



(51) International Patent Classification:

H04B 7/06 (2006.01) H04W 72/04 (2009.01)

H04L 5/00 (2006.01) H04W 76/18 (2018.01)

H04W 16/28 (2009.01) H04W 76/19 (2018.01)

H04W 52/02 (2009.01) H04W 76/28 (2018.01)

(21) International Application Number:

PCT/EP2020/054858

(22) International Filing Date:

25 February 2020 (25.02.2020)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

62/809,809 25 February 2019 (25.02.2019) US

(71) Applicant: NOKIA TECHNOLOGIES OY [FI/FI];

Karakaari 7, 02610 Espoo (FI).

(72) Inventors: KOSKELA, Timo; Suojuksuntie 2 B 7, 90670

Oulu (FI). TURPINEN, Samuli Heikki; Salongintie 15,

91100 Ii (FI). KAIKKONEN, Jorma Johannes; Kuuse-

lantie 8, 90800 Oulu (FI). ENESCU, Mihai; Haukilan-

denkatu 1A 164, 02200 Espoo (FI). HAKOLA, Sami-Juk-

ka; Peikontie 7, 90450 Kempele (FI). KARJALAINEN,

Juha Pekka; Huiskilantie 6, 90540 Oulu (FI).

(74) Agent: NOKIA EPO REPRESENTATIVES; Nokia

Technologies Oy, Karakaari 7, 02610 Espoo (FI).

(81) Designated States (unless otherwise indicated, for every

kind of national protection available): AE, AG, AL, AM,

AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ,

CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO,

DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN,

HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP,

KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME,

MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ,  
OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA,  
SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR,  
TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every

kind of regional protection available): ARIPO (BW, GH,

GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ,

UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ,

TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK,

EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV,

MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM,

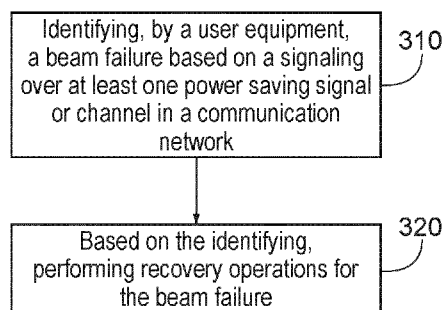
TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW,

KM, ML, MR, NE, SN, TD, TG).

Published:

— with international search report (Art. 21(3))

(54) Title: METHOD FOR BEAM FAILURE DETECTION



(57) Abstract: The present invention addresses an apparatus, method and computer program product for identifying, at a user equipment, a beam failure based on a signaling over at least one power saving signal or channel in a communication network, and performing recovery operations for the beam failure.

FIG. 3

## METHOD FOR BEAM FAILURE DETECTION

### TECHNICAL FIELD:

**[0001]** The teachings in accordance with the exemplary embodiments of this invention relate generally to signaling to enable improved detection and recovery of beam failure and, more specifically, relate to use of a use of power saving signal and/or channel design to enable improved detection and recovery of beam failure.

### BACKGROUND:

**[0002]** This section is intended to provide a background or context to the invention that is recited in the claims. The description herein may include concepts that could be pursued, but are not necessarily ones that have been previously conceived or pursued. Therefore, unless otherwise indicated herein, what is described in this section is not prior art to the description and claims in this application and is not admitted to be prior art by inclusion in this section.

**[0003]** Certain abbreviations that may be found in the description and/or in the Figures are herewith defined as follows:

|           |                                                  |
|-----------|--------------------------------------------------|
| WUS       | wake-up signal                                   |
| BFD       | beam failure detection                           |
| BFD-RS    | beam failure detection reference signal          |
| CE        | control element                                  |
| CBRA      | contention Based Random Access                   |
| CFRA      | contention Free Random Access                    |
| CORESET   | common control resource set                      |
| CSI-RS    | channel state information reference signal       |
| DRX       | discontinuous reception                          |
| EMTC      | enhanced machine-type communication              |
| eFEMTC    | even further Enhanced Machine Type Communication |
| FE-NB-IOT | further enhanced narrow band internet of things  |

|        |                                         |
|--------|-----------------------------------------|
| IoT    | internet of things                      |
| MAC    | medium access control                   |
| MAC-CE | medium access control – control element |
| OOS    | out-of-synchronization                  |
| PDCCH  | physical downlink control channel       |
| PUCCH  | physical uplink control channel         |
| QCL    | quasi co-location                       |
| RS     | reference signal (such as CSI-RS/SSB)   |
| SR     | Scheduling Request                      |
| SSB    | synchronization signal block            |
| TCI    | transmission configuration indicator    |

**[0004]** In Rel-15 NR, supported power saving mechanisms largely rely on mechanisms developed in LTE-A, e.g. by relying on a discontinuous reception (DRX) concept with PDCCH monitoring without taking into account multi-antenna panel as well as bandwidth part aspects at all. Therefore, there is a need to enhance UE power saving mechanisms in NR Rel-16 beyond, especially at above 6GHz communication.

**[0005]** Example embodiments of the invention work to at least to address these needs including taking into account such multi-antenna panels.

#### BRIEF DESCRIPTION OF THE DRAWINGS:

**[0006]** The above and other aspects, features, and benefits of various embodiments of the present disclosure will become more fully apparent from the following detailed description with reference to the accompanying drawings, in which like reference signs are used to designate like or equivalent elements. The drawings are illustrated for facilitating better understanding of the embodiments of the disclosure and are not necessarily drawn to scale, in which:

**[0007]** FIG. 1A shows an example TCI table configured for a UE;

**[0008]** FIG. 1B shows an example of WUS usage in Rel-15 LTE for paging when UE is in IDLE mode;

[0009] FIG. 2 shows a high level block diagram of various devices used in carrying out various aspects of the invention; and

[0010] FIG. 3 shows a method which can be performed by an apparatus in accordance with example embodiments of the invention.

#### DETAILED DESCRIPTION:

[0011] In this invention, there is proposed a novel signaling and channel design that to at least enable improved detection and recovery of beam failure.

[0012] Example embodiments of the invention are related to 3GPP New Radio (NR) physical layer design in Rel16 and onwards. More specifically, the invention focuses to enhance power efficiency of user equipment (UE) equipped with multiple antenna panels at high carrier frequencies.

[0013] Regarding TCI State Frame Work for PDCCH (TS 38.213), for determining the transmit beam for the PDCCH it has been agreed that each CORESET may be associated to one or multiple TCI states. In case the CORESET is associated with more than one TCI states, MAC-CE level activation signaling is used to control that which one of the multiple TCI states is active at a time per CORESET. Search space set related parameters associated to the CORESET define time domain monitoring pattern from which the UE knows when to monitor certain CORESET and then from associated (active) TCI state of the CORESET the UE knows how to set its RX beam. FIG. 1A provides an exemplary TCI table configured for the UE where QCL type A means Doppler spread, Doppler shift, delay spread, average delay and QCL type D means spatial RX. Thus, when TCI index 0 determines source RS(s) for a certain physical signal or channel, the UE can determine that it can set its RX beam as it set for receiving the SS/PBCH block #n. Correspondingly, when TCI index 1 determines source RS(s) for a certain physical signal or channel, the UE can determine that it can set its RX beam as it set for receiving the CSI-RS # (of RS set #B).

[0014] **QCL, Quasi Co-location Assumption (TS 38.213/214)**

**[0015]** When two different signals share the same QCL type, they share the same indicated properties. As an example, the QCL properties may be e.g. delay spread, average delay, Doppler spread, Doppler shift, spatial RX, QCL type A means Doppler spread, Doppler shift, delay spread, and/or average delay, and QCL type D means spatial RX. Currently 38.214 lists following QCL types:

- 'QCL-TypeA': {Doppler shift, Doppler spread, average delay, delay spread}
- 'QCL-TypeB': {Doppler shift, Doppler spread}
- 'QCL-TypeC': {Doppler shift, average delay}
- 'QCL-TypeD': {Spatial Rx parameter}

**[0016]** As a further example if a CSI-RS and SSB have the type D QCL assumption between each other, it means that UE may utilize same RX spatial filter (beam) to receive these signals.

**[0017]** In 3GPP RAN1, wake-up signal (WUS) has been considered in Rel-15 LTE in eFEMTC (even Further Enhanced Machine Type Communication) and FE-NB-IOT (Further Enhanced Narrow Band Internet of Things) study/work items (SI/WI). The main driver for the use of WUS is to reduce power consumption of PDCCH monitoring at UE-side. A periodic monitoring of PDCCH for paging translates to a shortened UE battery life in idle mode. The reason of this is that during the monitoring of PDCCH the following issues needs to be performed: FFT computation, channel estimation, blind decoding PDCCH candidates for each configured search space as well as related decoding of channel coding. In Rel-15 eFEMTC, the monitoring need of PDCCH can be reduced by using WUS to indicate UE whether PDCCH needs to be monitored or not for IDLE mode paging. As a result of this, UE power consumption can be reduced.

**[0018]** In context of Rel-16 NR UE power saving, in RAN1-94bis meeting, power saving signal/channel for based wake-up and go-to-sleep (GTS) were discussed.

**[0019]** The power saving signal/channel itself can be any signal or channel defined for this operation e.g. sequence (similar to synchronization sequence) or even a PDCCH channel that UE only monitors for the detection of specific DCI format (downlink control channel). The signal or channel may be configured by network and the monitoring occasions are also configured by network where the UE monitors the presence (or absence) or determines the information signalled by the signal to determine if it shall wake up (e.g. to monitor PDCCH) on the next on-duration of a DRX cycle. Alternatively, the power saving signal channel can be transmitted during on duration e.g. at the beginning and it may determine whether UE continues e.g. to monitor PDCCH at least for the duration of ON duration.

**[0020]** The WUS monitoring (note that at the time of this application remains in open discussion) may mean that specific DCI format or specific signaling sequence (similar to synchronization sequence) is monitored by UE to determine if it needs to monitor all the configured PDCCH search spaces during ON DURATION. Without WUS, UE would always stay awake for PDCCH monitoring for the duration of ON DURATION which consumes additional power if NW has no data to schedule for UE.

**[0021]** Monitoring of these signals is configured by network. E.g. for wake-up triggering, wake-up signal/channel is used as a trigger for UE to indicate whether it needs to monitor DCI during the following/next DRX onDuration. The wake-up or GTS indications may be specific signals or channels that UE is monitoring and the UE actions may be determined based on the presence or absence of such signals or channels. In one example of a “Wake-Up channel” would be a specific DCI format that UE is decoding in order to determine presence of an indication. If the wake-up is not indicated for UE, UE can skip monitoring the DCI (according to normal search space configuration) during next onDuration and enter back into sleep mode or perform other tasks such as measurements. Correspondingly, UE could be indicated to go back to sleep based on power saving signal/channel e.g. while inactivity timer is running i.e. during onDuration.

**[0022]** As an example related to release 15 where the WUS is used is illustrated in FIG. 1A. As similarly stated above, FIG. 1A provides an exemplary TCI table configured for the UE where QCL type A means Doppler spread, Doppler shift, delay spread, average delay and QCL type D means spatial RX. As shown in FIG. 1A there is

for a TCI index 110 of 0, 1, to M-1 a source RX set 120, a source RX index 130, and a QCL type 140.

**[0023]** FIG. 1B shows an example of WUS usage in Rel-15 LTE for paging when UE is in IDLE mode. As shown in FIG. 1B there is shown a bandwidth and symbol including a WUS preamble/RS 150, a PDCCH 160, and a PDSCH 170. As shown in FIG. 1B the WUS preamble/RS 150 indicates whether the UE needs to monitor PDCCH for paging or not, and there is a delay in the decision. Following the PDCCH 160 of FIG. 1B there is the PDSCH.

**[0024]** In Release 15 beam failure recovery regarding a beam failure detection reference signal the Network configures a UE with a set of reference signals for monitoring the quality of the control channel link or links. Typically, these reference signals are configured to be QCL'd (e.g. spatially) with PDCCH DMRS i.e. these reference signals correspond to downlink beams used to transmit PDCCH. The quality of the PDCCH is estimated based on the corresponding (QCLs) DL RS. If a signal is configured for monitoring/estimating PDCCH quality it is referred as beam failure detection reference signal. This set may be referred as q0 or beam failure detection RS or BFD-RS. Downlink Beams are identified by reference signal, either SS/PBCH block index or CSI-RS resource index. Network may configure the BFD-RS list using RRC signaling or it may be possible to use combined RRC + MAC CE signaling.

**[0025]** When UE is not explicitly configured with BFD-RS list, it determines the BFD-RS resources implicitly based on the configured/indicated/activated PDCCH-TCI states per CORESET i.e. the downlink reference signals (CSI-RS, SS/PBCH block) that are QCL'd (e.g. spatially) with PDCCH DMRS, or in other words, PDCCH beams. SS/PBCH block may be included in the beam failure detection RS set (q0) either directly or indirectly i.e. SSB may be configured as TRS (tracking reference signal) and the TRS may be configured as BFD-RS implicitly or explicitly.

**[0026]        Declaring beam failure**

**[0027]** Physical layer assesses the quality of the radio link (based on BFD-RS in set of q0) periodically. Assessment is done per BFD-RS and when the radio link

condition of each BFD-RS in the beam failure detection set is considered to be in failure condition i.e. the hypothetical PDCCH BLER estimated using the RS is above the configured threshold, a beam failure instance (BFI) indication is provided to higher layer (MAC). One example of BLER threshold value may be the out of sync threshold used for radio link monitoring OOS/Qout = 10% (which corresponds to specific SINR value). Evaluation and indication of beam failure is done periodically. In case the at least one BFD-RS is not in failure condition, no indication is provided to higher layer. The indication interval is determined based on the periodicity of beam failure detection resources. MAC layer implements a counter to count the BFI indications from the PHY layer and if the BFI counter reaches maximum value (configured by the network) a beam failure is declared. This counter can be configured to be supervised by a timer: each time MAC receives BFI indication from lower layer a timer is started. Once the timer expires, the BFI counter is reset (counter value is set to zero).

**[0028]** In Rel. 15 beam failure detection it is required that all the BFD-RS signals (beam failure detection RS) are in failure condition before a beam failure instance is indicated (and eventually beam failure could be declared and recovery initiated). Also, the beam failure detection mechanism is similar in DRX and non-DRX but in DRX operation e.g. the reference signals used for detection are the same and all the BFD-RS need to be in failure condition but the indication interval is scaled according to DRX period i.e. in DRX the evaluation period is typically longer than in non-DRX.

**[0029]** In current discussions the reception power saving signal/channel has been configured for UE has not been discussed in detail, other than the potential procedure it triggers such as to wake up UE and/or indicate UE to go to sleep. Furthermore, the beam failure detection as performed in release 15 would potentially increase latency of detecting failure (or not detecting at all since all the RS need to be in failure condition) and indicating it to network which may cause network to waste transmission resources for trying schedule UE.

**[0030]** As the power saving signal/channel reception determines whether or not UE shall start monitoring PDCCH according to search space configuration it would be beneficial to improve/enhance the beam failure detection and recovery procedure of what has been defined and specified in release 15.

**[0031]** The technical problem to be solved would be to enhance current release 15 beam failure detection that would be potentially too slow to detect or would not react fast enough for the failure of essential channel/signal (where the failure may mean that the signal or channel quality is not sufficient for reliable reception or detection ) from UE perspective.

**[0032]** Regarding other proposals, such as directed to TX side beam sweeping for WUS transmission. These submissions assume that due to DRX (UE in sleeps) the UE-gNB beam alignment “drifts” so that there would be a potential signal quality degradation for WUS reception (thus gNB sweeps at TX side). In addition, at the time of this application none of these submission explicitly disclose any beam failure detection in DRX when WUS is configured, nor does it disclose any assumption for spatial reference for WUS reception. Example embodiments of the invention address at least these issues.

**[0033]** In addition, in some proposals the partial failure would be indicated in periodic PUCCH beam report by using special RSRP value for the reported beam. However, WUS/ power saving signal/channel specific mechanisms have not been discussed, and there is no definition at the time of this application for partial beam failure, other than e.g. that subset of control channels fail (not in the specification)

**[0034]** Example embodiments of the invention provide enhancements for single and multiple beam failure detection and recovery enhancements. Operations in accordance with the example embodiments can work using a signal or channel such as related to a WUS or Go to sleep type of signal or channel while a device or UE configured with power saving signal/channel is in a DRX mode of operation, and/or such as while the UE is in an active mode of operation. In more general view it is possible to use the methods herein to associate specific signal and/or channel with a reference signal to perform failure detection on the said signal or channel. The methods are not limited in particular use of DRX (e.g. DRX OFF/ON cycles) and can be used e.g. when there is no DRX configured.

**[0035]** Before describing the example embodiments of the invention in detail, reference is made to FIG. 2 for illustrating a simplified block diagram of various

electronic devices that are suitable for use in practicing the example embodiments of this invention.

**[0036]** FIG.2 shows a block diagram of one possible and non-limiting exemplary system in which the example embodiments of the invention may be practiced. In FIG. 2, a user equipment (UE) 10 is in wireless communication with a wireless network 1. A UE is a wireless, typically mobile device that can access a wireless network. The UE 10 includes one or more processors DP 10A, one or more memories MEM 10B, and one or more transceivers TRANS 10D interconnected through one or more buses. Each of the one or more transceivers TRANS 10D includes a receiver and a transmitter. The one or more buses may be address, data, or control buses, and may include any interconnection mechanism, such as a series of lines on a motherboard or integrated circuit, fiber optics or other optical communication equipment, and the like. The one or more transceivers TRANS 10D are connected to one or more antennas for communication 11 and 14 to gNB 12 and gNB 13, respectively. The one or more memories MEM 10B include computer program code PROG 10C. The UE 10 communicates with gNB 12 and/or gNB 13 via a wireless link 111.

**[0037]** The gNB 12 (NR/5G Node B or possibly an evolved NB) is a base station such as a master or secondary node base station (e.g. for NR or LTE long term evolution) that communicates with devices such as gNB 13 and UE 10 of FIG. 2. The gNB 12 provides access to wireless devices such as the UE 10 to the wireless network 1. The gNB 12 includes one or more processors DP 12A, one or more memories MEM 12C, and one or more transceivers TRANS 12D interconnected through one or more buses. In accordance with the example embodiments these TRANS 12D can include X2 and/or Xn interfaces for use to perform the example embodiments of the invention. Each of the one or more transceivers TRANS 12D includes a receiver and a transmitter. The one or more transceivers TRANS 12D are connected to one or more antennas for communication over at least link 11 with the UE 10. The one or more memories MEM 12B and the computer program code PROG 12C are configured to cause, with the one or more processors DP 12A, the gNB 12 to perform one or more of the operations as described herein. The gNB 12 may communicate with another gNB or eNB, such as the gNB 13. Further, the link 11 and or any other link may be wired or wireless or both and may implement, e.g. an X2 or Xn interface. Further the link 11 may be through other network devices such as, but not

limited to an NCE/MME/SGW device such as the NCE 14 of FIG. 2.

**[0038]** The gNB 13 (NR/5G Node B or possibly an evolved NB) is a base station such as a master or secondary node base station (e.g. for NR or LTE long term evolution) that communicates with devices such as the gNB 12 and/or UE 10 and/or the wireless network 1. The gNB 13 includes one or more processors DP 13A, one or more memories MEM 13B, one or more network interfaces, and one or more transceivers TRANS 12D interconnected through one or more buses. In accordance with the example embodiments these network interfaces of gNB 13 can include X2 and/or Xn interfaces for use to perform the example embodiments of the invention. Each of the one or more transceivers TRANS 13D includes a receiver and a transmitter connected to one or more antennas. The one or more memories MEM 13B include computer program code PROG 13C. For instance, the one or more memories MEM 13B and the computer program code PROG 13C are configured to cause, with the one or more processors DP 13A, the gNB 13 to perform one or more of the operations as described herein. The gNB 13 may communicate with another gNB and/or eNB such as the gNB 12 and the UE 10 or any other device using, e.g. link 11 or another link. These links maybe wired or wireless or both and may implement, e.g. an X2 or Xn interface. Further, as stated above the link 11 may be through other network devices such as, but not limited to an NCE/MME/SGW device such as the NCE 14 of FIG. 2.

**[0039]** The one or more buses of the device of FIG. 2 may be address, data, or control buses, and may include any interconnection mechanism, such as a series of lines on a motherboard or integrated circuit, fiber optics or other optical communication equipment, wireless channels, and the like. For example, the one or more transceivers TRANS 12D, TRANS 13D and/or TRANS 10D may be implemented as a remote radio head (RRH), with the other elements of the gNB 12 being physically in a different location from the RRH, and the one or more buses 157 could be implemented in part as fiber optic cable to connect the other elements of the gNB 12 to a RRH.

**[0040]** It is noted that although FIG. 2 shows network nodes e.g. base stations as a gNB 12 and a gNB 13, these devices can incorporate an eNodeB or eNB such as for LTE, and would still be configurable to perform example embodiments of the invention.

**[0041]** Also it is noted that description herein indicates that “cells” perform functions, but it should be clear that the gNB that forms the cell will perform the functions. The cell makes up part of a gNB. That is, there can be multiple cells per gNB.

**[0042]** The wireless network 1 may include a network control element (NCE) 14 that may include MME (Mobility Management Entity)/SGW (Serving Gateway) functionality, and which provides connectivity with a further network, such as a telephone network and/or a data communications network (e.g. the Internet). The gNB 12 and the gNB 13 are coupled via a link 13 and/or link 14 to the NCE 14.

**[0043]** The NCE 14 includes one or more processors DP 14A, one or more memories MEM 14B, and one or more network interfaces (N/W I/F(s)), interconnected through one or more buses coupled with the link 13 and/or 14. In accordance with the example embodiments these network interfaces can include X2 and/or Xn interfaces for use to perform the example embodiments of the invention. The one or more memories MEM 14B include computer program code PROG 14C. The one or more memories MEM14B and the computer program code PROG 14C are configured to, with the one or more processors DP 14A, cause the NCE 14 to perform one or more operations which may be needed to support the operations in accordance with the example embodiments of the invention.

**[0044]** The wireless Network 1 may implement network virtualization, which is the process of combining hardware and software network resources and network functionality into a single, software-based administrative entity, a virtual network. Network virtualization involves platform virtualization, often combined with resource virtualization. Network virtualization is categorized as either external, combining many networks, or parts of networks, into a virtual unit, or internal, providing network-like functionality to software containers on a single system. Note that the virtualized entities that result from the network virtualization are still implemented, at some level, using hardware such as processors DP10, DP12A, DP13A, and/or DP14A and memories MEM 10B, MEM 12B, MEM 13B, and/or MEM 14B, and also such virtualized entities create technical effects.

**[0045]** The computer readable memories MEM 12B, MEM 13B, and MEM 14B

may be of any type suitable to the local technical environment and may be implemented using any suitable data storage technology, such as semiconductor based memory devices, flash memory, magnetic memory devices and systems, optical memory devices and systems, fixed memory and removable memory. The computer readable memories MEM 12B, MEM 13B, and MEM 14B may be means for performing storage functions. The processors DP10, DP12A, DP13A, and DP14A may be of any type suitable to the local technical environment, and may include one or more of general purpose computers, special purpose computers, microprocessors, digital signal processors (DSPs) and processors based on a multi-core processor architecture, as non-limiting examples. The processors DP10, DP12A, DP13A, and DP14A may be means for performing functions, such as controlling the UE 10, gNB 12, gNB 13, and other functions as described herein.

**[0046]** In general, the various embodiments of the user equipment 10 can include, but are not limited to, cellular telephones such as smart phones, tablets, personal digital assistants (PDAs) having wireless communication capabilities, portable computers having wireless communication capabilities, image capture devices such as digital cameras having wireless communication capabilities, gaming devices having wireless communication capabilities, music storage and playback appliances having wireless communication capabilities, Internet appliances permitting wireless Internet access and browsing, tablets with wireless communication capabilities, as well as portable units or terminals that incorporate combinations of such functions.

**[0047]** In accordance with an example embodiment of the invention, when UE is configured to monitoring power saving signal/channel i.e. when it is not monitoring PDCCH as during active time (or is not monitoring PDCCH according to search space configuration) it is proposed that UE performs beam failure detection/recovery in such a manner as:

- UE determines implicitly or explicitly by NW configuration a specific TCI state (downlink reference signal such as CSI-RS/SSB) to be QCL'd with power saving signal/channel. As an example, UE determines the reception characteristics of the power saving signal or channel based on indicated TCI state. That can be either one of the currently active TCI States for PDCCH or some other TCI state

configured for UE or a TCI state for PDSCH. As an example a specific TCI state is indicated that share the QCL assumption with the power saving signal or channel. This QCL assumption may be one of e.g. typeA and/or typed but not limited to those. Thus it may be considered that one of the TCI states is “active” for reception of power saving signal or channel. In case this active TCI state is associated with multiple RS with different QCL types one of the RS is selected. In some case the RS with type D may be selected. In some cases the RS with typeA may be selected. Thus, the power saving signal or channel may be associated with specific downlink reference signal (SSB/CSI-RS);

- This TCI state or states (there may be multiple power saving signals transmitted by a network using different beams and thus they may be associated to different downlink RS) that are associated to power saving signal/channel reception is/are included in beam failure detection resource set of q0 or alternatively to specific temporary or alternative set of failure detection reference signals i.e. set q0\_temp. One example, RS corresponding to power saving signal or channel may correspond to the active TCI state for PDCCH and in implicit configuration it may already be included in the set of q0. In this case UE may determine to trigger partial beam failure based on the quality of that specific RS (or in case multiple power saving signals or channels are configured, on one or all the RSs) In some cases these may be referred as first set of beam failure detection reference signals and second set of beam failure detection reference signals where the first set may be used when UE is specific mode e.g. in non-DRX mode and second set when UE is not in non-DRX mode or is in DRX-mode. In general view the different sets may be used by UE in different operation modes or in different UE stated. As one further example, the set of q0 may contain the BFD-RS configured implicitly or explicitly by network for UE to determine failure on configured control channels (PDCCH) while set of q0\_temp may contain BFD-RS determining the failure condition for power saving signal or channel i.e. the signal or channel cannot be reliably received by UE. UE may e.g. derive the hypothetical failure rate or an error rate of the power saving signal or channel based on the QCL'd reference signal;
- When UE is in DRX mode operation i.e., and / or monitoring power saving

signal/channel:

- Option1: UE determines the beam failure detection reference signal for beam failure detection based on the alternative set of  $q0\_temp$ . When all the reference signals in  $q0\_temp$  are in failure condition (when this set contains BFD-RS associated with power saving signal or channel) UE is allowed to trigger beam failure. This triggering may mean that UE provides indication to higher layer i.e. beam failure instance or a beam failure may be declared based on this indication. In some cases UE may declare beam failure or indicate beam failure instance or trigger indication /recovery of partial beam failure when one of the BFD-RS in that set is in failure condition.
- Option2: UE is allowed to trigger partial beam failure on set of  $q0$  to indicate failure of the at least one BFD-RS corresponding to power saving signal/channel. In this option, when the RS corresponding power saving signal or channel is included in the set of  $q0$ , UE triggers either indication of beam failure instance to higher layer, declared beam failure, indicates partial beam failure to higher layer or may indicate power saving signal or channel specific failure indication to higher layer to trigger failure detection/declaration. In this option UE may trigger partial failure indication regardless on operation mode (DRX / non-DRX / monitoring power save signal / monitoring PDCCH according to search space configuration), or it may trigger failure indication only in specific mode e.g. in DRX or when it monitors power saving signal/channel. It should be understood that triggering failure may mean that beam failure instance indication to higher layer provided, or UE declares beam failure or a partial beam failure instance is indicated or a power saving signal or channel specific failure/failure instance indication is provided to higher layer.
- Option3: If power saving signal/channel is transmitted using multiple beam (repeated) UE determines the  $q0\_temp$  to include at the RSs corresponding to the repeated beams to the  $q0\_temp$ .

- In one example when UE is not in DRX mode (is in active time decoding PDCCH according to search space configuration or is in non-DRX mode) the q0\_temp is not active but the q0 is used instead. Alternatively, when only q0 is used (option2) the partial failure may be triggered based on power saving signal when UE is in DRX mode (or monitoring power save signal). Alternatively the partial failure may be triggered regardless of the operation mode.
  - o In one example the higher layer indication of failure/failure instance means L1 indication to MAC. However any method herein is not limited to particular layer.

**[0048]** In accordance with example embodiments of the invention:

- BFD can in normal mode, when no power-saving mode, such as DRX mode is active, be based on a maximum detection failure rate of a control channel, such as PDCCH, transmitted using a respective beam setting. This detection rate can be estimated based on downlink RS transmitted in said beam with known QCL relation to said control channel (or with known QCL relation to RS of the control channel, such as DMRS in PDCCH);
- In a power saving mode, such as DRX mode, the UE may not monitor DL transmissions continuously. Instead, the UE may monitor the quality of the PDCCH, for example through a configured association of a RS with known QCL relation, only during certain monitoring intervals, such as onDurations in DRX mode. This reduced monitoring effort compromises the reliability of the BFD procedure;

**[0049]** It is noted that this reliability problem of the BFD procedure can become more urgent when monitoring indication signals, such as WUS, are introduced, as information on a monitoring indication signal will frequently instruct a UE to skip monitoring of DL signals or channels (e.g. PDCCH) during at least one subsequent monitoring interval (e.g. DRX cycle). In other words, an introduction of monitoring indication signals will further reduce the UE's monitoring effort for BFD.

**[0050]** In accordance with example embodiments of the invention at least the

above problem can be mitigated when information for BFD can be inferred from DL signals associated with transmissions of monitoring indicators signals or channels. What may be needed to be known for this purpose is the relation between a suitable monitoring indication associated signal and said control channel, i.e. which properties of the control channel can be inferred from properties of said monitoring indication associated signal. In other words, a QCL relation between the control channel and the monitoring indicator signal needs to be known. This QCL relation may be configured through one or more TCI states between the control channel (including control channel associated signals, such as control channel associated RS) and the monitoring indicator signal or channel (including monitoring indication associated signals, such as monitoring indication associated RS).

**[0051]** The monitoring indication signal may be a power saving signal or power saving channel, and the UE may determine one or more reception characteristics of the monitoring indication signal based on one or more reception characteristics of a monitoring indication associated signal (e.g. a RS transmitted in a corresponding monitoring indication channel) and one or more first QCL relations between the monitoring indication signal and the monitoring indication associated signal. The one or more first QCL relations may be configured through first TCI states.

**[0052]** The UE in power saving mode may determine one or more reception characteristics of the downlink control channel, based on one or more reception characteristics of the monitoring indication signal based on one or more second QCL relations between the control channel and the monitoring indication signal. The one or more second QCL relations may be configured through second TCI states.

**[0053] UE may use one of following methods for recovering from power saving signal/channel beam failure:**

**[0054]** In one aspect, when UE has determined that downlink RS (such as CSI-RS/SSB)) corresponding to power saving signal/channel (e.g. TCI state of PDCCH, the corresponding RS used for failure detection of power saving signal/channel beam) UE starts monitoring of PDCCH according to search space configuration (i.e. monitoring PDCCH as it would do on DRX ON duration, In other words UE enters on duration and

is in non-DRX mode). where:

- Upon declaring power saving signal/channel beam failure by UE, regardless of whether the power saving signal or channel is detected or not by UE, it wakes up for PDCCH monitoring on the next DRX on-duration. As the network may have tried send power saving signal/channel to reach UE to wake it up for monitoring PDCCH.
  - o During ON duration or when exits DRX mode, UE may indicate network on the partial failure/ or beam failure or failure on specific signal such as power saving signal or channel;
- Alternatively/additionally, the PDCCH monitoring is started immediately, UE enters immediately on duration or starts monitoring PDCCH according to search space configuration.

**[0055]** In one aspect, the methods described herein to trigger partial beam failure or indication of beam failure instance or declaration of beam failure may allow UE to trigger beam failure recovery: in this case it may indicate e.g. another TCI state active for PDCCH as new candidate which implicitly indicates network that DL RS corresponding to power saving signal/channel is in failure condition. It may also indicate explicitly the failed TCI state to network to indicate the failure of power saving signal or channel

**[0056]** In one aspect, UE is allowed to trigger SR/RACH (CFRA/CBRA) to indicate the failure or indicate failure of specific BFD-RS (e.g. corresponding to power saving signal/channel). Specific uplink signalling message may be used for indicating partial failure in case of power saving signal/channel failure or such indication can be provided using an uplink MAC CE or PUCCH. This signalling can be performed after indicating the power saving signal/channel beam failure to the network, UE could be either assumed to monitor onDuration always or stop DRX until beam recovery procedure has been completed. Completion may include network reconfiguring UE with new configuration for power saving signal /channel reception i.e. provided new beam or beams (TCI state or states) for power saving signal/channel reception.

**[0057] Modifying Beam Failure Detection Parameters**

**[0058]** In one aspect Beam failure detection parameters such as Maximum number of beam failure instances that are counted at MAC may have different value when UE is monitoring power saving signal/channel and/or when UE performs failure detection based on the second set of BFD-RS/q0\_temp. Also, power saving signal/channel or partial beam failure specific counters (and thus indications) may be defined e.g. if partial failure indications are provided to higher layer.

**[0059] Implementation details for Beam Failure Detection:**

**[0060]** Included below are only some of the optional operations (e.g. Option 1, Option 2, and Option 3 as disclosed). These options are only examples and it is note that at least these options as well as further options can be performed based on the example embodiments of the invention as discussed herein.

**[0061]** Option 1:

**[0062]** When UE is configured to monitor power saving signal/channel (i.e. it is not monitoring PDCCH according to search space configuration), an alternative parameter set may be used for beam failure detection:

- UE temporarily determines to include the downlink reference signal that is QCL'd in terms of Type-D (or any QCL type determined to be suitable) with power saving signal/channel to the beam failure detection RS set of q0. When UE e.g. receives power saving signal/channel, or starts PDCCH monitoring due to any reason, the temporary set is deactivated and the previous set of q0 (implicitly or explicitly configured) is used. In accordance with example embodiments:
  - Temporary failure detection configuration is active/in use when UE is not decoding PDCCH according to search space configuration and UE has been configured to monitor power saving signal/channel to determine whether it starts monitoring PDCCH according to search space configuration;
  - Temporary configuration may be updated according to reconfiguration of power saving signal and/or channel;
  - Alternatively, the RS set may be referred as e.g. q0\_temp which is used

when UE is monitoring power saving signal/channel;

- Beam failure instance is determined based on set of  $q_0$ \_temp, when PDCCH is not monitored according to search space configuration e.g. when UE is in DRX off duration and monitoring only power saving signal/channel in specific time instances, or in a power saving signal/channel window.
- In some cases it the power saving signal or channel monitoring may be performed during ON duration to e.g. determine if UE shall monitor the PDCCH according to search space configuration for the rest of the duration of the ON duration. In other words the monitoring instance or time window for power saving signal or channel is a part of the ON duration of the DRX cycle.

**[0063]** In non-DRX mode UE should determine failure for all the PDCCH beams i.e. it would use the set  $q_0$ . In some cases if the power saving signal does not correspond to any PDCCH beams i.e. it would be considered as additional signal in  $q_0$ , UE may trigger beam failure when all the BFD-RS corresponding to PDCCH beams are in failure condition it can trigger partial failure when the RS corresponding to the power saving signal/channel is in failure condition in the set of  $q_0$ . In case the power saving signal corresponds to the RS used for failure detection of a configured PDCCH in set  $q_0$ , UE may trigger partial beam failure when at least that specific RS is in failure condition. The temporary set can be deactivated when UE has detected power saving signal/channel and starts monitoring PDCCH.

**[0064]** Option 2:

**[0065]** UE is allowed to declare partial beam failure when at least a specific BFD-RS is in failure condition:

- UE is allowed to trigger partial beam failure when a BFD-RS corresponds to the power saving signal/channel QCL reference or the PDCCH beam/DL RS corresponding power saving signal/channel transmission is in failure condition:
  - UE is allowed to indicate BFI (beam failure instance) or partial beam failure instance indication to MAC layer based on subset of BFD-RS in failure condition. MAC counts the BFI indications and the partial BFI

indication may have specific counter.

**[0066]** Option 3:

**[0067]** In case gNB sweeps the power saving signal/channel signal using N-TX beams (i.e. the power saving signal/channel is repeated in specific set of beams, power saving signal/channel candidate beams) UE determines the set of BFD-RS (referred e.g. as  $q0\_temp$  to) include the reference signals corresponding to the N-TX candidates.

- In this case the failure detection is performed in a manner that all BFD-RS in set of  $q0\_temp$  have to be in failure condition in order to L1 indicate beam failure instance to higher layer or in general in order to declare beam failure.

**[0068]** In general power saving signal/channel beam failure may be determined either by declaration in MAC (based on BFI indication by lower layer) or by some other means e.g. a special indication to MAC on partial beam failure by lower layer.

**[0069]** In one further embodiment UE may perform beam failure detection based on  $q0$  in DRX and in non-DRX mode according to respective monitoring intervals and in parallel determine power saving signal or channel failure on temporary set. If either of the sets are in failure condition (or a failure is declared), failure recovery actions can be initiated by UE. Alternatively, UE may determine partial failure based on the RS corresponding to the power saving signal or channel and full beam failure (i.e. all RS in the set are in failure condition) in parallel when the RS is included in the set of  $q0$ .

**[0070]** In one further embodiment, UE may perform failure detection based on set  $q0$  in DRX and in non-DRX mode and if the RS corresponding to the power saving signal or channel is included in the set of  $q0$ , UE may determine partial beam failure based on the said RS either in DRX mode or in non-DRX mode. Alternatively, the partial failure may only be determined during non-DRX mode when UE is monitoring the power saving signal or channel.

**[0071]** In some of the embodiments, when UE determines beam failure or partial beam failure based on the RS corresponding to the power saving signal or channel it may determine normal beam failure (or full or non-partial beam failure) in parallel. In one

example the beam failure detection for power saving signal or channel and for PDCCH (based on activated TCI states for PDCCH reception) may be independent procedures also when the RS corresponding power saving signal or channel is included in the set of  $q_0$  or is same as the RS used for determining failure for specific activated TCI state for PDCCH.

**[0072]** In one further embodiment UE may perform failure detection the power saving signal or channel by monitoring the RS corresponding to the power saving signal or channel in DRX mode (or when monitoring power saving signal/channel or when it is not monitoring PDCCH according to search space configuration) more frequently than the RS for the set of  $q_0$ . In DRX mode the BFD monitoring periodicity may be relaxed compared to non-DRX mode and UE may monitor the temporary set more frequently i.e. without DRX relaxation or with less relaxation in DRX mode. If the RS for monitoring power saving signal/channel is included in the set of  $q_0$  e.g. if it corresponds to beam used for PDCCH transmission for UE, it may monitor that specific RS more frequently.

**[0073]        Modifying Beam Failure Detection Parameters**

**[0074]** In one aspect Beam failure detection parameters such as Maximum number of beam failure instances that are counted at MAC may have different value when UE is monitoring power saving signal/channel. Also power saving signal/channel or partial beam failure specific counters (and thus indications) may be defined.

**[0075]** In one aspect, MAC may employ different parameters/parameter set for beam failure detection procedure when UE is configured to monitor power saving signal/channel compared to the case UE is configured to monitor PDCCH. These parameters may comprise either all or subset of the beamFailureDetectionTimer, beamFailureInstanceMaxCount, etc.

**[0076]** In one option the beamFailureDetectionTimer length is determined based on the power saving signal/channel periodicity when UE is configured to monitor power saving signal/channel. For instance, RRC configures a number of periods for the timer and the UE determines the length based on the number of periods and period length.

[0077] In another option the UE may reset the BFI\_COUNTER if PDCCH reception is successful once PDCCH monitoring is started after the power saving mode.

[0078] In one example aspect the power saving signal/channel monitoring may be performed during DRX off duration (in a specific instance/occasion or in a monitoring window, or in the beginning of DRX on duration. Additionally, or alternatively the power saving signal/channel monitoring may be performed within a time window either on DRX or in non-DRX. It may be also defined that when UE is not monitoring PDCCH according to search space configuration (i.e. during DRX-ON when UE is not monitoring power saving signal or channel) it is considered to be in power saving signal/channel monitoring state in DRX-OFF and the proposed methods in accordance with example embodiments of the invention as described herein can be applied to these aspects.

[0079] It should be understood that the proposed methods can also be used in general for partial beam failure detection and recovery i.e. network may indicate specific set of downlink signals that UE monitors for partial failure.

[0080] FIG. 3 illustrates operations which may be performed by a device such as, but not limited to, a device (e.g. the UE 10 as in FIG. 2). As shown in step 310 of FIG. 3 there is identifying, by a user equipment, a beam failure based on a signaling over at least one power saving signal or channel in a communication network. Then as shown in step 320 of FIG. 3 there is, based on the identifying, performing recovery operations for the beam failure.

[0081] In accordance with the example aspects of the invention as described in the paragraph above, wherein the identifying is using a specific transmission configuration indicator state for the at least one power saving signal or channel.

[0082] In accordance with the example aspects of the invention as described in the paragraphs above, wherein the specific indicator state is a transmission configuration indicator state.

[0083] In accordance with the example aspects of the invention as described in the paragraphs above, wherein the user equipment is in one of a discontinuous reception

mode or a non- discontinuous reception mode or active mode.

**[0084]** In accordance with the example aspects of the invention as described in the paragraphs above, wherein the specific transmission configuration indicator state is using at least one beam failure detection reference signal, wherein each of the at least one beam failure detection reference signal comprises a beam failure detection resource set.

**[0085]** In accordance with the example aspects of the invention as described in the paragraphs above, wherein the recovery operations comprises sending toward the communication network using specific uplink signaling an indication of a specific beam failure detection reference signal of the at least one beam failure detection reference signal for the beam failure, wherein the uplink signaling is using one of a medium access control element or a physical uplink control channel.

**[0086]** In accordance with the example aspects of the invention as described in the paragraphs above, wherein the beam failure detection resource set comprises at least one of at least one q0 resource set and at least one q0\_temp resource set.

**[0087]** In accordance with the example aspects of the invention as described in the paragraphs above, wherein the at least one q0 resource set and at least one q0\_temp resource set comprises more than one set of beam failure detection reference signals.

**[0088]** In accordance with the example aspects of the invention as described in the paragraphs above, wherein at least one set of the more than one set of beam failure detection reference signals can be used when the user equipment is in a specific mode and another at least one set of beam failure detection reference signals can be used when the user equipment is not the specific mode.

**[0089]** In accordance with the example aspects of the invention as described in the paragraphs above, wherein the specific mode comprises a discontinuous reception mode.

**[0090]** In accordance with the example aspects of the invention as described in the paragraphs above, wherein based on the user equipment being in the discontinuous

reception mode, the at least one q0\_temp resource set is included in the at least one beam failure detection reference signal wherein the at least one q0\_temp resource set comprises at least one transmission configuration indicator state corresponding to the at least one power saving signal or channel.

**[0091]** In accordance with the example aspects of the invention as described in the paragraphs above, wherein determining the beam failure comprises triggering a partial beam failure based on reference signals in the the at least one q0 resource set that are quasi co-located in terms of at least one of type-D and type-A, with the at least one power saving signal or channel.

**[0092]** In accordance with the example aspects of the invention as described in the paragraphs above, wherein the at least one q0\_temp resource set is in use when the user equipment is not decoding a physical downlink control channel according to a search space configuration.

**[0093]** In accordance with the example aspects of the invention as described in the paragraphs above, wherein the at least one q0\_temp resource set is updated according to a reconfiguration of the at least one power saving signal or channel.

**[0094]** In accordance with the example aspects of the invention as described in the paragraphs above, wherein the indication of the beam failure instance comprises an indication of a partial beam failure based on specific resources of the beam failure detection resource set being in a failure condition in set of q0.

**[0095]** In accordance with the example aspects of the invention as described in the paragraphs above, wherein the indication of the beam failure instance comprises an indication of beam failure based on resources of the beam failure detection resource set being in a failure condition in at least one set of the at least one q0\_temp set.

**[0096]** A non-transitory computer-readable medium (MEM 10B as in FIG. 2) storing program code (PROG 10C as in FIG. 2), the program code executed by at least one processor (DP 10A as in FIG. 2) to perform the operations as at least described in the paragraphs above.

**[0097]** In accordance with an example embodiment of the invention as described above there is an apparatus comprising: means for identifying (TRANS 10D, MEM 10B, PROG 10C, and DP 10A as in FIG. 2), by a user equipment (UE 10 as in FIG. 2), a beam failure based on a signaling over at least one power saving signal or channel in a communication network; and means, based on the identifying, for performing (TRANS 10D, MEM 10B, PROG 10C, and DP 10A as in FIG. 2) recovery operations for the beam failure.

**[0098]** In the example aspect of the invention according to the paragraph above, wherein at least the means for identifying and performing comprises transceiver [TRANS 10D] a non-transitory computer readable medium [MEM 10B] encoded with a computer program [PROG 10C] executable by at least one processor [DP 10A].

**[0099]** At least some advantages to perform operations in accordance with example embodiments of the invention include:

- + UE is enabled to more quickly react to failure when specific signal can be considered to be in failure condition such as wake up / go to sleep;
- + network resources are saved since UE is allowed to indicate failure when potentially subset of specific downlink RS are in failure condition, and network does not try to schedule UE when UE is not able to receive PDCCH with good quality.

**[00100]** In general, the various embodiments may be implemented in hardware or special purpose circuits, software, logic or any combination thereof. For example, some aspects may be implemented in hardware, while other aspects may be implemented in firmware or software which may be executed by a controller, microprocessor or other computing device, although example embodiments of the invention are not limited thereto.

**[00101]** While various aspects of the invention may be illustrated and described as block diagrams, flow charts, or using some other pictorial representation, it is well understood that these blocks, apparatus, systems, techniques or methods described herein

may be implemented in, as non-limiting examples, hardware, software, firmware, special purpose circuits or logic, general purpose hardware or controller or other computing devices, or some combination thereof.

**[00102]** Embodiments of the inventions may be practiced in various components such as integrated circuit modules. The design of integrated circuits is by and large a highly automated process. Complex and powerful software tools are available for converting a logic level design into a semiconductor circuit design ready to be etched and formed on a semiconductor substrate.

**[00103]** The word "exemplary" is used herein to mean "serving as an example, instance, or illustration." Any embodiment described herein as "exemplary" is not necessarily to be construed as preferred or advantageous over other embodiments. All of the embodiments described in this Detailed Description are exemplary embodiments provided to enable persons skilled in the art to make or use the invention and not to limit the scope of the invention which is defined by the claims.

**[00104]** The foregoing description has provided by way of exemplary and non-limiting examples a full and informative description of the best method and apparatus presently contemplated by the inventors for carrying out example embodiments of the invention. However, various modifications and adaptations may become apparent to those skilled in the relevant arts in view of the foregoing description, when read in conjunction with the accompanying drawings and the appended claims. However, all such and similar modifications of the teachings of this invention will still fall within the scope of this invention.

**[00105]** It should be noted that the terms "connected," "coupled," or any variant thereof, mean any connection or coupling, either direct or indirect, between two or more elements, and may encompass the presence of one or more intermediate elements between two elements that are "connected" or "coupled" together. The coupling or connection between the elements can be physical, logical, or a combination thereof. As employed herein two elements may be considered to be "connected" or "coupled" together by the use of one or more wires, cables and/or printed electrical connections, as well as by the use of electromagnetic energy, such as electromagnetic energy having

wavelengths in the radio frequency region, the microwave region and the optical (both visible and invisible) region, as several non-limiting and non-exhaustive examples.

**[00106]** Furthermore, some of the features of the preferred embodiments of this invention could be used to advantage without the corresponding use of other features. As such, the foregoing description should be considered as merely illustrative of the principles of the invention, and not in limitation thereof.

CLAIMS

1. An apparatus comprising:  
at least one processor; and  
at least one memory including computer program code, the at least one memory and the computer program code configured, with the at least one processor, to cause the apparatus at least to  
identify, at a user equipment, a beam failure based on a signaling over at least one power saving signal or channel in a communication network, and  
perform recovery operations for the beam failure.
2. The apparatus according to claim 1, wherein the identifying uses a specific transmission configuration indicator state for the at least one power saving signal or channel.
3. The apparatus according to claim 2, wherein the specific transmission configuration indicator state is a transmission configuration indicator state.
4. The apparatus according to any one of claims 2 to 3, wherein the specific transmission configuration indicator state uses at least one beam failure detection reference signal, wherein each of the at least one beam failure detection reference signal comprises a beam failure detection resource set.
5. The apparatus according to claim 4, wherein the recovery operations comprises sending toward the communication network, using specific uplink signaling, an indication of a specific beam failure detection reference signal of the at least one beam failure detection reference signal for the beam failure, wherein the uplink signaling uses one of a medium access control element or a physical uplink control channel.
6. The apparatus according any one of claims 4 to 5, wherein the beam failure detection resource set comprises at least one of at least one q0 resource set and at least one q0\_temp resource set.

7. The apparatus according to claim 6, wherein the at least one q0 resource set and at least one q0\_temp resource set comprises more than one set of beam failure detection reference signals.

8. The apparatus according to claims 7, wherein at least one set of the more than one set of beam failure detection reference signals can be used when the user equipment is in a specific mode and another at least one set of beam failure detection reference signals can be used when the user equipment is not in the specific mode.

9. The apparatus according to claim 8, wherein the specific mode comprises a discontinuous reception mode.

10. The apparatus according to any one of claims 7 to 9, wherein based on the user equipment being in the discontinuous reception mode, the at least one q0\_temp resource set is included in the at least one beam failure detection reference signal wherein the at least one q0\_temp resource set comprises at least one transmission configuration indicator state corresponding to the at least one power saving signal or channel.

11. The apparatus according to any one of claims 7 to 10, wherein determining the beam failure comprises triggering a partial beam failure based on reference signals in the the at least one q0 resource set that are quasi co-located in terms of at least one of type-D and type-A, with the at least one power saving signal or channel.

12. The apparatus according to any one of claims 7 to 11, wherein the at least one q0\_temp resource set is in use when the user equipment is not decoding a physical downlink control channel according to a search space configuration.

13. The apparatus according to any one of claims 7 to 12, wherein the at least one q0\_temp resource set is updated according to a reconfiguration of the at least one power saving signal or channel.

14. The apparatus according to any one of claims 7 to 13, wherein an indication of a beam failure instance comprises an indication of a partial beam failure

based on specific resources of the beam failure detection resource set being in a failure condition in set of q0.

15. The apparatus according to any one of claims 7 to 13, wherein an indication of a beam failure instance comprises an indication of beam failure based on resources of the beam failure detection resource set being in a failure condition in at least one set of the at least one q0\_temp set.

16. A method comprising:  
identifying, at a user equipment, a beam failure based on a signaling over at least one power saving signal or channel in a communication network, and  
performing recovery operations for the beam failure.

17. The method according to claim 16, wherein the identifying uses a specific transmission configuration indicator state for the at least one power saving signal or channel.

18. The method according to claim 17, wherein the specific transmission configuration indicator state is a transmission configuration indicator state.

19. The method according to any one of claims 17 to 18, wherein the specific transmission configuration indicator state uses at least one beam failure detection reference signal, wherein each of the at least one beam failure detection reference signal comprises a beam failure detection resource set.

20. The method according to claim 19, wherein the recovery operations comprises sending toward the communication network, using specific uplink signaling, an indication of a specific beam failure detection reference signal of the at least one beam failure detection reference signal for the beam failure, wherein the uplink signaling uses one of a medium access control element or a physical uplink control channel.

21. The method according any one of claims 19 to 20, wherein the beam failure detection resource set comprises at least one of at least one q0 resource set and

at least one q0\_temp resource set.

22. The method according to claim 21, wherein the at least one q0 resource set and at least one q0\_temp resource set comprises more than one set of beam failure detection reference signals.

23. The method according to claims 22, wherein at least one set of the more than one set of beam failure detection reference signals can be used when the user equipment is in a specific mode and another at least one set of beam failure detection reference signals can be used when the user equipment is not in the specific mode.

24. The method according to claim 23, wherein the specific mode comprises a discontinuous reception mode.

25. The method according to any one of claims 22 to 24, wherein based on the user equipment being in the discontinuous reception mode, the at least one q0\_temp resource set is included in the at least one beam failure detection reference signal wherein the at least one q0\_temp resource set comprises at least one transmission configuration indicator state corresponding to the at least one power saving signal or channel.

26. The method according to any one of claims 22 to 25, wherein determining the beam failure comprises triggering a partial beam failure based on reference signals in the the at least one q0 resource set that are quasi co-located in terms of at least one of type-D and type-A, with the at least one power saving signal or channel.

27. The method according to any one of claims 22 to 26, wherein the at least one q0\_temp resource set is in use when the user equipment is not decoding a physical downlink control channel according to a search space configuration.

28. The method according to any one of claims 22 to 27, wherein the at least one q0\_temp resource set is updated according to a reconfiguration of the at least one power saving signal or channel.

29. The method according to any one of claims 22 to 28, wherein an indication of a beam failure instance comprises an indication of a partial beam failure based on specific resources of the beam failure detection resource set being in a failure condition in set of  $q_0$ .

30. The method according to any one of claims 22 to 28, wherein an indication of a beam failure instance comprises an indication of beam failure based on resources of the beam failure detection resource set being in a failure condition in at least one set of the at least one  $q_0\_temp$  set.

31. A computer program product comprising a non-transitory computer-readable storage medium bearing computer program code embodied therein for use with a computer, the computer program code comprising code for performing the method of any one of claims 16 to 30.

32. An apparatus comprising means for:  
identifying, at a user equipment, a beam failure based on a signaling over at least one power saving signal or channel in a communication network; and  
performing recovery operations for the beam failure.

| TCI Index<br>110 | Source RS set<br>120 | Source RX set<br>130          | QCL Type<br>140 |
|------------------|----------------------|-------------------------------|-----------------|
| 0                | RS set #A            | SS/PSCCH block #n (of set #A) | A+D             |
| 1                | RS set #B            | TRS #b (of set #B)            | A               |
|                  |                      | CSt-RS#c (of set #B)          | D               |
| —                | —                    | —                             | —               |
| M-1              | RS set #E            | CSt-RS #b) of the set #E)     | A+D             |

FIG. 1A

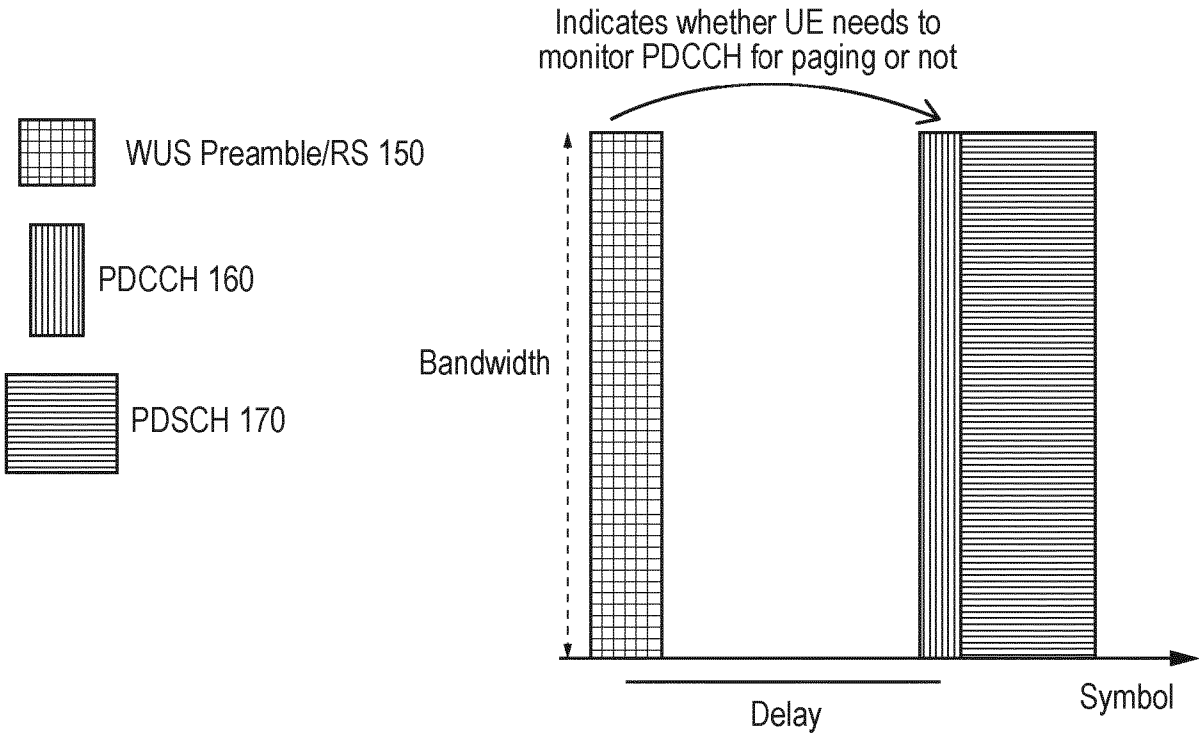


FIG. 1B

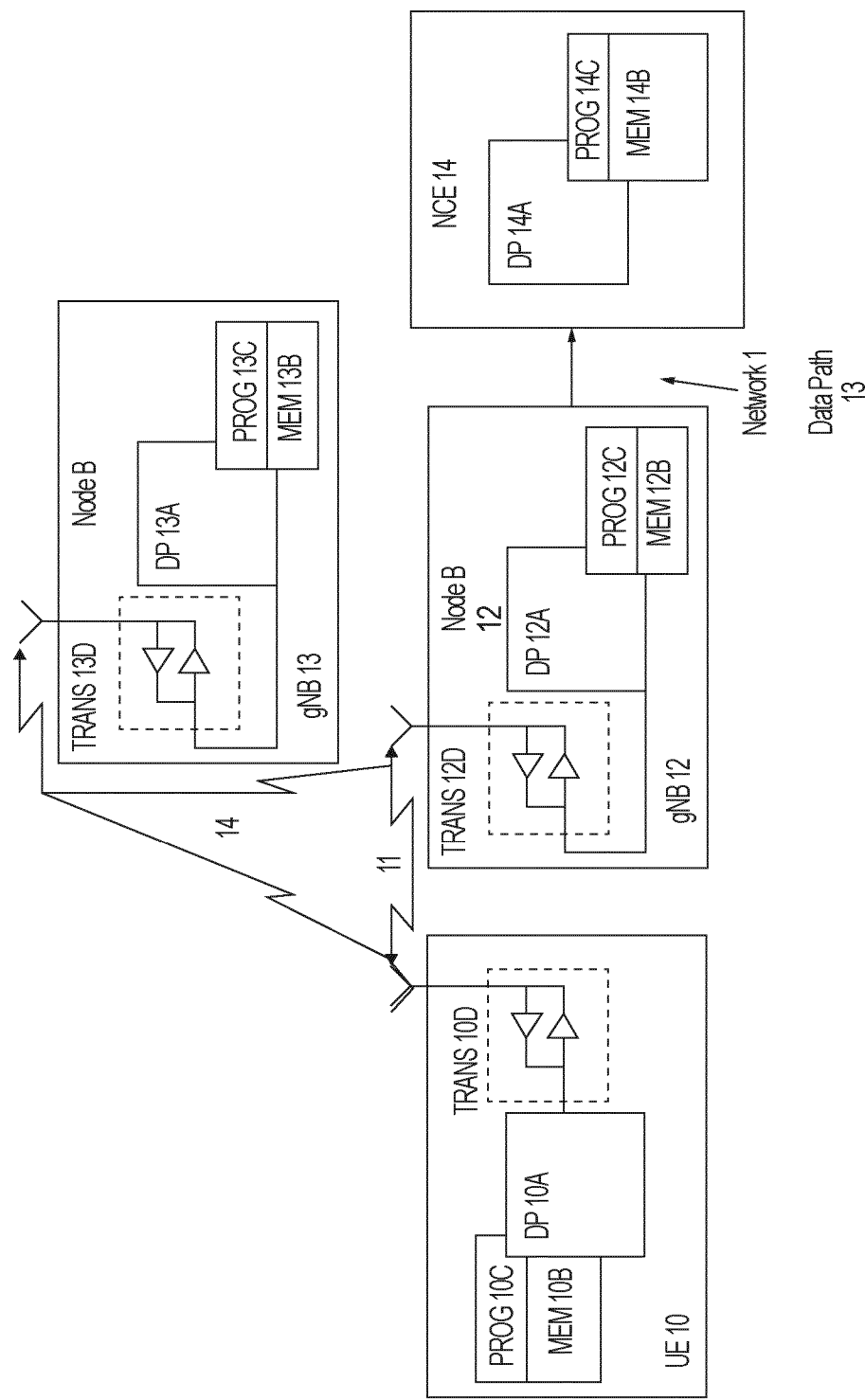


FIG. 2

3/3

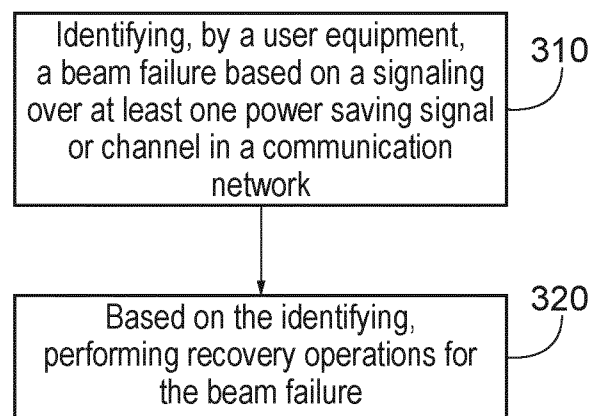


FIG. 3

## INTERNATIONAL SEARCH REPORT

International application No  
PCT/EP2020/054858

| A. CLASSIFICATION OF SUBJECT MATTER                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                   |                                                                      |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------|
| INV.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | H04B7/06<br>H04W76/18                                                                                                                                             | H04L5/00<br>H04W76/19                                                |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | H04W16/28<br>H04W76/28                                                                                                                                            | H04W52/02<br>H04W72/04                                               |
| ADD.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                                                                   |                                                                      |
| According to International Patent Classification (IPC) or to both national classification and IPC                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                                   |                                                                      |
| B. FIELDS SEARCHED                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                                                                   |                                                                      |
| Minimum documentation searched (classification system followed by classification symbols)<br>H04B H04W H04L                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                                                                   |                                                                      |
| Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                                   |                                                                      |
| Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)<br>EPO-Internal, COMPENDEX, INSPEC, 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 2019/037498 A1 (TSENG YUNG-LAN [TW] ET AL) 31 January 2019 (2019-01-31)                                                                                        | 1-5,<br>16-20,<br>31,32                                              |
| Y                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | paragraph [0026] - paragraph [0028];<br>figure 1<br>paragraph [0035] - paragraph [0036];<br>figure 3<br>paragraph [0037] - paragraph [0040];<br>figure 4; table 1 | 6-15,<br>21-30                                                       |
| X                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | -----<br>WO 2018/174586 A1 (LG ELECTRONICS INC [KR]) 27 September 2018 (2018-09-27)                                                                               | 1,16,31,<br>32                                                       |
| A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | paragraph [0195] - paragraph [0198];<br>figure 9                                                                                                                  | 2-15,<br>17-30                                                       |
| X,P                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | paragraph [0209] - paragraph [0227]<br>& EP 3 606 257 A1 (LG ELECTRONICS INC [KR]) 5 February 2020 (2020-02-05)<br>-----<br>-/-                                   | 1,16,31,<br>32                                                       |
| <input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input checked="" type="checkbox"/> See patent family annex.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                                                                   |                                                                      |
| * Special categories of cited documents :<br>"A" document defining the general state of the art which is not considered to be of particular relevance<br>"E" earlier application or patent but published on or after the international filing date<br>"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)<br>"O" document referring to an oral disclosure, use, exhibition or other means<br>"P" document published prior to the international filing date but later than the priority date claimed<br>"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<br>"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<br>"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<br>"&" document member of the same patent family |                                                                                                                                                                   |                                                                      |
| Date of the actual completion of the international search<br><br>13 May 2020                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                                   | Date of mailing of the international search report<br><br>26/05/2020 |
| Name and mailing address of the ISA/<br>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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                                                                   | Authorized officer<br><br>Cabañas Prieto, Ana                        |

## INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2020/054858

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Relevant to claim No.   |
|-----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|
| Y         | NOKIA: "CR to TS 38.133: Implementation of endorsed draft CRs from RAN4-88bis and RAN4-89",<br>3GPP DRAFT; RP-182763, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE<br>,<br>vol. TSG RAN, no. Sorrento, Italy;<br>20181210 - 20181213<br>11 December 2018 (2018-12-11),<br>XP051575391,<br>Retrieved from the Internet:<br>URL: <a href="http://www.3gpp.org/ftp/tsg%5Fran/TSG%5FRAN/TSGR%5F82/Docs/RP%2D182763%2Ezip">http://www.3gpp.org/ftp/tsg%5Fran/TSG%5FRAN/TSGR%5F82/Docs/RP%2D182763%2Ezip</a><br>[retrieved on 2018-12-11]                                                                         | 6-15,<br>21-30          |
| A         | page 58 - page 66<br>page 76 - page 85                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 1-5,<br>16-20,<br>31,32 |
| Y         | -----<br>"3rd Generation Partnership Project; Technical Specification Group Radio Access Network; NR; Physical layer procedures for control (Release 15)",<br>3GPP DRAFT; 38213-F40, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE<br>,<br>16 January 2019 (2019-01-16), XP051686991,<br>Retrieved from the Internet:<br>URL: <a href="http://www.3gpp.org/ftp/3guInternal/3GPP%5Fultimate%5Fversions%5Fto%5Fbe%5Ftransposed/sentToDpc/38213%2Df40%2Ezip">http://www.3gpp.org/ftp/3guInternal/3GPP%5Fultimate%5Fversions%5Fto%5Fbe%5Ftransposed/sentToDpc/38213%2Df40%2Ezip</a><br>[retrieved on 2019-01-16] | 6-15,<br>21-30          |
| A         | page 11 - page 14<br><br>-----<br>-/--                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 1-5,<br>16-20,<br>31,32 |

## INTERNATIONAL SEARCH REPORT

International application No  
PCT/EP2020/054858

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages                                                                                                                                                                                                                                                                                                                                                                                                                           | Relevant to claim No. |
|-----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| A         | <p>"3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Release 15 Description; Summary of Rel-15 Work Items (Release 15)",<br/>3GPP STANDARD; TECHNICAL REPORT; 3GPP TR 21.915, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE, vol. TSG SA, no. V0.2.0, 13 July 2018 (2018-07-13), pages 1-89, XP051474985,<br/>[retrieved on 2018-07-13]<br/>page 28</p> <p>-----</p> | 1-32                  |
| A         | <p>WO 2019/032248 A1 (QUALCOMM INC [US])<br/>14 February 2019 (2019-02-14)<br/>paragraph [0075] - paragraph [0088];<br/>figure 2</p> <p>-----</p>                                                                                                                                                                                                                                                                                                                                                            | 1-32                  |

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2020/054858

| Patent document<br>cited in search report |    | Publication<br>date | Patent family<br>member(s) | Publication<br>date |
|-------------------------------------------|----|---------------------|----------------------------|---------------------|
| US 2019037498                             | A1 | 31-01-2019          | NONE                       |                     |
| -----                                     |    |                     |                            |                     |
| WO 2018174586                             | A1 | 27-09-2018          | CN 110447295 A             | 12-11-2019          |
|                                           |    |                     | EP 3606257 A1              | 05-02-2020          |
|                                           |    |                     | JP 2020511875 A            | 16-04-2020          |
|                                           |    |                     | KR 20190123783 A           | 01-11-2019          |
|                                           |    |                     | US 2020036430 A1           | 30-01-2020          |
|                                           |    |                     | WO 2018174586 A1           | 27-09-2018          |
| -----                                     |    |                     |                            |                     |
| WO 2019032248                             | A1 | 14-02-2019          | CN 110999411 A             | 10-04-2020          |
|                                           |    |                     | US 2019053153 A1           | 14-02-2019          |
|                                           |    |                     | WO 2019032248 A1           | 14-02-2019          |
| -----                                     |    |                     |                            |                     |