



(51) International Patent Classification:

H04B 7/06 (2006.01) H04L 5/00 (2006.01)
H04B 7/0404 (2017.01)

(21) International Application Number:

PCT/IB2024/059924

(22) International Filing Date:

10 October 2024 (10.10.2024)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

63/589,142 10 October 2023 (10.10.2023) US

(71) Applicant: **TELEFONAKTIEBOLAGET LM ERICSSON (PUBL)** [SE/SE]; SE-164 83, Stockholm (SE).

(72) Inventors: **NILSSON, Andreas**; Seminariegatan 16, SE-413 13 Göteborg (SE). **JACOBSSON, Sven**; Antennagatan 9 lgh 1701, SE-421 33 Västra Frölunda (SE).

(74) Agent: **MACENKO, Marc**; 76 Hunter Street, Suite 200, Apex, North Carolina 27502 (US).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ,

CA, CH, CL, CN, CO, CR, CU, CV, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IQ, IR, IS, IT, JM, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, MG, MK, MN, MU, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, CV, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SC, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, ME, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

- with international search report (Art. 21(3))
- in black and white; the international application as filed contained color or greyscale and is available for download from PATENTSCOPE

(54) Title: SRS ANTENNA SWITCHING FOR 3 TX UES

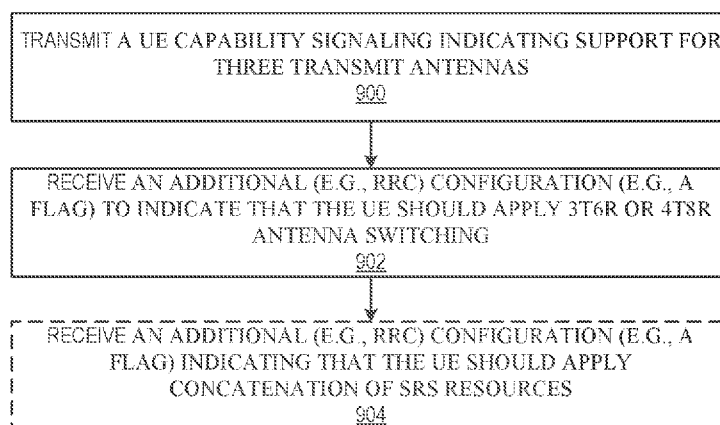


FIG. 9

(57) Abstract: Systems and methods for Sounding Reference Signal (SRS) antenna switching for a three Transmit (TX) User Equipment (UE) are provided. In some embodiments, a method performed by a UE includes: transmitting a UE capability signaling indicating support for three transmit antennas; and receiving a Radio Resource Control (RRC) configuration to indicate that the UE should apply a first or a second antenna switching. In this way, the number of Orthogonal Frequency Division Multiplexing (OFDM) symbols required to sound a certain number of UE RX antennas is reduced compared to using legacy SRS antenna switching configurations.



SRS ANTENNA SWITCHING FOR 3 TX UEsRELATED APPLICATIONS

[0001] This application claims the benefit of provisional patent application serial number 63/589,142, filed October 10, 2023, the disclosure of which is hereby incorporated herein by reference in its entirety.

TECHNICAL FIELD

[0001] The present disclosure relates generally to antenna switching.

BACKGROUND

[0002] Numerology

[0003] In the time domain, NR DL and UL transmissions are organized into equally sized subframes of 1 ms each. A subframe is further divided into multiple slots of equal duration. The slot length depends on the numerology (i.e., on the SCS and the CP). For 15 kHz SCS, there is only one slot per subframe. In general, for $15 \cdot 2^\mu$ kHz SCS, where $\mu \in \{0,1,2,3,4\}$ is the SCS configuration, there are 2^μ slots per subframe. Each slot consists of 14 symbols (unless extended CP is configured for which each slot consists of 12 symbols).

[0004] In the frequency domain, a channel bandwidth is divided into RBs each corresponding to 12 contiguous subcarriers. One subcarrier during one symbol interval forms one RE, which is the smallest physical resource in NR.

[0005] Carrier aggregation

[0006] NR supports CA of up to 16 CCs. A UE capable of CA can transmit/receive on multiple CCs at the same time, where different CCs may be of different channel bandwidths and/or duplex schemes (i.e., TDD or FDD). In FR1 (i.e., for operating bands n1—n105), channel bandwidths up to 100 MHz are supported. In FR2 (i.e., for operating bands n257—n263), channel bandwidths up to 400 MHz are supported. 3GPP TS 38.101-1 and 3GPP TS 38.101-2 lists operating bands supporting (contiguous and non-contiguous) intra-band CA and inter-band CA for FR1 and FR2, respectively. With intra-band CA, CCs are in the same operating band. With inter-band CA, CCs are in different operating bands.

[0007] In NR specification, a CC is referred to as a cell. One of said cells is known as the PCell and is the cell that the UE initially connects to. After the UE is connected, one or multiple SCells can be additionally configured. Furthermore, said SCells can be dynamically (via MAC

CE signaling) activated/deactivated. When CA is not configured, UE will transmit/receive only on the PCell. The number of cells need not be the same in the DL and UL. Typically, since there is often more DL traffic than UL traffic, there are more DL cells than UL cells.

[0008] The RBs within a cell (across the channel bandwidth) are known as CRBs and are numbered starting from 0. The first subcarrier in CRB 0 is known as reference point A, which is signaled to the UE as part of SIB1.

[0009] Bandwidth parts

[0010] NR is designed to support very large channel bandwidths (up to 400 MHz), but not all UEs are capable of handling such large channel bandwidth. For this reason, a UE can operate in a contiguous subset of the CRBs within a cell. This subset is called a BWP.

[0011] A UE can be configured with up to four DL BWPs and up to four UL BWPs per serving cell, where different numerologies can be configured for different BWPs. The starting position and bandwidth of a BWP is RRC configured. Only one DL and one UL BWP can be active at the same time per serving cell. For TDD, the active DL and UL BWP must share the same center frequency. For FDD, this is not required. In the DL, a UE does not expect to receive, e.g., PDCCH and/or PDSCH outside the active BWP. In the UL, a UE is not expected to transmit, e.g., PUCCH and/or PUSCH outside of the active BWP.

[0012] The NW can switch active BWP, e.g., via DCI signaling. For example, DCI Format 1_1 (used for scheduling DL transmissions) and DCI Format 0_1 (used for scheduling UL transmissions) includes an up to 2-bit “BWP indicator” field for switching BWP for DL and UL transmissions, respectively.

[0013] The RBs within a BWP are known as PRBs and are numbered starting from 0. When the NW schedules a DL or UL transmission, a set of VRBs, which are mapped to PRBs, are signaled. In the DL, interleaved and non-interleaved mapping is supported. In the UL, only non-interleaved mapping is supported, for which there is a one-to-one mapping between VRBs and CRBs. In what follows, unless otherwise stated, a one-to-one mapping between VRBs and PRBs is assumed, and simply use RBs to refer to both VRBs and CRBs.

[0014] SRS

[0015] SRS is an UL RS, based on Zadoff-Chu sequences, used for providing CSI to the NW. The usage of SRS includes, e.g., deriving the appropriate transmission/reception beams and/or to perform link adaptation (i.e., setting the transmission rank and the MCS), and for determining PDSCH and PUSCH precoding matrices.

[0016] SRS configuration

[0017] The SRS is configured via RRC signaling, where parts of the configuration can be updated (for reduced latency) via MAC CE signaling. When configuring SRS transmissions, the gNB configures, through the *SRS-Config* IE, a list of SRS resources and a list of SRS resource sets (see below snippet of ASN from 3GPP TS 38.331 version 17.2.0):

```
SRS-Config ::=
    SEQUENCE {
        srs-ResourceSetToReleaseList      SEQUENCE
        (SIZE(1..maxNrofSRS-ResourceSets)) OF SRS-ResourceSetId
    OPTIONAL,    -- Need N
        srs-ResourceSetToAddModList      SEQUENCE
        (SIZE(1..maxNrofSRS-ResourceSets)) OF SRS-ResourceSet
    OPTIONAL,    -- Need N
        srs-ResourceToReleaseList        SEQUENCE
        (SIZE(1..maxNrofSRS-Resources)) OF SRS-ResourceId
    OPTIONAL,    -- Need N
        srs-ResourceToAddModList         SEQUENCE
        (SIZE(1..maxNrofSRS-Resources)) OF SRS-Resource
    OPTIONAL,    -- Need N
        ...
    }
```

[0018] SRS resource(s) will be transmitted as part of an SRS resource set, where each SRS resource set contains one or more SRS resources, and where all SRS resources in an SRS resource set must share the same time-domain behavior.

[0019] NR supports configuration of up to 16 SRS resource sets and 64 SRS resources per BWP. Furthermore, NR supports periodic (p-SRS), semi-persistent (sp-SRS), or aperiodic (ap-SRS) SRS transmissions:

[0020] Periodic (p-SRS): SRS resource sets and SRS resources are RRC configured. SRS resource configuration includes slot periodicity and offset, which determines SRS transmission occasions.

[0021] Semi-persistent (sp-SRS): SRS resource sets and SRS resources are RRC configured. SRS resource configuration includes slot periodicity and offset, and SRS transmissions are activated/deactivated using MAC CE signaling.

[0022] Aperiodic (ap-SRS): SRS resource sets and SRS resources are RRC configured. SRS resource set configuration includes slot offset, and SRS transmissions are dynamically triggered via 2-bit “SRS request” field in DCI.

[0023] In short, the SRS resource-set configuration determines, e.g., SRS usage, PC parameters, and slot offset for ap-SRS. The SRS resource configuration determines, e.g., the SRS time-and-frequency allocation, the SRS sequence, the periodicity and offset for p-SRS/sp-SRS.

[0024] SRS resource set configuration

[0025] An SRS resource set is configured with the following in RRC (see ASN code in 3GPP TS 38.331 version 17.2.0):

```

SRS-ResourceSet ::=
    srs-ResourceSetId
    srs-ResourceIdList
    (SIZE(1..maxNrofSRS-ResourcesPerSet)) OF SRS-ResourceId
    OPTIONAL, -- Cond Setup
    resourceType
        aperiodic
            aperiodicSRS-ResourceTrigger
            (1..maxNrofSRS-TriggerStates-1),
            csi-RS
        ResourceId
        NonCodebook
        slotOffset
        (1..32)
    S
        ...,
        [[
            aperiodicSRS-ResourceTriggerList
            (SIZE(1..maxNrofSRS-TriggerStates-2))
            INTEGER (1..maxNrofSRS-TriggerStates-1)
            ]],
        },
        semi-persistent
            associatedCSI-RS
        ResourceId
        NonCodebook
        ...
        },
        periodic
            associatedCSI-RS
        ResourceId
        NonCodebook
        ...
    },
    usage
    {beamManagement, codebook, nonCodebook, antennaSwitching},
    alpha
    OPTIONAL, -- Need S
    p0
    OPTIONAL, -- Cond Setup
    pathlossReferenceRS
    Config
        srs-PowerControlAdjustmentStates
        sameAsFci2, separateClosedLoop}
    Need S
        ...,
        [[
            pathlossReferenceRSList-r16
            PathlossReferenceRSList-r16}
        Need M

```

```

SEQUENCE {
    SRS-ResourceSetId,
    SEQUENCE
    CHOICE {
        SEQUENCE {
            INTEGER
            NZP-CSI-RS-
            OPTIONAL, -- Cond
            INTEGER
            OPTIONAL, -- Need
        },
        SEQUENCE {
            NZP-CSI-RS-
            OPTIONAL, -- Cond
        },
        SEQUENCE {
            NZP-CSI-RS-
            OPTIONAL, -- Cond
        },
        ENUMERATED
        Alpha
        INTEGER (-202..24)
        PathlossReferenceRS-
        OPTIONAL, -- Need M
        ENUMERATED {
            OPTIONAL, --
        },
        SetupRelease {
            OPTIONAL --

```

```

    ]],
    [[
        usagePDC-r17                                ENUMERATED {true}
OPTIONAL, -- Need R
        availableSlotOffsetList-r17                  SEQUENCE
(SIZE(1..4)) OF AvailableSlotOffset-r17              OPTIONAL,
-- Need R
        followUnifiedTCIstateSRS-r17                ENUMERATED {enabled}
OPTIONAL -- Need R
    ]]
}

```

[0026] An SRS resource set is configurable with respect to, e.g.,

[0027] The resource type, which is configured by the higher-layer parameter *resourceType* determines whether the SRS resource set is periodic, semi-persistent, or aperiodic. For ap-SRS, the slot offset is configured by the higher-layer parameter *slotOffset* and sets the delay from the PDCCH trigger reception to the start of the SRS transmission.

[0028] The resource usage, which is configured by the higher-layer parameter *usage* determines constraints and assumptions on the resource properties (see 3GPP TS 38.214 for further details). SRS resource sets can be configured with one of four different usages: *antennaSwitching*, *codebook*, *nonCodebook*, or *beamManagement*.

- An SRS resource set that is configured with usage *antennaSwitching* is used for reciprocity-based DL precoding (i.e., used to sound the channel in the UL so that the gNB can use reciprocity to set a suitable DL precoders). The UE is expected to transmit one SRS port per UE antenna port.
- An SRS resource set that is configured with usage *codebook* is used for CB-based UL transmission (i.e., used to sound the different UE antennas and help the gNB to determine/signal a suitable UL precoder, transmission rank, and MCS for PUSCH transmission). There are up to two SRS resources in an SRS resource set with usage *codebook*. How SRS ports are mapped to UE antenna ports is, however, up to UE implementation and not known to the gNB.
- An SRS resource set that is configured with usage *nonCodebook* is used for NCB-based UL transmission. Specifically, the UE transmits one SRS resource per candidate beam (suitable candidate beams are determined by the UE based on CSI-RS measurements in the DL and, hence, reciprocity needs to hold). The gNB can then, by indicating a subset of these SRS resources, determine which UL beam(s) that the UE should apply for PUSCH transmission. One UL layer will be transmitted per indicated SRS resource.

Note that how the UE maps SRS ports to antenna ports is up to UE implementation and not known to the gNB.

- An SRS resource set that is configured with usage *beamManagement* is used (mainly for frequency bands above 6 GHz (i.e., for FR2)) to evaluate different UE analog beams (e.g., panels). The UE transmits one SRS resource per analog beam, and the gNB will perform an RSRP measurement per transmitted SRS resource and, in this way, determine a suitable UE beam that is reported to the UE.

[0029] The associated CSI-RS (this configuration is only applicable for NCB-based UL transmission) for each of the possible resource types.

- For ap-SRS, the associated CSI-RS resource is determined by the higher-layer parameter *csi-RS*.
- For p-SRS/sp-SRS, the associated CSI-RS resource is determined by the higher-layer parameter *associatedCSI-RS*.

[0030] The PC parameters, e.g., *alpha* and *p0* are used for setting the SRS transmission power. SRS has its own UL PC scheme in NR (see 3GPP TS 38.213 for further details), which specifies how the UE should split the available output power between two or more SRS ports during one SRS transmit occasion (an SRS transmit occasion is a time window within a slot where SRS transmission is performed).

[0031] In NR Rel-17, dynamic/available SRS slot offset indication for ap-SRS was introduced and is configured by the higher-layer parameter *availableSlotOffsetList-r17*, which lists (up to) 4 slot offsets measured from the legacy slot offset *k* configured by the higher-layer parameter *slotOffset*. The DCI triggering the ap-SRS includes a (up to) 2-bit “SRS offset indicator” which indicates a value *t* from the list of slot offsets. If the DCI is transmitted in slot *n*, the ap-SRS is transmitted in the *t*th available slot after slot *n* + *k*, where an available slot is a slot that fits all SRS resources in the SRS resource set and that satisfies UE capability on minimum timing requirement.

[0032] SRS resource configuration

[0033] Each SRS resource is configured with the following in RRC (see below ASN code from 3GPP TS 38.331 version 17.2.0):

<pre> SRS-Resource ::= srs-ResourceId nrofSRS-Ports ports2, ports4}, ptrs-PortIndex OPTIONAL, -- Need R transmissionComb n2 combOffset-n2 (0..1), cyclicShift-n2 (0..7) }, n4 combOffset-n4 (0..3), cyclicShift-n4 (0..11) } }, resourceMapping startPosition nrofSymbols n2, n4}, repetitionFactor n2, n4} }, freqDomainPosition freqDomainShift freqHopping c-SRS b-SRS b-hop }, groupOrSequenceHopping neither, groupHopping, sequenceHopping }, resourceType aperiodic ... }, semi-persistent periodicityAndOffset-sp PeriodicityAndOffset, ... }, periodic </pre>	<pre> SEQUENCE { SRS-ResourceId, ENUMERATED {port1, ENUMERATED {n0, n1 } CHOICE { SEQUENCE { INTEGER INTEGER SEQUENCE { INTEGER INTEGER SEQUENCE { INTEGER (0..5), ENUMERATED {n1, ENUMERATED {n1, INTEGER (0..67), INTEGER (0..268), SEQUENCE { INTEGER (0..63), INTEGER (0..3), INTEGER (0..3) ENUMERATED { CHOICE { SEQUENCE { SEQUENCE { SRS- SEQUENCE { </pre>
--	---


```

        srs-DLorJoint-TCIState-r17          TCI-StateId
    }
OPTIONAL    -- Need R
    ]]
}

```

[0034] An SRS resource is configurable with respect to, e.g.,

[0035] The number of SRS ports (1, 2, or 4), configured by the higher-layer parameter *nrofSRS-Ports*.

[0036] The transmission comb, i.e., mapping to every 2nd, 4th, or 8th (in NR Rel-17) subcarrier, configured by the higher-layer parameter *transmissionComb*, which includes:

- The higher-layer parameter *combOffset* determines the comb offset(s), i.e., which subcarriers that should be used for the SRS resource. For four-port SRS resource it is possible for an SRS resource to occupy two comb offsets, with two SRS ports per SRS resource. Configuring different comb offsets over SRS resources enables multiplexing of multiple SRS resources on a same SRS bandwidth.
- The higher-layer parameter *cyclicShift* determines the CS(s) for the SRS resource. For multi-port SRS resources, different SRS ports use different CSs, where the CSs are equidistantly spaced. Configuring different CSs over SRS resources enables multiplexing of multiple SRS resources on a same comb offset, but there is a limit on how many CSs that can be used per comb offset: 8 CSs for comb 2, 12 CSs for comb 4, and 6 CSs for comb 8.

[0037] The time-domain position within a given slot, configured with the higher-layer parameter *resourceMapping*, which includes:

- The time-domain start position that (in NR Rel-15) is limited to be one of the last 6 symbols, configured by the higher-layer parameter *startPosition*. In NR Rel-16, the start position was extended to any of the symbols in a slot.
- The number of symbols that (in NR Rel-15) can be set to 1, 2 or 4, configured by the higher-layer parameter *nrofSymbols*. In NR Rel-17, the number of symbols was extended to include also 8, 10, 12, and 14.
- The repetition factor that (in NR Rel-15) can be set to 1, 2 or 4, configured by the higher-layer parameter *repetitionFactor*. When the repetition factor is larger than 1, the same frequency resources are used multiple times across symbols, used to improve the coverage as this allows more energy to be collected by the receiver. The repetition factor

must be integer divisible by the number of symbols. In NR Rel-17, the repetition factor was extended to include also 5, 6, 7, 8, 10, 12, and 14.

[0038] Figure 1 illustrates an example of how an SRS resource could be allocated in time and frequency within a slot in NR Rel-15/Rel-16/Rel-17 (note that semi-persistent/periodic SRS resources typically span several slots). In NR Rel-15, SRS can occupy up to 4 of the last 6 symbols in a slot. In NR Rel-16, SRS can occupy up to 4 of all symbols in a slot. In NR Rel-17, SRS can occupy up to 14 of all symbols in a slot.

[0039] The SRS frequency-hopping pattern, frequency-domain position, and frequency-domain position shift of an SRS resource (i.e., which part of the BWP that is occupied by the SRS resource) is set through the following:

- The higher-layer parameter the *freqHopping* which contains parameters *c-SRS*, *b-SRS*, and *b-hop* which determines the SRS bandwidth (the smallest possible sounding bandwidth is 4 RBs):
 - *c-SRS*, which determines “configured bandwidth” (see Figure 1).
 - *b-hop*, which determines the “hopping bandwidth” (see Figure 1).
 - *b-SRS*, which determines the “per-hop bandwidth” (see Figure 1).
- The higher-layer parameter *freqDomainPosition*, which determines the start of the SRS hopping bandwidth relative to the SRS configured bandwidth (see Figure 1).
- The higher-layer parameter *freqDomainShift*, which determines the start of the SRS configured bandwidth relative to the start of the BWP (see Figure 1).

[0040] The higher-layer parameter *resourceType* determines whether the SRS resource is periodic, semi-persistent, or aperiodic. For sp-SRS and p-SRS, the slot offset and periodicity is configured by the higher-layer parameter *periodicityAndOffset*.

[0041] The higher-layer parameter *sequenceId* specifies how the SRS sequence is initialized.

- The higher-layer parameter *spatialRelationInfo* configures the spatial relation for the SRS beam with respect to another RS (which could be another SRS, an SSB, or a CSI-RS). If an SRS resource has a spatial relation to another SRS resource, it should be transmitted using the same virtualization as for the other SRS resource.

[0042] In NR Rel-17, SRS partial frequency sounding was introduced and is configured by the higher-layer parameter *partialFreqSounding*. When partial frequency sounding is configured, an SRS resource will span only a subset (one half or one quarter) of the SRS per-hop bandwidth, which subset of the sounding bandwidth is configurable and may vary over symbols). SRS partial frequency sounding can be combined with SRS repetition and SRS frequency hopping.

[0043] SRS port mapping

[0044] An SRS port is mapped to a subset of the subcarriers in the configured SRS bandwidth. Specifically, the frequency-domain starting position for SRS port $p_i = 1000 + i$ can be written as follows:

$$k_0^{(p_i)} = N_{sc}^{RB} \cdot n_{\text{shift}} + k_{TC}^{(p_i)} \cdot n_{\text{offset}}^{FH} + n_{\text{offset}}^{RPFS}.$$

[0045] Here, $N_{sc}^{RB} = 12$ is the number of subcarriers per RB, n_{offset}^{FH} and n_{offset}^{RPFS} is the starting position for frequency hopping and partial frequency sounding, respectively, and n_{shift} is the frequency-domain shift. Furthermore, the port-specific comb offset $k_{TC}^{(p_i)}$ depends on the RRC-configured comb offset $\bar{k}_{TC}$ as follows:

$$k_{TC}^{(p_i)} = \begin{cases} (\bar{k}_{TC} + K_{TC}/2) \bmod K_{TC} & \text{if } N_{ap}^{SRS} = 4, p_i \in \{1001, 1003\}, \text{ and } n_{SRS}^{cs, \max} = 6 \\ (\bar{k}_{TC} + K_{TC}/2) \bmod K_{TC} & \text{if } N_{ap}^{SRS} = 4, p_i \in \{1001, 1003\}, \text{ and } n_{SRS}^{cs, \max} \geq n_{SRS}^{cs, \max}/2 \\ \bar{k}_{TC} & \text{otherwise.} \end{cases}$$

[0046] Here, K_{TC} is the comb, N_{ap}^{SRS} is the number of SRS ports, and $n_{SRS}^{cs, \max}$ is the number of CSs per comb offset, which depends on the comb as follows: $n_{SRS}^{cs, \max} = 8$ if $K_{TC} = 2$, $n_{SRS}^{cs, \max} = 12$ if $K_{TC} = 4$, and $n_{SRS}^{cs, \max} = 6$ if $K_{TC} = 8$.

[0047] Figure 2 illustrates multiplexing 2 and 4 single-port SRS resources (with varying comb offset) using comb 2 and 4, respectively. Here, SRS resource k is configured with comb offset k . Figure 2 shows an example of how multiple SRS resources can be multiplexed onto a same set of RBs by configuring different comb offsets.

[0048] The SRS base sequences (i.e., Zadoff-Chu sequences) are pairwise orthogonal under CSs. Utilizing this property, it is possible to multiplex multiple SRS ports on a same comb offset by using different CSs (and the same base sequence) for different SRS ports. For multi-port SRS resources, different SRS ports belonging to the same SRS resource will use a port-specific CS per SRS port. Specifically, the cyclic shift α_i for antenna port p_i is given by

$$\alpha_i = 2\pi \frac{n_{SRS}^{cs, i}}{n_{SRS}^{cs, \max}}.$$

Where $n_{SRS}^{cs, i}$ depends on the RRC-configured cyclic shift n_{SRS}^{cs} as follows:

$$n_{\text{SRS}}^{\text{cs},i} = \begin{cases} \left(n_{\text{SRS}}^{\text{cs}} + \frac{n_{\text{SRS}}^{\text{cs,max}} \lfloor (p_i - 1000)/2 \rfloor}{N_{\text{ap}}^{\text{SRS}}/2} \right) \bmod n_{\text{SRS}}^{\text{cs,max}} & \text{if } N_{\text{ap}}^{\text{SRS}} = 4 \text{ and } n_{\text{SRS}}^{\text{cs,max}} = 6 \\ \left(n_{\text{SRS}}^{\text{cs}} + \frac{n_{\text{SRS}}^{\text{cs,max}} (p_i - 1000)}{N_{\text{ap}}^{\text{SRS}}} \right) \bmod n_{\text{SRS}}^{\text{cs,max}} & \text{otherwise.} \end{cases}$$

[0049] Figure 3 illustrates multiplexing of SRS resources on a same comb offset. Here, the comb is 4 such that the number of CSs per comb offset is 12, the 4-port SRS resource 0 is configured with CS 0, the 2-port SRS resource 1 is configured with CS 2, the 1-port SRS resource 2 is configured with CS 5, and the 1-port SRS resource 3 is configured with CS 11. Figure 3 shows an example of how multiple SRS resources (each with one or more SRS ports) can be mapped onto a same comb offset by configuring different cyclic shifts.

[0050] It is worth mentioning that there are drawbacks associated with using a large comb and/or occupying multiple CSs per comb offset: For frequency-selective channels, the orthogonality between the SRS sequences may be lost if the delay spread is large. For 4-port SRS resources configured with comb 2 or 4, it is possible to spread SRS ports over two different comb offsets (where two different pairs of CS are used over the two comb offsets) to increase robustness towards delay spread. For 4-port SRS resources configured with comb 8, two comb offsets must be used (where the same pair of CSs is used over the two comb offsets). Spreading ports over multiple comb offsets increases robustness towards delay spread. Figures 4A and 4B illustrate spreading CSs over two comb offsets for 4-port SRS resources configured with comb 4 (Figure 4A) and comb 8 (Figure 4B). In Figures 4A and 4B, examples are shown of possible CS and comb offset allocation for a 4-port SRS resource configured with comb 4 (Figure 4A) and comb 8 (Figure 4B).

[0051] SRS antenna switching

[0052] For reciprocity-based DL precoding, SRS is used to obtain CSI in the UL. It is desirable for the NW to sound all UE antennas (where sounding an antenna implies that SRS is transmitted from that antenna) but costly to equip the UE with many Tx chains (UEs typically have more Rx chains than Tx chains). Therefore, NR supports SRS antenna switching for UEs equipped with more Rx chains than Tx chains. If a UE supports antenna switching, it will report so by means of UE-capability signaling (see, e.g., Table 1).

[0053] Table 1 SRS antenna-switching capabilities supported by the UE (copied from 3GPP TS 38.306):

<i>supportedSRS-TxPortSwitch</i>	<i>supportedSRS-TxPortSwitch-v1610</i>
<i>t1r2</i>	<i>t1r1-t1r2</i>
<i>t1r4</i>	<i>t1r1-t1r2-t1r4</i>
<i>t2r4</i>	<i>t1r1-t1r2-t2r2-t2r4</i>
<i>t2r2</i>	<i>t1r1-t2r2</i>
<i>t4r4</i>	<i>t1r1-t2r2-t4r4</i>
<i>t1r4-t2r4</i>	<i>t1r1-t1r2-t2r2-t1r4-t2r4</i>

[0054] The left column Table 1 lists UE capabilities for SRS antenna-switching that can be reported by a UE in NR Rel-15. For example, if a UE reports *t1r2* it means that it has two antennas (it has two Rx chains) but can only transmit from one of those antennas at a time (it has one Tx chain). In this case, NW can configure 1T2R antenna switching with two one-port SRS resources in an SRS resource set with usage *antennaSwitching*. The two SRS resources must be configured in different OFDM symbols and separated, at least, by a guard period that depends on the SCS (see Clause 6.2.1.2 of 3GPP TS 38.214 for further details) such that both antennas can be sounded, with an antenna switch in between.

[0055] In general, x TyR SRS antenna switching can be configured for a UE with x Tx chains and y Rx chains. Figure 5 shows examples of x TyR SRS antenna switching for UE architectures with $x = y/2$ Tx chains and y Rx chains.

[0056] In NR Rel-16, additional UE capabilities for SRS antenna-switching were introduced, which are shown in the right column of Table 1. Here, UE can indicate support for sounding only a subset of Rx antennas, which can save UE power consumption and SRS overhead at the cost of reduced channel knowledge at the gNB. For example, the UE capability *t1r1-t1r2* indicates that the gNB can configure one single-port SRS resource (no antenna switching) or two single-port SRS resources (same as for the capability *t1r2* described above) per SRS resource set with usage *antennaSwitching*.

[0057] In NR Rel-17, antenna switching was extended to up to 6 or 8 Rx ports, and 1, 2, or 4 Tx chains. UE can indicate support for antenna-switching configurations beyond 4 Rx via higher-layer parameter *srs-AntennaSwitchingBeyond4RX-r17* (see 3GPP TS 38.306 for further details).

[0058] SRS repetition and/or frequency hopping

[0059] Figure 6 illustrates SRS transmission over four symbols in one UL slot with frequency hopping. Figure 7 illustrates SRS transmission over four symbols in one UL slot with repetition. SRS coverage can be increased for an SRS resource through repetition and/or frequency hopping. An example of SRS frequency hopping is provided in Figure 6. Here, different parts of the SRS bandwidth are sounded in each of four different OFDM symbols, which means that SRS coverage improves (by four times compared to SRS transmission in a single symbol), at the cost of more symbols being used for SRS and a shorter sequence length per OFDM symbol. An example of SRS repetition is provided in Figure 6. Here, one SRS resource is repeated in four consecutive OFDM symbols, which means that SRS coverage improves (by four times compared SRS transmission in a single symbol) at the cost of more symbols being used for SRS and decreased SRS (multiplexing) capacity.

[0060] It is worth pointing out that SRS repetition and frequency hopping can be used together and, that for p-SRS/sp-SRS, the frequency-hopping pattern continues beyond the slot boundary. Figure 8 illustrates SRS transmission over two adjacent UL slots using both frequency hopping and repetition. In Figure 8, a p-SRS resource (with periodicity one) is shown over two adjacent UL slots. Here, the frequency-hopping configuration is the same as in Figure 6, the repetition factor is 2, and the number of SRS symbols per slot is 4. For ap-SRS, on the other hand, all parts of the configured bandwidth must be sounded within a slot.

SUMMARY

[0061] Systems and methods for Sounding Reference Signal (SRS) antenna switching for a three Transmit (TX) User Equipment (UE) are provided. In some embodiments, a method performed by a UE includes: transmitting a UE capability signaling indicating support for three transmit antennas; and receiving a Radio Resource Control (RRC) configuration to indicate that the UE should apply a first or a second antenna switching. In this way, the number of Orthogonal Frequency Division Multiplexing (OFDM) symbols required to sound a certain number of UE RX antennas is reduced compared to using legacy SRS antenna switching configurations.

[0062] In some embodiments, the first and the second antenna switching is one of: 3T6R or 4T8R antenna switching; 3T3R or 3T6R antenna switching; 3T8R antenna switching; and any combination of these. In some embodiments, the UE capability signaling comprises: a new bitfield that includes one or more of the following entries: {t3r3, t3r4r, t3r6, t3r8}.

[0063] In some embodiments, the UE capability signaling indicates if the UE supports one or more of the corresponding SRS antenna-switching configurations. In some embodiments, if the UE capability signaling indicates $txry$, the UE can be configured with $xTyR$ antenna switching.

[0064] In some embodiments, if a UE has 3 Tx and 4 Rx, the UE indicates support for legacy $t2r4$ antenna switching, which can be used to sound the 4 UE RX antennas in two OFDM symbols + one symbols gap period. In some embodiments, if a UE has 3Tx and 4 Rx, the UE indicates support for new $t3r3$ antenna switching. In some embodiments, the UE sounds 3 SRS ports two times, and 2 SRS ports a third time.

[0065] In some embodiments, three ports are contained in one or more SRS resources. In some embodiments, the three ports consist of one of the following: a 4-port SRS resource where the UE blanks one of the SRS ports; two or three concatenated SRS resources, where the total number of SRS ports over the concatenated SRS resources is equal to three; and a new three port SRS resource is introduced and used.

[0066] In some embodiments, the power scaling for all SRS ports should be the same, such that the UE should apply the same power per SRS port regardless of if there are two or three SRS ports transmitted per SRS resource. In some embodiments, for an SRS transmission occasion where an SRS resource containing m SRS ports is transmitted, belonging to an SRS resource set with usage 'antennaSwitching' including also, at least, one SRS resource with three ports, the SRS power is $m/3$ of the SRS power for an SRS transmission occasion where an SRS resource containing three SRS ports is transmitted.

[0067] In some embodiments, if the UE is configured with one or more SRS resource sets with usage antenna switching and where SRS resources with different number of ports are configured in the SRS resource sets, the UE knows that it should concatenate the SRS resources to build three-port SRS resources.

[0068] In some embodiments, receiving an additional configuration indicating that the UE should apply concatenation of SRS resources. In some embodiments, the RRC configuration is configured in SRS resource IE as specified in TS 38.331. In some embodiments, the RRC configuration is configured in SRS resource set IE as specified in TS 38.331.

BRIEF DESCRIPTION OF THE DRAWINGS

[0069] 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.

[0070] Figure 1 illustrates an example of how a Sounding Reference Signal (SRS) resource could be allocated in time and frequency within a slot in New Radio (NR) Rel-15/Rel-16/Rel-17;

[0071] Figure 2 illustrates multiplexing two and four single-port SRS resources (with varying comb offset) using comb 2 and 4, respectively;

[0072] Figure 3 illustrates multiplexing of SRS resources on a same comb offset;

[0073] Figures 4A and 4B illustrate spreading Cyclic Shifts (CSs) over two comb offsets for 4-port SRS resources configured with comb 4 (Figure 4A) and comb 8 (Figure 4B);

[0074] Figure 5 shows examples of x TyR SRS antenna switching for User Equipment (UE) architectures with $x = y/2$ Tx chains and y Rx chains;

[0075] Figure 6 illustrates SRS transmission over four symbols in one Uplink (UL) slot with frequency hopping;

[0076] Figure 7 illustrates SRS transmission over four symbols in one UL slot with repetition;

[0077] Figure 8 illustrates SRS transmission over two adjacent UL slots using both frequency hopping and repetition;

[0078] Figure 9 illustrates a method performed by a UE, according to some embodiments disclosed herein;

[0079] Figure 10 illustrates a method performed by a network node, according to some embodiments disclosed herein;

[0080] Figure 11 shows an example of a communication system in accordance with some embodiments;

[0081] Figure 12 shows a UE in accordance with some embodiments;

[0082] Figure 13 shows a network node in accordance with some embodiments;

[0083] Figure 14 is a block diagram of a host, which may be an embodiment of the host of Figure 11, in accordance with various aspects described herein;

[0084] Figure 15 is a block diagram illustrating a virtualization environment in which functions implemented by some embodiments may be virtualized; and

[0085] Figure 16 shows a communication diagram of a host communicating via a network node with a UE over a partially wireless connection in accordance with some embodiments.

DETAILED DESCRIPTION

[0086] 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 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.

[0087] Some of the embodiments contemplated herein will now be described more fully with reference to the accompanying drawings. Embodiments are provided by way of example to convey the scope of the subject matter to those skilled in the art.

[0088] There currently exist certain challenge(s). Legacy NR (i.e., up to Rel-18), specification supports UL transmission for 1, 2, 4, or 8 (in NR Rel-18) Tx chains. In practice, however, commercial UEs (e.g., smartphones) are restricted to 1—2 Tx chains due to factors such as PA cost and power consumption, and the limited size of commercial smartphones.

[0089] Recently, CPE devices (targeting FWA deployments) supporting three TX chains (e.g., MediaTek T830 CPE platform) have started to appear on the market. During recent trials, record-setting UL throughputs have been achieved for such devices via UL CA, where 1 Tx on a 2.1GHz FDD band was combined with 2 Tx a 3.5GHz TDD band. For NR to support such devices, during the RAN#101 plenary meeting, it was agreed that there will be a NR Rel-18 RAN4 work item on supporting 3 Tx UL transmission over two bands (RP-21719). However, 3 Tx UL transmission in a same band will not be supported in NR Rel-18. For this reason, 3 Tx UL transmission in a same cell has been proposed as a potential RAN1 work item in NR Rel-19 (RP-232612), with strong support from, in particular, chipset/device vendors and operators.

[0090] Legacy NR (i.e., up to Rel-18), does not support 3 Tx UL transmission in the same cell. For example, as explained herein, an SRS resource only can be configured with 1, 2, 4, or 8 SRS ports, a TPMI field can only indicate a precoder over 1, 2, 4 or 8 SRS ports, and an SRI field can only indicate up to 1, 2, 4 or 8 SRS resources.

[0091] For a 3 TX UE, the current specified antenna switching schemes are sub-optimal with regard to the number of OFDM symbols required for the SRS transmission, since the UE only would be able to use SRS antenna switching configurations with maximum 2 ports per SRS resource (corresponding to 2TyR antenna-switching configurations).

[0092] Certain aspects of the disclosure and their embodiments may provide solutions to these or other challenges. Some embodiments disclosed herein describe several methods on how to enable SRS antenna switching configurations for a UE with three TX chains.

[0093] Certain embodiments may provide one or more of the following technical advantages. The number of OFDM symbols required to sound a certain number of UE RX antennas is reduced compared to using legacy SRS antenna switching configurations.

[0094] The following embodiments are related to a UE with three TX chains.

[0095] Embodiment related to UE capability signaling

[0096] In one embodiment, a new bitfield is introduced during UE capability signaling that includes one or more of the following entries: {t3r3, t3r4r, t3r6, t3r8}, where a UE can indicate if it supports one or more of the corresponding SRS antenna-switching configurations. I.e., if NW receives UE capability signaling indicating t_{xry} , it can configure UE with $xTyR$ antenna switching.

[0097] In one embodiment, the t3r4 entry is removed and the bitfield can only indicate one or more of the following entries {t3r3, t3r6, t3r8}. In this case, if a UE has 3Tx and 4 Rx, the UE might instead indicate support for legacy t2r4 antenna switching, which can be used to sound the 4 UE RX antennas in two OFDM symbols + one symbols gap period, or new t3r3 antenna switching, which gives the NW only partial channel knowledge (i.e., 3 of 4 Rx antennas) at the cost of reduced UL overhead.

[0098] Embodiment related to T3R8 antenna switching

[0099] In one embodiment, SRS antenna switching configuration for t3r8 is introduced, where the UE sounds 3 SRS ports two times, and 2 SRS ports a third time, i.e., 3+3+2, i.e., different number of SRS ports are included in different SRS resources for antenna switching which is not the case in legacy NR). One benefit with this solution is that only 3 OFDM symbols (and 2 additional gap periods) compared to using t2r8, which requires 4 OFDM symbol (and 3 additional gap periods).

[0100] In one embodiment, the three ports are contained in one or more SRS resources consisting of one of the following options (see a related application).:

- A 4-port SRS resource where the UE blanks one of the SRS ports.
- Two or three concatenated SRS resources, where the total number of SRS ports over the concatenated SRS resources is equal to three (i.e., either 1+1+1 SRS ports for three different SRS resources or 1+2 SRS ports for two different SRS resources).
- A new three port SRS resource is introduced and used

[0101] In one embodiment, the power scaling for all SRS ports should be the same, such that the UE should apply the same power per SRS port regardless of if there are two or three SRS ports transmitted per SRS resource. I.e., for an SRS transmission occasion where an SRS resource containing m SRS ports is transmitted, belonging to an SRS resource set with usage 'antennaSwitching' including also, at least, one SRS resource with 3 ports, the SRS power is $m/3$

of the SRS power for an SRS transmission occasion where an SRS resource containing 3 SRS ports is transmitted. One benefit with this solution is that it simplifies the gNB channel estimation and precoder selection, since all the SRS are transmitted with the same output power.

[0102] Embodiments related to configuration of 3TyR SRS antenna switching for the case where a 4-port SRS resource is used and where one SRS port is dropped by the UE (more detailed information about this configuration is provided in a related application).

[0103] Currently the UE is configured with one or more SRS resource(s) in one or more SRS resource set(s) with usage antenna switching and depending on the number of SRS resources and the number of SRS ports per SRS resource, the UE knows which SRS antenna configuration to apply. However, in case the UE, e.g., supports both t36r and t48r, it will in this case be configured with two 4-port SRS resources with usage antenna switching, and the UE does not know whether it should apply 3T6R or 4T8R antenna switching. Hence, in one embodiment, an additional RRC configuration (e.g., a flag) is introduced, which can be used to indicate that the UE should apply one of the two options. In one embodiment, the RRC configuration is configured per in SRS resource IE as specified in TS 38.331. In one embodiment, the RRC configuration is configured per in SRS resource set IE as specified in TS 38.331.

[0104] Embodiments related to configuration of 3TyR SRS antenna switching for the case where a two or more SRS resources, either three single-port SRS resources, or one two port SRS resource and one single-port SRS resource, are concatenated to sound 3 SRS ports (more detailed information about this configuration is provided in see a related application).

[0105] Currently the UE is configured with one or more SRS resources in one or more SRS resource sets with usage antenna switching and depending on the number of SRS resources and the number of SRS ports per SRS resource, the UE knows which SRS antenna configuration to apply. However, in case the UE support t36r and where two or more SRS resources are concatenated to form a three-port SRS resource, this will not work anymore. Hence, in one embodiment, if the UE is configured with one or more SRS resource sets with usage antenna switching and where SRS resources with different number of ports are configured in the SRS resource sets, the UE knows that it should concatenate the SRS resources to build three-port SRS resources. So for example, a UE supporting 3t6r that is configured with an SRS resource set with usage antennaSwitching and where the SRS resource 1 has one SRS port, SRS resource 2 has two SRS ports, SRS resource 3 has 1 SRS port and SRS resource 4 has two SRS ports, the UE knows that it should concatenate e.g. SRS resource 1 and SRS resource 2 to one three port SRS resource, and concatenate SRS resource 3 and SRS resource 4 into one three-port SRS

resource, and therefore the UE knows that it should perform SRS antenna switching with usage 3t6r. This means that in a configuration for antenna switching, some of the SRS resources can be transmitted in the same OFDM symbol, while other SRS resource need to be transmitted in separate OFDM symbols (typically with a gap period in between), which differs from legacy NR where different SRS resources are always transmitted in different OFDM symbols with a gap period in between. For example, in the example mentioned above for 3t6r, a first 2-port SRS resource + a first single-port SRS resource can be configured/transmitted in one OFDM symbol, and a second 2-port SRS resource + a second single-port SRS resource can be configured/transmitted in another OFDM symbol, but the two single port SRS resources cannot be transmitted in a same OFDM symbol and the two 2-port SRS resource cannot be transmitted in the same OFDM symbol.

[0106] In one embodiment, an additional RRC configuration (e.g., a flag) is introduced, which can be used to indicate that the UE should apply concatenation of SRS resources and hence that the SRS configuration corresponds to one of the 3TyR SRS antenna switching configurations. In one embodiment, the RRC configuration is configured in SRS resource IE as specified in TS 38.331. In one embodiment, the RRC configuration is configured in SRS resource set IE as specified in TS 38.331.

[0107] Figure 9 illustrates a method performed by a UE, according to some embodiments disclosed herein. In some embodiments, the UE transmits (step 900) a UE capability signaling indicating support for three transmit antennas. In some embodiments, the UE receives (step 902) an additional (e.g., RRC) configuration (e.g., a flag) to indicate that the UE should apply 3T6R or 4T8R antenna switching. In some embodiments, the UE receives (904) an additional (e.g., RRC) configuration (e.g., a flag) indicating that the UE should apply concatenation of SRS resources (e.g., and hence that the SRS configuration corresponds to one of the 3TyR SRS antenna switching configurations).

[0108] Figure 10 illustrates a method performed by a network node, according to some embodiments disclosed herein. In some embodiments, the network node receives (step 1000) a UE capability signaling indicating support for three transmit antennas. In some embodiments, the network node transmits (step 1002) an additional (e.g., RRC) configuration (e.g., a flag) to indicate that the UE should apply 3T6R or 4T8R antenna switching. In some embodiments, the network node transmits (1004) an additional (e.g., RRC) configuration (e.g., a flag) indicating that the UE should apply concatenation of SRS resources (e.g., and hence that the SRS configuration corresponds to one of the 3TyR SRS antenna switching configurations).

[0109] Figure 11 shows an example of a communication system 1100 in accordance with some embodiments.

[0110] In the example, the communication system 1100 includes a telecommunication network 1102 that includes an access network 1104, such as a Radio Access Network (RAN), and a core network 1106, which includes one or more core network nodes 1108. The access network 1104 includes one or more access network nodes, such as network nodes 1110A and 1110B (one or more of which may be generally referred to as network nodes 1110), or any other similar Third Generation Partnership Project (3GPP) access nodes or non-3GPP Access Points (APs). Moreover, as will be appreciated by those of skill in the art, a network node is not necessarily limited to an implementation in which a radio portion and a baseband portion are supplied and integrated by a single vendor. Thus, it will be understood that network nodes include disaggregated implementations or portions thereof. For example, in some embodiments, the telecommunication network 1102 includes one or more Open-RAN (ORAN) network nodes. An ORAN network node is a node in the telecommunication network 1102 that supports an ORAN specification (e.g., a specification published by the O-RAN Alliance, or any similar organization) and may operate alone or together with other nodes to implement one or more functionalities of any node in the telecommunication network 1102, including one or more network nodes 1110 and/or core network nodes 1108.

[0111] Examples of an ORAN network node include an Open Radio Unit (O-RU), an Open Distributed Unit (O-DU), an Open Central Unit (O-CU), including an O-CU Control Plane (O-CU-CP) or an O-CU User Plane (O-CU-UP), a RAN intelligent controller (near-real time or non-real time) hosting software or software plug-ins, such as a near-real time control application (e.g., xApp) or a non-real time control application (e.g., rApp), or any combination thereof (the adjective “open” designating support of an ORAN specification). The network node may support a specification by, for example, supporting an interface defined by the ORAN specification, such as an A1, F1, W1, E1, E2, X2, Xn interface, an open fronthaul user plane interface, or an open fronthaul management plane interface. Moreover, an ORAN access node may be a logical node in a physical node. Furthermore, an ORAN network node may be implemented in a virtualization environment (described further below) in which one or more network functions are virtualized. For example, the virtualization environment may include an O-Cloud computing platform orchestrated by a Service Management and Orchestration Framework via an O-2 interface defined by the O-RAN Alliance or comparable technologies. The network nodes 1110 facilitate direct or indirect connection of User Equipment (UE), such as by connecting UEs 1112A, 1112B, 1112C,

and 1112D (one or more of which may be generally referred to as UEs 1112) to the core network 1106 over one or more wireless connections.

[0112] Example wireless communications over a wireless connection include transmitting and/or receiving wireless signals using electromagnetic waves, radio waves, infrared waves, and/or other types of signals suitable for conveying information without the use of wires, cables, or other material conductors. Moreover, in different embodiments, the communication system 1100 may include any number of wired or wireless networks, network nodes, UEs, 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. The communication system 1100 may include and/or interface with any type of communication, telecommunication, data, cellular, radio network, and/or other similar type of system.

[0113] The UEs 1112 may be any of a wide variety of communication devices, including wireless devices arranged, configured, and/or operable to communicate wirelessly with the network nodes 1110 and other communication devices. Similarly, the network nodes 1110 are arranged, capable, configured, and/or operable to communicate directly or indirectly with the UEs 1112 and/or with other network nodes or equipment in the telecommunication network 1102 to enable and/or provide network access, such as wireless network access, and/or to perform other functions, such as administration in the telecommunication network 1102.

[0114] In the depicted example, the core network 1106 connects the network nodes 1110 to one or more hosts, such as host 1116. These connections may be direct or indirect via one or more intermediary networks or devices. In other examples, network nodes may be directly coupled to hosts. The core network 1106 includes one more core network nodes (e.g., core network node 1108) that are structured with hardware and software components. Features of these components may be substantially similar to those described with respect to the UEs, network nodes, and/or hosts, such that the descriptions thereof are generally applicable to the corresponding components of the core network node 1108. Example core network nodes include functions of one or more of a Mobile Switching Center (MSC), Mobility Management Entity (MME), Home Subscriber Server (HSS), Access and Mobility Management Function (AMF), Session Management Function (SMF), Authentication Server Function (AUSF), Subscription Identifier De-Concealing Function (SIDF), Unified Data Management (UDM), Security Edge Protection Proxy (SEPP), Network Exposure Function (NEF), and/or a User Plane Function (UPF).

[0115] The host 1116 may be under the ownership or control of a service provider other than an operator or provider of the access network 1104 and/or the telecommunication network 1102 and may be operated by the service provider or on behalf of the service provider. The host 1116

may host a variety of applications to provide one or more service. Examples of such applications include live and pre-recorded audio/video content, data collection services such as retrieving and compiling data on various ambient conditions detected by a plurality of UEs, analytics functionality, social media, functions for controlling or otherwise interacting with remote devices, functions for an alarm and surveillance center, or any other such function performed by a server.

[0116] As a whole, the communication system 1100 of Figure 11 enables connectivity between the UEs, network nodes, and hosts. In that sense, the communication system 1100 may be configured to operate according to predefined rules or procedures, such as specific standards that include, but are not limited to: Global System for Mobile Communications (GSM); Universal Mobile Telecommunications System (UMTS); Long Term Evolution (LTE), and/or other suitable Second, Third, Fourth, or Fifth Generation (2G, 3G, 4G, or 5G) standards, or any applicable future generation standard (e.g., Sixth Generation (6G)); Wireless Local Area Network (WLAN) standards, such as the Institute of Electrical and Electronics Engineers (IEEE) 802.11 standards (WiFi); and/or any other appropriate wireless communication standard, such as the Worldwide Interoperability for Microwave Access (WiMax), Bluetooth, Z-Wave, Near Field Communication (NFC) ZigBee, LiFi, and/or any Low Power Wide Area Network (LPWAN) standards such as LoRa and Sigfox.

[0117] In some examples, the telecommunication network 1102 is a cellular network that implements 3GPP standardized features. Accordingly, the telecommunication network 1102 may support network slicing to provide different logical networks to different devices that are connected to the telecommunication network 1102. For example, the telecommunication network 1102 may provide Ultra Reliable Low Latency Communication (URLLC) services to some UEs, while providing enhanced Mobile Broadband (eMBB) services to other UEs, and/or massive Machine Type Communication (mMTC)/massive Internet of Things (IoT) services to yet further UEs.

[0118] In some examples, the UEs 1112 are configured to transmit and/or receive information without direct human interaction. For instance, a UE may be designed to transmit information to the access network 1104 on a predetermined schedule, when triggered by an internal or external event, or in response to requests from the access network 1104. Additionally, a UE may be configured for operating in single- or multi-Radio Access Technology (RAT) or multi-standard mode. For example, a UE may operate with any one or combination of WiFi, New Radio (NR), and LTE, i.e., being configured for Multi-Radio Dual Connectivity (MR-DC), such as Evolved UMTS Terrestrial RAN (E-UTRAN) NR - Dual Connectivity (EN-DC).

[0119] In the example, a hub 1114 communicates with the access network 1104 to facilitate indirect communication between one or more UEs (e.g., UE 1112C and/or 1112D) and network nodes (e.g., network node 1110B). In some examples, the hub 1114 may be a controller, router, content source and analytics, or any of the other communication devices described herein regarding UEs. For example, the hub 1114 may be a broadband router enabling access to the core network 1106 for the UEs. As another example, the hub 1114 may be a controller that sends commands or instructions to one or more actuators in the UEs. Commands or instructions may be received from the UEs, network nodes 1110, or by executable code, script, process, or other instructions in the hub 1114. As another example, the hub 1114 may be a data collector that acts as temporary storage for UE data and, in some embodiments, may perform analysis or other processing of the data. As another example, the hub 1114 may be a content source. For example, for a UE that is a Virtual Reality (VR) headset, display, loudspeaker or other media delivery device, the hub 1114 may retrieve VR assets, video, audio, or other media or data related to sensory information via a network node, which the hub 1114 then provides to the UE either directly, after performing local processing, and/or after adding additional local content. In still another example, the hub 1114 acts as a proxy server or orchestrator for the UEs, in particular if one or more of the UEs are low energy IoT devices.

[0120] The hub 1114 may have a constant/persistent or intermittent connection to the network node 1110B. The hub 1114 may also allow for a different communication scheme and/or schedule between the hub 1114 and UEs (e.g., UE 1112C and/or 1112D), and between the hub 1114 and the core network 1106. In other examples, the hub 1114 is connected to the core network 1106 and/or one or more UEs via a wired connection. Moreover, the hub 1114 may be configured to connect to a Machine-to-Machine (M2M) service provider over the access network 1104 and/or to another UE over a direct connection. In some scenarios, UEs may establish a wireless connection with the network nodes 1110 while still connected via the hub 1114 via a wired or wireless connection. In some embodiments, the hub 1114 may be a dedicated hub – that is, a hub whose primary function is to route communications to/from the UEs from/to the network node 1110B. In other embodiments, the hub 1114 may be a non-dedicated hub – that is, a device which is capable of operating to route communications between the UEs and the network node 1110B, but which is additionally capable of operating as a communication start and/or end point for certain data channels.

[0121] Figure 12 shows a UE 1200 in accordance with some embodiments. As used herein, a UE refers to a device capable, configured, arranged, and/or operable to communicate wirelessly with network nodes and/or other UEs. Examples of a UE include, but are not limited to, a smart

phone, mobile phone, cell phone, Voice over Internet Protocol (VoIP) phone, wireless local loop phone, desktop computer, Personal Digital Assistant (PDA), wireless camera, gaming console or device, music storage device, playback appliance, wearable terminal device, wireless endpoint, mobile station, tablet, laptop, Laptop Embedded Equipment (LEE), Laptop Mounted Equipment (LME), smart device, wireless Customer Premise Equipment (CPE), vehicle, vehicle-mounted or vehicle embedded/integrated wireless device, etc. Other examples include any UE identified by the 3GPP, including a Narrowband Internet of Things (NB-IoT) UE, a Machine Type Communication (MTC) UE, and/or an enhanced MTC (eMTC) UE.

[0122] A UE may support Device-to-Device (D2D) communication, for example by implementing a 3GPP standard for sidelink communication, Dedicated Short-Range Communication (DSRC), Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I), or Vehicle-to-Everything (V2X). In other examples, a 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 (e.g., a smart sprinkler controller). Alternatively, a UE may represent a device that is not intended for sale to, or operation by, an end user but which may be associated with or operated for the benefit of a user (e.g., a smart power meter).

[0123] The UE 1200 includes processing circuitry 1202 that is operatively coupled via a bus 1204 to an input/output interface 1206, a power source 1208, memory 1210, a communication interface 1212, and/or any other component, or any combination thereof. Certain UEs may utilize all or a subset of the components shown in Figure 12. 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.

[0124] The processing circuitry 1202 is configured to process instructions and data and may be configured to implement any sequential state machine operative to execute instructions stored as machine-readable computer programs in the memory 1210. The processing circuitry 1202 may be implemented as one or more hardware-implemented state machines (e.g., in discrete logic, Field Programmable Gate Arrays (FPGAs), Application Specific Integrated Circuits (ASICs), etc.); programmable logic together with appropriate firmware; one or more stored computer programs, 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 1202 may include multiple Central Processing Units (CPUs).

[0125] In the example, the input/output interface 1206 may be configured to provide an interface or interfaces to an input device, output device, or one or more input and/or output devices. Examples of an output device include 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. An input device may allow a user to capture information into the UE 1200. Examples of an input device 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, a biometric sensor, etc., or any combination thereof. An output device may use the same type of interface port as an input device. For example, a Universal Serial Bus (USB) port may be used to provide an input device and an output device.

[0126] In some embodiments, the power source 1208 is structured as a battery or battery pack. Other types of power sources, such as an external power source (e.g., an electricity outlet), photovoltaic device, or power cell, may be used. The power source 1208 may further include power circuitry for delivering power from the power source 1208 itself, and/or an external power source, to the various parts of the UE 1200 via input circuitry or an interface such as an electrical power cable. Delivering power may be, for example, for charging of the power source 1208. Power circuitry may perform any formatting, converting, or other modification to the power from the power source 1208 to make the power suitable for the respective components of the UE 1200 to which power is supplied.

[0127] The memory 1210 may be or be configured to include memory such as Random Access Memory (RAM), Read Only Memory (ROM), Programmable ROM (PROM), Erasable PROM (EPROM), Electrically EPROM (EEPROM), magnetic disks, optical disks, hard disks, removable cartridges, flash drives, and so forth. In one example, the memory 1210 includes one or more application programs 1214, such as an operating system, web browser application, a widget, gadget engine, or other application, and corresponding data 1216. The memory 1210 may store, for use by the UE 1200, any of a variety of various operating systems or combinations of operating systems.

[0128] The memory 1210 may be configured to include a number of physical drive units, such as Redundant Array of Independent Disks (RAID), flash 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 RAM (SDRAM), external micro-DIMM SDRAM, smartcard memory such as a tamper resistant module in the form of a Universal Integrated Circuit Card (UICC) including one or more Subscriber Identity Modules (SIMs), such as a Universal SIM (USIM) and/or Internet Protocol Multimedia Services Identity Module (ISIM), other memory, or any combination thereof. The UICC may for example be an embedded UICC (eUICC), integrated UICC (iUICC) or a removable UICC commonly known as a 'SIM card.' The memory 1210 may allow the UE 1200 to access instructions, application programs, and 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 as or in the memory 1210, which may be or comprise a device-readable storage medium.

[0129] The processing circuitry 1202 may be configured to communicate with an access network or other network using the communication interface 1212. The communication interface 1212 may comprise one or more communication subsystems and may include or be communicatively coupled to an antenna 1222. The communication interface 1212 may include one or more transceivers used to communicate, such as by communicating with one or more remote transceivers of another device capable of wireless communication (e.g., another UE or a network node in an access network). Each transceiver may include a transmitter 1218 and/or a receiver 1220 appropriate to provide network communications (e.g., optical, electrical, frequency allocations, and so forth). Moreover, the transmitter 1218 and receiver 1220 may be coupled to one or more antennas (e.g., the antenna 1222) and may share circuit components, software, or firmware, or alternatively be implemented separately.

[0130] In the illustrated embodiment, communication functions of the communication interface 1212 may include cellular communication, WiFi communication, LPWAN communication, data communication, voice communication, multimedia communication, short-range communications such as Bluetooth, NFC, 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. Communications may be implemented according to one or more communication protocols and/or standards, such as IEEE 802.11, Code Division Multiplexing Access (CDMA), Wideband CDMA (WCDMA), GSM, LTE, NR, UMTS, WiMax, Ethernet, Transmission Control Protocol/Internet Protocol (TCP/IP), Synchronous Optical Networking (SONET), Asynchronous Transfer Mode (ATM), Quick User Datagram Protocol Internet Connection (QUIC), Hypertext Transfer Protocol (HTTP), and so forth.

[0131] Regardless of the type of sensor, a UE may provide an output of data captured by its sensors, through its communication interface 1212, via a wireless connection to a network node. Data captured by sensors of a UE can be communicated through a wireless connection to a network node via another UE. The output may be periodic (e.g., once every 15 minutes if it reports the sensed temperature), random (e.g., to even out the load from reporting from several sensors), in response to a triggering event (e.g., when moisture is detected an alert is sent), in response to a request (e.g., a user initiated request), or a continuous stream (e.g., a live video feed of a patient).

[0132] As another example, a UE comprises an actuator, a motor, or a switch related to a communication interface configured to receive wireless input from a network node via a wireless connection. In response to the received wireless input the states of the actuator, the motor, or the switch may change. For example, the UE may comprise a motor that adjusts the control surfaces or rotors of a drone in flight according to the received input or to a robotic arm performing a medical procedure according to the received input.

[0133] A UE, when in the form of an IoT device, may be a device for use in one or more application domains, these domains comprising, but not limited to, city wearable technology, extended industrial application, and healthcare. Non-limiting examples of such an IoT device are a device which is or which is embedded in: a connected refrigerator or freezer, a television, a connected lighting device, an electricity meter, a robot vacuum cleaner, a voice controlled smart speaker, a home security camera, a motion detector, a thermostat, a smoke detector, a door/window sensor, a flood/moisture sensor, an electrical door lock, a connected doorbell, an air conditioning system like a heat pump, an autonomous vehicle, a surveillance system, a weather monitoring device, a vehicle parking monitoring device, an electric vehicle charging station, a smart watch, a fitness tracker, a head-mounted display for Augmented Reality (AR) or VR, a wearable for tactile augmentation or sensory enhancement, a water sprinkler, an animal- or item-tracking device, a sensor for monitoring a plant or animal, an industrial robot, an Unmanned Aerial Vehicle (UAV), and any kind of medical device, like a heart rate monitor or a remote controlled surgical robot. A UE in the form of an IoT device comprises circuitry and/or software in dependence of the intended application of the IoT device in addition to other components as described in relation to the UE 1200 shown in Figure 12.

[0134] As yet another specific example, in an IoT scenario, a UE 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 UE and/or a network node. The UE may in this case be an M2M device, which may in a 3GPP context be referred to as an MTC device. As one particular example, the UE may implement the 3GPP NB-IoT standard. In other scenarios, a UE

may represent a vehicle, such as a car, a bus, a truck, a ship, an airplane, or other equipment that is capable of monitoring and/or reporting on its operational status or other functions associated with its operation.

[0135] In practice, any number of UEs may be used together with respect to a single use case. For example, a first UE might be or be integrated in a drone and provide the drone's speed information (obtained through a speed sensor) to a second UE that is a remote controller operating the drone. When the user makes changes from the remote controller, the first UE may adjust the throttle on the drone (e.g., by controlling an actuator) to increase or decrease the drone's speed. The first and/or the second UE can also include more than one of the functionalities described above. For example, a UE might comprise the sensor and the actuator and handle communication of data for both the speed sensor and the actuators.

[0136] Figure 13 shows a network node 1300 in accordance with some embodiments. As used herein, network node refers to equipment capable, configured, arranged, and/or operable to communicate directly or indirectly with a UE and/or with other network nodes or equipment in a telecommunication network. Examples of network nodes include, but are not limited to, APs (e.g., radio APs), Base Stations (BSs) (e.g., radio BSs, Node Bs, evolved Node Bs (eNBs), NR Node Bs (gNBs)), and O-RAN nodes or components of an O-RAN node (e.g., O-RU, O-DU, O-CU).

[0137] Base stations may be categorized based on the amount of coverage they provide (or, stated differently, their transmit power level) and so, depending on the provided amount of coverage, may 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 all) parts of a distributed radio base station such as centralized digital units, distributed units (e.g., in an O-RAN access node), and/or Remote Radio Units (RRUs), sometimes referred to as Remote Radio Heads (RRHs). Such RRUs 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).

[0138] Other examples of network nodes include multiple Transmission Point (multi-TRP) 5G access nodes, Multi-Standard Radio (MSR) equipment such as MSR BSs, network controllers such as Radio Network Controllers (RNCs) or BS Controllers (BSCs), Base Transceiver Stations (BTSs), transmission points, transmission nodes, Multi-Cell/Multicast Coordination Entities (MCEs), Operation and Maintenance (O&M) nodes, Operations Support System (OSS) nodes, Self-Organizing Network (SON) nodes, positioning nodes (e.g., Evolved Serving Mobile Location Centers (E-SMLCs)), and/or Minimization of Drive Tests (MDTs).

[0139] The network node 1300 includes processing circuitry 1302, memory 1304, a communication interface 1306, and a power source 1308. The network node 1300 may be composed of multiple physically separate components (e.g., a NodeB component and an RNC component, or a BTS component and a BSC component, etc.), which may each have their own respective components. In certain scenarios in which the network node 1300 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, the network node 1300 may be configured to support multiple RATs. In such embodiments, some components may be duplicated (e.g., separate memory 1304 for different RATs) and some components may be reused (e.g., a same antenna 1310 may be shared by different RATs). The network node 1300 may also include multiple sets of the various illustrated components for different wireless technologies integrated into network node 1300, for example GSM, WCDMA, LTE, NR, WiFi, Zigbee, Z-wave, Long Range Wide Area Network (LoRaWAN), Radio Frequency Identification (RFID), or Bluetooth wireless technologies. These wireless technologies may be integrated into the same or different chip or set of chips and other components within the network node 1300.

[0140] The processing circuitry 1302 may comprise a combination of one or more of a microprocessor, controller, microcontroller, CPU, DSP, ASIC, FPGA, 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 1300 components, such as the memory 1304, to provide network node 1300 functionality.

[0141] In some embodiments, the processing circuitry 1302 includes a System on a Chip (SOC). In some embodiments, the processing circuitry 1302 includes one or more of Radio Frequency (RF) transceiver circuitry 1312 and baseband processing circuitry 1314. In some embodiments, the RF transceiver circuitry 1312 and the baseband processing circuitry 1314 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 the RF transceiver circuitry 1312 and the baseband processing circuitry 1314 may be on the same chip or set of chips, boards, or units.

[0142] The memory 1304 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, RAM, 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 the processing circuitry 1302. The memory 1304 may store any suitable instructions, data, or information, including a computer program, software, an application including one or more of logic, rules, code, tables, and/or other instructions capable of being executed by the processing circuitry 1302 and utilized by the network node 1300. The memory 1304 may be used to store any calculations made by the processing circuitry 1302 and/or any data received via the communication interface 1306. In some embodiments, the processing circuitry 1302 and the memory 1304 are integrated.

[0143] The communication interface 1306 is used in wired or wireless communication of signaling and/or data between a network node, access network, and/or UE. As illustrated, the communication interface 1306 comprises port(s)/terminal(s) 1316 to send and receive data, for example to and from a network over a wired connection. The communication interface 1306 also includes radio front-end circuitry 1318 that may be coupled to, or in certain embodiments a part of, the antenna 1310. The radio front-end circuitry 1318 comprises filters 1320 and amplifiers 1322. The radio front-end circuitry 1318 may be connected to the antenna 1310 and the processing circuitry 1302. The radio front-end circuitry 1318 may be configured to condition signals communicated between the antenna 1310 and the processing circuitry 1302. The radio front-end circuitry 1318 may receive digital data that is to be sent out to other network nodes or UEs via a wireless connection. The radio front-end circuitry 1318 may convert the digital data into a radio signal having the appropriate channel and bandwidth parameters using a combination of the filters 1320 and/or the amplifiers 1322. The radio signal may then be transmitted via the antenna 1310. Similarly, when receiving data, the antenna 1310 may collect radio signals which are then converted into digital data by the radio front-end circuitry 1318. The digital data may be passed to the processing circuitry 1302. In other embodiments, the communication interface 1306 may comprise different components and/or different combinations of components.

[0144] In certain alternative embodiments, the network node 1300 does not include separate radio front-end circuitry 1318; instead, the processing circuitry 1302 includes radio front-end circuitry and is connected to the antenna 1310. Similarly, in some embodiments, all or some of the RF transceiver circuitry 1312 is part of the communication interface 1306. In still other embodiments, the communication interface 1306 includes the one or more ports or terminals 1316, the radio front-end circuitry 1318, and the RF transceiver circuitry 1312 as part of a radio unit (not shown), and the communication interface 1306 communicates with the baseband processing circuitry 1314, which is part of a digital unit (not shown).

[0145] The antenna 1310 may include one or more antennas, or antenna arrays, configured to send and/or receive wireless signals. The antenna 1310 may be coupled to the radio front-end circuitry 1318 and may be any type of antenna capable of transmitting and receiving data and/or signals wirelessly. In certain embodiments, the antenna 1310 is separate from the network node 1300 and connectable to the network node 1300 through an interface or port.

[0146] The antenna 1310, the communication interface 1306, and/or the processing circuitry 1302 may be configured to perform any receiving operations and/or certain obtaining operations described herein as being performed by the network node 1300. Any information, data, and/or signals may be received from a UE, another network node, and/or any other network equipment. Similarly, the antenna 1310, the communication interface 1306, and/or the processing circuitry 1302 may be configured to perform any transmitting operations described herein as being performed by the network node 1300. Any information, data, and/or signals may be transmitted to a UE, another network node, and/or any other network equipment.

[0147] The power source 1308 provides power to the various components of the network node 1300 in a form suitable for the respective components (e.g., at a voltage and current level needed for each respective component). The power source 1308 may further comprise, or be coupled to, power management circuitry to supply the components of the network node 1300 with power for performing the functionality described herein. For example, the network node 1300 may be connectable to an external power source (e.g., the power grid or an electricity outlet) via input circuitry or an interface such as an electrical cable, whereby the external power source supplies power to power circuitry of the power source 1308. As a further example, the power source 1308 may comprise a source of power in the form of a battery or battery pack which is connected to, or integrated in, power circuitry. The battery may provide backup power should the external power source fail.

[0148] Embodiments of the network node 1300 may include additional components beyond those shown in Figure 13 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. For example, the network node 1300 may include user interface equipment to allow input of information into the network node 1300 and to allow output of information from the network node 1300. This may allow a user to perform diagnostic, maintenance, repair, and other administrative functions for the network node 1300.

[0149] Figure 14 is a block diagram of a host 1400, which may be an embodiment of the host 1116 of Figure 11, in accordance with various aspects described herein. As used herein, the host 1400 may be or comprise various combinations of hardware and/or software including a

standalone server, a blade server, a cloud-implemented server, a distributed server, a virtual machine, container, or processing resources in a server farm. The host 1400 may provide one or more services to one or more UEs.

[0150] The host 1400 includes processing circuitry 1402 that is operatively coupled via a bus 1404 to an input/output interface 1406, a network interface 1408, a power source 1410, and memory 1412. Other components may be included in other embodiments. Features of these components may be substantially similar to those described with respect to the devices of previous figures, such as Figures 12 and 13, such that the descriptions thereof are generally applicable to the corresponding components of the host 1400.

[0151] The memory 1412 may include one or more computer programs including one or more host application programs 1414 and data 1416, which may include user data, e.g., data generated by a UE for the host 1400 or data generated by the host 1400 for a UE. Embodiments of the host 1400 may utilize only a subset or all of the components shown. The host application programs 1414 may be implemented in a container-based architecture and may provide support for video codecs (e.g., Versatile Video Coding (VVC), High Efficiency Video Coding (HEVC), Advanced Video Coding (AVC), Moving Picture Experts Group (MPEG), VP9) and audio codecs (e.g., Free Lossless Audio Codec (FLAC), Advanced Audio Coding (AAC), MPEG, G.711), including transcoding for multiple different classes, types, or implementations of UEs (e.g., handsets, desktop computers, wearable display systems, and heads-up display systems). The host application programs 1414 may also provide for user authentication and licensing checks and may periodically report health, routes, and content availability to a central node, such as a device in or on the edge of a core network. Accordingly, the host 1400 may select and/or indicate a different host for Over-The-Top (OTT) services for a UE. The host application programs 1414 may support various protocols, such as the HTTP Live Streaming (HLS) protocol, Real-Time Messaging Protocol (RTMP), Real-Time Streaming Protocol (RTSP), Dynamic Adaptive Streaming over HTTP (DASH or MPEG-DASH), etc.

[0152] Figure 15 is a block diagram illustrating a virtualization environment 1500 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 any device described herein, 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. Some or all of the functions described herein may be implemented as virtual components executed by one or more Virtual Machines (VMs) implemented in one or more virtual

environments 1500 hosted by one or more of hardware nodes, such as a hardware computing device that operates as a network node, UE, core network node, or host. Further, in embodiments in which the virtual node does not require radio connectivity (e.g., a core network node or host), then the node may be entirely virtualized. In some embodiments, the virtualization environment 1500 includes components defined by the O-RAN Alliance, such as an O-Cloud environment orchestrated by a Service Management and Orchestration Framework via an O-2 interface.

[0153] Applications 1502 (which may alternatively be called software instances, virtual appliances, network functions, virtual nodes, virtual network functions, etc.) are run in the virtualization environment 1500 to implement some of the features, functions, and/or benefits of some of the embodiments disclosed herein.

[0154] Hardware 1504 includes processing circuitry, memory that stores software and/or instructions executable by hardware processing circuitry, and/or other hardware devices as described herein, such as a network interface, input/output interface, and so forth. Software may be executed by the processing circuitry to instantiate one or more virtualization layers 1506 (also referred to as hypervisors or VM Monitors (VMMs)), provide VMs 1508A and 1508B (one or more of which may be generally referred to as VMs 1508), and/or perform any of the functions, features, and/or benefits described in relation with some embodiments described herein. The virtualization layer 1506 may present a virtual operating platform that appears like networking hardware to the VMs 1508.

[0155] The VMs 1508 comprise virtual processing, virtual memory, virtual networking, or interface and virtual storage, and may be run by a corresponding virtualization layer 1506. Different embodiments of the instance of a virtual appliance 1502 may be implemented on one or more of the VMs 1508, and the implementations may be made in different ways. 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, which can be located in data centers and customer premise equipment.

[0156] In the context of NFV, a VM 1508 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 the VMs 1508, and that part of the hardware 1504 that executes that VM, be it hardware dedicated to that VM and/or hardware shared by that VM with others of the VMs 1508, forms separate virtual network elements. Still in the context of NFV, a virtual network function is responsible for handling specific network functions that run in one or more VMs 1508 on top of the hardware 1504 and corresponds to the application 1502.

[0157] The hardware 1504 may be implemented in a standalone network node with generic or specific components. The hardware 1504 may implement some functions via virtualization. Alternatively, the hardware 1504 may be part of a larger cluster of hardware (e.g., such as in a data center or CPE) where many hardware nodes work together and are managed via management and orchestration 1510, which, among others, oversees lifecycle management of the applications 1502. In some embodiments, the hardware 1504 is coupled to one or more radio units that each include one or more transmitters and one or more receivers that may be coupled to one or more antennas. Radio units may communicate directly with other hardware nodes 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 RAN or a base station. In some embodiments, some signaling can be provided with the use of a control system 1512 which may alternatively be used for communication between hardware nodes and radio units.

[0158] Figure 16 shows a communication diagram of a host 1602 communicating via a network node 1604 with a UE 1606 over a partially wireless connection in accordance with some embodiments. Example implementations, in accordance with various embodiments, of the UE (such as the UE 1112A of Figure 11 and/or the UE 1200 of Figure 12), the network node (such as the network node 1110A of Figure 11 and/or the network node 1300 of Figure 13), and the host (such as the host 1116 of Figure 11 and/or the host 1400 of Figure 14) discussed in the preceding paragraphs will now be described with reference to Figure 16.

[0159] Like the host 1400, embodiments of the host 1602 include hardware, such as a communication interface, processing circuitry, and memory. The host 1602 also includes software, which is stored in or is accessible by the host 1602 and executable by the processing circuitry. The software includes a host application that may be operable to provide a service to a remote user, such as the UE 1606 connecting via an OTT connection 1650 extending between the UE 1606 and the host 1602. In providing the service to the remote user, a host application may provide user data which is transmitted using the OTT connection 1650.

[0160] The network node 1604 includes hardware enabling it to communicate with the host 1602 and the UE 1606. The connection 1660 may be direct or pass through a core network (like the core network 1106 of Figure 11) and/or one or more other intermediate networks, such as one or more public, private, or hosted networks. For example, an intermediate network may be a backbone network or the Internet.

[0161] The UE 1606 includes hardware and software, which is stored in or accessible by the UE 1606 and executable by the UE's processing circuitry. The software includes a client application, such as a web browser or operator-specific "app" that may be operable to provide a

service to a human or non-human user via the UE 1606 with the support of the host 1602. In the host 1602, an executing host application may communicate with the executing client application via the OTT connection 1650 terminating at the UE 1606 and the host 1602. In providing the service to the user, the UE's client application may receive request data from the host's host application and provide user data in response to the request data. The OTT connection 1650 may transfer both the request data and the user data. The UE's client application may interact with the user to generate the user data that it provides to the host application through the OTT connection 1650.

[0162] The OTT connection 1650 may extend via the connection 1660 between the host 1602 and the network node 1604 and via a wireless connection 1670 between the network node 1604 and the UE 1606 to provide the connection between the host 1602 and the UE 1606. The connection 1660 and the wireless connection 1670, over which the OTT connection 1650 may be provided, have been drawn abstractly to illustrate the communication between the host 1602 and the UE 1606 via the network node 1604, without explicit reference to any intermediary devices and the precise routing of messages via these devices.

[0163] As an example of transmitting data via the OTT connection 1650, in step 1608, the host 1602 provides user data, which may be performed by executing a host application. In some embodiments, the user data is associated with a particular human user interacting with the UE 1606. In other embodiments, the user data is associated with a UE 1606 that shares data with the host 1602 without explicit human interaction. In step 1610, the host 1602 initiates a transmission carrying the user data towards the UE 1606. The host 1602 may initiate the transmission responsive to a request transmitted by the UE 1606. The request may be caused by human interaction with the UE 1606 or by operation of the client application executing on the UE 1606. The transmission may pass via the network node 1604 in accordance with the teachings of the embodiments described throughout this disclosure. Accordingly, in step 1612, the network node 1604 transmits to the UE 1606 the user data that was carried in the transmission that the host 1602 initiated, in accordance with the teachings of the embodiments described throughout this disclosure. In step 1614, the UE 1606 receives the user data carried in the transmission, which may be performed by a client application executed on the UE 1606 associated with the host application executed by the host 1602.

[0164] In some examples, the UE 1606 executes a client application which provides user data to the host 1602. The user data may be provided in reaction or response to the data received from the host 1602. Accordingly, in step 1616, the UE 1606 may provide user data, which may be performed by executing the client application. In providing the user data, the client application

may further consider user input received from the user via an input/output interface of the UE 1606. Regardless of the specific manner in which the user data was provided, the UE 1606 initiates, in step 1618, transmission of the user data towards the host 1602 via the network node 1604. In step 1620, in accordance with the teachings of the embodiments described throughout this disclosure, the network node 1604 receives user data from the UE 1606 and initiates transmission of the received user data towards the host 1602. In step 1622, the host 1602 receives the user data carried in the transmission initiated by the UE 1606.

[0165] One or more of the various embodiments improve the performance of OTT services provided to the UE 1606 using the OTT connection 1650, in which the wireless connection 1670 forms the last segment. More precisely, the teachings of these embodiments may improve the e.g., data rate, latency, power consumption, etc. and thereby provide benefits such as e.g., reduced user waiting, relaxed restriction on file size, improved content resolution, better responsiveness, extended battery lifetime, etc.

[0166] In an example scenario, factory status information may be collected and analyzed by the host 1602. As another example, the host 1602 may process audio and video data which may have been retrieved from a UE for use in creating maps. As another example, the host 1602 may collect and analyze real-time data to assist in controlling vehicle congestion (e.g., controlling traffic lights). As another example, the host 1602 may store surveillance video uploaded by a UE. As another example, the host 1602 may store or control access to media content such as video, audio, VR, or AR which it can broadcast, multicast, or unicast to UEs. As other examples, the host 1602 may be used for energy pricing, remote control of non-time critical electrical load to balance power generation needs, location services, presentation services (such as compiling diagrams etc. from data collected from remote devices), or any other function of collecting, retrieving, storing, analyzing, and/or transmitting data.

[0167] In some examples, 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 the OTT connection 1650 between the host 1602 and the UE 1606 in response to variations in the measurement results. The measurement procedure and/or the network functionality for reconfiguring the OTT connection 1650 may be implemented in software and hardware of the host 1602 and/or the UE 1606. In some embodiments, sensors (not shown) may be deployed in or in association with other devices through which the OTT connection 1650 passes; the sensors may participate in the measurement procedure by supplying values of the monitored quantities exemplified above, or by supplying values of other physical quantities from which software may compute or estimate the monitored

quantities. The reconfiguring of the OTT connection 1650 may include message format, retransmission settings, preferred routing, etc.; the reconfiguring need not directly alter the operation of the network node 1604. Such procedures and functionalities may be known and practiced in the art. In certain embodiments, measurements may involve proprietary UE signaling that facilitates measurements of throughput, propagation times, latency, and the like by the host 1602. The measurements may be implemented in that software causes messages to be transmitted, in particular empty or ‘dummy’ messages, using the OTT connection 1650 while monitoring propagation times, errors, etc.

[0168] Although the computing devices described herein (e.g., UEs, network nodes, hosts) may include the illustrated combination of hardware components, other embodiments may comprise computing devices with different combinations of components. It is to be understood that these computing devices may comprise any suitable combination of hardware and/or software needed to perform the tasks, features, functions, and methods disclosed herein. Determining, calculating, obtaining, or similar operations described herein may be performed by processing circuitry, which may process information 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. Moreover, while components are depicted as single boxes located within a larger box or nested within multiple boxes, in practice computing devices may comprise multiple different physical components that make up a single illustrated component, and functionality may be partitioned between separate components. For example, a communication interface may be configured to include any of the components described herein, and/or the functionality of the components may be partitioned between the processing circuitry and the communication interface. In another example, non-computationally intensive functions of any of such components may be implemented in software or firmware and computationally intensive functions may be implemented in hardware.

[0169] In certain embodiments, some or all of the functionality described herein may be provided by processing circuitry executing instructions stored in memory, which in certain embodiments may be a computer program product in the form of a non-transitory computer-readable storage medium. In alternative embodiments, some or all of the functionality may be provided by the processing circuitry without executing instructions stored on a separate or discrete device-readable storage medium, such as in a hardwired manner. In any of those particular embodiments, whether executing instructions stored on a non-transitory computer-readable

storage medium or not, the processing circuitry can be configured to perform the described functionality. The benefits provided by such functionality are not limited to the processing circuitry alone or to other components of the computing device but are enjoyed by the computing device as a whole and/or by end users and a wireless network generally.

[0170] Those skilled in the art will recognize improvements and modifications to the embodiments of the present disclosure. All such improvements and modifications are considered within the scope of the concepts disclosed herein.

[0171] EMBODIMENTS

[0172] Group A Embodiments

[0173] Embodiment 1: A method performed by a User Equipment, UE, the method comprising one or more of: transmitting (900) a UE capability signaling indicating support for three transmit antennas.

[0174] Embodiment 2: The method of any of the previous embodiments wherein: the UE capability signaling comprises a new bitfield that includes one or more of the following entries: {t3r3, t3r4r, t3r6, t3r8}.

[0175] Embodiment 3: The method of any of the previous embodiments wherein: the UE capability signaling indicates if the UE supports one or more of the corresponding SRS antenna-switching configurations.

[0176] Embodiment 4: The method of any of the previous embodiments wherein: if the UE capability signaling indicates txry, the UE can be configured with xTyR antenna switching.

[0177] Embodiment 5: The method of any of the previous embodiments wherein: the t3r4 entry is removed and the bitfield can only indicate one or more of the following entries {t3r3, t3r6, t3r8}.

[0178] Embodiment 6: The method of any of the previous embodiments wherein: if a UE has 3Tx and 4 Rx, the UE indicates support for legacy t2r4 antenna switching, which can be used to sound the 4 UE RX antennas in two OFDM symbols + one symbols gap period.

[0179] Embodiment 7: The method of any of the previous embodiments wherein: if a UE has 3Tx and 4 Rx, the UE indicates support for new t3r3 antenna switching, which gives the NW only partial channel knowledge (i.e., 3 of 4 Rx antennas) at the cost of reduced UL overhead.

[0180] Embodiment 8: The method of any of the previous embodiments wherein: the UE sounds 3 SRS ports two times, and 2 SRS ports a third time (i.e., 3+3+2).

[0181] Embodiment 9: The method of any of the previous embodiments wherein: three ports are contained in one or more SRS resources.

[0182] Embodiment 10: The method of the previous embodiment wherein: the three ports consist of one of the following: a 4-port SRS resource where the UE blanks one of the SRS ports; two or three concatenated SRS resources, where the total number of SRS ports over the concatenated SRS resources is equal to three (e.g., either 1+1+1 SRS ports for three different SRS resources or 1+2 SRS ports for two different SRS resources); and a new three port SRS resource is introduced and used.

[0183] Embodiment 11: The method of any of the previous embodiments wherein: the power scaling for all SRS ports should be the same, such that the UE should apply the same power per SRS port regardless of if there are two or three SRS ports transmitted per SRS resource.

[0184] Embodiment 12: The method of any of the previous embodiments wherein: for an SRS transmission occasion where an SRS resource containing m SRS ports is transmitted, belonging to an SRS resource set with usage 'antennaSwitching' including also, at least, one SRS resource with 3 ports, the SRS power is $m/3$ of the SRS power for an SRS transmission occasion where an SRS resource containing 3 SRS ports is transmitted.

[0185] Embodiment 13: The method of any of the previous embodiments further comprising: receiving (902) an additional (e.g., RRC) configuration (e.g., a flag) to indicate that the UE should apply 3T6R or 4T8R antenna switching.

[0186] Embodiment 14: The method of any of the previous embodiments wherein: the configuration is configured per in SRS resource IE as specified in TS 38.331.

[0187] Embodiment 15: The method of any of the previous embodiments wherein: the configuration is configured per in SRS resource set IE as specified in TS 38.331.

[0188] Embodiment 16: The method of any of the previous embodiments wherein: if the UE is configured with one or more SRS resource sets with usage antenna switching and where SRS resources with different number of ports are configured in the SRS resource sets, the UE knows that it should concatenate the SRS resources to build three-port SRS resources.

[0189] Embodiment 17: The method of any of the previous embodiments further comprising: receiving (904) an additional (e.g., RRC) configuration (e.g., a flag) indicating that the UE should apply concatenation of SRS resources (e.g., and hence that the SRS configuration corresponds to one of the 3TyR SRS antenna switching configurations).

[0190] Embodiment 18: The method of any of the previous embodiments wherein: the RRC configuration is configured in SRS resource IE as specified in TS 38.331.

[0191] Embodiment 19: The method of any of the previous embodiments wherein: the RRC configuration is configured in SRS resource set IE as specified in TS 38.331.

[0192] Embodiment 20: The method of any of the previous embodiments, further comprising: providing user data; and forwarding the user data to a host via the transmission to the network node.

[0193] Group B Embodiments

[0194] Embodiment 21: A method performed by a network node, the method comprising one or more of: receiving (1000) a UE capability signaling indicating support for three transmit antennas.

[0195] Embodiment 22: The method of any of the previous embodiments wherein: the UE capability signaling comprises a new bitfield that includes one or more of the following entries: {t3r3, t3r4r, t3r6, t3r8}.

[0196] Embodiment 23: The method of any of the previous embodiments wherein: the UE capability signaling indicates if the UE supports one or more of the corresponding SRS antenna-switching configurations.

[0197] Embodiment 24: The method of any of the previous embodiments wherein: if the UE capability signaling indicates t_xr_y, the UE can be configured with xTyR antenna switching.

[0198] Embodiment 25: The method of any of the previous embodiments wherein: the t3r4 entry is removed and the bitfield can only indicate one or more of the following entries {t3r3, t3r6, t3r8}.

[0199] Embodiment 26: The method of any of the previous embodiments wherein: if a UE has 3Tx and 4 Rx, the UE indicates support for legacy t2r4 antenna switching, which can be used to sounds the 4 UE RX antennas in two OFDM symbols + one symbols gap period.

[0200] Embodiment 27: The method of any of the previous embodiments wherein: if a UE has 3Tx and 4 Rx, the UE indicates support for new t3r3 antenna switching, which gives the NW only partial channel knowledge (i.e., 3 of 4 Rx antennas) at the cost of reduced UL overhead.

[0201] Embodiment 28: The method of any of the previous embodiments wherein: the UE sounds 3 SRS ports two times, and 2 SRS ports a third time (i.e., 3+3+2).

[0202] Embodiment 29: The method of any of the previous embodiments wherein: three ports are contained in one or more SRS resources.

[0203] Embodiment 30: The method of the previous embodiment wherein: the three ports consist of one of the following: a 4-port SRS resource where the UE blanks one of the SRS ports; two or three concatenated SRS resources, where the total number of SRS ports over the concatenated SRS resources is equal to three (e.g., either 1+1+1 SRS ports for three different SRS resources or 1+2 SRS ports for two different SRS resources); and a new three port SRS resource is introduced and used.

[0204] Embodiment 31: The method of any of the previous embodiments wherein: the power scaling for all SRS ports should be the same, such that the UE should apply the same power per SRS port regardless of if there are two or three SRS ports transmitted per SRS resource.

[0205] Embodiment 32: The method of any of the previous embodiments wherein: for an SRS transmission occasion where an SRS resource containing m SRS ports is transmitted, belonging to an SRS resource set with usage 'antennaSwitching' including also, at least, one SRS resource with 3 ports, the SRS power is $m/3$ of the SRS power for an SRS transmission occasion where an SRS resource containing 3 SRS ports is transmitted.

[0206] Embodiment 33: The method of any of the previous embodiments further comprising: transmitting (1002) an additional (e.g., RRC) configuration (e.g., a flag) to indicate that the UE should apply 3T6R or 4T8R antenna switching.

[0207] Embodiment 34: The method of any of the previous embodiments wherein: the configuration is configured per in SRS resource IE as specified in TS 38.331.

[0208] Embodiment 35: The method of any of the previous embodiments wherein: the configuration is configured per in SRS resource set IE as specified in TS 38.331.

[0209] Embodiment 36: The method of any of the previous embodiments wherein: if the UE is configured with one or more SRS resource sets with usage antenna switching and where SRS resources with different number of ports are configured in the SRS resource sets, the UE knows that it should concatenate the SRS resources to build three-port SRS resources.

[0210] Embodiment 37: The method of any of the previous embodiments further comprising: transmitting (1004) an additional (e.g., RRC) configuration (e.g., a flag) indicating that the UE should apply concatenation of SRS resources (e.g., and hence that the SRS configuration corresponds to one of the 3TyR SRS antenna switching configurations).

[0211] Embodiment 38: The method of any of the previous embodiments wherein: the RRC configuration is configured in SRS resource IE as specified in TS 38.331.

[0212] Embodiment 39: The method of any of the previous embodiments wherein: the RRC configuration is configured in SRS resource set IE as specified in TS 38.331.

[0213] Embodiment 40: The method of any of the previous embodiments, further comprising: obtaining user data; and forwarding the user data to a host or a user equipment.

[0214] Group C Embodiments

[0215] Embodiment 41: A user equipment, comprising: processing circuitry configured to perform any of the steps of any of the Group A embodiments; and power supply circuitry configured to supply power to the processing circuitry.

[0216] Embodiment 42: A network node, the network node comprising: processing circuitry configured to perform any of the steps of any of the Group B embodiments; and power supply circuitry configured to supply power to the processing circuitry.

[0217] Embodiment 43: A user equipment (UE), the UE comprising: an antenna configured to send and receive wireless signals; radio front-end circuitry connected to the antenna and to processing circuitry, and configured to condition signals communicated between the antenna and the processing circuitry; the processing circuitry being configured to perform any of the steps of any of the Group A embodiments; an input interface connected to the processing circuitry and configured to allow input of information into the UE to be processed by the processing circuitry; an output interface connected to the processing circuitry and configured to output information from the UE that has been processed by the processing circuitry; and a battery connected to the processing circuitry and configured to supply power to the UE.

[0218] Embodiment 44: A host configured to operate in a communication system to provide an over-the-top (OTT) service, the host comprising: processing circuitry configured to provide user data; and a network interface configured to initiate transmission of the user data to a network node in a cellular network for transmission to a user equipment (UE), the network node having a

communication interface and processing circuitry, the processing circuitry of the network node configured to perform any of the operations of any of the Group B embodiments to transmit the user data from the host to the UE.

[0219] Embodiment 45: The host of the previous embodiment, wherein: the processing circuitry of the host is configured to execute a host application that provides the user data; and the UE comprises processing circuitry configured to execute a client application associated with the host application to receive the transmission of user data from the host.

[0220] Embodiment 46: A method implemented in a host configured to operate in a communication system that further includes a network node and a user equipment (UE), the method comprising: providing user data for the UE; and initiating a transmission carrying the user data to the UE via a cellular network comprising the network node, wherein the network node performs any of the operations of any of the Group B embodiments to transmit the user data from the host to the UE.

[0221] Embodiment 47: The method of the previous embodiment, further comprising, at the network node, transmitting the user data provided by the host for the UE.

[0222] Embodiment 48: The method of any of the previous 2 embodiments, wherein the user data is provided at the host by executing a host application that interacts with a client application executing on the UE, the client application being associated with the host application.

[0223] Embodiment 49: A communication system configured to provide an over-the-top (OTT) service, the communication system comprising: a host comprising: processing circuitry configured to provide user data for a user equipment (UE), the user data being associated with the over-the-top service; and a network interface configured to initiate transmission of the user data toward a cellular network node for transmission to the UE, the network node having a communication interface and processing circuitry, the processing circuitry of the network node configured to perform any of the operations of any of the Group B embodiments to transmit the user data from the host to the UE.

[0224] Embodiment 50: The communication system of the previous embodiment, further comprising: the network node; and/or the UE.

[0225] Embodiment 51: A host configured to operate in a communication system to provide an over-the-top (OTT) service, the host comprising: processing circuitry configured to initiate receipt of user data; and a network interface configured to receive the user data from a network

node in a cellular network, the network node having a communication interface and processing circuitry, the processing circuitry of the network node configured to perform any of the operations of any of the Group B embodiments to receive the user data from a user equipment (UE) for the host.

[0226] Embodiment 52: The host of the previous 2 embodiments, wherein: the processing circuitry of the host is configured to execute a host application that receives the user data; and the host application is configured to interact with a client application executing on the UE, the client application being associated with the host application.

[0227] Embodiment 53: The host of the any of the previous 2 embodiments, wherein the initiating receipt of the user data comprises requesting the user data.

[0228] Embodiment 54: A method implemented by a host configured to operate in a communication system that further includes a network node and a user equipment (UE), the method comprising: at the host, initiating receipt of user data from the UE, the user data originating from a transmission which the network node has received from the UE, wherein the network node performs any of the steps of any of the Group B embodiments to receive the user data from the UE for the host.

[0229] Embodiment 55: The method of the previous embodiment, further comprising at the network node, transmitting the received user data to the host.

[0230] Embodiment 56: A host configured to operate in a communication system to provide an over-the-top (OTT) service, the host comprising: processing circuitry configured to provide user data; and a network interface configured to initiate transmission of the user data to a cellular network for transmission to a user equipment (UE), wherein the UE comprises a communication interface and processing circuitry, the communication interface and processing circuitry of the UE being configured to perform any of the operations of any of the Group A embodiments to receive the user data from the host.

[0231] Embodiment 57: The host of the previous embodiment, wherein the cellular network further includes a network node configured to communicate with the UE to transmit the user data to the UE from the host.

[0232] Embodiment 58: The host of the previous 2 embodiments, wherein: the processing circuitry of the host is configured to execute a host application, thereby providing the user data;

and the host application is configured to interact with a client application executing on the UE, the client application being associated with the host application.

[0233] Embodiment 59: A method implemented by a host operating in a communication system that further includes a network node and a user equipment (UE), the method comprising: providing user data for the UE; and initiating a transmission carrying the user data to the UE via a cellular network comprising the network node, wherein the UE performs any of the operations of any of the Group A embodiments to receive the user data from the host.

[0234] Embodiment 60: The method of the previous embodiment, further comprising: at the host, executing a host application associated with a client application executing on the UE to receive the user data from the host application.

[0235] Embodiment 61: The method of the previous embodiment, further comprising: at the host, transmitting input data to the client application executing on the UE, the input data being provided by executing the host application, wherein the user data is provided by the client application in response to the input data from the host application.

[0236] Embodiment 62: A host configured to operate in a communication system to provide an over-the-top (OTT) service, the host comprising: processing circuitry configured to provide user data; and a network interface configured to initiate transmission of the user data to a cellular network for transmission to a user equipment (UE), wherein the UE comprises a communication interface and processing circuitry, the communication interface and processing circuitry of the UE being configured to perform any of the steps of any of the Group A embodiments to transmit the user data to the host.

[0237] Embodiment 63: The host of the previous embodiment, wherein the cellular network further includes a network node configured to communicate with the UE to transmit the user data from the UE to the host.

[0238] Embodiment 64: The host of the previous 2 embodiments, wherein: the processing circuitry of the host is configured to execute a host application, thereby providing the user data; and the host application is configured to interact with a client application executing on the UE, the client application being associated with the host application.

[0239] Embodiment 65: A method implemented by a host configured to operate in a communication system that further includes a network node and a user equipment (UE), the method comprising: at the host, receiving user data transmitted to the host via the network node

by the UE, wherein the UE performs any of the steps of any of the Group A embodiments to transmit the user data to the host.

[0240] Embodiment 66: The method of the previous embodiment, further comprising: at the host, executing a host application associated with a client application executing on the UE to receive the user data from the UE.

[0241] Embodiment 67: The method of the previous 2 embodiments, further comprising: at the host, transmitting input data to the client application executing on the UE, the input data being provided by executing the host application, wherein the user data is provided by the client application in response to the input data from the host application.

ABBREVIATIONS

At least some of the following abbreviations may be used in this disclosure. If 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
ap-SRS	Aperiodic SRS
ASN	Abstract Syntax Notation
BPSK	Binary Phase Shift Keying
BWP	Bandwidth Part
CA	Carrier Aggregation
CB	Codebook
CC	Component Carrier
CDM	Code Division Multiplexing
CE	Control Element
CP-OFDM	Cyclic Prefix OFDM
CPE	Consumer Peripheral Equipment
CRB	Carrier RB
CG	Configured Grant
CS	Cyclic Shift
CS-RNTI	Configured Scheduling RNTI
CSI	Channel State Information
DCI	Downlink Control Information
DFT	Discrete Fourier Transform
DFT-S-OFDM	DFT Spread OFDM
DG	Dynamic Grant
DL	Downlink
DMRS	Demodulation RS
FD-OCC	Frequency Domain OCC
FDD	Frequency-Division Multiplexing
FR1	Frequency Range 1
FR2	Frequency Range 2
FWA	Fixed Wireless Access
IDFT	Inverse DFT
gNB	gNodeB
IE	Information Element
LSB	Least Significant Bit
LTE	Long Term Evolution
MAC	Medium Access Control
MCS	Modulation and Coding Scheme
MIB	Master Information Block
MIMO	Multiple-Input Multiple-Output
MSB	Most Significant Bit
MU	Multi-User
NCB	Non-Codebook
NDI	New Data Indicator
NR	New Radio
NW	Network
OCC	Orthogonal Cover Code

OFDM	Orthogonal Frequency Division Multiplexing
p-SRS	Periodic SRS
PA	Power Amplifier
PAPR	Peak-to-Average Power Ratio
PC	Power Control
PCell	Primary Cell
PDCCH	Physical Downlink Control Channel
PDSCH	Physical Downlink Shared Channel
PRB	Physical RB
PSD	Power Spectral Density
PTRS	Phase Tracking Reference Signal
PUCCH	Physical Uplink Control Channel
PUSCH	Physical Uplink Shared Channel
QPSK	Quadrature Phase-Shift Keying
RB	Resource Block
RBG	Resource Block Group
RE	Resource Element
RF	Radio Frequency
RS	Reference Signal
RSRP	RS Received Power
RIV	Resource Indication Value
RNTI	Radio Network Temporary Identifier
RRC	Radio Resource Control
RV	Redundancy Version
Rx	Receive
SCS	Subcarrier Spacing
SCell	Secondary Cell
SIB1	System Information Block 1
SLIV	Start and Length Indicator Value
sp-SRS	Semi-Persistent SRS
SNR	Signal-to-Noise Ratio
SRI	SRS Resource Indicator
SRS	Sounding Reference Signal
SRSI	SRS Resource Set Indicator
SSB	Synchronization Signal Block
SU	Single-User
SUL	Supplementary Uplink
TB	Transport Block
TD-OCC	Time Domain OCC
TDD	Time-Division Duplexing
Tx	Transmit
UE	User Equipment
UL	Uplink
VRB	Virtual RB
1x RTT	CDMA2000 1x Radio Transmission Technology
3GPP	3rd Generation Partnership Project
5G	5th Generation
6G	6th Generation
ABS	Almost Blank Subframe
ARQ	Automatic Repeat Request
AWGN	Additive White Gaussian Noise

BCCH	Broadcast Control Channel
BCH	Broadcast Channel
CA	Carrier Aggregation
CC	Carrier Component
CCCH SDU	Common Control Channel SDU
CDMA	Code Division Multiplexing Access
CGI	Cell Global Identifier
CIR	Channel Impulse Response
CP	Cyclic Prefix
CPICH	Common Pilot Channel
CPICH	E_c/N_0 CPICH Received energy per chip divided by the power density in the band
CQI	Channel Quality information
C-RNTI	Cell RNTI
CSI	Channel State Information
DCCH	Dedicated Control Channel
DL	Downlink
DM	Demodulation
DMRS	Demodulation Reference Signal
DRX	Discontinuous Reception
DTX	Discontinuous Transmission
DTCH	Dedicated Traffic Channel
DUT	Device Under Test
E-CID	Enhanced Cell-ID (positioning method)
eMBMS	evolved Multimedia Broadcast Multicast Services
E-SMLC	Evolved-Serving Mobile Location Centre
ECGI	Evolved CGI
eNB	E-UTRAN NodeB
ePDCCH	Enhanced Physical Downlink Control Channel
E-SMLC	Evolved Serving Mobile Location Center
E-UTRA	Evolved UTRA
E-UTRAN	Evolved UTRAN
FDD	Frequency Division Duplex
FFS	For Further Study
gNB	Base station in NR
GNSS	Global Navigation Satellite System
HARQ	Hybrid Automatic Repeat Request
HO	Handover
HSPA	High Speed Packet Access
HRPD	High Rate Packet Data
IE	Information Element
LOS	Line of Sight
LPP	LTE Positioning Protocol
LTE	Long-Term Evolution
MAC	Medium Access Control
MAC	Message Authentication Code
MBSFN	Multimedia Broadcast multicast service Single Frequency Network
MBSFN ABS	MBSFN Almost Blank Subframe
MDT	Minimization of Drive Tests
MIB	Master Information Block
MME	Mobility Management Entity
MSC	Mobile Switching Center

NPDCCH	Narrowband Physical Downlink Control Channel
NR	New Radio
OCNG	OFDMA Channel Noise Generator
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiple Access
OSS	Operations Support System
OTDOA	Observed Time Difference of Arrival
O&M	Operation and Maintenance
PBCH	Physical Broadcast Channel
P-CCPCH	Primary Common Control Physical Channel
PCell	Primary Cell
PCFICH	Physical Control Format Indicator Channel
PDCCH	Physical Downlink Control Channel
PDCP	Packet Data Convergence Protocol
PDP	Profile Delay Profile
PDSCH	Physical Downlink Shared Channel
PGW	Packet Gateway
PHICH	Physical Hybrid-ARQ Indicator Channel
PLMN	Public Land Mobile Network
PMI	Precoder Matrix Indicator
PRACH	Physical Random Access Channel
PRS	Positioning Reference Signal
PSS	Primary Synchronization Signal
PUCCH	Physical Uplink Control Channel
PUSCH	Physical Uplink Shared Channel
RACH	Random Access Channel
QAM	Quadrature Amplitude Modulation
RAN	Radio Access Network
RAT	Radio Access Technology
RLC	Radio Link Control
RLM	Radio Link Management
RNC	Radio Network Controller
RNTI	Radio Network Temporary Identifier
RRC	Radio Resource Control
RRM	Radio Resource Management
RS	Reference Signal
RSCP	Received Signal Code Power
RSRP	Reference Symbol Received Power OR Reference Signal Received Power
RSRQ	Reference Signal Received Quality OR Reference Symbol Received Quality
RSSI	Received Signal Strength Indicator
RSTD	Reference Signal Time Difference
SCH	Synchronization Channel
SCell	Secondary Cell
SDAP	Service Data Adaptation Protocol
SDU	Service Data Unit
SFN	System Frame Number
SGW	Serving Gateway
SI	System Information
SIB	System Information Block
SNR	Signal to Noise Ratio
SON	Self Optimized Network

SRS	Sounding Reference Signal
SS	Synchronization Signal
SSS	Secondary Synchronization Signal
TDD	Time Division Duplex
TDOA	Time Difference of Arrival
TOA	Time of Arrival
TSS	Tertiary Synchronization Signal
TTI	Transmission Time Interval
UE	User Equipment
UL	Uplink
USIM	Universal Subscriber Identity Module
UTDOA	Uplink Time Difference of Arrival
WCDMA	Wide CDMA
WLAN	Wide Local Area Network

CLAIMS

1. A method performed by a User Equipment, UE, the method comprising:
transmitting (900) a UE capability signaling indicating support for three transmit antennas;
and
receiving (902) a Radio Resource Control, RRC, configuration to indicate that the UE should apply a first or a second antenna switching.
2. The method of claim 1 wherein the first and the second antenna switching comprises one of the group consisting of: 3T6R or 4T8R antenna switching; 3T3R or 3T6R antenna switching; 3T8R antenna switching; and any combination of these.
3. The method of claim 1 wherein the UE capability signaling comprises: a new bitfield that includes one or more of the following entries: {t3r3, t3r4r, t3r6, t3r8}.
4. The method of any of claims 1-3 wherein:
the UE capability signaling indicates if the UE supports one or more corresponding Sounding Reference Signal, SRS, antenna-switching configurations.
5. The method of any of claims 1-4 wherein:
if the UE capability signaling indicates txry, the UE can be configured with xTyR antenna switching.
6. The method of any of claims 1-5 wherein:
if a UE has 3 Tx and 4 Rx, the UE indicates support for legacy t2r4 antenna switching, which can be used to sound the 4 UE RX antennas in two Orthogonal Frequency Division Multiplexing, OFDM, symbols + one symbols gap period.
7. The method of any of claims 1-6 wherein:
if a UE has 3 Tx and 4 Rx, the UE indicates support for new t3r3 antenna switching.
8. The method of any of claims 1-7 wherein:
when UE is configured with 3T8R antenna switching, the UE sounds 3 SRS ports two

times, and 2 SRS ports a third time.

9. The method of any of claims 1-8 wherein: three ports are contained in one or more SRS resources.

10. The method of claim 9 wherein: the three ports consist of one of the following:
a 4-port SRS resource where the UE blanks one of the SRS ports;
two or three concatenated SRS resources, where the total number of SRS ports over the concatenated SRS resources is equal to three; and
a new three port SRS resource is introduced and used.

11. The method of any of claims 1-10 wherein:
power scaling for all SRS ports should be the same, such that the UE should apply same power per SRS port regardless of if there are two or three SRS ports transmitted per SRS resource.

12. The method of any of claims 1-11 wherein:
for an SRS transmission occasion where an SRS resource containing m SRS ports is transmitted, belonging to an SRS resource set with usage 'antennaSwitching' including also, at least, one SRS resource with three ports, the SRS power is $m/3$ of the SRS power for an SRS transmission occasion where an SRS resource containing three SRS ports is transmitted.

13. The method of any of claims 1-12 wherein:
if the UE is configured with one or more SRS resource sets with usage antenna switching and where SRS resources with different number of ports are configured in the SRS resource sets, the UE knows that it should concatenate the SRS resources to build three-port SRS resources.

14. The method of any of claims 1-13 further comprising:
receiving an additional configuration indicating that the UE should blank one SRS port for a 4-port SRS resource.

15. The method of claim 14 wherein: the configuration is configured in an SRS resource Information Element, IE, as specified in TS 38.331.

16. The method of claim 14 wherein: the configuration is configured in an SRS resource set Information Element, IE, as specified in TS 38.331.
17. A method performed by a network node, the method comprising:
 - receiving (1000) a User Equipment, UE, capability signaling indicating support for three transmit antennas; and
 - transmitting (1002) a Radio Resource Control, RRC, configuration to indicate that the UE should apply a first or a second antenna switching.
18. The method of claim 17 wherein the first and the second antenna switching comprises one of the group consisting of: 3T6R or 4T8R antenna switching; 3T3R or 3T6R antenna switching; 3T8R antenna switching; and any combination of these.
19. The method of claim 17 wherein:
 - the UE capability signaling comprises a new bitfield that includes one or more of the following entries: {t3r3, t3r4r, t3r6, t3r8}.
20. The method of any of claims 17-19 wherein:
 - the UE capability signaling indicates if the UE supports one or more corresponding Sounding Reference Signal, SRS, antenna-switching configurations.
21. The method of any of claims 17-20 wherein:
 - if the UE capability signaling indicates txry, the UE can be configured with xTyR antenna switching.
22. The method of any of claims 17-21 wherein:
 - if a UE has 3 Tx and 4 Rx, the UE indicates support for legacy t2r4 antenna switching, which can be used to sound the 4 UE RX antennas in two Orthogonal Frequency Divisional Multiplexing, OFDM, symbols + one symbols gap period.
23. The method of any of claims 17-22 wherein:
 - if a UE has 3 Tx and 4 Rx, the UE indicates support for new t3r3 antenna switching, which gives the network node only partial channel knowledge at the cost of reduced Uplink, UL, overhead.

24. The method of any of claims 17-23 wherein: when UE is configured with 3T8R antenna switching, the UE sounds 3 SRS ports two times, and 2 SRS ports a third time.
25. The method of any of claims 17-24 wherein: three ports are contained in one or more SRS resources.
26. The method of claims 17-25 wherein: the three ports consist of one of the following:
a 4-port SRS resource where the UE blanks one of the SRS ports;

two or three concatenated SRS resources, where a total number of SRS ports over the concatenated SRS resources is equal to three; and
a new three port SRS resource is introduced and used.
27. The method of any of claims 17-26 wherein: power scaling for all SRS ports should be the same, such that the UE should apply the same power per SRS port regardless of if there are two or three SRS ports transmitted per SRS resource.
28. The method of any of claims 17-27 wherein:
for an SRS transmission occasion where an SRS resource containing m SRS ports is transmitted, belonging to an SRS resource set with usage 'antennaSwitching' including also, at least, one SRS resource with 3 ports, the SRS power is $m/3$ of the SRS power for an SRS transmission occasion where an SRS resource containing 3 SRS ports is transmitted.
29. The method of any of claims 17-28 wherein:
if the UE is configured with one or more SRS resource sets with usage antenna switching and where SRS resources with different number of ports are configured in the SRS resource sets, the UE knows that it should concatenate the SRS resources to build three-port SRS resources.
30. The method of any of claims 17-29 further comprising:
transmitting an additional configuration indicating that the UE should blank one SRS port for a 4-port SRS resource.
31. The method of any of claims 17-30 wherein: the RRC configuration is configured per in a SRS resource Information Element, IE, as specified in TS 38.331.

32. The method of any of claims 17-31 wherein: the RRC configuration is configured per in SRS resource set IE as specified in TS 38.331.
33. A User Equipment, UE, (1200) comprising processing circuitry (1202) and memory (1210), the memory (1210) comprising instructions to cause the UE (1200) to:
transmit a UE capability signaling indicating support for three transmit antennas; and
receive a Radio Resource Control, RRC, configuration to indicate that the UE should apply a first or a second antenna switching.
34. The UE (1200) of claim 33 further operable to implement the features of any of claims 2-16.
35. A computer-readable medium comprising instructions which, when executed on at least one processor, cause the at least one processor to carry out the method according to any one of claims 1 to 16.
36. A network node (1300) comprising processing circuitry (1302) and memory (1304), the memory (1304) comprising instructions to cause the network node (1300) to:
receive a User Equipment, UE, capability signaling indicating support for three transmit antennas; and
transmit a Radio Resource Control, RRC, configuration to indicate that the UE should apply a first or a second antenna switching.
37. The network node (1300) of claim 36 further operable to implement the features of any of claims 18-32.
38. A computer-readable medium comprising instructions which, when executed on at least one processor, cause the at least one processor to carry out the method according to any one of claims 17 to 32.

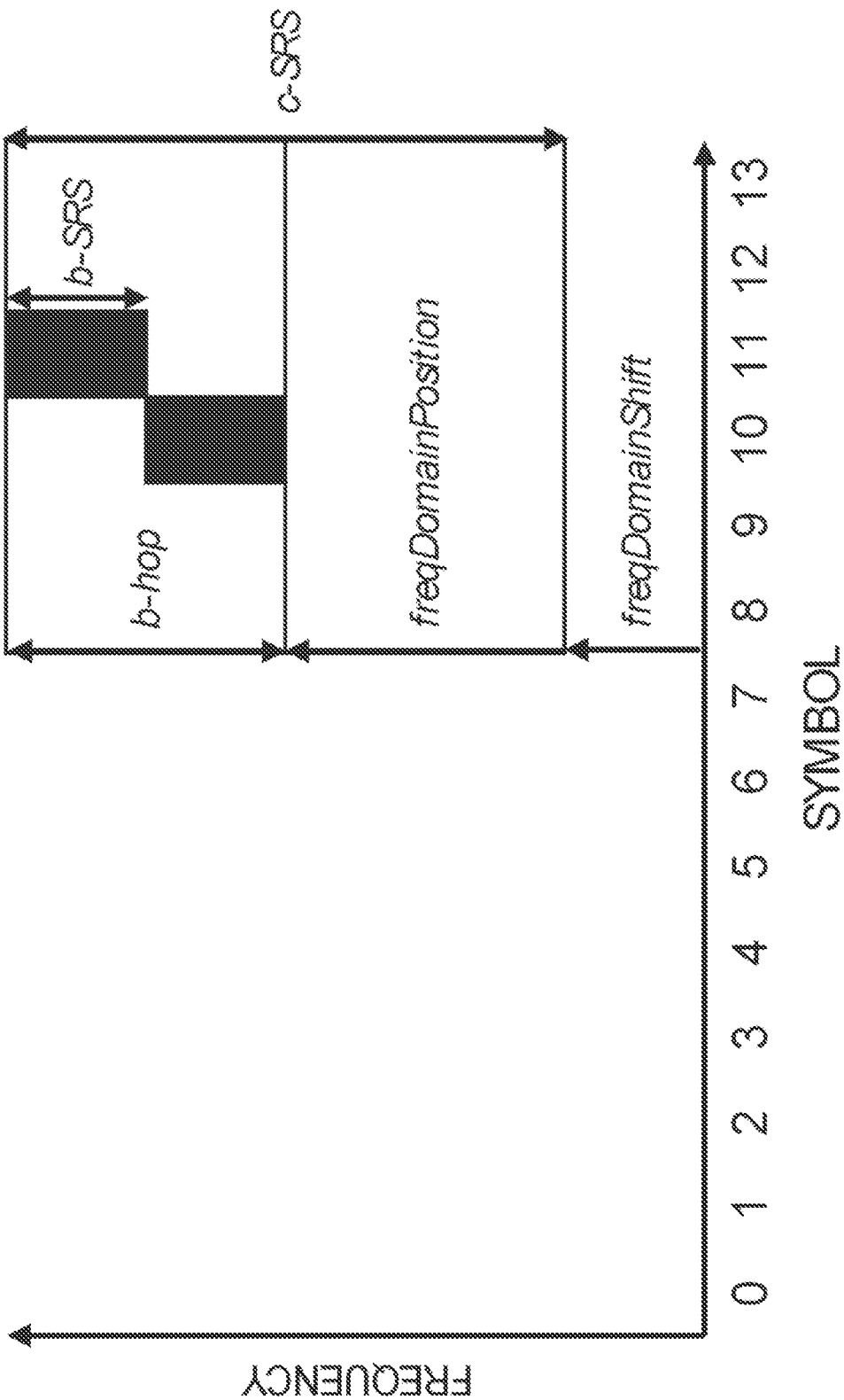


FIG. 1

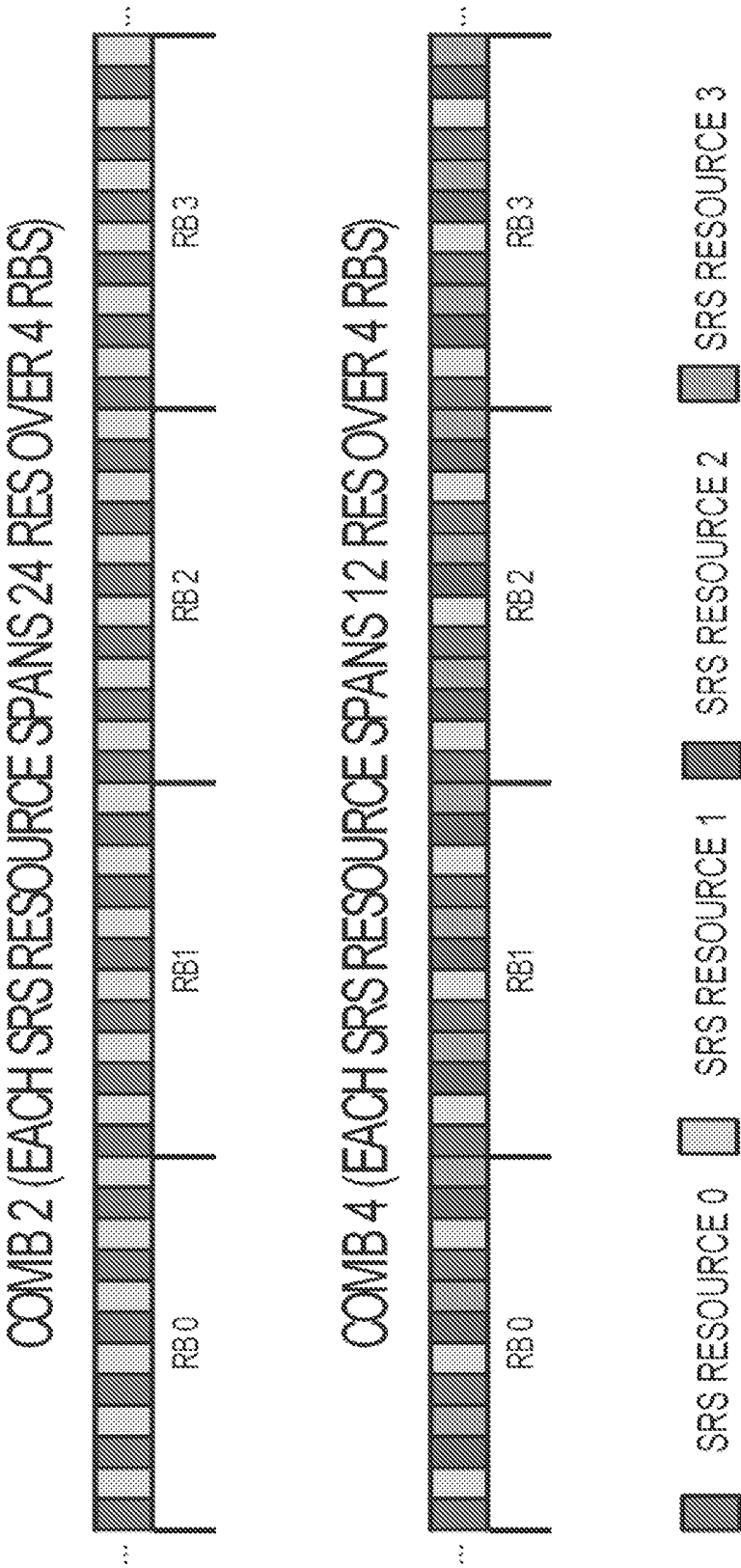
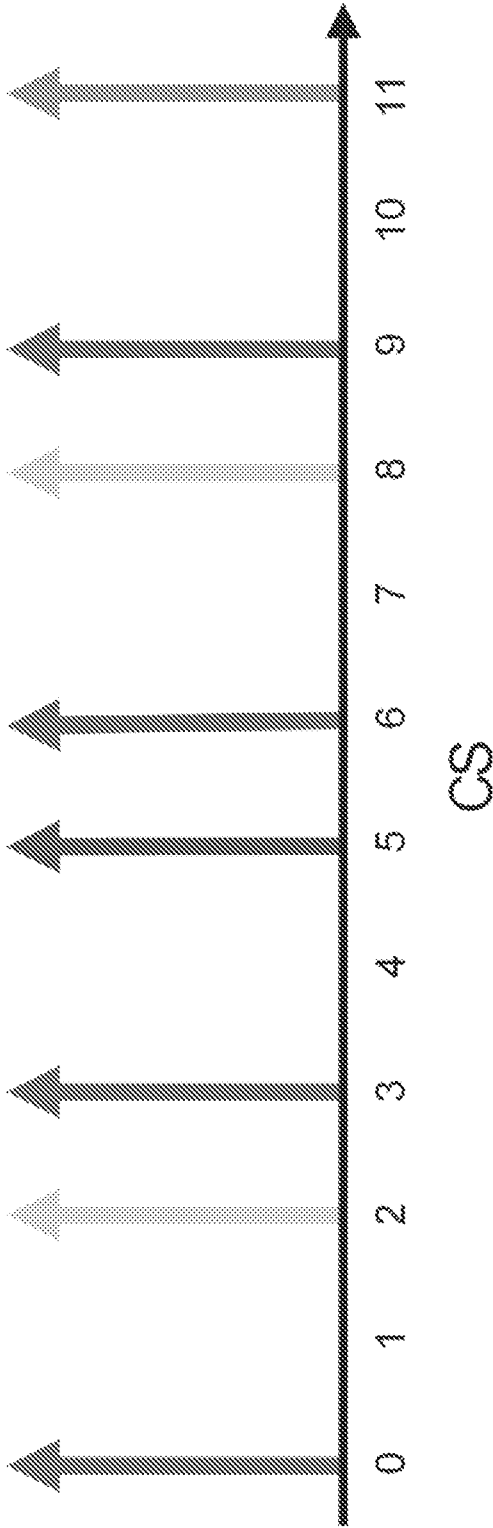


FIG. 2

COMB 4



- SRS RESOURCE 1 (2 PORTS)
- SRS RESOURCE 3 (1 PORT)
- SRS RESOURCE 0 (4 PORTS)
- SRS RESOURCE 2 (1 PORT)

FIG. 3

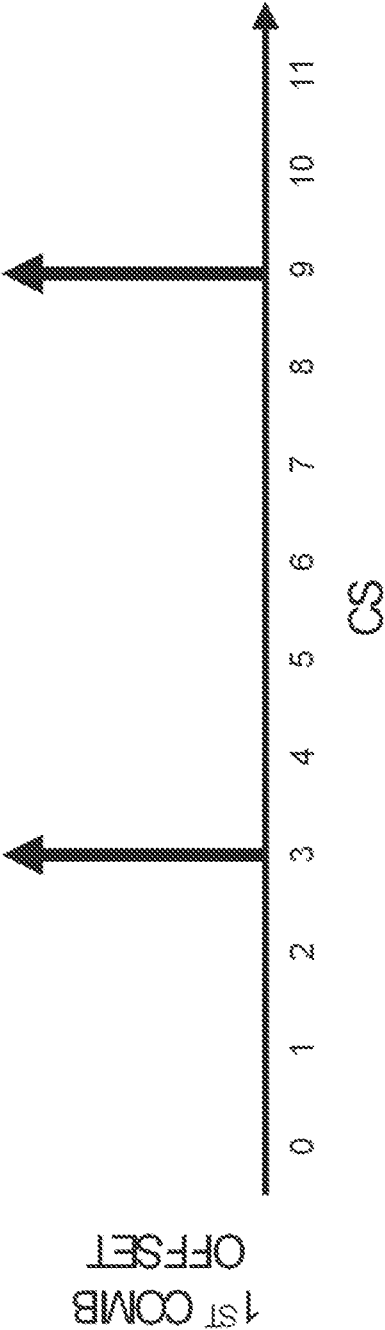
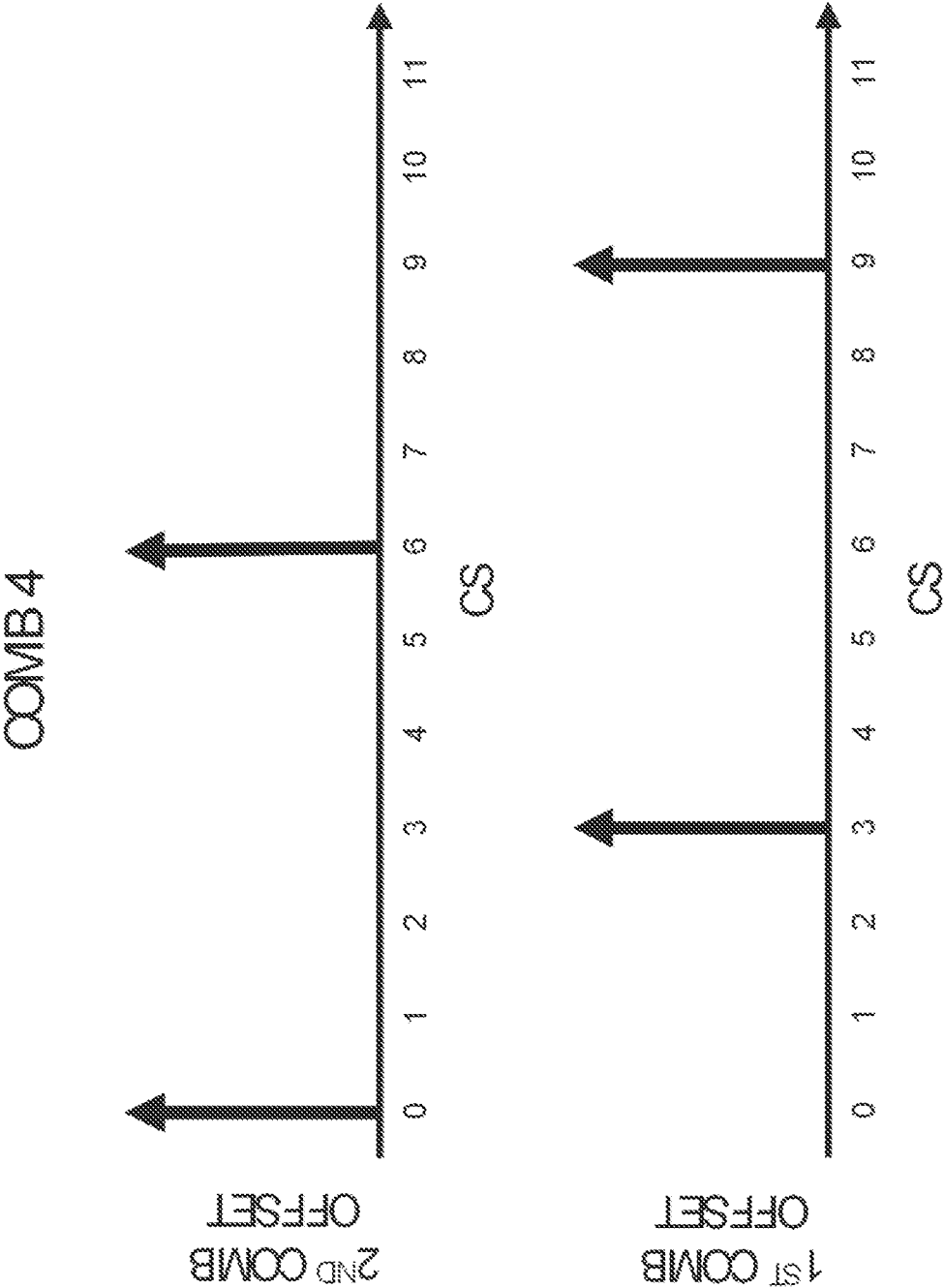


FIG. 4A

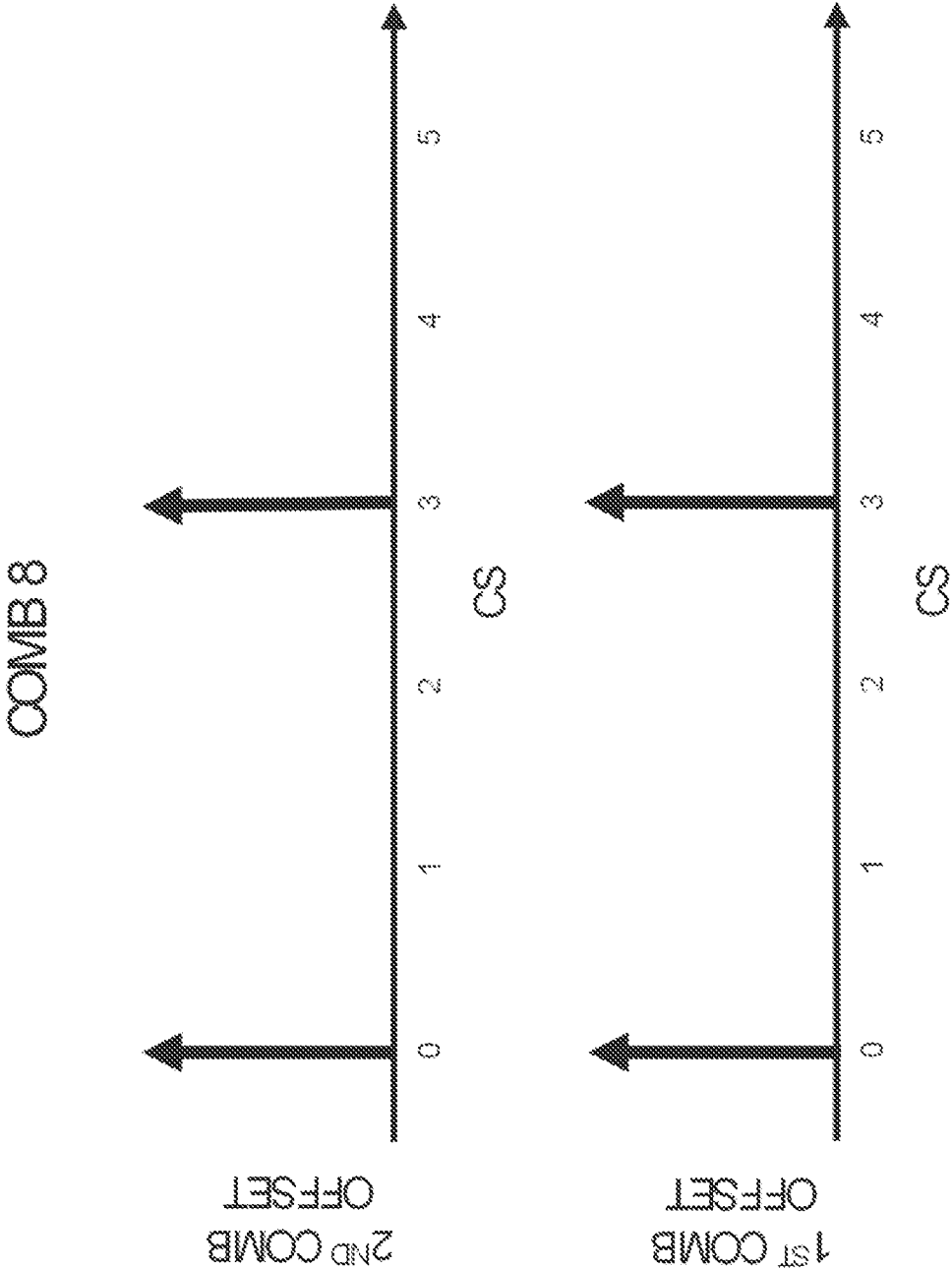
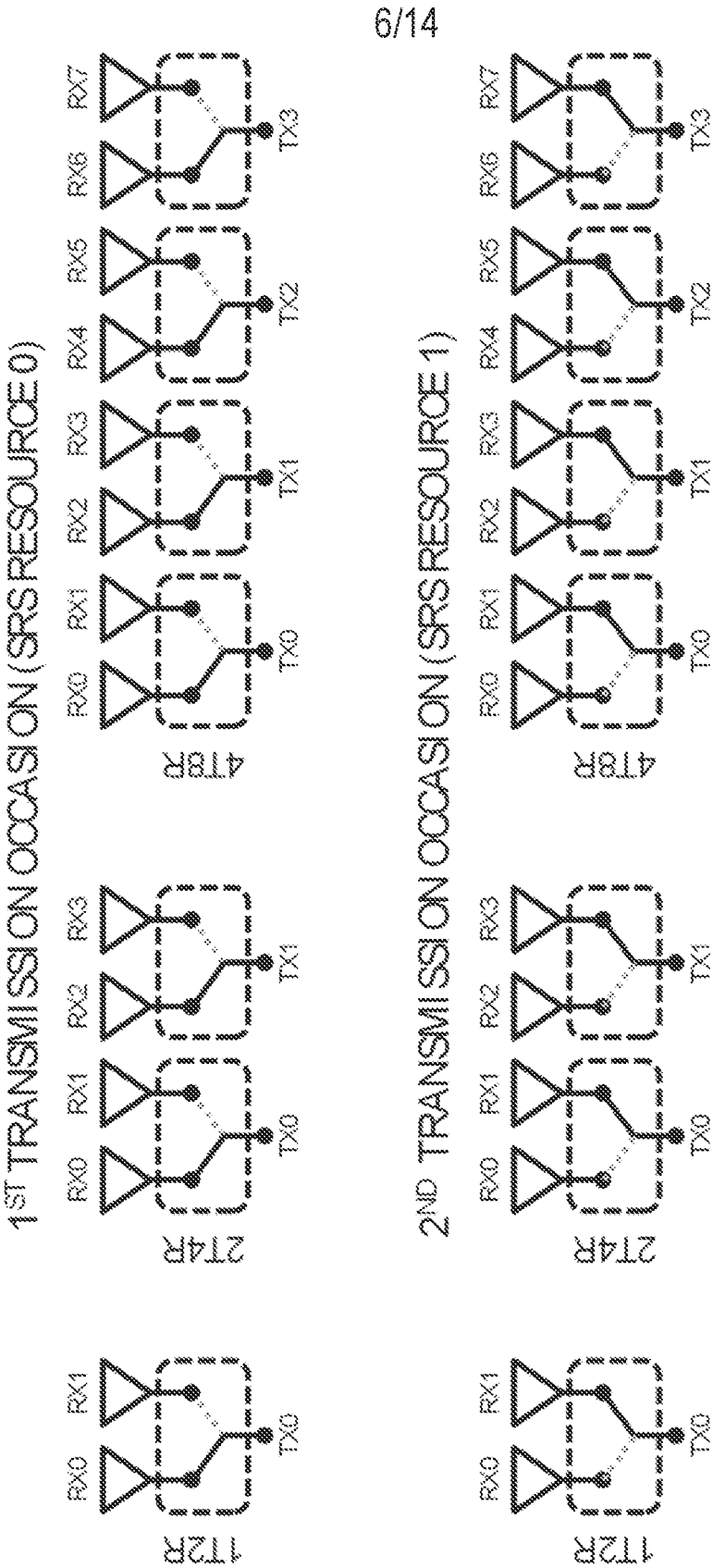


FIG. 4B



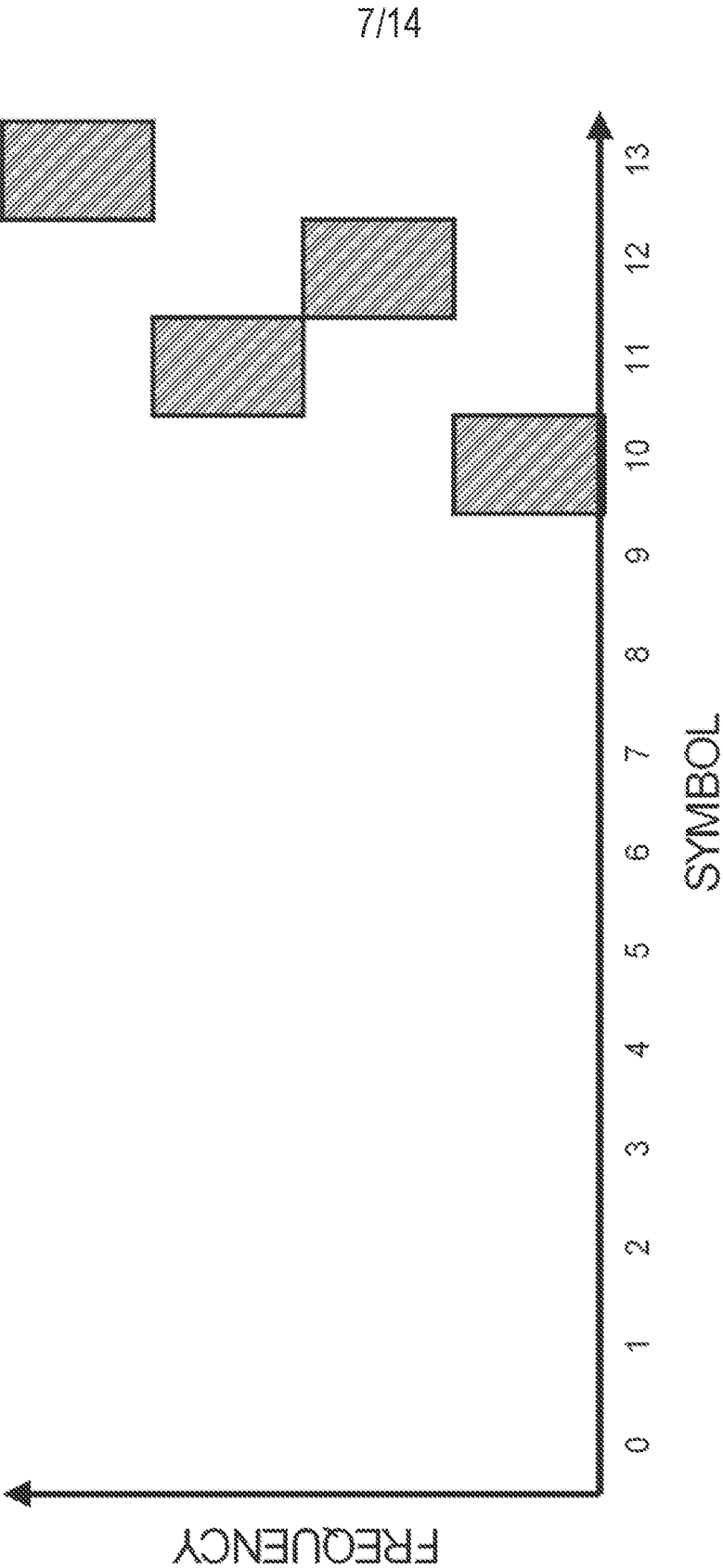


FIG. 6

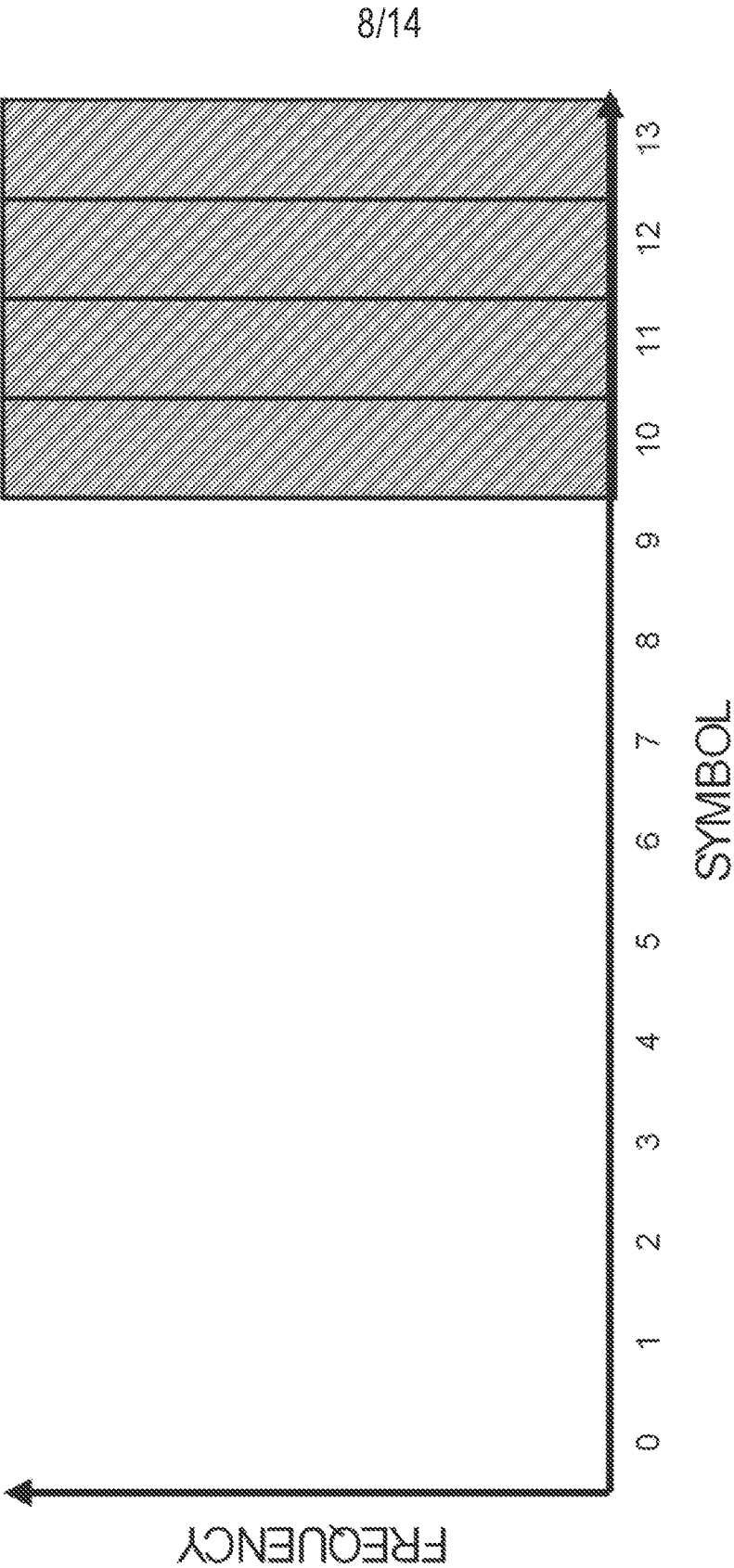


FIG. 7

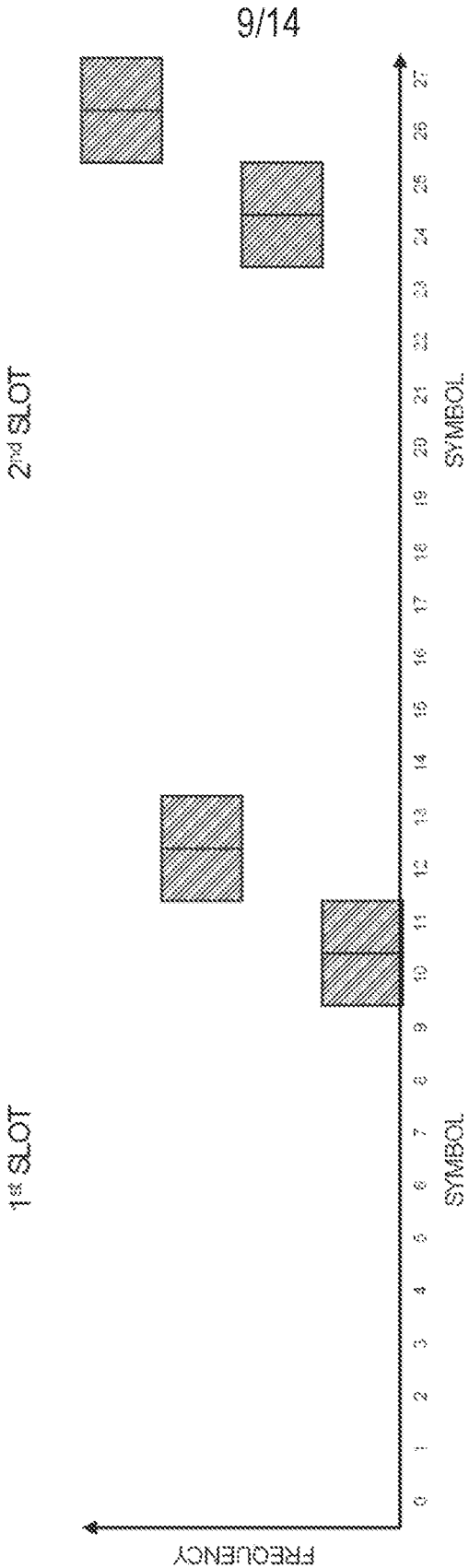
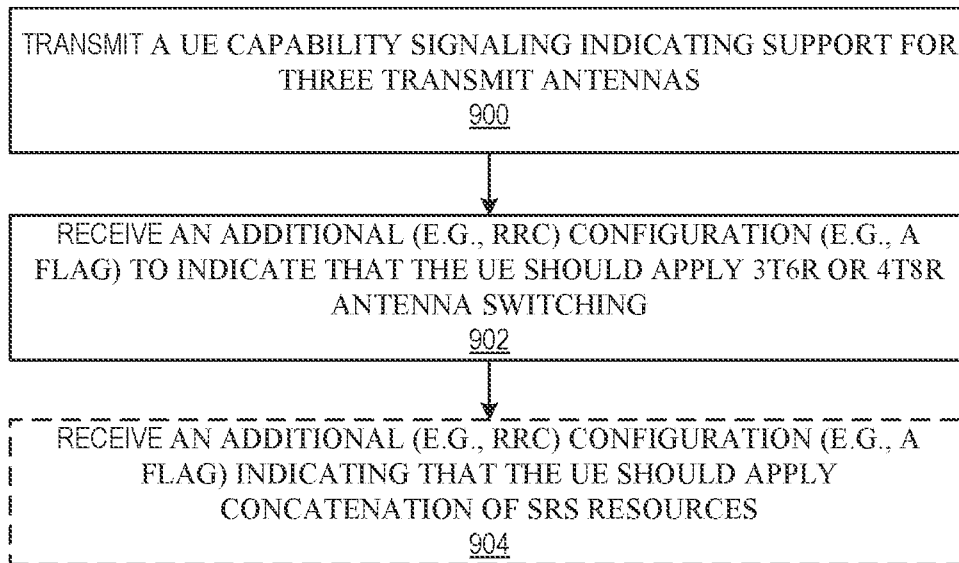
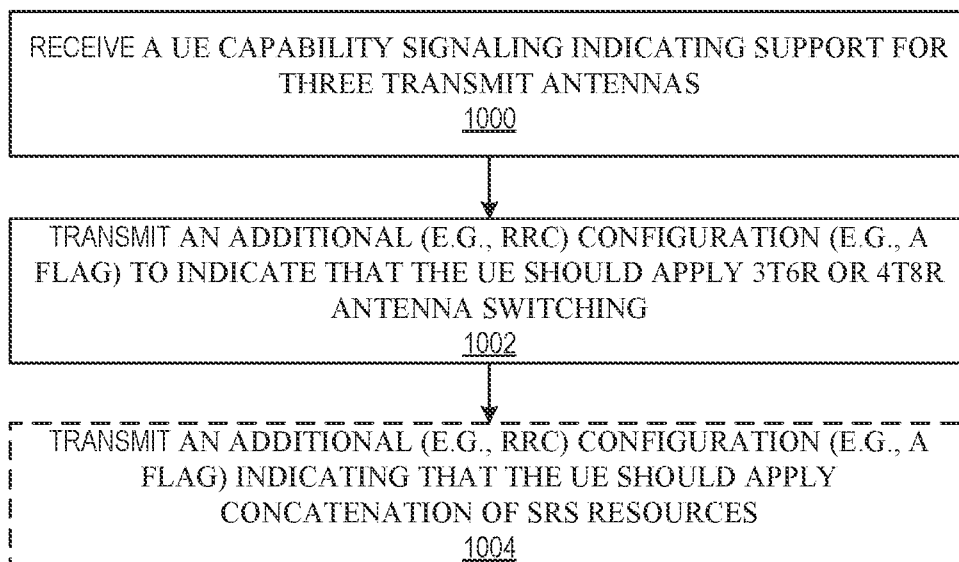
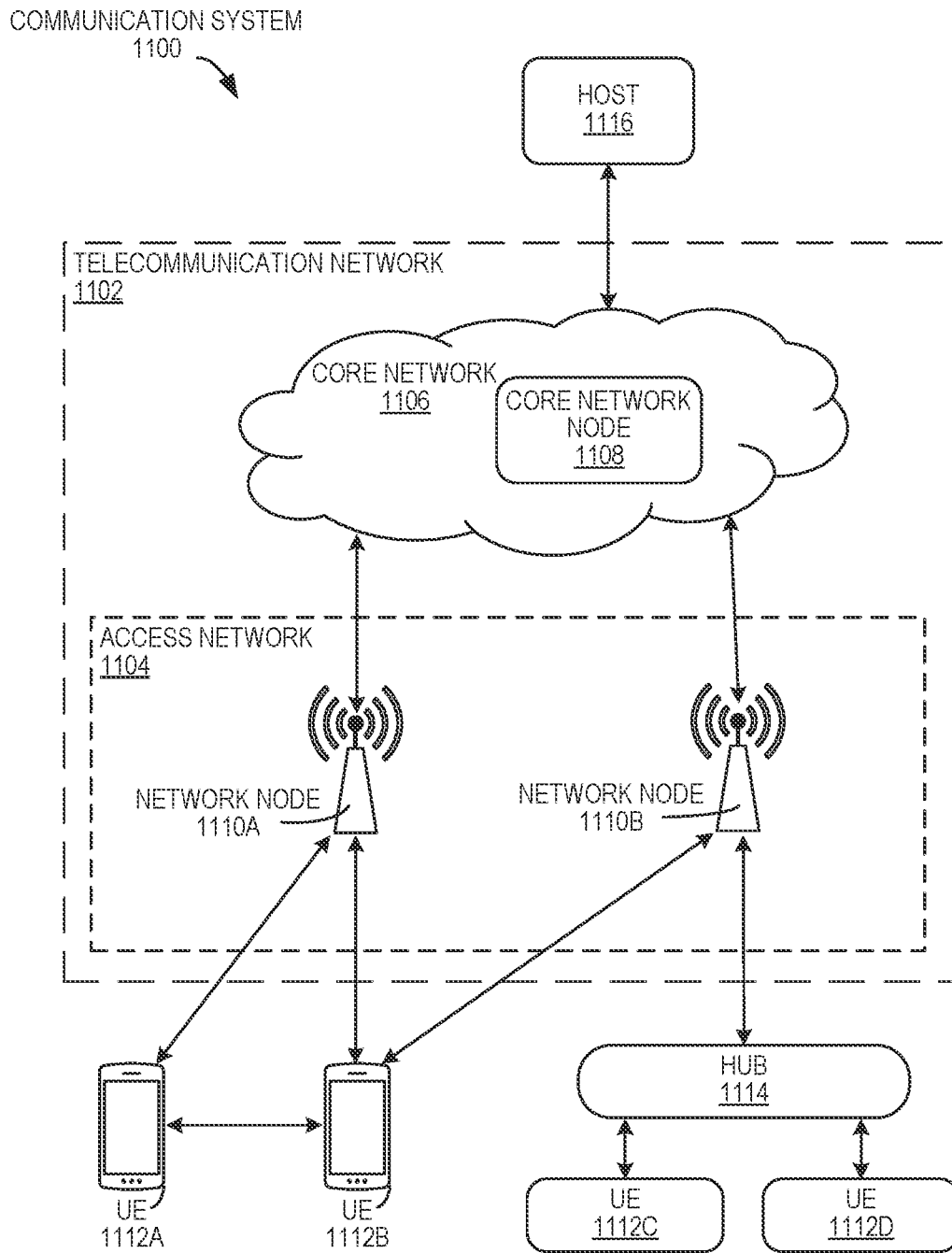


FIG. 8

10/14

**FIG. 9****FIG. 10**

11/14



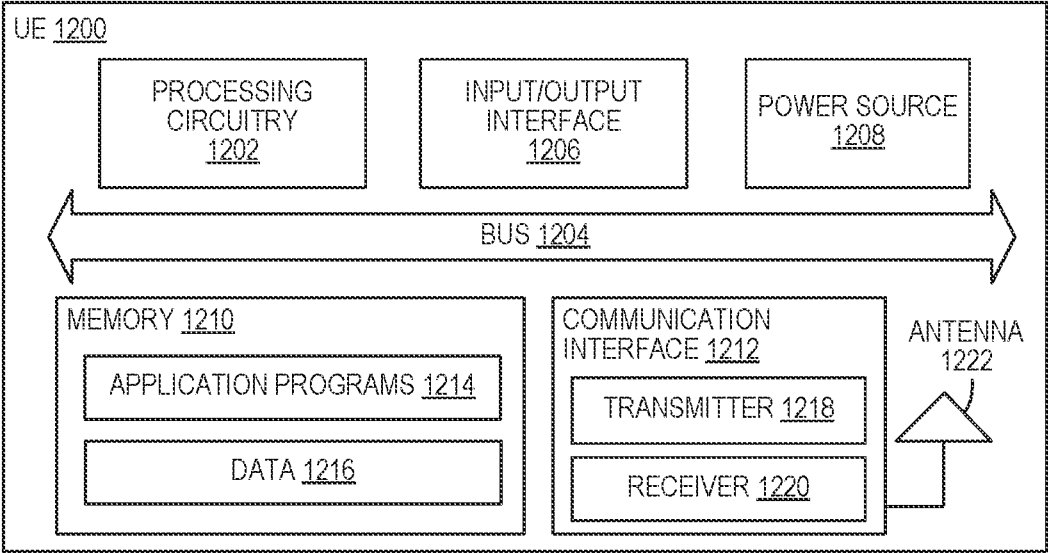


FIG. 12

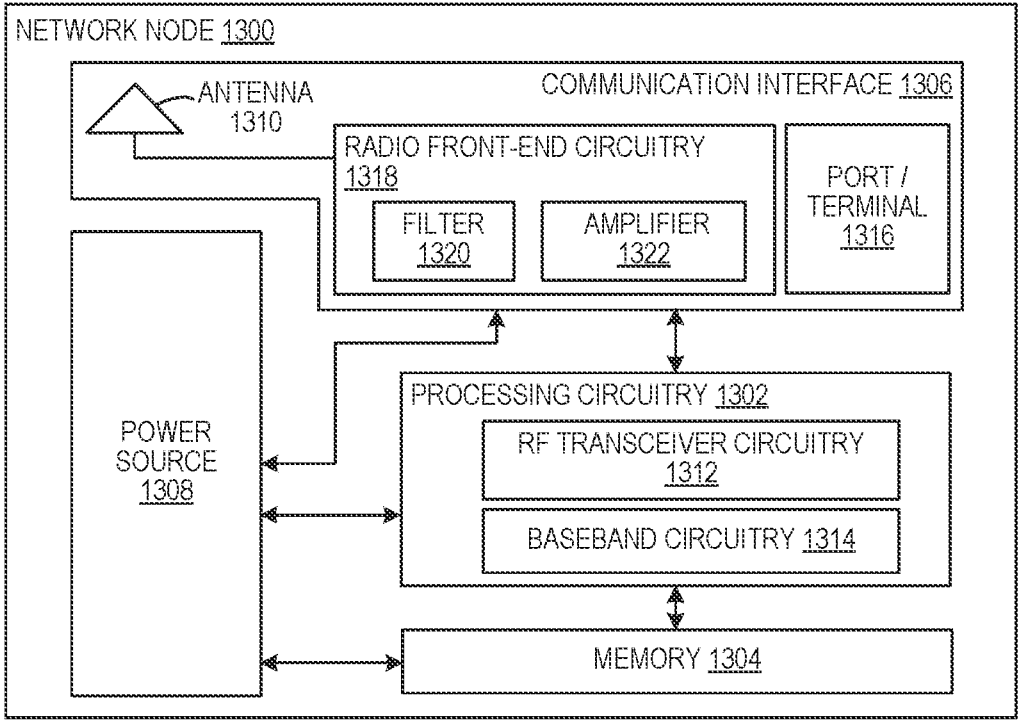


FIG. 13

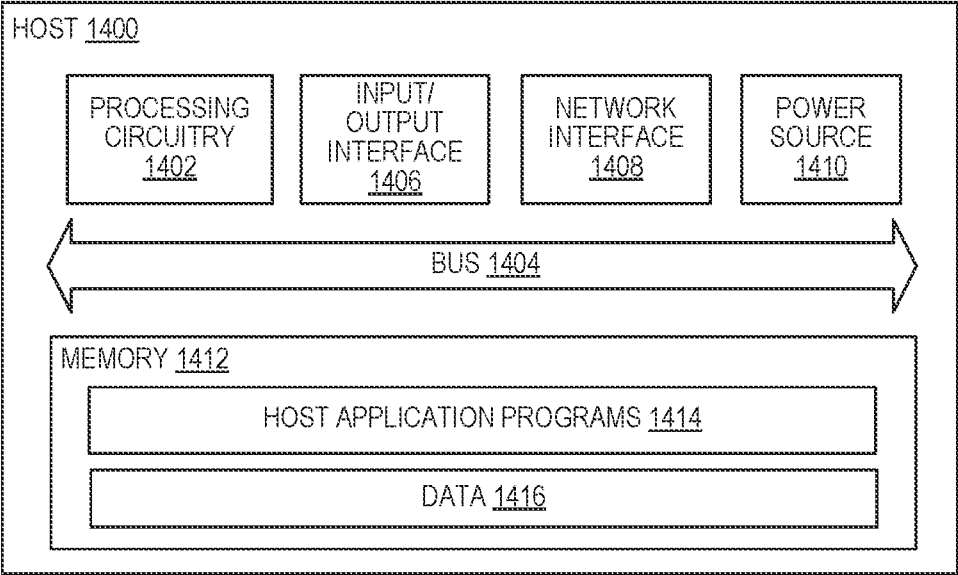


FIG. 14

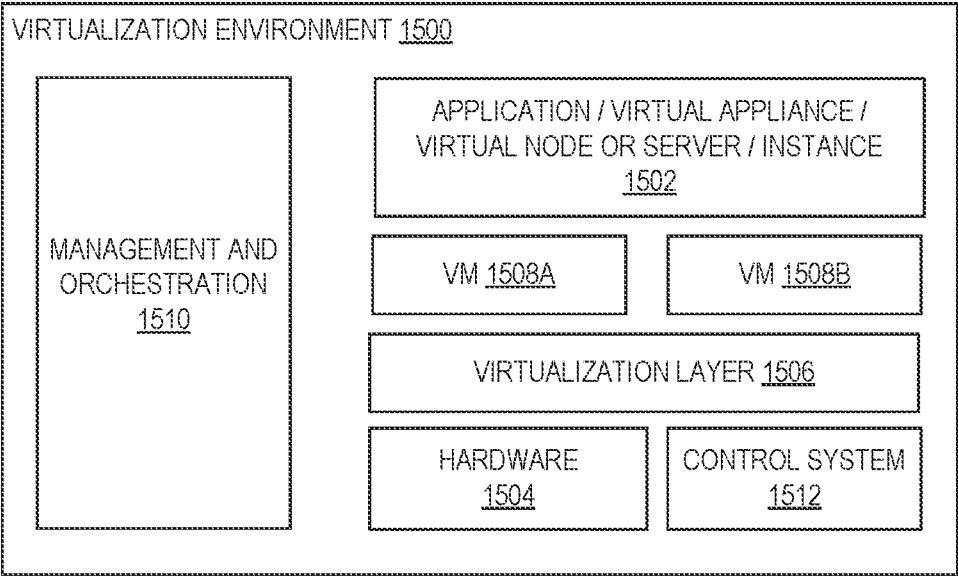


FIG. 15

14/14

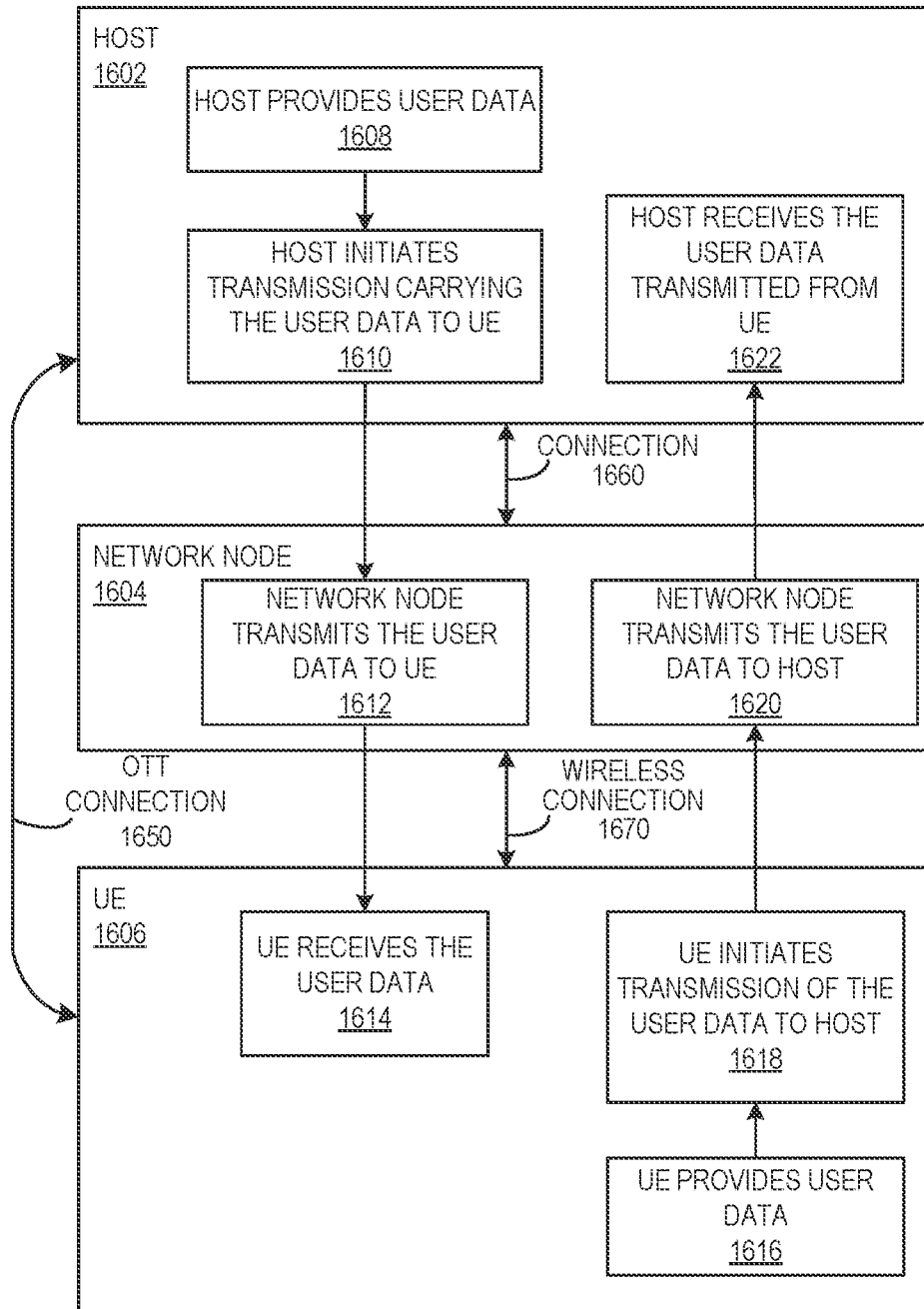


FIG. 16

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2024/059924

A. CLASSIFICATION OF SUBJECT MATTER INV. H04B7/06 H04B7/0404 H04L5/00 ADD.		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) H04B H04L Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal, INSPEC, WPI Data		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2023/147639 A1 (GO SEONGWON [KR] ET AL) 11 May 2023 (2023-05-11) paragraphs [0264], [0269], [0274], [0277], [0281], [0203] ----- -/-	1 - 38
☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 6 December 2024		Date of mailing of the international search report 02/01/2025
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Belloni, Paolo

INTERNATIONAL SEARCH REPORT

International application No

PCT/IB2024/059924

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	HUAWEI ET AL: "Enhancements on SRS in Rel-17", 3GPP DRAFT; R1-2110786, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG1, no. e-Meeting; 20211111 - 20211119 6 November 2021 (2021-11-06), XP052074567, Retrieved from the Internet: URL:https://ftp.3gpp.org/tsg_ran/WG1_RL1/TSGR1_107-e/Docs/R1-2110786.zip R1-2110786.docx [retrieved on 2021-11-06] Section 3.1 -----	6,22
A	WO 2023/097555 A1 (QUALCOMM INC [US]; WANG RUNXIN [US] ET AL.) 8 June 2023 (2023-06-08) paragraphs [0082], [0083] -----	7-9,24, 25
A	ERICSSON: "Rel-15 SRS power scaling in UL power control", 3GPP DRAFT; R1-1811499 SRS POWER SCALING IN UL POWER CONTROL, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG1, no. Chengdu, China; 20181008 - 20181012 29 September 2018 (2018-09-29), XP051518902, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/tsg%5Fran/WG1%5FRL1/TSGR1%5F94b/Docs/R1%2D1811499%2Ezip [retrieved on 2018-09-29] Section 5 and Alternative 3 on page 8 -----	11,12, 27,28
A	WO 2023/055106 A1 (LG ELECTRONICS INC [KR]) 6 April 2023 (2023-04-06) paragraph [0175] -----	13,29
A	US 2023/105787 A1 (CHEN BO [CN] ET AL) 6 April 2023 (2023-04-06) paragraph [0038] -----	14,30

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2024/059924

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2023147639 A1	11-05-2023	EP 4123917 A1 KR 20220144828 A US 2023147639 A1 WO 2021187967 A1	25-01-2023 27-10-2022 11-05-2023 23-09-2021
WO 2023097555 A1	08-06-2023	CN 118202738 A EP 4442056 A1 WO 2023097555 A1	14-06-2024 09-10-2024 08-06-2023
WO 2023055106 A1	06-04-2023	CN 118020261 A EP 4412136 A1 JP 2024537760 A KR 20240072997 A US 2024397490 A1 WO 2023055106 A1	10-05-2024 07-08-2024 16-10-2024 24-05-2024 28-11-2024 06-04-2023
US 2023105787 A1	06-04-2023	CN 115211193 A EP 4118905 A1 US 2023105787 A1 WO 2021179248 A1	18-10-2022 18-01-2023 06-04-2023 16-09-2021