

## ***SFTD AND ANR SPECIFIC REPORTING***

### Related Applications

**[0001]** This application claims the benefit of provisional patent application serial number 62/632,861, filed February 20, 2018, the disclosure of which is hereby incorporated herein by reference in its entirety.

### Technical Field

**[0002]** The present disclosure relates to a wireless network and, more specifically, to System Frame Number (SFN) Frame Time Difference (SFTD) reporting and Automatic Neighbor Relations (ANR) reporting in a cellular communications network.

### Background

#### 15 *Reporting Configuration in New Radio (NR)*

**[0003]** The Evolved Universal Terrestrial Radio Access Network (E-UTRAN) Dual Connectivity (EN-DC) essential reporting configurations for NR have been already agreed in Third Generation Partnership Project (3GPP) RAN2 forum and are also captured in the Radio Resource Control (RRC) specifications (see 3GPP Technical Specification (TS) 38.331 v15.0.1). Based on these reporting configurations, the network can configure the User Equipment (UE) to report periodically or based on certain event triggers. Currently, standardized event triggers are based on Long Term Evolution (LTE) like events i.e., A1-A6 events. In addition to event triggered and periodical report triggering, there is also a place holder for “reportCGI”, which is used for Automatic Neighbor Relations (ANR) specific purposes. The reporting configurations are provided in the information element ReportConfigNR, which is described in the following excerpt from 3GPP TS 38.311 v15.0.1:

\*\*\*\*\*

#### 30 *ReportConfigNR*

The IE *ReportConfigNR* specifies criteria for triggering of an NR measurement reporting event. Measurement reporting events are based on cell measurement results, which can either be derived based on SS/PBCH block or CSI-RS. These events are labelled AN with N equal to 1, 2 and so on.

Event A1: Serving becomes better than absolute threshold;

- Event A2: Serving becomes worse than absolute threshold;
- Event A3: Neighbour becomes amount of offset better than PCell/PSCell;
- Event A4: Neighbour becomes better than absolute threshold;
- 5 Event A5: PCell/PSCell becomes worse than absolute threshold1 AND Neighbour becomes better than another absolute threshold2.
- Event A6: Neighbour becomes amount of offset better than SCell.

### ***ReportConfigNR* information element**

```

10 -- ASN1START
-- TAG-REPORT-CONFIG-START

ReportConfigNR ::=
    SEQUENCE {
        reportType
            CHOICE {
                periodical
                    PeriodicalReportConfig,
15                eventTriggered
                    EventTriggerConfig,
-- reportCGI is to be completed before the end of Rel-15.
                reportCGI
                    ENUMERATED {ffsTypeAndValue},
                ...
            }
20    }

-- FFS / TODO: Consider separating trigger configuration (trigger, periodic, ...) from report
configuration.
-- Current structure allows easier definition of new events and new report types e.g. CGI, etc.
25 EventTriggerConfig ::=
    SEQUENCE {
        eventId
            CHOICE {
                eventA1
                    SEQUENCE {
                        a1-Threshold
                            MeasTriggerQuantity,
                        reportOnLeave
                            BOOLEAN,
30                        hysteresis
                            Hysteresis,
                        timeToTrigger
                            TimeToTrigger
                    },
                eventA2
                    SEQUENCE {
                        a2-Threshold
                            MeasTriggerQuantity,
35                        reportOnLeave
                            BOOLEAN,
                        hysteresis
                            Hysteresis,
                        timeToTrigger
                            TimeToTrigger
                    },
                eventA3
                    SEQUENCE {
40                        a3-Offset
                            MeasTriggerQuantityOffset,
                        reportOnLeave
                            BOOLEAN,
                        hysteresis
                            Hysteresis,
                        timeToTrigger
                            TimeToTrigger,
                    }
            }
    }

```

```

        useWhiteCellList          BOOLEAN

    },
    eventA4                      SEQUENCE {
5        a4-Threshold            MeasTriggerQuantity,
        reportOnLeave             BOOLEAN,
        hysteresis                Hysteresis,
        timeToTrigger             TimeToTrigger,
10        useWhiteCellList       BOOLEAN

    },
    eventA5                      SEQUENCE {
        a5-Threshold1            MeasTriggerQuantity,
        a5-Threshold2            MeasTriggerQuantity,
15        reportOnLeave           BOOLEAN,
        hysteresis                Hysteresis,
        timeToTrigger             TimeToTrigger,
        useWhiteCellList         BOOLEAN

20    },
    eventA6                      SEQUENCE {
        a6-Offset                MeasTriggerQuantityOffset,
        reportOnLeave             BOOLEAN,
        hysteresis                Hysteresis,
25        timeToTrigger           TimeToTrigger,
        useWhiteCellList         BOOLEAN

    },
    ...
30 },

rsType                          ENUMERATED {ssb, csi-rs},

-- Common reporting config (at least to periodical and eventTriggered)
35 reportInterval                ReportInterval,
reportAmount                    ENUMERATED {r1, r2, r4, r8, r16, r32, r64, infinity},

-- Cell reporting configuration
reportQuantityCell              MeasReportQuantity,
40 maxReportCells                INTEGER (1..maxCellReport),

-- RS index reporting configuration
reportQuantityRsIndexes          MeasReportQuantity          OPTIONAL,    -- Need M
    maxNrofRSIndexesToReport      INTEGER (1..maxNrofIndexesToReport) OPTIONAL, -- Need M
45 includeBeamMeasurements        BOOLEAN,

-- If configured the UE includes the best neighbour cells per serving frequency

```

```

reportAddNeighMeas      ENUMERATED {setup}
OPTIONAL,               -- Need R
...

5  }

PeriodicalReportConfig ::=
    rsType               ENUMERATED {ss, csi-rs},

10  -- Common reporting config (at least to periodical and eventTriggered)
    reportInterval       ReportInterval,
    reportAmount         ENUMERATED {r1, r2, r4, r8, r16, r32, r64, infinity},

    -- Cell reporting configuration
15  reportQuantityCell   MeasReportQuantity,
    maxReportCells       INTEGER (1..maxCellReport),

    -- RS index reporting configuration
    reportQuantityRsIndexes MeasReportQuantity OPTIONAL, -- Need R
20  maxNrofRsIndexesToReport INTEGER (1..maxNrofIndexesToReport) OPTIONAL, -- Need R
    includeBeamMeasurements BOOLEAN,
    ...

}

25  MeasTriggerQuantity ::=
    rsrp                RSRP-Range,
    rsrq                RSRQ-Range,
    sinr                SINR-Range
30  }

MeasTriggerQuantityOffset ::=
    rsrp                INTEGER (ffsValue),
    rsrq                INTEGER (ffsValue),
35  sinr                INTEGER (ffsValue)
}

40  MeasReportQuantity ::=
    rsrp                BOOLEAN,
    rsrq                BOOLEAN,
45  sinr                BOOLEAN
}

```

```
-- TAG-REPORT-CONFIG-START
```

```
-- ASN1STOP
```

```
*****
```

### *ANR Mechanism in LTE and NR*

**[0004]** With the introduction of LTE, support for ANR was introduced, which removed, or significantly decreased, the manual configuration work done by the operators for setting up neighbor relations. The ANR function in LTE relies on the always-on transmission of System Information, enabling the UE to retrieve the Enhanced Cell Global Identity (ECGI) of any unknown neighbor cells as part of the ANR solution.

**[0005]** The procedure is illustrated in Figure 1. In step 1, the UE sends a measurement report to the serving enhanced or evolved Node B (eNB). The measurement report contains the Physical Cell Identity (PCI) of cell B. The eNB then instructs the UE to read the ECGI, the Tracking Area Code (TAC), and all available Public Land Mobile Network (PLMN) Identity(ies) (ID(s)) of cell B. The neighbor cell broadcasts its PLMN IDs, TAC, etc. in the System Information Block 1 (SIB1) message. After measuring these values, the UE reports the detected ECGI to the serving eNB, and the eNB decides to add this neighbor relation. The eNB can use the PCI and ECGI to look up a transport layer address to the new eNB, update the Neighbor Relation list, and, if needed, setup a new X2 interface towards this eNB.

**[0006]** The first standard release for 5th generation mobile networks (i.e., the first standard release for NR) will be for non-standalone (NSA) NR networks, utilizing existing LTE radio and Evolved Packet Core (EPC) network with the addition of an NR carrier. The NSA NR nodes will always have an LTE node as a master node, and System Information need not to be transmitted in NR, as the UE will not camp in NR. For the UE to aid in the ANR procedure, the reporting configuration of NR already has a place holder for reporting the CGI of the unknown neighbor cell. The place holder is called "reportCGI". However, details of how to configure such a reporting configuration are not finalized yet.

*Single Frequency Network (SFN) –Frame Time Difference (SFTD) Reporting*

**[0007]** In LTE, SFN and Subframe Time Difference (SSTD) measurement configuration was used to get the time difference between the Primary Cell (PCell) and the Primary Secondary Cell (PSCell). In Release 15, for EN-DC purposes, it has been agreed that the SFTD measurements can be configured by the Master eNB (MeNB), and the report received by the MeNB will be forwarded to the Secondary gNB (SgNB) (where “gNB” denotes a NR base station) so that both nodes are aware of the time difference between each other. Further, it was agreed that the SSTD measurement reporting is extended for cells that not configured in the case that no PSCell is configured. This is useful in aiding the network to configure relevant Sync signal Measurement Timing Configuration (SMTC) windows.

Agreements from RAN2#99bis:

- 1: SSTD measurements for EN-DC are supported with the following principles (as in LTE):
  - a. MeNB can configure SFN/subframe offset reporting for PSCell only when EN-DC is configured.
  - b. UE only needs to read MIB to measure/report SFN/subframe offset.
  - c. MeNB forwards the SFN/subframe offset from MeNB to SgNB using “SCG-ConfigInfo” (FFS on IE name).
  - d. One shot reporting (i.e. eNB configures measurement and UE sends single report to eNB, not periodical).

Agreements from RAN2#100:

- 1: The network can configure the NR SSTD measurement whenever a NR PSCell is configured
- 2: NR SSTD measurement reporting is extended for cells that are not yet configured in the case that no NR PSCell is configured

**[0008]** There currently exist certain challenges. In the existing reporting configuration of NR, there is a place holder for reporting CGI. However, the details of this configuration are yet to be standardized. Additionally, the SFTD reporting configuration is under discussion in NR and the details of this configuration are not yet specified.

Summary

**[0009]** Systems and methods for System Frame Number (SFN) Frame Time Difference (SFTD) reporting are disclosed. Embodiments of a method of operation of a User

Equipment (UE) in a wireless network to perform SFTD measurements between a Primary Cell (PCell) of the UE and one or more other cells is provided. In some embodiments, the method comprises receiving, from a network node in the wireless network, a list of cells for which the UE can report SFTD measurements. The method further comprises performing  
 5 SFTD measurements and reporting the SFTD measurements in accordance with the list of cells for which the UE can report SFTD measurements. In this manner, SFTD reporting is provided in an efficient manner.

**[0010]** In some embodiments, performing SFTD measurements comprises performing an SFTD measurement between the PCell of the UE and a second cell, the second cell  
 10 being a cell in the list of cells for which the UE can report SFTD measurements. Further, reporting the SFTD measurements in accordance with the list of cells for which the UE can report SFTD measurements comprises reporting the SFTD measurement to the network node.

**[0011]** In some embodiments, the list of cells comprises one or more New Radio (NR) cells. Further, in some embodiments, the PCell is a Long Term Evolution (LTE) cell. In some embodiments, reporting the SFTD measurements in accordance with the list of cells for which the UE can report SFTD measurements comprises reporting the SFTD measurements, in accordance with the list of cells for which the UE can report SFTD measurements, when no NR cell is configured as a Primary Secondary Cell (PSCell) of the  
 15 UE. In some embodiments, the method further comprises, when an NR cell is configured as a PSCell for the UE, performing a SFTD measurement between the PCell of the UE and the NR PSCell and reporting the SFTD measurement between the PCell of the UE and the NR PSCell.

**[0012]** In some embodiments, receiving the list of cells for which the UE can report  
 25 SFTD measurements comprises receiving a Radio Resource Control (RRC) Connection Reconfiguration message comprising the list of cells for which the UE can report SFTD measurements or receiving an RRC Connection Resume message comprising the list of cells for which the UE can report SFTD measurements.

**[0013]** Embodiments of a UE are also disclosed. In some embodiments, a UE for  
 30 performing SFTD measurements between a PCell of the UE and one or more other cells in a wireless network is adapted to receive, from a network node in the wireless network, a list of cells for which the UE can report SFTD measurements. The UE is further adapted to

perform SFTD measurements and report the SFTD measurements in accordance with the list of cells for which the UE can report SFTD measurements.

**[0014]** In some embodiments, a UE for performing SFTD measurements between a PCell of the UE and one or more other cells in a wireless network comprises an interface comprising radio front-end circuitry and processing circuitry associated with the interface. The processing circuitry is operable to cause the UE to receive, from a network node in the wireless network, a list of cells for which the UE can report SFTD measurements, perform SFTD measurements, and report the SFTD measurements in accordance with the list of cells for which the UE can report SFTD measurements.

**[0015]** In some embodiments, the SFTD measurements comprise a SFTD measurement between the PCell of the UE and a second cell, the second cell being a cell in the list of cells for which the UE can report SFTD measurements.

**[0016]** In some embodiments, the list of cells comprises one or more NR cells. Further, in some embodiments, the PCell is a LTE cell. In some embodiments, in order to report the SFTD measurements in accordance with the list of cells for which the UE can report SFTD measurements, the processing circuitry is further configured to cause the UE to report the SFTD measurements, in accordance with the list of cells for which the UE can report SFTD measurements, when no NR cell is configured as a PSCell of the UE. Further, in some embodiments, the processing circuitry is further configured to cause the UE to, when a NR cell is configured as a PSCell for the UE, perform a SFTD measurement between the PCell of the UE and the NR PSCell and report the SFTD measurement between the PCell of the UE and the NR PSCell.

**[0017]** In some embodiments, in order to receive the list of cells for which the UE can report SFTD measurements, the processing circuitry is further configured to cause the UE to receive a RRC Connection Reconfiguration message comprising the list of cells for which the UE can report SFTD measurements or receiving an RRC Connection Resume message comprising the list of cells for which the UE can report SFTD measurements.

#### Brief Description of the Drawings

**[0018]** The accompanying drawing figures incorporated in and forming a part of this specification illustrate several aspects of the disclosure, and together with the description serve to explain the principles of the disclosure.

**[0019]** Figure 1 illustrates an Automatic Neighbor Relations (ANR) procedure;

**[0020]** Figure 2 illustrates a process in which a User Equipment (UE) is configured, by a network node, with a list of cells for which the UE can report Single Frequency Network (SFN) –Frame Time Difference (SFTD) measurements in accordance with some  
5 embodiments of the present disclosure;

**[0021]** Figure 3 illustrates an example of a wireless network in which embodiments of the present disclosure may be implemented;

**[0022]** Figure 4 illustrates one embodiment of a UE in accordance with various aspects described herein;

10 **[0023]** Figure 5 is a schematic block diagram illustrating a virtualization environment in which functions implemented by some embodiments may be virtualized;

**[0024]** Figure 6 illustrates an example of a communication system in which embodiments of the present disclosure may be implemented;

15 **[0025]** Figure 7 illustrates additional details regarding the host computer, base station, and UE in the communication system of Figure 6 in accordance with some embodiments of the present disclosure; and

**[0026]** Figures 8 through 11 are flowcharts illustrating methods implemented in a communication system, in accordance with some embodiments of the present disclosure.

## 20 Detailed Description

**[0027]** The embodiments set forth below represent information to enable those skilled in the art to practice the embodiments and illustrate the best mode of practicing the embodiments. Upon reading the following description in light of the accompanying drawing figures, those skilled in the art will understand the concepts of the disclosure and will  
25 recognize applications of these concepts not particularly addressed herein. It should be understood that these concepts and applications fall within the scope of the disclosure.

**[0028]** Generally, all terms used herein are to be interpreted according to their ordinary meaning in the relevant technical field, unless a different meaning is clearly given and/or is implied from the context in which it is used. All references to a/an/the element, apparatus,  
30 component, means, step, etc. are to be interpreted openly as referring to at least one instance of the element, apparatus, component, means, step, etc., unless explicitly stated otherwise. The steps of any methods disclosed herein do not have to be performed in the

exact order disclosed, unless a step is explicitly described as following or preceding another step and/or where it is implicit that a step must follow or precede another step. Any feature of any of the embodiments disclosed herein may be applied to any other embodiment, wherever appropriate. Likewise, any advantage of any of the embodiments may apply to any other embodiments, and vice versa. Other objectives, features and advantages of the enclosed embodiments will be apparent from the following description.

**[0029]** There currently exist certain challenges. In the existing reporting configuration of Third Generation Partnership Project (3GPP) New Radio (NR), there is a place holder “*reportCGI*” in the reporting configuration. This placeholder is to be used for reporting Cell Global Identity (CGI) for Automatic Neighbor Relations (ANR) specific purposes. However, the details of this configuration are yet to be standardized. Additionally, the Single Frequency Network (SFN) –Frame Time Difference (SFTD) reporting configuration is under discussion in NR and the details of this configuration are not yet specified.

**[0030]** Certain aspects of the present disclosure and their embodiments may provide solutions to these or other challenges. In this disclosure, embodiments of a reporting configuration for SFTD reporting and ANR related reporting are proposed. With these proposals, ANR can be supported for Non-Standalone (NSA) NR without relying on System Information transmissions from NR, by using existing LTE neighbor relations to find the Internet Protocol (IP) address of any unknown NR nodes.

**[0031]** There are, proposed herein, various embodiments which address one or more of the issues disclosed herein. Certain embodiments may provide one or more of the following technical advantages. For example, the proposed embodiments provide a combined way to provide SFTD reporting and ANR reporting in a compact manner. This may allow for the UE to report SSTD measurements for a list of cells. These and other technical advantages may be readily apparent from the following description. Particular embodiments may provide some, none, or all of these technical advantages.

**[0032]** Some of the embodiments contemplated herein will now be described more fully with reference to the accompanying drawings. Other embodiments, however, are contained within the scope of the subject matter disclosed herein, the disclosed subject matter should not be construed as limited to only the embodiments set forth herein; rather, these embodiments are provided by way of example to convey the scope of the subject matter to those skilled in the art.

## 1 ANR Specific Configurations

**[0033]** In LTE, the Information Element (IE) *reportCGI* was configured as part of periodical measurement reporting with periodicity of infinity. Basically, it is a one-shot  
 5 reporting. In NR, this parameter is already agreed to be part of *reportType* parameter, but its configuration is for further study and has not been agreed upon yet. Further, improvements have been suggested. For instance, it has been proposed to provide a list of cells for which the User Equipment (UE) is expected to provide CGI reporting. It has also been proposed to configure the cell(s) for which to report the CGI in *reportConfig* rather  
 10 than in *measObject*. However, all the above configurations are based on a report, either event triggered or periodical, received from the UE that contains a Physical Cell Identity (PCI) that is not amongst the known neighbors for the serving cell. It is to be noted that, as in LTE, in the above mechanisms, the UE is unaware of any neighbor list, and the UE cannot pro-actively detect the presence of an unknown neighbor in the area.

**[0034]** In this regard, the following example is provided to show how the *reportCGI* IE could be included in the *ReportConfigNR*.

```
ReportConfigNR ::= SEQUENCE {
    reportType CHOICE {
        periodical PeriodicalReportConfig,
        eventTriggered EventTriggerConfig,
        -- reportCGI is to be completed before the end of Rel-15.
        reportCGI ENUMERATED {ffsTypeAndValue},
        ...
    }
}
```

**[0035]** One solution proposed herein provides a way in which the UE can actively identify a cell which might cause a PCI confusion or a cell which could be potentially not in the neighbor list of the serving cell.

### 1.1 Additional Neighbor Cell Detection

**[0036]** The UE is configured with Sync signal Measurement Timing Configuration (SMTC) windows that inform the UE as to where to find the Synchronization Signal (SS) / Physical Broadcast Channel (PBCH) blocks (also referred to as SS blocks or SSBs) in the  
 35 corresponding frequency. All the transmissions of the SS/PBCH blocks should happen within this window. The window can be up to 5 milliseconds (ms) long, and its periodicity

can be configured amongst {5,10,20,40,80,160} ms. The UE is not expected to perform any Radio Resource Management (RRM) measurements outside of this SMTC window.

**[0037]** The SS/PBCH blocks transmitted from a cell will contain Primary Synchronization Signal (PSS), Secondary Synchronization Signal (SSS), and PBCH. The contents of the PBCH will, amongst other things, include the timing index that informs the UE as to whether the detected SS/PBCH block is the first SS/PBCH block from that cell, or a second SS/PBCH block from that cell, or a third SS/PBCH block from that cell, etc. Based on this information, the UE can detect if there is any cell whose SS/PBCH block transmission is falling outside the configured SMTC window. One method that can be used by the UE to do so is given below. Note that this is just an example embodiment and further optimizations can be performed on this. For example, instead of considering every detected SS/PBCH block, the UE may consider only the strongest SS/PBCH block from a given PCI. The example process is as follows:

- For each detected SS/PBCH block identifier at the UE
  - If the detected SS/PBCH block identifier (beam index) is larger than 1:
    - Based on the detected timing index (SS/PBCH block identifier → beam index), find the possible transmission instance of the first SS/PBCH block identifier from that cell
    - Check if this first transmission of SS/PBCH block occurs before the start of the SMTC window.
      - If so, then the UE declares the detection of a candidate unknown neighbor cell

## 1.2 PCI Confusion Detection

**[0038]** The UE performs SS/PBCH block measurements within the SMTC window. During this time, the UE expects the SS/PBCH block indices from the same cell (e.g., SS/PBCH block indices that have same PCI encoded in PSS+SSS) to arrive in increasing order, as the SS/PBCH block index indicates the timing information. Therefore, if the UE detects two different SS/PBCH blocks from the same cell (e.g., having the same PCI) within the same SMTC window, and if those detected SS/PBCH blocks do not occur in a gradual increasing order, then the UE can declare that there is more than one cell that is covering the area and transmitting the same PCI. This detection could be based on arrival of

SS/PBCH blocks in non-ascending order and/or if detected SS/PBCH block indices between successive SS/PBCH transmission locations is not in gradual ascending order, as per the expected transmission sequence. This can be declared as PCI confusion detection.

### 5 1.3 *ReportConfigNR* Contents

**[0039]** Based on the above, the reporting configuration from NR can be updated as follows. This is one embodiment of such a configuration.

**[0040]** If the network would like to get an ‘additional neighbor cell detection’ related reporting, the network can configure the UE to trigger the measurement report if such a cell  
 10 is detected by setting a flag *reportTriggering* in *OneShotReportConfig* and setting *reportPurpose* to *cellOutsideSMTCWindowDetection* or *cellOutsideSMTCWindowDetectionORPCIConfusionDetection*. In such a report, the UE includes the cell that was detected within the SMTC window but could have other SS/PBCH blocks transmitted prior to the start of the SMTC window.

**[0041]** If the network would like to get an ‘PCI confusion detection’ related reporting, the network can configure the UE to trigger the measurement report if such a cell is detected by setting a flag *reportTriggering* in *OneShotReportConfig* and setting *reportPurpose* to *PCIConfusionDetection* or *cellOutsideSMTCWindowDetectionORPCIConfusionDetection*. In such a report, the UE includes the PCI that was detected to be having potential PCI  
 15 confusion issue and potentially the UE can also include the GCID of these cells by using autonomous gaps to read the GCID of these cells.

**[0042]** One example of a modified *ReportConfigNR* IE including the aforementioned aspects to enable additional neighbor cell detection related reporting and PCI confusion detection related reporting is as follows:

25

#### ***ReportConfigNR* information element**

30

35

```
-- ASN1START
-- TAG-REPORT-CONFIG-START

ReportConfigNR ::=
  reportType
    periodical
    eventTriggered
  -- reportCGI is to be completed before the end of Rel-15.
  oneShotReport
  ...
}
}
```

5

10

```
OneShotReportConfig ::= SEQUENCE {
    reportPurpose      ENUMERATED {cellOutsideSMTCWindowDetection, PCIConfusionDetection,
cellOutsideSMTCWindowDetectionORPCIConfusionDetection, reportCGI},
    -- Common reporting config (at least to periodical and eventTriggered)
    cellsForWhichToReport      CellIndexList      OPTIONAL,    -- Cond R
    reportTriggering            BOOLEAN            OPTIONAL,
    si-RequestForHO             ENUMERATED {setup}  OPTIONAL,    -- Cond reportCGI
    includeMultiBandInfo        ENUMERATED {true}  OPTIONAL,    -- Cond reportCGI
}
```

| ReportConfigNR field descriptions |                                                                                                                                                                                                                                                                                                                                                                                                                         |
|-----------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>cellsForWhichToReport</b>      | If the field <i>reportPurpose</i> is set to <i>reportCGI</i> , the UE shall acquire the CSG identity, tracking area code, list of PLMN identities for each of the cell listed in the <i>cellsForWhichToReport</i> field.                                                                                                                                                                                                |
| <b>reportTriggering</b>           | A boolean flag that indicates whether the UE can trigger the measurement report based on the detection criterion as specified for autonomous detection of unknown neighbour cell detection criterion. This field can be configured only when the <i>reportPurpose</i> is set to <i>cellOutsideSMTCWindowDetection</i> or <i>PCIConfusionDetection</i> or <i>cellOutsideSMTCWindowDetectionORPCIConfusionDetection</i> . |
| <b>includeMultiBandInfo</b>       | If this field is present, the UE shall acquire and include multi band information in the measurement report.                                                                                                                                                                                                                                                                                                            |
| <b>reportSSTD-Meas</b>            | If this field is set to <i>true</i> , the UE shall measure SSTD between the PCell and the PSCell as specified in TS 36.214 [48] and ignore the <i>triggerQuantity</i> , <i>reportQuantity</i> and <i>maxReportCells</i> fields. E-UTRAN only sets this field to <i>true</i> when setting <i>triggerType</i> to <i>periodical</i> and <i>purpose</i> to <i>reportStrongestCells</i> .                                    |
| <b>si-RequestForHO</b>            | The field applies to the <i>reportCGI</i> functionality, and when the field is included, the UE is allowed to use autonomous gaps in acquiring system information from the neighbour cell, applies a different value for T321, and includes different fields in the measurement report.                                                                                                                                 |

| Conditional presence | Explanation                                                                                                                                                                                    |
|----------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>reportCGI</i>     | The field is optional, need OR, in case <i>purpose</i> is included and set to <i>reportCGI</i> ; otherwise the field is not present and the UE shall delete any existing value for this field. |

2 SFTD Reporting Configurations

- 15
- 20
- 25
- [0043]** SFTD measurements are used to find the time difference between the two different cells of which one will be a PCell. In 3GPP, it has been agreed that the network can configure for NR SFTD measurements whenever a NR PSCell is configured, and, if no NR cell is configured as PSCell, then the network could request the UE to report SFTD measurements towards other NR cells also.

**[0044]** Based on these agreements, the network could configure a list of cells for which the UE can report the SFTD measurements. One example of this is illustrated in Figure 2. Optional steps are represented by dashed lines in Figure 2. In particular, Figure 2 illustrates a process in which a UE is configured, by a network node, with a list of cells for which the UE can report SFTD measurements in accordance with some embodiments of the present disclosure. As illustrated, the network node configures the UE with a list of

cells for which the UE can report SFTD measurements (step 200). As described herein, in some embodiments, the list of cells is provided in an Information Element (e.g., *the ReportConfigNR* Information Element), which is transmitted in an RRC message such as an RRC connection reconfiguration message or an RRC connection resume message, as will be appreciated by one of skill in the art upon reading this disclosure. The UE receives this list and optionally performs SFTD measurements in accordance with the list (step 202). In other words, the UE performs SFTD measurements for cells in the list. The UE reports the SFTD measurements for at least some of those cells to the network node (step 204).

**[0045]** In this disclosure, it is proposed to use a similar mechanism to configure the reporting configurations related to SFTD measurements to that of ANR related measurements. In the case of ANR related configurations, it was earlier proposed to provide a list of cells for which the UE is to report CGI measurements. It was also earlier proposed to configure this list in the reporting configuration rather than in *measObject*. A similar mechanism can be adopted for SFTD measurement related reporting configuration. Based on this, one example of SFTD reporting configuration is given below.

**[0046]** By configuring the UE with *oneShotReport* having *reportPurpose* set to *reportSFTD*, the UE will perform SFTD measurements. The reporting configuration can additionally include '*cellsForWhichToReport*' which indicates the UE as to for which cells the UE shall perform SFTD measurements and include in the measurement report.

#### ***ReportConfigNR* information element**

```
-- ASN1START
-- TAG-REPORT-CONFIG-START

ReportConfigNR ::=
    reportType
        periodical
        eventTriggered
-- reportCGI is to be completed before the end of Rel-15.
    oneShotReport
    ...
}

OneShotReportConfig ::=
    reportPurpose      ENUMERATED {cellOutsideSMTCWindowDetection, PCIConfusionDetection,
cellOutsideSMTCWindowDetectionORPCIConfusionDetection, reportCGI, reportSFTD},

    -- Common reporting config (at least to periodical and eventTriggered)
    cellsForWhichToReport CellIndexList      OPTIONAL,    -- Need R
    reportTriggering      BOOLEAN            OPTIONAL,
```

**[0047]** In some embodiments, the network can configure a threshold (instead of *cellsForWhichToReport* or as an additional parameter with *cellsForWhichToReport*) that indicates to the UE to include only those cells in the measurement report whose measured quality is within the configured threshold (i.e., satisfies the configured threshold for reporting).

**[0048]** In yet another embodiment, the SFTD measurements configured in LTE can be captured as given below. These various embodiments are shown as changes to 3GPP TS 36.331, with the amended text shown with highlighting, underlining, and bold text. Although specific names and terms for IEs are used in these proposals, it will be appreciated that these names and terms are used for illustrative purposes. Different names and terms may be adopted in the standard without deviating from the functionality disclosed herein.

### *1<sup>st</sup> Change*

#### 5.5 Measurements

##### **5.5.1 Introduction**

**[0049]** The UE reports measurement information in accordance with the measurement configuration as provided by E-UTRAN. E-UTRAN provides the measurement configuration applicable for a UE in RRC\_CONNECTED by means of dedicated signaling, i.e. using the *RRCConnectionReconfiguration* or *RRCConnectionResume* message.

**[0050]** The UE can be requested to perform the following types of measurements:

- Intra-frequency measurements: measurements at the downlink carrier frequency(ies) of the serving cell(s).
- Inter-frequency measurements: measurements at frequencies that differ from any of the downlink carrier frequency(ies) of the serving cell(s).
- Inter-RAT measurements of NR frequencies.
- Inter-RAT measurements of UTRA frequencies.
- Inter-RAT measurements of GERAN frequencies.
- Inter-RAT measurements of CDMA2000 HRPD or CDMA2000 1xRTT or WLAN frequencies.
- CBR measurements.

**[0051]** The measurement configuration includes the following parameters:

1. **Measurement objects:** The objects on which the UE shall perform the measurements.
  - For intra-frequency and inter-frequency measurements a measurement object is a single E-UTRA carrier frequency. Associated with this carrier frequency, E-UTRAN can configure a list of cell specific offsets, a list of 'blacklisted' cells and a list of 'whitelisted' cells. Blacklisted cells are not considered in event evaluation or measurement reporting.

- For inter-RAT NR measurements a measurement object is a single NR carrier frequency. Associated with this carrier frequency, E-UTRAN can configure a list of 'blacklisted' cells. Blacklisted cells are not considered in event evaluation or measurement reporting.
- 5      - For inter-RAT UTRA measurements a measurement object is a set of cells on a single UTRA carrier frequency.
- For inter-RAT GERAN measurements a measurement object is a set of GERAN carrier frequencies.
- For inter-RAT CDMA2000 measurements a measurement object is a set of cells on a single (HRPD or 1xRTT) carrier frequency.
- 10      - For inter-RAT WLAN measurements a measurement object is a set of WLAN identifiers and optionally a set of WLAN frequencies.
- For CBR measurements a measurement object is a set of transmission resource pools for V2X sidelink communication.

NOTE 1: Some measurements using the above mentioned measurement objects, only concern a single cell, e.g. measurements used to report neighbouring cell system information, PCell UE Rx-Tx time difference, or a pair of cells, e.g. SSTD measurements between the PCell and the PSCell, or SFTD measurements between the PCell and an NR cell.

2. **Reporting configurations:** A list of reporting configurations where each reporting configuration consists of the following:
- Reporting criterion: The criterion that triggers the UE to send a measurement report. This can either be periodical or a single event description.
  - Reporting format: The quantities that the UE includes in the measurement report and associated information (e.g. number of cells to report).

## 2<sup>nd</sup> Change

### 25      5.5.3      Performing measurements

#### 5.5.3.1      General

**[0052]**      For all measurements, except for UE Rx–Tx time difference measurements, RSSI, UL PDCP Packet Delay per QCI measurement, channel occupancy measurements, CBR measurement, and except for WLAN measurements of Band, Carrier Info, Available Admission Capacity, Backhaul Bandwidth, Channel Utilization, and Station Count, the UE applies the layer 3 filtering as specified in 5.5.3.2, before using the measured results for evaluation of reporting criteria or for measurement reporting. When performing measurements on NR carriers, the UE derives the cell quality as specified in 5.5.3.3 and the beam quality as specified in 5.5.3.3a.

35      **[0053]**      The UE shall:

- 1> whenever the UE has a *measConfig*, perform RSRP and RSRQ measurements for each serving cell as follows:
- 2> for the PCell, apply the time domain measurement resource restriction in accordance with *measSubframePatternPCell*, if configured;

- 2> if the UE supports CRS based discovery signals measurement:
  - 3> for each SCell in deactivated state, apply the discovery signals measurement timing configuration in accordance with *measDS-Config*, if configured within the *measObject* corresponding to the frequency of the SCell;
- 5 1> if the UE has a *measConfig* with *rs-sinr-Config* configured, perform RS-SINR (as indicated in the associated *reportConfig*) measurements as follows:
  - 2> perform the corresponding measurements on the frequency indicated in the associated *measObject* using available idle periods or using autonomous gaps as necessary;
- 10 1> for each *measId* included in the *measIdList* within *VarMeasConfig*:
  - 2> if the *purpose* for the associated *reportConfig* is set to *reportCGI*:
    - 3> if *si-RequestForHO* is configured for the associated *reportConfig*:
      - 4> perform the corresponding measurements on the frequency and RAT indicated in the associated *measObject* using autonomous gaps as necessary;
    - 3> else:
      - 15 4> perform the corresponding measurements on the frequency and RAT indicated in the associated *measObject* using available idle periods or using autonomous gaps as necessary;
- 20 NOTE 1: If autonomous gaps are used to perform measurements, the UE is allowed to temporarily abort communication with all serving cell(s), i.e. create autonomous gaps to perform the corresponding measurements within the limits specified in TS 36.133 [16]. Otherwise, the UE only supports the measurements with the purpose set to *reportCGI* only if E-UTRAN has provided sufficient idle periods.
  - 3> try to acquire the global cell identity of the cell indicated by the *cellForWhichToReportCGI* in the associated *measObject* by acquiring the relevant system information from the concerned cell;
  - 3> if an entry in the *cellAccessRelatedInfoList* includes the selected PLMN, acquire the relevant system information from the concerned cell;
  - 25 3> if the cell indicated by the *cellForWhichToReportCGI* included in the associated *measObject* is an E-UTRAN cell:
    - 4> try to acquire the CSG identity, if the CSG identity is broadcast in the concerned cell;
    - 4> try to acquire the *trackingAreaCode* in the concerned cell;
    - 30 4> try to acquire the list of additional PLMN Identities, as included in the *plmn-IdentityList*, if multiple PLMN identities are broadcast in the concerned cell;
    - 4> if *cellAccessRelatedInfoList* is included, use *trackingAreaCode* and *plmn-IdentityList* from the entry of *cellAccessRelatedInfoList* containing the selected PLMN;
    - 4> if the *includeMultiBandInfo* is configured:
      - 35 5> try to acquire the *freqBandIndicator* in the *SystemInformationBlockType1* of the concerned cell;
      - 5> try to acquire the list of additional frequency band indicators, as included in the *multiBandInfoList*, if multiple frequency band indicators are included in the *SystemInformationBlockType1* of the concerned cell;
      - 5> try to acquire the *freqBandIndicatorPriority*, if the *freqBandIndicatorPriority* is included in the *SystemInformationBlockType1* of the concerned cell;
  - 40 NOTE 2: The 'primary' PLMN is part of the global cell identity.

- 3> if the cell indicated by the *cellForWhichToReportCGI* included in the associated *measObject* is a UTRAN cell:
  - 4> try to acquire the LAC, the RAC and the list of additional PLMN Identities, if multiple PLMN identities are broadcast in the concerned cell;
- 5
  - 4> try to acquire the CSG identity, if the CSG identity is broadcast in the concerned cell;
- 3> if the cell indicated by the *cellForWhichToReportCGI* included in the associated *measObject* is a GERAN cell:
  - 4> try to acquire the RAC in the concerned cell;
- 10
  - 3> if the cell indicated by the *cellForWhichToReportCGI* included in the associated *measObject* is a CDMA2000 cell and the *cdma2000-Type* included in the *measObject* is *typeHRPD*:
    - 4> try to acquire the Sector ID in the concerned cell;
  - 3> if the cell indicated by the *cellForWhichToReportCGI* included in the associated *measObject* is a CDMA2000 cell and the *cdma2000-Type* included in the *measObject* is *typeLXRTT*:
    - 4> try to acquire the BASE ID, SID and NID in the concerned cell;
- 15
  - 2> if the *ul-DelayConfig* is configured for the associated *reportConfig*:
    - 3> ignore the *measObject*;
    - 3> configure the PDCP layer to perform UL PDCP Packet Delay per QCI measurement;
  - 2> else:
    - 3> if a measurement gap configuration is setup; or
- 20
  - 3> if the UE does not require measurement gaps to perform the concerned measurements:
    - 4> if *s-Measure* is not configured; or
    - 4> if *s-Measure* is configured and the PCell RSRP, after layer 3 filtering, is lower than this value; or
    - 4> if the associated *measObject* concerns NR; or
    - 4> if *measDS-Config* is configured in the associated *measObject*.
- 25
  - 5> if the UE supports CSI-RS based discovery signals measurement; and
  - 5> if the *eventId* in the associated *reportConfig* is set to *eventC1* or *eventC2*, or if *reportStrongestCSI-RSs* is included in the associated *reportConfig*.
- 30
  - 6> perform the corresponding measurements of CSI-RS resources on the frequency indicated in the concerned *measObject*, applying the discovery signals measurement timing configuration in accordance with *measDS-Config* in the concerned *measObject*;
  - 6> if *reportCRS-Meas* is included in the associated *reportConfig*, perform the corresponding measurements of neighbouring cells on the frequencies indicated in the concerned *measObject* as follows:
    - 7> for neighbouring cells on the primary frequency, apply the time domain measurement resource restriction in accordance with *measSubframePatternConfigNeigh*, if configured in the concerned *measObject*;
  - 7> apply the discovery signals measurement timing configuration in accordance with *measDS-Config* in the concerned *measObject*;
- 35
  - 7> apply the discovery signals measurement timing configuration in accordance with *measDS-Config* in the concerned *measObject*;

5> else:

6> perform the corresponding measurements of neighbouring cells on the frequencies and RATs indicated in the concerned *measObject* as follows:

5 7> for neighbouring cells on the primary frequency, apply the time domain measurement resource restriction in accordance with *measSubframePatternConfigNeigh*, if configured in the concerned *measObject*;

7> if the UE supports CRS based discovery signals measurement, apply the discovery signals measurement timing configuration in accordance with *measDS-Config*, if configured in the concerned *measObject*;

10 4> if the *ue-RxTxTimeDiffPeriodical* is configured in the associated *reportConfig*:

5> perform the UE Rx–Tx time difference measurements on the PCell;

4> if the *reportSSTD-Meas* is set to *true* or *pSCell* in the associated *reportConfig*:

5> perform SSTD measurements between the PCell and the PSCell;

4> if the *reportSFTD-Meas* is set to *pSCell* in the associated *reportConfig*:

15 5> perform SFTD measurements between the PCell and the NR PSCell;

4> if the *reportSFTD-Meas* is set to *neighborCells* in the associated *reportConfig*:

5> perform SFTD measurements between the PCell and each of the detected NR neighbor cell;

4> if the *measRSSI-ReportConfig* is configured in the associated *reportConfig*:

20 5> perform the RSSI and channel occupancy measurements on the frequency indicated in the associated *measObject*;

2> perform the evaluation of reporting criteria as specified in 5.5.4;

The UE capable of CBR measurement when configured to transmit non-P2X related V2X sidelink communication shall:

25 1> if in coverage on the frequency used for V2X sidelink communication transmission as defined in TS 36.304 [4, 11.4]; or

1> if the concerned frequency is included in *v2x-InterFreqInfoList* in *RRCConnectionReconfiguration* or in *v2x-InterFreqInfoList* within *SystemInformationBlockType21*:

2> if the UE is in *RRC\_IDLE*:

3> if the concerned frequency is the camped frequency:

30 4> perform CBR measurement on the pools in *v2x-CommTxPoolNormalCommon* and *v2x-CommTxPoolExceptional* if included in *SystemInformationBlockType21*;

3> else if *v2x-CommTxPoolNormal* or *v2x-CommTxPoolExceptional* is included in *v2x-InterFreqInfoList* for the concerned frequency within *SystemInformationBlockType21*:

35 4> perform CBR measurement on pools in *v2x-CommTxPoolNormal* and *v2x-CommTxPoolExceptional* in *v2x-InterFreqInfoList* for the concerned frequency in *SystemInformationBlockType21*;

3> else if the concerned frequency broadcasts *SystemInformationBlockType21*:

- 4> perform CBR measurement on pools in *v2x-CommTxPoolNormalCommon* and *v2x-CommTxPoolExceptional* if included in *SystemInformationBlockType21* broadcast on the concerned frequency;
- 2> if the UE is in RRC\_CONNECTED:
- 5 3> if *tx-ResourcePoolToAddList* is included in *VarMeasConfig*:
- 4> perform CBR measurements on each resource pool indicated in *tx-ResourcePoolToAddList*;
- 3> if the concerned frequency is the PCell's frequency:
- 10 4> perform CBR measurement on the pools in *v2x-CommTxPoolNormalDedicated* or *v2x-SchedulingPool* if included in *RRCCONNECTIONRECONFIGURATION*, *v2x-CommTxPoolExceptional* if included in *SystemInformationBlockType21* for the concerned frequency and *v2x-CommTxPoolExceptional* if included in *mobilityControlInfoV2X*;
- 3> else if *v2x-CommTxPoolNormal*, *v2x-SchedulingPool* or *v2x-CommTxPoolExceptional* is included in *v2x-InterFreqInfoList* for the concerned frequency within *RRCCONNECTIONRECONFIGURATION*:
- 15 4> perform CBR measurement on pools in *v2x-CommTxPoolNormal*, *v2x-SchedulingPool*, and *v2x-CommTxPoolExceptional* if included in *v2x-InterFreqInfoList* for the concerned frequency in *RRCCONNECTIONRECONFIGURATION*;
- 3> else if the concerned frequency broadcasts *SystemInformationBlockType21*:
- 4> perform CBR measurement on pools in *v2x-CommTxPoolNormalCommon* and *v2x-CommTxPoolExceptional* if included in *SystemInformationBlockType21* for the concerned frequency;
- 20 1> else:
- 2> perform CBR measurement on pools in *v2x-CommTxPoolList* in *SL-V2X-Preconfiguration* for the concerned frequency;
- NOTE 3: The *s-Measure* defines when the UE is required to perform measurements. The UE is however allowed to perform measurements also when the PCell RSRP exceeds *s-Measure*, e.g., to measure cells broadcasting a CSG identity following use of the autonomous search function as defined in TS 36.304 [4].
- 25 NOTE 4: The UE may not perform the WLAN measurements it is configured with e.g. due to connection to another WLAN based on user preferences as specified in TS 23.402 [75] or due to turning off WLAN.

### 3<sup>rd</sup> Change

## 30 Measurement report triggering

### 5.5.4.1 General

**[0054]** If security has been activated successfully, the UE shall:

- 1> for each *measId* included in the *measIdList* within *VarMeasConfig*:
- 2> if the corresponding *reportConfig* includes a purpose set to *reportStrongestCellsForSON*:
- 35 3> consider any neighbouring cell detected on the associated frequency to be applicable;
- 2> else if the corresponding *reportConfig* includes a purpose set to *reportCGI*:
- 3> consider any neighbouring cell detected on the associated frequency/ set of frequencies (GERAN) which has a physical cell identity matching the value of the *cellForWhichToReportCGI* included in the corresponding *measObject* within the *VarMeasConfig* to be applicable;

- 2> else if the corresponding *reportConfig* includes a purpose set to *reportLocation*:
  - 3> consider only the PCell to be applicable;
- 2> else:
  - 3> if the corresponding *measObject* concerns E-UTRA:
    - 5 4> if the *ue-RxTxTimeDiffPeriodical* is configured in the corresponding *reportConfig*:
      - 5> consider only the PCell to be applicable;
    - 4> else if the *reportSSTD-Meas* is set to *true* in the corresponding *reportConfig*:
      - 5> consider the PSCell to be applicable;
    - 4> else if the *eventA1* or *eventA2* is configured in the corresponding *reportConfig*:
      - 10 5> consider only the serving cell to be applicable;
    - 4> else if *eventC1* or *eventC2* is configured in the corresponding *reportConfig*; or if *reportStrongestCSI-RSs* is included in the corresponding *reportConfig*:
      - 15 5> consider a CSI-RS resource on the associated frequency to be applicable when the concerned CSI-RS resource is included in the *measCSI-RS-ToAddModList* defined within the *VarMeasConfig* for this *measId*;
    - 4> else if *measRSSI-ReportConfig* is configured in the corresponding *reportConfig*:
      - 5> consider the resource indicated by the *rmtc-Config* on the associated frequency to be applicable;
    - 4> else if *tx-ResourcePoolToAddList* is configured in the *measObject*:
      - 20 5> consider the transmission resource pools indicated by the *tx-ResourcePoolToAddList* defined within the *VarMeasConfig* for this *measId* to be applicable;
    - 4> else:
      - 5> if *useWhiteCellList* is set to *TRUE*:
        - 25 6> consider any neighbouring cell detected on the associated frequency to be applicable when the concerned cell is included in the *whiteCellsToAddModList* defined within the *VarMeasConfig* for this *measId*;
      - 5> else:
        - 6> consider any neighbouring cell detected on the associated frequency to be applicable when the concerned cell is not included in the *blackCellsToAddModList* defined within the *VarMeasConfig* for this *measId*;
    - 30 5> for events involving a serving cell on one frequency and neighbours on another frequency, consider the serving cell on the other frequency as a neighbouring cell;
    - 4> if the corresponding *reportConfig* includes *alternativeTimeToTrigger* and if the UE supports *alternativeTimeToTrigger*:
      - 35 5> use the value of *alternativeTimeToTrigger* as the time to trigger instead of the value of *timeToTrigger* in the corresponding *reportConfig* for cells included in the *altTTT-CellsToAddModList* of the corresponding *measObject*;
  - 3> else if the corresponding *measObject* concerns UTRA or CDMA2000:

- 4> consider a neighbouring cell on the associated frequency to be applicable when the concerned cell is included in the *cellsToAddModList* defined within the *VarMeasConfig* for this *measId* (i.e. the cell is included in the white-list);

NOTE 0: The UE may also consider a neighbouring cell on the associated UTRA frequency to be applicable when the concerned cell is included in the *csg-allowedReportingCells* within the *VarMeasConfig* for this *measId*, if configured in the corresponding *measObjectUTRA* (i.e. the cell is included in the range of physical cell identities for which reporting is allowed).

- 3> else if the corresponding *measObject* concerns GERAN:

- 4> consider a neighbouring cell on the associated set of frequencies to be applicable when the concerned cell matches the *ncc-Permitted* defined within the *VarMeasConfig* for this *measId*;

- 3> else if the corresponding *measObject* concerns WLAN:

- 4> consider a WLAN on the associated set of frequencies, as indicated by *carrierFreq* or on all WLAN frequencies when *carrierFreq* is not present, to be applicable if the WLAN matches all WLAN identifiers of at least one entry within *wlan-Id-List* for this *measId*;

- 3> else if the corresponding *measObject* concerns NR:

4> if the *reportSFTD-Meas* is set to *pSCell* in the corresponding *reportConfig*:

5> consider the PSCell to be applicable;

4> else if the *reportSFTD-Meas* is set to *neighborCells*, in the corresponding *reportConfig* and no NR PSCell is configured:

5> consider any neighbouring NR cell detected on the associated frequency to be applicable;

- 2> if the *triggerType* is set to *event* and if the entry condition applicable for this event, i.e. the event corresponding with the *eventId* of the corresponding *reportConfig* within *VarMeasConfig*, is fulfilled for one or more applicable cells for all measurements after layer 3 filtering taken during *timeToTrigger* defined for this event within the *VarMeasConfig*, while the *VarMeasReportList* does not include a measurement reporting entry for this *measId* (a first cell triggers the event):

- 3> include a measurement reporting entry within the *VarMeasReportList* for this *measId*;

- 3> set the *numberOfReportsSent* defined within the *VarMeasReportList* for this *measId* to 0;

- 3> include the concerned cell(s) in the *cellsTriggeredList* defined within the *VarMeasReportList* for this *measId*;

- 3> if the UE supports T312 and if *useT312* is included for this event and if T310 is running:

- 4> if T312 is not running:

5> start timer T312 with the value configured in the corresponding *measObject*;

- 3> initiate the measurement reporting procedure, as specified in 5.5.5;

- 2> if the *triggerType* is set to *event* and if the entry condition applicable for this event, i.e. the event corresponding with the *eventId* of the corresponding *reportConfig* within *VarMeasConfig*, is fulfilled for one or more applicable cells not included in the *cellsTriggeredList* for all measurements after layer 3 filtering taken during *timeToTrigger* defined for this event within the *VarMeasConfig* (a subsequent cell triggers the event):

- 3> set the *numberOfReportsSent* defined within the *VarMeasReportList* for this *measId* to 0;

- 3> include the concerned cell(s) in the *cellsTriggeredList* defined within the *VarMeasReportList* for this *measId*;

- 3> if the UE supports T312 and if *useT312* is included for this event and if T310 is running:
  - 4> if T312 is not running:
    - 5> start timer T312 with the value configured in the corresponding *measObject*;
  - 3> initiate the measurement reporting procedure, as specified in 5.5.5;
- 5 2> if the *triggerType* is set to *event* and if the leaving condition applicable for this event is fulfilled for one or more of the cells included in the *cellsTriggeredList* defined within the *VarMeasReportList* for this *measId* for all measurements after layer 3 filtering taken during *timeToTrigger* defined within the *VarMeasConfig* for this event:
  - 10 3> remove the concerned cell(s) in the *cellsTriggeredList* defined within the *VarMeasReportList* for this *measId*;
  - 3> if the UE supports T312 and if *useT312* is included for this event and if T310 is running:
    - 4> if T312 is not running:
      - 5> start timer T312 with the value configured in the corresponding *measObject*;
    - 15 3> if *reportOnLeave* is set to *TRUE* for the corresponding reporting configuration or if *a6-ReportOnLeave* is set to *TRUE* for the corresponding reporting configuration:
      - 4> initiate the measurement reporting procedure, as specified in 5.5.5;
    - 3> if the *cellsTriggeredList* defined within the *VarMeasReportList* for this *measId* is empty:
      - 4> remove the measurement reporting entry within the *VarMeasReportList* for this *measId*;
      - 4> stop the periodical reporting timer for this *measId*, if running;
  - 20 2> if the *triggerType* is set to *event* and if the entry condition applicable for this event, i.e. the event corresponding with the *eventId* of the corresponding *reportConfig* within *VarMeasConfig*, is fulfilled for one or more applicable CSI-RS resources for all measurements after layer 3 filtering taken during *timeToTrigger* defined for this event within the *VarMeasConfig*, while the *VarMeasReportList* does not include an measurement reporting entry for this *measId* (i.e. a first CSI-RS resource triggers the event):
    - 25 3> include a measurement reporting entry within the *VarMeasReportList* for this *measId*;
    - 3> set the *numberOfReportsSent* defined within the *VarMeasReportList* for this *measId* to 0;
    - 3> include the concerned CSI-RS resource(s) in the *csi-RS-TriggeredList* defined within the *VarMeasReportList* for this *measId*;
    - 3> initiate the measurement reporting procedure, as specified in 5.5.5;
  - 30 2> if the *triggerType* is set to *event* and if the entry condition applicable for this event, i.e. the event corresponding with the *eventId* of the corresponding *reportConfig* within *VarMeasConfig*, is fulfilled for one or more applicable CSI-RS resources not included in the *csi-RS-TriggeredList* for all measurements after layer 3 filtering taken during *timeToTrigger* defined for this event within the *VarMeasConfig* (i.e. a subsequent CSI-RS resource triggers the event):
    - 35 3> set the *numberOfReportsSent* defined within the *VarMeasReportList* for this *measId* to 0;
    - 3> include the concerned CSI-RS resource(s) in the *csi-RS-TriggeredList* defined within the *VarMeasReportList* for this *measId*;
    - 3> initiate the measurement reporting procedure, as specified in 5.5.5;
  - 40 2> if the *triggerType* is set to *event* and if the leaving condition applicable for this event is fulfilled for one or more of the CSI-RS resources included in the *csi-RS-TriggeredList* defined within the *VarMeasReportList* for

this *measId* for all measurements after layer 3 filtering taken during *timeToTrigger* defined within the *VarMeasConfig* for this event:

- 3> remove the concerned CSI-RS resource(s) in the *csi-RS-TriggeredList* defined within the *VarMeasReportList* for this *measId*;
- 5 3> if *c1-ReportOnLeave* is set to *TRUE* for the corresponding reporting configuration or if *c2-ReportOnLeave* is set to *TRUE* for the corresponding reporting configuration:
  - 4> initiate the measurement reporting procedure, as specified in 5.5.5;
- 3> if the *csi-RS-TriggeredList* defined within the *VarMeasReportList* for this *measId* is empty:
  - 4> remove the measurement reporting entry within the *VarMeasReportList* for this *measId*;
  - 10 4> stop the periodical reporting timer for this *measId*, if running;
- 2> if the *triggerType* is set to *event* and if the entry condition applicable for this event, i.e. the event corresponding with the *eventId* of the corresponding *reportConfig* within *VarMeasConfig*, is fulfilled for one or more applicable transmission resource pools for all measurements taken during *timeToTrigger* defined for this event within the *VarMeasConfig*, while the *VarMeasReportList* does not include an measurement reporting entry for this *measId* (a first transmission resource pool triggers the event):
  - 15 3> include a measurement reporting entry within the *VarMeasReportList* for this *measId*;
  - 3> set the *numberOfReportsSent* defined within the *VarMeasReportList* for this *measId* to 0;
  - 3> include the concerned transmission resource pool(s) in the *poolsTriggeredList* defined within the *VarMeasReportList* for this *measId*;
  - 20 3> initiate the measurement reporting procedure, as specified in 5.5.5;
- 2> if the *triggerType* is set to *event* and if the entry condition applicable for this event, i.e. the event corresponding with the *eventId* of the corresponding *reportConfig* within *VarMeasConfig*, is fulfilled for one or more applicable transmission resource pools not included in the *poolsTriggeredList* for all measurements taken during *timeToTrigger* defined for this event within the *VarMeasConfig* (a subsequent transmission resource pool triggers the event):
  - 25 3> set the *numberOfReportsSent* defined within the *VarMeasReportList* for this *measId* to 0;
  - 3> include the concerned transmission resource pool(s) in the *poolsTriggeredList* defined within the *VarMeasReportList* for this *measId*;
  - 3> initiate the measurement reporting procedure, as specified in 5.5.5;
- 30 2> if the *triggerType* is set to *event* and if the leaving condition applicable for this event is fulfilled for one or more applicable transmission resource pools included in the *poolsTriggeredList* defined within the *VarMeasReportList* for this *measId* for all measurements taken during *timeToTrigger* defined within the *VarMeasConfig* for this event:
  - 35 3> remove the concerned transmission resource pool(s) from the *poolsTriggeredList* defined within the *VarMeasReportList* for this *measId*;
  - 3> if the *poolsTriggeredList* defined within the *VarMeasReportList* for this *measId* is empty:
    - 4> remove the measurement reporting entry within the *VarMeasReportList* for this *measId*;
    - 4> stop the periodical reporting timer for this *measId*, if running;
- 2> if *measRSSI-ReportConfig* is included and if a (first) measurement result is available:
  - 40 3> include a measurement reporting entry within the *VarMeasReportList* for this *measId*;

- 3> set the *numberOfReportsSent* defined within the *VarMeasReportList* for this *measId* to 0;
- 3> initiate the measurement reporting procedure as specified in 5.5.5 immediately when RSSI sample values are reported by the physical layer after the first L1 measurement duration;
- 5 2> else if the *purpose* is included and set to *reportStrongestCells*, *reportStrongestCellsForSON*, *reportLocation* or *sidelink* and if a (first) measurement result is available:
  - 3> include a measurement reporting entry within the *VarMeasReportList* for this *measId*;
  - 3> set the *numberOfReportsSent* defined within the *VarMeasReportList* for this *measId* to 0;
  - 3> if the *purpose* is set to *reportStrongestCells* and *reportStrongestCSI-RSs* is not included:
    - 4> if the *triggerType* is set to *periodical* and the corresponding *reportConfig* includes the *ul-DelayConfig*:
      - 10 5> initiate the measurement reporting procedure, as specified in 5.5.5, immediately after a first measurement result is provided by lower layers;
    - 4> else if the corresponding measurement object concerns WLAN:
      - 5> initiate the measurement reporting procedure, as specified in 5.5.5, immediately after the quantity to be reported becomes available for the PCell and for the applicable WLAN(s);
    - 15 4> else if the *reportAmount* exceeds 1:
      - 5> initiate the measurement reporting procedure, as specified in 5.5.5, immediately after the quantity to be reported becomes available for the PCell;
    - 4> else (i.e. the *reportAmount* is equal to 1):
      - 20 5> initiate the measurement reporting procedure, as specified in 5.5.5, immediately after the quantity to be reported becomes available for the PCell and for the strongest cell among the applicable cells, or becomes available for the pair of PCell and the PSCell in case of SSTD measurements, or becomes available for each of the pair of PCell and an NR cell in case of SFTD measurements;
  - 3> else if the *purpose* is set to *reportLocation*:
    - 25 4> initiate the measurement reporting procedure, as specified in 5.5.5, immediately after both the quantity to be reported for the PCell and the location information become available;
  - 3> else if the *purpose* is set to *sidelink*:
    - 4> initiate the measurement reporting procedure as specified in 5.5.5 immediately after both the quantity to be reported for the PCell and the CBR measurement result become available;
  - 3> else:
    - 30 4> initiate the measurement reporting procedure, as specified in 5.5.5, when it has determined the strongest cells on the associated frequency;
- 2> upon expiry of the periodical reporting timer for this *measId*:
  - 3> initiate the measurement reporting procedure, as specified in 5.5.5;
- 35 2> if the *purpose* is included and set to *reportCGI* and if the UE acquired the information needed to set all fields of *cgi-Info* for the requested cell:
  - 3> include a measurement reporting entry within the *VarMeasReportList* for this *measId*;
  - 3> set the *numberOfReportsSent* defined within the *VarMeasReportList* for this *measId* to 0;
  - 3> stop timer T321;

3> initiate the measurement reporting procedure, as specified in 5.5.5;

2> upon expiry of the T321 for this *measId*:

3> include a measurement reporting entry within the *VarMeasReportList* for this *measId*;

3> set the *numberOfReportsSent* defined within the *VarMeasReportList* for this *measId* to 0;

5 3> initiate the measurement reporting procedure, as specified in 5.5.5;

NOTE 2: The UE does not stop the periodical reporting with *triggerType* set to *event* or to *periodical* while the corresponding measurement is not performed due to the PCell RSRP being equal to or better than *s-Measure* or due to the measurement gap not being setup.

10 NOTE 3: If the UE is configured with DRX, the UE may delay the measurement reporting for event triggered and periodical triggered measurements until the Active Time, which is defined in TS 36.321 [6].

#### 4<sup>th</sup> Change

##### 5.5.5 Measurement reporting

15 **[0055]** The purpose of this procedure is to transfer measurement results from the UE to E-UTRAN. The UE shall initiate this procedure only after successful security activation.

**[0056]** For the *measId* for which the measurement reporting procedure was triggered, the UE shall set the *measResults* within the *MeasurementReport* message as follows:

1> set the *measId* to the measurement identity that triggered the measurement reporting;

1> set the *measResultPCell* to include the quantities of the PCell;

20 1> set the *measResultServFreqList* to include for each E-UTRA SCell that is configured, if any, within *measResultSCell* the quantities of the concerned SCell, if available according to performance requirements in [16], except if *purpose* for the *reportConfig* associated with the *measId* that triggered the measurement reporting is set to *reportLocation*;

25 1> if the *reportConfig* associated with the *measId* that triggered the measurement reporting includes *reportAddNeighMeas*:

2> for each E-UTRA serving frequency for which *measObjectId* is referenced in the *measIdList*, other than the frequency corresponding with the *measId* that triggered the measurement reporting:

3> set the *measResultServFreqList* to include within *measResultBestNeighCell* the *physCellId* and the quantities of the best non-serving cell, based on RSRP, on the concerned serving frequency;

30 1> if the *triggerType* is set to *event*, and if the corresponding *measObject* concerns NR; and if *eventId* is set to *eventB1* or *eventB2*; or

1> if the *triggerType* is set to *event*, and if *eventId* is set to *eventA3* or *eventA4* or *eventA5*:

2> if *purpose* for the *reportConfig* associated with the *measId* that triggered the measurement reporting is set to a value other than *reportLocation*:

35 3> set the *measResultServFreqListNR* to include for each NR serving frequency, if any, the following:

4> set *measResultSCell* to include the available results of the NR serving cell, if meeting performance requirements in [16];

- 4> if the *reportConfig* associated with the *measId* that triggered the measurement reporting includes *reportAddNeighMeas*:
- 5> set *measResultBestNeighCell* to include the available results of the best non-serving cell, based on RSRP;
- 5 5> for each (serving or neighbouring) cell for which the UE reports results according to the previous, additionally include available beam results according to the following:
- 6> if *maxRS-IndexReport* is configured, set *measResultCellRS-Index* to include results of up to *maxRS-IndexReport* beams whose quantity is above *threshRS-Index* defined in the *VarMeasConfig* for the corresponding *measObject* and in order of decreasing quantity, same as used for cell reporting, and as follows:
- 10 7> select and order beams based on the reporting quantity determined as specified in 5.5.5.2;
- TBC Ordering for beams based on NR principles as reflected in TPR2-1801646;
- 7> include *ssbIndex*;
- 15 7> if *reportQuantityRS-IndexNR* and *reportRS-IndexResultsNR* are configured, for each quantity indicated, include the corresponding measurement result;
- TBC Whether to introduce a similar bit as in NR e.g. add if *reportQuantityRS-IndexNR* and *reportRS-IndexResults* are configured
- TBC Reporting of available results based on NR principles as reflected in TPR2-1800951:
- 1> if there is at least one applicable neighbouring cell to report:
- 20 2> set the *measResultNeighCells* to include the best neighbouring cells up to *maxReportCells* in accordance with the following:
- 3> if the *triggerType* is set to *event*:
- 4> include the cells included in the *cellsTriggeredList* as defined within the *VarMeasReportList* for this *measId*;
- 25 3> else:
- 4> include the applicable cells for which the new measurement results became available since the last periodical reporting or since the measurement was initiated or reset;
- NOTE 1: The reliability of the report (i.e. the certainty it contains the strongest cells on the concerned frequency) depends on the measurement configuration i.e. the *reportInterval*. The related performance requirements are specified in TS 36.133 [16].
- 30 3> for each cell that is included in the *measResultNeighCells*, include the *physCellId*;
- 3> if the *triggerType* is set to *event*, or the *purpose* is set to *reportStrongestCells* or to *reportStrongestCellsForSON*:
- 35 4> for each included cell, include the layer 3 filtered measured results in accordance with the *reportConfig* for this *measId*, ordered as follows:
- 5> if the *measObject* associated with this *measId* concerns E-UTRA:
- 6> set the *measResult* to include the quantity(ies) indicated in the *reportQuantity* within the concerned *reportConfig* in order of decreasing *triggerQuantity*, i.e. the best cell is included first;
- 5> if the *measObject* associated with this *measId* concerns NR:

- 6> set the *measResultCell* to include the quantity(ies) indicated in the *reportQuantityCellNR* within the concerned *reportConfig* in order of decreasing quantity according to *bN-ThresholdYNR*, i.e. the best cell is included first;
- 5 6> if *maxRS-IndexReport* is configured, set *measResultCellRS-Index* to include results of up to *maxRS-IndexReport* beams whose quantity is above *threshRS-Index* defined in the *VarMeasConfig* for the corresponding *measObject* and in order of decreasing quantity, same as used for cell reporting, and as follows:
  - 7> select and order beams based on the reporting quantity determined as specified in 5.5.5.2;
  - TBC      Ordering for beams based on NR principles as reflected in TPR2-1801646;
  - 10 7> include *ssbIndex*;
  - 7> if *reportQuantityRS-IndexNR* and *reportRS-IndexResultsNR* are configured, for each quantity indicated, include the corresponding measurement result;
  - TBC      Whether to introduce a similar bit as in NR e.g. add if *reportQuantityRS-IndexNR* and *reportRS-IndexResults* are configured
- 15 5> if the *measObject* associated with this *measId* concerns UTRA FDD and if *ReportConfigInterRAT* includes the *reportQuantityUTRA-FDD*:
  - 6> set the *measResult* to include the quantities indicated by the *reportQuantityUTRA-FDD* in order of decreasing *measQuantityUTRA-FDD* within the *quantityConfig*, i.e. the best cell is included first;
- 20 5> if the *measObject* associated with this *measId* concerns UTRA FDD and if *ReportConfigInterRAT* does not include the *reportQuantityUTRA-FDD*; or
  - 5> if the *measObject* associated with this *measId* concerns UTRA TDD, GERAN or CDMA2000:
    - 25 6> set the *measResult* to the quantity as configured for the concerned RAT within the *quantityConfig* in order of either decreasing quantity for UTRA and GERAN or increasing quantity for CDMA2000 *pilotStrength*, i.e. the best cell is included first;
- 3> else if the *purpose* is set to *reportCGI*:
  - 4> if the mandatory present fields of the *cgi-Info* for the cell indicated by the *cellForWhichToReportCGI* in the associated *measObject* have been obtained:
    - 5>      if the *includeMultiBandInfo* is configured:
      - 30 6> include the *freqBandIndicator*;
      - 6>      if the cell broadcasts the *multiBandInfoList*, include the *multiBandInfoList*;
      - 6> if the cell broadcasts the *freqBandIndicatorPriority*, include the *freqBandIndicatorPriority*;
    - 5> if the cell broadcasts a CSG identity:
      - 6> include the *csg-Identity*;
      - 35 6> include the *csg-MemberStatus* and set it to *member* if the cell is a CSG member cell;
  - 5> if the *si-RequestForHO* is configured within the *reportConfig* associated with this *measId*:
    - 6> include the *cgi-Info* containing all the fields other than the *plmn-IdentityList* that have been successfully acquired;

- 6> include, within the *cgi-Info*, the field *plmn-IdentityList* in accordance with the following:
- 7> if the cell is a CSG member cell, determine the subset of the PLMN identities, starting from the second entry of PLMN identities in the broadcast information, that meet the following conditions:
    - 5 a) equal to the RPLMN or an EPLMN; and
    - b) the CSG whitelist of the UE includes an entry comprising of the concerned PLMN identity and the CSG identity broadcast by the cell;
  - 7> if the subset of PLMN identities determined according to the previous includes at least one PLMN identity, include the *plmn-IdentityList* and set it to include this subset of the PLMN identities;
  - 7> if the cell is a CSG member cell, include the *primaryPLMN-Suitable* if the primary PLMN meets conditions a) and b) specified above;
- 5> else:
- 6> include the *cgi-Info* containing all the fields that have been successfully acquired and in accordance with the following:
    - 7> include in the *plmn-IdentityList* the list of identities starting from the second entry of PLMN Identities in the broadcast information;
- 1> for the cells included according to the previous (i.e. covering the PCell, the SCells, the best non-serving cells on serving frequencies as well as neighbouring EUTRA cells) include results according to the extended RSRQ if corresponding results are available according to the associated performance requirements defined in 36.133 [16];
- 1> if there is at least one applicable CSI-RS resource to report:
- 2> set the *measResultCSI-RS-List* to include the best CSI-RS resources up to *maxReportCells* in accordance with the following:
    - 3> if the *triggerType* is set to *event*:
      - 25 4> include the CSI-RS resources included in the *csi-RS-TriggeredList* as defined within the *VarMeasReportList* for this *measId*;
    - 3> else:
      - 4> include the applicable CSI-RS resources for which the new measurement results became available since the last periodical reporting or since the measurement was initiated or reset;
- NOTE 2: The reliability of the report (i.e. the certainty it contains the strongest CSI-RS resources on the concerned frequency) depends on the measurement configuration i.e. the *reportInterval*. The related performance requirements are specified in TS 36.133 [16].
- 3> for each CSI-RS resource that is included in the *measResultCSI-RS-List*:
    - 4> include the *measCSI-RS-Id*;
    - 35 4> include the layer 3 filtered measured results in accordance with the *reportConfig* for this *measId*, ordered as follow:
      - 5> set the *csi-RSRP-Result* to include the quantity indicated in the *reportQuantity* within the concerned *reportConfig* in order of decreasing *triggerQuantityCSI-RS*, i.e. the best CSI-RS resource is included first;

- 4> if *reportCRS-Meas* is included within the associated *reportConfig*, and the cell indicated by *physCellId* of this CSI-RS resource is not a serving cell:
  - 5> set the *measResultNeighCells* to include the cell indicated by *physCellId* of this CSI-RS resource, and include the *physCellId*;
- 5 5> set the *rsrpResult* to include the RSRP of the concerned cell, if available according to performance requirements in [16];
- 5> set the *rsrqResult* to include the RSRQ of the concerned cell, if available according to performance requirements in [16];
- 1> if the *ue-RxTxTimeDiffPeriodical* is configured within the corresponding *reportConfig* for this *measId*;
- 10 2> set the *ue-RxTxTimeDiffResult* to the measurement result provided by lower layers;
- 2> set the *currentSFN*;
- 1> if the *measRSSI-ReportConfig* is configured within the corresponding *reportConfig* for this *measId*:
  - 2> set the *rsi-Result* to the average of sample value(s) provided by lower layers in the *reportInterval*;
  - 2> set the *channelOccupancy* to the rounded percentage of sample values which are beyond to the *channelOccupancyThreshold* within all the sample values in the *reportInterval*;
- 15 1> if uplink PDCP delay results are available:
  - 2> set the *ul-PDCP-DelayResultList* to include the uplink PDCP delay results available;
- 1> if the *includeLocationInfo* is configured in the corresponding *reportConfig* for this *measId* or if *purpose* for the *reportConfig* associated with the *measId* that triggered the measurement reporting is set to *reportLocation*; and detailed location information that has not been reported is available, set the content of the *locationInfo* as follows:
  - 2> include the *locationCoordinates*;
  - 2> if available, include the *gnss-TOD-msec*, except if *purpose* for the *reportConfig* associated with the *measId* that triggered the measurement reporting is set to *reportLocation*;
- 20 1> if the *reportSSTD-Meas* is set to *true* or *pSCell* within the corresponding *reportConfig* for this *measId*:
  - 25 2> set the *measResultSSTD* to the measurement results provided by lower layers;
- 1> if the *reportSFTD-Meas* is set to *neighborCells* or *pSCell* within the corresponding *reportConfigInterRAT* for this *measId*;
- 2> set the *measResultSFTD* to the measurement results provided by lower layers;

30 5<sup>th</sup> Change

### 6.3.5 Measurement information elements

<omitted text>

#### *MeasResults*

- 35 **[0057]** The IE *MeasResults* covers measured results for intra-frequency, inter-frequency and inter- RAT mobility.

**MeasResults** information element

```

-- ASN1START

5 MeasResults ::=
    measId
    measResultPCell
    rsrpResult
    rsrqResult
    },
10 measResultNeighCells
    measResultListEUTRA
    measResultListUTRA
    measResultListGERAN
    measResultsCDMA2000
15 ...,
    measResultNeighCellListNR-r15
    MeasResultCellListNR-r15
    OPTIONAL,
    ...,
20 [[ measResultForECID-r9
    MeasResultForECID-r9
    OPTIONAL
    ]],
    [[ locationInfo-r10
    LocationInfo-r10
    OPTIONAL,
    measResultServFreqList-r10
    MeasResultServFreqList-r10
    OPTIONAL
    ]],
25 [[ measId-v1250
    MeasId-v1250
    OPTIONAL,
    measResultPCell-v1250
    RSRQ-Range-v1250
    OPTIONAL,
    measResultCSI-RS-List-r12
    MeasResultCSI-RS-List-r12
    OPTIONAL
    ]],
30 [[ measResultForRSSI-r13
    MeasResultForRSSI-r13
    OPTIONAL,
    measResultServFreqListExt-r13
    MeasResultServFreqListExt-r13
    OPTIONAL,
    measResultSSTD-r13
    MeasResultSSTD-r13
    OPTIONAL,
    measResultPCell-v1310
    SEQUENCE {
        rs-sinr-Result-r13
        RS-SINR-Range-r13
    }
    OPTIONAL,
35 ul-PDCP-DelayResultList-r13
    UL-PDCP-DelayResultList-r13
    OPTIONAL,
    measResultListWLAN-r13
    MeasResultListWLAN-r13
    OPTIONAL
    ]],
    [[ measResultPCell-v1360
    RSRP-Range-v1360
    OPTIONAL
    ]],
40 [[ measResultListCBR-r14
    MeasResultListCBR-r14
    OPTIONAL,
    measResultListWLAN-r14
    MeasResultListWLAN-r14
    OPTIONAL
    ]],
    [[ measResultServFreqListNR-r15
    MeasResultServFreqListNR-r15
    OPTIONAL
    ]],
45 ]
)

MeasResultListEUTRA ::= SEQUENCE (SIZE (1..maxCellReport)) OF MeasResultEUTRA

MeasResultEUTRA ::= SEQUENCE {
50 physCellId
    PhysCellId,
    cgi-Info
    SEQUENCE {
        cellGlobalId
        CellGlobalIdEUTRA,
        trackingAreaCode
        TrackingAreaCode,
        plmn-IdentityList
        PLMN-IdentityList2
    }
    OPTIONAL,
55 measResult
    SEQUENCE {
        rsrpResult
        RSRP-Range
        OPTIONAL,
        rsrqResult
        RSRQ-Range
        OPTIONAL,
        ...,
60 [[ additionalSI-Info-r9
        AdditionalSI-Info-r9
        OPTIONAL
        ]],
        [[ primaryPLMN-Suitable-r12
        ENUMERATED {true}
        OPTIONAL,
        measResult-v1250
        RSRQ-Range-v1250
        OPTIONAL
        ]],
65 [[ rs-sinr-Result-r13
        RS-SINR-Range-r13
        OPTIONAL,
        cgi-Info-v1310
        SEQUENCE {
            freqBandIndicator-r13
            FreqBandIndicator-r11
            OPTIONAL,
            multiBandInfoList-r13
            MultiBandInfoList-r11
            OPTIONAL,
            freqBandIndicatorPriority-r13
            ENUMERATED {true}
            OPTIONAL
        }
        OPTIONAL,
70 ]],
    [[
        measResult-v1360
        RSRP-Range-v1360
        OPTIONAL
    ]],
}

```

```

    ]
  }
}

5 MeasResultServFreqListNR-r15 ::= SEQUENCE (SIZE (1..maxServCell-r13)) OF MeasResultServFreqNR-r15

MeasResultServFreqNR-r15 ::= SEQUENCE {
10   carrierFreq-r15          GSCN-ValueNR-r15,
   measResultSCell-r15        MeasResultCellNR-r15          OPTIONAL,
   measResultBestNeighCell-r15 MeasResultCellNR-r15          OPTIONAL,
   ...
}

15 MeasResultCellListNR-r15 ::= SEQUENCE (SIZE (1..maxCellReport)) OF MeasResultCellNR-r15

MeasResultCellNR-r15 ::= SEQUENCE {
20   pci-r15          PhysCellIdNR-r15,
   measResultCell-r15 MeasResultNR-r15,
   measResultRS-IndexList-r15 MeasResultSSB-IndexList-r15 OPTIONAL,
   ...
}

25 MeasResultNR-r15 ::= SEQUENCE {
   rsrpResult-r15          RSRP-RangeNR-r15          OPTIONAL,
   rsrqResult-r15          RSRQ-RangeNR-r15          OPTIONAL,
   rs-sinr-Result-r15      RS-SINR-RangeNR-r15       OPTIONAL,
measResultSFTD-r15      MeasResultSFTD-r15          OPTIONAL
   ...
}

30 MeasResultSSB-IndexList-r15 ::= SEQUENCE (SIZE (1..maxRS-Index-r15)) OF MeasResultSSB-Index-r15

MeasResultSSB-Index-r15 ::= SEQUENCE {
35   ssb-Index-r15          RS-IndexNR-r15,
   measResultSSB-Index-r15 MeasResultNR-r15          OPTIONAL,
   ...
}

40 MeasResultServFreqList-r10 ::= SEQUENCE (SIZE (1..maxServCell-r10)) OF MeasResultServFreq-r10

MeasResultServFreqListExt-r13 ::= SEQUENCE (SIZE (1..maxServCell-r13)) OF MeasResultServFreq-r13

45 MeasResultServFreq-r10 ::= SEQUENCE {
   servFreqId-r10          ServCellIndex-r10,
   measResultSCell-r10      SEQUENCE {
       rsrpResultSCell-r10    RSRP-Range,
       rsrqResultSCell-r10    RSRQ-Range
   }
50   measResultBestNeighCell-r10 SEQUENCE {
       physCellId-r10         PhysCellId,
       rsrpResultNCell-r10     RSRP-Range,
       rsrqResultNCell-r10     RSRQ-Range
   }
   ...
55   [[ measResultSCell-v1250    RSRQ-Range-v1250    OPTIONAL,
       measResultBestNeighCell-v1250 RSRQ-Range-v1250    OPTIONAL
   ]],
   [[ measResultSCell-v1310      SEQUENCE {
       rs-sinr-Result-r13        RS-SINR-Range-r13
60   } OPTIONAL,
       measResultBestNeighCell-v1310 SEQUENCE {
       rs-sinr-Result-r13        RS-SINR-Range-r13
65   } OPTIONAL
   ]],
}

70 MeasResultServFreq-r13 ::= SEQUENCE {
   servFreqId-r13          ServCellIndex-r13,
   measResultSCell-r13      SEQUENCE {
       rsrpResultSCell-r13    RSRP-Range,
       rsrqResultSCell-r13    RSRQ-Range-r13,
       rs-sinr-Result-r13      RS-SINR-Range-r13    OPTIONAL
   }
   ...
}

```

```

measResultBestNeighCell-r13      SEQUENCE {
    physCellId-r13                PhysCellId,
    rsrpResultNCell-r13           RSRP-Range,
    rsrqResultNCell-r13           RSRQ-Range-r13,
    rs-sinr-Result-r13           RS-SINR-Range-r13  OPTIONAL,
}                                OPTIONAL,
...,
[[ measResultBestNeighCell-v1360 SEQUENCE {
    rsrpResultNCell-v1360         RSRP-Range-v1360
}                                OPTIONAL
]]
]
}

MeasResultCSI-RS-List-r12 ::= SEQUENCE (SIZE (1..maxCellReport)) OF MeasResultCSI-RS-r12

MeasResultCSI-RS-r12 ::= SEQUENCE {
    measCSI-RS-Id-r12            MeasCSI-RS-Id-r12,
    csi-RSRP-Result-r12          CSI-RSRP-Range-r12,
    ...
}

MeasResultListUTRA ::= SEQUENCE (SIZE (1..maxCellReport)) OF MeasResultUTRA

MeasResultUTRA ::= SEQUENCE {
    physCellId                  CHOICE {
        fdd                     PhysCellIdUTRA-FDD,
        tdd                     PhysCellIdUTRA-TDD
    },
    cgi-Info                    SEQUENCE {
        cellGlobalId            CellGlobalIdUTRA,
        locationAreaCode        BIT STRING (SIZE (16))  OPTIONAL,
        routingAreaCode         BIT STRING (SIZE (8))   OPTIONAL,
        plmn-IdentityList       PLMN-IdentityList2      OPTIONAL,
    }
    measResult                  SEQUENCE {
        utra-RSCP                INTEGER (-5..91)        OPTIONAL,
        utra-EcN0                INTEGER (0..49)          OPTIONAL,
        ...,
        [[ additionalSI-Info-r9   AdditionalSI-Info-r9    OPTIONAL
        ]],
        [[ primaryPLMN-Suitable-r12 ENUMERATED {true}    OPTIONAL
        ]]
    }
}

MeasResultListGERAN ::= SEQUENCE (SIZE (1..maxCellReport)) OF MeasResultGERAN

MeasResultGERAN ::= SEQUENCE {
    carrierFreq                CarrierFreqGERAN,
    physCellId                 PhysCellIdGERAN,
    cgi-Info                   SEQUENCE {
        cellGlobalId            CellGlobalIdGERAN,
        routingAreaCode         BIT STRING (SIZE (8))  OPTIONAL,
    }
    measResult                  SEQUENCE {
        rssi                    INTEGER (0..63),
        ...
    }
}

MeasResultsCDMA2000 ::= SEQUENCE {
    preRegistrationStatusHRPD   BOOLEAN,
    measResultListCDMA2000     MeasResultListCDMA2000
}

MeasResultListCDMA2000 ::= SEQUENCE (SIZE (1..maxCellReport)) OF MeasResultCDMA2000

MeasResultCDMA2000 ::= SEQUENCE {
    physCellId                 PhysCellIdCDMA2000,
    cgi-Info                   CellGlobalIdCDMA2000  OPTIONAL,
    measResult                  SEQUENCE {
        pilotPnPhase            INTEGER (0..32767)      OPTIONAL,
        pilotStrength            INTEGER (0..63),

```

```

    ...
}
}

5 MeasResultListWLAN-r13 ::= SEQUENCE (SIZE (1..maxCellReport)) OF MeasResultWLAN-r13

MeasResultListWLAN-r14 ::= SEQUENCE (SIZE (1..maxWLAN-Id-Report-r14)) OF MeasResultWLAN-r13

10 MeasResultWLAN-r13 ::= SEQUENCE {
    wlan-Identifiers-r13          WLAN-Identifiers-r12,
    carrierInfoWLAN-r13          WLAN-CarrierInfo-r13 OPTIONAL,
    bandWLAN-r13                 WLAN-BandIndicator-r13 OPTIONAL,
    rssiWLAN-r13                 WLAN-RSSI-Range-r13,
    availableAdmissionCapacityWLAN-r13 INTEGER (0..31250) OPTIONAL,
15 backhaulDL-BandwidthWLAN-r13 WLAN-backhaulRate-r12 OPTIONAL,
    backhaulUL-BandwidthWLAN-r13 WLAN-backhaulRate-r12 OPTIONAL,
    channelUtilizationWLAN-r13   INTEGER (0..255) OPTIONAL,
    stationCountWLAN-r13         INTEGER (0..65535) OPTIONAL,
20 connectedWLAN-r13            ENUMERATED {true} OPTIONAL,
    ...
}

MeasResultListCBR-r14 ::= SEQUENCE (SIZE (1..maxCBR-Report-r14)) OF MeasResultCBR-r14

25 MeasResultCBR-r14 ::= SEQUENCE {
    poolIdentity-r14             SL-V2X-TxPoolReportIdentity-r14,
    cbr-PSSCH-r14               SL-CBR-r14,
    cbr-PSCCH-r14               SL-CBR-r14 OPTIONAL
30 }

MeasResultForECID-r9 ::= SEQUENCE {
    ue-RxTxTimeDiffResult-r9    INTEGER (0..4095),
    currentSFN-r9               BIT STRING (SIZE (10))
35 }

PLMN-IdentityList2 ::= SEQUENCE (SIZE (1..5)) OF PLMN-Identity

AdditionalSI-Info-r9 ::= SEQUENCE {
    csg-MemberStatus-r9         ENUMERATED {member} OPTIONAL,
40 csg-Identity-r9              CSG-Identity OPTIONAL
}

MeasResultForRSSI-r13 ::= SEQUENCE {
    rssi-Result-r13             RSSI-Range-r13,
    channelOccupancy-r13        INTEGER (0..100),
45 ...
}

UL-PDCP-DelayResultList-r13 ::= SEQUENCE (SIZE (1..maxQCI-r13)) OF UL-PDCP-DelayResult-r13

50 UL-PDCP-DelayResult-r13 ::= SEQUENCE {
    qci-Id-r13                  ENUMERATED {qci1, qci2, qci3, qci4, spare4, spare3, spare2,
    excessDelay-r13              spare1},
    excessDelay-r13              INTEGER (0..31),
55 ...
}

-- ASN1STOP

```

| <b>MeasResults field descriptions</b> |                                                                                                                                                                                                                                                                                                                                                                                |
|---------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>availableAdmissionCapacityWLAN</b> | Indicates the available admission capacity of WLAN as defined in IEEE 802.11-2012 [67].                                                                                                                                                                                                                                                                                        |
| <b>backhaulDL-BandwidthWLAN</b>       | Indicates the backhaul available downlink bandwidth of WLAN, equal to Downlink Speed times Downlink Load defined in Wi-Fi Alliance Hotspot 2.0 [76].                                                                                                                                                                                                                           |
| <b>backhaulUL-BandwidthWLAN</b>       | Indicates the backhaul available uplink bandwidth of WLAN, equal to Uplink Speed times Uplink Load defined in Wi-Fi Alliance Hotspot 2.0 [76].                                                                                                                                                                                                                                 |
| <b>bandWLAN</b>                       | Indicates the WLAN band.                                                                                                                                                                                                                                                                                                                                                       |
| <b>carrierInfoWLAN</b>                | Indicates the WLAN channel information.                                                                                                                                                                                                                                                                                                                                        |
| <b>cbr-PSSCH</b>                      | Indicates the CBR measurement results on the PSSCH of the pool indicated by <i>poolIdentity</i> . If <i>adjacencyPSCCH-PSSCH</i> is set to <i>TRUE</i> for the pool indicated by <i>poolIdentity</i> , this field indicates the CBR measurement of both the PSSCH and PSCCH resources which are measured together.                                                             |
| <b>cbr-PSCCH</b>                      | Indicates the CBR measurement results on the PSCCH of the pool indicated by <i>poolIdentity</i> . This field is only included if <i>adjacencyPSCCH-PSSCH</i> is set to <i>FALSE</i> for the pool indicated by <i>poolIdentity</i> .                                                                                                                                            |
| <b>channelOccupancy</b>               | Indicates the percentage of samples when the RSSI was above the configured <i>channelOccupancyThreshold</i> for the associated <i>reportConfig</i> .                                                                                                                                                                                                                           |
| <b>channelUtilizationWLAN</b>         | Indicates WLAN channel utilization as defined in IEEE 802.11-2012 [67].                                                                                                                                                                                                                                                                                                        |
| <b>connectedWLAN</b>                  | Indicates whether the UE is connected to the WLAN for which the measurement results are applicable.                                                                                                                                                                                                                                                                            |
| <b>csg-MemberStatus</b>               | Indicates whether or not the UE is a member of the CSG of the neighbour cell.                                                                                                                                                                                                                                                                                                  |
| <b>currentSFN</b>                     | Indicates the current system frame number when receiving the UE Rx-Tx time difference measurement results from lower layer.                                                                                                                                                                                                                                                    |
| <b>excessDelay</b>                    | Indicates excess queueing delay ratio in UL, according to excess delay ratio measurement report mapping table, as defined in TS 36.314 [71, Table 4.2.1.1.1-1]                                                                                                                                                                                                                 |
| <b>locationAreaCode</b>               | A fixed length code identifying the location area within a PLMN, as defined in TS 23.003 [27].                                                                                                                                                                                                                                                                                 |
| <b>measId</b>                         | Identifies the measurement identity for which the reporting is being performed. If the <i>measId-v1250</i> is included, the <i>measId</i> (i.e. without a suffix) is ignored by eNB.                                                                                                                                                                                           |
| <b>measResult</b>                     | Measured result of an E-UTRA cell;<br>Measured result of a UTRA cell;<br>Measured result of a GERAN cell or frequency;<br>Measured result of a CDMA2000 cell;<br>Measured result of a WLAN;<br>Measured result of UE Rx-Tx time difference;<br><br>Measured result of UE SFN, radio frame and subframe timing difference; or<br>Measured result of RSSI and channel occupancy. |
| <b>measResultCSI-RS-List</b>          | Measured results of the CSI-RS resources in discovery signals measurement.                                                                                                                                                                                                                                                                                                     |
| <b>measResultListCDMA2000</b>         | List of measured results for the maximum number of reported best cells for a CDMA2000 measurement identity.                                                                                                                                                                                                                                                                    |
| <b>measResultListEUTRA</b>            | List of measured results for the maximum number of reported best cells for an E-UTRA measurement identity. For BL UEs or UEs in CE, when operating in CE Mode B, <i>measResult-v1360</i> is reported if the measured RSRP is less than -140 dBm.                                                                                                                               |
| <b>measResultListGERAN</b>            | List of measured results for the maximum number of reported best cells or frequencies for a GERAN measurement identity.                                                                                                                                                                                                                                                        |
| <b>measResultListUTRA</b>             | List of measured results for the maximum number of reported best cells for a UTRA measurement identity.                                                                                                                                                                                                                                                                        |

| <b>MeasResults</b> field descriptions |                                                                                                                                                                                                                                                                                                            |
|---------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>measResultListWLAN</b>             | List of measured results for the maximum number of reported best WLAN outside the WLAN mobility set and connected WLAN, if any, for a WLAN measurement identity.                                                                                                                                           |
| <b>measResultPCell</b>                | Measured result of the PCell. For BL UEs or UEs in CE, when operating in CE Mode B, <i>measResultPCell-v1360</i> is reported if the measured RSRP is less than -140 dBm.                                                                                                                                   |
| <b>measResultsCDMA2000</b>            | Contains the CDMA2000 HRPD pre-registration status and the list of CDMA2000 measurements.                                                                                                                                                                                                                  |
| <b>MeasResultServFreqList</b>         | Measured results of the serving frequencies: the measurement result of each SCell, if any, and of the best neighbouring cell on each serving frequency. For BL UEs or UEs in CE, when operating in CE Mode B, <i>measResultBestNeighCell-v1360</i> is reported if the measured RSRP is less than -140 dBm. |
| <b>pilotPnPhase</b>                   | Indicates the arrival time of a CDMA2000 pilot, measured relative to the UE's time reference in units of PN chips, see C.S0005 [25]. This information is used in either SRVCC handover or enhanced 1xRTT CS fallback procedure to CDMA2000 1xRTT.                                                          |
| <b>pilotStrength</b>                  | CDMA2000 Pilot Strength, the ratio of pilot power to total power in the signal bandwidth of a CDMA2000 Forward Channel. See C.S0005 [25] for CDMA2000 1xRTT and C.S0024 [26] for CDMA2000 HRPD.                                                                                                            |
| <b>poolIdentity</b>                   | The identity of the transmission resource pool which is corresponding to the <i>poolReportId</i> configured in a resource pool for V2X sidelink communication.                                                                                                                                             |
| <b>plmn-IdentityList</b>              | The list of PLMN Identity read from broadcast information when the multiple PLMN Identities are broadcast.                                                                                                                                                                                                 |
| <b>preRegistrationStatusHRPD</b>      | Set to TRUE if the UE is currently pre-registered with CDMA2000 HRPD. Otherwise set to FALSE. This can be ignored by the eNB for CDMA2000 1xRTT.                                                                                                                                                           |

| MeasResults field descriptions |                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|--------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>qci-Id</b>                  | Indicates QCI value for which <i>excessDelay</i> is provided, according to TS 36.314 [71].                                                                                                                                                                                                                                                                                                                                              |
| <b>routingAreaCode</b>         | The RAC identity read from broadcast information, as defined in TS 23.003 [27].                                                                                                                                                                                                                                                                                                                                                         |
| <b>rsrpResult</b>              | Measured RSRP result of an E-UTRA cell.<br>The <i>rsrpResult</i> is only reported if configured by the eNB.                                                                                                                                                                                                                                                                                                                             |
| <b>rsrqResult</b>              | Measured RSRQ result of an E-UTRA cell.<br>The <i>rsrqResult</i> is only reported if configured by the eNB.                                                                                                                                                                                                                                                                                                                             |
| <b>rssi</b>                    | GERAN Carrier RSSI. RXLEV is mapped to a value between 0 and 63, TS 45.008 [28]. When mapping the RXLEV value to the RSSI bit string, the first/leftmost bit of the bit string contains the most significant bit.                                                                                                                                                                                                                       |
| <b>rssi-Result</b>             | Measured RSSI result in dBm.                                                                                                                                                                                                                                                                                                                                                                                                            |
| <b>rs-sinr-Result</b>          | Measured RS-SINR result of an E-UTRA or NR cell. The <i>rs-sinr-Result</i> is only reported if configured by the eNB.                                                                                                                                                                                                                                                                                                                   |
| <b>rssiWLAN</b>                | Measured WLAN RSSI result in dBm.                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>stationCountWLAN</b>        | Indicates the total number stations currently associated with this WLAN as defined in IEEE 802.11-2012 [67].                                                                                                                                                                                                                                                                                                                            |
| <b>ue-RxTxTimeDiffResult</b>   | UE Rx-Tx time difference measurement result of the PCell, provided by lower layers. If <i>ue-RxTxTimeDiffPeriodicalTDD-r13</i> is set to <i>TRUE</i> , the measurement mapping is according to EUTRAN TDD UE Rx-Tx time difference report mapping in TS 36.133 [16] and measurement result includes $N_{TAoffset}$ , else the measurement mapping is according to EUTRAN FDD UE Rx-Tx time difference report mapping in TS 36.133 [16]. |
| <b>utra-EcN0</b>               | According to CPICH_Ec/No in TS 25.133 [29] for FDD. Fourteen spare values. The field is not present for TDD.                                                                                                                                                                                                                                                                                                                            |
| <b>utra-RSCP</b>               | According to CPICH_RSCP in TS 25.133 [29] for FDD and P-CCPCH_RSCP in TS 25.123 [30] for TDD. Thirty-one spare values.                                                                                                                                                                                                                                                                                                                  |
| <b>wlan-Identifiers</b>        | Indicates the WLAN parameters used for identification of the WLAN for which the measurement results are applicable.                                                                                                                                                                                                                                                                                                                     |

MeasResultSSTD

**[0058]** The IE *MeasResultSSTD* consists of SFN, radio frame and subframe boundary difference between the PCell and the PSCell as specified in TS 36.214 [48] and TS 36.133 [16].

MeasResultSSTD information element

```
10  -- ASN1START
MeasResultSSTD-r13 ::= SEQUENCE {
    sfn-OffsetResult-r13          INTEGER (0..1023),
    frameBoundaryOffsetResult-r13 INTEGER (-5..4),
    subframeBoundaryOffsetResult-r13 INTEGER (0..127)
}
15  -- ASN1STOP
```

| <i>MeasResultSSTD</i> field descriptions |                                                                                                                                                   |
|------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>sfn-OffsetResult</i>                  | Indicates the SFN difference between the PCell and the PSCell as an integer value according to TS 36.214 [48].                                    |
| <i>frameBoundaryOffsetResult</i>         | Indicates the frame boundary difference between the PCell and the PSCell as an integer value according to TS 36.214 [48].                         |
| <i>subframeBoundaryOffsetResult</i>      | Indicates the subframe boundary difference between the PCell and the PSCell as an integer value according to the mapping table in TS 36.133 [16]. |

*MeasResultSFTD*

**[0059]** The IE *MeasResultSFTD* consists of SFN and radio frame boundary difference between the PCell and an NR PSCell or a set of cells as specified in TS 36.214 [48] and TS 36.133 [16].

*MeasResultSFTD* information element

```
-- ASN1START
MeasResultSFTD-r15 ::= SEQUENCE (SIZE(1.. maxCellSFTDMeas)) OF MeasurementResultSFTD-r15
MeasurementResultSFTD-r15 ::= SEQUENCE {
    sfn-OffsetResult-r15      INTEGER (0..1023),
    frameBoundaryOffsetResult-r13  INTEGER (-30720..30719)
}
-- ASN1STOP
```

| <u><i>MeasResultSSTD</i> field descriptions</u> |                                                                                                                                                      |
|-------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------|
| <u><i>sfn-OffsetResult</i></u>                  | <u>Indicates the SFN difference between the PCell and the PSCell as an integer value according to TS 36.214 [48].</u>                                |
| <u><i>frameBoundaryOffsetResult</i></u>         | <u>Indicates the frame boundary difference between the PCell and the NR PSCell or neighbor cell as an integer value according to TS 36.214 [48].</u> |

<omitted text>

– *ReportConfigInterRAT*

**[0060]** The IE *ReportConfigInterRAT* specifies criteria for triggering of an inter-RAT measurement reporting event. The inter-RAT measurement reporting events for NR, UTRAN, GERAN and CDMA2000 are labelled BN with *N* equal to 1, 2 and so on. The inter-RAT measurement reporting events for WLAN are labelled WN with *N* equal to 1, 2 and so on.

Event B1: Neighbour becomes better than absolute threshold;

Event B2: PCell becomes worse than absolute threshold1 AND Neighbour becomes better than another absolute threshold2.

Event W1: WLAN becomes better than a threshold;

5 Event W2: All WLAN inside WLAN mobility set become worse than a threshold1 and a WLAN outside WLAN mobility set becomes better than a threshold2;

Event W3: All WLAN inside WLAN mobility set become worse than a threshold.

**[0061]** The b1 and b2 event thresholds for CDMA2000 are the CDMA2000 pilot detection thresholds are expressed as an unsigned binary number equal to  $[-2 \times 10 \log_{10} E_c/I_0]$  in units of 0.5dB, see C.S0005 [25] for details.

### **ReportConfigInterRAT information element**

```

-- ASN1START
ReportConfigInterRAT ::=
15   triggerType
      event
      eventId
      eventB1
          b1-Threshold
          b1-ThresholdUTRA
          b1-ThresholdGERAN
          b1-ThresholdCDMA2000
20      },
      eventB2
          b2-Threshold1
          b2-Threshold2
          b2-Threshold2UTRA
          b2-Threshold2GERAN
          b2-Threshold2CDMA2000
25      },
      ...,
      eventW1-r13
          w1-Threshold-r13
30      },
      eventW2-r13
          w2-Threshold1-r13
          w2-Threshold2-r13
40      },
      eventW3-r13
          w3-Threshold-r13
45      },
      eventB1-NR
          b1-ThresholdNR-r15
          reportOnLeave-r15
          b2-Threshold1-r15
          b2-Threshold2NR-r15
          reportOnLeave-r15
50      },
      hysteresis
      timeToTrigger
55      },
      periodical
      purpose
60      },
      SEQUENCE {
          CHOICE {
              SEQUENCE {
                  CHOICE {
                      SEQUENCE {
                          CHOICE {
                              ThresholdUTRA,
                              ThresholdGERAN,
                              ThresholdCDMA2000
                          }
                      },
                      SEQUENCE {
                          ThresholdEUTRA,
                          CHOICE {
                              ThresholdUTRA,
                              ThresholdGERAN,
                              ThresholdCDMA2000
                          }
                      }
                  }
              },
              SEQUENCE {
                  WLAN-RSSI-Range-r13
              },
              SEQUENCE {
                  WLAN-RSSI-Range-r13,
                  WLAN-RSSI-Range-r13
              },
              SEQUENCE {
                  WLAN-RSSI-Range-r13
              },
              SEQUENCE {
                  ThresholdNR-r15 OPTIONAL, -- Need ON
                  BOOLEAN OPTIONAL -- Need ON
              },
              SEQUENCE {
                  ThresholdEUTRA OPTIONAL, -- Need ON
                  ThresholdNR-r15 OPTIONAL, -- Need ON
                  BOOLEAN OPTIONAL -- Need ON
              }
          }
      },
      Hysteresis,
      TimeToTrigger
      SEQUENCE {
          ENUMERATED {
              reportStrongestCells,
              reportStrongestCellsForSON,
              reportCGI
          }
      }
  }
-- ASN1END

```

```

    },
    maxReportCells          INTEGER (1..maxCellReport),
    reportInterval          ReportInterval,
    reportAmount            ENUMERATED {r1, r2, r4, r8, r16, r32, r64, infinity},
    ...,
    [[ si-RequestForHO-r9    ENUMERATED {setup}          OPTIONAL    -- Cond reportCGI
    ]],
    [[ reportQuantityUTRA-FDD-r10    ENUMERATED {both}          OPTIONAL    -- Need OR
    ]],
    [[ includeLocationInfo-r11    BOOLEAN                OPTIONAL    -- Need ON
    ]],
    [[ b2-Threshold1-v1250        CHOICE {
        release                NULL,
        setup                  RSRQ-Range-v1250
    }                                OPTIONAL    -- Need ON
    ]],
    [[ reportQuantityWLAN-r13      ReportQuantityWLAN-r13    OPTIONAL    -- Need ON
    ]],
    [[ reportAnyWLAN-r14          BOOLEAN                OPTIONAL    -- Need ON
    ]],
    [[ reportQuantityCellNR-r15    ReportQuantityNR-r15      OPTIONAL,    -- Need ON
    maxRS-IndexReport-r15        INTEGER (1..maxRS-Index-r15)  OPTIONAL,    -- Need ON,
    reportQuantityRS-IndexNR-r15  ReportQuantityNR-r15      OPTIONAL,    -- Need ON
    reportRS-IndexResultsNR       BOOLEAN                OPTIONAL,    -- Need ON
    measResultSRB-r15            ENUMERATED {pCell, neighborCells} OPTIONAL    --
    Need ON
    ]],
    ]],
    )

ThresholdUTRA ::=
    utra-RSCP          CHOICE{
    utra-EcN0           INTEGER (-5..91),
                     INTEGER (0..49)
    }

ThresholdGERAN ::=
    INTEGER (0..63)

ThresholdCDMA2000 ::=
    INTEGER (0..63)

ReportQuantityNR-r15 ::=
    ss-rsrp            BOOLEAN,
    ss-rsrq            BOOLEAN,
    ss-sinr            BOOLEAN
    )

ReportQuantityWLAN-r13 ::=
    SEQUENCE {
    bandRequestWLAN-r13    ENUMERATED {true}    OPTIONAL,    -- Need OR
    carrierInfoRequestWLAN-r13    ENUMERATED {true}    OPTIONAL,    -- Need OR
    availableAdmissionCapacityRequestWLAN-r13    ENUMERATED {true}    OPTIONAL,    -- Need OR
    backhaulDL-BandwidthRequestWLAN-r13    ENUMERATED {true}    OPTIONAL,    -- Need OR
    backhaulUL-BandwidthRequestWLAN-r13    ENUMERATED {true}    OPTIONAL,    -- Need OR
    channelUtilizationRequestWLAN-r13    ENUMERATED {true}    OPTIONAL,    -- Need OR
    stationCountRequestWLAN-r13    ENUMERATED {true}    OPTIONAL,    -- Need OR
    ...
    }

-- ASN1STOP

```

| <b>ReportConfigInterRAT field descriptions</b> |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>availableAdmissionCapacityRequestWLAN</b>   | The value true indicates that the UE shall include, if available, WLAN Available Admission Capacity in measurement reports.                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>backhaulDL-BandwidthRequestWLAN</b>         | The value true indicates that the UE shall include, if available, WLAN Backhaul Downlink Bandwidth in measurement reports.                                                                                                                                                                                                                                                                                                                                                                                               |
| <b>backhaulUL-BandwidthRequestWLAN</b>         | The value true indicates that the UE shall include, if available, WLAN Backhaul Uplink Bandwidth in measurement reports.                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>bandRequestWLAN</b>                         | The value true indicates that the UE shall include WLAN band in measurement reports.                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>bN-ThresholdM</b>                           | Threshold to be used in inter RAT measurement report triggering condition for event number bN. If multiple thresholds are defined for event number bN, the thresholds are differentiated by M.                                                                                                                                                                                                                                                                                                                           |
| <b>carrierInfoRequestWLAN</b>                  | The value true indicates that the UE shall include, if available, WLAN Carrier Information in measurement reports.                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>channelUtilizationRequest-WLAN</b>          | The value true indicates that the UE shall include, if available, WLAN Channel Utilization in measurement reports.                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>eventId</b>                                 | Choice of inter-RAT event triggered reporting criteria.                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>maxReportCells</b>                          | Max number of cells, excluding the serving cell, to include in the measurement report. In case <i>purpose</i> is set to <i>reportStrongestCellsForSON</i> only value 1 applies. For inter-RAT WLAN, it is the maximum number of WLANs to include in the measurement report.                                                                                                                                                                                                                                              |
| <b>Purpose</b>                                 | <i>reportStrongestCellsForSON</i> applies only in case <i>reportConfig</i> is linked to a <i>measObject</i> set to <i>measObjectUTRA</i> or <i>measObjectCDMA2000</i> .                                                                                                                                                                                                                                                                                                                                                  |
| <b>reportAmount</b>                            | Number of measurement reports applicable for <i>triggerType event</i> as well as for <i>triggerType periodical</i> . In case <i>purpose</i> is set to <i>reportCGI</i> or <i>reportStrongestCellsForSON</i> only value 1 applies. In case <i>reportSSTD-Meas</i> is configured, only value 1 applies.                                                                                                                                                                                                                    |
| <b>reportAnyWLAN</b>                           | Indicates UE to report any WLAN AP meeting the triggering requirements, even if it is not included in the corresponding <i>MeasObjectWLAN</i> .                                                                                                                                                                                                                                                                                                                                                                          |
| <b>reportOnLeave</b>                           | Indicates whether or not the UE shall initiate the measurement reporting procedure when the leaving condition is met for a cell in <i>cellsTriggeredList</i> , as specified in 5.5.4.1.                                                                                                                                                                                                                                                                                                                                  |
| <b>reportQuantityUTRA-FDD</b>                  | The quantities to be included in the UTRA measurement report. The value <i>both</i> means that both the cpich RSCP and cpich EcNO quantities are to be included in the measurement report.                                                                                                                                                                                                                                                                                                                               |
| <b>reportSFTD-Meas</b>                         | <u>If this field is set to <i>pSCell</i>, the UE shall measure SSTD between the PCell and the PSCell as specified in TS 36.214 [48]. . If the field is set to <i>neighborCells</i>, the UE shall measure SFTD between the PCell and the NR cells, as specified in TS 36.214 [48]. E-UTRAN only includes this field when setting <i>triggerType</i> to <i>periodical</i> and <i>purpose</i> to <i>reportStrongestCells</i>. If included, the UE shall ignore the <i>triggerType</i> and <i>maxReportCells</i> fields.</u> |
| <b>si-RequestForHO</b>                         | The field applies to the <i>reportCGI</i> functionality, and when the field is included, the UE is allowed to use autonomous gaps in acquiring system information from the neighbour cell, applies a different value for T321, and includes different fields in the measurement report.                                                                                                                                                                                                                                  |

| ReportConfigInterRAT field descriptions      |                                                                                                                                                                                                                                                                                                                                                                       |
|----------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>availableAdmissionCapacityRequestWLAN</b> | The value true indicates that the UE shall include, if available, WLAN Available Admission Capacity in measurement reports.                                                                                                                                                                                                                                           |
| <b>backhaulDL-BandwidthRequestWLAN</b>       | The value true indicates that the UE shall include, if available, WLAN Backhaul Downlink Bandwidth in measurement reports.                                                                                                                                                                                                                                            |
| <b>backhaulUL-BandwidthRequestWLAN</b>       | The value true indicates that the UE shall include, if available, WLAN Backhaul Uplink Bandwidth in measurement reports.                                                                                                                                                                                                                                              |
| <b>bandRequestWLAN</b>                       | The value true indicates that the UE shall include WLAN band in measurement reports.                                                                                                                                                                                                                                                                                  |
| <b>stationCountRequestWLAN</b>               | The value true indicates that the UE shall include, if available, WLAN Station Count in measurement reports.                                                                                                                                                                                                                                                          |
| <b>b1-ThresholdGERAN, b2-Threshold2GERAN</b> | The actual value is field value – 110 dBm.                                                                                                                                                                                                                                                                                                                            |
| <b>b1-ThresholdUTRA, b2-Threshold2UTRA</b>   | <i>utra-RSCP</i> corresponds to CPICH_RSCP in TS 25.133 [29] for FDD and P-CCPCH_RSCP in TS 25.123 [30] for TDD.<br><i>utra-EcN0</i> corresponds to CPICH_Ec/No in TS 25.133 [29] for FDD, and is not applicable for TDD.<br>For <i>utra-RSCP</i> : The actual value is field value – 115 dBm.<br>For <i>utra-EcN0</i> : The actual value is (field value – 49)/2 dB. |
| <b>timeToTrigger</b>                         | Time during which specific criteria for the event needs to be met in order to trigger a measurement report.                                                                                                                                                                                                                                                           |
| <b>triggerType</b>                           | E-UTRAN does not configure the value <i>periodical</i> in case <i>reportConfig</i> is linked to a <i>measObject</i> set to <i>measObjectWLAN</i> .                                                                                                                                                                                                                    |

| Conditional presence | Explanation                                                                                                                                                                                    |
|----------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>reportCGI</i>     | The field is optional, need OR, in case <i>purpose</i> is included and set to <i>reportCGI</i> ; otherwise the field is not present and the UE shall delete any existing value for this field. |

**[0062]** Although the subject matter described herein may be implemented in any appropriate type of system using any suitable components, the embodiments disclosed herein are described in relation to a wireless network, such as the example wireless network illustrated in Figure 3. For simplicity, the wireless network of Figure 3 only depicts network 306, network nodes 360 and 360b, and WDs 310, 310b, and 310c. In practice, a wireless network may further include any additional elements suitable to support communication between wireless devices or between a wireless device and another communication device, such as a landline telephone, a service provider, or any other network node or end device. Of the illustrated components, network node 360 and wireless device (WD) 310 are depicted with additional detail. The wireless network may provide communication and other types of services to one or more wireless devices to facilitate the wireless devices' access to and/or use of the services provided by, or via, the wireless network.

**[0063]** The wireless network may comprise and/or interface with any type of communication, telecommunication, data, cellular, and/or radio network or other similar type of system. In some embodiments, the wireless network may be configured to operate according to specific standards or other types of predefined rules or procedures. Thus, particular embodiments of the wireless network may implement communication standards, such as Global System for Mobile Communications (GSM), Universal Mobile Telecommunications System (UMTS), Long Term Evolution (LTE), and/or other suitable 2G, 3G, 4G, or 5G standards; wireless local area network (WLAN) standards, such as the IEEE 802.11 standards; and/or any other appropriate wireless communication standard, such as the Worldwide Interoperability for Microwave Access (WiMax), Bluetooth, Z-Wave and/or ZigBee standards. However, in some preferred embodiments, the wireless network is configured to operate according to the 3GPP 5G standard, which is referred to as NR, as discussed above.

**[0064]** Network 306 may comprise one or more backhaul networks, core networks, IP networks, public switched telephone networks (PSTNs), packet data networks, optical networks, wide-area networks (WANs), local area networks (LANs), wireless local area networks (WLANs), wired networks, wireless networks, metropolitan area networks, and other networks to enable communication between devices.

**[0065]** Network node 360 and WD 310 comprise various components described in more detail below. These components work together in order to provide network node and/or wireless device functionality, such as providing wireless connections in a wireless network. In different embodiments, the wireless network may comprise any number of wired or wireless networks, network nodes, base stations, controllers, wireless devices, relay stations, and/or any other components or systems that may facilitate or participate in the communication of data and/or signals whether via wired or wireless connections.

**[0066]** As used herein, network node refers to equipment capable, configured, arranged and/or operable to communicate directly or indirectly with a wireless device and/or with other network nodes or equipment in the wireless network to enable and/or provide wireless access to the wireless device and/or to perform other functions (e.g., administration) in the wireless network. Examples of network nodes include, but are not limited to, access points (APs) (e.g., radio access points), base stations (BSs) (e.g., radio base stations, Node Bs, evolved Node Bs (eNBs), and gNBs). Base stations may be

categorized based on the amount of coverage they provide (or, stated differently, their transmit power level) and may then also be referred to as femto base stations, pico base stations, micro base stations, or macro base stations. A base station may be a relay node or a relay donor node controlling a relay. A network node may also include one or more (or  
5 all) parts of a distributed radio base station such as centralized digital units and/or remote radio units (RRUs), sometimes referred to as Remote Radio Heads (RRHs). Such remote radio units may or may not be integrated with an antenna as an antenna integrated radio. Parts of a distributed radio base station may also be referred to as nodes in a distributed antenna system (DAS). Yet further examples of network nodes include multi-standard  
10 radio (MSR) equipment such as MSR BSs, network controllers such as radio network controllers (RNCs) or base station controllers (BSCs), base transceiver stations (BTSs), transmission points, transmission nodes, multi-cell/multicast coordination entities (MCEs), core network nodes (e.g., MSCs, MMEs), O&M nodes, OSS nodes, SON nodes, positioning nodes (e.g., E-SMLCs), and/or MDTs. As another example, a network node  
15 may be a virtual network node as described in more detail below. More generally, however, network nodes may represent any suitable device (or group of devices) capable, configured, arranged, and/or operable to enable and/or provide a wireless device with access to the wireless network or to provide some service to a wireless device that has accessed the wireless network.

**[0067]** In Figure 3, network node 360 includes processing circuitry 370, device readable medium 380, interface 390, auxiliary equipment 384, power source 386, power circuitry 387, and antenna 362. Although network node 360 illustrated in the example wireless network of Figure 3 may represent a device that includes the illustrated combination of hardware components, other embodiments may comprise network nodes with different  
25 combinations of components. It is to be understood that a network node comprises any suitable combination of hardware and/or software needed to perform the tasks, features, functions and methods disclosed herein. Moreover, while the components of network node 360 are depicted as single boxes located within a larger box, or nested within multiple boxes, in practice, a network node may comprise multiple different physical components  
30 that make up a single illustrated component (e.g., device readable medium 380 may comprise multiple separate hard drives as well as multiple RAM modules).

**[0068]** Similarly, network node 360 may be composed of multiple physically separate components (e.g., a NodeB component and a RNC component, or a BTS component and a BSC component, etc.), which may each have their own respective components. In certain scenarios in which network node 360 comprises multiple separate components (e.g., BTS and BSC components), one or more of the separate components may be shared among several network nodes. For example, a single RNC may control multiple NodeBs. In such a scenario, each unique NodeB and RNC pair, may in some instances be considered a single separate network node. In some embodiments, network node 360 may be configured to support multiple radio access technologies (RATs). In such embodiments, some components may be duplicated (e.g., separate device readable medium 380 for the different RATs) and some components may be reused (e.g., the same antenna 362 may be shared by the RATs). Network node 360 may also include multiple sets of the various illustrated components for different wireless technologies integrated into network node 360, such as, for example, GSM, WCDMA, LTE, NR, WiFi, or Bluetooth wireless technologies. These wireless technologies may be integrated into the same or different chip or set of chips and other components within network node 360.

**[0069]** Processing circuitry 370 is configured to perform any determining, calculating, or similar operations (e.g., certain obtaining operations) described herein as being provided by a network node. These operations performed by processing circuitry 370 may include processing information obtained by processing circuitry 370 by, for example, converting the obtained information into other information, comparing the obtained information or converted information to information stored in the network node, and/or performing one or more operations based on the obtained information or converted information, and as a result of said processing making a determination.

**[0070]** Processing circuitry 370 may comprise a combination of one or more of a microprocessor, controller, microcontroller, central processing unit, digital signal processor, application-specific integrated circuit, field programmable gate array, or any other suitable computing device, resource, or combination of hardware, software and/or encoded logic operable to provide, either alone or in conjunction with other network node 360 components, such as device readable medium 380, network node 360 functionality. For example, processing circuitry 370 may execute instructions stored in device readable medium 380 or in memory within processing circuitry 370. Such functionality may include

providing any of the various wireless features, functions, or benefits discussed herein. In some embodiments, processing circuitry 370 may include a system on a chip (SOC).

**[0071]** In some embodiments, processing circuitry 370 may include one or more of radio frequency (RF) transceiver circuitry 372 and baseband processing circuitry 374. In some  
5 embodiments, radio frequency (RF) transceiver circuitry 372 and baseband processing circuitry 374 may be on separate chips (or sets of chips), boards, or units, such as radio units and digital units. In alternative embodiments, part or all of RF transceiver circuitry 372 and baseband processing circuitry 374 may be on the same chip or set of chips, boards, or units

10 **[0072]** In certain embodiments, some or all of the functionality described herein as being provided by a network node, base station, eNB or other such network device may be performed by processing circuitry 370 executing instructions stored on device readable medium 380 or memory within processing circuitry 370. In alternative embodiments, some or all of the functionality may be provided by processing circuitry 370 without executing  
15 instructions stored on a separate or discrete device readable medium, such as in a hard-wired manner. In any of those embodiments, whether executing instructions stored on a device readable storage medium or not, processing circuitry 370 can be configured to perform the described functionality. The benefits provided by such functionality are not limited to processing circuitry 370 alone or to other components of network node 360, but  
20 are enjoyed by network node 360 as a whole, and/or by end users and the wireless network generally.

**[0073]** Device readable medium 380 may comprise any form of volatile or non-volatile computer readable memory including, without limitation, persistent storage, solid-state memory, remotely mounted memory, magnetic media, optical media, random access  
25 memory (RAM), read-only memory (ROM), mass storage media (for example, a hard disk), removable storage media (for example, a flash drive, a Compact Disk (CD) or a Digital Video Disk (DVD)), and/or any other volatile or non-volatile, non-transitory device readable and/or computer-executable memory devices that store information, data, and/or instructions that may be used by processing circuitry 370. Device readable medium 380  
30 may store any suitable instructions, data or information, including a computer program, software, an application including one or more of logic, rules, code, tables, etc. and/or other instructions capable of being executed by processing circuitry 370 and, utilized by network

node 360. Device readable medium 380 may be used to store any calculations made by processing circuitry 370 and/or any data received via interface 390. In some embodiments, processing circuitry 370 and device readable medium 380 may be considered to be integrated.

5 **[0074]** Interface 390 is used in the wired or wireless communication of signaling and/or data between network node 360, network 306, and/or WDs 310. As illustrated, interface 390 comprises port(s)/terminal(s) 394 to send and receive data, for example to and from network 306 over a wired connection. Interface 390 also includes radio front end circuitry 392 that may be coupled to, or in certain embodiments a part of, antenna 362. Radio front  
10 end circuitry 392 comprises filters 398 and amplifiers 396. Radio front end circuitry 392 may be connected to antenna 362 and processing circuitry 370. Radio front end circuitry may be configured to condition signals communicated between antenna 362 and processing circuitry 370. Radio front end circuitry 392 may receive digital data that is to be sent out to other network nodes or WDs via a wireless connection. Radio front end circuitry  
15 392 may convert the digital data into a radio signal having the appropriate channel and bandwidth parameters using a combination of filters 398 and/or amplifiers 396. The radio signal may then be transmitted via antenna 362. Similarly, when receiving data, antenna 362 may collect radio signals which are then converted into digital data by radio front end circuitry 392. The digital data may be passed to processing circuitry 370. In other  
20 embodiments, the interface may comprise different components and/or different combinations of components.

**[0075]** In certain alternative embodiments, network node 360 may not include separate radio front end circuitry 392, instead, processing circuitry 370 may comprise radio front end circuitry and may be connected to antenna 362 without separate radio front end circuitry  
25 392. Similarly, in some embodiments, all or some of RF transceiver circuitry 372 may be considered a part of interface 390. In still other embodiments, interface 390 may include one or more ports or terminals 394, radio front end circuitry 392, and RF transceiver circuitry 372, as part of a radio unit (not shown), and interface 390 may communicate with baseband processing circuitry 374, which is part of a digital unit (not shown).

30 **[0076]** Antenna 362 may include one or more antennas, or antenna arrays, configured to send and/or receive wireless signals. Antenna 362 may be coupled to radio front end circuitry 390 and may be any type of antenna capable of transmitting and receiving data

and/or signals wirelessly. In some embodiments, antenna 362 may comprise one or more omni-directional, sector or panel antennas operable to transmit/receive radio signals between, for example, 2 GHz and 66 GHz. An omni-directional antenna may be used to transmit/receive radio signals in any direction, a sector antenna may be used to  
 5 transmit/receive radio signals from devices within a particular area, and a panel antenna may be a line of sight antenna used to transmit/receive radio signals in a relatively straight line. In some instances, the use of more than one antenna may be referred to as MIMO. In certain embodiments, antenna 362 may be separate from network node 360 and may be connectable to network node 360 through an interface or port.

10 **[0077]** Antenna 362, interface 390, and/or processing circuitry 370 may be configured to perform any receiving operations and/or certain obtaining operations described herein as being performed by a network node. Any information, data and/or signals may be received from a wireless device, another network node and/or any other network equipment. Similarly, antenna 362, interface 390, and/or processing circuitry 370 may be configured to  
 15 perform any transmitting operations described herein as being performed by a network node. Any information, data and/or signals may be transmitted to a wireless device, another network node and/or any other network equipment.

**[0078]** Power circuitry 387 may comprise, or be coupled to, power management circuitry and is configured to supply the components of network node 360 with power for performing  
 20 the functionality described herein. Power circuitry 387 may receive power from power source 386. Power source 386 and/or power circuitry 387 may be configured to provide power to the various components of network node 360 in a form suitable for the respective components (e.g., at a voltage and current level needed for each respective component). Power source 386 may either be included in, or external to, power circuitry 387 and/or  
 25 network node 360. For example, network node 360 may be connectable to an external power source (e.g., an electricity outlet) via an input circuitry or interface such as an electrical cable, whereby the external power source supplies power to power circuitry 387. As a further example, power source 386 may comprise a source of power in the form of a battery or battery pack which is connected to, or integrated in, power circuitry 387. The  
 30 battery may provide backup power should the external power source fail. Other types of power sources, such as photovoltaic devices, may also be used.

**[0079]** Alternative embodiments of network node 360 may include additional components beyond those shown in Figure 3 that may be responsible for providing certain aspects of the network node's functionality, including any of the functionality described herein and/or any functionality necessary to support the subject matter described herein.

5 For example, network node 360 may include user interface equipment to allow input of information into network node 360 and to allow output of information from network node 360. This may allow a user to perform diagnostic, maintenance, repair, and other administrative functions for network node 360.

**[0080]** As used herein, wireless device (WD) refers to a device capable, configured, arranged and/or operable to communicate wirelessly with network nodes and/or other wireless devices. Unless otherwise noted, the term WD may be used interchangeably herein with user equipment (UE). Communicating wirelessly may involve transmitting and/or receiving wireless signals using electromagnetic waves, radio waves, infrared waves, and/or other types of signals suitable for conveying information through air. In some embodiments, a WD may be configured to transmit and/or receive information without direct human interaction. For instance, a WD may be designed to transmit information to a network on a predetermined schedule, when triggered by an internal or external event, or in response to requests from the network. Examples of a WD include, but are not limited to, a smart phone, a mobile phone, a cell phone, a voice over IP (VoIP) phone, a wireless local loop phone, a desktop computer, a personal digital assistant (PDA), a wireless cameras, a gaming console or device, a music storage device, a playback appliance, a wearable terminal device, a wireless endpoint, a mobile station, a tablet, a laptop, a laptop-embedded equipment (LEE), a laptop-mounted equipment (LME), a smart device, a wireless customer-premise equipment (CPE), a vehicle-mounted wireless terminal device, etc. A WD may support device-to-device (D2D) communication, for example by implementing a 3GPP standard for sidelink communication, and may in this case be referred to as a D2D communication device. As yet another specific example, in an Internet of Things (IoT) scenario, a WD may represent a machine or other device that performs monitoring and/or measurements, and transmits the results of such monitoring and/or measurements to another WD and/or a network node. The WD may in this case be a machine-to-machine (M2M) device, which may in a 3GPP context be referred to as a machine-type communication (MTC) device. As one particular example, the WD may be a

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UE implementing the 3GPP narrow band internet of things (NB-IoT) standard. Particular examples of such machines or devices are sensors, metering devices such as power meters, industrial machinery, or home or personal appliances (e.g. refrigerators, televisions, etc.) personal wearables (e.g., watches, fitness trackers, etc.). In other scenarios, a WD may represent a vehicle or other equipment that is capable of monitoring and/or reporting on its operational status or other functions associated with its operation. A WD as described above may represent the endpoint of a wireless connection, in which case the device may be referred to as a wireless terminal. Furthermore, a WD as described above may be mobile, in which case it may also be referred to as a mobile device or a mobile terminal.

**[0081]** As illustrated, wireless device 310 includes antenna 311, interface 314, processing circuitry 320, device readable medium 330, user interface equipment 332, auxiliary equipment 334, power source 336 and power circuitry 337. WD 310 may include multiple sets of one or more of the illustrated components for different wireless technologies supported by WD 310, such as, for example, GSM, WCDMA, LTE, NR, WiFi, WiMAX, or Bluetooth wireless technologies, just to mention a few. These wireless technologies may be integrated into the same or different chips or set of chips as other components within WD 310.

**[0082]** Antenna 311 may include one or more antennas or antenna arrays, configured to send and/or receive wireless signals, and is connected to interface 314. In certain alternative embodiments, antenna 311 may be separate from WD 310 and be connectable to WD 310 through an interface or port. Antenna 311, interface 314, and/or processing circuitry 320 may be configured to perform any receiving or transmitting operations described herein as being performed by a WD. Any information, data and/or signals may be received from a network node and/or another WD. In some embodiments, radio front end circuitry and/or antenna 311 may be considered an interface.

**[0083]** As illustrated, interface 314 comprises radio front end circuitry 312 and antenna 311. Radio front end circuitry 312 comprise one or more filters 318 and amplifiers 316. Radio front end circuitry 314 is connected to antenna 311 and processing circuitry 320, and is configured to condition signals communicated between antenna 311 and processing circuitry 320. Radio front end circuitry 312 may be coupled to or a part of antenna 311. In some embodiments, WD 310 may not include separate radio front end circuitry 312; rather,

processing circuitry 320 may comprise radio front end circuitry and may be connected to antenna 311. Similarly, in some embodiments, some or all of RF transceiver circuitry 322 may be considered a part of interface 314. Radio front end circuitry 312 may receive digital data that is to be sent out to other network nodes or WDs via a wireless connection. Radio front end circuitry 312 may convert the digital data into a radio signal having the appropriate channel and bandwidth parameters using a combination of filters 318 and/or amplifiers 316. The radio signal may then be transmitted via antenna 311. Similarly, when receiving data, antenna 311 may collect radio signals which are then converted into digital data by radio front end circuitry 312. The digital data may be passed to processing circuitry 320. In other embodiments, the interface may comprise different components and/or different combinations of components.

**[0084]** Processing circuitry 320 may comprise a combination of one or more of a microprocessor, controller, microcontroller, central processing unit, digital signal processor, application-specific integrated circuit, field programmable gate array, or any other suitable computing device, resource, or combination of hardware, software, and/or encoded logic operable to provide, either alone or in conjunction with other WD 310 components, such as device readable medium 330, WD 310 functionality. Such functionality may include providing any of the various wireless features or benefits discussed herein. For example, processing circuitry 320 may execute instructions stored in device readable medium 330 or in memory within processing circuitry 320 to provide the functionality disclosed herein.

**[0085]** As illustrated, processing circuitry 320 includes one or more of RF transceiver circuitry 322, baseband processing circuitry 324, and application processing circuitry 326. In other embodiments, the processing circuitry may comprise different components and/or different combinations of components. In certain embodiments processing circuitry 320 of WD 310 may comprise a SOC. In some embodiments, RF transceiver circuitry 322, baseband processing circuitry 324, and application processing circuitry 326 may be on separate chips or sets of chips. In alternative embodiments, part or all of baseband processing circuitry 324 and application processing circuitry 326 may be combined into one chip or set of chips, and RF transceiver circuitry 322 may be on a separate chip or set of chips. In still alternative embodiments, part or all of RF transceiver circuitry 322 and baseband processing circuitry 324 may be on the same chip or set of chips, and application processing circuitry 326 may be on a separate chip or set of chips. In yet other alternative

embodiments, part or all of RF transceiver circuitry 322, baseband processing circuitry 324, and application processing circuitry 326 may be combined in the same chip or set of chips. In some embodiments, RF transceiver circuitry 322 may be a part of interface 314. RF transceiver circuitry 322 may condition RF signals for processing circuitry 320.

5 **[0086]** In certain embodiments, some or all of the functionality described herein as being performed by a WD may be provided by processing circuitry 320 executing instructions stored on device readable medium 330, which in certain embodiments may be a computer-readable storage medium. In alternative embodiments, some or all of the functionality may be provided by processing circuitry 320 without executing instructions stored on a separate  
10 or discrete device readable storage medium, such as in a hard-wired manner. In any of those particular embodiments, whether executing instructions stored on a device readable storage medium or not, processing circuitry 320 can be configured to perform the described functionality. The benefits provided by such functionality are not limited to processing circuitry 320 alone or to other components of WD 310, but are enjoyed by WD 310 as a  
15 whole, and/or by end users and the wireless network generally.

**[0087]** Processing circuitry 320 may be configured to perform any determining, calculating, or similar operations (e.g., certain obtaining operations) described herein as being performed by a WD. These operations, as performed by processing circuitry 320, may include processing information obtained by processing circuitry 320 by, for example,  
20 converting the obtained information into other information, comparing the obtained information or converted information to information stored by WD 310, and/or performing one or more operations based on the obtained information or converted information, and as a result of said processing making a determination.

**[0088]** Device readable medium 330 may be operable to store a computer program,  
25 software, an application including one or more of logic, rules, code, tables, etc. and/or other instructions capable of being executed by processing circuitry 320. Device readable medium 330 may include computer memory (e.g., Random Access Memory (RAM) or Read Only Memory (ROM)), mass storage media (e.g., a hard disk), removable storage media (e.g., a Compact Disk (CD) or a Digital Video Disk (DVD)), and/or any other volatile or non-  
30 volatile, non-transitory device readable and/or computer executable memory devices that store information, data, and/or instructions that may be used by processing circuitry 320. In

some embodiments, processing circuitry 320 and device readable medium 330 may be considered to be integrated.

**[0089]** User interface equipment 332 may provide components that allow for a human user to interact with WD 310. Such interaction may be of many forms, such as visual, 5 audial, tactile, etc. User interface equipment 332 may be operable to produce output to the user and to allow the user to provide input to WD 310. The type of interaction may vary depending on the type of user interface equipment 332 installed in WD 310. For example, if WD 310 is a smart phone, the interaction may be via a touch screen; if WD 310 is a smart meter, the interaction may be through a screen that provides usage (e.g., the number of 10 gallons used) or a speaker that provides an audible alert (e.g., if smoke is detected). User interface equipment 332 may include input interfaces, devices and circuits, and output interfaces, devices and circuits. User interface equipment 332 is configured to allow input of information into WD 310, and is connected to processing circuitry 320 to allow processing circuitry 320 to process the input information. User interface equipment 332 15 may include, for example, a microphone, a proximity or other sensor, keys/buttons, a touch display, one or more cameras, a USB port, or other input circuitry. User interface equipment 332 is also configured to allow output of information from WD 310, and to allow processing circuitry 320 to output information from WD 310. User interface equipment 332 may include, for example, a speaker, a display, vibrating circuitry, a USB port, a headphone 20 interface, or other output circuitry. Using one or more input and output interfaces, devices, and circuits, of user interface equipment 332, WD 310 may communicate with end users and/or the wireless network, and allow them to benefit from the functionality described herein.

**[0090]** Auxiliary equipment 334 is operable to provide more specific functionality which 25 may not be generally performed by WDs. This may comprise specialized sensors for doing measurements for various purposes, interfaces for additional types of communication such as wired communications etc. The inclusion and type of components of auxiliary equipment 334 may vary depending on the embodiment and/or scenario.

**[0091]** Power source 336 may, in some embodiments, be in the form of a battery or 30 battery pack. Other types of power sources, such as an external power source (e.g., an electricity outlet), photovoltaic devices or power cells, may also be used. WD 310 may further comprise power circuitry 337 for delivering power from power source 336 to the

various parts of WD 310 which need power from power source 336 to carry out any functionality described or indicated herein. Power circuitry 337 may in certain embodiments comprise power management circuitry. Power circuitry 337 may additionally or alternatively be operable to receive power from an external power source; in which case WD 310 may be connectable to the external power source (such as an electricity outlet) via input circuitry or an interface such as an electrical power cable. Power circuitry 337 may also in certain embodiments be operable to deliver power from an external power source to power source 336. This may be, for example, for the charging of power source 336. Power circuitry 337 may perform any formatting, converting, or other modification to the power from power source 336 to make the power suitable for the respective components of WD 310 to which power is supplied.

**[0092]** Figure 4 illustrates one embodiment of a UE in accordance with various aspects described herein. As used herein, a user equipment or UE may not necessarily have a user in the sense of a human user who owns and/or operates the relevant device. Instead, a UE may represent a device that is intended for sale to, or operation by, a human user but which may not, or which may not initially, be associated with a specific human user. A UE may also comprise any UE identified by the 3<sup>rd</sup> Generation Partnership Project (3GPP), including a NB-IoT UE that is not intended for sale to, or operation by, a human user. UE 400, as illustrated in Figure 4, is one example of a WD configured for communication in accordance with one or more communication standards promulgated by the 3<sup>rd</sup> Generation Partnership Project (3GPP), such as 3GPP's GSM, UMTS, LTE, and/or 5G standards. As mentioned previously, the term WD and UE may be used interchangeable. Accordingly, although Figure 4 is a UE, the components discussed herein are equally applicable to a WD, and vice-versa.

**[0093]** In Figure 4, UE 400 includes processing circuitry 401 that is operatively coupled to input/output interface 405, radio frequency (RF) interface 409, network connection interface 411, memory 415 including random access memory (RAM) 417, read-only memory (ROM) 419, and storage medium 421 or the like, communication subsystem 431, power source 433, and/or any other component, or any combination thereof. Storage medium 421 includes operating system 423, application program 425, and data 427. In other embodiments, storage medium 421 may include other similar types of information. Certain UEs may utilize all of the components shown in Figure 4, or only a subset of the

components. The level of integration between the components may vary from one UE to another UE. Further, certain UEs may contain multiple instances of a component, such as multiple processors, memories, transceivers, transmitters, receivers, etc.

**[0094]** In Figure 4, processing circuitry 401 may be configured to process computer instructions and data. Processing circuitry 401 may be configured to implement any sequential state machine operative to execute machine instructions stored as machine-readable computer programs in the memory, such as one or more hardware-implemented state machines (e.g., in discrete logic, FPGA, ASIC, etc.); programmable logic together with appropriate firmware; one or more stored program, general-purpose processors, such as a microprocessor or Digital Signal Processor (DSP), together with appropriate software; or any combination of the above. For example, the processing circuitry 401 may include two central processing units (CPUs). Data may be information in a form suitable for use by a computer.

**[0095]** In the depicted embodiment, input/output interface 405 may be configured to provide a communication interface to an input device, output device, or input and output device. UE 400 may be configured to use an output device via input/output interface 405. An output device may use the same type of interface port as an input device. For example, a USB port may be used to provide input to and output from UE 400. The output device may be a speaker, a sound card, a video card, a display, a monitor, a printer, an actuator, an emitter, a smartcard, another output device, or any combination thereof. UE 400 may be configured to use an input device via input/output interface 405 to allow a user to capture information into UE 400. The input device may include a touch-sensitive or presence-sensitive display, a camera (e.g., a digital camera, a digital video camera, a web camera, etc.), a microphone, a sensor, a mouse, a trackball, a directional pad, a trackpad, a scroll wheel, a smartcard, and the like. The presence-sensitive display may include a capacitive or resistive touch sensor to sense input from a user. A sensor may be, for instance, an accelerometer, a gyroscope, a tilt sensor, a force sensor, a magnetometer, an optical sensor, a proximity sensor, another like sensor, or any combination thereof. For example, the input device may be an accelerometer, a magnetometer, a digital camera, a microphone, and an optical sensor.

**[0096]** In Figure 4, RF interface 409 may be configured to provide a communication interface to RF components such as a transmitter, a receiver, and an antenna. Network

connection interface 411 may be configured to provide a communication interface to network 443a. Network 443a may encompass wired and/or wireless networks such as a local-area network (LAN), a wide-area network (WAN), a computer network, a wireless network, a telecommunications network, another like network or any combination thereof.

5 For example, network 443a may comprise a Wi-Fi network. Network connection interface 411 may be configured to include a receiver and a transmitter interface used to communicate with one or more other devices over a communication network according to one or more communication protocols, such as Ethernet, TCP/IP, SONET, ATM, or the like. Network connection interface 411 may implement receiver and transmitter functionality  
10 appropriate to the communication network links (e.g., optical, electrical, and the like). The transmitter and receiver functions may share circuit components, software or firmware, or alternatively may be implemented separately.

**[0097]** RAM 417 may be configured to interface via bus 402 to processing circuitry 401 to provide storage or caching of data or computer instructions during the execution of  
15 software programs such as the operating system, application programs, and device drivers. ROM 419 may be configured to provide computer instructions or data to processing circuitry 401. For example, ROM 419 may be configured to store invariant low-level system code or data for basic system functions such as basic input and output (I/O), startup, or reception of keystrokes from a keyboard that are stored in a non-volatile memory. Storage  
20 medium 421 may be configured to include memory such as RAM, ROM, programmable read-only memory (PROM), erasable programmable read-only memory (EPROM), electrically erasable programmable read-only memory (EEPROM), magnetic disks, optical disks, floppy disks, hard disks, removable cartridges, or flash drives. In one example, storage medium 421 may be configured to include operating system 423, application  
25 program 425 such as a web browser application, a widget or gadget engine or another application, and data file 427. Storage medium 421 may store, for use by UE 400, any of a variety of various operating systems or combinations of operating systems.

**[0098]** Storage medium 421 may be configured to include a number of physical drive units, such as redundant array of independent disks (RAID), floppy disk drive, flash  
30 memory, USB flash drive, external hard disk drive, thumb drive, pen drive, key drive, high-density digital versatile disc (HD-DVD) optical disc drive, internal hard disk drive, Blu-Ray optical disc drive, holographic digital data storage (HDDS) optical disc drive, external mini-

dual in-line memory module (DIMM), synchronous dynamic random access memory (SDRAM), external micro-DIMM SDRAM, smartcard memory such as a subscriber identity module or a removable user identity (SIM/RUIM) module, other memory, or any combination thereof. Storage medium 421 may allow UE 400 to access computer-executable instructions, application programs or the like, stored on transitory or non-transitory memory media, to off-load data, or to upload data. An article of manufacture, such as one utilizing a communication system may be tangibly embodied in storage medium 421, which may comprise a device readable medium.

**[0099]** In Figure 4, processing circuitry 401 may be configured to communicate with network 443b using communication subsystem 431. Network 443a and network 443b may be the same network or networks or different network or networks. Communication subsystem 431 may be configured to include one or more transceivers used to communicate with network 443b. For example, communication subsystem 431 may be configured to include one or more transceivers used to communicate with one or more remote transceivers of another device capable of wireless communication such as another WD, UE, or base station of a radio access network (RAN) according to one or more communication protocols, such as IEEE 802.3, CDMA, WCDMA, GSM, LTE, UTRAN, WiMax, or the like. Each transceiver may include transmitter 433 and/or receiver 435 to implement transmitter or receiver functionality, respectively, appropriate to the RAN links (e.g., frequency allocations and the like). Further, transmitter 433 and receiver 435 of each transceiver may share circuit components, software or firmware, or alternatively may be implemented separately.

**[0100]** In the illustrated embodiment, the communication functions of communication subsystem 431 may include data communication, voice communication, multimedia communication, short-range communications such as Bluetooth, near-field communication, location-based communication such as the use of the global positioning system (GPS) to determine a location, another like communication function, or any combination thereof. For example, communication subsystem 431 may include cellular communication, Wi-Fi communication, Bluetooth communication, and GPS communication. Network 443b may encompass wired and/or wireless networks such as a local-area network (LAN), a wide-area network (WAN), a computer network, a wireless network, a telecommunications network, another like network or any combination thereof. For example, network 443b may

be a cellular network, a Wi-Fi network, and/or a near-field network. Power source 413 may be configured to provide alternating current (AC) or direct current (DC) power to components of UE 400.

**[0101]** The features, benefits and/or functions described herein may be implemented in one of the components of UE 400 or partitioned across multiple components of UE 400. Further, the features, benefits, and/or functions described herein may be implemented in any combination of hardware, software or firmware. In one example, communication subsystem 431 may be configured to include any of the components described herein. Further, processing circuitry 401 may be configured to communicate with any of such components over bus 402. In another example, any of such components may be represented by program instructions stored in memory that when executed by processing circuitry 401 perform the corresponding functions described herein. In another example, the functionality of any of such components may be partitioned between processing circuitry 401 and communication subsystem 431. In another example, the non-computationally intensive functions of any of such components may be implemented in software or firmware and the computationally intensive functions may be implemented in hardware.

**[0102]** Figure 5 is a schematic block diagram illustrating a virtualization environment 500 in which functions implemented by some embodiments may be virtualized. In the present context, virtualizing means creating virtual versions of apparatuses or devices which may include virtualizing hardware platforms, storage devices and networking resources. As used herein, virtualization can be applied to a node (e.g., a virtualized base station or a virtualized radio access node) or to a device (e.g., a UE, a wireless device or any other type of communication device) or components thereof and relates to an implementation in which at least a portion of the functionality is implemented as one or more virtual components (e.g., via one or more applications, components, functions, virtual machines or containers executing on one or more physical processing nodes in one or more networks).

**[0103]** In some embodiments, some or all of the functions described herein may be implemented as virtual components executed by one or more virtual machines implemented in one or more virtual environments 500 hosted by one or more of hardware nodes 530. Further, in embodiments in which the virtual node is not a radio access node or

does not require radio connectivity (e.g., a core network node), then the network node may be entirely virtualized.

**[0104]** The functions may be implemented by one or more applications 520 (which may alternatively be called software instances, virtual appliances, network functions, virtual nodes, virtual network functions, etc.) operative to implement some of the features, functions, and/or benefits of some of the embodiments disclosed herein. Applications 520 are run in virtualization environment 500 which provides hardware 530 comprising processing circuitry 560 and memory 590. Memory 590 contains instructions 595 executable by processing circuitry 560 whereby application 520 is operative to provide one or more of the features, benefits, and/or functions disclosed herein.

**[0105]** Virtualization environment 500, comprises general-purpose or special-purpose network hardware devices 530 comprising a set of one or more processors or processing circuitry 560, which may be commercial off-the-shelf (COTS) processors, dedicated Application Specific Integrated Circuits (ASICs), or any other type of processing circuitry including digital or analog hardware components or special purpose processors. Each hardware device may comprise memory 590-1 which may be non-persistent memory for temporarily storing instructions 595 or software executed by processing circuitry 560. Each hardware device may comprise one or more network interface controllers (NICs) 570, also known as network interface cards, which include physical network interface 580. Each hardware device may also include non-transitory, persistent, machine-readable storage media 590-2 having stored therein software 595 and/or instructions executable by processing circuitry 560. Software 595 may include any type of software including software for instantiating one or more virtualization layers 550 (also referred to as hypervisors), software to execute virtual machines 540 as well as software allowing it to execute functions, features and/or benefits described in relation with some embodiments described herein.

**[0106]** Virtual machines 540, comprise virtual processing, virtual memory, virtual networking or interface and virtual storage, and may be run by a corresponding virtualization layer 550 or hypervisor. Different embodiments of the instance of virtual appliance 520 may be implemented on one or more of virtual machines 540, and the implementations may be made in different ways.

**[0107]** During operation, processing circuitry 560 executes software 595 to instantiate the hypervisor or virtualization layer 550, which may sometimes be referred to as a virtual machine monitor (VMM). Virtualization layer 550 may present a virtual operating platform that appears like networking hardware to virtual machine 540.

5 **[0108]** As shown in Figure 5, hardware 530 may be a standalone network node with generic or specific components. Hardware 530 may comprise antenna 5225 and may implement some functions via virtualization. Alternatively, hardware 530 may be part of a larger cluster of hardware (e.g. such as in a data center or customer premise equipment (CPE)) where many hardware nodes work together and are managed via management and  
10 orchestration (MANO) 5100, which, among others, oversees lifecycle management of applications 520.

**[0109]** Virtualization of the hardware is in some contexts referred to as network function virtualization (NFV). NFV may be used to consolidate many network equipment types onto industry standard high volume server hardware, physical switches, and physical storage,  
15 which can be located in data centers, and customer premise equipment.

**[0110]** In the context of NFV, virtual machine 540 may be a software implementation of a physical machine that runs programs as if they were executing on a physical, non-virtualized machine. Each of virtual machines 540, and that part of hardware 530 that executes that virtual machine, be it hardware dedicated to that virtual machine and/or  
20 hardware shared by that virtual machine with others of the virtual machines 540, forms a separate virtual network elements (VNE).

**[0111]** Still in the context of NFV, Virtual Network Function (VNF) is responsible for handling specific network functions that run in one or more virtual machines 540 on top of hardware networking infrastructure 530 and corresponds to application 520 in Figure 5.

25 **[0112]** In some embodiments, one or more radio units 5200 that each include one or more transmitters 5220 and one or more receivers 5210 may be coupled to one or more antennas 5225. Radio units 5200 may communicate directly with hardware nodes 530 via one or more appropriate network interfaces and may be used in combination with the virtual components to provide a virtual node with radio capabilities, such as a radio access node  
30 or a base station.

**[0113]** In some embodiments, some signaling can be effected with the use of control system 5230 which may alternatively be used for communication between the hardware nodes 530 and radio units 5200.

**[0114]** With reference to Figure 6, in accordance with an embodiment, a communication system includes telecommunication network 610, such as a 3GPP-type cellular network, which comprises access network 611, such as a radio access network, and core network 614. Access network 611 comprises a plurality of base stations 612a, 612b, 612c, such as NBs, eNBs, gNBs or other types of wireless access points, each defining a corresponding coverage area 613a, 613b, 613c. Each base station 612a, 612b, 612c is connectable to core network 614 over a wired or wireless connection 615. A first UE 691 located in coverage area 613c is configured to wirelessly connect to, or be paged by, the corresponding base station 612c. A second UE 692 in coverage area 613a is wirelessly connectable to the corresponding base station 612a. While a plurality of UEs 691, 692 are illustrated in this example, the disclosed embodiments are equally applicable to a situation where a sole UE is in the coverage area or where a sole UE is connecting to the corresponding base station 612.

**[0115]** Telecommunication network 610 is itself connected to host computer 630, which may be embodied in the hardware and/or software of a standalone server, a cloud-implemented server, a distributed server or as processing resources in a server farm. Host computer 630 may be under the ownership or control of a service provider, or may be operated by the service provider or on behalf of the service provider. Connections 621 and 622 between telecommunication network 610 and host computer 630 may extend directly from core network 614 to host computer 630 or may go via an optional intermediate network 620. Intermediate network 620 may be one of, or a combination of more than one of, a public, private or hosted network; intermediate network 620, if any, may be a backbone network or the Internet; in particular, intermediate network 620 may comprise two or more sub-networks (not shown).

**[0116]** The communication system of Figure 6 as a whole enables connectivity between the connected UEs 691, 692 and host computer 630. The connectivity may be described as an over-the-top (OTT) connection 650. Host computer 630 and the connected UEs 691, 692 are configured to communicate data and/or signaling via OTT connection 650, using access network 611, core network 614, any intermediate network 620 and possible further

infrastructure (not shown) as intermediaries. OTT connection 650 may be transparent in the sense that the participating communication devices through which OTT connection 650 passes are unaware of routing of uplink and downlink communications. For example, base station 612 may not or need not be informed about the past routing of an incoming  
 5 downlink communication with data originating from host computer 630 to be forwarded (e.g., handed over) to a connected UE 691. Similarly, base station 612 need not be aware of the future routing of an outgoing uplink communication originating from the UE 691 towards the host computer 630.

**[0117]** Example implementations, in accordance with an embodiment, of the UE, base  
 10 station and host computer discussed in the preceding paragraphs will now be described with reference to Figure 7. In communication system 700, host computer 710 comprises hardware 715 including communication interface 716 configured to set up and maintain a wired or wireless connection with an interface of a different communication device of communication system 700. Host computer 710 further comprises processing circuitry 718,  
 15 which may have storage and/or processing capabilities. In particular, processing circuitry 718 may comprise one or more programmable processors, application-specific integrated circuits, field programmable gate arrays or combinations of these (not shown) adapted to execute instructions. Host computer 710 further comprises software 711, which is stored in or accessible by host computer 710 and executable by processing circuitry 718. Software  
 20 711 includes host application 712. Host application 712 may be operable to provide a service to a remote user, such as UE 730 connecting via OTT connection 750 terminating at UE 730 and host computer 710. In providing the service to the remote user, host application 712 may provide user data which is transmitted using OTT connection 750.

**[0118]** Communication system 700 further includes base station 720 provided in a  
 25 telecommunication system and comprising hardware 725 enabling it to communicate with host computer 710 and with UE 730. Hardware 725 may include communication interface 726 for setting up and maintaining a wired or wireless connection with an interface of a different communication device of communication system 700, as well as radio interface 727 for setting up and maintaining at least wireless connection 770 with UE 730 located in  
 30 a coverage area (not shown in Figure 7) served by base station 720. Communication interface 726 may be configured to facilitate connection 760 to host computer 710. Connection 760 may be direct or it may pass through a core network (not shown in Figure

7) of the telecommunication system and/or through one or more intermediate networks outside the telecommunication system. In the embodiment shown, hardware 725 of base station 720 further includes processing circuitry 728, which may comprise one or more programmable processors, application-specific integrated circuits, field programmable gate arrays or combinations of these (not shown) adapted to execute instructions. Base station 720 further has software 721 stored internally or accessible via an external connection.

**[0119]** Communication system 700 further includes UE 730 already referred to. Its hardware 735 may include radio interface 737 configured to set up and maintain wireless connection 770 with a base station serving a coverage area in which UE 730 is currently located. Hardware 735 of UE 730 further includes processing circuitry 738, which may comprise one or more programmable processors, application-specific integrated circuits, field programmable gate arrays or combinations of these (not shown) adapted to execute instructions. UE 730 further comprises software 731, which is stored in or accessible by UE 730 and executable by processing circuitry 738. Software 731 includes client application 732. Client application 732 may be operable to provide a service to a human or non-human user via UE 730, with the support of host computer 710. In host computer 710, an executing host application 712 may communicate with the executing client application 732 via OTT connection 750 terminating at UE 730 and host computer 710. In providing the service to the user, client application 732 may receive request data from host application 712 and provide user data in response to the request data. OTT connection 750 may transfer both the request data and the user data. Client application 732 may interact with the user to generate the user data that it provides.

**[0120]** It is noted that host computer 710, base station 720 and UE 730 illustrated in Figure 7 may be similar or identical to host computer 630, one of base stations 612a, 612b, 612c and one of UEs 691, 692 of Figure 6, respectively. This is to say, the inner workings of these entities may be as shown in Figure 7 and independently, the surrounding network topology may be that of Figure 6.

**[0121]** In Figure 7, OTT connection 750 has been drawn abstractly to illustrate the communication between host computer 710 and UE 730 via base station 720, without explicit reference to any intermediary devices and the precise routing of messages via these devices. Network infrastructure may determine the routing, which it may be configured to hide from UE 730 or from the service provider operating host computer 710,

or both. While OTT connection 750 is active, the network infrastructure may further take decisions by which it dynamically changes the routing (e.g., on the basis of load balancing consideration or reconfiguration of the network).

**[0122]** Wireless connection 770 between UE 730 and base station 720 is in accordance with the teachings of the embodiments described throughout this disclosure. One or more of the various embodiments improve the performance of OTT services provided to UE 730 using OTT connection 750, in which wireless connection 770 forms the last segment. More precisely, the teachings of these embodiments may improve the data rate, latency and power consumption, and thereby provide benefits such as reduced user waiting time, relaxed restriction on file size, better responsiveness, and extended battery lifetime.

**[0123]** A measurement procedure may be provided for the purpose of monitoring data rate, latency and other factors on which the one or more embodiments improve. There may further be an optional network functionality for reconfiguring OTT connection 750 between host computer 710 and UE 730, in response to variations in the measurement results. The measurement procedure and/or the network functionality for reconfiguring OTT connection 750 may be implemented in software 711 and hardware 715 of host computer 710 or in software 731 and hardware 735 of UE 730, or both. In embodiments, sensors (not shown) may be deployed in or in association with communication devices through which OTT connection 750 passes; the sensors may participate in the measurement procedure by supplying values of the monitored quantities exemplified above, or supplying values of other physical quantities from which software 711, 731 may compute or estimate the monitored quantities. The reconfiguring of OTT connection 750 may include message format, retransmission settings, preferred routing etc.; the reconfiguring need not affect base station 720, and it may be unknown or imperceptible to base station 720. Such procedures and functionalities may be known and practiced in the art. In certain embodiments, measurements may involve proprietary UE signaling facilitating host computer 710's measurements of throughput, propagation times, latency and the like. The measurements may be implemented in that software 711 and 731 causes messages to be transmitted, in particular empty or 'dummy' messages, using OTT connection 750 while it monitors propagation times, errors etc.

**[0124]** Figure 8 is a flowchart illustrating a method implemented in a communication system, in accordance with one embodiment. The communication system includes a host

computer, a base station and a UE which may be those described with reference to Figures 6 and 7. For simplicity of the present disclosure, only drawing references to Figure 8 will be included in this section. In step 810, the host computer provides user data. In substep 811 (which may be optional) of step 810, the host computer provides the user data by executing a host application. In step 820, the host computer initiates a transmission carrying the user data to the UE. In step 830 (which may be optional), the base station transmits to the UE the user data which was carried in the transmission that the host computer initiated, in accordance with the teachings of the embodiments described throughout this disclosure. In step 840 (which may also be optional), the UE executes a client application associated with the host application executed by the host computer.

**[0125]** Figure 9 is a flowchart illustrating a method implemented in a communication system, in accordance with one embodiment. The communication system includes a host computer, a base station and a UE which may be those described with reference to Figures 6 and 7. For simplicity of the present disclosure, only drawing references to Figure 9 will be included in this section. In step 910 of the method, the host computer provides user data. In an optional substep (not shown) the host computer provides the user data by executing a host application. In step 920, the host computer initiates a transmission carrying the user data to the UE. The transmission may pass via the base station, in accordance with the teachings of the embodiments described throughout this disclosure. In step 930 (which may be optional), the UE receives the user data carried in the transmission.

**[0126]** Figure 10 is a flowchart illustrating a method implemented in a communication system, in accordance with one embodiment. The communication system includes a host computer, a base station and a UE which may be those described with reference to Figures 6 and 7. For simplicity of the present disclosure, only drawing references to Figure 10 will be included in this section. In step 1010 (which may be optional), the UE receives input data provided by the host computer. Additionally or alternatively, in step 1020, the UE provides user data. In substep 1021 (which may be optional) of step 1020, the UE provides the user data by executing a client application. In substep 1011 (which may be optional) of step 1010, the UE executes a client application which provides the user data in reaction to the received input data provided by the host computer. In providing the user data, the executed client application may further consider user input received from the user.

Regardless of the specific manner in which the user data was provided, the UE initiates, in

substep 1030 (which may be optional), transmission of the user data to the host computer. In step 1040 of the method, the host computer receives the user data transmitted from the UE, in accordance with the teachings of the embodiments described throughout this disclosure.

5 **[0127]** Figure 11 is a flowchart illustrating a method implemented in a communication system, in accordance with one embodiment. The communication system includes a host computer, a base station and a UE which may be those described with reference to Figures 6 and 7. For simplicity of the present disclosure, only drawing references to Figure 11 will be included in this section. In step 1110 (which may be optional), in accordance with the  
10 teachings of the embodiments described throughout this disclosure, the base station receives user data from the UE. In step 1120 (which may be optional), the base station initiates transmission of the received user data to the host computer. In step 1130 (which may be optional), the host computer receives the user data carried in the transmission initiated by the base station.

15 **[0128]** Any appropriate steps, methods, features, functions, or benefits disclosed herein may be performed through one or more functional units or modules of one or more virtual apparatuses. Each virtual apparatus may comprise a number of these functional units. These functional units may be implemented via processing circuitry, which may include one or more microprocessor or microcontrollers, as well as other digital hardware, which may  
20 include digital signal processors (DSPs), special-purpose digital logic, and the like. The processing circuitry may be configured to execute program code stored in memory, which may include one or several types of memory such as read-only memory (ROM), random-access memory (RAM), cache memory, flash memory devices, optical storage devices, etc. Program code stored in memory includes program instructions for executing one or more  
25 telecommunications and/or data communications protocols as well as instructions for carrying out one or more of the techniques described herein. In some implementations, the processing circuitry may be used to cause the respective functional unit to perform corresponding functions according one or more embodiments of the present disclosure.

**[0129]** At least some of the following abbreviations may be used in this disclosure. If  
30 there is an inconsistency between abbreviations, preference should be given to how it is used above. If listed multiple times below, the first listing should be preferred over any subsequent listing(s).

|    |          |                                          |
|----|----------|------------------------------------------|
|    | • 3GPP   | Third Generation Partnership Project     |
|    | • 5G     | Fifth Generation                         |
|    | • AP     | Access Point                             |
|    | • ASIC   | Application Specific Integrated Circuit  |
| 5  | • BSC    | Base Station Controller                  |
|    | • BTS    | Base Transceiver Station                 |
|    | • CD     | Compact Disk                             |
|    | • COTS   | Commercial Off-the-Shelf                 |
|    | • CPE    | Customer Premise Equipment               |
| 10 | • CPU    | Central Processing Unit                  |
|    | • D2D    | Device-to-Device                         |
|    | • DAS    | Distributed Antenna System               |
|    | • DSP    | Digital Signal Processor                 |
|    | • DVD    | Digital Video Disk                       |
| 15 | • eNB    | Enhanced or Evolved Node B               |
|    | • E-SMLC | Evolved Serving Mobile Location Center   |
|    | • FPGA   | Field Programmable Gate Array            |
|    | • GHz    | Gigahertz                                |
|    | • gNB    | New Radio Base Station                   |
| 20 | • GSM    | Global System for Mobile Communications  |
|    | • IoT    | Internet of Things                       |
|    | • IP     | Internet Protocol                        |
|    | • LEE    | Laptop Embedded Equipment                |
|    | • LME    | Laptop Mounted Equipment                 |
| 25 | • LTE    | Long Term Evolution                      |
|    | • M2M    | Machine-to-Machine                       |
|    | • MANO   | Management and Orchestration             |
|    | • MCE    | Multi-Cell/Multicast Coordination Entity |
|    | • MDT    | Minimization of Drive Tests              |
| 30 | • MIMO   | Multiple Input Multiple Output           |
|    | • MME    | Mobility Management Entity               |

|    |          |                                      |
|----|----------|--------------------------------------|
|    | • MSC    | Mobile Switching Center              |
|    | • MSR    | Multi-Standard Radio                 |
|    | • MTC    | Machine Type Communication           |
|    | • NB-IoT | Narrowband Internet of Things        |
| 5  | • NFV    | Network Function Virtualization      |
|    | • NIC    | Network Interface Controller         |
|    | • NR     | New Radio                            |
|    | • O&M    | Operation and Maintenance            |
|    | • OSS    | Operations Support System            |
| 10 | • OTT    | Over-the-Top                         |
|    | • PDA    | Personal Digital Assistant           |
|    | • P-GW   | Packet Data Network Gateway          |
|    | • RAM    | Random Access Memory                 |
|    | • RAN    | Radio Access Network                 |
| 15 | • RAT    | Radio Access Technology              |
|    | • RF     | Radio Frequency                      |
|    | • RNC    | Radio Network Controller             |
|    | • ROM    | Read Only Memory                     |
|    | • RRH    | Remote Radio Head                    |
| 20 | • RRU    | Remote Radio Unit                    |
|    | • SCEF   | Service Capability Exposure Function |
|    | • SOC    | System on a Chip                     |
|    | • SON    | Self-Organizing Network              |
|    | • UE     | User Equipment                       |
| 25 | • USB    | Universal Serial Bus                 |
|    | • V2I    | Vehicle-to-Infrastructure            |
|    | • V2V    | Vehicle-to-Vehicle                   |
|    | • V2X    | Vehicle-to-Everything                |
|    | • VMM    | Virtual Machine Monitor              |
| 30 | • VNE    | Virtual Network Element              |
|    | • VNF    | Virtual Network Function             |

- VoIP           Voice over Internet Protocol
- WCDMA       Wideband Code Division Multiple Access
- WiMax        Worldwide Interoperability for Microwave Access

**[0130]**   Those skilled in the art will recognize improvements and modifications to the  
5   embodiments of the present disclosure. All such improvements and modifications are  
considered within the scope of the concepts disclosed herein.

Claims

What is claimed is:

1. A method of operation of a User Equipment, UE, in a wireless network to perform  
 5 System Frame Number, SFN, Frame Time Difference, SFTD, measurements between a Primary Cell, PCell, of the UE and one or more other cells, the method comprising:  
     receiving (200), from a network node in the wireless network, a list of cells for which the UE can report SFTD measurements;  
     performing (202) SFTD measurements; and  
 10      reporting (204) the SFTD measurements in accordance with the list of cells for which the UE can report SFTD measurements.
2. The method of claim 1, wherein:  
     performing SFTD measurements comprises performing an SFTD measurement  
 15 between the PCell of the UE and a second cell, the second cell being a cell in the list of cells for which the UE can report SFTD measurements; and  
     reporting the SFTD measurements in accordance with the list of cells for which the UE can report SFTD measurements comprises reporting the SFTD measurements to the network node.  
 20
3. The method of claim 1 or 2, wherein the list of cells comprises one or more New Radio, NR, cells.
4. The method of claim 3, wherein the PCell is a Long Term Evolution, LTE, cell.  
 25
5. The method of claim 3 or 4, wherein reporting the SFTD measurements in accordance with the list of cells for which the UE can report SFTD measurements comprises:  
     reporting the SFTD measurements, in accordance with the list of cells for which the  
 30 UE can report SFTD measurements, when no NR cell is configured as a Primary Secondary Cell, PSCell, of the UE.

6. The method of claim 5, further comprising, when an NR cell is configured as a PSCell for the UE:

performing a SFTD measurement between the PCell of the UE and the NR PSCell;  
and

5 reporting the SFTD measurement between the PCell of the UE and the NR PSCell.

7. The method of any one of claims 1 to 6, wherein receiving the list of cells for which the UE can report SFTD measurements comprises receiving a Radio Resource Control, RRC, Connection Reconfiguration message comprising the list of cells for which the UE  
10 can report SFTD measurements or receiving an RRC Connection Resume message comprising the list of cells for which the UE can report SFTD measurements.

8. A User Equipment, UE, for performing System Frame Number, SFN, Frame Time Difference, SFTD, measurements between a Primary Cell, PCell, of the UE and one or  
15 more other cells in a wireless network, the UE adapted to:

receive, from a network node in the wireless network, a list of cells for which the UE can report SFTD measurements;

perform SFTD measurements; and

report the SFTD measurements in accordance with the list of cells for which the UE  
20 can report SFTD measurements.

9. The UE of claim 8, wherein the UE is further adapted to perform the method of any one of embodiments 2 to 7.

25 10. A User Equipment, UE, for performing System Frame Number, SFN, Frame Time Difference, SFTD, measurements between a Primary Cell, PCell, of the UE and one or more other cells in a wireless network, the UE comprising:

an interface comprising radio front-end circuitry; and

processing circuitry associated with the interface, the processing circuitry operable to  
30 cause the UE to:

receive, from a network node in the wireless network, a list of cells for which the UE can report SFTD measurements;

perform SFTD measurements; and  
report the SFTD measurements in accordance with the list of cells for which  
the UE can report SFTD measurements.

- 5 11. The UE of claim 10, wherein the SFTD measurements comprise a SFTD  
measurement between the PCell of the UE and a second cell, the second cell being a cell  
in the list of cells for which the UE can report SFTD measurements.
- 10 12. The UE of claim 10 or 11, wherein the list of cells comprises one or more New  
Radio, NR, cells.
13. The method of claim 12, wherein the PCell is a Long Term Evolution, LTE, cell.
- 15 14. The UE of claim 12 or 13, wherein, in order to report the SFTD measurements in  
accordance with the list of cells for which the UE can report SFTD measurements, the  
processing circuitry is further configured to cause the UE to:  
report the SFTD measurements, in accordance with the list of cells for which the UE  
can report SFTD measurements, when no NR cell is configured as a Primary Secondary  
Cell, PSCell, of the UE.
- 20 15. The UE of claim 14, wherein the processing circuitry is further configured to cause  
the UE to, when a NR cell is configured as a PSCell for the UE:  
perform a SFTD measurement between the PCell of the UE and the NR PSCell; and  
report the SFTD measurement between the PCell of the UE and the NR PSCell.
- 25 16. The UE of any one of claims 10 to 15, wherein, in order to receive the list of cells for  
which the UE can report SFTD measurements, the processing circuitry is further configured  
to cause the UE to receive a Radio Resource Control, RRC, Connection Reconfiguration  
message comprising the list of cells for which the UE can report SFTD measurements or  
30 receive an RRC Connection Resume message comprising the list of cells for which the UE  
can report SFTD measurements.