of the actual completion of the international search 04-07-2017	Date of mailing of the international search report 05-07-2017
Name and mailing address of the ISA/SE Patent- och registreringsverket Box 5055 S-102 42 STOCKHOLM Facsimile No. + 46 8 666 02 86	Authorized officer Sanja Sain Telephone No. + 46 8 782 28 00

Continuation of: second sheet

International Patent Classification (IPC)

H04W 72/12 (2009.01)

H04L 5/00 (2006.01)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/IB2016/056826

WO	2016064049 A1	28/04/2016	CN	106797248 A	31/05/2017
			WO	2016064059 A1	28/04/2016
			WO	2016064039 A1	28/04/2016
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