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(71) Applicant: NOKIA TECHNOLOGIES OY [FI/FI]; Karaportti 3, 02610 Espoo (FI).

(72) Inventors: KOSKELA, Timo; Harjapäänkatu 32 B 30, 90120 Oulu (FI). TURTINEN, Samuli; Poolatie 3 A, 91100 Ii (FI). PIRSKANEN, Juho; Karjakonkaari 42, 36200 Kangasala (FI).

(74) Agents: NOKIA TECHNOLOGIES OY et al.; Ari Aarnio, IPR Department, Karakaari 7, 02610 Espoo (FI).

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(54) Title: RANDOM ACCESS PREAMBLE SELECTION

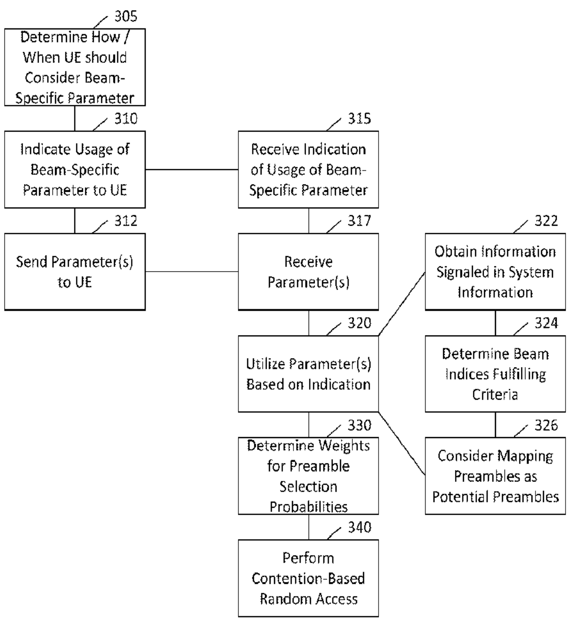

Figure 3

(57) Abstract: Various communication systems may benefit from the appropriate selection of aspects of operation of the communication system. For example, certain wireless communication systems, such as fifth generation (5G), long term evolution advanced (LTE-A), and wireless local area network (WLAN) communication systems, may benefit from appropriate random access preamble selection. A method can include determining that a user equipment should consider at least one beam-specific parameter. The method can also include indicating to the user equipment to consider the at least one beam-specific parameter.

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TITLE:

Random Access Preamble Selection

CROSS-REFERENCE TO RELATED APPLICATION:

[0001] This application is related to and claims the benefit and priority of U.S. Provisional Patent Application No. 62/323,081, filed on April 15, 2016, the entirety of which is hereby incorporated herein by reference.

BACKGROUND:

Field:

[0002] Various communication systems may benefit from the appropriate selection of aspects of operation of the communication system. For example, certain wireless communication systems, such as fifth generation (5G), long term evolution advanced (LTE-A), and wireless local area network (WLAN) communication systems, may benefit from appropriate random access preamble selection.

Description of the Related Art:

[0003] 5G radio access may rely on different transceiver architectures: digital, analog, or so-called hybrid, which utilizes a hybrid of digital baseband processing, such as multiple input multiple output (MIMO) and /or digital precoding. Although some of the following discussion refers to analog beamforming, fully analog or hybrid transceiver, the described techniques, methods, and systems may be applied also to digital beamforming transceiver architecture

[0004] Beamforming is used in the provision of cell coverage to compensate the increased path loss when operating on higher frequencies. The aforementioned transceiver architectures provide ways of implementing beamforming in future systems depending on the cost and complexity limitations. As an example, systems deployed to lower frequencies such as sub 6 GHz may be implemented by using fully digital architecture. The higher frequencies where the number of antenna elements required for cell coverage may range from tens to hundreds may be implemented by using hybrid-architecture, or even fully analog architecture. These systems, architectures, and frequency bands are provided by way of illustration and not limitation. The same principles can be applied other architectures or frequency bands, even though an artificial division of lower and higher frequencies is made in this example, for ease of explanation.

[0005] In 5G, a so-called sweeping sub-frame may be introduced to provide coverage for common control channel signaling with beam forming. Sweeping sub-frame includes sweeping blocks (SB) where a single block covers a specific area of the cell with a set of active beams.

[0006] Figure 1 illustrates a sweeping sub-frame. Total number of beams required to cover required cell area is typically much larger than the number of concurrent active beams the access point is able to form. Therefore access points need to sweep through the cell coverage area in the time domain by activating different set of beams on each SB. Depending on the number of active beams per sweep block and the total number of beams required to cover a cell area, multiple sweep blocks may be needed. Also, the number of sweep blocks per sub-frame is limited by the length of each sweep. As an example, one SB duration may be one or two symbols, of orthogonal frequency division multiplexing (OFDM). In some cases one SB duration may be even more than two symbols, depending on such factors as the amount of information transmitted in each SB. If there are 14 symbols per sub-frame and no guard symbols or uplink control and downlink control symbols are present, the sweeping sub-frame would be able to accommodate 7 SBs (each SB is 2 symbols). Depending on the number of SBs required to cover a cell, not only in azimuth plane but also in elevation plane, multiple sweeping sub-frames may be needed.

[0007] The active beam depicted in Figure 1 may be used for either transmitting or receiving information. Thus, the sweeping sub-frame can be defined as downlink sweeping sub-frame or an uplink sub-frame. Further, assuming time division duplex (TDD) system and reciprocity between downlink and uplink channels, to cover cell area on uplink and downlink direction with same beam configurations per sweeping block essentially the same SBs need to be defined on uplink and downlink direction.

[0008] As an example of downlink direction, if downlink common control channel coverage is provided by the sweeping sub-frame, each SBs would carry essential cell access information such as downlink (DL) synchronization signals, system information such as master information block (MIB)/ system information block (SIB) or the like (including physical random access channel (PRACH)/ random access channel (RACH) configurations), as well as paging or any control information that needs to be broadcasted in a cell). In the uplink direction the sweeping sub-frame/sub-frames may accommodate resources for random access channel and/or other uplink channels requiring periodic availability such as scheduling request (SR).

[0009] In a beam formed system where the cell coverage is provided by multiple beams, it may be beneficial to identify a single beam in a sweep block for example by using beam specific reference signals enabling a user equipment (UE) to perform beam level detection/separation. The beam specific reference symbols are reused in the next SB but the SB identifier (which may be explicitly signaled in each SB or calculated by using time domain mapping to a known time reference) is used to separate beams of different SBs. Thus one way to calculate beam identifier is to simply calculate Beam_RS_ID*Sweep_Block_ID. In a special case where only one beam is formed per SB (e.g. a system using fully analog beamforming) the SB identifier is the beam identifier. Identifying beams may be beneficial in some cases, such as when a UE indicates to the network the preferred communication beam during initial access or refers to a specific beam when reporting measurements.

SUMMARY:

[0010] According to a first embodiment, a method can include detecting a plurality of signal beams and measuring signal strength of each beam of the plurality of signal beams. The method can further include selecting a first beam of the plurality of signal beams having a highest signal strength of the plurality of signal beams and selecting a second beam of the plurality of signal beams having a signal strength above a threshold. Finally the method can include performing random access channel resource selection from random access channel resources of the first beam and random access channel resources of the second beam, for random access transmission.

[0011] According to a second embodiment, a method can include determining that a user equipment should consider at least one beam-specific parameter. The method can also include indicating to the user equipment to consider the at least one beam-specific parameter.

[0012] In a variant, the at least one beam-specific parameter can include a beam-specific random access channel parameter.

[0013] In a variant, the indicating can indicate to the user equipment how to use the at least one beam-specific parameter in a random access channel procedure.

[0014] In a variant, the at least one beam-specific parameter can include at least one of a beam reception level offset, a beam reception level reference threshold, or a preamble selection weight.

[0015] In a variant, the at least one beam-specific parameter can include at least one beam-specific back-off indicator.

[0016] In a variant, the indication of the at least one beam-specific parameter can include sending the at least one beam-specific parameter in system information broadcast in a system information block.

[0017] In a variant, the system information block can be transmitted during a specific downlink sub-frame or on a downlink shared channel on resources that are explicitly scheduled.

[0018] According to a third embodiment, a method can include receiving, at a user equipment, an indication to consider at least one beam-specific parameter. The method can also include utilizing, by a user equipment, the at least one beam-specific parameter to select a beam-specific preamble based on the indication.

[0019] In a variant, the utilization of the at least one beam-specific parameter can include calculating a set of available contention-based preambles in cell during a random access channel procedure.

[0020] In a variant, the utilization of the at least one beam-specific parameter can include at least one of obtaining information signaled in system information; determining beam indices fulfilling criteria determined by the at least one beam-specific parameter; and considering preambles that map to the determined beam indices as potential preambles for contention-based random access channel access.

[0021] In a variant, the method can further include determining weights for determining preamble selection probabilities in random selection of preambles.

[0022] The third embodiment can include the same variants with respect to the various parameters as the second embodiment.

[0023] According to fourth, fifth and sixth embodiments, an apparatus can include means for performing the method according to the first, second and third embodiments respectively, in any of their variants.

[0024] According to seventh, eighth and ninth embodiments, an apparatus can include at least one processor and at least one memory and computer program code. The at least one memory and the computer program code can be configured to, with the at least one processor, cause the apparatus at least to perform the method according to the first, second and third embodiments respectively, in any of their variants.

[0025] According to tenth, eleventh and twelfth embodiments, a computer program product may encode instructions for performing a process including the method according to the first, second and third embodiments respectively, in any of their variants.

[0026] According to thirteenth, fourteenth and fifteenth embodiments, a non-transitory computer readable medium may encode instructions that, when executed in hardware, perform a process including the method according to the first, second and third embodiments respectively, in any of their variants.

[0027] According to sixteenth, seventeenth and eighteenth embodiments, a system may include at least one apparatus according to the fifth or eighth embodiments in communication with at least one apparatus according to the sixth or ninth embodiments, respectively in any of their variants.

BRIEF DESCRIPTION OF THE DRAWINGS:

[0028] For proper understanding of the invention, reference should be made to the accompanying drawings, wherein:

[0029] Figure 1 illustrates a sweeping sub-frame.

[0030] Figure 2 illustrates mapping of preambles to slots.

[0031] Figure 3 illustrates a method according to certain embodiments.

[0032] Figure 4 illustrates a system according to certain embodiments.

DETAILED DESCRIPTION:

[0033] When performing initial access to a system via a random access channel (RACH) procedure in a beam formed system, a UE can indicate a preferred communication beam to an access point by selecting randomly an RA-preamble from a beam specific set of preambles. To determine a preferred, for example best or strongest, communication beam a UE may perform a set of measurements on the (beam specific) reference signals transmitted during a downlink sweep. The UE may detect multiple beams during the DL sweep. In real radio wave propagation environments the coverage areas of different beams may overlap, for example transmissions may be reflected from the surroundings so that multiple beams can reach a UE, the beams may be aligned to overlap with one another, or there may be significant side lobes of certain beams overlapping with other beams.

[0034] The RACH/PRACH configuration signaled by higher layers, such as radio resource control (RRC), in for example SIB (in LTE RACH/PRACH configuration is provided in SIB2) can provide a UE with the necessary information in order to determine the time and frequency location of the PRACH resources, for example the preamble resources, but also information about the beam specific mapping of the preambles.

[0035] The PRACH channel can be mapped to UL sweeping sub-frames so that during one sweep block the PRACH resources map to the beams which are active on during that PRACH. A sub-frame can potentially contain multiple sweep blocks. In one example the PRACH resources, called PRACH slots, may be mapped in the frequency domain so that each beam index maps to one or multiple slots or multiple beams share the preambles of one RACH slot. Each slot can include one or more physical resource blocks (PRBs) and can have a length of at least one symbol.

[0036] Figure 2 illustrates mapping of preambles to slots. More particularly, Figure 2 illustrates mapping of beam specific preambles to RACH slots where two beams have dedicated RACH slots, or two beams share the preambles of one RACH slot.

[0037] As the PRACH slot length may vary from one symbol to multiple symbols, depending on the requirements, such as cell size or delay spread, there may not be a one to one mapping of downlink and uplink sweep blocks. Thus, one potential configuration is that when downlink sweep block occupies one symbol the corresponding uplink (UL) sweep block may occupy two symbols.

[0038] With beam forming, for example when using analog beamforming, it may be desirable to avoid excessive periodic signals in either downlink (DL) or UL direction. One way to overcome this is that periodic signals such as scheduling request (SR) resources can be multiplexed with RACH resources (or SR resources can be allocated from the RACH resources) in the frequency domain in the UL sweep block. However, this also decreases the available RACH preamble space, as there is a limited amount of frequency resources, and thus RACH slots, available per UL sweep block

[0039] One way to increase RACH preamble space, or number of preambles, per beam is to configure more RACH slots in time domain, for example more UL sweep blocks, but this also increases overhead.

[0040] One alternative way to expand the preamble base is to allow the UE to initiate simultaneously multiple RACH procedures per cell by transmitting on RACH resources mapping to multiple beams. This increases the probability that the UE will receive random access response (RAR) corresponding to at least one of the beams but may also increase the collision probability when multiple UEs transmit in a similar manner. Also, this approach may increase resource utilization, the network may have to schedule RAR to each of the detected preambles. Furthermore, this approach may increase UE complexity as the UE may need specified mechanisms to handle multiple RACH procedures.

[0041] Some beams may be more crowded than other beams in a system. For example, more UEs may access from one place/beam, which may also increase the probability of collisions during random access.

[0042] Certain embodiments leverage the potential of a UE detecting multiple beams during a DL sweep but in a manner such that the network (NW) is able to provide access control and ensure sufficient quality for the random access procedure and potentially for any subsequent message transfers.

[0043] Certain embodiments can expand the set of preambles that the UE uses to consider in the random selection when performing the initial access or when performing access on the RACH channel in general. Examples of performing access on the RACH channel general include, but are not limited to, recovering from a beam (link) failure, sending SR when no SR resources are available, obtaining UL synchronization, and the like. This expanded set of preambles can spread the random access load and reduce collision probability.

[0044] To expand the number of preambles, the NW can instruct the UE to consider multiple beams for initial access by configuring thresholds to consider beams relative to the best beam. With beam specific preambles in the system, the number of available preambles for random selection can increase.

[0045] Certain embodiments provide a method that includes a signaling procedure that may reduce collision probability on RACH preambles in a beam formed system.

[0046] Figure 3 illustrates a method according to certain embodiments. The method can include, at 310, indicating to a user equipment to consider at least one beam-specific parameter, such as a beam-specific random access channel parameter. For example, a network element can indicate to a user equipment that a particular beam-specific parameter is to be taken into account when selecting multiple beams.

[0047] To expand the number of preambles, the NW can instruct the UE to consider multiple beams for initial access by configuring thresholds. These thresholds can be used to judge beams relative to a best beam. With beam specific preambles in the system, the number of available preambles for random selection may increase.

[0048] Although the NW can instruct the UE to select multiple beams, only the beams that are above threshold may be considered by the UE. As the UE may hear multiple beams with very different power levels, it is to the advantage of both the NW and the UE that beams with too low quality are not considered but beams with good quality are considered, so that, for example, the message exchange after preamble transmission can be carried out.

[0049] Thus, for example, the method can include indicating in system information when and/or how to consider at least one of the following set of beam specific RACH parameters in RACH procedure: BeamRxLevelOffset, BeamRxLevelReferenceThreshold, or PreambleSelectionWeight. Accordingly, the at least one beam-specific parameter can include at least one of a beam reception level offset, a beam reception level reference threshold, or a preamble selection weight, of which BeamRxLevelOffset, BeamRxLevelReferenceThreshold, or PreambleSelectionWeight are examples. Other parameters may include, for example, a beam-specific back-off indicator. Each of these parameters is discussed below, by way of illustration and example.

[0050] This indicating can be performed on a network side, based on a determination at 305 as to what to indicate. Thus, at 305, the method can include determining that, when, and/or how a user equipment should consider at least one beam-specific parameter. The indicating at 310 can then proceed accordingly, and the indication can be received at the use equipment at 315.

[0051] The method can also include, at 320, utilizing, by a UE, at least one of the parameters, based on the indication. More particularly, the method can include utilizing, by the user equipment, at least one beam-specific parameter to select a beam-specific preamble.

[0052] For example, the method can include utilizing the parameters to calculate a set of available contention based preambles in a cell during a RACH procedure. The utilizing can include one or more of the following operations at 322, 324, and 326.

[0053] The method can include, at 322, obtaining information signaled in system information, such as in system information block (SIB). The method can also, or alternatively, include at 324 determining beam indices fulfilling criteria determined by beam specific RACH parameters. Moreover, the method can also or alternatively include, at 326, considering the preambles that map to determined beam indices as potential preambles for contention based RACH access.

[0054] The method can also include, at 330, determining, when signaled, the appropriate weights for determining preamble selection probabilities in random selection of preambles.

[0055] The method can further include the network side, at 312, sending the parameters, for example RACH configuration parameters, which can be received at the UE at 317. The parameters can be sent in system information broadcast in a system information block such as SIB2 or the like. The SIB may be transmitted during a specific downlink sweep (in sweep blocks mapped to one or multiple sub-frames) or on downlink shared channel (DL-SCH) on resources that are explicitly scheduled. Alternatively, rather than receiving the parameters from the network, the UE may be pre-configured with parameters or may determine the parameters autonomously from the network. One way to indicate a pre-determined set of parameters is to map specific parameters to, for example, a specific RACH / PRACH configuration index.

[0056] The UE can measure and determine the beam index with best quality by reference signal received power (RSRP) and/or reference signal received quality (RSRQ) and can set these values for BeamRxLevelReference. Some example NW side parameters are discussed below.

[0057] BeamRxLevelOffset can indicate the beam specific RX level offset value from the BeamRxLevelReference for determining whether the preambles mapping to the beam index can be considered in the random selection of contention based preambles. When a beam specific RX level is higher (alternatively, equal or higher) than BeamRxLevelThreshold where BeamRxLevelThreshold = BeamRxLevelReference + BeamRxLevelOffset, the beam specific contention based preambles can be considered in the random selection.

[0058] BeamRxLevelOffset may have one explicit value such as 0, -3dB, -6dB, -9dB, or the like. The value of BeamRxLevelOffset can be signaled by a logical value of, for example, 0…7.

[0059] One value of BeamRxLevelOffset may be reserved to indicate that such offset is not in use. For example, the value of “0” may be the reserved value. Alternatively the configuration information element (IE) may be optionally present in the configuration.

[0060] Alternatively, the offset value may be a step size, such as 1dB, 3dB, or 6dB, so that when utilized in combination with weighting parameter, each further step size reduces the probability of selecting the preambles affiliated with that beam index.

[0061] BeamRxLevelReferenceThreshold can indicate a threshold level to determine whether the BeamRxLevelOffset parameter is used for determining the available set of preambles for contention based access.

[0062] If the BeamRxLevelReference, for example the level of the strongest beam, is below the quality/level indicated by BeamRxLevelReferenceThreshold, the UE may not consider preambles of multiple beams to be available for random selection

[0063] Alternatively, BeamRxLevelReferenceThreshold may indicate a scaling factor for the BeamRxLevelOffset. Thus, the lower the RX quality of the strongest beam the lower the value of BeamRxLevelOffset*scaling_factor results. Thus, stricter criteria can be imposed for determining preambles' space when the signal quality is weak.

[0064] PreambleSelectionWeight is another parameter that can be used. For example, in certain embodiments, the NW may signal selection weights for the preambles that are determined to be available. For example, if the UE detects a beam which RX level is 3dB below the RX level of the strongest beam, the preambles may have equal probability with the preambles of the strongest beam but the preambles of a beam which RX level is 6dB below the strongest one may have weighted probability of 0.8, or any configured number. Thus, the UE may be less likely to select preambles of such beams, while the beams can remain in the set of selectable preambles.

[0065] In certain embodiments, the NW may explicitly signal the number of measurements the UE is required to perform before it is allowed to determine preambles of additional beams as available. Such measurement configuration may also be predetermined rather than explicit signaling being used.

[0066] In certain embodiments, when signaled in system information, the UE can transmit a beam report in RACH MSG3 or in the first UL message during RACH procedure. The beam report format may be implicitly determined by the RACH parameters in SIB2 or explicitly triggered by network when allocating resources for MSG3.

[0067] If determined by the RACH parameters, the UE can include the beam_index+RSRP/RSRQ value of all the beams it considered in the RACH procedure. Alternatively, there can be a fixed format such that the UE can report, for example, the two strongest beams detected during or prior to a random access procedure.

[0068] In one option, a truncated beam report may be determined and sent if there is not enough room in the UL grant sent in MSG2. In another option, the beam report, which may optionally be truncated, can list the beam indices in quality order. The beam report, whether truncated or not, may be a medium access control (MAC) control element (CE) or a radio resource control (RRC) level message.

[0069] In certain embodiments, a NW may signal a beam-specific back-off indicator (BBI) in an RAR. The beam specific back-off indicator can indicate that the UE(s) receiving the back-off indicator, and optionally a value, is prohibited from sending a RACH preamble mapping to the beam for rand_uniform(0,N milliseconds), where N can be a predetermined value or the signaled value.

[0070] When signaled by the network, the UE can be allowed to re-initiate a RACH procedure by utilizing a preamble mapping to another beam(s) where, in one example, the beam received power level is at least higher than RACH re-initiate threshold level = BeamRxLevelReference + BeamRxLevelOffset*re-initiate_factor.

[0071] By signaling the re-initiate_factor parameter, the NW may further ensure that the UE initiates the RACH procedure only to beams with quality. Such parameter may also be preconfigured.

[0072] Alternatively, such a threshold level may also obligate the UE to select the next RACH preamble from a set fulfilling the criteria, for example excluding the beam that received the back-off indicator. In one example, when the UE has re-initiated a RACH procedure to an another beam, the UE may be allowed to ramp-up the preamble transmission power to compensate the RXlevel difference, or compensate it with specific scaling factor, so that the difference is only partially compensated.

[0073] The method can also include, at 340, the user equipment performing a contention-based random access procedure. This random access procedure can be performed based on the determined preambles from the preceding steps of the method.

[0074] Figure 4 illustrates a system according to certain embodiments of the invention. It should be understood that each block of the flowchart of Figure 3 may be implemented by various means or their combinations, such as hardware, software, firmware, one or more processors and/or circuitry. In one embodiment, a system may include several devices, such as, for example, network element 410 and user equipment (UE) or user device 420. The system may include more than one UE 420 and more than one network element 410, although only one of each is shown for the purposes of illustration. A network element can be an access point, a base station, an eNode B (eNB), or any other network element.

[0075] Each of these devices may include at least one processor or control unit or module, respectively indicated as 414 and 424. At least one memory may be provided in each device, and indicated as 415 and 425, respectively. The memory may include computer program instructions or computer code contained therein, for example for carrying out the embodiments described above. One or more transceiver 416 and 426 may be provided, and each device may also include an antenna, respectively illustrated as 417 and 427. Although only one antenna each is shown, many antennas and multiple antenna elements may be provided to each of the devices. Other configurations of these devices, for example, may be provided. For example, network element 410 and UE 420 may be additionally configured for wired communication, in addition to wireless communication, and in such a case antennas 417 and 427 may illustrate any form of communication hardware, without being limited to merely an antenna.

[0076] Transceivers 416 and 426 may each, independently, be a transmitter, a receiver, or both a transmitter and a receiver, or a unit or device that may be configured both for transmission and reception. The transmitter and/or receiver (as far as radio parts are concerned) may also be implemented as a remote radio head which is not located in the device itself, but in a mast, for example. It should also be appreciated that according to the “liquid” or flexible radio concept, the operations and functionalities may be performed in different entities, such as nodes, hosts or servers, in a flexible manner. In other words, division of labor may vary case by case. One or more functionalities may also be implemented as a virtual application that is provided as software that can run on a server.

[0077] A user device or user equipment 420 may be a mobile station (MS) such as a mobile phone or smart phone or multimedia device, a computer, such as a tablet, provided with wireless communication capabilities, personal data or digital assistant

(PDA) provided with wireless communication capabilities, smart watch, vehicle communication system, portable media player, digital camera, pocket video camera, navigation unit provided with wireless communication capabilities or any combinations thereof. The user device or user equipment 420 may be a sensor or smart meter, or other device that may usually be configured for a single location.

[0078] In an exemplifying embodiment, an apparatus, such as a node or user device, may include means for carrying out embodiments described above in relation to Figure 3.

[0079] Processors 414 and 424 may be embodied by any computational or data processing device, such as a central processing unit (CPU), digital signal processor (DSP), application specific integrated circuit (ASIC), programmable logic devices (PLDs), field programmable gate arrays (FPGAs), digitally enhanced circuits, or comparable device or a combination thereof. The processors may be implemented as a single controller, or a plurality of controllers or processors. Additionally, the processors may be implemented as a pool of processors in a local configuration, in a cloud configuration, or in a combination thereof.

[0080] For firmware or software, the implementation may include modules or units of at least one chip set (e.g., procedures, functions, and so on). Memories 415 and 425 may independently be any suitable storage device, such as a non-transitory computer-readable medium. A hard disk drive (HDD), random access memory (RAM), flash memory, or other suitable memory may be used. The memories may be combined on a single integrated circuit as the processor, or may be separate therefrom. Furthermore, the computer program instructions may be stored in the memory and which may be processed by the processors can be any suitable form of computer program code, for example, a compiled or interpreted computer program written in any suitable programming language. The memory or data storage entity is typically internal but may also be external or a combination thereof, such as in the case when additional memory capacity is obtained from a service provider. The memory may be fixed or removable.

[0081] The memory and the computer program instructions may be configured, with the processor for the particular device, to cause a hardware apparatus such as network element 410 and/or UE 420, to perform any of the processes described above (see, for example, Figure 3). Therefore, in certain embodiments, a non-transitory computer-readable medium may be encoded with computer instructions or one or more computer program (such as added or updated software routine, applet or macro) that, when executed in hardware, may perform a process such as one of the processes described herein. Computer programs may be coded by a programming language, which may be a high-level programming language, such as objective-C, C, C++, C#, Java, etc., or a low-level programming language, such as a machine language, or assembler. Alternatively, certain embodiments of the invention may be performed entirely in hardware.

[0082] Furthermore, although Figure 4 illustrates a system including a network element 410 and a UE 420, embodiments of the invention may be applicable to other configurations, and configurations involving additional elements, as illustrated and discussed herein. For example, multiple user equipment devices and multiple network elements may be present, or other nodes providing similar functionality, such as nodes that combine the functionality of a user equipment and an access point, such as a relay node.

[0083] Certain embodiments may have various benefits and/or advantages. For example, certain embodiments may decrease the collision probability for the UE's random access. For example, when the UE has multiple beams to select from, the beam report in RA MSG3 can be used for the NW to determine the best beam.

[0084] The back-off indicator mechanism can allow faster access for the UEs to which it would be possible via other beams. Moreover, the back-off indicator mechanism may provide a fast and flexible way to distribute the RACH load between beams. Moreover, the offset/threshold parameters may serve as longer term mechanism to adjust the RACH load between or among beams.

[0085] One having ordinary skill in the art will readily understand that the invention as discussed above may be practiced with steps in a different order, and/or with hardware elements in configurations which are different than those which are disclosed. Therefore, although the invention has been described based upon these preferred embodiments, it would be apparent to those of skill in the art that certain modifications, variations, and alternative constructions would be apparent, while remaining within the spirit and scope of the invention.

[0086] List of Abbreviations

[0087] BBI Beam Specific Back-off Indicator

[0088] MAC CE MAC Control Element

[0089] MSG2 Message 2 in RACH procedure (or the first network side message after receiving UE's preamble transmission

[0090] MSG3 Message 3 in RACH procedure (or the first UE side message containing data)

[0091] RACH Random Access Channel

[0092] UE User Equipment

WE CLAIM:

1. A method, comprising:

detecting a plurality of signal beams;

measuring signal strength of each beam of the plurality of signal beams;

selecting a first beam of the plurality of signal beams having a highest signal strength of the plurality of signal beams;

selecting a second beam of the plurality of signal beams having a signal strength above a threshold; and

performing random access channel resource selection from random access channel resources of the first beam and random access channel resources of the second beam, for random access transmission.

2. The method of claim 1, further comprising:

performing random access using the selected random access channel resources.

3. The method of claim 1 or claim 2, wherein the random access channel resource selection comprises random or weighted random selection between the random access channel resources of the first beam and random access channel resources of the second beam.

4. The method of any of claims 1 through 3, further comprising

receiving a negative acknowledgment to the random access transmission; and

based on the negative acknowledgment, considering a beam-specific back off value for the first beam and the second beam.

5. The method of any of claims 1 through 4, wherein the method is performed by a user equipment.

6. The method of any of claims 1 through 5, wherein at least one of the first beam or the second beam comprises a beam of an access node.

7. A method, comprising:

determining that a user equipment should consider at least one beam-specific parameter; and

indicating to the user equipment to consider the at least one beam-specific parameter.

8. The method of claim 7, wherein the at least one beam-specific parameter comprises a beam-specific random access channel parameter.

9. The method of claim 7 or claim 8, wherein the indicating indicates to the user equipment how to use the at least one beam-specific parameter in a random access channel procedure.

10. The method of any of claims 7-9, wherein the at least one beam-specific parameter comprises at least one of a beam reception level offset, a beam reception level reference threshold, or a preamble selection weight.

11. The method of any of claims 7-10, wherein the at least one beam-specific parameter comprises at least one beam-specific back-off indicator.

12. The method of any of claims 7-11, wherein the indication of the at least one beam-specific parameter comprises sending the at least one beam-specific parameter in system information broadcast in a system information block.

13. The method of any of claims 7-12, wherein the system information block is transmitted during a specific downlink sub-frame or on a downlink shared channel on resources that are explicitly scheduled.

14. A method, comprising:

receiving, at a user equipment, an indication to consider at least one beam-specific parameter; and utilizing, by a user equipment, the at least one beam-specific parameter to select a beam-specific preamble based on the indication.

15. The method of claim 14, wherein the utilization of the at least one beam-specific parameter comprises calculating a set of available contention-based preambles in cell during a random access channel procedure.

16. The method of claim 14 or claim 15, wherein the utilization of the at least one beam-specific parameter comprises at least one of obtaining information signaled in system information; determining beam indices fulfilling criteria determined by the at least one beam-specific parameter; and considering preambles that map to the determined beam indices as potential preambles for contention-based random access channel access.

17. The method of any of claims 14-16, further comprising:

determining weights for determining preamble selection probabilities in random selection of preambles.

18. The method of any of claims 14-17, wherein the at least one beam-specific parameter comprises a beam-specific random access channel parameter.

19. The method of any of claims 14-18, wherein the indicating indicates to the user equipment how to use the at least one beam-specific parameter in a random access channel procedure.

20. The method of any of claims 14-19, wherein the at least one beam-specific parameter comprises at least one of a beam reception level offset, a beam reception level reference threshold, or a preamble selection weight.

21. The method of any of claims 14-20, wherein the at least one beam-specific parameter comprises at least one beam-specific back-off indicator.

22. An apparatus, comprising:

means for detecting a plurality of signal beams;

means for measuring signal strength of each beam of the plurality of signal beams;

means for selecting a first beam of the plurality of signal beams having a highest signal strength of the plurality of signal beams;

means for selecting a second beam of the plurality of signal beams having a signal strength above a threshold; and

means for performing random access channel resource selection from random access channel resources of the first beam and random access channel resources of the second beam, for random access transmission.

23. The apparatus of claim 22, further comprising means for performing the method according to any of claims 2-6.

24. An apparatus, comprising:

means for determining that a user equipment should consider at least one beam-specific parameter; and

means for indicating to the user equipment to consider the at least one beam-specific parameter.

25. The apparatus of claim 24, further comprising means for performing the method according to any of claims 8-13.

26. An apparatus, comprising:

means for receiving, at a user equipment, an indication to consider at least one beam-specific parameter; and

means for utilizing, by a user equipment, the at least one beam-specific parameter to select a beam-specific preamble based on the indication.

27. The apparatus of claim 26, further comprising means for performing the method according to any of claims 15-21.

28. An apparatus, comprising:

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 a process, the process comprising the method according to any of claims 1-21.

29. A computer program product encoding instructions for performing a process, the process comprising the method according to any of claims 1-21.

30. A non-transitory computer readable medium encoded with instructions that, when executed in hardware, perform a process, the process comprising the method according to any of claims 1-21.

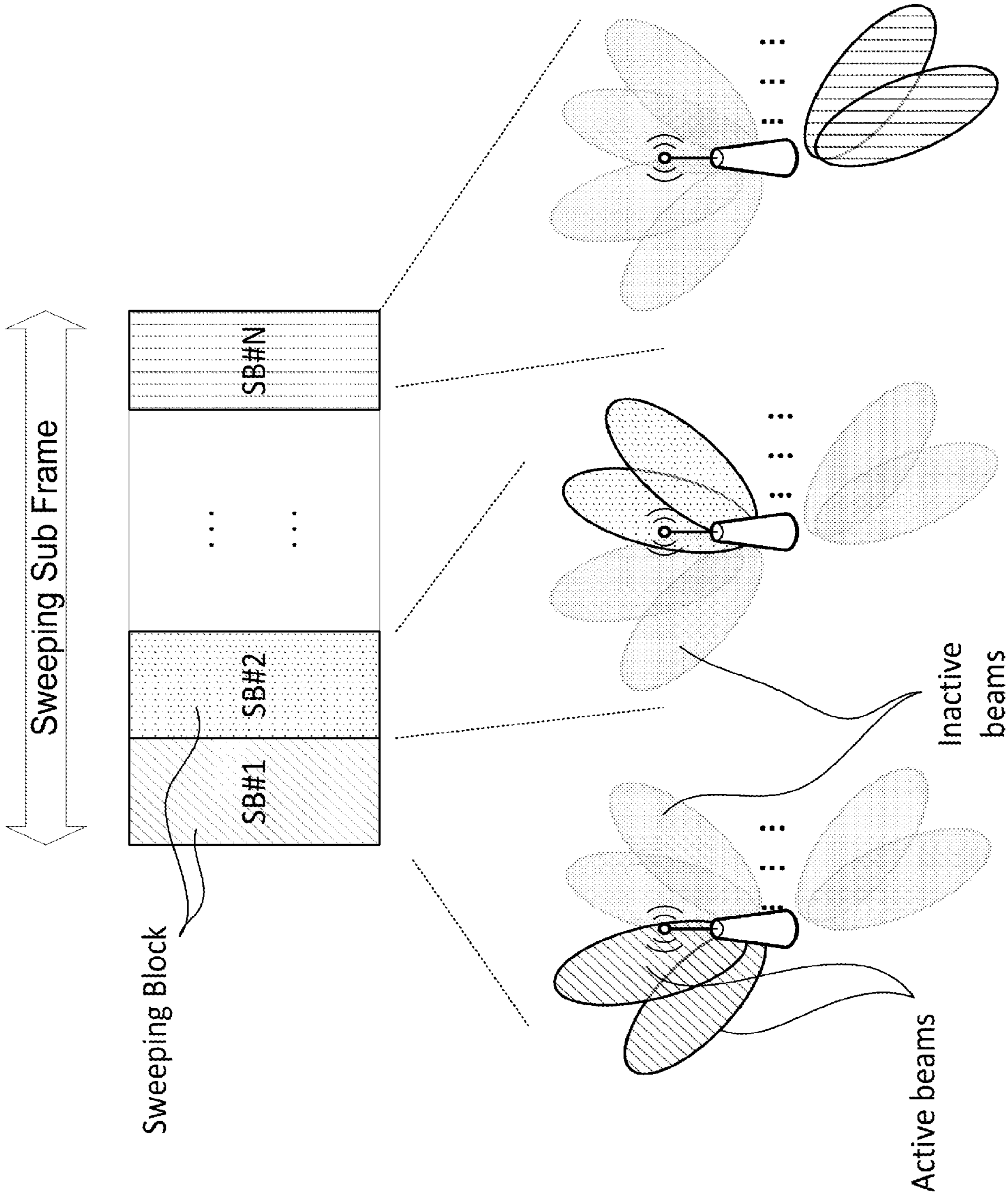

Sweeping Sub Frame
SB#1
SB#2
SB#N
Sweeping Block
Inactive beams
Active beams

Figure 1

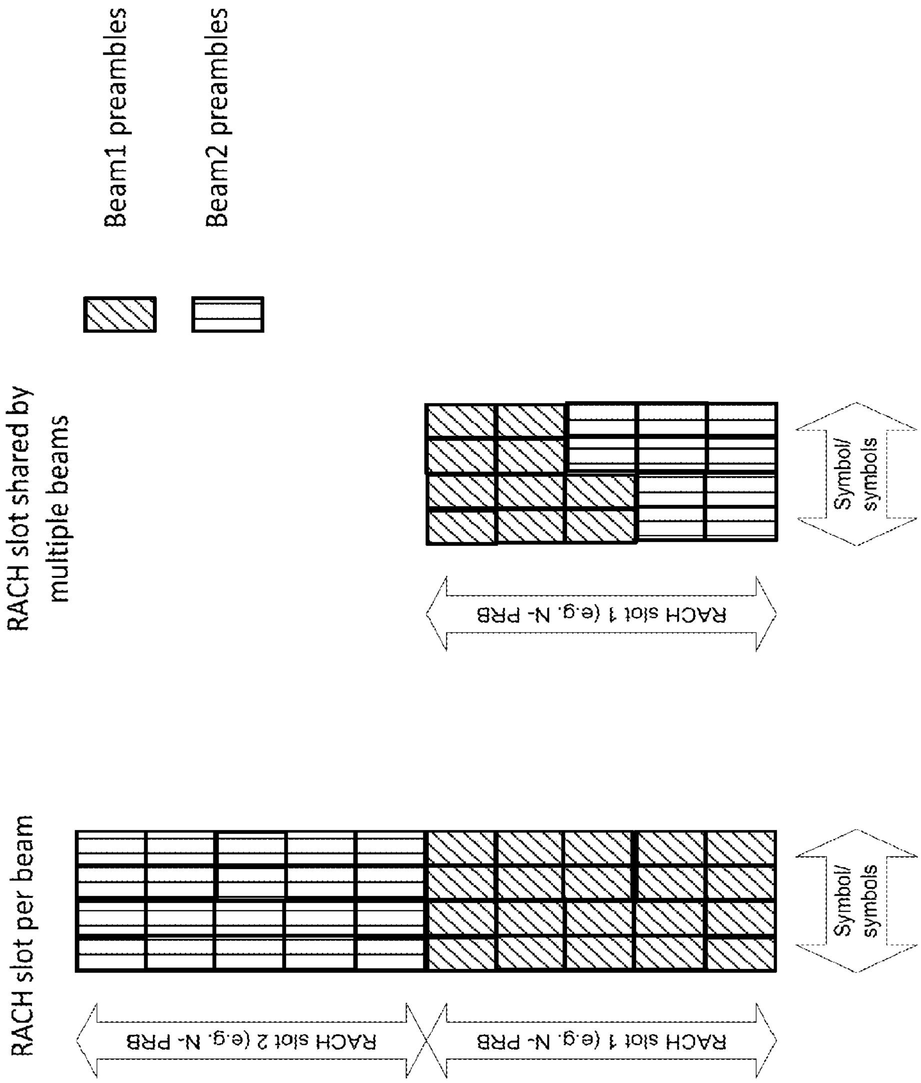

RACH slot shared by multiple beams
Beam1 preambles
Beam2 preambles
RACH slot 1 (e.g. N- PRB
Symbol/ symbols
RACH slot per beam
RACH slot 2 (e.g. N- PRB
RACH slot 1 (e.g. N- PRB
Symbol/ symbols

Figure 2

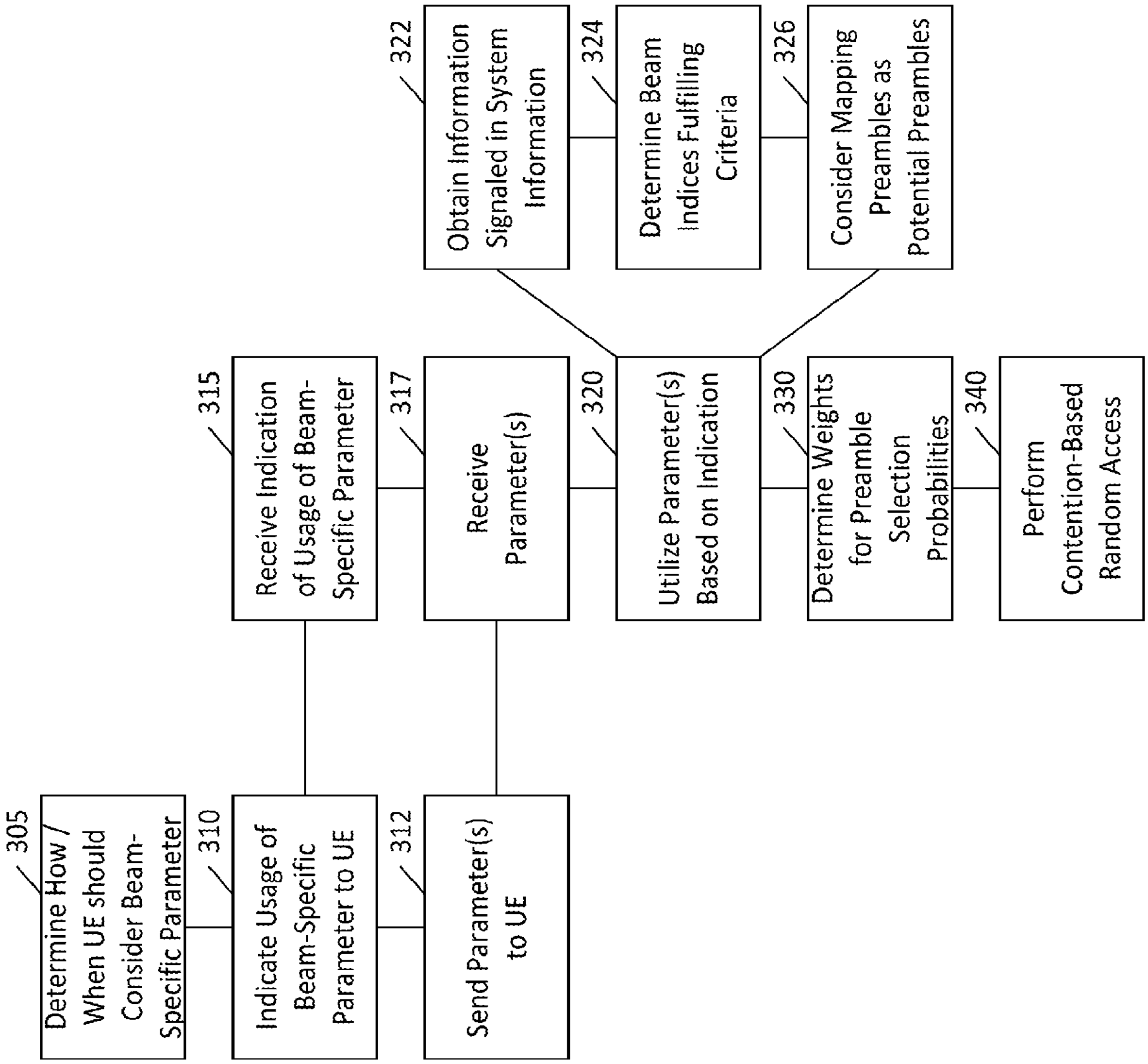
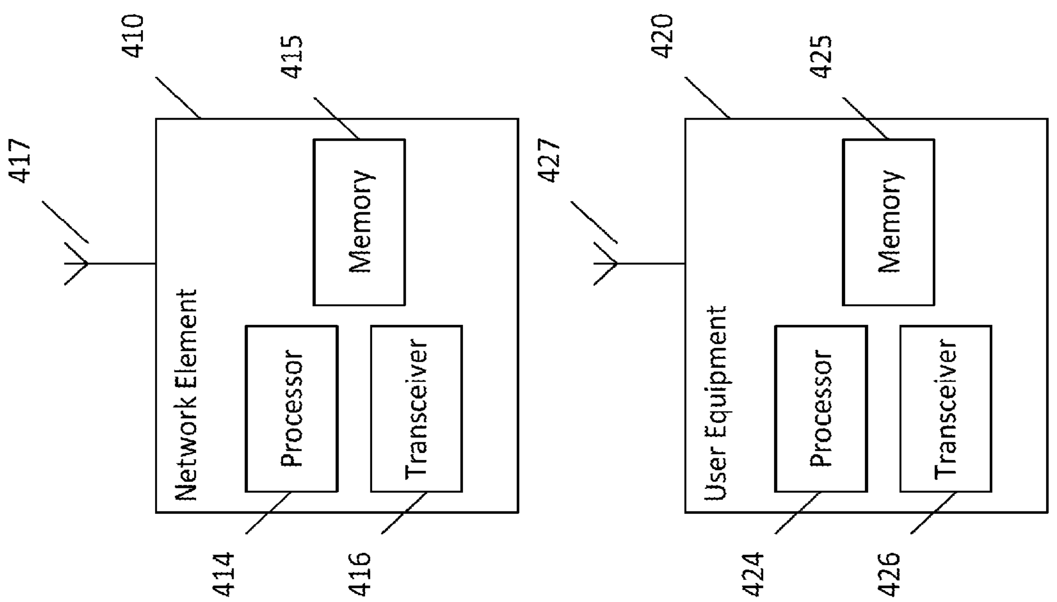

305
Determine How / When UE should Consider Beam-Specific Parameter
310
Indicate Usage of Beam-Specific Parameter to UE
312
Send Parameter(s) to UE
315
Receive Indication of Usage of Beam-Specific Parameter
317
Receive Parameter(s)
320
Utilize Parameter(s) Based on Indication
322
Obtain Information Signaled in System Information
324
Determine Beam Indices Fulfilling Criteria
326
Consider Mapping Preambles as Potential Preambles
330
Determine Weights for Preamble Selection Probabilities
340
Perform Contention-Based Random Access

Figure 3



410
415
417
Memory
Network Element
Processor
Transceiver
414
416
420
425
427
Memory
User Equipment
Processor
Transceiver
424
426

Figure 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI2017/050250

A. **CLASSIFICATION OF SUBJECT MATTER**

See extra sheet

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: H04B, H04L, H04W.

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

FI, SE, NO, DK

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

EPODOC, EPO-Internal full-text databases, WPIAP, XP3GPP, XPAIP, XPESP, XPETSI, XPI3E, XPIEE, XPIETF, XPIOP, XPIPCOM, XPJPEG, XPMISC, XPOAC, XPRD, XPTK, COMPDX, INSPEC, NPL, Internet, ESPACENET

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	US 2016021549 A1 (SUBRAMANIAN SUNDAR [US] et al.) 21 January 2016 (21.01.2016)	
X	Abstract; paragraphs [0006], [0030]-[0038], [0046]-[0047], [0054], [0059]-[0063], [0070]-[0078], [0081]; figures 2, 4, 8, 10-11; claim 3.	1-3, 5-6, 22-23, 28-30
Y	Paragraphs [0006], [0038], [0046]-[0047], [0061], [0070]-[0078], [0081].	4
	US 2014177607 A1 (LI YING [US] et al.) 26 June 2014 (26.06.2014)	
X	Abstract; paragraphs [0006]-[0008], [0044]-[0045], [0052], [0075], [0080]-[0087], [0101]-[0113], [0120]-[0122], [0132]-[0134], [0163]-[0166], [0179]-[0184], [0199]-[0205], [0210], [0212]-[0214], [0242]-[0243], [0250]-[0251], [0263]-[0271], [0275], [0278], [0288]-[0292], [0358]; figures 8, 12A, 18A-19.	1-3, 5-14, 18-30
Y	paragraphs [0101]-[0105], [0122], [0234], [0242]-[0243], [0258]-[0270], [0275], [0286]-[0287], [0358], figures 18A-19.	15-17

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

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

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

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
07 June 2017 (07.06.2017)	08 June 2017 (08.06.2017)

Name and mailing address of the ISA/FI	Authorized officer
Finnish Patent and Registration Office P.O. Box 1160, FI-00101 HELSINKI, Finland	Harald Kaaja
Facsimile No. +358 9 6939 5328	Telephone No. +358 9 6939 500

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2014286300 A1 (CHOI YUN-SEOK [KR] et al.) 25 September 2014 (25.09.2014) Abstract; paragraphs [0025]-[0037]; figures 1, 3; claim 1.	4
Y	US 2014376466 A1 (JEONG CHEOL [KR] et al.) 25 December 2014 (25.12.2014) Abstract; paragraphs [0037], [0042]-[0051], [0058]-[0066], [0074]-[0082], [0085]-[0086]; figures 3, 6-7.	15-17
A	WO 2015144256 A1 (ERICSSON TELEFON AB L M [SE]) 01 October 2015 (01.10.2015) The whole document.	1-30
A	US 2015382205 A1 (LEE MOON-IL [US] et al.) 31 December 2015 (31.12.2015) The whole document.	1-30

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		EP 3170271 A1	24/05/2017
		KR 20170032296 A	22/03/2017
		WO 2016010686 A1	21/01/2016
US 2014177607 A1	26/06/2014	US 9468022 B2	11/10/2016
		CN 105122662 A	02/12/2015
		EP 2939349 A1	04/11/2015
		KR 20150100653 A	02/09/2015
		WO 2014104758 A1	03/07/2014
US 2014286300 A1	25/09/2014	KR 20130054662 A	27/05/2013
		WO 2013073825 A1	23/05/2013
US 2014376466 A1	25/12/2014	KR 20150000304 A	02/01/2015
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		EP 3123803 A1	01/02/2017
		US 2017006638 A1	05/01/2017
US 2015382205 A1	31/12/2015	CN 104956606 A	30/09/2015
		EP 2949055 A1	02/12/2015
		TW 201445896 A	01/12/2014
		WO 2014116928 A1	31/07/2014

CLASSIFICATION OF SUBJECT MATTER

IPC
H04W 16/28 (2009.01)
H04W 74/08 (2009.01)
H04B 7/06 (2006.01)
H04B 7/08 (2006.01)