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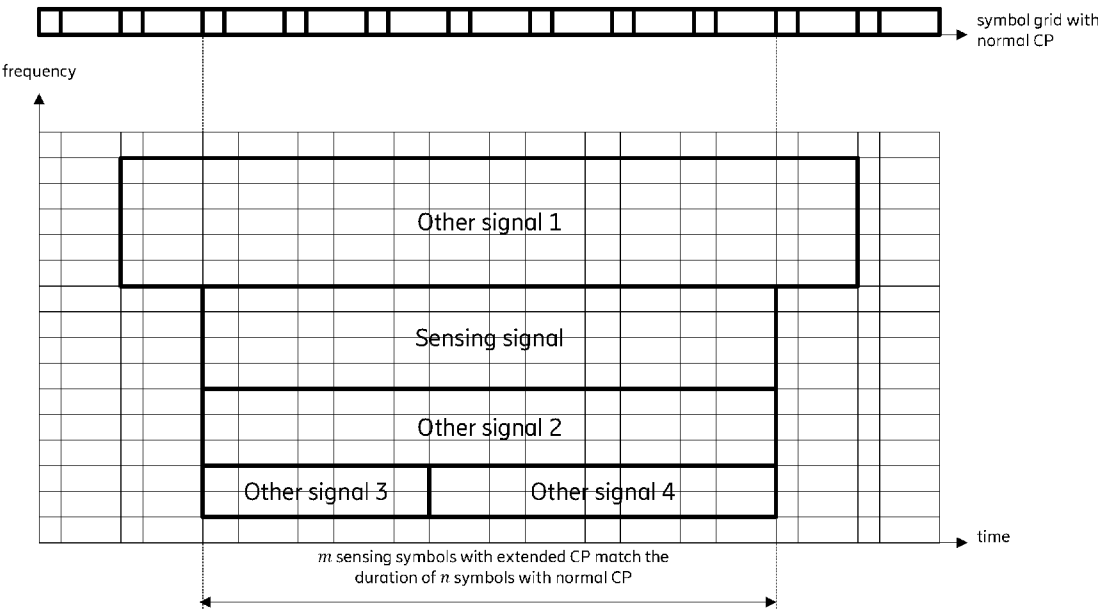


Fig. 4

(57) Abstract: There is disclosed a method of operating a radio node in a wireless communication network, the radio node being adapted for wireless communication utilising communication signalling based on a first symbol duration T1, and being adapted for sensing and/or radar operation, the method comprising performing a sensing operation based on sensing signalling, the sensing signalling being based on a second symbol duration T2, wherein T2 > T1 and the sensing signalling comprises M symbols having second symbol duration T2, wherein M is an integer number of at least 1, wherein M × T2 = N × T1, wherein N is an integer number larger than 1. The disclosure also pertains to related devices and methods.

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Joint Communication and Sensing

Technical field

This disclosure pertains to wireless communication and radar technology, in particular for high frequencies.

Background

For future wireless communication systems, combining wireless communication and sensing (radar) is discussed, in particular using the same spectrum and/or hardware for both. This is sometimes referred to as Joint Communication and Sensing (JCAS). Combining these functionalities brings a number of challenges.

Summary

It is an object of this disclosure to provide approaches of handling JCAS, in particular regarding multiplexing of communication signalling and sensing signalling. The approaches described may be utilised for one or more different frequencies ranges. For example, they may be implemented for frequency ranges (e.g., carrier bandwidth and/or system bandwidth) for sensing signalling and/or communication signalling of 1 GHz or more, 2GHz or more, 5 GHz or more, or 6 GHz or more, or 10 GHz or more, and/or for millimeter wave communication, in particular for radio carrier frequencies around and/or above 52.6 GHz, which may be considered high radio frequencies (high frequency) and/or millimetre waves. The carrier frequency/ies may be between 52.6 and 140 GHz, e.g. with a lower border between 52.6, 55, 60, 71 GHz and/or a higher border between 71, 72, 90, 114, 140 GHz or higher, in particular between 55 and 90 GHz, or between 60 and 72 GHz; however, higher frequencies may be considered, in particular frequency of 71GHz or 72GHz or above, and/or 100 GHz or above, and/or 140 GHz or above. The carrier frequency may in particular refer to a center frequency or maximum frequency of the carrier. The radio nodes and/or network described herein may operate in wide-band, e.g. with a carrier bandwidth (or bandwidth or carrier aggregation) of 400MHz or more, in particular 1 GHz or more, or 2 GHz or more, or even larger, e.g. 6 GHz or more, or 8 GHz or more; the scheduled or allocated bandwidth may be the carrier bandwidth, or be smaller, e.g. depending on channel and/or procedure. In some cases, operation may be based on an OFDM wave-form or a SC-FDM wave-form (e.g., downlink and/or uplink), in particular a FDF-SC-FDM-based wave-form. However, operation based on a single carrier wave-form, e.g. SC-FDE (which may be pulse-shaped or Frequency Domain Filtered, e.g. based on modulation scheme and/or MCS), may be considered for downlink and/or uplink. In general, different wave-forms may be used for different communication directions. Communicating using or utilising a carrier and/or beam may correspond to operating using or utilising the carrier and/or beam, and/or may comprise transmitting

on the carrier and/or beam and/or receiving on the carrier and/or beam. Operation may be based on and/or associated to a numerology, which may indicate a subcarrier spacing and/or duration of an allocation unit and/or an equivalent thereof, e.g., in comparison to an OFDM based system. A subcarrier spacing or equivalent frequency interval may for example correspond to 960 kHz, or 1920 kHz, e.g. representing the bandwidth of a subcarrier or equivalent.

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The approaches are particularly advantageously implemented in a future 6th Generation (6G) telecommunication network or 6G radio access technology or network (RAT/RAN), in particular according to 3GPP (3rd Generation Partnership Project, a standardisation organization). A suitable RAN may in particular be a RAN according to NR, for example release 18 or later, or LTE Evolution. However, the approaches may also be used with other RAT, for example future 5.5G systems or IEEE based systems.

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There is disclosed a method of operating a radio node in a wireless communication network. The radio node is adapted for wireless communication utilising communication signalling based on a first symbol duration $T1$ and/or a first cyclic prefix duration $TC1$, and is adapted for sensing and/or radar operation. The method comprises performing a sensing operation based on sensing signalling, the sensing signalling being based on a second symbol duration $T2$ and/or second cyclic prefix duration $TC2$. $T2 > T1$ and/or $TC2 > TC1$ holds, and the sensing signalling comprises M symbols having second symbol duration $T2$, wherein M is an integer number of at least 1, wherein $M \times T2 = N \times T1$, wherein N is an integer number larger than 1 (or equal to 1, e.g., if $T1=T2$), but $TC2 \neq TC1$. Alternatively, or additionally, the method may comprise transmitting and/or receiving communication signalling comprising M symbols having a second symbol duration $T2$, e.g., based on a received extended duration signalling indication.

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A radio node for a wireless communication network is described. The radio node is adapted for wireless communication utilising communication signalling based on a first symbol duration $T1$ and/or a first cyclic prefix duration $TC1$, and is adapted for sensing and/or radar operation. The radio node is adapted for performing a sensing operation based on sensing signalling, the sensing signalling being based on a second symbol duration $T2$ and/or second cyclic prefix duration $TC2$, wherein $T2 > T1$ and/or $TC2 > TC1$. The sensing signalling comprises M symbols having second symbol duration $T2$, wherein M is an integer number of at least 1, wherein $M \times T2 = N \times T1$, wherein N is an integer number larger than 1 (or equal to 1, e.g., if $T1=T2$, but $TC2 \neq TC1$). Alternatively, or additionally, the radio node may be adapted for transmitting and/or receiving communication signalling comprising M symbols having a second symbol duration $T2$, e.g., based on a received extended duration signalling indication (e.g., to adapt its timing to ongoing

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sensing operation).

Approaches described herein may facilitate sensing operation in the context of a wireless communication framework, with increased sensing range, with low signalling overhead.

It may be considered that the first symbol duration, $T1$, may be based on a first cyclic prefix duration $TC1$, and the second symbol duration, $T2$, may be based on a second cyclic prefix duration $TC2$, wherein $TC2 > TC1$. $TC1$ may correspond to a normal cyclic prefix, e.g., according to a numerology. $TC2$ may correspond to an extended CP prefix (e.g., extended compared to the first and/or normal CP, and/or extended according to a numerology available for communication and/or sensing signalling). This may be an efficient manner of providing a suitable range for sensing signalling, in particular in a communication network which may operate based on OFDM signalling, and/or signalling utilising a CP. The symbol proper durations associated to the first symbol duration may be the same as, or different than, the symbol proper duration associated to the second symbol duration; in some cases, the symbol proper duration ($TP2$) associated to the second symbol duration $T2$ may be shorter than the symbol proper duration ($TP1$) associated to the first symbol duration $T1$, e.g., for identical symbol durations with different duration CPs. 75 80 85

The first symbol duration may be based on a first symbol proper duration $TP1$, and the second symbol duration may be based on a second symbol proper duration $TP2$, wherein in some cases there may hold $TP2 > TP1$, or there may hold $TP2 = TP1$. However, in some cases, $TP2 < TP1$ may hold, e.g., to provide equal duration symbols with different duration CPs. This may allow adapting symbol durations for a desired use-cases, e.g. to allow minimization of M , and/or N , and/or to adapt to configurable $TC2$. 90

It may be considered that the M symbols may comprise $M1$ sensing symbols, and/or $M2$ communication symbols, and/or $M3$ guard symbols, wherein $M = M1 + M2 + M3$, wherein $M1$ may be zero or an integer number of 1 or larger, and/or $M2$ may be zero or an integer number of 1 or larger, and/or $M3$ may be zero or an integer number of 1 or larger. Thus, a combination of different symbols may be provided, e.g., for embedding sensing pulses into signalling. For example, a short pulse may be embedded such that the requirements for M , N are fulfilled even if M is larger than the number of symbols used for the sensing. It may be considered that M symbols of communication signalling are transmitted and/or received analogously, e.g., when multiplexing and/or operating multiple wireless devices, e.g., in the same beam. 95 100

In some cases, the first symbol duration $T1$ and/or the second symbol duration $T2$ may be based on a numerology configured for communication signalling. The numerology may 105

indicate and/or define the CP duration, e.g. TC1 and/or TC2, and/or symbol proper duration, e.g., TP1 and/or TP2, and/or T1 and/or T2. The numerology may be configured, e.g., with higher layer signalling (e.g., RRC signalling and/or broadcast signalling), in particular to a wireless device. The configuration may indicate a numerology for communication signalling and/or sensing signalling; they may be mappable to each other in an unambiguous way, e.g., according to a standard definition (e.g., with defining and/or configuring the numerology for communication signalling, the numerology for sensing signalling, and/or T2 and/or TP2 and/or TC2 may be derivable and/or defined, and/or vice versa). Hence, efficient control signalling may be provided. 110 115

It may be considered that performing a sensing operation may comprise transmitting and/or receiving, and/or monitoring for, the sensing signalling. The operation may be scheduled to a radio node, e.g., to a wireless device, for example by a network node. The sensing operation may be performed in a mono-static, bi-static or multi-static scenario.

In some cases, the radio node may be a network node, or a wireless device. Approaches described herein may be utilised complementarily, e.g. pertaining to signalling direction and/or use case. 120

It may be considered that the second symbol duration T2 (and/or TC2) may be based on, and/or may correspond to, a range (e.g., a distance) for a sensing operation, e.g., a maximum range and/or target range and/or desired range. T2 and/or TC2 may be adapted such that sensing signalling may be received within a CP duration; adaption may be configured and/or scheduled (e.g., with physical layer signalling), e.g., indicating T2 and/or TC2 and/or TP2. 125

In general, the second symbol duration T2, and/or a second cyclic prefix duration TC2, and/or TP2, may be configured and/or configurable and/or predefined. Configuration may be with physical layer signalling and/or higher layer signalling. This may allow efficient use of control signalling and/or flexibility for sensing, in particular regarding range. 130

In general, a symbol may be based on, and/or represent, and/or correspond to, and/or comprise, and/or consist of, a cyclic prefix and a symbol proper (and/or an appendix, e.g. a cyclic appendix). A symbol duration may be considered to be based on a cyclic prefix duration if the symbol comprises a cyclic prefix, and/or the symbol duration comprises the duration of the cyclic prefix. A cyclic prefix of a communication symbol, and/or associated to communication signalling, may be a normal CP (or short CP); a cyclic prefix of a sensing symbol, and/or associated to sensing signalling, may be an extended (or longer CP), e.g. longer than a normal CP. 135 140

The M symbols associated to sensing signalling (and/or comprised therein) may in general be consecutive in time domain, and/or each of the M symbols may be neighbouring to at least on other of the M symbols. Each of the M symbols may have the second symbol duration T2, and/or have a CP with duration TC2, and/or an extended cyclic prefix. In general, $M < N$, or $M = N$ may hold, e.g., depending on durations of T1 and/or T2 and/or TC1 and/or TC2 and/or TP1 and/or TP2. Utilising signalling having and/or based on, and/or signalling being based on, a symbol duration and/or CP duration and/or symbol proper duration, may refer to, and/or indicate, that signalling according to symbols and/or symbol time intervals corresponding to the duration/s is utilised and/or a device is correspondingly adapted. For example, communication signalling may have a transmission timing structure with symbols having duration T1 and/or CP having duration TC1; sensing signalling, and/or associated symbols may have a symbol duration T2 and/or CP of TC2. 145 150

It may be considered that sensing signalling comprises multiplexed communication signalling, e.g., in time domain and/or frequency domain; in this case, the communication signalling may comprise M symbols with duration T2, which may be communication signalling (or symbols) and/or reference signalling (or symbols), which may be associated to communication signalling. Performing a sensing operation may be based on a received extended duration signalling indication. The indication may be transmitted as control signalling, e.g., physical layer control signalling, and/or representing a DCI or SCI message, and/or transmitted on a PDCCH and/or PSSCH, and/or higher layer signalling, e.g. MAC layer signalling and/or RRC layer signalling. For example, physical layer signalling may indicate and/or trigger and/or schedule the sensing signalling and/or communication signalling, and/or signalling comprising M symbols of duration T2 each, and/or may indicate, and/or point to, and/or index a configuration and/or a predefinition, e.g. a configuration provided with higher-layer signalling, wherein the configuration and/or a predefinition (e.g., a predefined table) may indicate M, and/or T2 and/or TC2, and/or N, and/or TC1 and/or T1. In general, configuring may utilise and/or be based on and/or may comprise transmitting control signalling, e.g., physical layer control signalling, and/or representing a DCI or SCI message, and/or transmitted on a PDCCH and/or PSSCH, and/or higher layer signalling, e.g. MAC layer signalling and/or RRC layer signalling and/or broadcast signalling. 155 160 165 170

Sensing and/or radar operation may be used interchangeably. Sensing operation may be performed in a sensing mode. Communication may be performed in a communication mode. Different antenna arrangements and/or different nodes may operate in different modes; in some cases, different antenna arrangements of the same radio node may operate in different modes, e.g. using frequency domain multiplexing (e.g., in addition to and/or 175

overlaid on time domain multiplexing). Sensing operation may comprise transmitting and/or receiving sensing signalling. Sensing signalling may be signalling intended to be bounced of one more targets, e.g. to determine a presence, and/or a location, and/or velocity, and/or speed of the target/s from the reflected signalling. Sensing operation may be mono-static, or in some cases bistatic or multi-static. 180

It may be considered that the communication signalling is based on a multi-carrier waveform, e.g. an OFDM waveform, for example a DFT-s-OFDM based waveform, and/or that the communication signalling is based on a waveform with cyclic appendix. A cyclic appendix may generally be a cyclic prefix, or a cyclic suffix. The appendix may represent a repetition of a part of signalling carried by a symbol at its start (suffix) or end (prefix), which may be appended at the opposite of the symbol (end or start); e.g. a cyclic prefix may be considered a repetition of the signalling at the end of the symbol it pertains to. A cyclic appendix may be associated to a specific symbol, it may have a duration shorter than the symbol duration, e.g. less than 1/4 of the symbol duration, or less than 1/6. 185 190

The radio node may operate in TDD mode, e.g. switching between DL periods and UL periods. A DL period may be a period in which the radio node operates using DL transmissions, an UL period may be a period in which the radio node operates using UL transmissions (e.g., a network node may transmit during DL, and receive during UL, and vice versa for a wireless device). It may be considered that there is a TDD guard period between DL and UL periods and/or between UL and DL periods, which may comprise a number of symbol time intervals, e.g. 10 or more symbols, or 12 or more symbols; there may be the same duration for guard periods for DL/UL and UL/DL, or different ones. The guard period may allow switching circuitry between the different communication directions and/or handling of interference (in particular considering that DL signalling tends to much more powerful than (received) UL signalling). Time domain multiplexing of sensing signalling and communication signalling may refer to and/or include and/or comprise and/or represent switching between communication mode and sensing mode such that at different times, different modes are used at least for a part of the circuitry and/or antenna arrangements and/or signalling associated to the radio node. An antenna arrangement may comprise one or more antenna elements and/or sub-arrays and/or panels; different antenna arrangements may comprise different antenna elements and/or sub-arrays and/or panels. Different antenna arrangements and/or panels and/or sub-arrays and/or elements may be adapted to be controlled or controllable separately from each other. There may be the same number of DL and UL periods and/or the same duration associated to DL and UL (at least over a certain time interval, e.g. alternating such that one DL period is followed by one UL period, or vice versa, or different numbers or durations, e.g. (roughly) 3:1 (e.g., 3 DL periods followed by a TDD guard period and 1 UL period), or (roughly) 205 210 215

2:1, or even (roughly) 1:2 or 1:NU with NU 3 or larger, for UL heavy scenarios. UL period durations may be the same as DL period durations, or different. The distribution and/or duration of DL and UL periods may be referred to as TDD pattern; the TDD pattern may be dynamically controllable (e.g., with DCI signalling), and/or configured or configurable, e.g. with higher layer signalling like RRC signalling or RLC signalling, and/or may be semi-statically configurable or configured. The TDD pattern may describe the smallest time domain distribution of DL period/s and/or UL period/s and/or TDD guard period/s repeated over time, e.g. in one or more frames and/or subframes and/or slots and/or a time duration covering multiple repetitions of the TDD pattern. It may be considered that operating in sensing mode may comprise both transmission and reception by the same radio node, independent of the TDD period associated to a communication mode. It may be considered that a sensing mode and/or sensing interval may be inserted and/or embedded and/or multiplexed into a time period nominally associated to DL and/or UL and/or a TDD guard period, in particular a DL/UL guard period.

The sensing signalling and communication signalling may be transmitted by the same transmitting node, e.g. the radio node, or by different nodes. In particular, it may be considered that the radio node transmits both communication signalling and sensing signalling, and may additionally monitor for and/or receive a reflection of the sensing signalling, e.g. in a mono-static scenario. In some cases, the radio node may receive the communication signalling and the sensing signalling, and/or may additionally transmit the sensing signalling, e.g. in a mono-static scenario. In some cases, the radio may transmit the communication signalling and receive (and/or monitor for) the sensing signalling, and additionally may transmit the sensing signalling, or vice versa. It should be considered that the receiving sensing signalling may comprise, and/or be based on monitoring for the sensing signalling, e.g. utilising one or more reception beams and/or beam sweeping. Received or monitored for sensing signalling may represent reflected and/or diffracted sensing signalling, e.g. after impacting a target object and/or obstacle. Operation using sensing signalling and communication signalling may pertain to a specific time period, e.g. a joint operation interval, in which both communication and sensing is performed. There may be operational states of the radio node focussing on one type of operation, e.g. only communicating or sensing. Sensing signalling being frequency multiplexed (also known as being frequency domain multiplexed, or frequency duplexed) with communication signalling may refer to the sensing signalling having a different location in frequency domain than the communication signalling, e.g. in non-overlapping parts of the spectrum (non-overlapping bandwidths). In particular, sensing signalling may occupy a first frequency bandwidth, and the communication signalling may occupy a second frequency bandwidth, wherein the first and second frequency bandwidths may be non-overlapping

and/or disjunct and/or separated in frequency domain.

The radio node may for example be a wireless device or user equipment or terminal, or a network node or signalling radio node or base station. Thus, sensing functionality may be provided by common participants of a wireless communication network.

It may be considered that the radio node is adapted for utilising a number NP of antenna sub-arrays and/or panels, wherein NP may be an integer number of 4 or larger. An antenna sub-array may comprise a plurality of antenna elements, e.g. 4 or more, or 10 or more, or 50 or more, or 100 or more. An antenna sub-array, and/or the antenna elements associated thereto and/or comprised therein, may be associated and/or connected or connectable to one and/or the same antenna circuitry, and/or be jointly controllable for analog and/or digital beam-forming, and/or be operable for joint transmission or reception. A panel may comprise a support structure, e.g. plastics and/or metallic material and/or wood, supporting one or more antenna sub-arrays, which additionally may support additional circuitry like antenna circuitry and/or interface circuitry. Each antenna sub-array may be associated for one communication direction (e.g., reception or transmission) and/or one functionality, e.g. sensing or communication. It may be considered that antenna elements of an antenna sub-array share the same polarisation, e.g. horizontal or vertical. In some cases, NP may be an even number, wherein it may be considered that NP/2 antenna sub-arrays (and/or their antenna elements) may be associated to a first polarisation (e.g., horizontal or vertical or left-circular or right-circular, or any other suitable polarisation) and the other NP/2 antenna sub-arrays are associated to a second polarisation, which may be orthogonal to the first polarisation. For example, the first polarisation may be horizontal with the second polarisation being vertical, or the first polarisation may be left-circular and the second polarisation may be right-circular. This allows multiple beams to be operated, with good flexibility and/or large signalling capacity. In general, an antenna arrangement associated to a radio node may comprise one or more antenna sub-arrays, in particular an even number of antenna sub-arrays. In general, at different times, different antenna sub-arrays and/or panels may be used for different functions, e.g. transmission or reception, and/or sensing or communication. The polarisation of an antenna element may be associated to a specific operation direction, e.g. for transmission or reception. Depending on signalling direction (transmission or reception), polarisation may be different. For example, an antenna sub-array may be associated to a first polarisation for transmission, and a second polarisation for reception, or vice versa. This may be achieved, for example, by providing crossed linear antenna elements for the sub-arrays, with associated connections/circuitry according to polarisation.

In particular, it may be considered that the sensing signalling is transmitted and/or re-

ceived, e.g. by the radio node, utilising a first set of antenna elements and/or antenna sub-arrays and/or antenna panels, and the communication signalling is transmitted and/or received, e.g., by the radio node, utilising a second set of antenna elements and/or antenna sub-arrays and/or antenna panels. The first set may comprise different sub-arrays and/or antenna elements and/or antenna panels than the second set. The first set may comprise one or more antenna sub-arrays and/or panels, e.g. NC sub-arrays and/or panels, in particular an even number. It may be considered that the second set may comprise one or more antenna sub-arrays and/or panels, e.g., NS sub-arrays, in particular an even number. It may be considered that $NC+NS=NP$. In some cases, the NC and/or NS sub-arrays and/or panels may comprise equal number of antenna sub-arrays and/or panels associated to first and second polarisations (in general, an antenna sub-array may be considered associated to a polarisation if all its antenna elements are associated to the same polarisation). It may be considered that different antenna sub-arrays are used for transmitting sensing signalling and receiving signalling, wherein the same polarisation may be associated to transmitting and receiving of sensing signalling.

It may be considered that the sensing signalling and the communication signalling are transmitted and/or received in an operation time interval, for example a slot, or an integer number N of symbol time intervals or allocation units or block symbols. The operation time interval may correspond to 1 ms or less, or 0.5 ms or less, or .1 ms or less, and/or N may be 1000 or less, or 300 or less, or 200 or less, or 100 or less, or 20 or less. Thus, the radio node may operate both signalling types in short timescales. Within the operation time interval, the sensing signalling and communication signalling may be operated time multiplexed, or simultaneously, or both (in different sub-intervals).

In some variants, the sensing signalling and the communication signalling may be transmitted and/or received at least partly, or fully, overlapping in time, e.g. in an operation time interval, or one or more sub-intervals thereof. Partly overlapping in time may refer to part of the sensing signalling not overlapping with the communication signalling, fully overlapping may refer to all of the sensing signalling overlapping with communication signalling (in time domain, in particular within the operation time interval and/or one or more sub-intervals thereof).

In particular, the sensing signalling may in general be transmitted in a sensing time interval, and a reflection of the sensing signalling may be monitored for (and/or received) in a monitoring time interval, wherein the sensing time interval and the monitoring time interval may at least partly, or fully, overlap in time. The sensing time interval and/or the monitoring time interval may be part of an operation time interval, e.g. comprised therein, for example as sub-intervals, or covering the operation time interval. Thus, short

timescale joint operation is facilitated.

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It may be considered that a first antenna sub-array and/or antenna panel may be used for transmitting sensing signalling, a second antenna sub-array and/or antenna panel may be used for monitoring and/or receiving a reflection of the sensing signalling. Two or more antenna sub-arrays and/or panels may be used for communicating utilising communication signalling., e.g. during the operation time interval. The first and second sub-array and/or panel may be of different polarisation. In particular for large NP (e.g., 8 or larger), this may facilitate sensing operation with comparatively low impact on communication operation.

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In general, sensing signalling and communication signalling occupy the same frequency spectrum, e.g. the same carrier. Frequency multiplexing may generally refer to different locations of the frequency spectrum being assigned to sensing signalling and communication signalling, e.g. different parts of the carrier bandwidth; additionally, different bandwidths may be assigned to sensing signalling and communication signalling. Spectrum re-use thusly may be provided. This may refer to operation time interval/s.

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It may be considered that the sensing signalling may occupy a bandwidth (first frequency bandwidth, or first bandwidth) of 350 MHz or less, or 300 MHz or less, and/or 10% or less of a carrier or system bandwidth, or 5% or less of a carrier or system bandwidth, and/or 10% or less of the bandwidth (second frequency bandwidth, or second bandwidth) used for communication signalling, and/or 7% or less of the bandwidth used for communication signalling. This may refer to operation time interval/s; outside of such, different bandwidth sizes may be used, e.g. if only communication signalling is used for a longer time (e.g., 5 or more times the operation time interval duration, or 10 or 20 or 50 or more times the operation time interval duration), the full carrier/system bandwidth may be applied for communication signalling. Thus, bandwidth limitation may be ameliorated.

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In some variants, sensing signalling may occupy a first frequency bandwidth (or first bandwidth), and the communication signalling may occupy a second frequency bandwidth (second bandwidth), wherein further a frequency gap may exist, or be, or be located, between the first frequency bandwidth and the second frequency bandwidth. The second frequency bandwidth may be larger in size than the first frequency bandwidth, e.g. it may be SM times the size, wherein SM may be 3 or more, or 5 or more, or 10 or more, or 15 or more. The gap may correspond to a bandwidth smaller than the second frequency bandwidth, and/or may be smaller than the first frequency bandwidth. The gap may correspond to a guard bandwidth, e.g. limiting interference between the first and second frequency bandwidths.

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In general, the communication signalling may be based on an OFDM wave-form, for example a DFT-s-OFDM based wave-form. This may facilitated reliable communication with high capacity.

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Approaches described herein facilitate using hardware of a communication radio node for radar or sensing, with limited overhead or loss of efficiency.

Sensing signalling may generally be represented by reference signalling. Sensing signalling of different types may differ in terms of numerology and/or wave-form and/or modulation symbol sequence and/or sequence root and/or duration and/or frequency bandwidth and/or density (e.g., in time domain and/or frequency domain) and/or code and/or timing, in particular regarding periodicity) and/or beam shape or beam size.

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The communication signalling and/or sensing signalling may be based on an OFDM wave-form, e.g. OFDM and/or SC-FDM. Transmitting and/or receiving sensing signalling may be considered operating utilising sensing signalling. It may be considered that operating utilising communication signalling, and/or communicating utilising communication signalling, may comprise transmitting the communication signalling and/or receiving the communication signalling. Depending on whether the radio node is adapted for full-duplex operation or not, operating utilising sensing signalling may comprise operating in the same direction (e.g., both operations comprise or consists of transmitting, or both comprise or consist of receiving), or in different directions (for either or both operations, or between operations and/or for one operation). Thus, different use cases and types of setup (mono-static or multi-static) may be considered.

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In some cases, operating utilising sensing signalling may comprise transmitting the sensing signalling and/or receiving the sensing signalling. In general, receiving sensing signalling may comprise receiving reflections of the sensing signalling; the reflections may be shifted in time relative to the transmitting signalling (due to propagation delay); the shift in time may two symbol time intervals or less, or one symbol time interval or less, or the duration of a cyclic prefix or less. The range of the sensing signalling may be configured accordingly. In general, operating utilising sensing signalling may comprise performing sensing and/or determining the presence (or absence) of an object and/or determining one or more properties of one or more objects (sensing targets).

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It may be considered that the communication signalling is based on an OFDM wave-form, e.g. OFDM, or DFT-s-OFDM, or pulse-shaped DFT-s-OFDM. Such a wave-form is particularly suitable for wireless communication at high frequencies and/or with high communication loads. In some cases, the sensing signalling may be based on an OFDM wave-form, e.g. OFDM, or DFT-s-OFDM, or pulse-shaped DFT-s-OFDM, or an OFTS

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based wave-form. The sensing signalling wave-form may be based on the same wave-form as the communication signalling, which allows easy reuse of configurations and circuitries. In some cases, it may be based on a different wave-form, allowing flexibility, e.g. for different use cases and functionalities.

The radio node may be a wireless device or user equipment or terminal. Alternatively, it may be a network node or signalling radio node. A radio node adapted for wireless communication may be a radio node adapted for transmitting and/or receiving communication signalling, and/or for operating with signalling in conformance with a communication standard, e.g. according to a 3GPP standard, and/or adapted for communicating utilising control signalling in conformance with a standard (not necessarily data signalling). A radio node adapted for operating with signalling in conformance with a communication standard may be adapted for utilising signalling and/or waveforms according to the standard, and/or circuitry capable of producing such waveforms and/or signalling. Communication signalling may be. and/or comprise, data signalling and/or control signalling and/or reference signalling, e.g. according to a wireless communication standard like a 3GPP standard or IEEE standard. A radio node adapted for sensing operation and/or radar operation may be adapted for, and/or be configured or configurable, for transmitting and/or receiving signalling for sensing or radar functionality, in particular according to a configuration for sensing and/or processing signalling. The radio node may share circuitry like processing circuitry and/or radio circuitry and/or antenna circuitry and/or antenna elements and/or sub-arrays between communication signalling and sensing operation and/or sensing signalling. The sensing operation may be mono-static and/or multi-static. Sensing signalling may be reference signalling, and/or may be communication signalling and/or signalling dedicated for sensing. Sensing signalling may have different types of signalling, e.g. based on, or associated to use and/or object and/or sensing function (e.g., which parameters of an object are to be determined). Multiplexing communication signalling and sensing signalling in a multiplexing time interval may correspond to the communication signalling and the sensing signalling being transmitted in the multiplexing time interval, e.g. by the same node or different nodes. Operating utilising communication signalling may comprise transmitting and/or receiving communication signalling. Operating utilising sensing signalling may comprise transmitting and/or receiving sensing signalling. A radio node may be adapted for mono-static operation. In this case, it may be adapted for full-duplex operation, transmitting and receiving in fully or at least partially overlapping time intervals (e.g., corresponding to, and/or at least partially overlapping with, the multiplexing time interval), such that it may receive reflected sensing signalling it transmitted itself (due to the large speed of radio waves, the reflected sensing signalling will often be received while the radio node

still transmits sensing signalling). The radio circuitry and/or processing circuitry and/or antenna circuitry of a radio node may be adapted both for handling communication signalling and sensing signalling. The radio node may be adapted for full-duplex operation, and/or half-duplex operation. Full duplex may refer to transmitting and receiving at the same time, e.g. using the same or different circuitries, and/or using different antenna sub-arrays or separately operable antenna sub-arrays or antenna elements.

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The sensing signalling may be beam-formed. The communication signalling may be beam-formed. Different beams, in particular narrower beams, may be used for the sensing signalling than the communication signalling. In some cases, the beam shapes of sensing signalling may be different for different occurrences and/or signalling types and/or functionalities of sensing signalling. Beam-switching may be performed when switching from communication signalling to sensing signalling, and vice versa. Sensing signalling may be transmitted with a sensing beam and/or isotropically or with a default beam; it may be received with a reception beam, or with a default or isotropic reception. A sensing beam may be swept through a spatial angle, e.g. according to a sweeping scheme to perform sensing in the spatial angle.

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A DFT-s-OFDM based wave-form may be a wave-form constructed by performing a DFT-spreading operation on modulation symbols mapped to a frequency interval (e.g., sub-carriers), e.g. to provide a time-variable signal. A DFT-s-OFDM based wave-form may also be referred to a SC-FDM wave-form. It may be considered to provide good PAPR characteristics, allowing optimised operation of power amplifiers, in particular for high frequencies. In general, the approaches described herein may also be applicable to Single-Carrier based wave-forms, e.g. FDE-based wave-forms. Communication, e.g. on data channel/s and/or control channel/s, may be based on, and/o utilise, a DFT-s-OFDM based wave-form, or a Single-Carrier based wave-form.

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Communication may in particular on multiple communication links and/or beams and/or with multiple targets (e.g., TRPs or other forms of transmission sources also receiving) and/or multiple layers at the same time; different reference signalings for multiple transmission or reception may be based on different sequence roots and/or combs and/or cyclic shifts. Thus, high throughput may be achieved, with low interference. In general, different reference signalings (e.g., of the same type) may be associated to different transmission sources and/or beams and/or layers, in particular if transmitted simultaneously and/or overlapping in time (e.g., considering different timing advance values if transmitted in uplink). For example, there may be first reference signalling transmitted using a first transmission source and/or first beam and/or first layer, and second reference signalling transmitted using a first transmission source and/or first beam and/or first layer.

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There is also described a program product comprising instructions causing processing circuitry to control and/or perform a method as described herein. Moreover, a carrier medium arrangement carrying and/or storing a program product as described herein is considered. An information system comprising, and/or connected or connectable, to a radio node is also disclosed.

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Brief description of the drawings

The drawings are provided to illustrate concepts and approaches described herein, and are not intended to limit their scope. The drawings comprise:

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Figure 1, showing an exemplary radar pulse train used for sensing;

Figure 2, showing an exemplary sensing signalling scenario;

Figure 3, showing a further exemplary sensing signalling scenario;

Figure 4, showing a further exemplary sensing signalling scenario;

Figure 5, showing a further exemplary sensing signalling scenario;

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Figure 6, showing an exemplary wireless device; and

Figure 7, showing an exemplary network node.

Detailed description

Joint communication and sensing (JCAS) is emerging as one of the use cases in future wireless cellular communication such as 6G. In one approach, it may be considered using cellular communication (radio) nodes (base stations/UEs) to sense the environment by either using the communication-specific signals and/or dedicated sensing signals, and provide information such as location, shape, speed, etc. of the objects in the surrounding. Some of the possible applications of sensing using cellular communication systems are traffic monitoring and crash avoidance, gesture/motion detection, presence detection of objects or persons, vital sign detection, environment mapping, particle/pollution detection, etc. In general, joint communication and sensing may comprise and/or be based on utilising radio nodes for a communication network for sensing and/or radar operation, e.g. sharing radio circuitry and/or antennas and/or resources.

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Tighter integration of communication and sensing may be provided. By reusing existing macro infrastructure, sensing can be added at low cost. Sensing can be using both to improve network performance and to add new features such as traffic monitoring and surveillance. If the same hardware is used for radar and communication, performance

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and capacity of both systems may suffer. Radar signalling may be considered sensing signalling and vice versa in this discussion. For example, to monitor a traffic intersection, detect approaching vehicles and their speed, a large part of available resources may be used for radar operation, lowering resources available for communication. Approaches described herein facilitate efficient operation of joint communication and sensing, with limited impact of sensing operation on communication capabilities.

Sensing can be done either using a single node, i.e. the transmitter and receiver are co-located and/or associated to the same radio node (mono-static) or multiple nodes, in which case the transmitter(s) and receiver(s) may be in different locations (multi-static); in some variants of multi-static approaches, one or more nodes may have transmitter and receiver and/or may operate for transmitting and receiving. One particular challenge with the mono-static scenario in joint communications and sensing is that if the same radio node is used for simultaneous transmission and reception, then it has to be capable of full-duplex communication (the received signals will be shifted in time to the transmitted one, but usually overlap in time). This may be particularly challenging, since the received signal levels in a cellular communications may be lower than the transmitted signals by several orders of magnitude; reception of such signals may be facilitated by certain approaches or designs considered to reduce interference. In a mono-static radar setup, simultaneous transmission and reception (and thus full duplex) is unavoidable if it should be possible to detect targets close to the base stations (targets far enough away may be less challenging from this point of view since the echo (reflected signal) may arrive after the BS stopped transmitting).

A multi-static scenario may not require simultaneous transmission and reception from the same node. However, one challenge in using communication nodes in multi-static scenario is that the neighbouring nodes must be in different duplex directions (uplink and downlink, or sidelink, or transmission and reception modes), which means that different time division duplex (TDD) configurations in the two cells may be used. This is also rather challenging, since using different TDD configurations in neighbouring cells can give rise to large inter-cell interference, especially from the downlink transmission in one cell to the uplink reception in the other cell, as downlink signalling usually has significantly larger power levels than uplink signalling.

In some applications, sensing may improve network performance and/or add new features such as traffic monitoring and surveillance. If the same hardware is used for radar and communication, performance and capacity of both systems may suffer in comparison to using separated dedicated equipment for both. If, for example, a traffic intersection is monitored, to detect approaching vehicles and their speed, significant parts of the available

resources (e.g., half) may be required for radar operation.

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The available carrier or system bandwidth in 6G at high frequencies is expected to be very wide, e.g. covering one GHz or more, in particular 5GHz or more. There are several regions with ≈ 6 GHz contiguous spectra (bandwidth) available for high frequencies (above 90 GHz).

Sensing, also referred to as active sensing, may generally refer to transmitting signalling and/or receiving reflection/s of this signalling, e.g. radar signalling and/or communication signalling; Sensing may comprise and/or be based on processing received (reflected) signalling to determine one or more properties of a target object, e.g. position and/or speed (total speed, or a component thereof, e.g. to direction of the receiver) and/or shape and/or size and/or velocity (total, or a component thereof) and/or surface structure and/or reflexivity of a reflecting object, e.g. based on one or more signalling characteristics of the transmitted (radar) signalling and/or one or more signalling characteristics of the received (radar) signalling, and/or based on one or more changes and/or shifts and/or differences and/or delta (e.g., one value subtracted from another value) between one or more signalling characteristics of the transmitted signalling and/or received signalling. For a multi-static case, the receiving node may be informed about the one or more signalling characteristics, e.g. based on configuration (e.g, higher layer signalling like RRC signalling or MAC layer signalling, or F1 signalling, or X2 signalling, or physical layer signalling).

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Sensing signal processing is described in the following. In active sensing, a signal or signalling like radar signalling is transmitted to probe the environment, and the received reflections are used to estimate for example position and/or speed and/or velocity of the object/s in a range covered by the signalling. Depending on the required accuracy and range for the position and speed of the object/s, there are certain requirements on the duration, bandwidth, and periodicity of the signalling or signal to be used.

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In a typical pulse radar, a sequence of wave-forms or symbols or signals (e.g., spreading codes) with chip duration T and signal integration duration of T_{int} with periodicity T_r are transmitted for a duration T_f (there is one transmission or signalling occurrence in each T_r). The choice of these parameters determine range (sensing range, if wave-forms are identical), range resolution, velocity or speed (speed or velocity range), and speed/velocity resolution for sensing targets. L and M may represent integer numbers (of chips or symbols in a period corresponding to the periodicity, and number of transmission occurrences in T_f , respectively).

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Depending on the use case, a sensing signal design may be tailored to meet fundamental

requirements on: Range resolution (R_r) representing the minimum distinguishable distance between two objects; and/or

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(Unambiguous) range (R_u), representing the maximum distance where an object can be located for (e.g., guaranteed, and/or within a desired error range) detection; and/or

Speed or Velocity range (v_u), representing the maximum range of speed or velocity of moving object that can be measured; and/or

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Speed or Velocity resolution (v_r), representing the smallest change in the speed or velocity of the moving object that can be measured.

The parameters of a sensing signal (which in general may also be referred to as sensing signalling, or radar signal, or radar signalling) may include a bandwidth, like a minimum bandwidth, and/or a duration like a minimum duration of the sensing signal, and/or a a minimum and/or maximum repetition periodicity, and/or a minimum duration of the sensing frame (a time interval in which sensing signalling may be transmitted), may be designed such above sensing requirement/s are met. Table 1 below shows the relationship between the sensing requirements and the sensing signal parameters, with c denoting the speed of light, f_c representing the carrier frequency.

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Table 1

Required bandwidth	$BW_{min} = c/2R_r$
Minimum gap between sensing signals	$T_{rmin} = 2R_u/c$
Maximum gap between sensing signals	$T_{rmax} = c/4f_c v_u$
Required sensing frame duration	$T_f = c/2f_c v_r$

At the receiver, the reflected signal (e.g., reflected from one or more objects and/or from the surrounding) is received, and may be matched and/or filtered with the transmitted wave-form to give the delay (e.g., representing the distance of the object), and/or the phase rotation between consecutive wave forms, e.g. representing the Doppler shift due to the movement of the object. In general, the above-mentioned signal generation and receiver processing may be common to all types of sensing methods and signals, and is not limited to a pulse radar. In a joint communication and sensing scenario, the choice of wave-form may depend on what wave-form is more suitable for both communication and sensing, although this is not a requirement, and the wave-forms for the two systems may be different. The following description of receiver processing is independent of the wave-form type and is equally applicable to wave-forms, as well as any typical communication wave-form such as OFDM, DFT-s-OFDM, etc. As one example, the wave-form may comprise, and/or be based on, and/or represent, and/or be one or several OFDM or DFT-S-OFDM symbols (or even sub-symbols), and/or block symbols, as it is the common wave-form used in most of the existing wireless access links (used for wireless and/or

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cellular communication). A sensing signal may be based on OFDM symbols, in particular a train of OFDM symbols as sensing signalling; such train may be repeated a plurality of times, e.g. according to a periodicity, e.g. in one or more sensing frames. A train of symbols may represent a sequence of symbols, each of which may carry and/or represent a sequence of modulation symbols (e.g., for a OFDM based wave-form), which may be mapped to frequency domain; each symbol may carry the same or a different sequence. In some cases, a sequence may be mapped over multiple symbols, e.g. frequency first. A common receiver processing may comprise and/or be based on performing an FFT per sequence occurrence, e.g. a train of symbols, for example transforming delay domain into subcarrier (frequency) domain, and an IFFT per subcarrier across the sequence occurrences, for example transforming time-domain into Doppler domain. Then peaks, e.g. all peaks, beyond a threshold may be identified, and the delay and Doppler values associated with each peak (representing a target) may be considered corresponding to delay and velocity or speed of the target.

The communication nodes involved in sensing may be UEs, base stations, or a combination thereof, including - Base-station transmission of signal for sensing, UE reception of signal for sensing - UE transmission of signal for sensing, base-station reception of signal for sensing - Base-station transmission of signal for sensing, base-station reception of signal for sensing - UE transmission of signal for sensing, UE reception of signal for sensing

For cellular communications, such as 5G, this could mean that the sensing signal can be a DL reference signal, or a UL reference signal, a sidelink reference signal. Also the sensing signal can be any of the existing signals, such as DL positioning reference signal (PRS), CSI-RS, DM-RS; and UL sounding reference signal (SRS), a new sensing/positioning specific signal, or the communication signal itself. Combinations of these signals may also be used. Although sensing is viewed mostly as estimating channel based on known reference signals, it is possible to perform sensing based on data. In this case, either data is known at the receiver (e.g. mono-static scenario) or it has to be decoded first so that the channel can be estimated subsequently.

In active sensing, a signal is transmitted to probe the environment and the received reflections are used to estimate position/speed of the objects in the range. In a typical pulse radar, a sequence of pulses is transmitted, as shown exemplarily in Figure 1. At the receiver, the reflected signal from the surrounding is received and is matched/filtered with the transmitted waveform to give the delay (distance of the object); the phase rotation between consecutive waveforms may be determined to give the doppler shift (velocity) due to the movement of the object. In a joint communication and sensing scenario, the choice of waveform may depend on what waveform is more suitable for both communication and

sensing, although this is not a requirement, and the waveforms for the two systems can be same or different. As one example, the waveform may comprise one or several OFDM or DFTS-OFDM symbols (or even sub-symbols), as it is the common waveform used in most of the existing wireless access links and is used in the following description.

A common receiver processing comprises performing (after frequency-domain matched filtering) an IFFT per symbol occurrence (transforming subcarrier domain into delay domain), and an FFT per delay sample/peak (across symbols) (transforming time-domain into Doppler domain). Then all peaks beyond a threshold are identified and the delay and Doppler values associated with each peak (target) may be considered to correspond to delay and velocity of the target/s.

Figure 2 shows an exemplary transmitted sensing signal (a single symbol in this example), together with an echo received from a near target and a far away target. To be able to do frequency-domain processing, even the echo received from a far target should arrive within the CP. Assuming NR 30 kHz numerology, the maximum sensing distance is around 350 m, which can be very limiting.

One possibility to extend the range for sensing is to use a symbol with a longer (extended) cyclic prefix compared to a cyclic prefix used for communication; such an approach is described below. However, in some alternatives a longer symbol duration may be used, e.g., with an appendix, and/or a symbol structure not necessary including an extend CP, but a more suitable (for sensing) structure.

In most cases communication signals use normal CP (most wireless environment have a delay spread that fits into the normal CP). However, for sensing – as shown above – usage of the normal CP can be limiting. Therefore, communication may use a normal CP while the sensing signal may be based on a signal structure with extended CP. When a symbol with extended CP (for sensing) is inserted into the frame structure with normal CP (for communication) it shifts the time grid (symbol boundaries) for all subsequent symbols, as shown in Figure 3. All receivers receiving symbols after such a symbol has been inserted should be aware of, and/or adapt to this shift to keep synchronisation.

To avoid that all receivers (in principle for the remaining duration of the communication session) need to be aware of the time shift (which would require signalling overhead) resulting from the transmission of a sensing symbol with extended CP, it may be considered:

- A sensing transmission (and/or sensing signalling) may always consist of M symbols (in time domain) such that the duration of the M sensing symbols (with extended CP) match the duration of N symbols with normal CP (N, M being integers larger

than 1 (or in some cases $M=1$)); and/or

- Symbols in some time-surrounding (preceding and/or following the sensing symbol/s) of sensing symbol(s) (with extended CP) are also transmitted with extended CP such that duration of sensing symbol(s) and the symbols in the time-surrounding match the duration of N symbols with normal CP; thus, sensing signalling may in total comprise M symbols, of which M_1 may be for sensing, M_2 may be for communication, M_3 may be guarding symbols and/or carry reference signalling.

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Accordingly, a time shift may be limited to a localised time interval (using above terminology, to a duration of N symbols with normal CP). Following this time interval, symbol boundaries are aligned again and receivers receiving symbols after this time interval don't need to know about the shift. It may be considered that during the time interval, no transmission occurs only to intended receivers of sensing signalling, e.g., multiplexed sensing signalling with communication signalling. The receivers may operate on an indication of the time shift, e.g., implicitly by being scheduled for reception of sensing signalling.

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The impact of a symbol boundary shift that is introduced by a sensing symbol with extended CP may be limited to a short time interval. Outside this time interval, symbol boundaries are aligned, and a receiver receiving symbols after this time interval does not need to know the shift in symbol boundaries. This simplifies signaling.

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A sensing signal (sensing signalling, or one occurrence thereof) may consist of, and/or comprise, and/or be represented by, multiple symbols (M) (with extended CP) such that its duration fits the duration of an integer number (N) of symbols with normal CP, see Figure 4 (Note: The shown sensing signal corresponds to one pulse as shown in Figure 1). As an example, using NR numerologies, $M=6$ and $N=7$.

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In Figure 4, other signals (e.g. communication signals) using different subcarriers may also use symbols with extended CP during the duration when the sensing signal is transmitted. Signals transmitted on different subcarriers than the sensing signal (potentially with a small guard band between) could also use symbols with normal CP. While in principle even signals transmitted on overlapping subcarriers, but different spatial layers, could use symbols with normal CP, it may be considered that such signals also use extended CP since this may simplify receiver processing.

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Receivers receiving symbols with extended CP may be informed and/or aware when symbols with extended CP are transmitted. As can be seen from Figure 4, the deviation in symbol boundaries (from the symbol grid with normal CP) may be limited to n symbol durations with normal CP.

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Sensing symbol(s) plus symbol(s) in local time-surrounding (all with extended CP) may match the duration of integer number of symbols with normal CP.

A sensing signal consisting of multiple symbols (or a very long single symbol with extended CP) may be used, (e.g., stretching the total duration to n symbols with normal CP). However, shorter sensing signalling may be useful in some scenarios. It may be considered transmittin a sensing signal (sensing signalling) consisting of, and/or comprising, and/or being represented by, one or more symbols, e.g. as needed, in particular according to a use case. Preceding and/or following the sensing signalling there may be one or more other signals (also with extended CP), e.g., communiatio signalling and/or reference signalling, such that the total duration of symbols with extended CP (sensing signal and other signals, other signal 2 and 3 in Figure 5) matches the total duration of an integer number of symbols with normal CP, see Figure 5 (Note: The shown sensing signal corresponds to one pulse in Figure 1).

It may be considered that wireless devices or UEs that are expected to be scheduled with extended CP (either because they are sensing UEs, or should be able to transmit/receive data close to transmissions (to others) with extended CP) may be configured with this feature, e.g. via RRC. Such a configuration could then configure a field in the DCI indicating if a transmission uses normal or extended CP. If a transmission can extend over time periods with normal and extended CP, the configuration together with DCI may provide this information as well. For example, a time grid could be configured at which CP lengths may be switched. The DCI field can then indicate normal/extended CP for each time interval, either by a bitmap indicating CP length for each overlapped time interval (up to a max scheduling length) or a shorter bitfield indicating after which time interval the CP is switched together with first used CP length. Other control signalling than a DCI may be used, e.g. higher layer signalling, for example using MAC signalling or RRC signalling. length used.

Communication may be based on (DFTS-)OFDM; OFDM based radar may be used to allow re-use of as much hardware as possible.

Figure 6 schematically shows a radio node, in particular a wireless device or terminal or a UE (User Equipment). Radio node 10 comprises processing circuitry (which may also be referred to as control circuitry) 20, which may comprise a controller connected to a memory. Any module of the radio node 10, e.g. a communicating module or determining module, may be implemented in and/or executable by, the processing circuitry 20, in particular as module in the controller. Radio node 10 also comprises radio circuitry 22 providing receiving and transmitting or transceiving functionality (e.g., one or more transmitters and/or receivers and/or transceivers), the radio circuitry 22 being connected

or connectable to the processing circuitry. An antenna circuitry 24 of the radio node 10 is connected or connectable to the radio circuitry 22 to collect or send and/or amplify signals. Radio circuitry 22 and the processing circuitry 20 controlling it are configured for cellular communication with a network, e.g. a RAN as described herein, and/or for sidelink communication (which may be within coverage of the cellular network, or out of coverage; and/or may be considered non-cellular communication and/or be associated to a non-cellular wireless communication network). Radio node 10 may generally be adapted to carry out any of the methods of operating a radio node like terminal or UE disclosed herein; in particular, it may comprise corresponding circuitry, e.g. processing circuitry, and/or modules, e.g. software modules. It may be considered that the radio node 10 comprises, and/or is connected or connectable, to a power supply. A DFE may be considered part of radio circuitry; an analog frontend may be associated to radio circuitry and/or antenna circuitry.

Figure 7 schematically shows a radio node 100, which may in particular be implemented as a network node 100, for example an eNB or gNB or similar for NR. Radio node 100 comprises processing circuitry (which may also be referred to as control circuitry) 120, which may comprise a controller connected to a memory. Any module, e.g. transmitting module and/or receiving module and/or configuring module of the node 100 may be implemented in and/or executable by the processing circuitry 120. The processing circuitry 120 is connected to control radio circuitry 122 of the node 100, which provides receiver and transmitter and/or transceiver functionality (e.g., comprising one or more transmitters and/or receivers and/or transceivers). An antenna circuitry 124 may be connected or connectable to radio circuitry 122 for signal reception or transmittance and/or amplification. Node 100 may be adapted to carry out any of the methods for operating a radio node or network node disclosed herein; in particular, it may comprise corresponding circuitry, e.g. processing circuitry, and/or modules. The antenna circuitry 124 may be connected to and/or comprise an antenna array. The node 100, respectively its circuitry, may be adapted to perform any of the methods of operating a network node or a radio node as described herein; in particular, it may comprise corresponding circuitry, e.g. processing circuitry, and/or modules. The radio node 100 may generally comprise communication circuitry, e.g. for communication with another network node, like a radio node, and/or with a core network and/or an internet or local net, in particular with an information system, which may provide information and/or data to be transmitted to a user equipment. A DFE may be considered part of radio circuitry; an analog frontend may be associated to radio circuitry and/or antenna circuitry.

In general, the wireless device and/or network node may operate in, and/or the communication signalling may be in TDD operation. It should be noted that the transmission

of signalling from transmission sources may be synchronised and simultaneous; a shift in time may occur due to different propagation times, e.g. due to different beams and/or source locations.

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A data block may refer to a transport block, or a code block or a code block bundle. A code block may comprise and/or represent a number of (information) bits representing information (e.g., data or control information), to which there may be associated, and/or which may further include, bits for error detection coding, e.g. CRC. The bits for error detection coding may be determined based on the (information) bits, and/or may be error detection bits for the (information) bits. A code block bundle may comprise one or more code blocks; wherein each code block may have associated to it, and/or comprise, error correction bits. The error correction bits in a code block bundle may each pertain to an associated code block; error correction bits may be specific to only one code block, e.g. determined based on bits of only one code block. Different bits and/or groups of bits may be associated to different code blocks. Error correction bit/s associated to a code block may be associated to a single code block; this may refer to the error correction bits indicating correctness/incorrectness of the single code block, and/or calculated and/or determined based only on (information) bits of the single code block. Information bits may represent data and/or control information, e.g. associated to a data channel (data information/bits) and/or control channel (control information/bits) code block bundle may be a data block without error correction coding pertaining to more than one code block. A transport block may comprise error detection coding pertaining to a plurality of code blocks, e.g. covering the code blocks it consists of. A transport block may comprise one or more code blocks. It may be considered that a data block may be associated to, and or subject to, and/or correspond to, a, one and/or a single acknowledgement process, e.g. a specific HARQ process, which may correspond to and/or be represented by a HARQ identifier. A code block may correspond to a subpattern of an acknowledgement information bit pattern. In some cases, a data block may correspond and/or pertain and/or be subject to a plurality of acknowledgement processes, e.g. if there is one acknowledgement process per code block of the data block.

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A data block may comprise and/or represent information bits, which may be data bits (e.g., user data) and/or control information bits; the information bits may be associated to one or more data or control channels, e.g. transport channels and/or logical channels, and/or may be mapped to a specific and/or single physical channel, in particular a physical data channel, or in some cases, a physical control channel (in which case it may or may not be associated to a higher layer channel like a transport channel or logical channel). A data block may represent bits intended for transmission, e.g. encapsulating one or more higher layer data packets, e.g. one or more MAC layer data packets, e.g. one or more

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PDU (Protocol Data Unit) and/or SDUs (Service Data Unit); error correction bits, e.g. CRC; may be added in physical layer processing. It may be considered that bits of a data block are subject to physical layer processing like coding (e.g., forward error coding and/or adding error correction coding) and/or rate matching and/or scrambling, and/or modulation. Modulation may correspond to mapping of bits of the processed data block to modulation symbols, e.g. according to a modulation scheme and/or to a modulation space. The modulation symbols may be represented as a bit sequence until they are subject to analog conversion (or vice versa for reception). 820

A wireless device may in general comprise processing circuitry and/or radio circuitry, in particular a receiver and/or transceiver and/or transmitter, for performing measurement and/or to control beam switch and/or control beam-forming and/or receive and/or transmit signalling like communication signalling and/or sensing signalling. The wireless device may in particular be implemented as terminal or a user equipment. However, in some cases, e.g. relay and/or back-link and/or IAB scenarios, it may be implemented as network node or network radio node. A network node may in general comprise processing circuitry and/or radio circuitry, in particular a receiver and/or transceiver and/or transmitter, for transmitting reference signalling and/or a beam switch indication and/or for beam switching and/or to control beam switch and/or control beam-forming and/or receive and/or transmit signalling like communication signalling and/or sensing signalling.. 825 830 835

The second radio node may in particular be implemented as a network node, e.g. a network radio node and/or base station or a relay node or IAB node. However, in some cases, e.g. sidelink scenarios, the second radio node may be implemented as a wireless device or terminal, e.g. a user equipment.

In general, sensing signalling may be based on the same wave-form as the communication signalling. However, it may be based on a different wave-form in some variants. The sensing signalling may be OFDM based, for example, regular OFDM, or spread OFDM like DFT-s-OFDM, and/or pulse-shaped OFDM, or filter-bank based, or Single Carrier based. The communication signalling may be OFDM based, for example, regular OFDM, or spread OFDM like DFT-s-OFDM, and/or pulse-shaped OFDM, or filter-bank based, or Single Carrier based. The sensing signalling may be transmitted in a transmission timing structure corresponding to the transmission timing structure associated to the communication signalling, e.g. a frame structure, and/or be based on the same or a different numerology as the communication signalling. The timing structure (e.g., symbol duration or allocation unit duration) and/or types of modulation symbols carried by signalling may be based on the wave-form used. 840 845 850

In general, a block symbol may represent and/or correspond to an extension in time

domain, e.g. a time interval. A block symbol duration (the length of the time interval) may correspond to the duration of an OFDM symbol or a corresponding duration, and/or may be based and/or defined by a subcarrier spacing used (e.g., based on the numerology) or equivalent, and/or may correspond to the duration of a modulation symbol (e.g., for OFDM or similar frequency domain multiplexed types of signalling). It may be considered that a block symbol comprises a plurality of modulation symbols, e.g. based on a subcarrier spacing and/or numerology or equivalent, in particular for time domain multiplexed types (on the symbol level for a single transmitter) of signalling like single-carrier based signalling, e.g. SC-FDE or SC-FDMA (in particular, FDF-SC-FDMA or pulse-shaped SC-FDMA). The number of symbols may be based on and/or defined by the number of subcarrier to be DFTS-spread (for SC-FDMA) and/or be based on a number of FFT samples, e.g. for spreading and/or mapping, and/or equivalent, and/or may be predefined and/or configured or configurable. A block symbol in this context may comprise and/or contain a plurality of individual modulation symbols, which may be for example 1000 or more, or 3000 or more, or 3300 or more. The number of modulation symbols in a block symbol may be based and/or be dependent on a bandwidth scheduled for transmission of signalling in the block symbol. A block symbol and/or a number of block symbols (an integer smaller than 20, e.g. equal to or smaller than 14 or 7 or 4 or 2 or a flexible number) may be a unit (e.g., allocation unit) used for scheduling and/or allocation of resources, in particular in time domain. To a block symbol (e.g., scheduled or allocated) and/or block symbol group and/or allocation unit, there may be associated a frequency range and/or frequency domain allocation and/or bandwidth allocated for transmission.

An allocation unit, and/or a block symbol, may be associated to a specific (e.g., physical) channel and/or specific type of signalling, for example reference signalling. In some cases, there may be a block symbol associated to a channel that also is associated to a form of reference signalling and/or pilot signalling and/or tracking signalling associated to the channel, for example for timing purposes and/or decoding purposes (such signalling may comprise a low number of modulation symbols and/or resource elements of a block symbol, e.g. less than 10% or less than 5% or less than 1% of the modulation symbols and/or resource elements in a block symbol). To a block symbol, there may be associated resource elements; a resource element may be represented in time/frequency domain, e.g. by the smallest frequency unit carrying or mapped to (e.g., a subcarrier) in frequency domain and the duration of a modulation symbol in time domain. A block symbol may comprise, and/or to a block symbol may be associated, a structure allowing and/or comprising a number of modulation symbols, and/or association to one or more channels (and/or the structure may dependent on the channel the block symbol is associated to and/or is allocated or used for), and/or reference signalling (e.g., as discussed above), and/or

one or more guard periods and/or transient periods, and/or one or more affixes (e.g., 890
a prefix and/or suffix and/or one or more infixes (entered inside the block symbol)),
in particular a cyclic prefix and/or suffix and/or infix. A cyclic affix may represent
a repetition of signalling and/or modulation symbol/s used in the block symbol, with
possible slight amendments to the signalling structure of the affix to provide a smooth
and/or continuous and/or differentiable connection between affix signalling and signalling 895
of modulation symbols associated to the content of the block symbol (e.g., channel and/or
reference signalling structure). In some cases, in particular some OFDM-based wave-
forms, an affix may be included into a modulation symbol. In other cases, e.g. some
single carrier-based wave-forms, an affix may be represented by a sequence of modulation
symbols within the block symbol. It may be considered that in some cases a block symbol 900
is defined and/or used in the context of the associated structure.

Communicating may comprise transmitting or receiving. It may be considered that com-
municating like transmitting signalling is based on a SC-FDM based wave-form, and/or
corresponds to a Frequency Domain Filtered (FDF) DFTS-OFDM wave-form. However,
the approaches may be applied to a Single Carrier based wave-form, e.g. a SC-FDM or 905
SC-FDE-wave-form, which may be pulse-shaped/FDF-based. It should be noted that SC-
FDM may be considered DFT-spread OFDM, such that SC-FDM and DFTS-OFDM may
be used interchangeably. Alternatively, or additionally, the signalling (e.g., first signalling
and/or second signalling) and/or beam/s (in particular, the first received beam and/or
second received beam) may be based on a wave-form with CP or comparable guard time. 910
The received beam and the transmission beam of the first beam pair may have the same
(or similar) or different angular and/or spatial extensions; the received beam and the
transmission beam of the second beam pair may have the same (or similar) or different
angular and/or spatial extensions. It may be considered that the received beam and/or
transmission beam of the first and/or second beam pair have angular extension of 20 de- 915
grees or less, or 15 degrees or less, or 10 or 5 degrees or less, at least in one of horizontal or
vertical direction, or both; different beams may have different angular extensions. An ex-
tended guard interval or switching protection interval may have a duration corresponding
to essentially or at least N CP (cyclic prefix) durations or equivalent duration, wherein
N may be 2, or 3 or 4. An equivalent to a CP duration may represent the CP duration 920
associated to signalling with CP (e.g., SC-FDM-based or OFDM-based) for a wave-form
without CP with the same or similar symbol time duration as the signalling with CP.
Pulse-shaping (and/or performing FDF for) a modulation symbol and/or signalling, e.g.
associated to a first subcarrier or bandwidth, may comprise mapping the modulation
symbol (and/or the sample associated to it after FFT) to an associated second subcar- 925
rier or part of the bandwidth, and/or applying a shaping operation regarding the power

and/or amplitude and/or phase of the modulation symbol on the first subcarrier and the second subcarrier, wherein the shaping operation may be according to a shaping function. Pulse-shaping signalling may comprise pulse-shaping one or more symbols; pulse-shaped signalling may in general comprise at least one pulse-shaped symbol. Pulse-shaping may be performed based on a Nyquist-filter. It may be considered that pulse-shaping is performed based on periodically extending a frequency distribution of modulation symbols (and/or associated samples after FFT) over a first number of subcarrier to a larger, second number of subcarriers, wherein a subset of the first number of subcarriers from one end of the frequency distribution is appended at the other end of the first number of subcarriers.

In some variants, communicating may be based on a numerology (which may, e.g., be represented by and/or correspond to and/or indicate a subcarrier spacing and/or symbol time length) and/or an SC-FDM based wave-form (including a FDF-DFTS-FDM based wave-form) or a single-carrier based wave-form. Whether to use pulse-shaping or FDF on a SC-FDM or SC-based wave-form may depend on the modulation scheme (e.g., MCS) used. Such wave-forms may utilise a cyclic prefix and/or benefit particularly from the described approaches. Communicating may comprise and/or be based on beamforming, e.g. transmission beamforming and/or reception beamforming, respectively. It may be considered that a beam is produced by performing analog beamforming to provide the beam, e.g. a beam corresponding to a reference beam. Thus, signalling may be adapted, e.g. based on movement of the communication partner. A beam may for example be produced by performing analog beamforming to provide a beam corresponding to a reference beam. This allows efficient postprocessing of a digitally formed beam, without requiring changes to a digital beamforming chain and/or without requiring changes to a standard defining beam forming precoders. In general, a beam may be produced by hybrid beamforming, and/or by digital beamforming, e.g. based on a precoder. This facilitates easy processing of beams, and/or limits the number of power amplifiers/ADC/DCA required for antenna arrangements. It may be considered that a beam is produced by hybrid beamforming, e.g. by analog beamforming performed on a beam representation or beam formed based on digital beamforming. Monitoring and/or performing cell search may be based on reception beamforming, e.g. analog or digital or hybrid reception beamforming. The numerology may determine the length of a symbol time interval and/or the duration of a cyclic prefix. The approaches described herein are particularly suitable to SC-FDM, to ensure orthogonality, in particular subcarrier orthogonality, in corresponding systems, but may be used for other wave-forms. Communicating may comprise utilising a wave-form with cyclic prefix. The cyclic prefix may be based on a numerology, and may help keeping signalling orthogonal. Communicating may comprise, and/or be based on performing cell search, e.g. for a wireless device or terminal, or may comprise transmitting

cell identifying signalling and/or a selection indication, based on which a radio node receiving the selection indication may select a signalling bandwidth from a set of signalling bandwidths for performing cell search.

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A beam or beam pair may in general be targeted at one radio node, or a group of radio nodes and/or an area including one or more radio nodes. In many cases, a beam or beam pair may be receiver-specific (e.g., UE-specific), such that only one radio node is served per beam/beam pair. A beam pair switch or switch of received beam (e.g., by using a different reception beam) and/or transmission beam may be performed at a border of a transmission timing structure, e.g. a slot border, or within a slot, for example between symbols. Some tuning of radio circuitry, e.g. for receiving and/or transmitting, may be performed. Beam pair switching may comprise switching from a second received beam to a first received beam, and/or from a second transmission beam to a first transmission beam. Switching may comprise inserting a guard period to cover retuning time; however, circuitry may be adapted to switch sufficiently quickly to essentially be instantaneous; this may in particular be the case when digital reception beamforming is used to switch reception beams for switching received beams.

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A reference beam (or reference signalling beam) may be a beam comprising reference signalling, based on which for example a set of beam signalling characteristics may be determined, e.g. measured and/or estimated. A signalling beam may comprise signalling like control signalling and/or data signalling and/or reference signalling. A reference beam may be transmitted by a source or transmitting radio node, in which case one or more beam signalling characteristics may be reported to it from a receiver, e.g. a wireless device. However, in some cases it may be received by the radio node from another radio node or wireless device. In this case, one or more beam signalling characteristics may be determined by the radio node. A signalling beam may be a transmission beam, or a reception beam. A set of signalling characteristics may comprise a plurality of subsets of beam signalling characteristics, each subset pertaining to a different reference beam. Thus, a reference beam may be associated to different beam signalling characteristics.

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A beam signalling characteristic, respectively a set of such characteristics, may represent and/or indicate a signal strength and/or signal quality of a beam and/or a delay characteristic and/or be associated with received and/or measured signalling carried on a beam. Beam signalling characteristics and/or delay characteristics may in particular pertain to, and/or indicate, a number and/or list and/or order of beams with best (e.g., lowest mean delay and/or lowest spread/range) timing or delay spread, and/or of strongest and/or best quality beams, e.g. with associated delay spread. A beam signalling characteristic may be based on measurement/s performed on reference signalling carried on the refer-

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ence beam it pertains to. The measurement/s may be performed by the radio node, or 1000
 another node or wireless device. The use of reference signalling allows improved accuracy
 and/or gauging of the measurements. In some cases, a beam and/or beam pair may be
 represented by a beam identity indication, e.g. a beam or beam pair number. Such an in-
 dication may be represented by one or more signalling sequences (e.g., a specific reference 1005
 signalling sequences or sequences), which may be transmitted on the beam and/or beam
 pair, and/or a signalling characteristic and/or a resource/s used (e.g., time/frequency
 and/or code) and/or a specific RNTI (e.g., used for scrambling a CRC for some messages
 or transmissions) and/or by information provided in signalling, e.g. control signalling
 and/or system signalling, on the beam and/or beam pair, e.g. encoded and/or provided
 in an information field or as information element in some form of message of signalling, 1010
 e.g. DCI and/or MAC and/or RRC signalling.

A reference beam may in general be one of a set of reference beams, the second set of
 reference beams being associated to the set of signalling beams. The sets being associated
 may refer to at least one beam of the first set being associated and/or corresponding to the 1015
 second set (or vice versa), e.g. being based on it, for example by having the same analog
 or digital beamforming parameters and/or precoder and/or the same shape before analog
 beamforming, and/or being a modified form thereof, e.g. by performing additional analog
 beamforming. The set of signalling beams may be referred to as a first set of beams, a
 set of corresponding reference beams may be referred to as second set of beams.

In some variants, a reference beam and/or reference beams and/or reference signalling may 1020
 correspond to and/or carry random access signalling, e.g. a random access preamble. Such
 a reference beam or signalling may be transmitted by another radio node. The signalling
 may indicate which beam is used for transmitting. Alternatively, the reference beams may
 be beams receiving the random access signalling. Random access signalling may be used
 for initial connection to the radio node and/or a cell provided by the radio node, and/or for 1025
 reconnection. Utilising random access signalling facilitates quick and early beam selection.
 The random access signalling may be on a random access channel, e.g. based on broadcast
 information provided by the radio node (the radio node performing the beam selection),
 e.g. with synchronisation signalling (e.g., SSB block and/or associated thereto). The
 reference signalling may correspond to synchronisation signalling, e.g. transmitted by the 1030
 radio node in a plurality of beams. The characteristics may be reported on by a node
 receiving the synchronisation signalling, e.g. in a random access process, e.g. a msg3
 for contention resolution, which may be transmitted on a physical uplink shared channel
 based on a resource allocation provided by the radio node.

A delay characteristic (which may correspond to delay spread information) and/or a 1035

measurement report may represent and/or indicate at least one of mean delay, and/or delay spread, and/or delay distribution, and/or delay spread distribution, and/or delay spread range, and/or relative delay spread, and/or energy (or power) distribution, and/or impulse response to received signalling, and/or the power delay profile of the received signals, and/or power delay profile related parameters of the received signal. A mean delay may represent the mean value and/or an averaged value of the delay spread, which may be weighted or unweighted. A distribution may be distribution over time/delay, e.g. of received power and/or energy of a signal. A range may indicate an interval of the delay spread distribution over time/delay, which may cover a predetermined percentage of the delay spread respective received energy or power, e.g. 50% or more, 75% or more, 90% or more, or 100%. A relative delay spread may indicate a relation to a threshold delay, e.g. of the mean delay, and/or a shift relative to an expected and/or configured timing, e.g. a timing at which the signalling would have been expected based on the scheduling, and/or a relation to a cyclic prefix duration (which may be considered on form of a threshold). Energy distribution or power distribution may pertain to the energy or power received over the time interval of the delay spread. A power delay profile may pertain to representations of the received signals, or the received signals energy/power, across time/delay. Power delay profile related parameters may pertain to metrics computed from the power delay profile. Different values and forms of delay spread information and/or report may be used, allowing a wide range of capabilities. The kind of information represented by a measurement report may be predefined, or be configured or configurable, e.g. with a measurement configuration and/or reference signalling configuration, in particular with higher layer signalling like RRC or MAC signalling and/or physical layer signalling like DCI signalling.

In general, different beam pair may differ in at least one beam; for example, a beam pair using a first received beam and a first transmission beam may be considered to be different from a second beam pair using the first received beam and a second transmission beam. A transmission beam using no precoding and/or beamforming, for example using the natural antenna profile, may be considered as a special form of transmission beam of a transmission beam pair. A beam may be indicated to a radio node by a transmitter with a beam indication and/or a configuration, which for example may indicate beam parameters and/or time/frequency resources associated to the beam and/or a transmission mode and/or antenna profile and/or antenna port and/or precoder associated to the beam. Different beams may be provided with different content, for example different received beams may carry different signalling; however, there may be considered cases in which different beams carry the same signalling, for example the same data signalling and/or reference signalling. The beams may be transmitted by the same node and/or

transmission point and/or antenna arrangement, or by different nodes and/or transmission points and/or antenna arrangements.

Communicating utilising a beam pair or a beam may comprise receiving signalling on a received beam (which may be a beam of a beam pair), and/or transmitting signalling on a beam, e.g. a beam of a beam pair. The following terms are to be interpreted from the point of view of the referred radio node: a received beam may be a beam carrying signalling received by the radio node (for reception, the radio node may use a reception beam, e.g. directed to the received beam, or be non-beamformed). A transmission beam may be a beam used by the radio node to transmit signalling. A beam pair may consist of a received beam and a transmission beam. The transmission beam and the received beam of a beam pair may be associated to each and/or correspond to each other, e.g. such that signalling on the received beam and signalling on a transmission beam travel essentially the same path (but in opposite directions), e.g. at least in a stationary or almost stationary condition. It should be noted that the terms “first” and “second” do not necessarily denote an order in time; a second signalling may be received and/or transmitted before, or in some cases simultaneous to, first signalling, or vice versa. The received beam and transmission beam of a beam pair may be on the same carrier or frequency range or bandwidth part, e.g. in a TDD operation; however, variants with FDD may be considered as well. Different beam pairs may operate on the same frequency ranges or carriers or bandwidth parts (e.g., such that transmission beams operate on the same frequency range or carriers or bandwidth part, and received beams on the same frequency range or carriers or bandwidth part (the transmission beam and received beams may be on the same or different ranges or carriers or BWPs). Communicating utilizing a first beam pair and/or first beam may be based on, and/or comprise, switching from the second beam pair or second beam to the first beam pair or first beam for communicating. The switching may be controlled by the network, for example a network node (which may be the source or transmitter of the received beam of the first beam pair and/or second beam pair, or be associated thereto, for example associated transmission points or nodes in dual connectivity). Such controlling may comprise transmitting control signalling, e.g. physical layer signalling and/or higher layer signalling. In some cases, the switching may be performed by the radio node without additional control signalling, for example based on measurements on signal quality and/or signal strength of beam pairs (e.g., of first and second received beams), in particular the first beam pair and/or the second beam pair. For example, it may be switched to the first beam pair (or first beam) if the signal quality or signal strength measured on the second beam pair (or second beam) is considered to be insufficient, and/or worse than corresponding measurements on the first beam pair indicate. Measurements performed on a beam pair (or beam) may in particular comprise

measurements performed on a received beam of the beam pair. It may be considered that the timing indication may be determined before switching from the second beam pair to the first beam pair for communicating. Thus, the synchronization may be in place and/or the timing indication may be available for synchronising) when starting communication utilizing the first beam pair or first beam. However, in some cases the timing indication may be determined after switching to the first beam pair or first beam. This may be in particular useful if first signalling is expected to be received after the switching only, for example based on a periodicity or scheduled timing of suitable reference signalling on the first beam pair, e.g. first received beam. In general, a reception beam of a node may be associated to and/or correspond to a transmission beam of the node, e.g. such that the (spatial) angle of reception of the reception beam and the (spatial) angle of transmission of the transmission beam at least partially, or essentially or fully, overlap and/or coincide, in particular for TDD operation and/or independent of frequency. Spatial correspondence between beams may be considered in some cases, e.g. such that a beam pair (e.g., transmission beam of a transmitting node and reception beam of a receiving node) may be considered to comprise corresponding beams (e.g., the reception beam is suitable and/or the best beam to receive transmissions on the transmission beam, e.g. based on a threshold signal quality and/or signal strength and/or measurements); to each of such beams, there may be an associated or corresponding complementary beam of the respective node (e.g., to a transmission beam of a beam pair, there may be associated a reception beam of the transmitting node, and/or to the reception beam of a beam pair, there may be associated a transmitting beam of the receiving node; if the beams (e.g., at least essentially or substantially) overlap (e.g., in spatial angle), in some cases a beam pair may be considered to indicate four beams (or actually, two beam pairs).

In some cases, to one or more beams or signals or signalings may be associated a Quasi-CoLocation (QCL) characteristic or set of characteristics, or QCL class (also referred to as QCL type) or QCL identity; beams or signal or signalings sharing such may be considered to be Quasi-Colocated. Quasi-Colocated beams or signals or signalings may be considered (e.g., by a receiver) as the same beam or originating from the same transmitter or transmission source, at least in regard to the QCL characteristic or set or class or identity, and/or to share the characteristic/s. QCL characteristics may pertain to propagation of signalling, and/or one or more delay characteristics, and/or pathloss, and/or signal quality, and/or signal strength, and/or beam direction, and/or beam shape (in particular, angle or area, e.g. area of coverage), and/or Doppler shift, and/or Doppler spread, and/or delay spread, and/or time synchronisation, and/or frequency synchronisation, and/or one or more other parameters, e.g. pertaining to a propagation channel and/or spatial RX parameter/s (which may refer to reception beam and/or transmission

beam, e.g. shape or coverage or direction). A QCL characteristic may pertain to a specific channel (e.g., physical layer channel like a control channel or data channel) and/or reference signalling type and/or antenna port. Different QCL classes or types may pertain to different QCL characteristics or sets of characteristics; a QCL class may define and/or pertain to one or more criteria and/or thresholds and/or ranges for one or more QCL characteristics beams have to fulfill to be considered Quasi-Colocated according to this class; a QCL identity may refer to and/or represent all beams being quasi-colocated, according to a QCL class. Different classes may pertain to one or more of the same characteristics (e.g., different classes may have different criteria and/or thresholds and/or ranges for one or more characteristics) and/or to different characteristics. A QCL indication may be seen as a form of beam indication, e.g. pertaining to all beams belonging to one QCL class and/or QCL identity and/or quasi-colocated beams. A QCL identity may be indicated by a QCL indication. In some cases, a beam, and/or a beam indication, may be considered to refer and/or represent a to a QCL identity, and/or to represent quasi-colocated beams or signals or signalings.

Transmission on multiple layers (multi-layer transmission) may refer to transmission of communication signalling and/or reference signalling simultaneously in one or more beams and/or using a plurality of transmission sources, e.g. controlled by one network node or one wireless device. The layers may refer to layers of transmission; a layer may be considered to represent one data or signalling stream. Different layers may carry different data and/or data streams, e.g., to increase data throughput. In some cases, the same data or data stream may be transported on different layers, e.g. to increase reliability. Multi-layer transmission may provide diversity, e.g. transmission diversity and/or spatial diversity. It may be considered that multi-layer transmission comprises 2, or more than 2 layers; the number of layers of transmission may be represented by a rank or rank indication.

A transmission source may in particular comprise, and/or be represented by, and/or associated to, an antenna or group of antenna elements or antenna sub-array or antenna array or transmission point or TRP or TP (Transmission Point) or access point. In some cases, a transmission source may be represented or representable, and/or correspond to, and/or associated to, an antenna port or layer of transmission, e.g. for multi-layer transmission. Different transmission sources may in particular comprise different and/or separately controllable antenna element/s or (sub-)arrays and/or be associated to different antenna ports. In particular, analog beamforming may be used, with separate analog control of the different transmission sources. An antenna port may indicate a transmission source, and/or a one or more transmission parameter, in particular of reference signalling associated to the antenna port. In particular, transmission parameters pertaining to,

and/or indicating a frequency domain distribution or mapping (e.g., which comb to use and/or which subcarrier or frequency offset to use, or similar) of modulation symbols of the reference signalling, and/or to which cyclic shift to use (e.g., to shift elements of a modulation symbol sequence, or a root sequence, or a sequence based on or derived from the root sequence) and/or to which cover code to use (e.g., (e.g., to shift elements of a modulation symbol sequence, or a root sequence, or a sequence based on or derived from the root sequence)). In some cases, a transmission source may represent a target for reception, e.g. if it is implemented as a TRP or AP (Access Point).

In some variants, reference signalling may be and/or comprise CSI-RS and/or PT-RS and/or DMRS, e.g. transmitted by the network node. In other variants, the reference signalling may be transmitted by a UE, e.g. to a network node or other UE, in which case it may comprise and/or be Sounding Reference signalling. Other, e.g. new, forms of reference signalling may be considered and/or used. In general, a modulation symbol of reference signalling respectively a resource element carrying it may be associated to a cyclic prefix.

Data signalling may be on a data channel, for example on a PDSCH or PSSCH, or on a dedicated data channel, e.g. for low latency and/or high reliability, e.g. a URLLC channel. Control signalling may be on a control channel, for example on a common control channel or a PDCCH or PSCCH, and/or comprise one or more DCI messages or SCI messages. Reference signalling may be associated to control signalling and/or data signalling, e.g. DM-RS and/or PT-RS.

Reference signalling, for example, may comprise DM-RS and/or pilot signalling and/or discovery signalling and/or synchronisation signalling and/or sounding signalling and/or phase tracking signalling and/or cell-specific reference signalling and/or user-specific signalling, in particular CSI-RS. Reference signalling in general may be signalling with one or more signalling characteristics, in particular transmission power and/or sequence of modulation symbols and/or resource distribution and/or phase distribution known to the receiver. Thus, the receiver can use the reference signalling as a reference and/or for training and/or for compensation. The receiver can be informed about the reference signalling by the transmitter, e.g. being configured and/or signalling with control signalling, in particular physical layer signalling and/or higher layer signalling (e.g., DCI and/or RRC signalling), and/or may determine the corresponding information itself, e.g. a network node configuring a UE to transmit reference signalling. Reference signalling may be signalling comprising one or more reference symbols and/or structures. Reference signalling may be adapted for gauging and/or estimating and/or representing transmission conditions, e.g. channel conditions and/or transmission path conditions and/or channel (or signal or

transmission) quality. It may be considered that the transmission characteristics (e.g., 1220
 signal strength and/or form and/or modulation and/or timing) of reference signalling are
 available for both transmitter and receiver of the signalling (e.g., due to being prede-
 fined and/or configured or configurable and/or being communicated). Different types of
 reference signalling may be considered, e.g. pertaining to uplink, downlink or sidelink,
 cell-specific (in particular, cell-wide, e.g., CRS) or device or user specific (addressed to 1225
 a specific target or user equipment, e.g., CSI-RS), demodulation-related (e.g., DMRS)
 and/or signal strength related, e.g. power-related or energy-related or amplitude-related
 (e.g., SRS or pilot signalling) and/or phase-related, etc.

References to specific resource structures like an allocation unit and/or block symbol
 and/or block symbol group and/or transmission timing structure and/or symbol and/or 1230
 slot and/or mini-slot and/or subcarrier and/or carrier may pertain to a specific numerol-
 ogy, which may be predefined and/or configured or configurable. A transmission timing
 structure may represent a time interval, which may cover one or more symbols. Some
 examples of a transmission timing structure are transmission time interval (TTI), sub-
 frame, slot and mini-slot. A slot may comprise a predetermined, e.g. predefined and/or 1235
 configured or configurable, number of symbols, e.g. 6 or 7, or 12 or 14. A mini-slot may
 comprise a number of symbols (which may in particular be configurable or configured)
 smaller than the number of symbols of a slot, in particular 1, 2, 3 or 4, or more symbols,
 e.g. less symbols than symbols in a slot. A transmission timing structure may cover a
 time interval of a specific length, which may be dependent on symbol time length and/or 1240
 cyclic prefix used. A transmission timing structure may pertain to, and/or cover, a specific
 time interval in a time stream, e.g. synchronized for communication. Timing structures
 used and/or scheduled for transmission, e.g. slot and/or mini-slots, may be scheduled in
 relation to, and/or synchronized to, a timing structure provided and/or defined by other
 transmission timing structures. Such transmission timing structures may define a timing 1245
 grid, e.g., with symbol time intervals within individual structures representing the small-
 est timing units. Such a timing grid may for example be defined by slots or subframes
 (wherein in some cases, subframes may be considered specific variants of slots). A trans-
 mission timing structure may have a duration (length in time) determined based on the
 durations of its symbols, possibly in addition to cyclic prefix/es used. The symbols of a 1250
 transmission timing structure may have the same duration, or may in some variants have
 different duration. The number of symbols in a transmission timing structure may be
 predefined and/or configured or configurable, and/or be dependent on numerology. The
 timing of a mini-slot may generally be configured or configurable, in particular by the
 network and/or a network node. The timing may be configurable to start and/or end at 1255
 any symbol of the transmission timing structure, in particular one or more slots.

A transmission quality parameter may in general correspond to the number R of retransmissions and/or number T of total transmissions, and/or coding (e.g., number of coding bits, e.g. for error detection coding and/or error correction coding like FEC coding) and/or code rate and/or BLER and/or BER requirements and/or transmission power level (e.g., minimum level and/or target level and/or base power level P0 and/or transmission power control command, TPC, step size) and/or signal quality, e.g. SNR and/or SIR and/or SINR and/or power density and/or energy density. 1260

A buffer state report (or buffer status report, BSR) may comprise information representing the presence and/or size of data to be transmitted (e.g., available in one or more buffers, for example provided by higher layers). The size may be indicated explicitly, and/or indexed to range/s of sizes, and/or may pertain to one or more different channel/s and/or acknowledgement processes and/or higher layers and/or channel groups/s, e.g., one or more logical channel/s and/or transport channel/s and/or groups thereof: The structure of a BSR may be predefined and/or configurable of configured, e.g. to override and/or amend a predefined structure, for example with higher layer signalling, e.g. RRC signalling. There may be different forms of BSR with different levels of resolution and/or information, e.g. a more detailed long BSR and a less detailed short BSR. A short BSR may concatenate and/or combine information of a long BSR, e.g. providing sums for data available for one or more channels and/or or channels groups and/or buffers, which might be represented individually in a long BSR; and/or may index a less-detailed range scheme for data available or buffered. A BSR may be used in lieu of a scheduling request, e.g. by a network node scheduling or allocating (uplink) resources for the transmitting radio node like a wireless device or UE or IAB node. 1265 1270 1275

There is generally considered a program product comprising instructions adapted for causing processing and/or control circuitry to carry out and/or control any method described herein, in particular when executed on the processing and/or control circuitry. Also, there is considered a carrier medium arrangement carrying and/or storing a program product as described herein. 1280

A carrier medium arrangement may comprise one or more carrier media. Generally, a carrier medium may be accessible and/or readable and/or receivable by processing or control circuitry. Storing data and/or a program product and/or code may be seen as part of carrying data and/or a program product and/or code. A carrier medium generally may comprise a guiding/transporting medium and/or a storage medium. A guiding/transporting medium may be adapted to carry and/or carry and/or store signals, in particular electromagnetic signals and/or electrical signals and/or magnetic signals and/or optical signals. A carrier medium, in particular a guiding/transporting medium, 1285 1290

may be adapted to guide such signals to carry them. A carrier medium, in particular a guiding/transporting medium, may comprise the electromagnetic field, e.g. radio waves or microwaves, and/or optically transmissive material, e.g. glass fiber, and/or cable. A storage medium may comprise at least one of a memory, which may be volatile or non-volatile, a buffer, a cache, an optical disc, magnetic memory, flash memory, etc. 1295

A system comprising one or more radio nodes as described herein, in particular a network node and a user equipment, is described. The system may be a wireless communication system, and/or provide and/or represent a radio access network. 1300

Moreover, there may be generally considered a method of operating an information system, the method comprising providing information. Alternatively, or additionally, an information system adapted for providing information may be considered. Providing information may comprise providing information for, and/or to, a target system, which may comprise and/or be implemented as radio access network and/or a radio node, in particular a network node or user equipment or terminal. Providing information may comprise transferring and/or streaming and/or sending and/or passing on the information, and/or offering the information for such and/or for download, and/or triggering such providing, e.g. by triggering a different system or node to stream and/or transfer and/or send and/or pass on the information. The information system may comprise, and/or be connected or connectable to, a target, for example via one or more intermediate systems, e.g. a core network and/or internet and/or private or local network. Information may be provided utilising and/or via such intermediate system/s. Providing information may be for radio transmission and/or for transmission via an air interface and/or utilising a RAN or radio node as described herein. Connecting the information system to a target, and/or providing information, may be based on a target indication, and/or adaptive to a target indication. A target indication may indicate the target, and/or one or more parameters of transmission pertaining to the target and/or the paths or connections over which the information is provided to the target. Such parameter/s may in particular pertain to the air interface and/or radio access network and/or radio node and/or network node. Example parameters may indicate for example type and/or nature of the target, and/or transmission capacity (e.g., data rate) and/or latency and/or reliability and/or cost, respectively one or more estimates thereof. The target indication may be provided by the target, or determined by the information system, e.g. based on information received from the target and/or historical information, and/or be provided by a user, for example a user operating the target or a device in communication with the target, e.g. via the RAN and/or air interface. For example, a user may indicate on a user equipment communicating with the information system that information is to be provided via a RAN, e.g. by selecting from a selection provided by the information system, for example on a user application 1305 1310 1315 1320 1325

or user interface, which may be a web interface. An information system may comprise one or more information nodes. An information node may generally comprise processing circuitry and/or communication circuitry. In particular, an information system and/or an information node may be implemented as a computer and/or a computer arrangement, e.g. a host computer or host computer arrangement and/or server or server arrangement. In some variants, an interaction server (e.g., web server) of the information system may provide a user interface, and based on user input may trigger transmitting and/or streaming information provision to the user (and/or the target) from another server, which may be connected or connectable to the interaction server and/or be part of the information system or be connected or connectable thereto. The information may be any kind of data, in particular data intended for a user or for use at a terminal, e.g. video data and/or audio data and/or location data and/or interactive data and/or game-related data and/or environmental data and/or technical data and/or traffic data and/or vehicular data and/or circumstantial data and/or operational data. The information provided by the information system may be mapped to, and/or mappable to, and/or be intended for mapping to, communication or data signalling and/or one or more data channels as described herein (which may be signalling or channel/s of an air interface and/or used within a RAN and/or for radio transmission). It may be considered that the information is formatted based on the target indication and/or target, e.g. regarding data amount and/or data rate and/or data structure and/or timing, which in particular may be pertaining to a mapping to communication or data signalling and/or a data channel. Mapping information to data signalling and/or data channel/s may be considered to refer to using the signalling/channel/s to carry the data, e.g. on higher layers of communication, with the signalling/channel/s underlying the transmission. A target indication generally may comprise different components, which may have different sources, and/or which may indicate different characteristics of the target and/or communication path/s thereto. A format of information may be specifically selected, e.g. from a set of different formats, for information to be transmitted on an air interface and/or by a RAN as described herein. This may be particularly pertinent since an air interface may be limited in terms of capacity and/or of predictability, and/or potentially be cost sensitive. The format may be selected to be adapted to the transmission indication, which may in particular indicate that a RAN or radio node as described herein is in the path (which may be the indicated and/or planned and/or expected path) of information between the target and the information system. A (communication) path of information may represent the interface/s (e.g., air and/or cable interfaces) and/or the intermediate system/s (if any), between the information system and/or the node providing or transferring the information, and the target, over which the information is, or is to be, passed on. A path may be (at least partly) undetermined when a target indication is provided, and/or the information is provided/transferred by

the information system, e.g. if an internet is involved, which may comprise multiple, dynamically chosen paths. Information and/or a format used for information may be packet-based, and/or be mapped, and/or be mappable and/or be intended for mapping, to packets. Alternatively, or additionally, there may be considered a method for operating a target device comprising providing a target indicating to an information system. More alternatively, or additionally, a target device may be considered, the target device being adapted for providing a target indication to an information system. In another approach, there may be considered a target indication tool adapted for, and/or comprising an indication module for, providing a target indication to an information system. The target device may generally be a target as described above. A target indication tool may comprise, and/or be implemented as, software and/or application or app, and/or web interface or user interface, and/or may comprise one or more modules for implementing actions performed and/or controlled by the tool. The tool and/or target device may be adapted for, and/or the method may comprise, receiving a user input, based on which a target indicating may be determined and/or provided. Alternatively, or additionally, the tool and/or target device may be adapted for, and/or the method may comprise, receiving information and/or communication signalling carrying information, and/or operating on, and/or presenting (e.g., on a screen and/or as audio or as other form of indication), information. The information may be based on received information and/or communication signalling carrying information. Presenting information may comprise processing received information, e.g. decoding and/or transforming, in particular between different formats, and/or for hardware used for presenting. Operating on information may be independent of or without presenting, and/or proceed or succeed presenting, and/or may be without user interaction or even user reception, for example for automatic processes, or target devices without (e.g., regular) user interaction like MTC devices, or for automotive or transport or industrial use. The information or communication signalling may be expected and/or received based on the target indication. Presenting and/or operating on information may generally comprise one or more processing steps, in particular decoding and/or executing and/or interpreting and/or transforming information. Operating on information may generally comprise relaying and/or transmitting the information, e.g. on an air interface, which may include mapping the information onto signalling (such mapping may generally pertain to one or more layers, e.g. one or more layers of an air interface, e.g. RLC (Radio Link Control) layer and/or MAC layer and/or physical layer/s). The information may be imprinted (or mapped) on communication signalling based on the target indication, which may make it particularly suitable for use in a RAN (e.g., for a target device like a network node or in particular a UE or terminal). The tool may generally be adapted for use on a target device, like a UE or terminal. Generally, the tool may provide multiple functionalities, e.g. for providing and/or selecting the target indication, and/or presenting, e.g.

video and/or audio, and/or operating on and/or storing received information. Providing a target indication may comprise transmitting or transferring the indication as signalling, and/or carried on signalling, in a RAN, for example if the target device is a UE, or the tool for a UE. It should be noted that such provided information may be transferred to the information system via one or more additionally communication interfaces and/or paths and/or connections. The target indication may be a higher-layer indication and/or the information provided by the information system may be higher-layer information, e.g. application layer or user-layer, in particular above radio layers like transport layer and physical layer. The target indication may be mapped on physical layer radio signalling, e.g. related to or on the user-plane, and/or the information may be mapped on physical layer radio communication signalling, e.g. related to or on the user-plane (in particular, in reverse communication directions). The described approaches allow a target indication to be provided, facilitating information to be provided in a specific format particularly suitable and/or adapted to efficiently use an air interface. A user input may for example represent a selection from a plurality of possible transmission modes or formats, and/or paths, e.g. in terms of data rate and/or packaging and/or size of information to be provided by the information system.

In general, a numerology and/or subcarrier spacing may indicate the bandwidth (in frequency domain) of a subcarrier of a carrier, and/or the number of subcarriers in a carrier and/or the numbering of the subcarriers in a carrier, and/or the symbol time length. Different numerologies may in particular be different in the bandwidth of a subcarrier. In some variants, all the subcarriers in a carrier have the same bandwidth associated to them. The numerology and/or subcarrier spacing may be different between carriers in particular regarding the subcarrier bandwidth. A symbol time length, and/or a time length of a timing structure pertaining to a carrier may be dependent on the carrier frequency, and/or the subcarrier spacing and/or the numerology. In particular, different numerologies may have different symbol time lengths, even on the same carrier.

signalling may generally comprise one or more (e.g., modulation) symbols and/or signals and/or messages. A signal may comprise or represent one or more bits. An indication may represent signalling, and/or be implemented as a signal, or as a plurality of signals. One or more signals may be included in and/or represented by a message. signalling, in particular control signalling, may comprise a plurality of signals and/or messages, which may be transmitted on different carriers and/or be associated to different signalling processes, e.g. representing and/or pertaining to one or more such processes and/or corresponding information. An indication may comprise signalling, and/or a plurality of signals and/or messages and/or may be comprised therein, which may be transmitted on different carriers and/or be associated to different acknowledgement signalling processes, e.g. representing

and/or pertaining to one or more such processes. Signalling associated to a channel may be transmitted such that represents signalling and/or information for that channel, and/or that the signalling is interpreted by the transmitter and/or receiver to belong to that channel. Such signalling may generally comply with transmission parameters and/or format/s for the channel. 1445

An antenna arrangement may comprise one or more antenna elements (radiating elements), which may be combined in antenna arrays. An antenna array or sub-array may comprise one antenna element, or a plurality of antenna elements, which may be arranged e.g. two dimensionally (for example, a panel) or three dimensionally. It may be considered that each antenna array or sub-array or element is separately controllable, respectively that different antenna arrays are controllable separately from each other. A single antenna element/radiator may be considered the smallest example of a sub-array. Examples of antenna arrays comprise one or more multi-antenna panels or one or more individually controllable antenna elements. An antenna arrangement may comprise a plurality of antenna arrays. It may be considered that an antenna arrangement is associated to a (specific and/or single) radio node, e.g. a configuring or informing or scheduling radio node, e.g. to be controlled or controllable by the radio node. An antenna arrangement associated to a UE or terminal may be smaller (e.g., in size and/or number of antenna elements or arrays) than the antenna arrangement associated to a network node. Antenna elements of an antenna arrangement may be configurable for different arrays, e.g. to change the beamforming characteristics. In particular, antenna arrays may be formed by combining one or more independently or separately controllable antenna elements or sub-arrays. The beams may be provided by analog beamforming, or in some variants by digital beamforming, or by hybrid beamforming combining analog and digital beamforming. The informing radio nodes may be configured with the manner of beam transmission, e.g. by transmitting a corresponding indicator or indication, for example as beam identify indication. However, there may be considered cases in which the informing radio node/s are not configured with such information, and/or operate transparently, not knowing the way of beamforming used. An antenna arrangement may be considered separately controllable in regard to the phase and/or amplitude/power and/or gain of a signal feed to it for transmission, and/or separately controllable antenna arrangements may comprise an independent or separate transmit and/or receive unit and/or ADC (analog-Digital-Converter, alternatively an ADC chain) or DCA (Digital-to-analog Converter, alternatively a DCA chain) to convert digital control information into an analog antenna feed for the whole antenna arrangement (the ADC/DCA may be considered part of, and/or connected or connectable to, antenna circuitry) or vice versa. A scenario in which an ADC or DCA is controlled directly for beamforming may be considered an analog beamforming scenario; 1450 1455 1460 1465 1470 1475

such controlling may be performed after encoding/decoding and/or after modulation symbols have been mapped to resource elements. This may be on the level of antenna arrangements using the same ADC/DCA, e.g. one antenna element or a group of antenna elements associated to the same ADC/DCA. Digital beamforming may correspond to a scenario in which processing for beamforming is provided before feeding signalling to the ADC/DCA, e.g. by using one or more precoder/s and/or by precoding information, for example before and/or when mapping modulation symbols to resource elements. Such a precoder for beamforming may provide weights, e.g. for amplitude and/or phase, and/or may be based on a (precoder) codebook, e.g. selected from a codebook. A precoder may pertain to one beam or more beams, e.g. defining the beam or beams. The codebook may be configured or configurable, and/or be predefined. DFT beamforming may be considered a form of digital beamforming, wherein a DFT procedure is used to form one or more beams. Hybrid forms of beamforming may be considered.

A beam may be defined by a spatial and/or angular and/or spatial angular distribution of radiation and/or a spatial angle (also referred to as solid angle) or spatial (solid) angle distribution into which radiation is transmitted (for transmission beamforming) or from which it is received (for reception beamforming). Reception beamforming may comprise only accepting signals coming in from a reception beam (e.g., using analog beamforming to not receive outside reception beam/s), and/or sorting out signals that do not come in in a reception beam, e.g. in digital postprocessing, e.g. digital beamforming. A beam may have a solid angle equal to or smaller than 4π sr (4π correspond to a beam covering all directions), in particular smaller than 2π , or π , or $\pi/2$, or $\pi/4$ or $\pi/8$ or $\pi/16$. In particular for high frequencies, smaller beams may be used. Different beams may have different directions and/or sizes (e.g., solid angle and/or reach). A beam may have a main direction, which may be defined by a main lobe (e.g., center of the main lobe, e.g. pertaining to signal strength and/or solid angle, which may be averaged and/or weighted to determine the direction), and may have one or more sidelobes. A lobe may generally be defined to have a continuous or contiguous distribution of energy and/or power transmitted and/or received, e.g. bounded by one or more contiguous or contiguous regions of zero energy (or practically zero energy). A main lobe may comprise the lobe with the largest signal strength and/or energy and/or power content. However, sidelobes usually appear due to limitations of beamforming, some of which may carry signals with significant strength, and may cause multi-path effects. A sidelobe may generally have a different direction than a main lobe and/or other side lobes, however, due to reflections a sidelobe still may contribute to transmitted and/or received energy or power. A beam may be swept and/or switched over time, e.g., such that its (main) direction is changed, but its shape (angular/solid angle distribution) around the main direction is not changed,

e.g. from the transmitter's views for a transmission beam, or the receiver's view for a reception beam, respectively. Sweeping may correspond to continuous or near continuous change of main direction (e.g., such that after each change, the main lobe from before the change covers at least partly the main lobe after the change, e.g. at least to 50 or 75 or 90 percent). Switching may correspond to switching direction non-continuously, e.g. such that after each change, the main lobe from before the change does not cover the main lobe after the change, e.g. at most to 50 or 25 or 10 percent. 1520

Signal strength may be a representation of signal power and/or signal energy, e.g. as seen from a transmitting node or a receiving node. A beam with larger strength at transmission (e.g., according to the beamforming used) than another beam does may not necessarily have larger strength at the receiver, and vice versa, for example due to interference and/or obstruction and/or dispersion and/or absorption and/or reflection and/or attrition or other effects influencing a beam or the signalling it carries. Signal quality may in general be a representation of how well a signal may be received over noise and/or interference. A beam with better signal quality than another beam does not necessarily have a larger beam strength than the other beam. Signal quality may be represented for example by SIR, SNR, SINR, BER, BLER, Energy per resource element over noise/interference or another corresponding quality measure. Signal quality and/or signal strength may pertain to, and/or may be measured with respect to, a beam, and/or specific signalling carried by the beam, e.g. reference signalling and/or a specific channel, e.g. a data channel or control channel. Signal strength may be represented by received signal strength, and/or relative signal strength, e.g. in comparison to a reference signal (strength). 1530 1535

Uplink or sidelink signalling may be OFDMA (Orthogonal Frequency Division Multiple Access) or SC-FDMA (Single Carrier Frequency Division Multiple Access) signalling. Downlink signalling may in particular be OFDMA signalling. However, signalling like communication signalling and/or sensing signalling is not limited thereto (Filter-Bank based signalling and/or Single-Carrier based signalling, e.g. SC-FDE signalling, may be considered alternatives). 1540 1545

A radio node may generally be considered a device or node adapted for wireless and/or radio (and/or millimeter wave) frequency communication, and/or for communication utilising an air interface, e.g. according to a communication standard.

A radio node may be a network node, or a user equipment or terminal. A network node may be any radio node of a wireless communication network, e.g. a base station and/or gNodeB (gNB) and/or eNodeB (eNB) and/or relay node and/or micro/nano/pico/femto node and/or transmission point (TP) and/or access point (AP) and/or other node, in 1550

particular for a RAN or other wireless communication network as described herein.

The terms user equipment (UE) and terminal may be considered to be interchangeable in the context of this disclosure. A wireless device, user equipment or terminal may represent an end device for communication utilising the wireless communication network, and/or be implemented as a user equipment according to a standard. Examples of user equipments may comprise a phone like a smartphone, a personal communication device, a mobile phone or terminal, a computer, in particular laptop, a sensor or machine with radio capability (and/or adapted for the air interface), in particular for MTC (Machine-Type-Communication, sometimes also referred to M2M, Machine-To-Machine), or a vehicle adapted for wireless communication. A user equipment or terminal may be mobile or stationary. A wireless device generally may comprise, and/or be implemented as, processing circuitry and/or radio circuitry, which may comprise one or more chips or sets of chips. The circuitry and/or circuitries may be packaged, e.g. in a chip housing, and/or may have one or more physical interfaces to interact with other circuitry and/or for power supply. Such a wireless device may be intended for use in a user equipment or terminal.

A radio node may generally comprise processing circuitry and/or radio circuitry. A radio node, in particular a network node, may in some cases comprise cable circuitry and/or communication circuitry, with which it may be connected or connectable to another radio node and/or a core network.

Circuitry may comprise integrated circuitry. Processing circuitry may comprise one or more processors and/or controllers (e.g., microcontrollers), and/or ASICs (Application Specific Integrated Circuitry) and/or FPGAs (Field Programmable Gate Array), or similar. It may be considered that processing circuitry comprises, and/or is (operatively) connected or connectable to one or more memories or memory arrangements. A memory arrangement may comprise one or more memories. A memory may be adapted to store digital information. Examples for memories comprise volatile and non-volatile memory, and/or Random Access Memory (RAM), and/or Read-Only-Memory (ROM), and/or magnetic and/or optical memory, and/or flash memory, and/or hard disk memory, and/or EPROM or EEPROM (Erasable Programmable ROM or Electrically Erasable Programmable ROM).

Radio circuitry may comprise one or more transmitters and/or receivers and/or transceivers (a transceiver may operate or be operable as transmitter and receiver, and/or may comprise joint or separated circuitry for receiving and transmitting, e.g. in one package or housing), and/or may comprise one or more amplifiers and/or oscillators and/or filters, and/or may comprise, and/or be connected or connectable to antenna circuitry and/or one or more antennas and/or antenna arrays. An antenna array may comprise one or

more antennas, which may be arranged in a dimensional array, e.g. 2D or 3D array, and/or antenna panels. A remote radio head (RRH) may be considered as an example of an antenna array. However, in some variants, an RRH may be also be implemented as a network node, depending on the kind of circuitry and/or functionality implemented therein. 1590

Communication circuitry may comprise radio circuitry and/or cable circuitry. Communication circuitry generally may comprise one or more interfaces, which may be air interface/s and/or cable interface/s and/or optical interface/s, e.g. laser-based. Interface/s may be in particular packet-based. Cable circuitry and/or a cable interfaces may comprise, and/or be connected or connectable to, one or more cables (e.g., optical fiber-based and/or wire-based), which may be directly or indirectly (e.g., via one or more intermediate systems and/or interfaces) be connected or connectable to a target, e.g. controlled by communication circuitry and/or processing circuitry. 1595 1600

Any one or all of the modules disclosed herein may be implemented in software and/or firmware and/or hardware. Different modules may be associated to different components of a radio node, e.g. different circuitries or different parts of a circuitry. It may be considered that a module is distributed over different components and/or circuitries. A program product as described herein may comprise the modules related to a device on which the program product is intended (e.g., a user equipment or network node) to be executed (the execution may be performed on, and/or controlled by the associated circuitry). 1605

A wireless communication network may be or comprise a radio access network and/or a backhaul network (e.g. a relay or backhaul network or an IAB network), and/or a Radio Access Network (RAN) in particular according to a communication standard. A communication standard may in particular a standard according to 3GPP and/or 5G, e.g. according to NR or LTE, in particular LTE Evolution. 1610

A wireless communication network may be and/or comprise a Radio Access Network (RAN), which may be and/or comprise any kind of cellular and/or wireless radio network, which may be connected or connectable to a core network. The approaches described herein are particularly suitable for a 5G network, e.g. LTE Evolution and/or NR (New Radio), respectively successors thereof. A RAN may comprise one or more network nodes, and/or one or more terminals, and/or one or more radio nodes. A network node may in particular be a radio node adapted for radio and/or wireless and/or cellular communication with one or more terminals. A terminal may be any device adapted for radio and/or wireless and/or cellular communication with or within a RAN, e.g. a user equipment (UE) or mobile phone or smartphone or computing device or vehicular communication device or device for machine-type-communication (MTC), etc. A terminal 1615 1620

may be mobile, or in some cases stationary. A RAN or a wireless communication network may comprise at least one network node and a UE, or at least two radio nodes. There may be generally considered a wireless communication network or system, e.g. a RAN or RAN system, comprising at least one radio node, and/or at least one network node and at least one terminal. 1625

Transmitting in downlink may pertain to transmission from the network or network node to the terminal. Transmitting in uplink may pertain to transmission from the terminal to the network or network node. Transmitting in sidelink may pertain to (direct) transmission from one terminal to another. Uplink, downlink and sidelink (e.g., sidelink transmission and reception) may be considered communication directions. In some variants, uplink and downlink may also be used to described wireless communication between network nodes, e.g. for wireless backhaul and/or relay communication and/or (wireless) network communication for example between base stations or similar network nodes, in particular communication terminating at such. It may be considered that backhaul and/or relay communication and/or network communication is implemented as a form of sidelink or uplink communication or similar thereto. 1630 1635 1640

Control information or a control information message or corresponding signalling (control signalling) may be transmitted on a control channel, e.g. a physical control channel, which may be a downlink channel or (or a sidelink channel in some cases, e.g. one UE scheduling another UE). For example, control information/allocation information may be signaled by a network node on PDCCH (Physical Downlink Control Channel) and/or a PDSCH (Physical Downlink Shared Channel) and/or a HARQ-specific channel. Acknowledgement signalling, e.g. as a form of control information or signalling like uplink control information/signalling, may be transmitted by a terminal on a PUCCH (Physical Uplink Control Channel) and/or PUSCH (Physical Uplink Shared Channel) and/or a HARQ-specific channel. Multiple channels may apply for multi-component/multi-carrier indication or signalling. 1645 1650

Transmitting acknowledgement signalling may in general be based on and/or in response to subject transmission, and/or to control signalling scheduling subject transmission. Such control signalling and/or subject signalling may be transmitted by a signalling radio node (which may be a network node, and/or a node associated to it, e.g. in a dual connectivity scenario. Subject transmission and/or subject signalling may be transmission or signalling to which ACK/NACK or acknowledgement information pertains, e.g. indicating correct or incorrect reception and/or decoding of the subject transmission or signalling. Subject signalling or transmission may in particular comprise and/or be represented by data signalling, e.g. on a PDSCH or PSSCH, or some forms of control signalling, 1655 1660

e.g. on a PDCCH or PSSCH, for example for specific formats.

A signalling characteristic may be based on a type or format of a scheduling grant and/or scheduling assignment, and/or type of allocation, and/or timing of acknowledgement signalling and/or the scheduling grant and/or scheduling assignment, and/or resources associated to acknowledgement signalling and/or the scheduling grant and/or scheduling assignment. For example, if a specific format for a scheduling grant (scheduling or allocating the allocated resources) or scheduling assignment (scheduling the subject transmission for acknowledgement signalling) is used or detected, the first or second communication resource may be used. Type of allocation may pertain to dynamic allocation (e.g., using DCI/PDCCH) or semi-static allocation (e.g., for a configured grant). Timing of acknowledgement signalling may pertain to a slot and/or symbol/s the signalling is to be transmitted. Resources used for acknowledgement signalling may pertain to the allocated resources. Timing and/or resources associated to a scheduling grant or assignment may represent a search space or CORESET (a set of resources configured for reception of PDCCH transmissions) in which the grant or assignment is received. Thus, which transmission resource to be used may be based on implicit conditions, requiring low signalling overhead.

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Scheduling may comprise indicating, e.g. with control signalling like DCI or SCI signalling and/or signalling on a control channel like PDCCH or PSCCH, one or more scheduling opportunities of a configuration intended to carry data signalling or subject signalling. The configuration may be represented or representable by, and/or correspond to, a table. A scheduling assignment may for example point to an opportunity of the reception allocation configuration, e.g. indexing a table of scheduling opportunities. In some cases, a reception allocation configuration may comprise 15 or 16 scheduling opportunities. The configuration may in particular represent allocation in time. It may be considered that the reception allocation configuration pertains to data signalling, in particular on a physical data channel like PDSCH or PSSCH. In general, the reception allocation configuration may pertain to downlink signalling, or in some scenarios to sidelink signalling. Control signalling scheduling subject transmission like data signalling may point and/or index and/or refer to and/or indicate a scheduling opportunity of the reception allocation configuration. It may be considered that the reception allocation configuration is configured or configurable with higher-layer signalling, e.g. RRC or MAC layer signalling. The reception allocation configuration may be applied and/or applicable and/or valid for a plurality of transmission timing intervals, e.g. such that for each interval, one or more opportunities may be indicated or allocated for data signalling. These approaches allow efficient and flexible scheduling, which may be semi-static, but may updated or reconfigured on useful timescales in response to changes of operation conditions.

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Control information, e.g., in a control information message, in this context may in particular be implemented as and/or represented by a scheduling assignment, which may indicate subject transmission for feedback (transmission of acknowledgement signalling), and/or reporting timing and/or frequency resources and/or code resources. Reporting timing may indicate a timing for scheduled acknowledgement signalling, e.g. slot and/or symbol and/or resource set. Control information may be carried by control signalling. 1700

Subject transmissions may comprise one or more individual transmissions. Scheduling assignments may comprise one or more scheduling assignments. It should generally be noted that in a distributed system, subject transmissions, configuration and/or scheduling may be provided by different nodes or devices or transmission points. Different subject transmissions may be on the same carrier or different carriers (e.g., in a carrier aggregation), and/or same or different bandwidth parts, and/or on the same or different layers or beams, e.g. in a MIMO scenario, and/or to same or different ports. Generally, subject transmissions may pertain to different HARQ or ARQ processes (or different sub-processes, e.g. in MIMO with different beams/layers associated to the same process identifier, but different sub-process-identifiers like swap bits). A scheduling assignment and/or a HARQ codebook may indicate a target HARQ structure. A target HARQ structure may for example indicate an intended HARQ response to a subject transmission, e.g. the number of bits and/or whether to provide code block group level response or not. However, it should be noted that the actual structure used may differ from the target structure, e.g. due to the total size of target structures for a subpattern being larger than the predetermined size. 1705 1710 1715

Transmitting acknowledgement signalling, also referred to as transmitting acknowledgement information or feedback information or simply as ARQ or HARQ feedback or feedback or reporting feedback, may comprise, and/or be based on determining correct or incorrect reception of subject transmission/s, e.g. based on error coding and/or based on scheduling assignment/s scheduling the subject transmissions. Transmitting acknowledgement information may be based on, and/or comprise, a structure for acknowledgement information to transmit, e.g. the structure of one or more subpatterns, e.g. based on which subject transmission is scheduled for an associated subdivision. Transmitting acknowledgement information may comprise transmitting corresponding signalling, e.g. at one instance and/or in one message and/or one channel, in particular a physical channel, which may be a control channel. In some cases, the channel may be a shared channel or data channel, e.g. utilising rate-matching of the acknowledgment information. The acknowledgement information may generally pertain to a plurality of subject transmissions, which may be on different channels and/or carriers, and/or may comprise data signalling and/or control signalling. The acknowledgment information may be based on a codebook, which may be based on one or more size indications and/or assignment 1720 1725 1730

indications (representing HARQ structures), which may be received with a plurality of control signalings and/or control messages, e.g. in the same or different transmission timing structures, and/or in the same or different (target) sets of resources. Transmitting acknowledgement information may comprise determining the codebook, e.g. based on control information in one or more control information messages and/or a configuration. A codebook may pertain to transmitting acknowledgement information at a single and/or specific instant, e.g. a single PUCCH or PUSCH transmission, and/or in one message or with jointly encoded and/or modulated acknowledgement information. Generally, acknowledgment information may be transmitted together with other control information, e.g. a scheduling request and/or measurement information.

Acknowledgement signalling may in some cases comprise, next to acknowledgement information, other information, e.g. control information, in particular, uplink or sidelink control information, like a scheduling request and/or measurement information, or similar, and/or error detection and/or correction information, respectively associated bits. The payload size of acknowledgement signalling may represent the number of bits of acknowledgement information, and/or in some cases the total number of bits carried by the acknowledgement signalling, and/or the number of resource elements needed. Acknowledgement signalling and/or information may pertain to ARQ and/or HARQ processes; an ARQ process may provide ACK/NACK (and perhaps additional feedback) feedback, and decoding may be performed on each (re-)transmission separately, without soft-buffering/soft-combining intermediate data, whereas HARQ may comprise soft-buffering/soft-combining of intermediate data of decoding for one or more (re-)transmissions.

Subject transmission may be data signalling or control signalling. The transmission may be on a shared or dedicated channel. Data signalling may be on a data channel, for example on a PDSCH or PSSCH, or on a dedicated data channel, e.g. for low latency and/or high reliability, e.g. a URLLC channel. Control signalling may be on a control channel, for example on a common control channel or a PDCCH or PSCCH, and/or comprise one or more DCI messages or SCI messages. In some cases, the subject transmission may comprise, or represent, reference signalling. For example, it may comprise DM-RS and/or pilot signalling and/or discovery signalling and/or sounding signalling and/or phase tracking signalling and/or cell-specific reference signalling and/or user-specific signalling, in particular CSI-RS. A subject transmission may pertain to one scheduling assignment and/or one acknowledgement signalling process (e.g., according to identifier or subidentifier), and/or one subdivision. In some cases, a subject transmission may cross the borders of subdivisions in time, e.g. due to being scheduled to start in one subdivision and extending into another, or even crossing over more than one subdivision. In this case, it may be considered that the subject transmission is associated to the subdivision it ends in.

It may be considered that transmitting acknowledgement information, in particular of acknowledgement information, is based on determining whether the subject transmission/s has or have been received correctly, e.g. based on error coding and/or reception quality. Reception quality may for example be based on a determined signal quality. Acknowledgement information may generally be transmitted to a signalling radio node and/or node arrangement and/or to a network and/or network node.

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Acknowledgement information, or bit/s of a subpattern structure of such information (e.g., an acknowledgement information structure, may represent and/or comprise one or more bits, in particular a pattern of bits. Multiple bits pertaining to a data structure or substructure or message like a control message may be considered a subpattern. The structure or arrangement of acknowledgement information may indicate the order, and/or meaning, and/or mapping, and/or pattern of bits (or subpatterns of bits) of the information. The structure or mapping may in particular indicate one or more data block structures, e.g. code blocks and/or code block groups and/or transport blocks and/or messages, e.g. command messages, the acknowledgement information pertains to, and/or which bits or subpattern of bits are associated to which data block structure. In some cases, the mapping may pertain to one or more acknowledgement signalling processes, e.g. processes with different identifiers, and/or one or more different data streams. The configuration or structure or codebook may indicate to which process/es and/or data stream/s the information pertains. Generally, the acknowledgement information may comprise one or more subpatterns, each of which may pertain to a data block structure, e.g. a code block or code block group or transport block. A subpattern may be arranged to indicate acknowledgement or non-acknowledgement, or another retransmission state like non-scheduling or non-reception, of the associated data block structure. It may be considered that a subpattern comprises one bit, or in some cases more than one bit. It should be noted that acknowledgement information may be subjected to significant processing before being transmitted with acknowledgement signalling. Different configurations may indicate different sizes and/or mapping and/or structures and/or pattern.

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An acknowledgment signalling process (providing acknowledgment information) may be a HARQ process, and/or be identified by a process identifier, e.g. a HARQ process identifier or sub-identifier. Acknowledgement signalling and/or associated acknowledgement information may be referred to as feedback or acknowledgement feedback. It should be noted that data blocks or structures to which subpatterns may pertain may be intended to carry data (e.g., information and/or systemic and/or coding bits). However, depending on transmission conditions, such data may be received or not received (or not received correctly), which may be indicated correspondingly in the feedback. In some cases, a subpattern of acknowledgement signalling may comprise padding bits, e.g. if the ac-

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knowledge information for a data block requires fewer bits than indicated as size of the subpattern. Such may for example happen if the size is indicated by a unit size larger than required for the feedback. 1810

Acknowledgment information may generally indicate at least ACK or NACK, e.g. pertaining to an acknowledgment signalling process, or an element of a data block structure like a data block, subblock group or subblock, or a message, in particular a control message. Generally, to an acknowledgment signalling process there may be associated one specific subpattern and/or a data block structure, for which acknowledgment information may be provided. Acknowledgement information may comprise a plurality of pieces of information, represented in a plurality of ARQ and/or HARQ structures. 1815

An acknowledgment signalling process may determine correct or incorrect reception, and/or corresponding acknowledgement information, of a data block like a transport block, and/or substructures thereof, based on coding bits associated to the data block, and/or based on coding bits associated to one or more data block and/or subblocks and/or subblock group/s. Acknowledgement information (determined by an acknowledgment signalling process) may pertain to the data block as a whole, and/or to one or more subblocks or subblock groups. A code block may be considered an example of a subblock, whereas a code block group may be considered an example of a subblock group. Accordingly, the associated subpattern may comprise one or more bits indicating reception status or feedback of the data block, and/or one or more bits indicating reception status or feedback of one or more subblocks or subblock groups. Each subpattern or bit of the subpattern may be associated and/or mapped to a specific data block or subblock or subblock group. In some variants, correct reception for a data block may be indicated if all subblocks or subblock groups are correctly identified. In such a case, the subpattern may represent acknowledgement information for the data block as a whole, reducing overhead in comparison to provide acknowledgement information for the subblocks or subblock groups. The smallest structure (e.g. subblock/subblock group/data block) the subpattern provides acknowledgement information for and/or is associated to may be considered its (highest) resolution. In some variants, a subpattern may provide acknowledgment information regarding several elements of a data block structure and/or at different resolution, e.g. to allow more specific error detection. For example, even if a subpattern indicates acknowledgment signalling pertaining to a data block as a whole, in some variants higher resolution (e.g., subblock or subblock group resolution) may be provided by the subpattern. A subpattern may generally comprise one or more bits indicating ACK/NACK for a data block, and/or one or more bits for indicating ACK/NACK for a subblock or subblock group, or for more than one subblock or subblock group. 1820 1825 1830 1835 1840

A subblock and/or subblock group may comprise information bits (representing the data to be transmitted, e.g. user data and/or downlink/sidelink data or uplink data). It may be considered that a data block and/or subblock and/or subblock group also comprises error one or more error detection bits, which may pertain to, and/or be determined based on, the information bits (for a subblock group, the error detection bit/s may be determined based on the information bits and/or error detection bits and/or error correction bits of the subblock/s of the subblock group). A data block or substructure like subblock or subblock group may comprise error correction bits, which may in particular be determined based on the information bits and error detection bits of the block or substructure, e.g. utilising an error correction coding scheme, in particular for forward error correction (FEC), e.g. LDPC or polar coding and/or turbo coding. Generally, the error correction coding of a data block structure (and/or associated bits) may cover and/or pertain to information bits and error detection bits of the structure. A subblock group may represent a combination of one or more code blocks, respectively the corresponding bits. A data block may represent a code block or code block group, or a combination of more than one code block groups. A transport block may be split up in code blocks and/or code block groups, for example based on the bit size of the information bits of a higher layer data structure provided for error coding and/or size requirements or preferences for error coding, in particular error correction coding. Such a higher layer data structure is sometimes also referred to as transport block, which in this context represents information bits without the error coding bits described herein, although higher layer error handling information may be included, e.g. for an internet protocol like TCP. However, such error handling information represents information bits in the context of this disclosure, as the acknowledgement signalling procedures described treat it accordingly.

In some variants, a subblock like a code block may comprise error correction bits, which may be determined based on the information bit/s and/or error detection bit/s of the subblock. An error correction coding scheme may be used for determining the error correction bits, e.g. based on LDPC or polar coding or Reed-Mueller coding. In some cases, a subblock or code block may be considered to be defined as a block or pattern of bits comprising information bits, error detection bit/s determined based on the information bits, and error correction bit/s determined based on the information bits and/or error detection bit/s. It may be considered that in a subblock, e.g. code block, the information bits (and possibly the error correction bit/s) are protected and/or covered by the error correction scheme or corresponding error correction bit/s. A code block group may comprise one or more code blocks. In some variants, no additional error detection bits and/or error correction bits are applied, however, it may be considered to apply either or both. A transport block may comprise one or more code block groups. It may be considered that

no additional error detection bits and/or error correction bits are applied to a transport block, however, it may be considered to apply either or both. In some specific variants, the code block group/s comprise no additional layers of error detection or correction coding, and the transport block may comprise only additional error detection coding bits, but no additional error correction coding. This may particularly be true if the transport block size is larger than the code block size and/or the maximum size for error correction coding. A subpattern of acknowledgement signalling (in particular indicating ACK or NACK) may pertain to a code block, e.g. indicating whether the code block has been correctly received. It may be considered that a subpattern pertains to a subgroup like a code block group or a data block like a transport block. In such cases, it may indicate ACK, if all subblocks or code blocks of the group or data/transport block are received correctly (e.g. based on a logical AND operation), and NACK or another state of non-correct reception if at least one subblock or code block has not been correctly received. It should be noted that a code block may be considered to be correctly received not only if it actually has been correctly received, but also if it can be correctly reconstructed based on soft-combining and/or the error correction coding.

A subpattern/HARQ structure may pertain to one acknowledgement signalling process and/or one carrier like a component carrier and/or data block structure or data block. It may in particular be considered that one (e.g. specific and/or single) subpattern pertains, e.g. is mapped by the codebook, to one (e.g., specific and/or single) acknowledgement signalling process, e.g. a specific and/or single HARQ process. It may be considered that in the bit pattern, subpatterns are mapped to acknowledgement signalling processes and/or data blocks or data block structures on a one-to-one basis. In some variants, there may be multiple subpatterns (and/or associated acknowledgment signalling processes) associated to the same component carrier, e.g. if multiple data streams transmitted on the carrier are subject to acknowledgement signalling processes. A subpattern may comprise one or more bits, the number of which may be considered to represent its size or bit size. Different bit n-tupels (n being 1 or larger) of a subpattern may be associated to different elements of a data block structure (e.g., data block or subblock or subblock group), and/or represent different resolutions. There may be considered variants in which only one resolution is represented by a bit pattern, e.g. a data block. A bit n-tupel may represent acknowledgement information (also referred to a feedback), in particular ACK or NACK, and optionally, (if $n \geq 1$), may represent DTX/DRX or other reception states. ACK/NACK may be represented by one bit, or by more than one bit, e.g. to improve disambiguity of bit sequences representing ACK or NACK, and/or to improve transmission reliability.

The acknowledgement information or feedback information may pertain to a plurality

of different transmissions, which may be associated to and/or represented by data block structures, respectively the associated data blocks or data signalling. The data block structures, and/or the corresponding blocks and/or signalling, may be scheduled for simultaneous transmission, e.g. for the same transmission timing structure, in particular within the same slot or subframe, and/or on the same symbol/s. However, alternatives with scheduling for non-simultaneous transmission may be considered. For example, the acknowledgment information may pertain to data blocks scheduled for different transmission timing structures, e.g. different slots (or mini-slots, or slots and mini-slots) or similar, which may correspondingly be received (or not or wrongly received). Scheduling signalling may generally comprise indicating resources, e.g. time and/or frequency resources, for example for receiving or transmitting the scheduled signalling. 1920 1925

Signalling may generally be considered to represent an electromagnetic wave structure (e.g., over a time interval and frequency interval), which is intended to convey information to at least one specific or generic (e.g., anyone who might pick up the signalling) target. A process of signalling may comprise transmitting the signalling. Transmitting signalling, in particular control signalling or communication signalling, e.g. comprising or representing acknowledgement signalling and/or resource requesting information, may comprise encoding and/or modulating. Encoding and/or modulating may comprise error detection coding and/or forward error correction encoding and/or scrambling. Receiving control signalling may comprise corresponding decoding and/or demodulation. Error detection coding may comprise, and/or be based on, parity or checksum approaches, e.g. CRC (Cyclic Redundancy Check). Forward error correction coding may comprise and/or be based on for example turbo coding and/or Reed-Muller coding, and/or polar coding and/or LDPC coding (Low Density Parity Check). The type of coding used may be based on the channel (e.g., physical channel) the coded signal is associated to. A code rate may represent the ratio of the number of information bits before encoding to the number of encoded bits after encoding, considering that encoding adds coding bits for error detection coding and forward error correction. Coded bits may refer to information bits (also called systematic bits) plus coding bits. 1930 1935 1940 1945

Communication signalling may comprise, and/or represent, and/or be implemented as, data signalling, and/or user plane signalling. Communication signalling may be associated to a data channel, e.g. a physical downlink channel or physical uplink channel or physical sidelink channel, in particular a PDSCH (Physical Downlink Shared Channel) or PSSCH (Physical Sidelink Shared Channel). Generally, a data channel may be a shared channel or a dedicated channel. Data signalling may be signalling associated to and/or on a data channel. 1950

An indication generally may explicitly and/or implicitly indicate the information it represents and/or indicates. Implicit indication may for example be based on position and/or resource used for transmission. Explicit indication may for example be based on a parametrisation with one or more parameters, and/or one or more index or indices, and/or one or more bit patterns representing the information. It may in particular be considered that control signalling as described herein, based on the utilised resource sequence, implicitly indicates the control signalling type. 1955 1960

A resource element may generally describe the smallest individually usable and/or encodable and/or decodable and/or modulatable and/or demodulatable time-frequency resource, and/or may describe a time-frequency resource covering a symbol time length in time and a subcarrier in frequency. A signal may be allocatable and/or allocated to a resource element. A subcarrier may be a subband of a carrier, e.g. as defined by a standard. A carrier may define a frequency and/or frequency band for transmission and/or reception. In some variants, a signal (jointly encoded/modulated) may cover more than one resource elements. A resource element may generally be as defined by a corresponding standard, e.g. NR or LTE. As symbol time length and/or subcarrier spacing (and/or numerology) may be different between different symbols and/or subcarriers, different resource elements may have different extension (length/width) in time and/or frequency domain, in particular resource elements pertaining to different carriers. 1965 1970

A resource generally may represent a time-frequency and/or code resource, on which signalling, e.g. according to a specific format, may be communicated, for example transmitted and/or received, and/or be intended for transmission and/or reception. 1975

A border symbol may generally represent a starting symbol or an ending symbol for transmitting and/or receiving. A starting symbol may in particular be a starting symbol of uplink or sidelink signalling, for example control signalling or data signalling. Such signalling may be on a data channel or control channel, e.g. a physical channel, in particular a physical uplink shared channel (like PUSCH) or a sidelink data or shared channel, or a physical uplink control channel (like PUCCH) or a sidelink control channel. If the starting symbol is associated to control signalling (e.g., on a control channel), the control signalling may be in response to received signalling (in sidelink or downlink), e.g. representing acknowledgement signalling associated thereto, which may be HARQ or ARQ signalling. An ending symbol may represent an ending symbol (in time) of downlink or sidelink transmission or signalling, which may be intended or scheduled for the radio node or user equipment. Such downlink signalling may in particular be data signalling, e.g. on a physical downlink channel like a shared channel, e.g. a PDSCH (Physical Downlink Shared Channel). A starting symbol may be determined based on, and/or in relation to, 1980 1985 1990

such an ending symbol.

Configuring a radio node, in particular a terminal or user equipment, may refer to the radio node being adapted or caused or set and/or instructed to operate according to the configuration. Configuring may be done by another device, e.g., a network node (for example, a radio node of the network like a base station or eNodeB) or network, in which case it may comprise transmitting configuration data to the radio node to be configured. Such configuration data may represent the configuration to be configured and/or comprise one or more instruction pertaining to a configuration, e.g. a configuration for transmitting and/or receiving on allocated resources, in particular frequency resources. A radio node may configure itself, e.g., based on configuration data received from a network or network node. A network node may utilise, and/or be adapted to utilise, its circuitry/ies for configuring. Allocation information may be considered a form of configuration data. Configuration data may comprise and/or be represented by configuration information, and/or one or more corresponding indications and/or message/s

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Generally, configuring may include determining configuration data representing the configuration and providing, e.g. transmitting, it to one or more other nodes (parallel and/or sequentially), which may transmit it further to the radio node (or another node, which may be repeated until it reaches the wireless device). Alternatively, or additionally, configuring a radio node, e.g., by a network node or other device, may include receiving configuration data and/or data pertaining to configuration data, e.g., from another node like a network node, which may be a higher-level node of the network, and/or transmitting received configuration data to the radio node. Accordingly, determining a configuration and transmitting the configuration data to the radio node may be performed by different network nodes or entities, which may be able to communicate via a suitable interface, e.g., an X2 interface in the case of LTE or a corresponding interface for NR. Configuring a terminal may comprise scheduling downlink and/or uplink transmissions for the terminal, e.g. downlink data and/or downlink control signalling and/or DCI and/or uplink control or data or communication signalling, in particular acknowledgement signalling, and/or configuring resources and/or a resource pool therefor.

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A resource structure may be considered to be neighboured in frequency domain by another resource structure, if they share a common border frequency, e.g. one as an upper frequency border and the other as a lower frequency border. Such a border may for example be represented by the upper end of a bandwidth assigned to a subcarrier n , which also represents the lower end of a bandwidth assigned to a subcarrier $n+1$. A resource structure may be considered to be neighboured in time domain by another resource structure, if they share a common border time, e.g. one as an upper (or right in the figures)

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border and the other as a lower (or left in the figures) border. Such a border may for example be represented by the end of the symbol time interval assigned to a symbol n , which also represents the beginning of a symbol time interval assigned to a symbol $n+1$.

Generally, a resource structure being neighboured by another resource structure in a domain may also be referred to as abutting and/or bordering the other resource structure in the domain.

A resource structure may general represent a structure in time and/or frequency domain, in particular representing a time interval and a frequency interval. A resource structure may comprise and/or be comprised of resource elements, and/or the time interval of a resource structure may comprise and/or be comprised of symbol time interval/s, and/or the frequency interval of a resource structure may comprise and/or be comprised of sub-carrier/s. A resource element may be considered an example for a resource structure, a slot or mini-slot or a Physical Resource Block (PRB) or parts thereof may be considered others. A resource structure may be associated to a specific channel, e.g. a PUSCH or PUCCH, in particular resource structure smaller than a slot or PRB.

Examples of a resource structure in frequency domain comprise a bandwidth or band, or a bandwidth part. A bandwidth part may be a part of a bandwidth available for a radio node for communicating, e.g. due to circuitry and/or configuration and/or regulations and/or a standard. A bandwidth part may be configured or configurable to a radio node. In some variants, a bandwidth part may be the part of a bandwidth used for communicating, e.g. transmitting and/or receiving, by a radio node. The bandwidth part may be smaller than the bandwidth (which may be a device bandwidth defined by the circuitry/configuration of a device, and/or a system bandwidth, e.g. available for a RAN). It may be considered that a bandwidth part comprises one or more resource blocks or resource block groups, in particular one or more PRBs or PRB groups. A bandwidth part may pertain to, and/or comprise, one or more carriers.

A carrier may generally represent a frequency range or band and/or pertain to a central frequency and an associated frequency interval. It may be considered that a carrier comprises a plurality of subcarriers. A carrier may have assigned to it a central frequency or center frequency interval, e.g. represented by one or more subcarriers (to each subcarrier there may be generally assigned a frequency bandwidth or interval). Different carriers may be non-overlapping, and/or may be neighbouring in frequency domain.

It should be noted that the term “radio” in this disclosure may be considered to pertain to wireless communication in general, and may also include wireless communication utilising millimeter waves, in particular above one of the thresholds 10 GHz or 20 GHz or 50 GHz or

52 GHz or 52.6 GHz or 60 GHz or 72 GHz or 100 GHz or 114 GHz. Such communication may utilise one or more carriers, e.g. in FDD and/or carrier aggregation. Upper frequency boundaries may correspond to 300 GHz or 200 GHz or 120 GHz or any of the thresholds larger than the one representing the lower frequency boundary.

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A radio node, in particular a network node or a terminal, may generally be any device adapted for transmitting and/or receiving radio and/or wireless signals and/or data, in particular communication data, in particular on at least one carrier. The at least one carrier may comprise a carrier accessed based on an LBT procedure (which may be called LBT carrier), e.g., an unlicensed carrier. It may be considered that the carrier is part of a carrier aggregate.

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Receiving or transmitting on a cell or carrier may refer to receiving or transmitting utilizing a frequency (band) or spectrum associated to the cell or carrier. A cell may generally comprise and/or be defined by or for one or more carriers, in particular at least one carrier for UL communication/transmission (called UL carrier) and at least one carrier for DL communication/transmission (called DL carrier). It may be considered that a cell comprises different numbers of UL carriers and DL carriers. Alternatively, or additionally, a cell may comprise at least one carrier for UL communication/transmission and DL communication/transmission, e.g., in TDD-based approaches.

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A channel may generally be a logical, transport or physical channel. A channel may comprise and/or be arranged on one or more carriers, in particular a plurality of subcarriers. A channel carrying and/or for carrying control signalling/control information may be considered a control channel, in particular if it is a physical layer channel and/or if it carries control plane information. Analogously, a channel carrying and/or for carrying data signalling/user information may be considered a data channel, in particular if it is a physical layer channel and/or if it carries user plane information. A channel may be defined for a specific communication direction, or for two complementary communication directions (e.g., UL and DL, or sidelink in two directions), in which case it may be considered to have two component channels, one for each direction. Examples of channels comprise a channel for low latency and/or high reliability transmission, in particular a channel for Ultra-Reliable Low Latency Communication (URLLC), which may be for control and/or data.

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In general, a symbol may represent and/or be associated to a symbol time length, which may be dependent on the carrier and/or subcarrier spacing and/or numerology of the associated carrier. Accordingly, a symbol may be considered to indicate a time interval having a symbol time length in relation to frequency domain. A symbol time length may be dependent on a carrier frequency and/or bandwidth and/or numerology and/or

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subcarrier spacing of, or associated to, a symbol. Accordingly, different symbols may have different symbol time lengths. In particular, numerologies with different subcarrier spacings may have different symbol time length. Generally, a symbol time length may be based on, and/or include, a guard time interval or cyclic extension, e.g. prefix or postfix.

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A sidelink may generally represent a communication channel (or channel structure) between two UEs and/or terminals, in which data is transmitted between the participants (UEs and/or terminals) via the communication channel, e.g. directly and/or without being relayed via a network node. A sidelink may be established only and/or directly via air interface/s of the participant, which may be directly linked via the sidelink communication channel. In some variants, sidelink communication may be performed without interaction by a network node, e.g. on fixedly defined resources and/or on resources negotiated between the participants. Alternatively, or additionally, it may be considered that a network node provides some control functionality, e.g. by configuring resources, in particular one or more resource pool/s, for sidelink communication, and/or monitoring a sidelink, e.g. for charging purposes.

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Sidelink communication may also be referred to as device-to-device (D2D) communication, and/or in some cases as ProSe (Proximity Services) communication, e.g. in the context of LTE. A sidelink may be implemented in the context of V2x communication (Vehicular communication), e.g. V2V (Vehicle-to-Vehicle), V2I (Vehicle-to-Infrastructure) and/or V2P (Vehicle-to-Person). Any device adapted for sidelink communication may be considered a user equipment or terminal.

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A sidelink communication channel (or structure) may comprise one or more (e.g., physical or logical) channels, e.g. a PSCCH (Physical Sidelink Control CHannel, which may for example carry control information like an acknowledgement position indication, and/or a PSSCH (Physical Sidelink Shared CHannel, which for example may carry data and/or acknowledgement signalling). It may be considered that a sidelink communication channel (or structure) pertains to and/or used one or more carrier/s and/or frequency range/s associated to, and/or being used by, cellular communication, e.g. according to a specific license and/or standard. Participants may share a (physical) channel and/or resources, in particular in frequency domain and/or related to a frequency resource like a carrier) of a sidelink, such that two or more participants transmit thereon, e.g. simultaneously, and/or time-shifted, and/or there may be associated specific channels and/or resources to specific participants, so that for example only one participant transmits on a specific channel or on a specific resource or specific resources, e.g., in frequency domain and/or related to one or more carriers or subcarriers.

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A sidelink may comply with, and/or be implemented according to, a specific standard,

e.g. an LTE-based standard and/or NR. A sidelink may utilise TDD (Time Division Duplex) and/or FDD (Frequency Division Duplex) technology, e.g. as configured by a network node, and/or preconfigured and/or negotiated between the participants. A user equipment may be considered to be adapted for sidelink communication if it, and/or its radio circuitry and/or processing circuitry, is adapted for utilising a sidelink, e.g. on one or more frequency ranges and/or carriers and/or in one or more formats, in particular according to a specific standard. It may be generally considered that a Radio Access Network is defined by two participants of a sidelink communication. Alternatively, or additionally, a Radio Access Network may be represented, and/or defined with, and/or be related to a network node and/or communication with such a node.

Communication or communicating may generally comprise transmitting and/or receiving signalling. Communication on a sidelink (or sidelink signalling) may comprise utilising the sidelink for communication (respectively, for signalling). Sidelink transmission and/or transmitting on a sidelink may be considered to comprise transmission utilising the sidelink, e.g. associated resources and/or transmission formats and/or circuitry and/or the air interface. Sidelink reception and/or receiving on a sidelink may be considered to comprise reception utilising the sidelink, e.g. associated resources and/or transmission formats and/or circuitry and/or the air interface. Sidelink control information (e.g., SCI) may generally be considered to comprise control information transmitted utilising a sidelink.

Generally, carrier aggregation (CA) may refer to the concept of a radio connection and/or communication link between a wireless and/or cellular communication network and/or network node and a terminal or on a sidelink comprising a plurality of carriers for at least one direction of transmission (e.g. DL and/or UL), as well as to the aggregate of carriers. A corresponding communication link may be referred to as carrier aggregated communication link or CA communication link; carriers in a carrier aggregate may be referred to as component carriers (CC). In such a link, data may be transmitted over more than one of the carriers and/or all the carriers of the carrier aggregation (the aggregate of carriers). A carrier aggregation may comprise one (or more) dedicated control carriers and/or primary carriers (which may e.g. be referred to as primary component carrier or PCC), over which control information may be transmitted, wherein the control information may refer to the primary carrier and other carriers, which may be referred to as secondary carriers (or secondary component carrier, SCC). However, in some approaches, control information may be sent over more than one carrier of an aggregate, e.g. one or more PCCs and one PCC and one or more SCCs.

A transmission may generally pertain to a specific channel and/or specific resources,

in particular with a starting symbol and ending symbol in time, covering the interval 2170
therebetween. A scheduled transmission may be a transmission scheduled and/or expected
and/or for which resources are scheduled or provided or reserved. However, not every
scheduled transmission has to be realized. For example, a scheduled downlink transmission
may not be received, or a scheduled uplink transmission may not be transmitted due to 2175
power limitations, or other influences (e.g., a channel on an unlicensed carrier being
occupied). A transmission may be scheduled for a transmission timing substructure (e.g.,
a mini-slot, and/or covering only a part of a transmission timing structure) within a
transmission timing structure like a slot. A border symbol may be indicative of a symbol
in the transmission timing structure at which the transmission starts or ends.

Predefined in the context of this disclosure may refer to the related information being 2180
defined for example in a standard, and/or being available without specific configuration
from a network or network node, e.g. stored in memory, for example independent of being
configured. Configured or configurable may be considered to pertain to the corresponding
information being set/configured, e.g. by the network or a network node.

A configuration or schedule, like a mini-slot configuration and/or structure configuration, 2185
may schedule transmissions, e.g. for the time/transmissions it is valid, and/or transmis-
sions may be scheduled by separate signalling or separate configuration, e.g. separate RRC
signalling and/or downlink control information signalling. The transmission/s scheduled
may represent signalling to be transmitted by the device for which it is scheduled, or
signalling to be received by the device for which it is scheduled, depending on which side 2190
of a communication the device is. It should be noted that downlink control information
or specifically DCI signalling may be considered physical layer signalling, in contrast to
higher layer signalling like MAC (Medium Access Control) signalling or RRC layer sig-
nalling. The higher the layer of signalling is, the less frequent/the more time/resource
consuming it may be considered, at least partially due to the information contained in such 2195
signalling having to be passed on through several layers, each layer requiring processing
and handling.

A scheduled transmission, and/or transmission timing structure like a mini-slot or slot,
may pertain to a specific channel, in particular a physical uplink shared channel, a physical
uplink control channel, or a physical downlink shared channel, e.g. PUSCH, PUCCH or 2200
PDSCH, and/or may pertain to a specific cell and/or carrier aggregation. A correspond-
ing configuration, e.g. scheduling configuration or symbol configuration may pertain to
such channel, cell and/or carrier aggregation. It may be considered that the scheduled
transmission represents transmission on a physical channel, in particular a shared phys-
ical channel, for example a physical uplink shared channel or physical downlink shared 2205

channel. For such channels, semi-persistent configuring may be particularly suitable.

Generally, a configuration may be a configuration indicating timing, and/or be represented or configured with corresponding configuration data. A configuration may be embedded in, and/or comprised in, a message or configuration or corresponding data, which may indicate and/or schedule resources, in particular semi-persistently and/or semi-statically.

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A control region of a transmission timing structure may be an interval in time and/or frequency domain for intended or scheduled or reserved for control signalling, in particular downlink control signalling, and/or for a specific control channel, e.g. a physical downlink control channel like PDCCH. The interval may comprise, and/or consist of, a number of symbols in time, which may be configured or configurable, e.g. by (UE-specific) dedicated signalling (which may be single-cast, for example addressed to or intended for a specific UE), e.g. on a PDCCH, or RRC signalling, or on a multicast or broadcast channel. In general, the transmission timing structure may comprise a control region covering a configurable number of symbols. It may be considered that in general the border symbol is configured to be after the control region in time. A control region may be associated, e.g. via configuration and/or determination, to one or more specific UEs and/or formats of PDCCH and/or DCI and/or identifiers, e.g. UE identifiers and/or RNTIs or carrier/cell identifiers, and/or be represented and/or associated to a CORESET and/or a search space.

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The duration of a symbol (symbol time length or interval) of the transmission timing structure may generally be dependent on a numerology and/or carrier, wherein the numerology and/or carrier may be configurable. The numerology may be the numerology to be used for the scheduled transmission.

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A transmission timing structure may comprise a plurality of symbols, and/or define an interval comprising several symbols (respectively their associated time intervals). In the context of this disclosure, it should be noted that a reference to a symbol for ease of reference may be interpreted to refer to the time domain projection or time interval or time component or duration or length in time of the symbol, unless it is clear from the context that the frequency domain component also has to be considered. Examples of transmission timing structures include slot, subframe, mini-slot (which also may be considered a substructure of a slot), slot aggregation (which may comprise a plurality of slots and may be considered a superstructure of a slot), respectively their time domain component. A transmission timing structure may generally comprise a plurality of symbols defining the time domain extension (e.g., interval or length or duration) of the transmission timing structure, and arranged neighboring to each other in a numbered sequence. A timing structure (which may also be considered or implemented as synchronisation structure)

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may be defined by a succession of such transmission timing structures, which may for example define a timing grid with symbols representing the smallest grid structures. A transmission timing structure, and/or a border symbol or a scheduled transmission may be determined or scheduled in relation to such a timing grid. A transmission timing structure of reception may be the transmission timing structure in which the scheduling control signalling is received, e.g. in relation to the timing grid. A transmission timing structure may in particular be a slot or subframe or in some cases, a mini-slot. 2245

Feedback signalling may be considered a form of control signalling, e.g. uplink or sidelink control signalling, like UCI (Uplink Control Information) signalling or SCI (Sidelink Control Information) signalling. Feedback signalling may in particular comprise and/or represent acknowledgement signalling and/or acknowledgement information and/or measurement reporting. 2250

signalling utilising, and/or on and/or associated to, resources or a resource structure may be signalling covering the resources or structure, signalling on the associated frequency/ies and/or in the associated time interval/s. It may be considered that a signalling resource structure comprises and/or encompasses one or more substructures, which may be associated to one or more different channels and/or types of signalling and/or comprise one or more holes (resource element/s not scheduled for transmissions or reception of transmissions). A resource substructure, e.g. a feedback resource structure, may generally be continuous in time and/or frequency, within the associated intervals. It may be considered that a substructure, in particular a feedback resource structure, represents a rectangle filled with one or more resource elements in time/frequency space. However, in some cases, a resource structure or substructure, in particular a frequency resource range, may represent a non-continuous pattern of resources in one or more domains, e.g. time and/or frequency. The resource elements of a substructure may be scheduled for associated signalling. 2255 2260 2265

Example types of signalling comprise signalling of a specific communication direction, in particular, uplink signalling, downlink signalling, sidelink signalling, as well as reference signalling (e.g., SRS or CRS or CSI-RS), communication signalling, control signalling, and/or signalling associated to a specific channel like PUSCH, PDSCH, PUCCH, PDCCH, PSCCH, PSSCH, etc.). 2270

In the context of this disclosure, there may be distinguished between dynamically scheduled or aperiodic transmission and/or configuration, and semi-static or semi-persistent or periodic transmission and/or configuration. The term “dynamic” or similar terms may generally pertain to configuration/transmission valid and/or scheduled and/or configured for (relatively) short timescales and/or a (e.g., predefined and/or configured and/or lim- 2275

ited and/or definite) number of occurrences and/or transmission timing structures, e.g. one or more transmission timing structures like slots or slot aggregations, and/or for one or more (e.g., specific number) of transmission/occurrences. Dynamic configuration may be based on low-level signalling, e.g. control signalling on the physical layer and/or MAC layer, in particular in the form of DCI or SCI. Periodic/semi-static may pertain to longer timescales, e.g. several slots and/or more than one frame, and/or a non-defined number of occurrences, e.g., until a dynamic configuration contradicts, or until a new periodic configuration arrives. A periodic or semi-static configuration may be based on, and/or be configured with, higher-layer signalling, in particular RCL layer signalling and/or RRC signalling and/or MAC signalling.

In this disclosure, for purposes of explanation and not limitation, specific details are set forth (such as particular network functions, processes and signalling steps) in order to provide a thorough understanding of the technique presented herein. It will be apparent to one skilled in the art that the present concepts and aspects may be practised in other variants and variants that depart from these specific details.

For example, the concepts and variants are partially described in the context of Long Term Evolution (LTE) or LTE-Advanced (LTE-A) or New Radio mobile or wireless communications technologies; however, this does not rule out the use of the present concepts and aspects in connection with additional or alternative mobile communication technologies such as the Global System for Mobile Communications (GSM) or IEEE standards as IEEE 802.11ad or IEEE 802.11 ay. While described variants may pertain to certain Technical Specifications (TSs) of the Third Generation Partnership Project (3GPP), it will be appreciated that the present approaches, concepts and aspects could also be realized in connection with different Performance Management (PM) specifications.

Moreover, those skilled in the art will appreciate that the services, functions and steps explained herein may be implemented using software functioning in conjunction with a programmed microprocessor, or using an Application Specific Integrated Circuit (ASIC), a Digital Signal Processor (DSP), a Field Programmable Gate Array (FPGA) or general purpose computer. It will also be appreciated that while the variants described herein are elucidated in the context of methods and devices, the concepts and aspects presented herein may also be embodied in a program product as well as in a system comprising control circuitry, e.g. a computer processor and a memory coupled to the processor, wherein the memory is encoded with one or more programs or program products that execute the services, functions and steps disclosed herein.

It is believed that the advantages of the aspects and variants presented herein will be fully understood from the foregoing description, and it will be apparent that various changes

may be made in the form, constructions and arrangement of the exemplary aspects thereof without departing from the scope of the concepts and aspects described herein or without sacrificing all of its advantageous effects. The aspects presented herein can be varied in many ways.

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Some useful abbreviations comprise

Abbreviation	Explanation
ABF	Analog beamformer, fanout to antenna+beamforming
ACK/NACK	Acknowledgment/Negative Acknowledgement
Ant	Antenna
ARQ	Automatic Repeat reQuest
BB	BaseBand
Beamindex IF	beamindex interface
BER	Bit Error Rate
BI	Beam Index
BLER	Block Error Rate
BPSK	Binary Phase Shift Keying
BWP	BandWidth Part
CAZAC	Constant Amplitude Zero Cross Correlation
CB	Code Block
CBB	Code Block Bundle
CBG	Code Block Group
CDM	Code Division Multiplex
CM	Cubic Metric
Comm RXBB	communication receiver baseband
CORESET	Control Resource Set
CP	Cyclic Prefix
CP rem	CP removal
CQI	Channel Quality Information
CRC	Cyclic Redundancy Check
CRS	Common reference signal
CSI	Channel State Information
CSI-RS	Channel state information reference signal
DAI	Downlink Assignment Indicator
DCI	Downlink Control Information
DFE	Digital Frontend
DFT	Discrete Fourier Transform
DFTS-FDM	DFT-spread-FDM
DM(-)RS	Demodulation reference signal(ing)
eMBB	enhanced Mobile BroadBand
FDD	Frequency Division Duplex
FDE	Frequency Domain Equalisation

FDF	Frequency Domain Filtering
FDM	Frequency Division Multiplex
FFT	Fast Fourier Transform
GPIO	General Purpose Input Output
HARQ	Hybrid Automatic Repeat Request
IAB	Integrated Access and Backhaul
IFFT	Inverse Fast Fourier Transform
Im	Imaginary part, e.g. for $\pi/2$ -BPSK modulation
IR	Impulse Response
ISI	Inter Symbol Interference
JCAS	Joint Communication and Sensing
MBB	Mobile Broadband
MCS	Modulation and Coding Scheme
MIMO	Multiple-input-multiple-output
MRC	Maximum-ratio combining
MRT	Maximum-ratio transmission
MU-MIMO	Multiuser multiple-input-multiple-output
OFDM/A	Orthogonal Frequency Division Multiplex/Multiple Access
PAPR	Peak to Average Power Ratio
PDCCH	Physical Downlink Control Channel
PDSCH	Physical Downlink Shared Channel
PRACH	Physical Random Access CHannel
PRB	Physical Resource Block
PUCCH	Physical Uplink Control Channel
PUSCH	Physical Uplink Shared Channel
(P)SCCH	(Physical) Sidelink Control Channel
PSS	Primary Synchronisation Signal(ing)
PT-RS	Phase Tracking Reference signalling
(P)SSCH	(Physical) Sidelink Shared Channel
QAM	Quadrature Amplitude Modulation
OCC	Orthogonal Cover Code
QPSK	Quadrature Phase Shift Keying
PSD	Power Spectral Density
RAN	Radio Access Network
RAT	Radio Access Technology
RB	Resource Block
RE	Resource Element
Re	Real part (e.g., for $\pi/2$ -BPSK) modulation

RF	Radio Frequency
RNTI	Radio Network Temporary Identifier
RRC	Radio Resource Control
RX	Receiver, Reception, Reception-related/side
SA	Scheduling Assignment
SC-FDE	Single Carrier Frequency Domain Equalisation
SC-FDM/A	Single Carrier Frequency Division Multiplex/Multiple Access
SCI	Sidelink Control Information
SINR	Signal-to-interference-plus-noise ratio
SIR	Signal-to-interference ratio
SNR	Signal-to-noise-ratio
SPI	Serial to Parallel Interface
SR	Scheduling Request
SRS	Sounding Reference Signal(ing)
SSS	Secondary Synchronisation Signal(ing)
SVD	Singular-value decomposition
TB	Transport Block
TDD	Time Division Duplex
TDM	Time Division Multiplex
T-RS	Tracking Reference signalling or Timing Reference signalling
TX	Transmitter, Transmission, Transmission-related/side
UCI	Uplink Control Information
UDC	Up-Down Converter, mixing from BB _i - $\downarrow$ RF
UE	User Equipment
URLLC	Ultra Low Latency High Reliability Communication
VL-MIMO	Very-large multiple-input-multiple-output
WD	Wireless Device
Wfg	Waveform Generator
ZC	Zadoff-Chu
ZF	Zero Forcing
ZP	Zero-Power, e.g. muted CSI-RS symbol

Abbreviations may be considered to follow 3GPP usage if applicable.

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CLAIMS

1. Method of operating a radio node in a wireless communication network, the radio node being adapted for wireless communication utilising communication signalling based on a first symbol duration $T1$, and being adapted for sensing and/or radar operation, the method comprising performing a sensing operation based on sensing signalling, the sensing signalling being based on a second symbol duration $T2$, wherein $T2 > T1$ and the sensing signalling comprises M symbols having second symbol duration $T2$, wherein M is an integer number of at least 1, wherein $M \times T2 = N \times T1$, wherein N is an integer number larger than 1. 2325
2. Radio node for a wireless communication network, the radio node being adapted for wireless communication utilising communication signalling based on a first symbol duration $T1$, and being adapted for sensing and/or radar operation, the radio node being adapted for performing a sensing operation based on sensing signalling, the sensing signalling being based on a second symbol duration $T2$, wherein $T2 > T1$ and the sensing signalling comprises M symbols having second symbol duration $T2$, wherein M is an integer number of at least 1, wherein $M \times T2 = N \times T1$, wherein N is an integer number larger than 1. 2330 2335
3. Method or device according to one of the preceding claims, wherein the first symbol duration is based on a first cyclic prefix duration $TC1$, and the second symbol duration is based on a second cyclic prefix duration $TC2$, wherein $TC2 > TC1$. 2340
4. Method or device according to one of the preceding claims, wherein the first symbol duration is based on a first symbol proper duration $TP1$, and the second symbol duration is based on a second symbol proper duration $TP2$, wherein $TP2 > TP1$ or $TP2 = TP1$.
5. Method or device according to one of the preceding claims, wherein the M symbols comprise $M1$ sensing symbols, and/or $M2$ communication symbols, and/or $M3$ guard symbols, wherein $M = M1 + M2 + M3$, wherein $M1$ may be zero or an integer number of 1 or larger, and/or $M2$ may be zero or an integer number of 1 or larger, and/or $M3$ may be zero or an integer number of 1 or larger. 2345
6. Method or device according to one of the preceding claims, wherein the first symbol duration $T1$ and/or the second symbol duration $T2$ is based on a numerology configured for communication signalling. 2350
7. Method or device according to one of the preceding claims, wherein performing a sensing operation comprises transmitting and/or receiving, and/or monitoring for, the sensing signalling.

8. Method or device according to one of the preceding claims, where the radio node is a network node, or a wireless device. 2355
9. Method or device according to one of the preceding claims, wherein the second symbol duration T2 is based on, and/or corresponds to a range for a sensing operation.
10. Method or device according to one of the preceding claims, wherein the second symbol duration T2, and/or a second cyclic prefix duration TC2, is configured and/or configurable and/or predefined. 2360
11. Program product comprising instructions causing processing circuitry to control and/or perform a method according to one of claims 1, or 3 to 10.
12. Carrier medium arrangement carrying and/or storing a program product according to claim 11. 2365

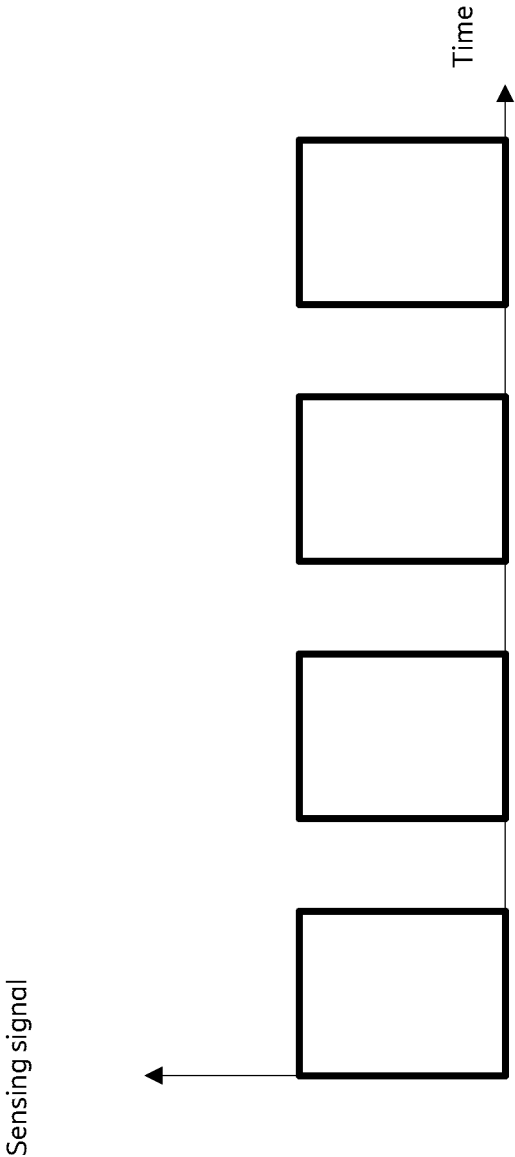


Fig. 1

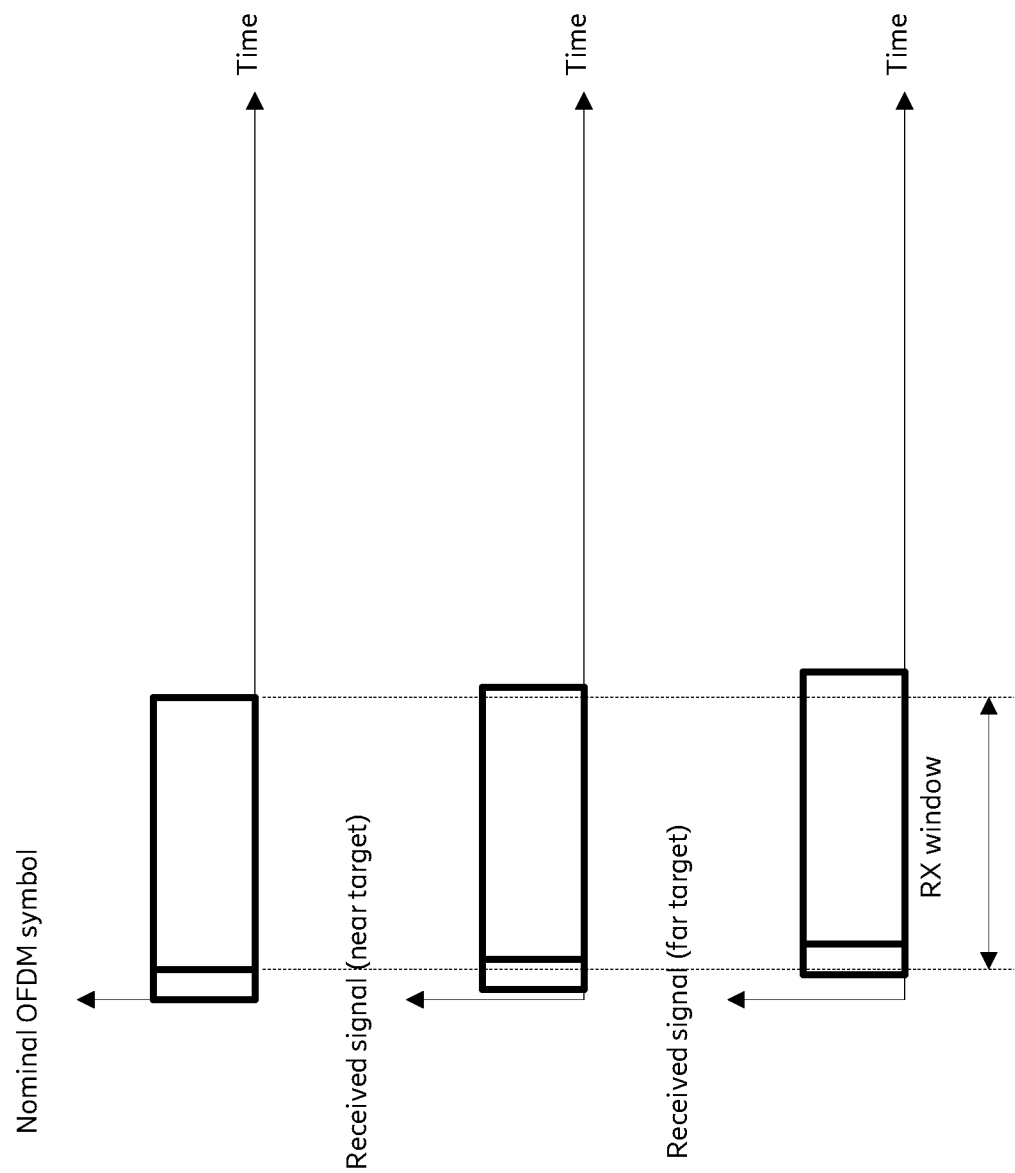


Fig. 2

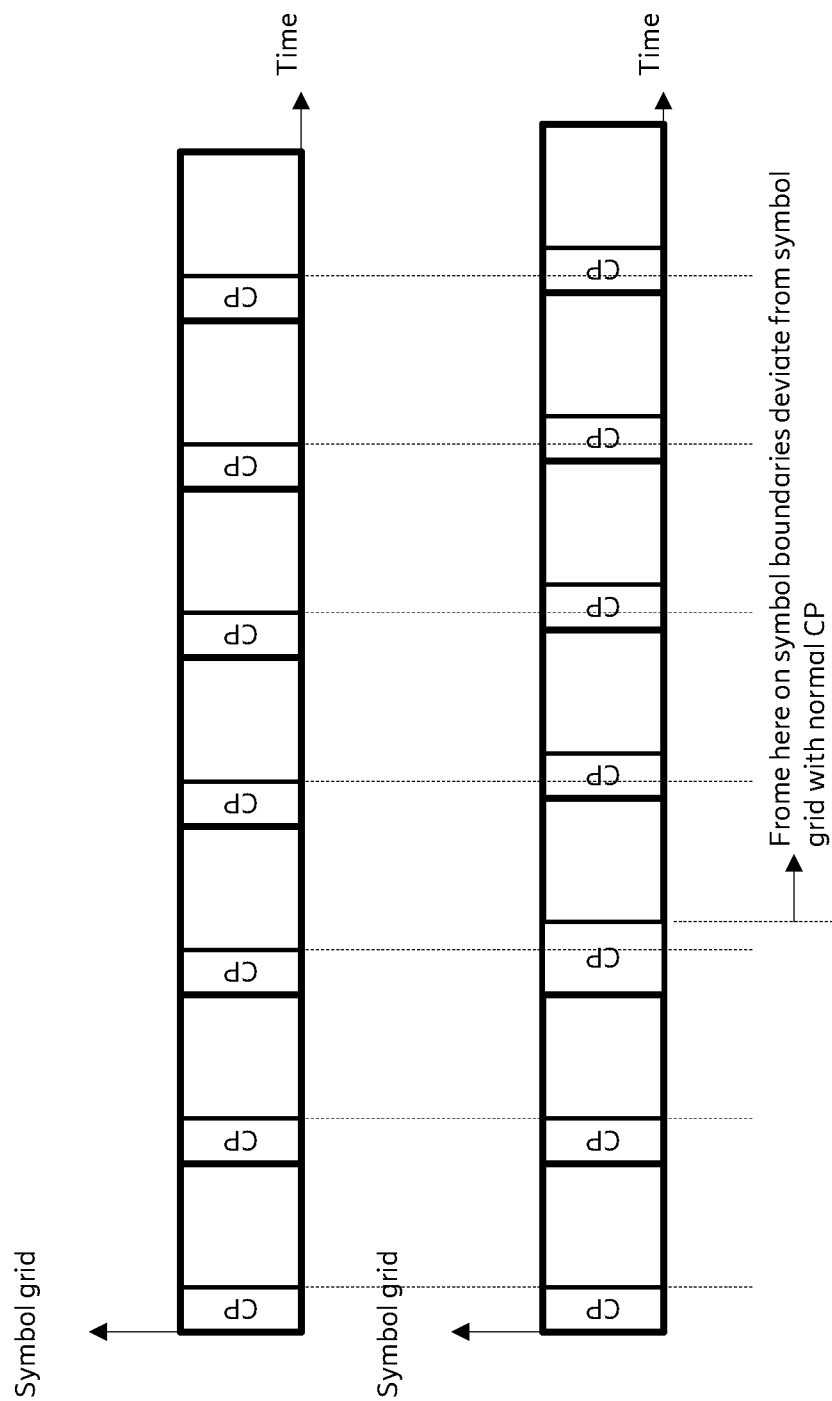


Fig. 3

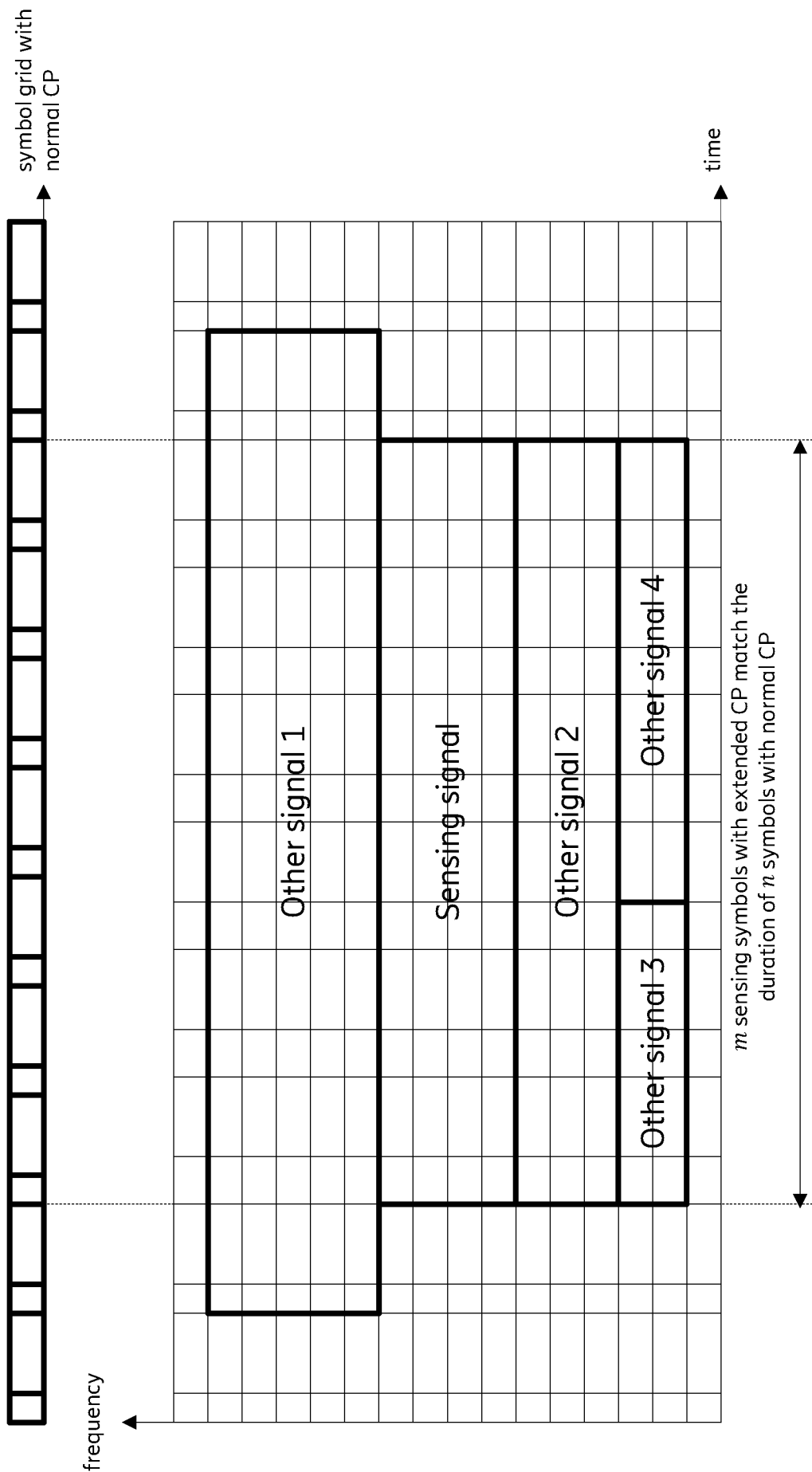


Fig. 4

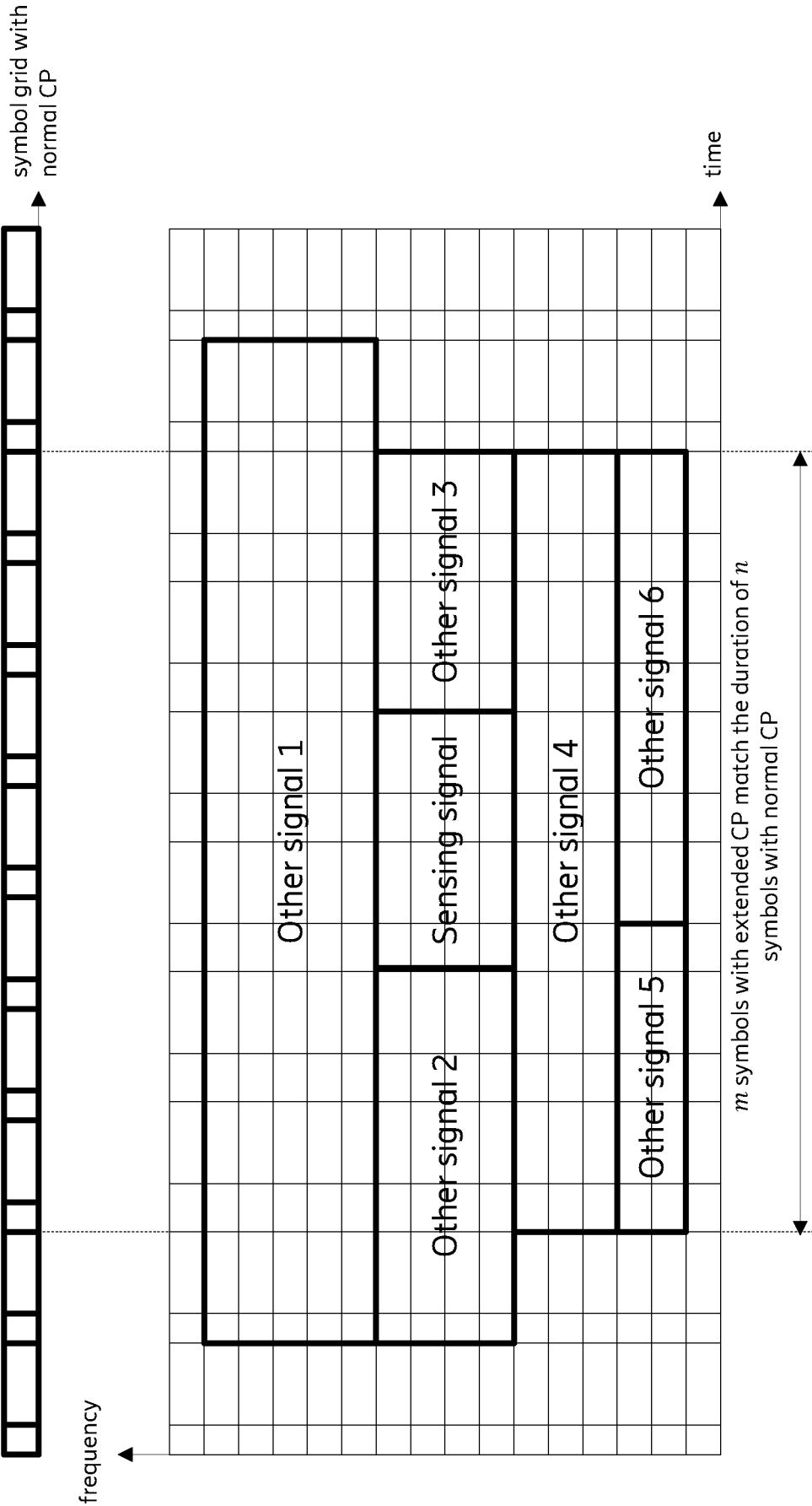


Fig. 5

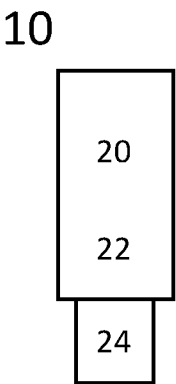


Fig. 6

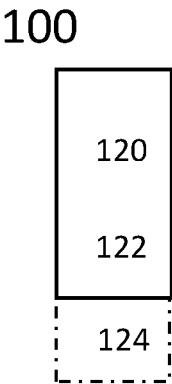


Fig. 7

INTERNATIONAL SEARCH REPORT

International application No

PCT/SE2023/050495

A. CLASSIFICATION OF SUBJECT MATTER

INV. G01S7/00 H04L27/26

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)

G01S H04L

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	WO 2023/080815 A1 (ERICSSON TELEFON AB L M [SE]) 11 May 2023 (2023-05-11) figures 8, 9 page 4, lines 18-21 page 7, lines 8-10 page 22, lines 29-30 pages 23, 24 pages 19, 20 -----	1-12
A	US 2021/286045 A1 (BAYESTEH ALIREZA [CA] ET AL) 16 September 2021 (2021-09-16) paragraphs [0058] - [0061], [0109] - [0114], [0118], [0260] -----	1-12



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

13 November 2023

Date of mailing of the international search report

29/11/2023

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/SE2023/050495

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2023080815	A1	11-05-2023	NONE

US 2021286045	A1	16-09-2021	CN 115280176 A 01-11-2022
		EP 4107542 A1 28-12-2022	
		US 2021286045 A1 16-09-2021	
		US 2023112477 A1 13-04-2023	
		WO 2021180210 A1 16-09-2021	
