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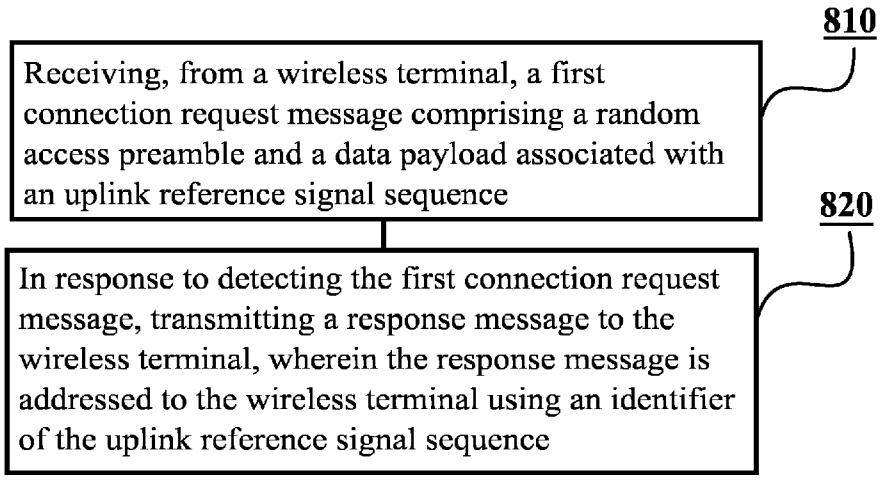



FIGURE 8

(57) Abstract: According to an example aspect of the present invention, there is provided a method comprising, receiving, from a wireless terminal, a first connection request message comprising a random access preamble and a data payload associated with an uplink reference signal sequence and in response to detecting the first connection request message, transmitting a response message to the wireless terminal, wherein the response message is addressed to the wireless terminal using an identifier of the uplink reference signal sequence.

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# RANDOM ACCESS IN WIRELESS COMMUNICATION NETWORKS

## FIELD

**[0001]** Various example embodiments relate in general to wireless communication networks, and random access in such networks.

## BACKGROUND

**[0002]** Random access may be used to access a wireless communication network, e.g., to request a dedicated channel to be arranged for a wireless terminal requesting the access. Random access procedures may be divided into two types on a general level. In case of contention-free random access, a random access resource may be designated to one wireless terminal. On the other hand, in case of contention-based random access a resource that is used for random access may be shared between several wireless terminals. Therefore, if multiple wireless terminals try to use the same, shared random access resource at the same time, collisions may occur and delay the random access process. Collisions may thus cause problems, especially when operating on unlicensed spectrum, because typically it is desirable to minimize delays to ensure good performance of wireless communication networks. Consequently there is a need to provide improvements for random access in wireless communication networks.

## SUMMARY

**[0003]** According to some aspects, there is provided the subject-matter of the independent claims. Some embodiments are defined in the dependent claims.

**[0004]** According to a first aspect, there is provided a first method comprising receiving, from a wireless terminal, a first connection request message comprising a random access preamble and a data payload associated with an uplink reference signal sequence and in response to detecting the first connection request message, transmitting a response message to the wireless terminal, wherein the response message is addressed to the wireless terminal using an identifier of the uplink reference signal sequence.

**[0005]** According to the first aspect, the response message may comprise the identifier of the uplink reference signal sequence.

**[0006]** According to the first aspect, the selected uplink reference signal sequence may be a demodulation reference signal sequence.

**[0007]** According to the first aspect, the response message may comprise an identifier of the random access preamble, and the method may further comprise addressing the response message to the wireless terminal using the identifier of the uplink reference signal and the identifier of the random access preamble.

**[0008]** According to the first aspect, the first method may further comprise detecting the random access preamble and the uplink reference signal successfully, detecting that decoding of the data payload associated with the uplink reference signal sequence was not successful and wherein transmitting comprises transmitting a random access response message to the wireless terminal, wherein the random access response message is addressed to the wireless terminal using the identifier of the uplink reference signal sequence.

**[0009]** According to the first aspect, the first method may further comprise, in response to transmitting a random access response message, receiving from the wireless terminal a second connection request message comprising at least part of the data payload associated with the uplink reference signal.

**[0010]** According to a second aspect, there is provided a second method comprising selecting a random access preamble and an uplink reference signal sequence for random access, transmitting a first connection request message comprising the selected random access preamble and a data payload associated with the selected uplink reference signal sequence and receiving a response message, wherein the response message is addressed to the wireless terminal using the selected uplink reference signal sequence.

**[0011]** According to the second aspect, the second method may further comprise identifying that the response message was addressed to the wireless terminal using the identifier of the uplink reference signal sequence.

**[0012]** According to the second aspect, the response message may comprise the identifier of the selected uplink reference signal sequence.

**[0013]** According to the second aspect, the selected uplink reference signal sequence may be a demodulation reference signal sequence.

**[0014]** According to the second aspect, the response message may comprise an identifier of the random access preamble, and the second method may further comprise identifying that the response message was addressed to the wireless terminal using the identifier of the uplink reference signal sequence and the identifier of the random access preamble.

**[0015]** According to the second aspect, the second method may further comprise selecting the uplink reference signal sequence randomly among a set of configured uplink reference signal sequences.

**[0016]** According to the second aspect, the second method may further comprise, wherein the response message is addressed to the wireless terminal using the identifier of the uplink reference signal sequence and in response to receiving the response message, continuing with a 4-step random access procedure by transmitting a second connection request message comprising at least part of the data payload associated with the uplink reference signal.

**[0017]** According to a third aspect of the present invention, there is provided an apparatus comprising at least one processing core, at least one memory including computer program code, the at least one memory and the computer program code being configured to, with the at least one processing core, cause the apparatus at least to perform the first method.

**[0018]** According to a fourth aspect of the present invention, there is provided an apparatus comprising at least one processing core, at least one memory including computer program code, the at least one memory and the computer program code being configured to, with the at least one processing core, cause the apparatus at least to perform the second method.

**[0019]** According to a fifth aspect of the present invention, there is provided an apparatus comprising means for performing the first method. According to a sixth aspect of the present invention, there is provided an apparatus comprising means for performing the second method.

**[0020]** According to a seventh aspect of the present invention, there is provided non-transitory computer readable medium having stored thereon a set of computer readable instructions that, when executed by at least one processor, cause an apparatus to at least perform the first method. According to an eighth aspect of the present invention, there is provided non-transitory computer readable medium having stored thereon a set of computer readable instructions that, when executed by at least one processor, cause an apparatus to at least perform the second method.

**[0021]** According to a ninth aspect of the present invention, there is provided a computer program configured to perform the first method. According to a tenth aspect of the present invention, there is provided a computer program configured to perform the second method.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0022]** FIGURE 1 illustrates an exemplary network scenario in accordance with at least some example embodiments;

**[0023]** FIGURE 2 illustrates an example of a 2-step random access procedure in accordance with at least some embodiments;

**[0024]** FIGURE 3 illustrates an example of a hybrid 2/4-step or a 4-step random access procedure in accordance with at least some embodiments;

**[0025]** FIGURE 4 illustrates an example apparatus capable of supporting at least some embodiments;

**[0026]** FIGURE 5 illustrates an example about the use of multiple uplink reference signal sequences in accordance with at least some embodiments;

**[0027]** FIGURE 6 illustrates an exemplary multiplexing of payloads in accordance with at least some embodiments;

**[0028]** FIGURE 7 illustrates an example payload in accordance with at least some embodiments;

**[0029]** FIGURE 8 illustrates a flow graph of a first method in accordance with at least some embodiments;

**[0030]** FIGURE 9 illustrates a flow graph of a second method in accordance with at least some embodiments.

## EMBODIMENTS

**[0031]** Random access in wireless communication networks may be improved by the procedures described herein. More specifically, a wireless network node may detect the transmission of a random access preamble and an uplink reference signal sequence successfully, even in the event that decoding an associated data payload associated with the uplink reference signal sequence was not successful. The wireless network node may thus transmit, in response to the detection, a response message to the connection request message, the response comprising an identifier of the uplink reference signal sequence.

**[0032]** The identifier of the uplink reference signal sequence may be used to address the response message to the wireless terminal, possibly together with an identifier of the random access preamble, thereby providing an extra degree of freedom for separating transmissions from different wireless terminals that have selected the same random access preamble.

**[0033]** FIGURE 1 illustrates an exemplary network scenario in accordance with at least some example embodiments. According to the example scenario of FIGURE 1, there may be a wireless communication system, which comprises one or more wireless terminals 110, wireless network node 120, and core network element 130. Wireless terminals 110 may be connected to BS 120 via air interface 115.

**[0034]** Wireless terminals 110 may comprise, for example, a User Equipment, UE, a smartphone, a cellular phone, a Machine-to-Machine, M2M, node, Machine-Type Communications node, MTC, an Internet of Things, IoT, node, a car telemetry unit, a laptop computer, a tablet computer or, indeed, another kind of suitable wireless terminal or mobile station. In the example system of FIGURE 1, wireless terminals 110 may communicate wirelessly with wireless network node 120, or with a cell of wireless network

node 120, via air interface 115. In some example embodiments, wireless network node 120 may be considered as a serving Base Station, BS, for wireless terminals 110.

**[0035]** Air interface 115 between wireless terminals 110 and BS 120 may be configured in accordance with a Radio Access Technology, RAT, which wireless terminals 110 and wireless network node 120 are configured to support. Examples of cellular RATs include Long Term Evolution, LTE, New Radio, NR, which may also be known as fifth generation, 5G, radio access technology and MulteFire. On the other hand, examples of non-cellular RATs include Wireless Local Area Network, WLAN, and Worldwide Interoperability for Microwave Access, WiMAX.

**[0036]** For example, in the context of LTE, wireless network node 120 may be referred to as eNB while in the context of NR, wireless network node 120 may be referred to as gNB. Wireless terminals 110 may be similarly referred to as UEs, e.g., in the context of LTE and NR. Also, for example in the context of WLAN, wireless network node 120 may be referred to as an access point. In any case, example embodiments are not restricted to any particular wireless technology. Instead, example embodiments may be exploited in any wireless communication network which uses random access.

**[0037]** Wireless network node 120 may be connected, directly or via at least one intermediate node, with core network 130 via interface 125. Core network 130 may be, in turn, coupled via interface 135 with another network (not shown in FIGURE 1), via which connectivity to further networks may be obtained, for example via a worldwide interconnection network. Wireless network node 120 may be connected with at least one other wireless network node as well via an inter-base station interface (not shown in FIGURE 1), even though in some example embodiments the inter-base station interface may be absent. Wireless network node 120 may be connected, directly or via at least one intermediate node, with core network 130 or with another core network.

**[0038]** Moreover, example embodiments may be exploited in various wireless communication networks. For instance, example embodiments may be exploited in cellular communication networks operating on unlicensed spectrum. The use of unlicensed spectrum, wherein for example NR-Unlicensed, NR-U, may be targeted to be deployed, may require that a Listen-Before-Talk, LBT, check is performed and passed before any transmission can be done over air interface 115. However, the LBT requirement may have a significant impact on the performance of the wireless communication network, because

LBT mechanism may induce delays depending on a degree of channel activity. More specifically, if the LBT check fails, the transmission needs to be postponed and another LBT check has to be performed for the transmission later, which causes unpredictable delays.

**[0039]** A wireless terminal may initiate communications towards a wireless network node using Contention-Free Random Access, CFRA, wherein a random access channel, or a resource, is dedicated to the wireless terminal for random access, or Contention-Based Random Access, CBRA, wherein a random access channel, or a resource, may be shared between multiple wireless terminals in the sense that said multiple wireless terminals are authorized to transmit on the random access channel.

**[0040]** In case of CBRA, a collision between two wireless terminals using this random access channel may be made less likely by using random access preambles. Random access preambles may be orthogonal to each other or have very low cross-correlation between each other. Since the random access preambles are orthogonal or have a very low cross-correlation, the wireless network node may be able to detect more than one transmission despite the transmissions taking place at the same time, over the same frequency resources. On the other hand, a collision may occur when at least two wireless terminals transmit on the random access channel at the same time using the same resource and the same random access preamble, such that the transmissions interfere with each other.

**[0041]** Different procedures may be used for random access, such as a 2-step random access procedure, a 4-step random access procedure or a hybrid 2/4-step random access procedure. FIGURE 2 illustrates an example of a 2-step random access procedure in accordance with at least some example embodiments. With reference to FIGURE 1, the random access procedure of FIGURE 2 may comprise signalling between wireless terminal 110 and wireless network node 120.

**[0042]** The random access procedure may be started, at step 210, by wireless terminal 110, by transmitting a first connection request message to wireless network node 120. The first connection request message may comprise a random access preamble, such as a Physical Random Access Channel, PRACH, preamble. The first connection request may also comprise a data transmission, i.e., a data payload. The data transmission may comprise for example an establishment cause and/or an identifier of wireless terminal 110,

such as a UE identifier. The data transmission may be transmitted over an uplink shared channel, such as a Physical Uplink Shared Channel, PUSCH. In some example embodiments, the first connection request of the 2-step random access procedure may be referred to as Message A, MsgA, as well.

**[0043]** If wireless network node 120 can both detect the random access preamble and decode successfully the data transmission, the wireless network node 120 may transmit, at step 220, a contention resolution message to wireless terminal 110, to acknowledge the reception of the connection request message and perform contention resolution. In some example embodiments, the contention resolution message may be referred to as Message B, MsgB. The contention resolution message may be referred to as a response message in general. The 2-step random access procedure may stop when wireless terminal 110 has received the contention resolution message.

**[0044]** FIGURE 3 illustrates an example of a hybrid 2/4-step or a 4-step random access procedure in accordance with at least some embodiments. With reference to FIGURE 1 again, the random access procedure of FIGURE 3 may comprise signalling between wireless terminal 110 and wireless network node 120.

**[0045]** In case of the hybrid 2/4-step random access procedure, the procedure may be started, at step 310, by wireless terminal 110, by transmitting a first connection request message to wireless network node 120. The first connection request message may comprise a random access preamble, such as a Physical Random Access Channel, PRACH, preamble. The first connection request may also comprise a data transmission, i.e., a data payload. The data transmission may be transmitted over an uplink shared channel, such as a Physical Uplink Shared Channel, PUSCH. In some example embodiments, the first connection request may be referred to as Message A, MsgA, as well.

**[0046]** If wireless network node 120 can decode successfully both, the random access preamble and the data transmission, wireless network node 110 may transmit, at step 320, a contention resolution message to wireless terminal 110 similarly as in the case of the 2-step random access procedure, to acknowledge reception of the connection request message and perform contention resolution. In some example embodiments, the contention resolution message may be referred to as Message B, MsgB, as well. That is to say, step 320 of the hybrid 2/4-step random access procedure may be exactly the same as step 220 of the 2-step random access procedure

**[0047]** However, if the wireless network node 120 cannot receive the first connection request successfully, i.e., the wireless network node 120 can detect the random access preamble but not decode successfully the data transmission, the wireless network node 120 may decide to fall back to the 4-step random access procedure. In such a case, wireless network node 120 may transmit, at step 320, a random access response to wireless terminal 110, to acknowledge reception of the random access preamble. The random access response may comprise at least one of a preamble ID corresponding to the random access preamble transmitted as part of the received connection request message, an identifier of wireless terminal 110, such as a UE identity and allocation of a radio resource for transmitting a second connection request message, i.e., Msg3. In some example embodiments, the random access response message may be referred to as Message 2, Msg2, as well. In general, the random access response may be referred to as a response to the first connection request message.

**[0048]** Upon receiving the random access response, wireless terminal 110 may, at step 330, transmit a second connection request to wireless network node 120. The second connection request may be transmitted on an uplink shared channel, such as PUSCH. In some example embodiments, the second connection request message may be referred to as Message 3, Msg3, as well. The second connection request may comprise at least partly the same information as transmitted in the data payload of the first connection request, such as an establishment cause and/or an identity of wireless terminal 110, but it may not be exactly the same data payload. In some embodiments, the second connection request message may not comprise the random access preamble for example.

**[0049]** If wireless network node 120 can receive the second connection request message successfully, wireless network node 120 may transmit, at step 340, a contention resolution message to wireless terminal 110, to acknowledge reception of the second connection request message. In some example embodiments, the contention resolution message may be referred to as Message 4, Msg4. The contention resolution message may be referred to as a response as well.

**[0050]** In case of the 4-step random access procedure, wireless terminal 110 may transmit, at step 310, the random access preamble (Msg1) and upon receiving the random access preamble, wireless network node 120 may, at step 320, transmit the random access response (Msg2). Moreover, wireless terminal 110 may, at step 330, transmit a first

connection request message (Msg3) in response to receiving the random access response. Consequently, wireless network node 120 may, at step 340, transmit a response, such as a contention resolution message (Msg4), in response to receiving the first connection request.

**[0051]** The 4-step CBRA procedure may often be considered as a default procedure, unless specific signalling is sent in the downlink by the wireless network node. However, in such a case the 4-step CBRA procedure and the hybrid 2/4-step CBRA procedure may need to coexist. Coexistence may be enabled by portioning random access preambles, such as PRACH preambles, into multiple groups in addition to partitioning random access preambles into resources for CBRA and CFRA. CBRA resources may be further partitioned in subsets as well, e.g., 46 PRACH preambles for 4-Step CBRA and 8 PRACH preambles for hybrid 2/4-Step CBRA for an example case where 10 PRACH preambles have been reserved for CFRA. Also, one option may be to partition in time (i.e., PRACH opportunities, in frequency (separate set of resources for each procedure)) or in spatial domain (beams) for expanding signalling space for random access preambles. A separation between random access preambles of the 4-step random access procedure and random access preambles of the hybrid 2/4-step random access procedure may be done to allow for a mechanism for the wireless terminal to indicate to the wireless network node whether it supports the 2-step random access procedure.

**[0052]** In case of the hybrid 2/4-step and the 2-step random access procedure, a number of uplink shared channel resources may need to be reserved on an uplink shared channel, such as PUSCH resource elements, to enable the transmission of the data part/payload of the first connection request message (MsgA). To avoid two separate LBT checks when operating in unlicensed spectrum, the reserved uplink shared channel resources may be scheduled so that those are contiguous in time with random access channel resources, such as PRACH resources, or carried in parallel in frequency at the same time as the random channel transmission. However, when operating in licensed spectrum, example embodiments may also be used in case the transmission of the random access preamble on a random access channel resource and data payload on an uplink shared resource of the first connection request message of the hybrid 2/4-Step and the 2-step CBRA procedure (MsgA) are separated in time. Embodiments of the present invention therefore provide improvements for operating on licensed and unlicensed spectrum.

**[0053]** During operation there may be uncertainty as to whether any transmission on a random access channel resources will happen or not, because such an action may be triggered due to various reasons, like uplink traffic, incoming handover, beam failure recovery, etc. For example, potential triggers for random access procedure can be found from the 3rd Generation Partnership Project, 3GPP, TS 38.300 standard specification. In case of the 4-step random access procedure, the overhead of the random access channel may be limited to the resources reserved for the random access preambles. However, in case of the hybrid 2/4-step random access procedure, a much larger set of resources may need to be reserved for the data part/payload of the first connection request message (MsgA).

**[0054]** Moreover, if there is no random access channel attempt, the reserved resources might potentially be wasted resources, because those are reserved from the system point of view, but only used occasionally. To minimize the amount of wasted resources, the number of uplink shared channel resources reserved for the first connection request message of the hybrid 2/4-step random access procedure (MsgA) may be limited, i.e., a fraction of the number of random access channel preambles available for the transmission related to MsgA. As such, the capacity of the hybrid 2/4-step random access procedure would be limited by the number of available uplink shared channel resources for which the main consequence is an increased number of required retransmissions the lower is the number of reserved uplink shared channel resources.

**[0055]** However, in unlicensed spectrum operation, as the purpose of the hybrid 2/4-step random access procedure is to reduce the number of access attempts due to LBT checks, then decreasing the contention space (i.e. the number of resources available for contention) would not be desirable because it would degrade performance and lead to an increased number of repetitions. In licensed spectrum operation, it is also desirable to have as few number of random access attempts as possible.

**[0056]** In some example embodiments, different uplink reference signal sequences, such as DMRS sequences or any uplink reference signal sequences that are for channel estimation and for coherent demodulation in general, may be used for transmitting the data payload, i.e., uplink shared channel part of the first connection request message of the hybrid 2/4-step random access procedure to increase the contention resolution space. Therefore, the likelihood of successful reception of the first connection request message of

the hybrid 2/4-step random access at the wireless network node may be improved because the wireless network node may be able to decode the transmission even if two or more wireless terminal would simultaneously transmit first connection request messages on the same uplink shared channel resources.

**[0057]** Moreover, example embodiment take advantage of the increased contention resolution space provided by the availability of multiple uplink reference signal sequences in the uplink shared channel part (comprising the data payload) of the first connection request message (MsgA), thereby reducing the number of random access channel transmission with the hybrid 2/4-step procedure..

**[0058]** FIGURE 4 illustrates an example apparatus capable of supporting at least some example embodiments. Illustrated is device 400, which may comprise, for example, wireless terminal 110 or wireless network node 120, or a device controlling wireless terminal 110 or wireless network node 120. Comprised in device 400 is processor 410, which may comprise, for example, a single- or multi-core processor wherein a single-core processor comprises one processing core and a multi-core processor comprises more than one processing core. Processor 410 may comprise, in general, a control device. Processor 410 may comprise more than one processor. Processor 410 may be a control device. A processing core may comprise, for example, a Cortex-A8 processing core manufactured by ARM Holdings or a Steamroller processing core produced by Advanced Micro Devices Corporation. Processor 410 may comprise at least one Qualcomm Snapdragon and/or Intel Atom processor. Processor 410 may comprise at least one application-specific integrated circuit, ASIC. Processor 410 may comprise at least one field-programmable gate array, FPGA. Processor 410 may be means for performing method steps in device 400. Processor 410 may be configured, at least in part by computer instructions, to perform actions.

**[0059]** A processor may comprise circuitry, or be constituted as circuitry or circuitries, the circuitry or circuitries being configured to perform phases of methods in accordance with example embodiments described herein. As used in this application, the term “circuitry” may refer to one or more or all of the following: (a) hardware-only circuit implementations, such as implementations in only analog and/or digital circuitry, and (b) combinations of hardware circuits and software, such as, as applicable: (i) a combination of analog and/or digital hardware circuit(s) with software/firmware and (ii) any portions of hardware processor(s) with software (including digital signal processor(s)), software, and

memory(ies) that work together to cause an apparatus, such as a mobile phone or server, to perform various functions) and (c) hardware circuit(s) and or processor(s), such as a microprocessor(s) or a portion of a microprocessor(s), that requires software (e.g., firmware) for operation, but the software may not be present when it is not needed for operation.

**[0060]** This definition of circuitry applies to all uses of this term in this application, including in any claims. As a further example, as used in this application, the term circuitry also covers an implementation of merely a hardware circuit or processor (or multiple processors) or portion of a hardware circuit or processor and its (or their) accompanying software and/or firmware. The term circuitry also covers, for example and if applicable to the particular claim element, a baseband integrated circuit or processor integrated circuit for a mobile device or a similar integrated circuit in server, a cellular network device, or other computing or network device.

**[0061]** Device 400 may comprise memory 420. Memory 420 may comprise random-access memory and/or permanent memory. Memory 420 may comprise at least one RAM chip. Memory 420 may comprise solid-state, magnetic, optical and/or holographic memory, for example. Memory 420 may be at least in part accessible to processor 410. Memory 420 may be at least in part comprised in processor 410. Memory 420 may be means for storing information. Memory 420 may comprise computer instructions that processor 410 is configured to execute. When computer instructions configured to cause processor 410 to perform certain actions are stored in memory 420, and device 400 overall is configured to run under the direction of processor 410 using computer instructions from memory 420, processor 410 and/or its at least one processing core may be considered to be configured to perform said certain actions. Memory 420 may be at least in part comprised in processor 410. Memory 420 may be at least in part external to device 400 but accessible to device 400.

**[0062]** Device 400 may comprise a transmitter 430. Device 400 may comprise a receiver 440. Transmitter 430 and receiver 440 may be configured to transmit and receive, respectively, information in accordance with at least one cellular or non-cellular standard. Transmitter 430 may comprise more than one transmitter. Receiver 440 may comprise more than one receiver. Transmitter 430 and/or receiver 440 may be configured to operate in accordance with Global System for Mobile communication, GSM, Wideband Code

Division Multiple Access, WCDMA, 5G/NR, Long Term Evolution, LTE, IS-95, Wireless Local Area Network, WLAN, Ethernet and/or Worldwide Interoperability for Microwave Access, WiMAX, standards, for example.

**[0063]** Device 400 may comprise a Near-Field Communication, NFC, transceiver 450. NFC transceiver 450 may support at least one NFC technology, such as Bluetooth, or similar technologies.

**[0064]** Device 400 may comprise User Interface, UI, 460. UI 460 may comprise at least one of a display, a keyboard, a touchscreen, a vibrator arranged to signal to a user by causing device 400 to vibrate, a speaker and a microphone. A user may be able to operate device 400 via UI 460, for example to accept incoming telephone calls, to originate telephone calls or video calls, to browse the Internet, to manage digital files stored in memory 420 or on a cloud accessible via transmitter 430 and receiver 440, or via NFC transceiver 450, and/or to play games.

**[0065]** Device 400 may comprise or be arranged to accept a user identity module 470. User identity module 470 may comprise, for example, a Subscriber Identity Module, SIM, card installable in device 400. A user identity module 470 may comprise information identifying a subscription of a user of device 400. A user identity module 470 may comprise cryptographic information usable to verify the identity of a user of device 400 and/or to facilitate encryption of communicated information and billing of the user of device 400 for communication effected via device 400.

**[0066]** Processor 410 may be furnished with a transmitter arranged to output information from processor 410, via electrical leads internal to device 400, to other devices comprised in device 400. Such a transmitter may comprise a serial bus transmitter arranged to, for example, output information via at least one electrical lead to memory 420 for storage therein. Alternatively to a serial bus, the transmitter may comprise a parallel bus transmitter. Likewise processor 410 may comprise a receiver arranged to receive information in processor 410, via electrical leads internal to device 400, from other devices comprised in device 400. Such a receiver may comprise a serial bus receiver arranged to, for example, receive information via at least one electrical lead from receiver 440 for processing in processor 410. Alternatively to a serial bus, the receiver may comprise a parallel bus receiver.

**[0067]** Device 400 may comprise further devices not illustrated in FIGURE 4. For example, where device 400 comprises a smartphone, it may comprise at least one digital camera. Some devices 400 may comprise a back-facing camera and a front-facing camera, wherein the back-facing camera may be intended for digital photography and the front-facing camera for video telephony. Device 400 may comprise a fingerprint sensor arranged to authenticate, at least in part, a user of device 400. In some example embodiments, device 400 lacks at least one device described above. For example, some devices 400 may lack a NFC transceiver 450 and/or user identity module 470.

**[0068]** Processor 410, memory 420, transmitter 430, receiver 440, NFC transceiver 450, UI 460 and/or user identity module 470 may be interconnected by electrical leads internal to device 400 in a multitude of different ways. For example, each of the aforementioned devices may be separately connected to a master bus internal to device 400, to allow for the devices to exchange information. However, as the skilled person will appreciate, this is only one example and depending on the example embodiment various ways of interconnecting at least two of the aforementioned devices may be selected without departing from the scope of the example embodiments.

**[0069]** In some example embodiments, a wireless network node, such as a BS/gNB, may be able to decode multiple simultaneous transmissions received over an uplink shared channel resource, e.g., a PUSCH resource. For instance, the wireless network node may be able to decode simultaneous transmissions from various wireless terminals, such as UEs, when each wireless terminal is assigned, or each wireless terminal selects, an orthogonal uplink reference signal sequence, e.g., an orthogonal DMRS sequence. In other words, the available uplink reference signal sequences may be exploited to add an extra degree of freedom for random access that can be exploited by the wireless network node for separating wireless terminals transmitting simultaneously over the same uplink shared random access resource.

**[0070]** Multiple orthogonal uplink reference signal sequences may be exploited for transmitting, by wireless terminals, first connection request messages, such as MsgA in case of the 2-step or the hybrid 2/4-step random access procedure. In other words, each wireless terminal that decides to perform random access may select independently one uplink reference signal for a connection request message, from a set of uplink reference signal sequences, to use when transmitting over a selected uplink shared resource. Even if

the wireless network node would be unable to decode the entire connection request message, the use of the multiple orthogonal uplink reference signal sequences would enable, e.g., assigning dedicated uplink shared channel resources to the wireless terminals for transmitting second connection requests (Msg3).

**[0071]** A signalling mechanism is therefore provided which makes it possible for the wireless network node to expand the signalling space for wireless terminals that are attempting a random access procedure. For example, assistance information may be included in a Downlink Control Information, DCI, that carries assistance information for the response message, from the wireless network node to the wireless terminal, which links to several uplink transmit properties from the connection request message of the 2-step RACH attempt, such as Random Access Radio Network Temporary Identifier, RA-RNTI, created from the physical resource and time, an identifier of the random access preamble and the DMRS chosen from the data part of the first connection request message.

**[0072]** For example, in the 2-step random access procedure the wireless terminal may transmit the data part, i.e., data payload of the first connection request (MsgA), over an uplink shared channel resource, such as PUSCH resource element which may be associated with a random access preamble, i.e., PRACH preamble, selected by the wireless terminal. Moreover, the wireless terminal may select independently and randomly one uplink reference signal sequence, e.g., a DMRS sequence, from a set of available uplink reference signal sequences. The set of available uplink reference signal sequences may be configured by the wireless network node and transmitted to the wireless terminal.

**[0073]** The wireless network node may address, i.e., direct, a response message to the wireless terminal using an identifier of the received the uplink reference signal sequence, and possibly an identifier of the random access resources, selected by the wireless terminal, possibly including the random access preamble. Thus falling back to the 4-step random access procedure is enabled if the wireless network node fails to decode the data payload of the first connection request correctly, i.e., reception of the data payload was unsuccessful. The wireless terminal may thus identify that the response message, such as a random access response message, was addressed to the wireless terminal using the identifier of the uplink reference signal sequence, and possibly the identifier of the random access preamble as well if received. The contention resolution space is therefore significantly increased by using uplink reference signal sequences for random access. The

wireless network node may assign a dedicated uplink shared resource, such as a PUSCH resource, for the wireless terminal using a response message, such as a random access response message, to be used for the transmission of the second connection request (Msg3) by the wireless terminal.

**[0074]** Moreover, in some example embodiments, the wireless network node may be able to identify and acknowledge a wireless terminal, which transmitted a first connection request message that was decoded successfully by the wireless network node, based on the uplink reference signal sequence, and possibly the random access preamble, selected by the wireless terminal. Therefore, the wireless network node may conclude the 2-step random access procedure by transmitting a response message, i.e., a contention resolution message. The contention resolution message may be addressed to the wireless terminal by adding an identity of the wireless terminal, signalled in the first connection request, to the contention resolution message. The wireless terminal may hence receive a contention resolution message comprising the identity of the wireless terminal, and upon receiving the contention resolution message, stop the 2-step random access procedure. Consequently, the wireless terminal may for example transmit data using an uplink grant received in the contention resolution message.

**[0075]** FIGURE 5 illustrates an example about the use of multiple uplink reference signal sequences in accordance with at least some embodiments. In FIGURE 5, random access preambles, such as PRACH preambles, are denoted by 510, uplink shared resources, such as PUSCH resource elements, are denoted by 520 and uplink reference signal sequences, such as DMRS sequences, are denoted by 530. Thus, there may be eight random access preambles 510 for wireless terminals to select one shared resource 520 available. In addition, there may be eight uplink reference signal sequences 530. That is to say, one wireless terminal may select a combination of one random access preamble 510 and one reference signal sequence 530 for transmission of a first connection request message, such as MsgA.

**[0076]** Moreover, an uplink shared resource selected by a first wireless terminal is denoted by 540 and an uplink reference signal sequence selected by the first wireless terminal is denoted by 545 while an uplink shared resource selected by a second wireless terminal is denoted by 550 and uplink reference signal sequence selected by the second wireless terminal is denoted by 555.

**[0077]** FIGURE 5 demonstrates behaviour of two wireless terminals in terms of the selection of random access preambles, uplink shared resources and uplink reference signal sequences. In case of (a), the first wireless terminal may have selected the second random access preamble 540 and the first uplink reference signal sequence 545 for transmission of a connection request message, such as MsgA or Msg3, while the second wireless terminal may have selected the sixth random access preamble 550 and the fourth uplink reference signal sequence 555 for transmission of a connection request message, such as MsgA or Msg3. Thus, there would be no preamble collision, even though there is a collision on the uplink shared resource, and a wireless network node may receive the first connection request messages correctly from both, the first and the second wireless terminal, if data payloads of the first connection request can be decoded correctly. Consequently, the wireless network node may respond by transmitting response messages, such as contention resolution messages, and the first and the second wireless terminal may stop the random access procedure upon receiving the contention resolution messages.

**[0078]** In case of (b) the first and the second wireless terminals may select the second random access preamble for transmission of the connection request messages which would lead to a preamble collision without the use of the uplink reference signal sequences 530. Example embodiments therefore allow separation of the two transmissions because the first wireless terminal may select the second uplink reference signal sequence for the transmission while the second wireless terminal may select the sixth uplink reference signal sequence, thereby enabling successful reception at the wireless network node. Consequently, the wireless network node may again respond by transmitting contention resolution messages if the wireless network node can detect the preambles and decode data payloads of the first connection request messages, such as MsgBs, to the first and the second wireless terminals. The contention resolution messages may comprise identifiers of the wireless terminals.

**[0079]** However, in some cases the wireless network node cannot decode the data payload of the first connection request message of the first and/or the second wireless terminal. Thus, in some embodiments, an identifier of the uplink reference signal, such as a DMRS sequence, selected by a wireless terminal for transmission of the first connection request message (MsgA) may be included in a random access response message (Msg2) in addition to the random access preamble selected by the wireless terminal. In this way, even if the data payload of the first connection request (MsgA) is not decoded correctly, by

performing uplink reference signal detection the wireless network node can separately address the random access response to both wireless terminals (i.e., address Msg2s to both UEs), thus resolving the preamble collision.

**[0080]** That is to say, the wireless network node may address the random access response message to the first wireless terminal using the identifier of the second uplink reference signal sequence and the identifier of the second random access preamble as well. Similarly, the wireless network node may address the random access response message to the second wireless terminal using the identifier of the sixth uplink reference signal sequence and the identifier of the second random access preamble as well. Thus, the first wireless terminal may identify that the random access response message comprising the identifier of the second uplink reference signal sequence was addressed to the first wireless terminal and the second wireless terminal may identify that the random access response message comprising the identifier of the sixth uplink reference signal sequence was addressed to the second wireless terminal.

**[0081]** Example embodiments may be described in terms of some steps that a wireless terminal, such as a UE, and a wireless network node, such as a BS/gNB, may perform, e.g., if the hybrid 2/4-step random access procedure is used. The random access procedure may be for example a CBRA procedure.

**[0082]** In some example embodiments, the wireless network node may first broadcast a configuration for random access. The configuration may comprise a set of random access preambles, such as PRACH preambles, to be used for the hybrid 2/4-step random access procedure by the wireless terminal. The configuration may also comprise time and frequency opportunities for a random access channel, such as PRACH, and uplink shared resource. The configuration may also comprise a mapping between the random access preambles and uplink shared resources, such as PUSCH resource elements. The mapping may indicate the uplink shared resources associated with each random access preamble.

**[0083]** Alternatively, or in addition, the configuration may comprise a set of uplink reference signal sequences, such as orthogonal DMRS sequences, for example per uplink shared resource. In some embodiments, the wireless network node may also signal an implicit or explicit indication whether the wireless terminal shall randomly select one of

the uplink reference signal sequences, when transmitting the data payload of the first connection request message, i.e., PUSCH part of MsgA.

**[0084]** The wireless terminal may want to try random access using the hybrid 2/4-step random access by selecting at least one of:

- a time and frequency for the random access channel, e.g., for the PRACH;
- a random access preamble from the set of random access preambles, e.g., by randomly selecting from the set of available PRACH preambles;
- an uplink reference signal sequence from the set of uplink reference signal sequences, e.g., by randomly selecting one from the set of available DMRS sequences

**[0085]** Upon performing the selection, the wireless terminal may transmit a first connection request message, such as MsgA, using the selected time and frequency PRACH resources, random access preamble and uplink reference signal sequence. For instance, a data payload may be transmitted in a corresponding uplink shared channel resource with the selected uplink reference signal sequence.

**[0086]** In general, selection of the uplink reference signal sequence may be left to wireless terminal 110, i.e, UE, randomization from a full set of available uplink reference signal sequences. In some example embodiments, it may be limited such that there is a direct mapping between a selected random access preamble and a selected uplink reference signal sequence. For instance, selection of the uplink reference signal sequence may be further limited such that one uplink reference signal sequence is reserved for common indication in subsequent signalling.

**[0087]** The wireless network node may attempt detection of all random access preambles of the set of configured random access preambles, i.e., active preambles. That is to say, the wireless network node may attempt detection of all random access preambles that were transmitted by at least one wireless terminal. Based on the active preambles the wireless network node may determine which uplink shared channel resources it needs to process next, to decode the transmitted payloads of the first connection request messages.

**[0088]** At each uplink shared channel resource, the wireless network node may attempt detection of each of the available uplink reference signal sequences and from the detected uplink reference signal sequences the wireless network node may try to decode

each of the corresponding data payloads. That is to say, the wireless network may detect an uplink reference signal sequence upon receiving a first connection request message and then attempt to decode a payload associated with the detected uplink reference signal sequence.

**[0089]** At the end of the decoding process, the wireless network node may determine a list of payloads that were decoded, i.e., received, successfully. The wireless network node may then acknowledge wireless terminals associated with the payloads that were decoded successfully by transmitting a contention resolution message, such as MsgB, thereby completing the 2-step random access procedure for these wireless terminals. In other words, the wireless network node may detect that decoding of the random access preamble was successful and decoding of the data payload associated with the uplink reference signal sequence was successful and then transmit a response message, such as a contention resolution message, MsgB.

**[0090]** Also, the wireless network node may determine a list of random access preambles and corresponding uplink reference signal sequences, which were detected as active but decoding of the corresponding payload was not successful. That is to say, the wireless network node may successfully detect the random access preamble and the uplink reference signal sequence, while the reception of associated data transmission/payload was not successful. The wireless network node may then respond to wireless terminals associated with the payloads that were not decoded successfully by transmitting a response message, such as a random access response message, Msg2, thereby falling back to the 4-step random access procedure for these wireless terminals.

**[0091]** The wireless network node may transmit the response message, such as the random access response message (Msg2), to the wireless terminals within a random access response window, possibly with identifiers for random access preambles, uplink reference signal sequences and/or uplink shared resources. Moreover, a wireless terminal receiving the contention resolution message may decode the message and stop the 2-step random access procedure.

**[0092]** On the other hand, a wireless terminal receiving a random access response message may decode the message and continue with the 4-step random access procedure, e.g., by transmitting a second connection request message (Msg3), possibly in uplink shared channel resources indicated in the random access response message. That is to say,

in the random access response message may comprise uplink shared channel resources to be used for the second connection request message.

**[0093]** The wireless network node may attempt decoding of transmissions in each of the uplink shared resources reserved for the second connection request message and for every successfully decoded payload, the wireless network node may trigger a transmission of a contention resolution message (Msg4). However, for the payloads that were not received successfully, i.e., decoding failed due to interference or unfavourable channel conditions, the wireless network node may trigger a Hybrid Automatic Repeat Request, HARQ, process. Wireless terminals that cannot carry out the random access procedure successfully, either due to exceeding the number of HARQ retransmissions or collisions (may be detected from the contention resolution message, Msg4), may back off and reattempt a transmission at a later opportunity.

**[0094]** FIGURE 6 illustrates an exemplary multiplexing of payloads in accordance with at least some embodiments. For instance, in the context of the hybrid 2/4-step random access procedure the payloads may be Medium Access Control, MAC, payloads of the contention resolution message of the 2-step random access procedure (MsgB) and the random access response of the 4-step random access procedure (Msg2). The payloads may be suitable at least for the traditional 4-step random access procedure, including both CBRA and CFRA, as well the hybrid 2/4-step CBRA. In FIGURE 6, the random access response of the 4-step random access procedure (Msg2) is denoted by 610 and the contention resolution message of the hybrid 2/4-step random access procedure (MsgB) is denoted by 620.

**[0095]** In some example embodiments, the preambles are partitioned into two groups, where the first group is reserved for the traditional 4-step access, while the second group is reserved for the 2/4-step CBRA.

**[0096]** Moreover, a MAC Packet Data Unit, PDU, transmitted in the random access response of the 4-step random access procedure (Msg2) may comprise several random access responses of the 4-step random access procedure (Msg2) 610 and/or several messages of the hybrid 2/4-step random access procedure (MsgB/Msg2) 620. Therefore, some example embodiments improve signalling by making it more efficient, because random access responses of the 4-step random access procedure (Msg2) 610 and several

messages of the hybrid 2/4-step random access procedure (MsgB/Msg2) 620 may be multiplexed as shown in FIGURE 6.

**[0097]** In some example embodiments, the MAC PDU may comprise three types of subPDUs: (a) MAC sub-header with Backoff Indicator; (b) Random Access Preamble Identity, RAPID (may be used for the acknowledgement of System Information, SI, requests); and (c) RAPID and random access response. For the hybrid 2/4-step access, (c) may be redefined to convey the random access response message (Msg2). In some example embodiments, both, the selected random access preamble, such as PRACH preamble, and the selected uplink reference sequence, such as and an orthogonal DMRS sequence, may be therefore addressed. For instance, an identifier of the uplink reference signal sequence may be introduced, such as an orthogonal DMRS sequence identity, DSEQID, for which the number of required bits may depend on the number of available DMRS sequences per PUSCH resource element. In some example embodiments, it may be assumed that there is a pre-defined mapping between the selected random access preamble and an uplink shared channel resource, such as PUSCH resource element,

**[0098]** In some example embodiments, an identifier for an identity of a DMRS sequence identity may indicate the actual sequence used, e.g., it may indicate the sequence used through a mapping algorithm, and there may be a set of reserved DMRS sequence identities that will indicate a group or all of the DMRS sequences identities as a group identifier. In this way, a reservation of ”code points” may be enabled that allows for ”catch-app” operation of the sequence identity. This may be useful for cases where it may not be possible to uniquely identify specific DMRS sequences that are being used.

**[0099]** FIGURE 7 illustrates an example data payload in accordance with at least some embodiments. The payload may be a payload for a random access response message (Msg2) of the hybrid 2/4-step random access procedure. The random access response message (Msg2) of the hybrid 2/4-step random access procedure may be defined as illustrated in FIGURE 7.

**[00100]** The payload may comprise subHeader 724. SubHeader 724 may be defined in accordance with 3GPP TS 38.321 standard specification for example. SubHeader may comprise *E* (1 bit) 710, *T* (1 bit) 712 and *RAPID* (6 bits) 714. The payload may also comprise Msg2 random access response 726. Msg2 random access response 726 may be defined in accordance with 3GPP TS 38.321 standard specification as well. Msg2 random

access response 726 may comprise *R* (1 bit) 716, *Timing Advance Command* (12 bits) 718, *uplink grant* (24 bits) 720 and *temporary Cell-Radio Network Temporary Identifier, C-RNTI,* (16 bits) 722.

**[00101]** Moreover, in the Temporary C-RNTI 722 the 3 most significant bits may be reserved for an identifier of the selected uplink reference signal sequence, such as the DSEQID, as an example. Alternatively, the identifier of the selected uplink reference signal sequence may be composed of the three least significant bits of the Temporary C-RNTI 722, such that the wireless network node may simply reserve a sequential block from a RNTI set, which may be simpler from an RNTI management point of view.

**[00102]** The contention resolution message in the context of the 2-step random access procedure (MsgB) may be different compared to the random access response of the 4-step random access procedure (Msg2). The contention resolution message in the context of the 2-step random access procedure (MsgB) may be transmitted when the data payload of the connection request message in the context of the 2-step random access procedure (MsgA) has been decoded successfully. The data payload of the connection request message in the context of the 2-step random access procedure (MsgA) may need to include an identifier of the wireless terminal and thus the contention resolution message in the context of the 2-step random access procedure (MsgB) may also reflect that same identifier in order to complete the collision resolution. In case the collision resolution fails (i.e. the identifier transmitted in the contention resolution message in the context of the 2-step random access procedure (MsgB) is different from the one that the wireless terminal transmitted in MsgA), then the user can re-start its 2/4-step random access procedure in the next available random access channel resource.

**[00103]** FIGURE 8 is a flow graph of a first method in accordance with at least some embodiments. The phases of the illustrated first method may be performed by wireless network node 120, or by a control device configured to control the functioning thereof, possibly when installed therein.

**[00104]** The first method may comprise, at step 810, receiving, from a wireless terminal, a first connection request message comprising a random access preamble and a data payload associated with an uplink reference signal sequence. Finally, the first method may comprise, at step 820, in response to detecting the first connection request message, transmitting a response message to the wireless terminal, wherein the response message is

addressed to the wireless terminal using an identifier of the uplink reference signal sequence.

**[00105]** FIGURE 9 is a flow graph of a second method in accordance with at least some embodiments. The phases of the illustrated second method may be performed by wireless terminal 110, or by a control device configured to control the functioning thereof, possibly when installed therein.

**[00106]** The second method may comprise, at step 910, selecting a random access preamble and an uplink reference signal sequence for random access. The second method may also comprise, at step 920, transmitting a first connection request message comprising the selected random access preamble and a data payload associated with the selected uplink reference signal sequence. Finally, the second method may comprise, at step 930, receiving a response message, wherein the response message is addressed to the wireless terminal using the selected uplink reference signal sequence.

**[00107]** It is to be understood that the embodiments disclosed are not limited to the particular structures, process steps, or materials disclosed herein, but are extended to equivalents thereof as would be recognized by those ordinarily skilled in the relevant arts. It should also be understood that terminology employed herein is used for the purpose of describing particular embodiments only and is not intended to be limiting.

**[00108]** Reference throughout this specification to one embodiment or an embodiment means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment. Thus, appearances of the phrases “in one embodiment” or “in an embodiment” in various places throughout this specification are not necessarily all referring to the same embodiment. Where reference is made to a numerical value using a term such as, for example, about or substantially, the exact numerical value is also disclosed.

**[00109]** As used herein, a plurality of items, structural elements, compositional elements, and/or materials may be presented in a common list for convenience. However, these lists should be construed as though each member of the list is individually identified as a separate and unique member. Thus, no individual member of such list should be construed as a de facto equivalent of any other member of the same list solely based on their presentation in a common group without indications to the contrary. In addition,

various embodiments and examples may be referred to herein along with alternatives for the various components thereof. It is understood that such embodiments, examples, and alternatives are not to be construed as de facto equivalents of one another, but are to be considered as separate and autonomous representations.

**[00110]** In an exemplary embodiment, an apparatus, such as, for example, a wireless terminal 110 or a wireless network node 120, or a control device configured to control the functioning thereof, possibly when installed therein, may comprise means for carrying out the embodiments described above and any combination thereof.

**[00111]** In an exemplary embodiment, a computer program may be configured to cause a method in accordance with the embodiments described above and any combination thereof. In an exemplary embodiment, a computer program product, embodied on a non-transitory computer readable medium, may be configured to control a processor to perform a process comprising the embodiments described above and any combination thereof.

**[00112]** In an exemplary embodiment, an apparatus, such as, for example, a wireless terminal 110 or a wireless network node 120, or a control device configured to control the functioning thereof, possibly when installed therein, may comprise at least one processor, and at least one memory including computer program code, wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus at least to perform the embodiments described above and any combination thereof.

**[00113]** Furthermore, the described features, structures, or characteristics may be combined in any suitable manner in one or more embodiments. In the preceding description, numerous specific details are provided, such as examples of lengths, widths, shapes, etc., to provide a thorough understanding of embodiments of the invention. One skilled in the relevant art will recognize, however, that the invention can be practiced without one or more of the specific details, or with other methods, components, materials, etc. In other instances, well-known structures, materials, or operations are not shown or described in detail to avoid obscuring aspects of the invention.

**[00114]** While the forgoing examples are illustrative of the principles of the embodiments in one or more particular applications, it will be apparent to those of ordinary skill in the art that numerous modifications in form, usage and details of implementation

can be made without the exercise of inventive faculty, and without departing from the principles and concepts of the invention. Accordingly, it is not intended that the invention be limited, except as by the claims set forth below.

**[00115]** The verbs “to comprise” and “to include” are used in this document as open limitations that neither exclude nor require the existence of also un-recited features. The features recited in depending claims are mutually freely combinable unless otherwise explicitly stated. Furthermore, it is to be understood that the use of "a" or "an", that is, a singular form, throughout this document does not exclude a plurality.

## INDUSTRIAL APPLICABILITY

**[00116]** At least some embodiments find industrial application in wireless communication networks, wherein random access is used. More specifically, at least some embodiments find industrial application in cellular communication networks, such as in 5G/NR networks, for example when operating in unlicensed spectrum.

ACRONYMS LIST

| | |
|---|---|
| 3GPP | 3rd Generation Partnership Project |
| BS | Base Station |
| C-RNTI | Cell-Radio Network Temporary Identifier |
| CBRA | Contention-Based Random Access |
| CFRA | Contention-Free Random Access |
| DCI | Downlink Control Information |
| DMRS | Demodulation Reference Signal |
| GSM | Global System for Mobile communication |
| IoT | Internet of Things |
| LBT | Listen-Before-Talk |
| LTE | Long-Term Evolution |
| M2M | Machine-to-Machine |
| MAC | Medium Access Control |
| MTC | Machine-Type Communications |
| NFC | Near-Field Communication |
| NR | New Radio |
| NR-U | NR-Unlicensed |
| OCC | Orthogonal Cover Code |
| P-RNTI | Paging – Radio Network Temporary Identifier |
| PDU | Packet Data Unit |
| PRACH | Physical Random Access Channel |
| PUSCH | Physical Uplink Shared Channel |

| | |
|---|---|
| RA-RNTI | Random Access Radio Network Temporary Identifier |
| RAPID | Random Access Preamble Identity |
| RAT | Radio Access Technology |
| RRC | Radio Resource Control |
| RRM | Radio Resource Management |
| SI | System Information |
| SIM | Subscriber Identity Module |
| UE | User Equipment |
| UI | User Interface |
| UL | Uplink |
| WCDMA | Wideband Code Division Multiple Access |
| WiMAX | Worldwide Interoperability for Microwave Access |
| WLAN | Wireless Local Area Network |

REFERENCE SIGNS LIST

| | |
|---|---|
| 110 | Wireless terminal, e.g., UE |
| 120 | Wireless network node, e.g., BS |
| 130 | Core network |
| 115, 125, 135 | Interfaces |
| 210 – 220 | Signalling steps in FIGURE 2 |
| 310 – 340 | Signalling steps in FIGURE 3 |
| 400 – 470 | Structure of the apparatus of FIGURE 4 |
| 510 | Random access preambles |
| 520 | Uplink shared resources |

| | |
|---|---|
| 530 | Uplink reference signal sequences |
| 540, 550 | Selected random access preambles |
| 545, 555 | Selected uplink reference signal sequences |
| 610 | Random access response of the 4-step random access procedure |
| 620 | Random access response of the hybrid 2/4-step random access procedure |
| 710 – 728 | Parts of the payload of FIGURE 7 |
| 810 – 820 | Phases of the first method in FIGURE 8 |
| 910 – 930 | Phases of the second method in FIGURE 9 |

CLAIMS:

1. A method for a wireless network node, comprising:
   - receiving, from a wireless terminal, a first connection request message comprising a random access preamble and a data payload associated with an uplink reference signal sequence; and
   - in response to detecting the first connection request message, transmitting a response message to the wireless terminal, wherein the response message is addressed to the wireless terminal using an identifier of the uplink reference signal sequence.

2. A method according to claim 1, wherein the response message comprises the identifier of the uplink reference signal sequence.

3. A method according to claim 1 or claim 2, wherein the selected uplink reference signal sequence is a demodulation reference signal sequence.

4. A method according to any of the preceding claims, wherein the response message comprises an identifier of the random access preamble, and the method further comprises:
   - addressing the response message to the wireless terminal using the identifier of the uplink reference signal and the identifier of the random access preamble.

5. A method according to any of the preceding claims, further comprising:
   - in response to transmitting a random access response message, receiving from the wireless terminal a second connection request message comprising at least part of the data payload associated with the uplink reference signal.

6. A method according any of the preceding claims, further comprising:
   - detecting the random access preamble and the uplink reference signal successfully;
   - detecting that decoding of the data payload associated with the uplink reference signal sequence was not successful; and

- wherein transmitting comprises transmitting a random access response message to the wireless terminal, wherein the random access response message is addressed to the wireless terminal using the identifier of the uplink reference signal sequence.

7. A method for a wireless terminal, comprising:

- selecting a random access preamble and an uplink reference signal sequence for random access;
- transmitting a first connection request message comprising the selected random access preamble and a data payload associated with the selected uplink reference signal sequence; and
- receiving a response message, wherein the response message is addressed to the wireless terminal using the selected uplink reference signal sequence.

8. A method according to claim 7, further comprising:

- identifying that the response message was addressed to the wireless terminal using the identifier of the uplink reference signal sequence.

9. A method according to claim 7 or claim 8, wherein the response message comprises the identifier of the selected uplink reference signal sequence.

10. A method according to any of claims 7 to 9, wherein the selected uplink reference signal sequence is a demodulation reference signal sequence.

11. A method according to any of claims 7 to 10, wherein the response message comprises an identifier of the random access preamble, and the method further comprises:

- identifying that the response message was addressed to the wireless terminal using the identifier of the uplink reference signal sequence and the identifier of the random access preamble.

12. A method according to any of claims 7 to 11, further comprising:

- selecting the uplink reference signal sequence randomly among a set of configured uplink reference signal sequences.

13. A method according to any of claims 7 to 12, further comprising:

- wherein the response message is addressed to the wireless terminal using the identifier of the uplink reference signal sequence ; and
- in response to receiving the response message, continuing with a 4-step random access procedure by transmitting a second connection request message comprising at least part of the data payload associated with the uplink reference signal.

14. An apparatus comprising at least one processing core, at least one memory including computer program code, the at least one memory and the computer program code being configured to, with the at least one processing core, cause the apparatus at least to perform:

- receive, from a wireless terminal, a first connection request message comprising a random access preamble and a data payload associated with an uplink reference signal sequence; and
- transmit, in response to detecting the first connection request message, a response message to the wireless terminal, wherein the response message is addressed to the wireless terminal using an identifier of the uplink reference signal sequence.

15. An apparatus according to claim 13, wherein the at least one memory and the computer program code are further configured to, with the at least one processing core, cause the apparatus at least to perform a method according to any of claims 2 – 6.

16. An apparatus comprising at least one processing core, at least one memory including computer program code, the at least one memory and the computer program code being configured to, with the at least one processing core, cause the apparatus at least to perform:

- select a random access preamble and an uplink reference signal sequence for random access;
- transmit a first connection request message comprising the selected random access preamble and a data payload associated with the selected uplink reference signal sequence; and
- receive a response message, wherein the response message is addressed to the wireless terminal using the selected uplink reference signal sequence.

17. An apparatus according to claim 16, wherein the at least one memory and the computer program code are further configured to, with the at least one processing core, cause the apparatus at least to perform a method according to any of claims 8 – 13.

18. An apparatus comprising:

- means for receiving, from a wireless terminal, a first connection request message comprising a random access preamble and a data payload associated with an uplink reference signal sequence; and
- means for transmitting, in response to detecting the first connection request message, a response message to the wireless terminal, wherein the response message is addressed to the wireless terminal using an identifier of the uplink reference signal sequence.

19. An apparatus according to claim 18, further comprising means for performing a method according to any of claims 2 – 6.

20. An apparatus comprising:

- means for selecting a random access preamble and an uplink reference signal sequence for random access;
- means for transmitting a first connection request message comprising the selected random access preamble and a data payload associated with the selected uplink reference signal sequence; and
- means for receiving a response message, wherein the response message is addressed to the wireless terminal using the selected uplink reference signal sequence.

21. A apparatus according to claim 20, further comprising means for performing a method according to any of claims 8 – 13.

22. A non-transitory computer readable medium having stored thereon a set of computer readable instructions that, when executed by at least one processor, cause an apparatus to at least perform a method according to any of claims 1 – 6 or 7 – 13.

23. A computer program configured to perform a method according to any of claims 1 – 6 or 7 – 13.

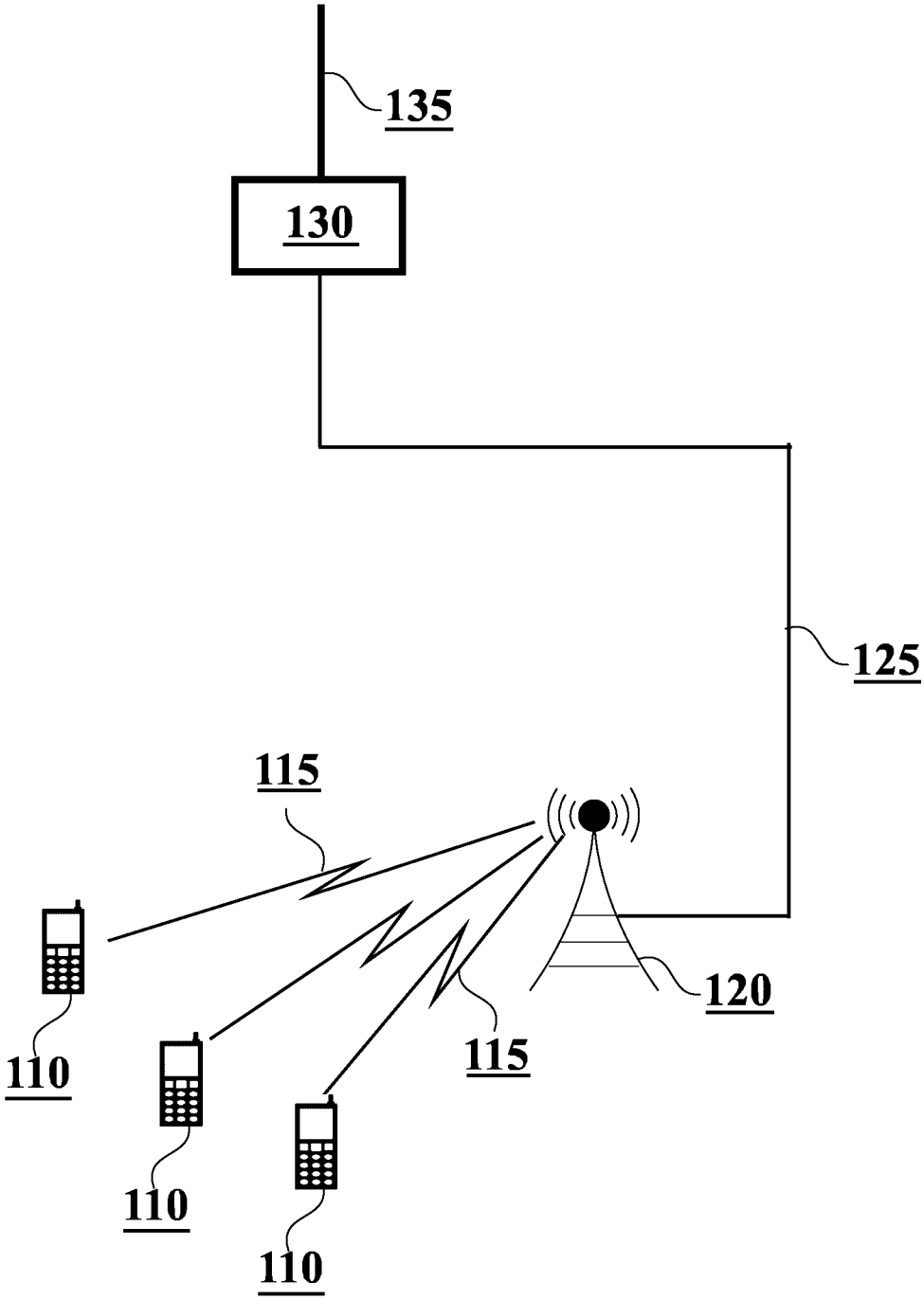



FIGURE 1

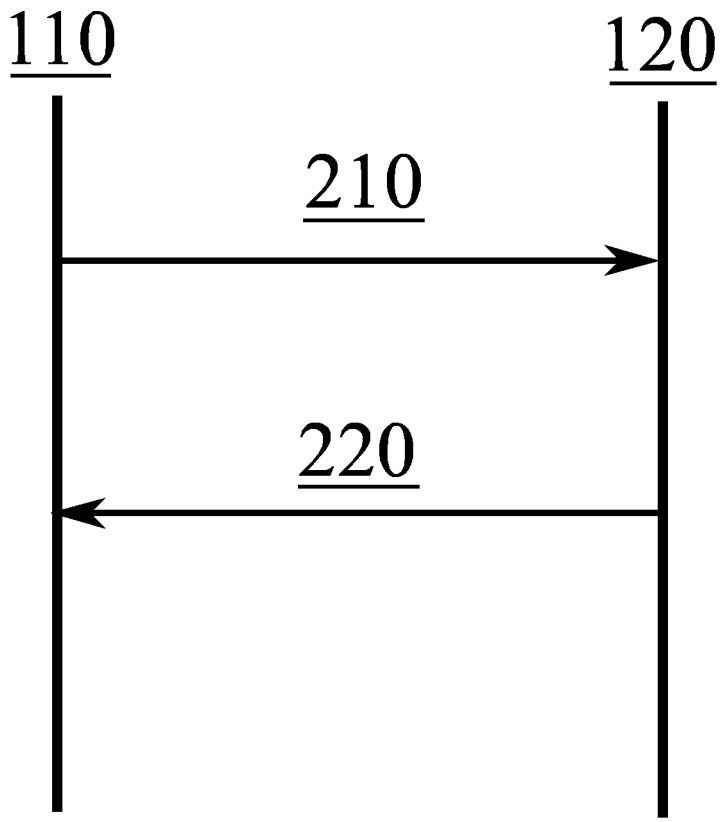



FIGURE 2

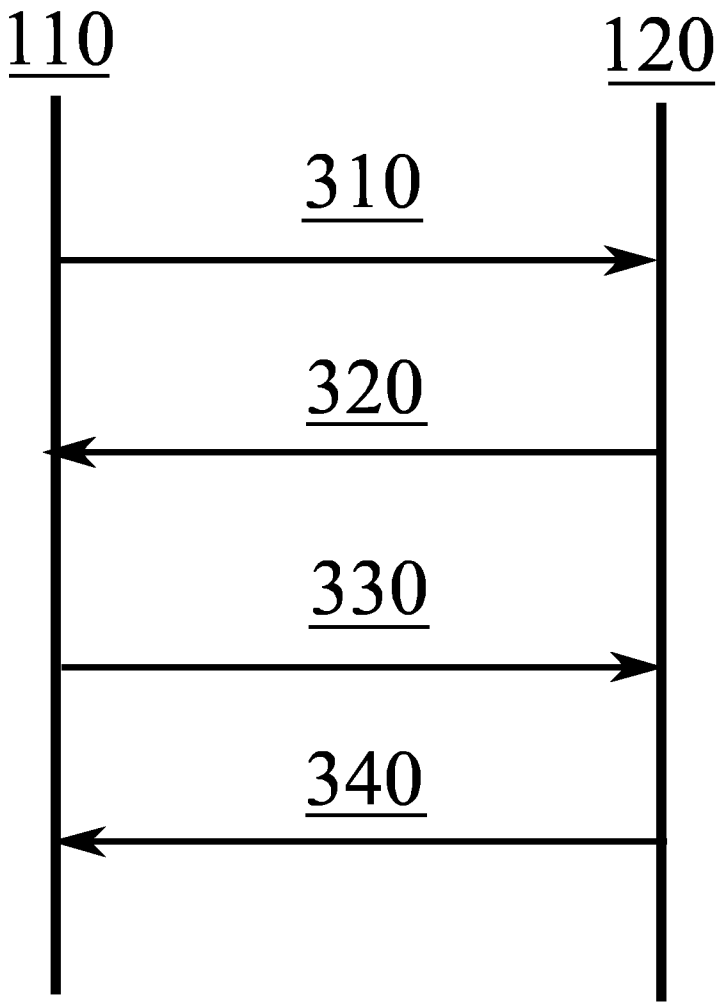



FIGURE 3

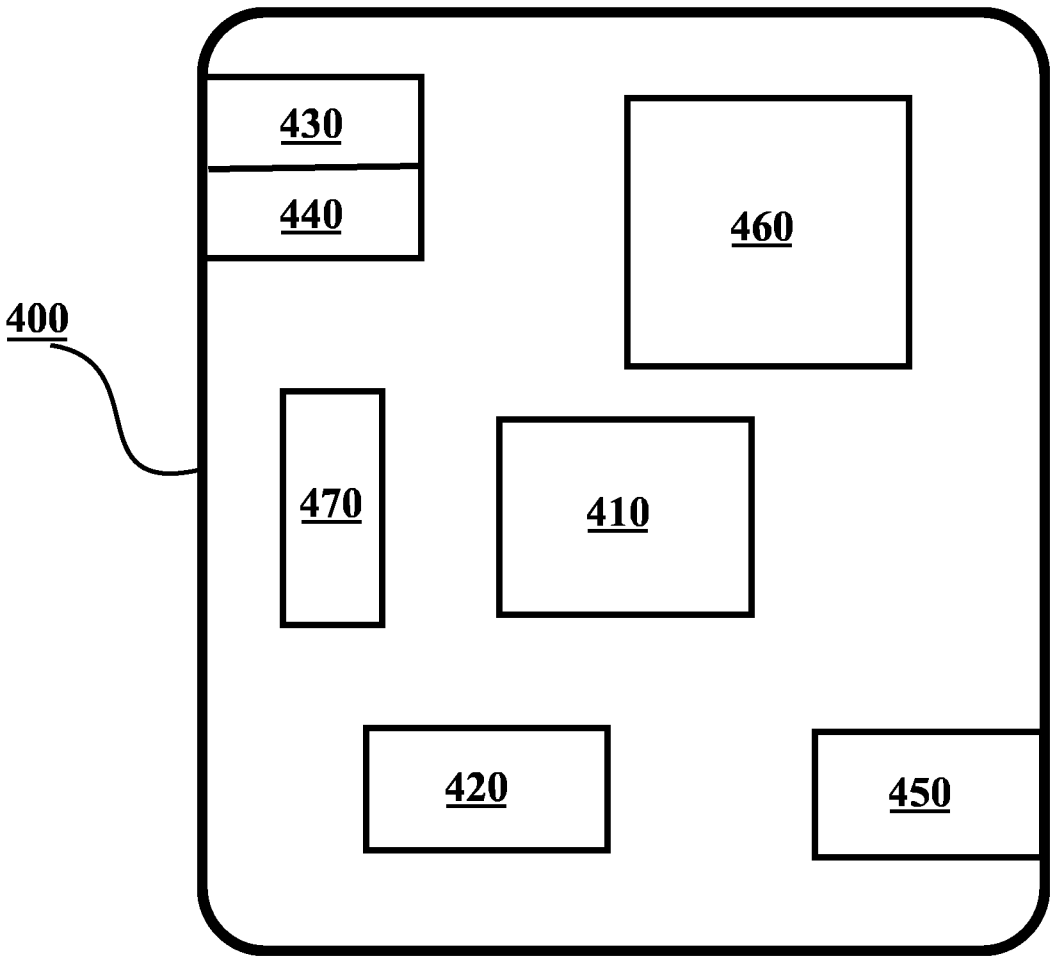



FIGURE 4

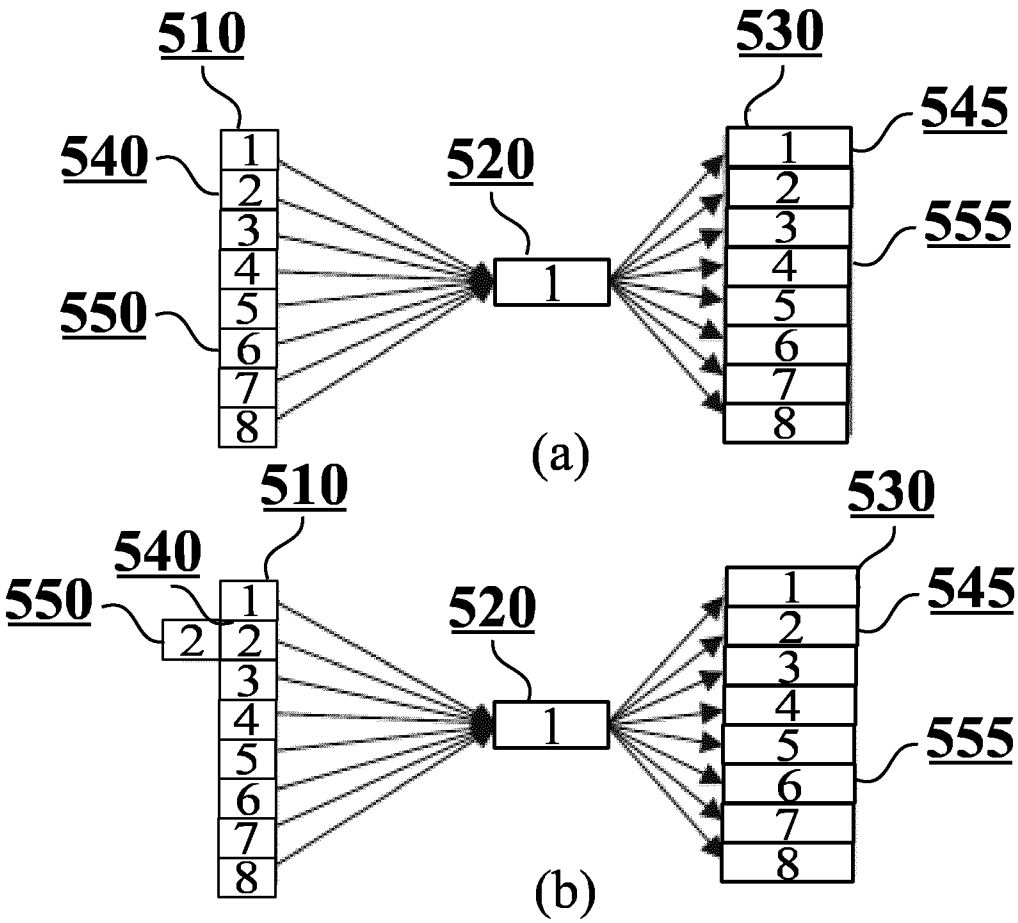

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(b)

FIGURE 5




FIGURE 6

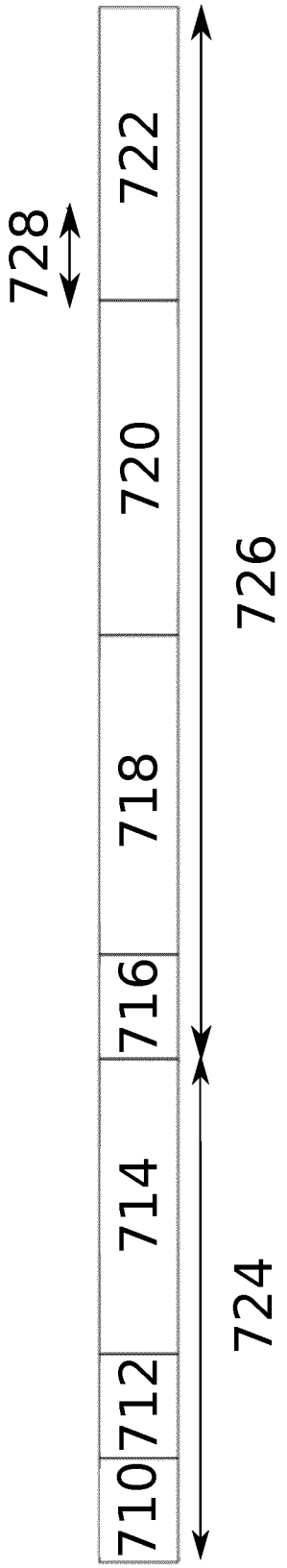



FIGURE 7

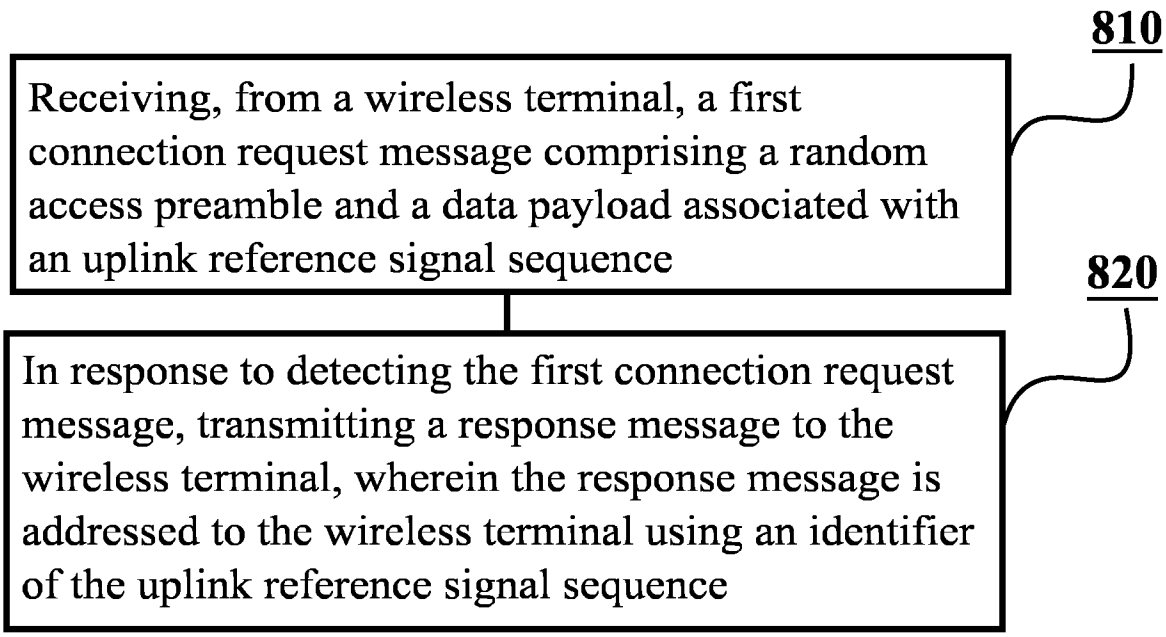

810
Receiving, from a wireless terminal, a first connection request message comprising a random access preamble and a data payload associated with an uplink reference signal sequence
820
In response to detecting the first connection request message, transmitting a response message to the wireless terminal, wherein the response message is addressed to the wireless terminal using an identifier of the uplink reference signal sequence

FIGURE 8

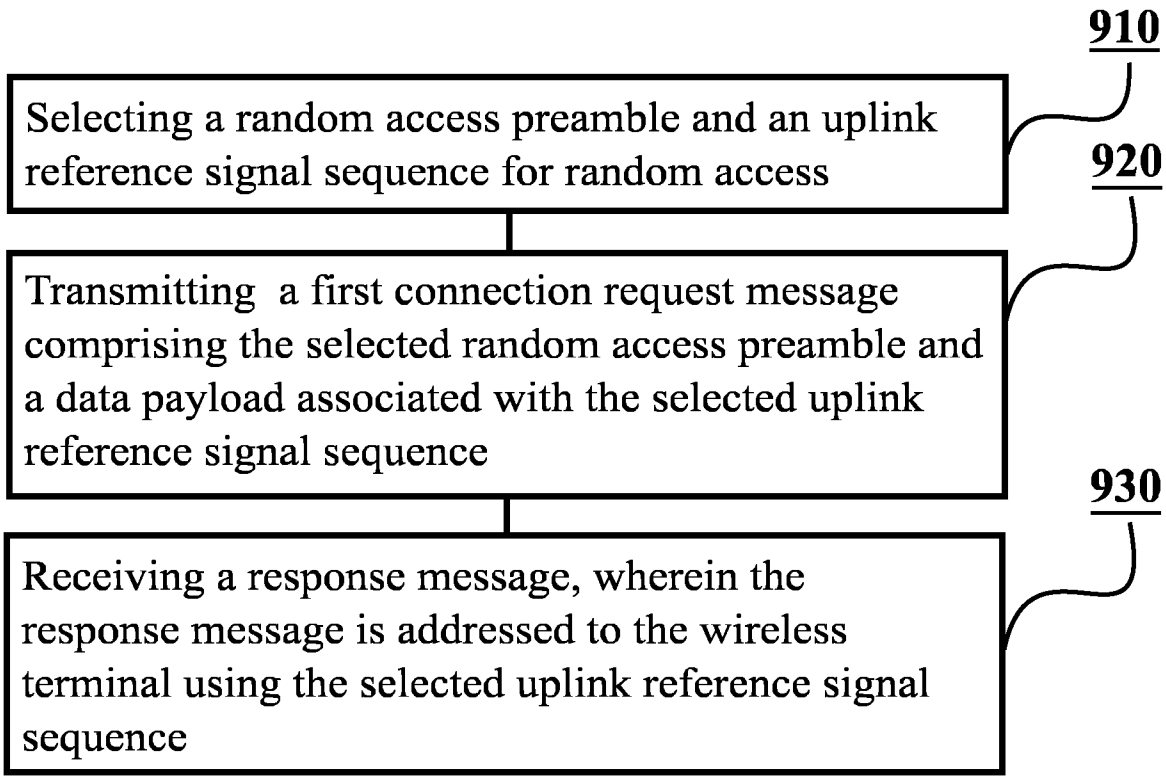

910
Selecting a random access preamble and an uplink reference signal sequence for random access
920
Transmitting a first connection request message comprising the selected random access preamble and a data payload associated with the selected uplink reference signal sequence
930
Receiving a response message, wherein the response message is addressed to the wireless terminal using the selected uplink reference signal sequence

FIGURE 9

# INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2019/053563

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04W74/08
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)
H04W

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | US 2018/124626 A1 (TSAI CHIOU-WEI [TW] ET AL) 3 May 2018 (2018-05-03)<br>RACH procedure using mapping configurations between preambles, RACH resources and DMRS sequences;<br>paragraph [0022] - paragraph [0043]<br>----- | 1-23 |
| A | WO 2017/209570 A1 (SAMSUNG ELECTRONICS CO LTD [KR]) 7 December 2017 (2017-12-07)<br><br>RACH using mapping between multiple access signatures, preambles and DMRS;<br>paragraph [0118] - paragraph [0141]<br>-----<br>-/-- | 1,7,14, 16,18, 20,22,23 |

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

[X] See patent family annex.

* Special categories of cited documents :

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

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"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 14 October 2019 | 22/10/2019 |

| Name and mailing address of the ISA/ | Authorized officer |
|---|---|
| European Patent Office, P.B. 5818 Patentlaan 2<br>NL - 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040,<br>Fax: (+31-70) 340-3016 | Tsapelis, Athanasios |

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Form PCT/ISA/210 (second sheet) (April 2005)

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
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| A | SAMSUNG: "NR 2-step random access procedure", 3GPP DRAFT; R1-1700892, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG1, no. Spokane, Wa; 20170116 - 20170120 16 January 2017 (2017-01-16), XP051208408, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/Meetings_3GPP_SYNC/RAN1/Docs/ [retrieved on 2017-01-16] NR 2 step RACH; paragraph [0002] ----- | 1,7,14, 16,18, 20,22,23 |

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Information on patent family members

International application No
PCT/EP2019/053563

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| | | TW 201919432 A | 16-05-2019 |
| | | US 2018124626 A1 | 03-05-2018 |
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| | | WO 2017209570 A1 | 07-12-2017 |