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(54) **Title:** COMMUNICATION WITH WIRELESS COMMUNICATIONS DEVICES USING RECEIVE ANTENNA PORT GROUPS

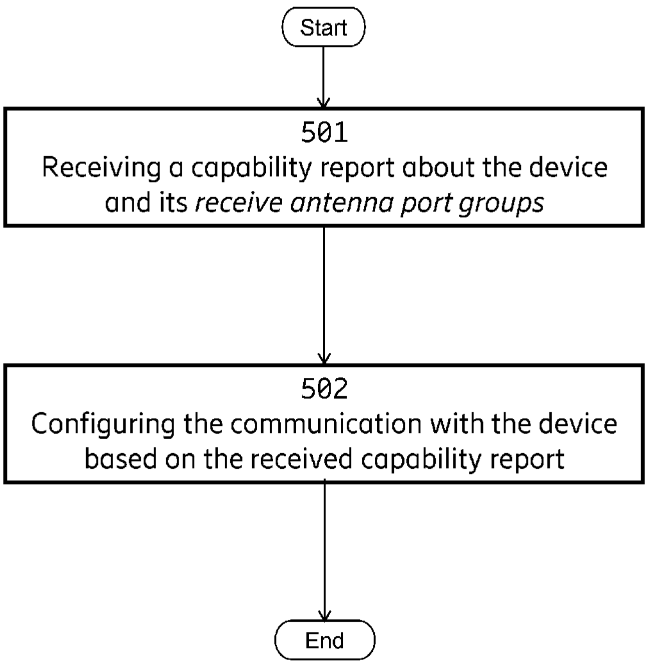

Fig. 5

(57) **Abstract:** A method, performed by a network node of a wireless communications network, for communicating with a wireless communications device which uses receive antenna port groups. The method comprises receiving (501) a capability message. The capability message indicates capabilities of the wireless communications device relating to receive antenna port groups of the wireless communications device. The method further comprises configuring (502) communication with the wireless communications device based on the received capability message.

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COMMUNICATION WITH WIRELESS COMMUNICATIONS DEVICES USING RECEIVE ANTENNA PORT GROUPS

TECHNICAL FIELD

The embodiments disclosed herein relate to communication with wireless communications devices using receive antenna port groups. A corresponding computer program and a computer program carrier are also disclosed.

BACKGROUND

In a typical wireless communication network, wireless devices, also known as wireless communication devices, mobile stations, stations (STA) and/or User Equipments (UE), communicate via a Local Area Network such as a Wi-Fi network or a Radio Access Network (RAN) to one or more core networks (CN). The RAN covers a geographical area which is divided into service areas or cell areas, which may also be referred to as a beam or a beam group, with each service area or cell area being served by a radio access node such as a radio access node e.g., a Wi-Fi access point or a radio base station (RBS), which in some networks may also be denoted, for example, a NodeB, eNodeB (eNB), or gNB as denoted in 5G. A service area or cell area is a geographical area where radio coverage is provided by the radio access node. The radio access node communicates over an air interface operating on radio frequencies with the wireless device within range of the radio access node.

Specifications for the Evolved Packet System (EPS), also called a Fourth Generation (4G) network, have been completed within the 3rd Generation Partnership Project (3GPP) and this work continues in the coming 3GPP releases. A Fifth Generation (5G) network also referred to as 5G New Radio (NR) has also been specified and work is now directed to further specifications of the 5G network. This work will continue in the coming 3GPP releases. The EPS comprises the Evolved Universal Terrestrial Radio Access Network (E-UTRAN), also known as the Long Term Evolution (LTE) radio access network, and the Evolved Packet Core (EPC), also known as System Architecture Evolution (SAE) core network. E-UTRAN/LTE is a variant of a 3GPP radio access network wherein the radio access nodes are directly connected to the EPC core network rather than to Radio Network Controllers (RNCs) used in 3G networks. In general, in E-UTRAN/LTE the functions of a 3G RNC are distributed between the radio access nodes, e.g. eNodeBs in LTE, and the core network. As such, the RAN of an EPS has an essentially “flat” architecture comprising radio access nodes connected directly to one or more core networks, i.e. they are not connected to RNCs. To compensate for that, the E-UTRAN specification defines a direct interface between the radio access nodes, this interface being denoted the X2 interface.

Wireless communication systems in 3GPP

Figure 1 illustrates a simplified wireless communication system. Consider the simplified wireless communication system in Figure 1, with a **UE 12**, which communicates with one or multiple **access nodes 103-104**, which in turn are connected to a **network node 106**. The access nodes 103-104 are part of the **radio access network 10**.

For wireless communication systems pursuant to 3GPP Evolved Packet System, (EPS), also referred to as Long Term Evolution, LTE, or 4G, standard specifications, such as specified in 3GPP TS 36.300 and related specifications, the access nodes 103-104 corresponds typically to Evolved NodeBs (eNBs) and the network node 106 corresponds typically to either a Mobility Management Entity (MME) and/or a Serving Gateway (SGW). The eNB is part of the radio access network 10, which in this case is the E-UTRAN (Evolved Universal Terrestrial Radio Access Network), while the MME and SGW are both part of the EPC (Evolved Packet Core network). The eNBs are inter-connected via the X2 interface, and connected to EPC via the S1 interface, more specifically via S1-C to the MME and S1-U to the SGW.

For wireless communication systems pursuant to 3GPP 5G System, 5GS (also referred to as New Radio, NR, or 5G) standard specifications, such as specified in 3GPP TS 38.300 and related specifications, on the other hand, the access nodes 103-104 correspond typically to an 5G NodeB (gNB) and the network node 106 corresponds typically to either a Access and Mobility Management Function (AMF) and/or a User Plane Function (UPF). The gNB is part of the radio access network 10, which in this case is the NG-RAN (Next Generation Radio Access Network), while the AMF and UPF are both part of the 5G Core Network (5GC). The gNBs are inter-connected via the Xn interface, and connected to 5GC via the NG interface, more specifically via NG-C to the AMF and NG-U to the UPF.

To support fast mobility between NR and LTE and avoid change of core network, LTE eNBs may also be connected to the 5G-CN via NG-U/NG-C and support the Xn interface. An eNB connected to 5GC is called a next generation eNB (ng-eNB) and is considered part of the NG-RAN. LTE connected to 5GC will not be discussed further in this document; however, it should be noted that most of the solutions/features described for LTE and NR in this document also apply to LTE connected to 5GC. In this document, when the term LTE is used without further specification it refers to LTE-EPC.

Multiple-input multiple-output (MIMO) is one of key physical layer technologies in 5G. A gNB equipped with many, e.g., 64 or more, antennas provide large array gains and/or performs spatial multiplexing of many users on the same time-frequency resources. Particularly, the spectral efficiency may be increased or, equivalently, the required power to satisfy a quality-of-service requirement may be decreased as the number of antennas increases.

In the following, the “device” may refer to a UE node, a Consumer Peripheral Equipment (CPE) node (for Fixed Wireless Access (FWA)), or nodes with similar functionalities.

In the following, the terms “receiver (Rx) chain” and “Rx port” may be used interchangeably. Also, the terms “transceiver (Tx) chain” and “Tx port” may be used interchangeably.

Due to the success of MIMO, it is expected that systems beyond 5G and 6G systems will make use of even larger arrays, not only at the gNB side, but also at the UE side. Indeed, equipping the UE with more antenna elements enables the UE to, in the DL, receive more Physical Downlink Shared Channel (PDSCH) layers, provide additional beamforming gain (via spatial combining) and/or perform interference mitigation. For this reason, support for receiving up to 8 PDSCH layers per UE was introduced in NR Rel-16. Sounding Reference Signal (SRS) antenna switching enhancements to support reciprocity-based DL precoding for a UE with 6Rx or 8Rx chains (and up to 4Tx chains) was introduced in NR Rel-17. Furthermore, even though UEs typically have more Rx chains than Tx chains, support for 8Tx UL transmission was introduced in NR Rel-18 for high-end UEs (e.g., an advanced CPE device for FWA deployments).

As mentioned above, 6Rx and 8Rx UEs may be supported already in previous 3GPP releases. However, due to complexity and cost, it may be difficult to use such a large number of Rx chains for real-world UEs (e.g., for handheld devices). Therefore, to enable practical implementations of 6Rx or 8Rx (or, even higher number of Rx chains) UEs, it is desirable to reduce the associated complexity and cost.

With this motivation, in the initial discussions for the topics of interest in Rel-19, it has been suggested to support lower-complexity 6Rx and 8Rx UEs, where the Rx chains are divided into *receive antenna port groups* (see, e.g., 3gpp RP-231928). **Figure 2** shows an example of such a setup for **a device 200** with Q *receive antenna port groups*

201, 202 and a total of N Rx chains. Here, the N-Rx receiver is divided into Q sub-receivers for independent MIMO detection. That is, each sub-receiver has dedicated and separated processing capability, and it corresponds to a limited number of Rx chains, i.e., a *receive antenna port group*. In Figure 2, the number of Rx ports per *receive antenna port group* is $M = N/Q$. In general, one may consider different numbers of Rx chains per *receive antenna port group*.

DL transmission from a network node, such as a base station, to low-complexity devices equipped with a plurality of *receive antenna port groups* is not supported by the existing NR specification. For example, the network node cannot distinguish which Rx ports that may be combined at the device and which cannot. Hence, for multi-Code Word (CW) transmission, the network node cannot ensure that a CW can be decoded based solely on the signal received over the Rx ports associated with a receive antenna port group at the device.

SUMMARY

An object of embodiments herein may be to obviate some of the problems related to DL transmission from a wireless communications network to low-complexity wireless communications devices equipped with a plurality of *receive antenna port groups.*

Embodiments herein address the above-described problem by methods for device capability reporting to the wireless communications network for low-complexity devices using *receive antenna port groups*. In other words, embodiments herein disclose methods in a network node to communicate with a wireless communications device using receive antenna port groups.

Such a report may contain different levels of information about each *receive antenna port group* and/or their relations with each other. Then, the capability report, which may be received from different nodes, such as a UE, an Operation, Administration, Maintenance (OAM) node, higher layers, another network node, enables the gNB to properly configure the communication with the low-complexity device.

According to an aspect, the object is achieved by a method for communicating with a wireless communications device, such as a UE, which uses receive antenna port groups. The method is performed by a network node of a wireless communications network, such as a radio access node.

The method comprises receiving a capability message. The capability message indicates capabilities of the wireless communications device relating to receive antenna port groups of the wireless communications device.

The method further comprises configuring communication with the wireless communications device based on the received capability message.

According to a further aspect, the object is achieved by a network node configured to perform the method according to the previous aspect.

According to a further aspect, the object is achieved by a method performed by a wireless communications device which uses receive antenna port groups, for communicating with a network node. The method comprises transmitting a capability message to a network node. The capability message indicates capabilities of the wireless communications device relating to receive antenna port groups of the wireless communications device.

The method further comprises receiving a configuration message from the network node. The configuration message configures communication with the network node.

According to a further aspect, the object is achieved by a wireless communications device configured to perform the method according to the previous aspect.

According to a further aspect, the object is achieved by a computer program comprising instructions, which when executed by a processor of the network node, causes the network node to perform actions according to any of the aspects above.

According to a further aspect, the object is achieved by a computer program comprising instructions, which when executed by a processor of the wireless communications device, causes the wireless communications device to perform actions according to any of the aspects above.

According to a further aspect, the object is achieved by a carrier comprising the computer program of the aspects above, wherein the carrier is one of an electronic signal, an optical signal, an electromagnetic signal, a magnetic signal, an electric signal, a radio signal, a microwave signal, or a computer-readable storage medium.

Embodiments herein enable capability reporting about low-complexity wireless communications devices using receive antenna port groups. This enables the network node to properly configure the DL communication with the wireless communications device. In this way, embodiments disclosed herein help to integrate such low-complexity wireless communications devices into the network and improves the business case for wireless communications devices with a large number of Rx chains.

BRIEF DESCRIPTION OF THE DRAWINGS

In the figures, features that appear in some embodiments are indicated by dashed lines.

The various aspects of embodiments disclosed herein, including particular features and advantages thereof, will be readily understood from the following detailed description and the accompanying drawings, in which:

Figure 1 is a block diagram schematically illustrating a simplified wireless communication system according to prior art,

Figure 2 is a block diagram schematically illustrating a wireless communications device with receive antenna port groups,

Figure 3 is a block diagram schematically illustrating a wireless communications network in which embodiments disclosed herein may be implemented,

Figure 4 is a combined signalling diagram and flow chart illustrating a method according to some embodiments herein,

Figure 5 is a flow chart illustrating a method performed by a network node of a wireless communications network according to some embodiments disclosed herein,

Figure 6 is a flow chart illustrating a method performed by a wireless communications device according to some embodiments disclosed herein,

Figure 7 is a block diagram schematically illustrating a wireless communications device,

Figure 8 is a block diagram schematically illustrating a network node,

Figure 9 schematically illustrates a telecommunication network connected via an intermediate network to a host computer.

Figure 10 is a generalized block diagram of a host computer communicating via a base station with a user equipment over a partially wireless connection.

Figures 11 to 14 are flowcharts illustrating methods implemented in a communication system including a host computer, a base station and a user equipment.

DETAILED DESCRIPTION

Examples of network nodes are NodeB, base station (BS), multi-standard radio (MSR) radio node such as MSR BS, eNodeB, gNodeB, MeNB, SeNB, location measurement unit (LMU), integrated access backhaul (IAB) node, network controller, radio network controller (RNC), base station controller (BSC), relay, donor node controlling relay, base transceiver station (BTS), Central Unit (e.g. in a gNB), Distributed Unit (e.g. in a gNB), Baseband Unit, Centralized Baseband, Centralized RAN (C-RAN), access point (AP), transmission points, transmission nodes, transmission reception point (TRP), Remote Radio Unit (RRU), Remote Radio Head (RRH), nodes in distributed antenna system (DAS), core network node (e.g. Mobile Switching Center (MSC), MME etc), Operation and Maintenance (O&M), Operational Support System (OSS), Self-Organizing Network (SON), positioning node (e.g. Evolved Serving Mobile Location Center (E-SMLC)), etc.

The non-limiting term UE refers to any type of wireless device communicating with a network node and/or with another UE in a cellular or mobile communication system. Examples of UEs are target device, device to device (D2D) UE, vehicular to vehicular (V2V) UE, machine type UE, Machine Type Communication (MTC) UE or UE capable of machine to machine (M2M) communication, Personal Digital Assistant (PDA), tablet, mobile terminals, smart phone, laptop embedded equipment (LEE), laptop mounted equipment (LME), Universal Serial Bus (USB) dongles etc.

The term radio access technology, or RAT, may refer to any RAT e.g. UTRA, E-UTRA, narrow band internet of things (NB-IoT), WiFi, Bluetooth, next generation RAT, New Radio (NR), 4G, 5G, 6G, future generation RAT etc. Any of the equipment denoted by the term node, network node or radio network node may be capable of supporting a single or multiple RATs.

The term signal or radio signal used herein may be any physical signal or physical channel. Examples of DL physical signals are reference signal (RS) such as Primary Synchronisation Signal (PSS), Secondary Synchronisation Signal (SSS), Channel State Information Reference Signal (CSI-RS), Demodulation Reference Signal (DMRS) signals in Synchronisation Signal (SS)/Physical Broadcast Channel (PBCH) block Synchronisation Signal Block (SSB), discovery reference signal (DRS), Cell-specific Reference Signals (CRS), Positioning Reference Signal (PRS) etc. RS may be periodic e.g. RS occasion carrying one or more RSs may occur with certain periodicity e.g. 20 ms, 40 ms etc. The RS may also be aperiodic. Each SSB may carry NR-PSS, NR-SSS and NR-PBCH in 4 successive symbols. One or multiple SSBs are transmitted in one SSB burst which is repeated with certain periodicity e.g. 5 ms, 10 ms, 20 ms, 40 ms, 80 ms and 160 ms. The UE is configured with information about the SSB on cells of certain carrier frequency by one or more SS/PBCH block measurement timing configuration (SMTC) configurations. The SMTC configuration comprising parameters such as SMTC periodicity, SMTC occasion length in time or duration, SMTC time offset wrt reference time (e.g. serving cell’s SFN) etc. Therefore, SMTC occasion may also occur with certain periodicity e.g. 5 ms, 10 ms, 20 ms, 40 ms, 80 ms and 160 ms. Examples of UL physical signals are reference signal such as SRS, DMRS etc. The term physical channel refers to any channel carrying higher layer information e.g. data, control etc. Examples of physical channels are PBCH, NPBCH, PDCCH, PDSCH, sPUCCH, sPDSCH. sPUCCH. sPUSCH, MPDCCH, NPDCCH, NPDSCH, E-PDCCH, PUSCH, PUCCH, NPUSCH etc.

The term time resource used herein may correspond to any type of physical resource or radio resource expressed in terms of length of time. Examples of time resources are: symbol, time slot, subframe, radio frame, Transmission Time Interval (TTI), interleaving time, slot, sub-slot, mini-slot, etc.

Embodiments herein relate to wireless communication networks in general. **Figure 3** is a schematic overview depicting **a wireless communications network 100** wherein embodiments herein may be implemented. The wireless communications network 100 comprises one or more RANs and one or more CNs. The wireless communications network 100 may use a number of different technologies, such as Wi-Fi, Long Term Evolution (LTE), LTE-Advanced, 5G, New Radio (NR), Wideband Code Division Multiple Access (WCDMA), Global System for Mobile communications/enhanced Data rate for GSM Evolution (GSM/EDGE), Worldwide Interoperability for Microwave Access (WiMax), or Ultra Mobile Broadband (UMB), just to mention a few possible implementations. Embodiments herein relate to recent technology trends that are of particular interest in a 5G context, however, embodiments are also applicable in further development of the existing wireless communication systems such as e.g. WCDMA and LTE and to future 6G wireless communication systems.

Network nodes operate in the wireless communications network 100. The network nodes may for example be access nodes such as **a first radio access node 111**. The first radio access node 111 provides radio coverage over a geographical area, a service area **referred to as a cell 115**, which may also be referred to as a beam or a beam group of a first radio access technology (RAT), such as 5G, LTE, Wi-Fi or similar. There may also be further cells, such as **a second cell 116**.

The first radio access node 111 may be a NR-RAN node, transmission and reception point e.g. a base station, a radio access node such as a Wireless Local Area Network (WLAN) access point or an Access Point Station (AP STA), an access controller, a base station, e.g. a radio base station such as a NodeB, an evolved Node B (eNB, eNode B), a gNB, a base transceiver station, a radio remote unit, an Access Point Base Station, a base station router, a transmission arrangement of a radio base station, a stand-alone access point or any other network unit capable of communicating with a wireless device within the service area depending e.g. on the radio access technology and terminology used. The first radio access node 111 may be referred to as a serving radio access node and it communicates with a UE with Downlink (DL) transmissions to the UE and Uplink (UL) transmissions from the UE.

A number of wireless communications devices operate in the wireless communication network 100, such as **a wireless communications device 121**. The wireless communications device 121 may be a UE. The wireless communications device 121 may further be an FWA node, or nodes with similar functionality.

The wireless communications device 121 may further be a mobile station, a non-access point (non-AP) STA, a STA, a user equipment and/or a wireless terminals, that communicate via one or more Access Networks (AN), e.g. RAN, e.g. via the first radio access node 111 to one or more core networks (CN) e.g. comprising a **CN node 130**, for example comprising an Access Management Function (AMF). It should be understood by the skilled in the art that “UE” is a non-limiting term which means any terminal, wireless communication terminal, user equipment, Machine Type Communication (MTC) device, Device to Device (D2D) terminal, or node e.g. smart phone, laptop, mobile phone, sensor, relay, mobile tablets or even a small base station communicating within a cell.

Methods herein may in a first aspect be performed by a network node, such as the first radio access node 111 and in in a second aspect by the wireless communications device 121. As an alternative, a Distributed Node (DN) and functionality, e.g. comprised in a **cloud 140** as shown in Figure 3, may be used for performing or partly performing the methods.

As explained above, network performance is improved by increasing the number of antennas at the gNB and/or the wireless communications devices. While it is probable that soon the number of gNB antennas will increase, it may be challenging to increase the number of antennas on the wireless communications devices, due to cost and complexity. For this reason, it is beneficial to develop low-complexity receivers for wireless communications devices with a large number of receive antennas using the *receive antenna port group* concept, as explained above. Then, the gNB may require some information about the capabilities and/or properties of such low-complexity wireless communications devices and their *receive antenna port groups*, which enables the gNB to properly configure the communication with the wireless communications device. Thus, the gNB may require some information about the capabilities and/or properties of the *receive* *antenna port groups* of such low-complexity wireless communications devices. To meet this need, embodiments herein disclose methods for capability reporting of low-complexity wireless communications devices using *receive antenna port groups*.

Embodiments herein will now be described in more detail. As mentioned above, embodiments disclosed herein address a problem of configuring DL transmission from the network to low-complexity wireless communications devices equipped with a plurality of receive antenna port groups.

Figure 4 is a combined signalling diagram and flow chart and illustrates example methods for communicating with a wireless communications device, such as the wireless communications device 121, which uses receive antenna port groups. Embodiments herein disclose methods to communicate with a wireless communications device using receive antenna port groups.

The signaling is between a wireless communications device, such as the wireless communications device 121, and a network node, such as the first radio access node 111.

The actions may be performed in any suitable order, for example in another order than given below. Specifically, the sub-actions may be performed in another order than given below.

Action 400:

The network node, such as the first radio access node 111, may configure or instruct the wireless communications device 121 on whether it wants the wireless communications device 121 to report a capability message to the network node.

Action 401:

The wireless communications device 121 reports/transmits the capability message to the network node, such as the first radio access node 111, wherein the capability message is indicating capabilities of the wireless communications device 121 and further indicating receive antenna port groups of the wireless communications device 121.The indicated capabilities of the wireless communications device 121 includes capabilities related to the receive antenna port groups of the wireless communications device 121.

Action 402:

Based on the received UE capability, the network node configures communication with the wireless communications device 121 based on the received capability message. The first radio access node 111 may perform the configuration.

Figure 5 is a flowchart and illustrates example methods performed by the network node 111 of the wireless communications network 100.

The methods of Figure 5 are methods for communicating with the wireless communications device, such as the wireless communications device 121, which uses receive antenna port groups.

The methods comprise one or more of the following actions, which actions may be taken in any suitable order.

The network node 111 is configured to communicate with the wireless communications device 121.

In **Action 501**, the network node 111 receives the capability message from the wireless communications device 121. The capability message may be a capability report. The capability report may be a report about the wireless communications device 121 and its receive antenna port groups. The capability message indicates capabilities of the wireless communications device 121 and further indicates receive antenna port groups of the wireless communications device 121. Thus, the capability message indicates capabilities of the wireless communications device 121 relating to receive antenna port groups of the wireless communications device 121.

The capability message may comprise information about each *receive antenna port group* and/or their relations with each other. In some embodiments disclosed herein a capability of the wireless communications device 121 relating to receive antenna port groups is a joint capability for several receive antenna port groups.

Note that support for wireless communications devices with multiple receive antenna port groups may be captured in NR standard specification without explicitly stating the number of receive antenna port groups. In one embodiment, the wireless communications device 121 instead indicates capability for a low-complexity receiver, from which one or multiple of the above capabilities, which may be related to properties, may be inferred (and other capabilities may then be explicitly/separately configured). Thus, the wireless communications device 121 may in some embodiments disclosed herein indicate its capability for a specific functionality rather than indicating its hardware setup. In one embodiment, it may be inferred that the number of Rx ports per receive antenna port group, e.g., for an 8 Rx UE, is half of the number of Rx ports at the wireless communications device 121, the maximum number of PDSCH layers per receive antenna port group is half of the maximum number of PDSCH layers supported by the wireless communications device 121, etc.

The capability message may comprise information about one or more of:

a. a total number of receive antennas;
b. a number of receive antenna port groups;
c. a number of receive antennas per each receive antenna port group;
d. a maximum number of spatial multiplexing layer(s) supported by the wireless communications device 121 for DL reception per each receive antenna port group;
e. a total number of transmitter chains;
f. a number of transmitter chains per receive antenna port group;
g. a maximum number of spatial multiplexing layer(s) supported by the wireless communications device 121 for UL transmission per each receive antenna port group for codebook-based UL transmission;
h. a maximum number of spatial multiplexing layer(s) supported by the wireless communications device 121 for UL transmission per each receive antenna port group for non-codebook-based UL transmission;
i. a configuration of the transmitter chains with respect to the receive antenna port groups;
j. Directions of the receive antenna port groups and/or relative directions of the receive antenna port groups with respect to each other (i.e., receive antenna port group being in the same or different directions);
k. Interference measurement or cancelation capabilities between receiver, chains belonging to different receive antenna port groups;
l. Combining capability between receive antenna port groups;
m. Interference measurement and/or cancelation capabilities between receiver chains belonging to the same receive antenna port group;
n. Capability for DL codebook-based operation via the receive antenna port groups;
o. Capability for reciprocity-based operation via the receive antenna port groups;
p. Support for switching between receive antenna port groups;
q. a switching delay for switching between receive antenna port groups;

r. ON/OFF capabilities in the receive antenna port groups (e.g. a capability to turn an Rx antenna port group on and off);
s. Antenna constellation per receive antenna port group, antenna polarizations, antenna/panel coordinates;
t. Support for Type I and/or Type II codebook-based operation via the receive antenna port groups;
u. Support for operation based on shared and/or separated Channel State Information Reference Signal, CSI-RS, resources per receive antenna port groups;
v. Maximum rank per receive antenna port group;
w. CSI processing unit, such as a Central Processing Unit (CPU), capability for different receive antenna port groups;
x. Capability to exchange control information via one or more of the receive antenna port groups;
y. a maximum number of CSI-RS ports per receive antenna port groups.

In some embodiments disclosed herein the capabilities relating to the receive antenna port groups comprises information about support for switching between receive antenna port groups and supported antenna switching schemes are received jointly for all receive antenna port groups, e.g., by indicating one or more of 2t6r, 2t8r, 4t8r, 3t6r, etc.

In some embodiments disclosed herein the capabilities relating to the receive antenna port groups comprises information about support for switching between receive antenna port groups and supported antenna switching schemes are received per receive antenna port group. For example, receive antenna port group 1 supports one or more of 1t4r, 2t4r, 1t3r, etc., and receive antenna port group 2 supports one or more of 1t4r, 2t4r, 1t3r, etc.

The configuration of the transmitter chains with respect to the receive antenna port groups may comprise information on whether or how the transmitter chains are associated with different receive antenna port groups or both.

In some embodiments disclosed herein the capability for DL codebook-based operation via the receive antenna port groups comprises support for transmission of multiple Precoding-Matrix Indicators (PMIs), per CSI-RS transmission. The PMI provides information about the precoding matrix used by the transmitter.

The capability for reciprocity-based operation via the receive antenna port groups may comprise support for SRS ports or resources grouping and mapping to each receive antenna port group.

By the configuration of the Tx chains with respect to the *receive antenna port groups* it is referred to, e.g., if the TX chains may be switched between RX antennas belonging to different *receive antenna port groups* or if TX chains only may be switched between RX antennas within each *receive antenna port group*. Also, by a capability for reciprocity-based operation via the *receive antenna port groups*, it is referred to, e.g., SRS port/resource mapping targeting the *receive antenna port groups*. Moreover, combining capability between receive antenna port groups may include, e.g., if the wireless communications device 121 is capable of co-phasing different receive antenna port groups to increase beamforming gain.

In some embodiments, the capability for different *receive antenna port groups* may be reported separately or jointly.

In some embodiments, the supported antenna switching schemes may be reported jointly over all *receive antenna port groups*, e.g., by indicating one or more of 2t6r, 2t8r, 4t8r, 3t6r, etc. In another embodiment, the supported antenna switching schemes may be reported per *receive antenna port group*, e.g., receive antenna port group 1 supports one or more of 1t4r, 2t4r, 1t3r, etc., and receive antenna port group 2 supports one or more of 1t4r, 2t4r, 1t3r, etc. In yet another embodiment, the configuration of the Tx chains with respect to the *receive antenna port groups* may contain information whether/how the Tx chains are associated with different *receive antenna port groups.*

In some embodiments, capability for DL codebook-based operation via the *receive antenna port groups* may include support for reporting of multiple Precoding Matrix Indicators (PMIs) per CSI-RS resource. In another embodiment, capability for reciprocity-based operation via the *receive antenna port groups* may include support for SRS ports/resources grouping and mapping to each *receive antenna port group.*

In some embodiments, a first subset of the capability information from the above list is a mandatory UE feature, while one or more subsets of the capability information from the above list is (are) optional UE feature(s), wherein a reported type of parameter of the first subset and the remaining subset(s) may be the same, but with different values. For example, the first subset may indicate the support of 2 layers per receive antenna group, while a second subset may indicate the support of 4 layers per antenna group. In some embodiments, the wireless communications device 121 signals the support of capabilities defined according the first subset. In another embodiment, the wireless communications device 121 signals the support of capabilities defined in the first subset, and the support of capabilities defined in one or multiple remaining subset(s).

Action 501 is related to action 401 above.

In **Action 502**, the network node 111 configures communication with the wireless communications device 121 based on the received capability message. The communication that is configured may be DL communication. In some other embodiments the communication that is configured is UL communication.

Here, in some embodiments, configuring the communication with the wireless communications device 121 based on the received report may include configuring DL codebook-based operation via the receive antenna port groups. In another embodiment, configuring the communication with the wireless communications device 121 based on the received report may include configuring codeword association to the receive antenna port groups.

In this way, the capability report enables the network node 111 to configure the communication to the wireless communications device 121 based on the indicated capabilities of the wireless communications device 121 relating to the receive antenna port groups of the wireless communications device 121. In some embodiments the capability report enables the network node 111 to configure the communication to the wireless communications device 121 based on *receive antenna port groups* properties. This guarantees a proper integration of such low-complexity wireless communications devices into the network and increases the chance for having wireless communications devices with a large number of receive antennas in near future.

Action 502 is related to action 402 above.

Figure 6 illustrates example methods performed by the wireless communications device 121. The wireless communications device 121 uses receive antenna port groups for wireless communication, more specifically for communicating with the network node

111 of the wireless communications network 100. The method is for communicating with the network node 111. The methods of Figure 6 are methods to communicate with a network node and to configure the communication with the network node.

The method comprises one or more of the following actions, which actions may be taken in any suitable order.

In **Action 601** the wireless communications device 121 reports/transmits the capability message to the network node. The capability message indicates capabilities of the wireless communications device 121 relating to receive antenna port groups of the wireless communications device 121.

Action 601 is related to action 401 and 501 above.

In **Action 602** the wireless communications device 121 receives a configuration message from the network node. This configuration message configures communication with the network node 111. As mentioned above, the network node 111 configures communication with the wireless communications device 121 based on the received capability message. Thus, the configuration message is based on the capability message transmitted by the wireless communications device 121 in action 601.

As mentioned above, the capability message may comprise information about each receive antenna port group and/or their relations with each other.

Action 602 is related to actions 402 and 502 above.

Figure 7 shows an example of the wireless communications device 121. **Figure 8** shows an example of the network node 111.

The network node 111 is adapted for communicating with the wireless communications device 121 which uses receive antenna port groups. The network node 111 is further adapted to receive a capability message. The capability message indicates capabilities of the wireless communications device 121 relating to receive antenna port groups of the wireless communications device 121.

The network node 111 is further adapted to configure communication with the wireless communications device 121 based on the received capability message.

In some embodiments disclosed herein the network node 111 is adapted to configure the communication with the wireless communications device 121 based on the received message by being adapted to configure DL codebook-based operation via the receive antenna port groups.

The network node 111 may be adapted to configure the communication with the wireless communications device 121 based on the received message by being adapted to configure codeword association to the receive antenna port groups.

The wireless communications device 121 is adapted for communicating with the network node 111 of the wireless communications network 100. The wireless communications device 121 is adapted to transmit the capability message to the network node 111. The capability message indicates capabilities of the wireless communications device 121 relating to receive antenna port groups of the wireless communications device 121.

The wireless communications device 121 is further adapted to receive the configuration message from the network node 111. The configuration message configures communication with the network node 111.

The wireless communications device 121 and the network node 111 may comprise a respective **input and output interface, IF, 706, 806** configured to communicate with each other, see Figures 7-8. The input and output interface may comprise a wireless receiver (not shown) and a wireless transmitter (not shown).

The embodiments herein may be implemented through a respective processor or one or more processors, such as the respective **processor 704 and 804,** of a processing circuitry in the wireless communications device 121 and the network node 111 and depicted in Figures 7-8 together with computer program code for performing the functions and actions of the embodiments herein. The program code mentioned above may also be provided as a computer program product, for instance in the form of a data carrier carrying computer program code for performing the embodiments herein when being loaded into the respective wireless communications device 121 and the network node 111. One such carrier may be in the form of a CD ROM disc. It is however feasible with other data carriers such as a memory stick. The computer program code may furthermore be provided as pure program code on a server and downloaded to the respective wireless communications device 121 and network node 111.

The wireless communications device 121 and the network node 111 may further comprise a respective **memory 702 and 802** comprising one or more memory units. The memory comprises instructions executable by the processor in the wireless communications device 121 and the network node 111.

Each respective memory 702 and 802 is arranged to be used to store e.g. information, data, configurations, and applications to perform the methods herein when being executed in the respective wireless communications device 121 and the network node 111.

In some embodiments, a respective **computer program 703 and 803** comprises instructions, which when executed by the respective processor 704, 804, cause the respective wireless communications device 121 and network node 111 to perform the actions above.

In some embodiments, a respective **carrier 705 and 805** comprises the respective computer program, wherein the carrier is one of an electronic signal, an optical signal, an electromagnetic signal, a magnetic signal, an electric signal, a radio signal, a microwave signal, or a computer-readable storage medium.

Those skilled in the art will also appreciate that the units in the units described above may refer to a combination of analog and digital circuits, and/or one or more processors configured with software and/or firmware, e.g. stored in the respective wireless communications device 121 and network node 111 described above. One or more of these processors, as well as the other digital hardware, may be included in a single Application-Specific Integrated Circuitry (ASIC), or several processors and various digital hardware may be distributed among several separate components, whether individually packaged or assembled into a system-on-a-chip (SoC).

With reference to **Figure 9**, in accordance with an embodiment, a communication system includes a telecommunication network 3210, such as a 3GPP-type cellular network, which comprises an access network 3211, such as a radio access network, and a core network 3214. The access network 3211 comprises a plurality of base stations 3212a, 3212b, 3212c, such as the access node 111, AP STAs NBs, eNBs, gNBs or other types of wireless access points, each defining a corresponding coverage area 3213a, 3213b, 3213c. Each base station 3212a, 3212b, 3212c is connectable to the core network

3214 over a wired or wireless connection 3215. A first user equipment (UE) such as a Non-AP STA 3291 located in coverage area 3213c is configured to wirelessly connect to, or be paged by, the corresponding base station 3212c. A second UE 3292 such as a Non-AP STA in coverage area 3213a is wirelessly connectable to the corresponding base station 3212a. While a plurality of UEs 3291, 3292 are illustrated in this example, the disclosed embodiments are equally applicable to a situation where a sole UE is in the coverage area or where a sole UE is connecting to the corresponding base station 3212.

The telecommunication network 3210 is itself connected to a host computer 3230, which may be embodied in the hardware and/or software of a standalone server, a cloud-implemented server, a distributed server or as processing resources in a server farm. The host computer 3230 may be under the ownership or control of a service provider, or may be operated by the service provider or on behalf of the service provider. The connections 3221, 3222 between the telecommunication network 3210 and the host computer 3230 may extend directly from the core network 3214 to the host computer 3230 or may go via an optional intermediate network 3220. The intermediate network 3220 may be one of, or a combination of more than one of, a public, private or hosted network; the intermediate network 3220, if any, may be a backbone network or the Internet; in particular, the intermediate network 3220 may comprise two or more sub-networks (not shown).

The communication system of Figure 9 as a whole enables connectivity between one of the connected UEs 3291, 3292 such as e.g. the UE 121, and the host computer 3230. The connectivity may be described as an over-the-top (OTT) connection 3250. The host computer 3230 and the connected UEs 3291, 3292 are configured to communicate data and/or signaling via the OTT connection 3250, using the access network 3211, the core network 3214, any intermediate network 3220 and possible further infrastructure (not shown) as intermediaries. The OTT connection 3250 may be transparent in the sense that the participating communication devices through which the OTT connection 3250 passes are unaware of routing of uplink and downlink communications. For example, a base station 3212 may not or need not be informed about the past routing of an incoming downlink communication with data originating from a host computer 3230 to be forwarded (e.g., handed over) to a connected UE 3291. Similarly, the base station 3212 need not be aware of the future routing of an outgoing uplink communication originating from the UE 3291 towards the host computer 3230.

Example implementations, in accordance with an embodiment, of the UE, base station and host computer discussed in the preceding paragraphs will now be described with reference to Figure 10. In a communication system 3300, a host computer 3310 comprises hardware 3315 including a communication interface 3316 configured to set up and maintain a wired or wireless connection with an interface of a different communication device of the communication system 3300. The host computer 3310 further comprises processing circuitry 3318, which may have storage and/or processing capabilities. In particular, the processing circuitry 3318 may comprise one or more programmable processors, application-specific integrated circuits, field programmable gate arrays or combinations of these (not shown) adapted to execute instructions. The host computer 3310 further comprises software 3311, which is stored in or accessible by the host computer 3310 and executable by the processing circuitry 3318. The software 3311 includes a host application 3312. The host application 3312 may be operable to provide a service to a remote user, such as a UE 3330 connecting via an OTT connection 3350 terminating at the UE 3330 and the host computer 3310. In providing the service to the remote user, the host application 3312 may provide user data which is transmitted using the OTT connection 3350.

The communication system 3300 further includes a base station 3320 provided in a telecommunication system and comprising hardware 3325 enabling it to communicate with the host computer 3310 and with the UE 3330. The hardware 3325 may include a communication interface 3326 for setting up and maintaining a wired or wireless connection with an interface of a different communication device of the communication system 3300, as well as a radio interface 3327 for setting up and maintaining at least a wireless connection 3370 with a UE 3330 located in a coverage area (not shown in Figure 10) served by the base station 3320. The communication interface 3326 may be configured to facilitate a connection 3360 to the host computer 3310. The connection 3360 may be direct or it may pass through a core network (not shown in Figure 10) of the telecommunication system and/or through one or more intermediate networks outside the telecommunication system. In the embodiment shown, the hardware 3325 of the base station 3320 further includes processing circuitry 3328, which may comprise one or more programmable processors, application-specific integrated circuits, field programmable gate arrays or combinations of these (not shown) adapted to execute instructions. The base station 3320 further has software 3321 stored internally or accessible via an external connection.

The communication system 3300 further includes the UE 3330 already referred to. Its hardware 3335 may include a radio interface 3337 configured to set up and maintain a wireless connection 3370 with a base station serving a coverage area in which the UE 3330 is currently located. The hardware 3335 of the UE 3330 further includes processing circuitry 3338, which may comprise one or more programmable processors, application-specific integrated circuits, field programmable gate arrays or combinations of these (not shown) adapted to execute instructions. The UE 3330 further comprises software 3331, which is stored in or accessible by the UE 3330 and executable by the processing circuitry 3338. The software 3331 includes a client application 3332. The client application 3332 may be operable to provide a service to a human or non-human user via the UE 3330, with the support of the host computer 3310. In the host computer 3310, an executing host application 3312 may communicate with the executing client application 3332 via the OTT connection 3350 terminating at the UE 3330 and the host computer 3310. In providing the service to the user, the client application 3332 may receive request data from the host application 3312 and provide user data in response to the request data. The OTT connection 3350 may transfer both the request data and the user data. The client application 3332 may interact with the user to generate the user data that it provides.
It is noted that the host computer 3310, base station 3320 and UE 3330 illustrated in Figure 10 may be identical to the host computer 3230, one of the base stations 3212a, 3212b, 3212c and one of the UEs 3291, 3292 of Figure 9, respectively. This is to say, the inner workings of these entities may be as shown in Figure 10 and independently, the surrounding network topology may be that of Figure 9.

In Figure 10, the OTT connection 3350 has been drawn abstractly to illustrate the communication between the host computer 3310 and the use equipment 3330 via the base station 3320, without explicit reference to any intermediary devices and the precise routing of messages via these devices. Network infrastructure may determine the routing, which it may be configured to hide from the UE 3330 or from the service provider operating the host computer 3310, or both. While the OTT connection 3350 is active, the network infrastructure may further take decisions by which it dynamically changes the routing (e.g., on the basis of load balancing consideration or reconfiguration of the network).

The wireless connection 3370 between the UE 3330 and the base station 3320 is in accordance with the teachings of the embodiments described throughout this disclosure. One or more of the various embodiments improve the performance of OTT services provided to the UE 3330 using the OTT connection 3350, in which the wireless connection 3370 forms the last segment. More precisely, the teachings of these embodiments may improve the data rate, latency, power consumption and thereby provide benefits such as reduced user waiting time, relaxed restriction on file size, better responsiveness, extended battery lifetime.

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 3350 between the host computer 3310 and UE 3330, in response to variations in the measurement results. The measurement procedure and/or the network functionality for reconfiguring the OTT connection 3350 may be implemented in the software 3311 of the host computer 3310 or in the software 3331 of the UE 3330, or both. In embodiments, sensors (not shown) may be deployed in or in association with communication devices through which the OTT connection 3350 passes; the sensors may participate in the measurement procedure by supplying values of the monitored quantities exemplified above, or supplying values of other physical quantities from which software 3311, 3331 may compute or estimate the monitored quantities. The reconfiguring of the OTT connection 3350 may include message format, retransmission settings, preferred routing etc.; the reconfiguring need not affect the base station 3320, and it may be unknown or imperceptible to the base station 3320. Such procedures and functionalities may be known and practiced in the art. In certain embodiments, measurements may involve proprietary UE signaling facilitating the host computer’s 3310 measurements of throughput, propagation times, latency and the like. The measurements may be implemented in that the software 3311, 3331 causes messages to be transmitted, in particular empty or ‘dummy’ messages, using the OTT connection 3350 while it monitors propagation times, errors etc.

Figure 11 is a flowchart illustrating a method implemented in a communication system, in accordance with one embodiment. The communication system includes a host computer, a base station such as a AP STA, and a UE such as a Non-AP STA which may be those described with reference to Figure 9 and Figure 10. For simplicity of the present disclosure, only drawing references to Figure 11 will be included in this section. In a first action 3410 of the method, the host computer provides user data. In an optional subaction 3411 of the first action 3410, the host computer provides the user data by executing a host application. In a second action 3420, the host computer initiates a transmission carrying the user data to the UE. In an optional third action 3430, the base station transmits to the UE the user data which was carried in the transmission that the host computer initiated, in accordance with the teachings of the embodiments described throughout this disclosure. In an optional fourth action 3440, the UE executes a client application associated with the host application executed by the host computer.

FIGURE 12 is a flowchart illustrating a method implemented in a communication system, in accordance with one embodiment. The communication system includes a host computer, a base station such as a AP STA, and a UE such as a Non-AP STA which may be those described with reference to Figure 9 and Figure 10. For simplicity of the present disclosure, only drawing references to Figure 12 will be included in this section. In a first action 3510 of the method, the host computer provides user data. In an optional subaction (not shown) the host computer provides the user data by executing a host application. In a second action 3520, the host computer initiates a transmission carrying the user data to the UE. The transmission may pass via the base station, in accordance with the teachings of the embodiments described throughout this disclosure. In an optional third action 3530, the UE receives the user data carried in the transmission.

FIGURE 13 is a flowchart illustrating a method implemented in a communication system, in accordance with one embodiment. The communication system includes a host computer, a base station such as a AP STA, and a UE such as a Non-AP STA which may be those described with reference to Figure 9 and Figure 10. For simplicity of the present disclosure, only drawing references to Figure 13 will be included in this section. In an optional first action 3610 of the method, the UE receives input data provided by the host computer. Additionally or alternatively, in an optional second action 3620, the UE provides user data. In an optional subaction 3621 of the second action 3620, the UE provides the user data by executing a client application. In a further optional subaction 3611 of the first action 3610, the UE executes a client application which provides the user data in reaction to the received input data provided by the host computer. In providing the user data, the executed client application may further consider user input received from the user. Regardless of the specific manner in which the user data was provided, the UE initiates, in an optional third subaction 3630, transmission of the user data to the host computer. In a fourth action 3640 of the method, the host computer receives the user data transmitted from the UE, in accordance with the teachings of the embodiments described throughout this disclosure.

FIGURE 14 is a flowchart illustrating a method implemented in a communication system, in accordance with one embodiment. The communication system includes a host computer, a base station such as a AP STA, and a UE such as a Non-AP STA which may be those described with reference to Figures 9 and 10. For simplicity of the present disclosure, only drawing references to Figure 14 will be included in this section. In an optional first action 3710 of the method, in accordance with the teachings of the embodiments described throughout this disclosure, the base station receives user data from the UE. In an optional second action 3720, the base station initiates transmission of the received user data to the host computer. In a third action 3730, the host computer receives the user data carried in the transmission initiated by the base station.

When using the word "comprise" or “comprising” it shall be interpreted as non-limiting, i.e. meaning "consist at least of".

The embodiments herein are not limited to the above described preferred embodiments. Various alternatives, modifications and equivalents may be used.

Abbreviations

Abbreviation Explanation

Abbreviation	Explanation
BS	Base station
CPE	Consumer peripheral equipment
CPU	CSI processing unit
FWA	Fixed wireless access
UE	User equipment
IRS	Intelligent reflecting surface
MIMO	Multiple-input-multiple-output
gNB	Next generation Node B
AOA	Angle-of-arrival
mmWave	Millimeter wave
NLOS	non-line of sight
NCR	Network controlled repeater
LOS	Line of sight
LS	Least squares
OAM	Operation, Administration, Maintenance

NUMBERED EMBODIMENTS

1. A method, performed by a network node 111 of a wireless communications network 100, for communicating with a wireless communications device 121, such as a UE, which uses receive antenna port groups, the method comprises:

   receiving a capability message, the capability message indicating capabilities of the wireless communications device 121 and further indicating receive antenna port groups of the wireless communications device 121; and

   configuring communication with the wireless communications device 121 based on the received capability message.

2. The method of embodiment 1, wherein the capability message is based on any one of RRC, MAC-CE, UCI signaling.

3. The method of embodiment 1 or 2, wherein the capability message is received from one of: the wireless communications device 121, an OAM node, higher layers, another network node.

4. The method of any of the embodiments 1-3, wherein the capability message is received from one of: the wireless communications device 121, an OAM node, higher layers, another network node.

5. The method of any of the embodiments 1-4, wherein the capability message includes information about one or more of:
   a. a total number of receive antennas,
   b. a number of *receive antenna port groups,*
   c. a number of receive antennas per each *receive antenna port group,*
   d. a maximum number of spatial multiplexing layer(s) support by the wireless communications device 121 for DL reception per each *receive antenna port group.*
   e. a total number of Tx chains,
   f. a number of TX chains per *receive antenna port group,*
   g. a maximum number of spatial multiplexing layer(s) supported by the wireless communications device 121 for UL transmission per each *receive antenna port group* for codebook-based UL transmission.

h. a maximum number of spatial multiplexing layer(s) supported by the wireless communications device 121 for UL transmission per each *receive antenna port group* for non-codebook-based UL transmission.
i. a configuration of the Tx chains with respect to the receive antenna port groups (e.g., if the TX chains may be switched between RX antennas belonging to different *receive antenna port groups* or if TX chains only may be switched between RX antennas within each *receive antenna port group*),
j. Directions of the *receive antenna port groups* and/or the relative directions of the *receive antenna port groups* with respect to each other (i.e., *receive antenna port group* being in the same or different directions),
k. Interference measurement/cancelation capabilities between RX chains belonging to different receive antenna port groups,
l. Combining capability between receive antenna port groups,
m. Interference measurement/cancelation capabilities between RX chains belonging to the same receive antenna port group,
n. Capability for DL codebook-based operation via the receive antenna port groups,
o. Capability for reciprocity-based operation via the receive antenna port groups (i.e., SRS port/resource mapping targeting the receive antenna port groups),
p. Support for switching between receive antenna port groups,
q. a switching delay for switching between receive antenna port groups,
r. ON/OFF capabilities in the *receive antenna port groups*,
s. Antennas' constellation (X-by-Y) per receive antenna port group, antenna polarizations or antenna/panel coordinates..
t. Support for Type I and/or Type II codebook-based operation via the *receive antenna port groups,*
u. Support for operation based on shared and/or separated CSI-RS resources per *receive antenna port groups*,
v. Maximum rank per *receive antenna port group*,
w. CSI processing unit (CPU) capability for different *receive antenna port groups*,
x. a device capability for legacy operations with or without *receive antenna port groups,*
y. Capability to exchange control information via one or more of the *receive antenna port groups*,
z. a maximum number of CSI-RS ports per *receive antenna port groups*,

6. The method of any of the embodiments 1-5, wherein a capability for different receive antenna port groups is reported separately or jointly.

7. The method of any of the embodiments 1-6, wherein supported antenna switching schemes are reported jointly over all receive antenna port groups, e.g., by indicating one or more of 2t6r, 2t8r, 4t8r, 3t6r, etc.

8. The method of any of the embodiments 1-7, wherein supported antenna switching schemes are reported per receive antenna port group, e.g., receive antenna port group 1 supports one or more of 1t4r, 2t4r, 1t3r, etc., and receive antenna port group 2 supports one or more of 1t4r, 2t4r, 1t3r, etc.

9. The method of any of the embodiments 1-8, wherein a configuration of the Tx chains with respect to the receive antenna port groups contains information whether or how the Tx chains are associated with different receive antenna port groups or both.

10. The method of embodiment 5, wherein the capability for DL codebook-based operation via the receive antenna port groups includes support for transmission of multiple PMIs per CSI-RS transmission.

11. The method of embodiment 5, wherein the capability for reciprocity-based operation via the receive antenna port groups includes support for SRS ports/resources grouping and mapping to each receive antenna port group.

12. The method of any of the embodiments 1-11, wherein configuring the communication with the wireless communications device 121 based on the received report includes DL codebook-based operation via the receive antenna port groups.

13. The method of any of the embodiments 1-12, wherein configuring the communication with the wireless communications device 121 based on the received report includes codeword association to the receive antenna port groups.

14. The method of any of the embodiments 1-13, wherein the wireless communications device 121 is a UE, a FWA node, or nodes with similar functionality.

15. A network node 111, adapted for communicating with a wireless communications device 121, such as a UE, which uses receive antenna port groups. The network node 111 is adapted to perform the method of embodiments 1-14.

16. A method, performed by a wireless communications device 121 which uses receive antenna port groups, for communicating with a network node, the method comprises:

    transmitting a capability message to a network node, the capability message indicating capabilities of the wireless communications device 121 and further indicating receive antenna port groups of the wireless communications device 121; and

    receiving a configuration message from the network node, the configuration message configures communication with the network node.

17. A wireless communications device 121, such as a UE, adapted for communicating with a network node. The wireless communications device 121 is adapted to perform the method of embodiment 16.

CLAIMS

1. A method, performed by a network node (111) of a wireless communications network (100), for communicating with a wireless communications device (121) which uses receive antenna port groups, the method comprises:

receiving (501) a capability message, the capability message indicating capabilities of the wireless communications device (121) relating to receive antenna port groups of the wireless communications device (121); and

configuring (502) communication with the wireless communications device (121) based on the received capability message.

2. The method of claim 1, wherein the capability message comprises information about each *receive antenna port group* and/or their relations with each other.

3. The method of any of the claims 1-2, wherein the capability message comprises information about one or more of:
   a. a total number of receive antennas;
   b. a number of *receive antenna port groups;*
   c. a number of receive antennas per each *receive antenna port group;*
   d. a maximum number of spatial multiplexing layer(s) supported by the wireless communications device (121) for Downlink, DL, reception per each *receive antenna port group;*
   e. a total number of transmitter chains;
   f. a number of transmitter chains per *receive antenna port group;*
   g. a maximum number of spatial multiplexing layer(s) supported by the wireless communications device (121) for Uplink, UL, transmission per each *receive antenna port group* for codebook-based UL transmission;
   h. a maximum number of spatial multiplexing layer(s) supported by the wireless communications device (121) for UL transmission per each *receive antenna port group* for non-codebook-based UL transmission;
   i. a configuration of the transmitter chains with respect to the receive antenna port groups;
   j. Directions of the *receive antenna port groups* and/or relative directions of the *receive antenna port groups* with respect to each other;
   k. Interference measurement or cancelation capabilities between receiver, chains belonging to different receive antenna port groups;

l. Combining capability between receive antenna port groups;
m. Interference measurement and/or cancelation capabilities between receiver chains belonging to the same receive antenna port group;
n. Capability for DL codebook-based operation via the receive antenna port groups;
o. Capability for reciprocity-based operation via the receive antenna port groups,
p. Support for switching between receive antenna port groups;
q. a switching delay for switching between receive antenna port groups;
r. ON/OFF capabilities in the *receive antenna port groups*;
s. Antenna constellation per receive antenna port group, antenna polarizations, antenna/panel coordinates;
t. Support for Type I and/or Type II codebook-based operation via the *receive antenna port groups;*
u. Support for operation based on shared and/or separated Channel State Information Reference Signal, CSI-RS, resources per *receive antenna port groups*;
v. Maximum rank per *receive antenna port group*;
w. CSI processing unit capability for different *receive antenna port groups*;
x. Capability to exchange control information via one or more of the *receive antenna port groups*; and
y. a maximum number of CSI-RS ports per *receive antenna port groups.*

4. The method of any of the claims 1-3, wherein a capability for different receive antenna port groups is received separately or jointly.

5. The method of any of the claims 1-4, wherein the capabilities relating to the receive antenna port groups comprises information about support for switching between receive antenna port groups and wherein supported antenna switching schemes are received jointly for all receive antenna port groups.

6. The method of any of the claims 1-4, wherein the capabilities relating to the receive antenna port groups comprises information about support for switching between receive antenna port groups and wherein supported antenna switching schemes are received per receive antenna port group.

7. The method of any of the claims 3-6, wherein the configuration of the transmitter chains with respect to the receive antenna port groups comprises information on whether or how the transmitter chains are associated with different receive antenna port groups or both.

8. The method of any of the claims 3-7, wherein the capability for DL codebook-based operation via the receive antenna port groups comprises support for transmission of multiple Precoding-Matrix Indicators, PMIs, per CSI-RS transmission.

9. The method of any of the claims 3-8, wherein the capability for reciprocity-based operation via the receive antenna port groups comprises support for Sounding Reference Signal, SRS, ports or resources grouping and mapping to each receive antenna port group.

10. The method of any of the claims 1-9, wherein configuring the communication with the wireless communications device (121) based on the received message comprises configuring DL codebook-based operation via the receive antenna port groups.

11. The method of any of the claims 1-10, wherein configuring the communication with the wireless communications device (121) based on the received message comprises configuring codeword association to the receive antenna port groups.

12. The method of any of the claims 1-11, wherein the wireless communications device (121) is a User Equipment, UE, a Fixed Wireless Access, FWA, node.

13. A network node (111) for a wireless communications network (100) and adapted for communicating with a wireless communications device (121) which uses receive antenna port groups, wherein the network node (111) is further adapted to:

receive a capability message, the capability message indicating capabilities of the wireless communications device (121) relating to receive antenna port groups of the wireless communications device (121); and

configure communication with the wireless communications device (121) based on the received capability message.

14. The network node (111) of claim 13, further configured to perform the method of any of the claims 2-12.

15. A computer program (803), comprising computer readable code units which when executed on at least one processor (801) of the network node (111) of claim 13, causes the network node (111) to perform the method according to any of the claims 1-12.

16. A method, performed by a wireless communications device (121) which uses receive antenna port groups, for communicating with a network node (111) of a wireless communications network (100), the method comprises:

transmitting (601) a capability message to a network node (111), the capability message indicating capabilities of the wireless communications device (121) relating to receive antenna port groups of the wireless communications device (121); and

receiving (602) a configuration message from the network node (111), the configuration message configures communication with the network node (111).

17. The method of claim 16, wherein the capability message comprises information about each receive antenna port group and/or their relations with each other.

18. The method of any of the claims 16-17, wherein the capability message comprises information about one or more of:

a. a total number of receive antennas;
b. a number of *receive antenna port groups;*
c. a number of receive antennas per each *receive antenna port group;*
d. a maximum number of spatial multiplexing layer(s) supported by the wireless communications device (121) for Downlink, DL, reception per each *receive antenna port group;*
e. a total number of transmitter chains;
f. a number of transmitter chains per *receive antenna port group;*
g. a maximum number of spatial multiplexing layer(s) supported by the wireless communications device (121) for Uplink, UL, transmission per each *receive antenna port group* for codebook-based UL transmission;
h. a maximum number of spatial multiplexing layer(s) supported by the wireless communications device (121) for UL transmission per each *receive antenna port group* for non-codebook-based UL transmission;

i. a configuration of the transmitter chains with respect to the receive antenna port groups;
j. Directions of the *receive antenna port groups* and/or relative directions of the *receive antenna port groups* with respect to each other;
k. Interference measurement or cancelation capabilities between receiver chains belonging to different receive antenna port groups;
l. Combining capability between receive antenna port groups;
m. Interference measurement/cancelation capabilities between receiver chains belonging to the same receive antenna port group;
n. Capability for DL codebook-based operation via the receive antenna port groups;
o. Capability for reciprocity-based operation via the receive antenna port groups;
p. Support for switching between receive antenna port groups;
q. a switching delay for switching between receive antenna port groups;
r. ON/OFF capabilities in the *receive antenna port groups*;
s. Antennas' constellation (X-by-Y) per receive antenna port group, antenna polarizations, antenna/panel coordinates;
t. Support for Type I and/or Type II codebook-based operation via the *receive antenna port groups;*
u. Support for operation based on shared and/or separated Channel State Information Reference Signal, CSI-RS, resources per *receive antenna port groups*;
v. Maximum rank per *receive antenna port group*;
w. CSI processing unit capability for different *receive antenna port groups*;
x. Capability to exchange control information via one or more of the *receive antenna port groups*;
y. a maximum number of CSI-RS ports per *receive antenna port groups*.

19. The method of any of the claims 16-18, wherein a capability for different receive antenna port groups is transmitted separately or jointly.

20. The method of any of the claims 16-19, wherein the capabilities relating to the receive antenna port groups comprises information about support for switching between receive antenna port groups and wherein supported antenna switching schemes are transmitted jointly for all receive antenna port groups.

21. The method of any of the claims 16-20, wherein the capabilities relating to the receive antenna port groups comprises information about support for switching between receive antenna port groups and wherein supported antenna switching schemes are transmitted per receive antenna port group.

22. The method of any of the claims 18-21, wherein the configuration of the transmitter chains with respect to the receive antenna port groups comprises information on whether or how the transmitter chains are associated with different receive antenna port groups or both.

23. The method of any of the claims 18-22, wherein the capability for DL codebook-based operation via the receive antenna port groups comprises support for transmission of multiple Precoding-Matrix Indicators, PMIs, per CSI-RS transmission.

24. The method of any of the claims 18-23, wherein the capability for reciprocity-based operation via the receive antenna port groups comprises support for Sounding Reference Signal, SRS, ports or resources grouping and mapping to each receive antenna port group.

25. A wireless communications device (121) adapted for communicating with a network node (111) of a wireless communications network (100), wherein the wireless communications device (121) is adapted to:

transmit a capability message to a network node (111), the capability message indicating capabilities of the wireless communications device (121) relating to receive antenna port groups of the wireless communications device (121); and

receive a configuration message from the network node (111), the configuration message configures communication with the network node (111).

26. The wireless communications device (121) of claim 25, wherein the wireless communications device (121) is further configured to perform the method of any of the claims 17-24.

27. A computer program (703), comprising computer readable code units which when executed on at least one processor (701) of the wireless communications device (121)

of claim 25, causes the wireless communications device (121) to perform the method according to any of the claims 16-24.

28. A carrier (705, 805) comprising the computer program (703, 803) according to claim 15 or 27, wherein the carrier (705, 805) is one of an electronic signal, an optical signal, a radio signal and a computer readable medium.

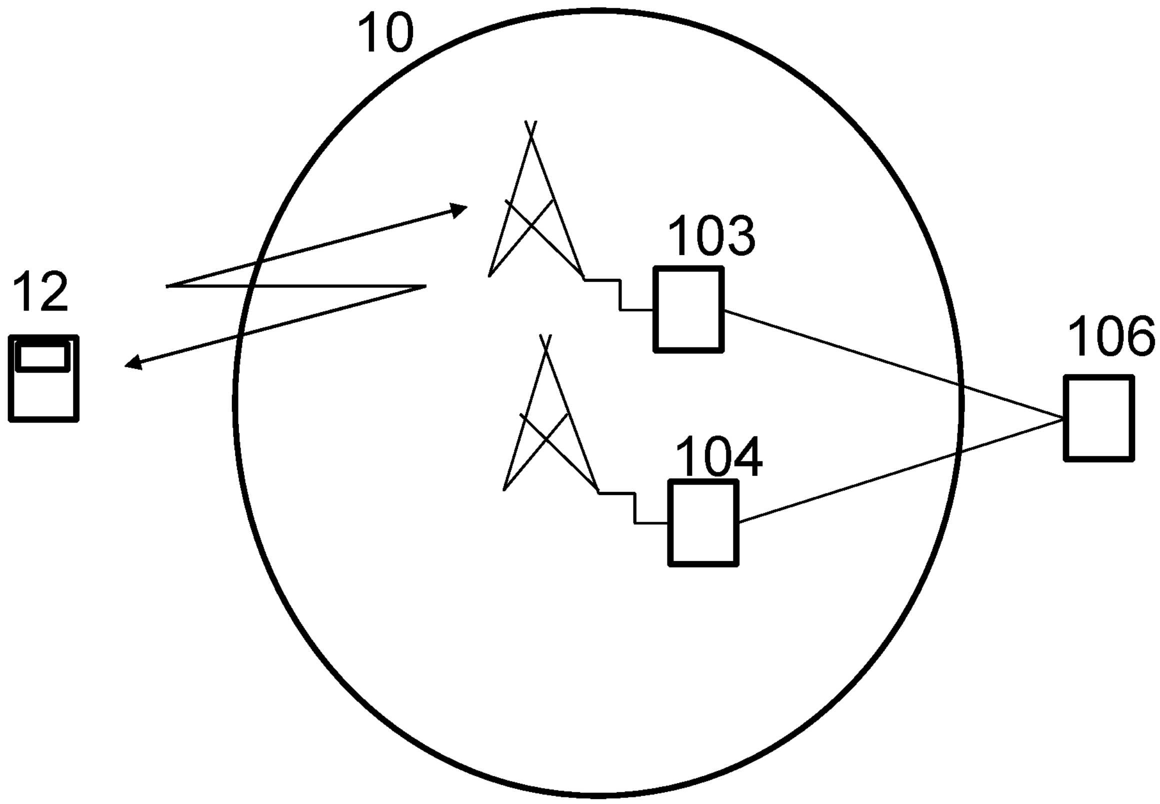
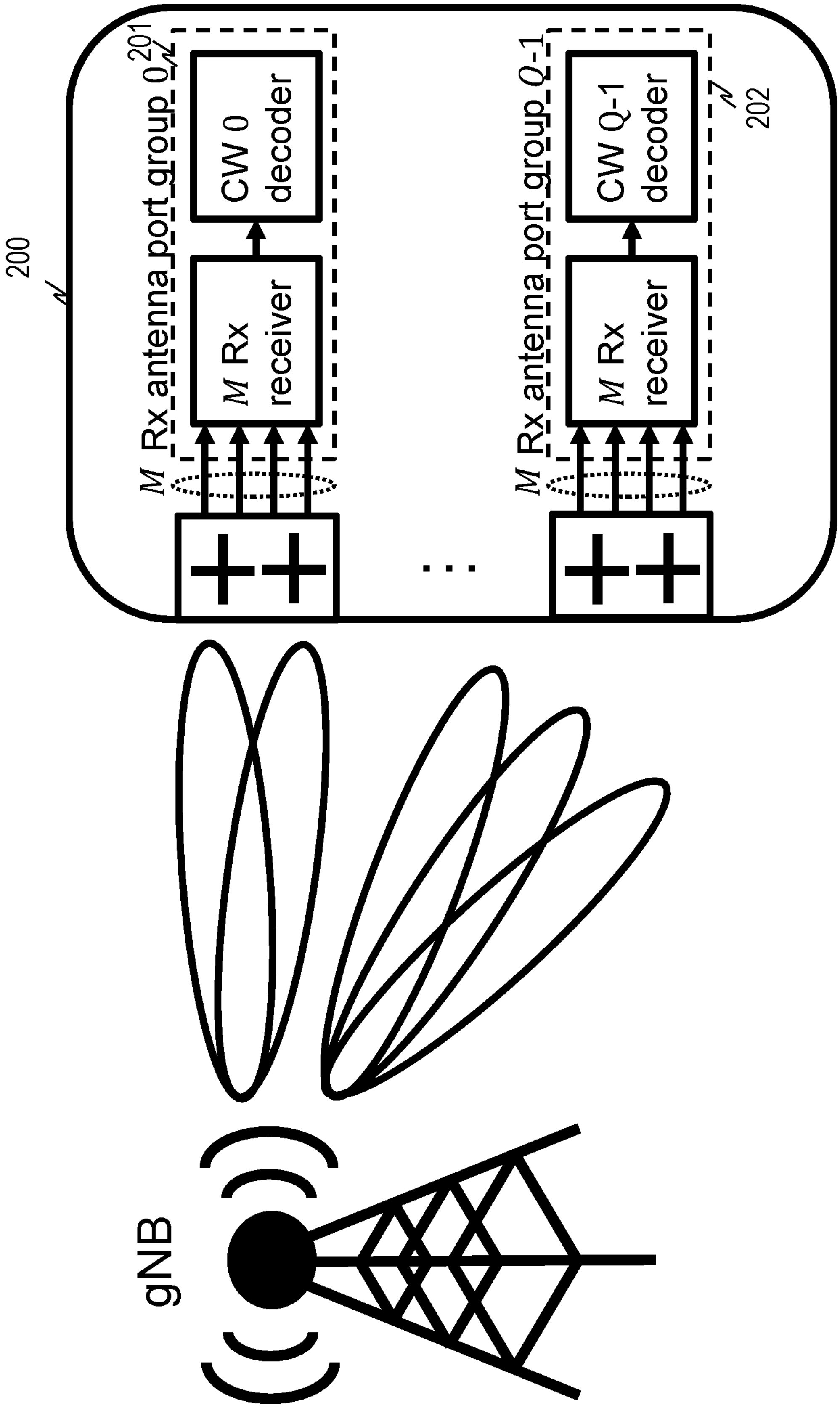


Fig. 1



200
201
202
M Rx antenna port group 0
CW 0 decoder
M Rx receiver
M Rx antenna port group Q-1
CW Q-1 decoder
M Rx receiver
M
M
...
gNB

Fig. 2

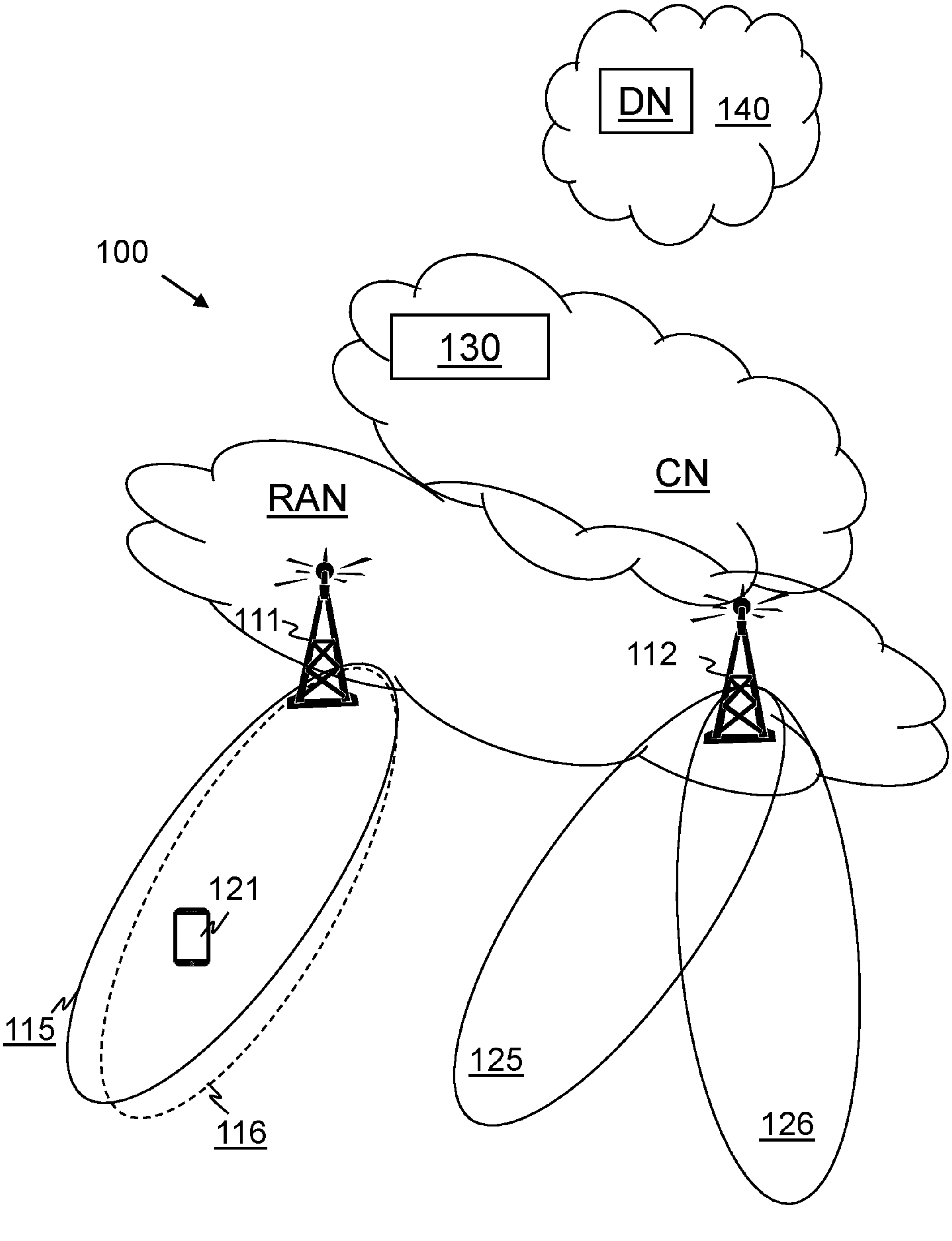


Fig. 3

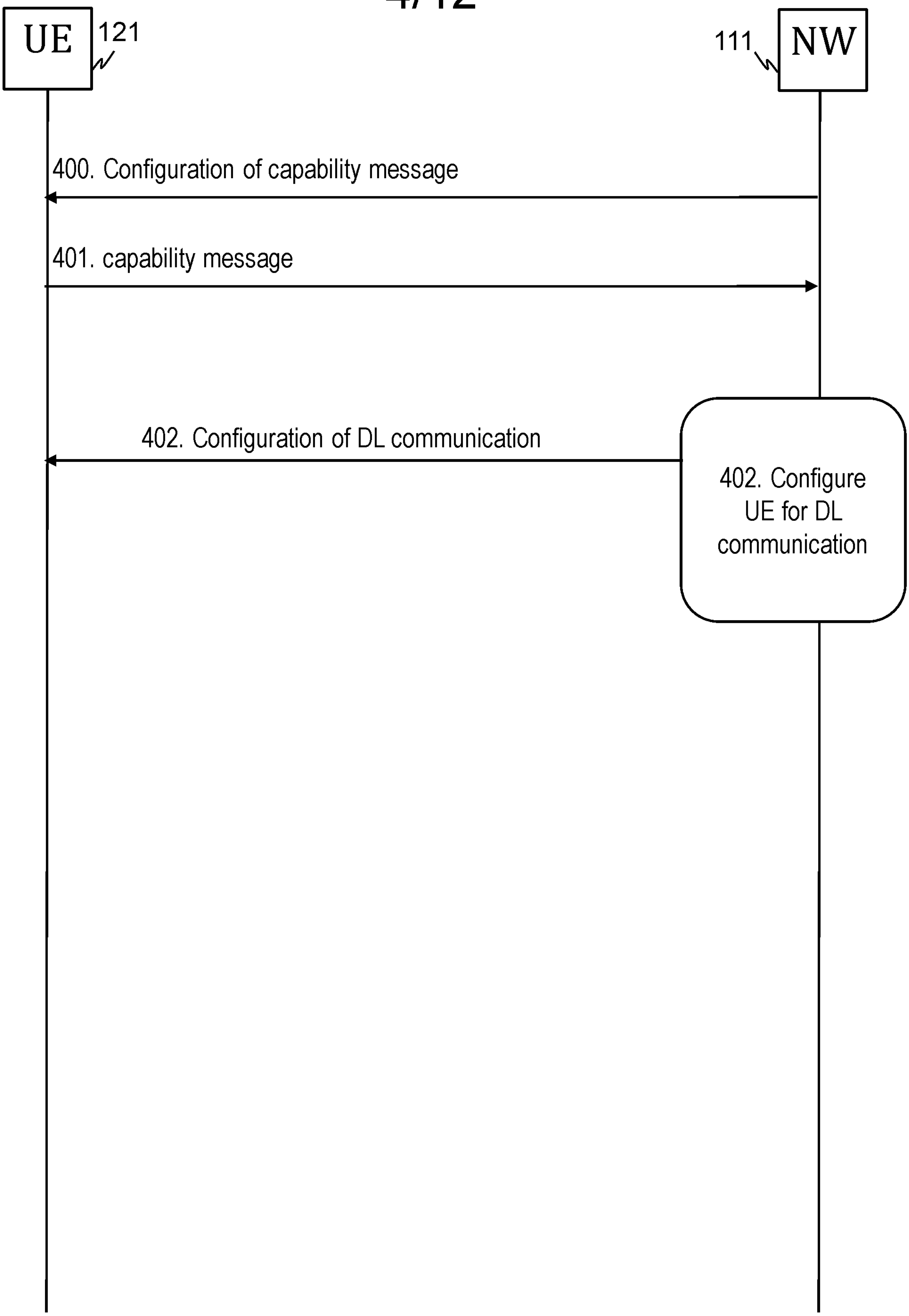

UE
121
111
NW
400. Configuration of capability message
401. capability message
402. Configuration of DL communication
402. Configure UE for DL communication

Fig. 4

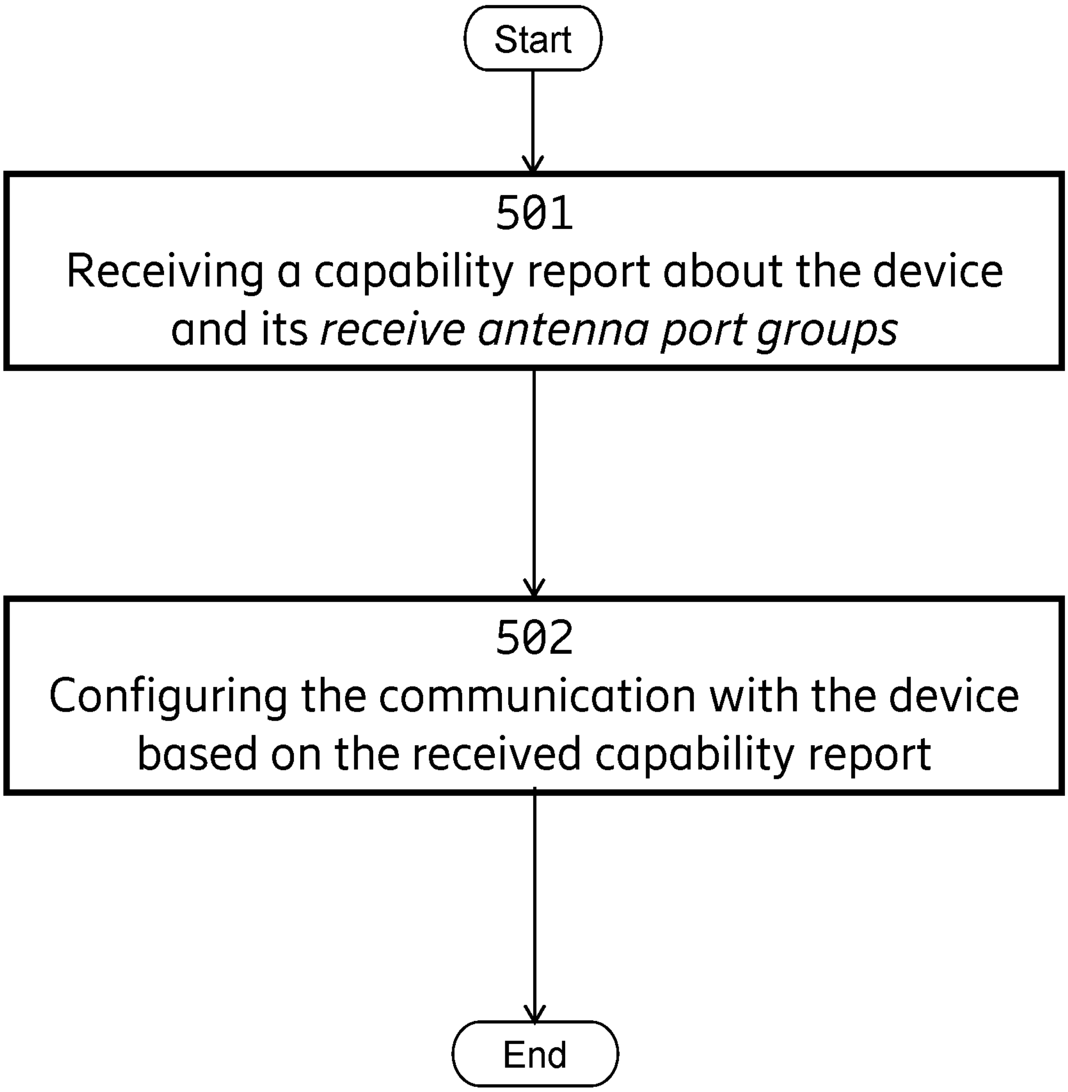

Start
501
Receiving a capability report about the device and its *receive antenna port groups*
502
Configuring the communication with the device based on the received capability report
End

Fig. 5

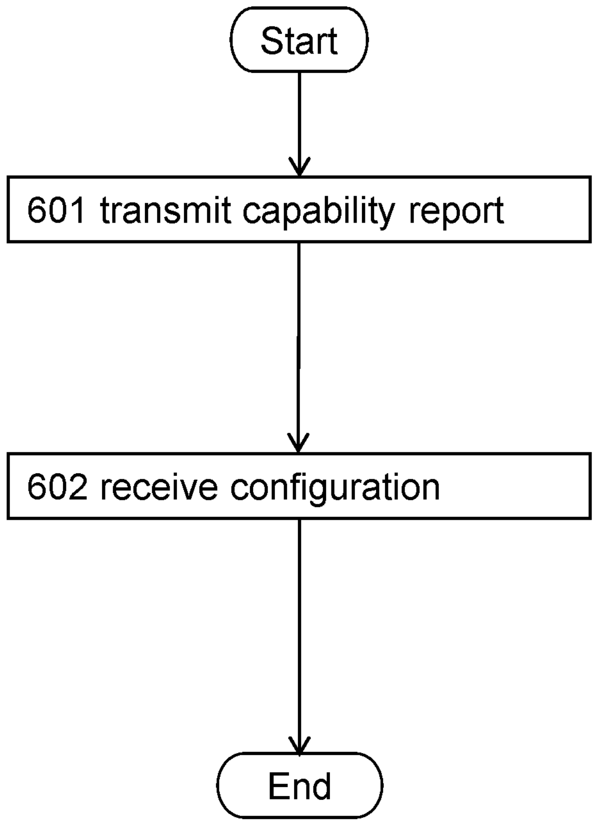

Start
601 transmit capability report
602 receive configuration
End

Fig. 6

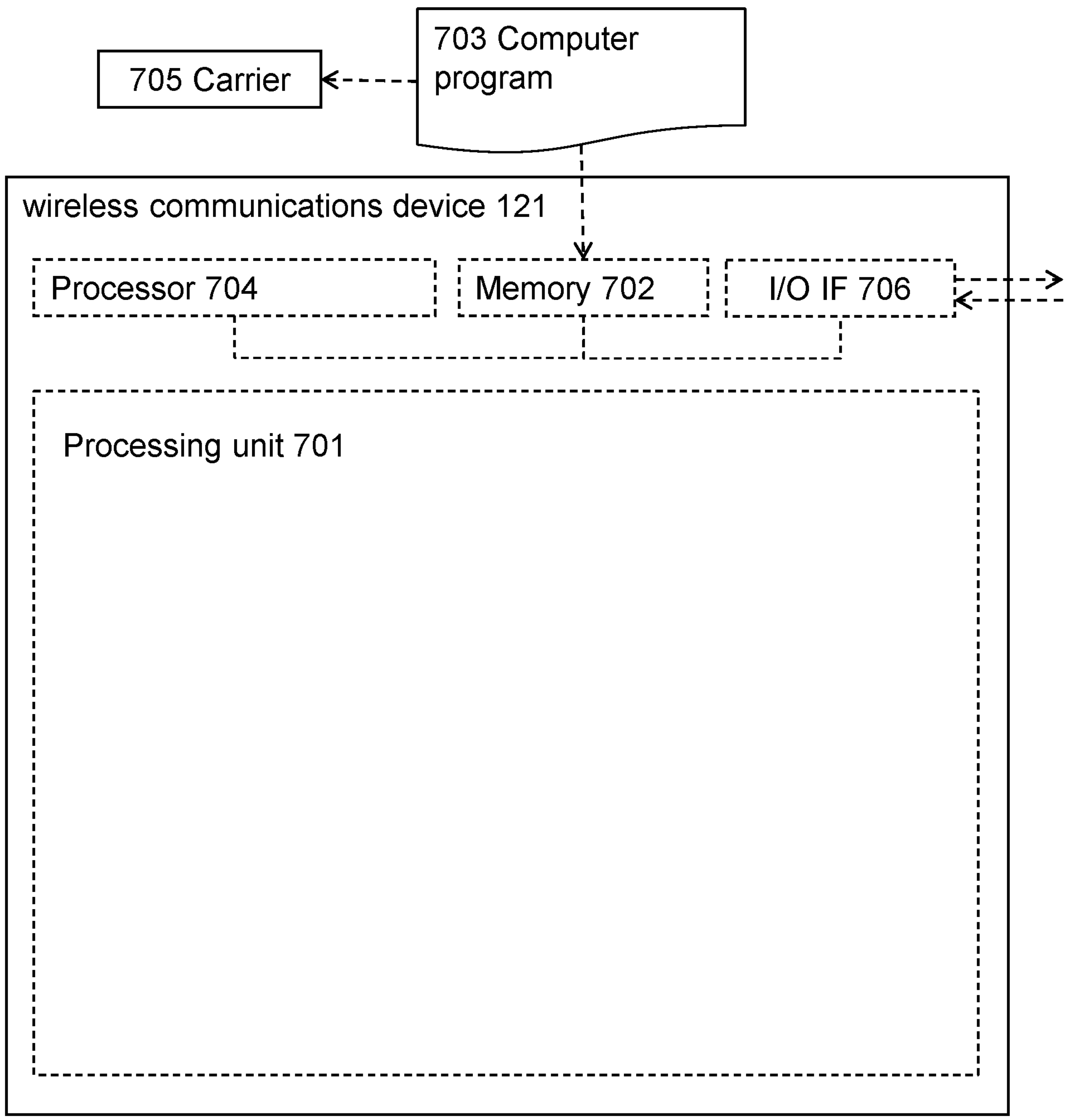

705 Carrier
703 Computer program
wireless communications device 121
Processor 704
Memory 702
I/O IF 706
Processing unit 701

Fig. 7

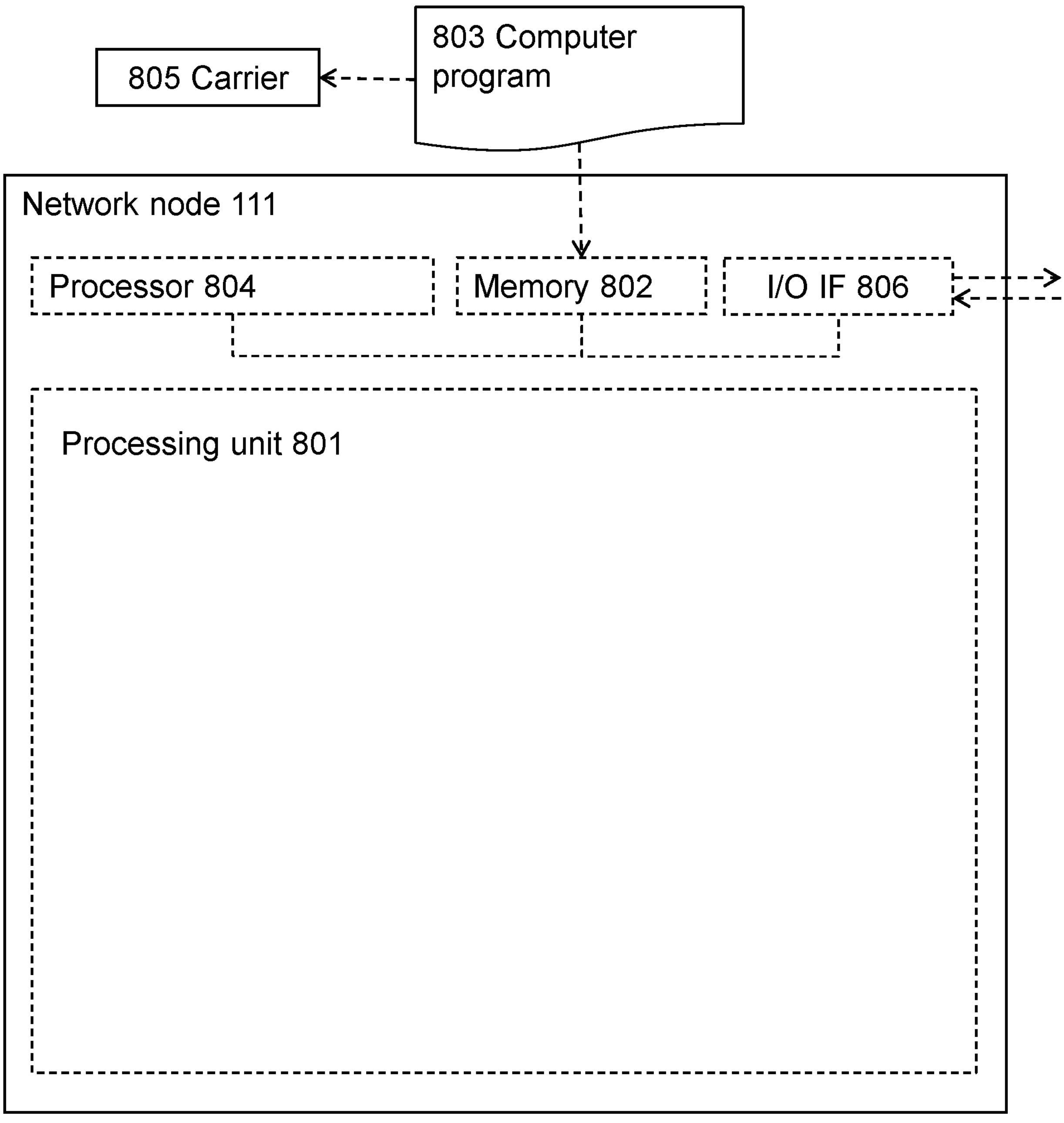

805 Carrier
803 Computer program
Network node 111
Processor 804
Memory 802
I/O IF 806
Processing unit 801

Fig. 8

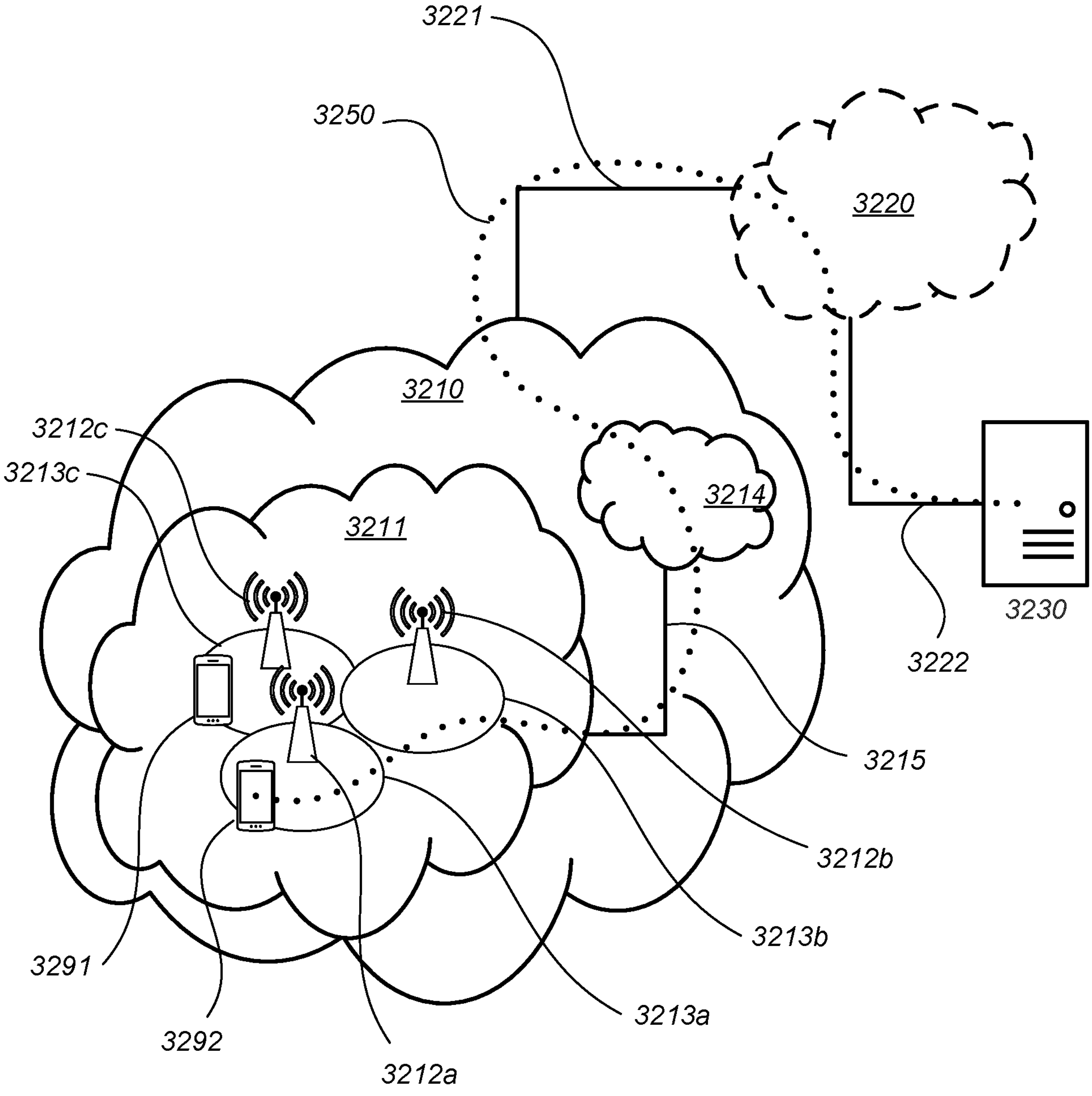

3221
3250
3220
3210
3212c
3213c
3214
3211
3230
3222
3215
3212b
3213b
3291
3213a
3292
3212a

Fig. 9

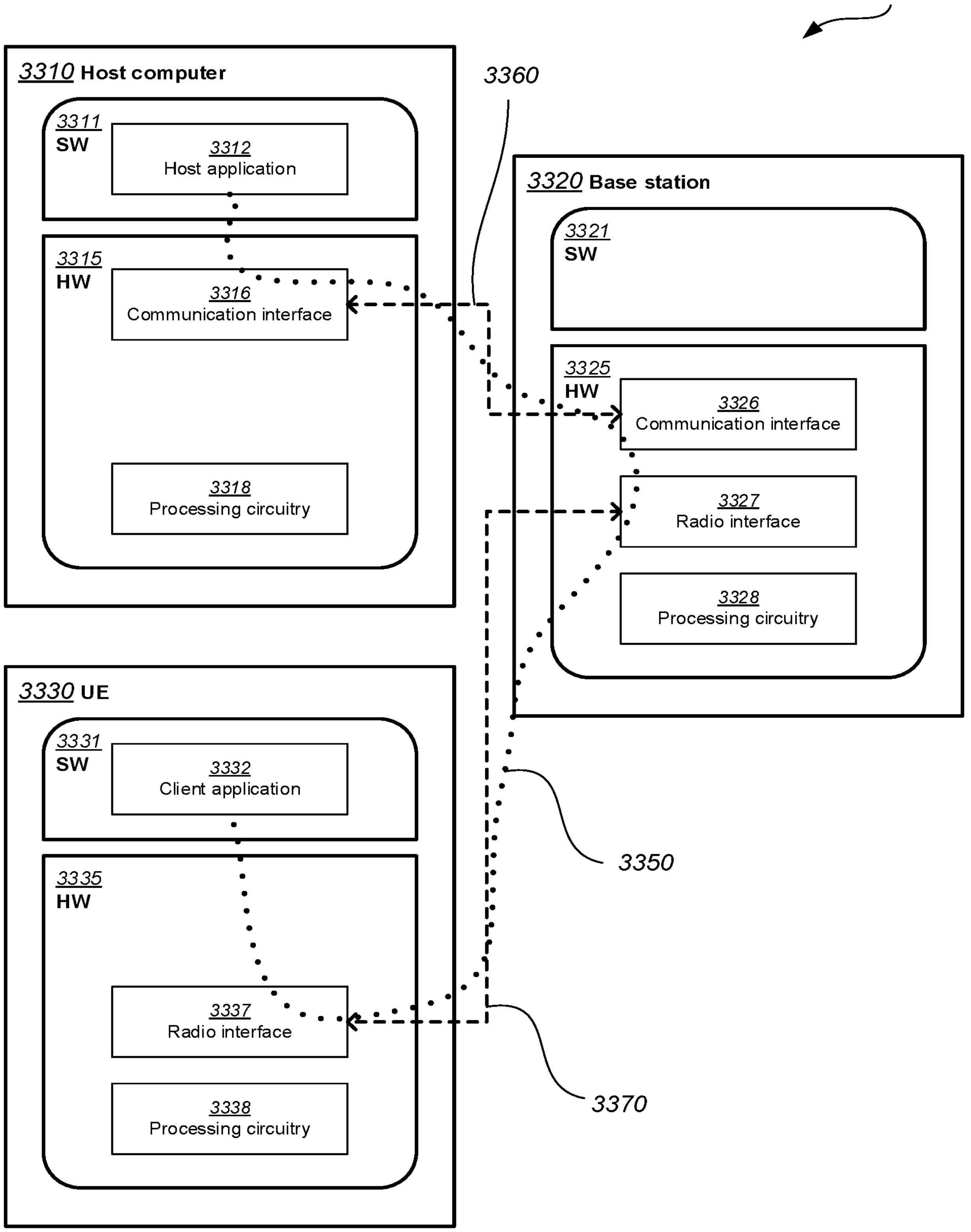

3300
3310 Host computer
3311
SW
3312
Host application
3315
HW
3316
Communication interface
3318
Processing circuitry
3360
3320 Base station
3321
SW
3325
HW
3326
Communication interface
3327
Radio interface
3328
Processing circuitry
3330 UE
3331
SW
3332
Client application
3335
HW
3337
Radio interface
3338
Processing circuitry
3350
3370

Fig. 10

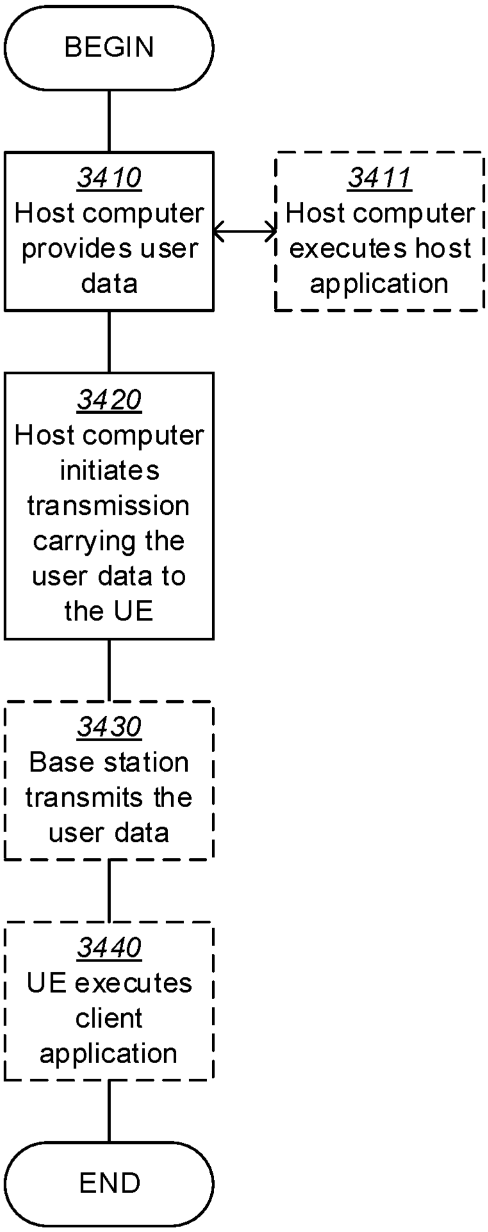

BEGIN
3410
Host computer provides user data
3411
Host computer executes host application
3420
Host computer initiates transmission carrying the user data to the UE
3430
Base station transmits the user data
3440
UE executes client application
END

Fig. 11

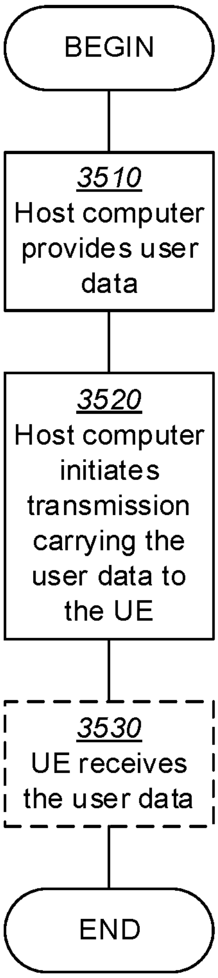

BEGIN
3510
Host computer provides user data
3520
Host computer initiates transmission carrying the user data to the UE
3530
UE receives the user data
END

Fig. 12

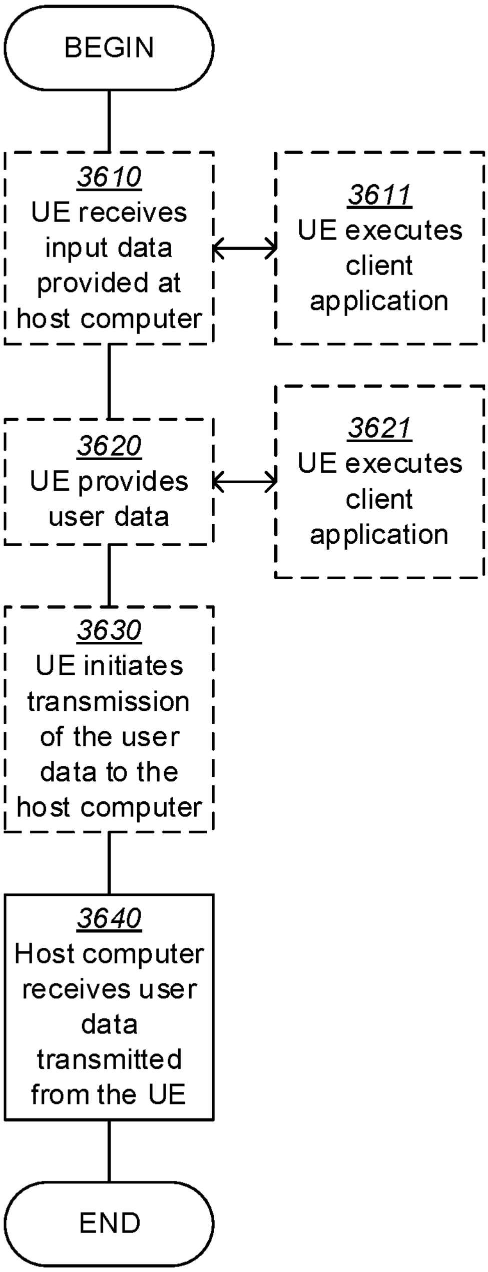

BEGIN
3610
UE receives input data provided at host computer
3611
UE executes client application
3620
UE provides user data
3621
UE executes client application
3630
UE initiates transmission of the user data to the host computer
3640
Host computer receives user data transmitted from the UE
END

Fig. 13

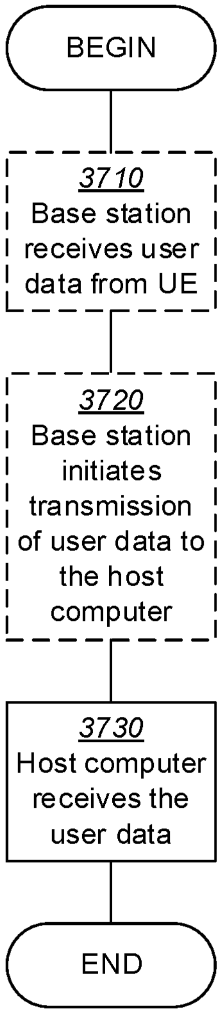

BEGIN
3710
Base station receives user data from UE
3720
Base station initiates transmission of user data to the host computer
3730
Host computer receives the user data
END

Fig. 14