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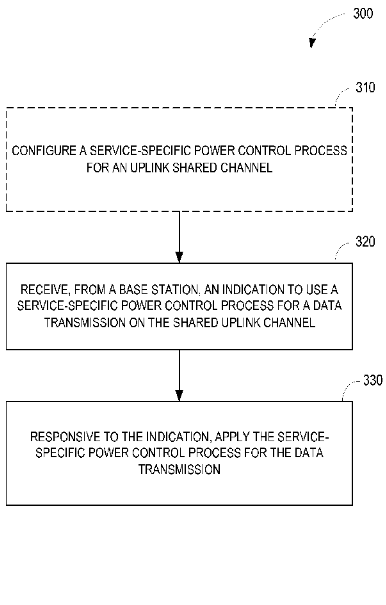

FIG. 2

(57) **Abstract:** Methods and apparatus are provided for providing service-specific power control for URLLC services, or other services, on an uplink shared channel. A user equipment (UE) is configured with a separate power control process for URLLC. The base station can then signal to use the separate power control process for URLLC services.

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SERVICE-SPECIFIC POWER CONTROL FOR NEXT RADIO COMMUNICATION NETWORKS

TECHNICAL FIELD

The present disclosure relates generally to power control in wireless communication systems and, more particularly, to service-specific power control in mixed numerology wireless communication systems.

BACKGROUND

Next Radio (NR) wireless communication systems will provide support for multiple types of services using a common radio access network (RAN). Services provided by NR wireless communication systems may, for example, include enhanced mobile broadband (eMBB), massive machine-type communication (mMTC), and ultra-reliable and low latency communication (URLLC). These services require different Quality of Service (QoS) in terms of delay, data rate, and packet loss rate. For example, URLLC requires low delay and/or high reliability. mMTC, which is often used for infrequent transmission of small packets, typically requires long battery lifetime but does not require low delay or high data rate. eMBB, in contrast, requires high data rates, often with strict requirements on delay, but typically less strict than in URLLC.

In order to fulfil the QoS requirements (e.g., delay) for different services, it has been proposed to use mixed numerologies on one carrier. In mixed numerology systems, the component carrier is divided into two or more sub-bands with different numerologies to support services with different QoS requirements. The subcarrier spacing and symbol duration in different sub-bands may be different.

NR systems are expected to use power control on the Physical Uplink Shared Channel (PUSCH), which may be either open-loop or closed-loop. In open-loop power control, a user equipment (UE) measures the strength of the signals received on the downlink and adjusts its transmit power based on the measurements. Generally, the transmit power is increased if the received signal strength decreases, and the transmit power is decreased if the received signal strength increases. In closed loop power control, the base station serving a UE sends transmit power control (TPC) commands to instruct the UE to increase or decrease depending on the strength of the received signal. It would be desirable to implement service-specific power control for different services utilizing the PUSCH. For example, service dependent power control would enable the transmission power for URLLC on the uplink (UL) to be boosted relative to other services, such as eMBB.

Under the current standard, it is possible to set up separate power control loops for a configured grant and dynamic grant on the uplink in the same cell. However, the current standard does not support separate service-specific power control. One problem is that retransmissions only use a dynamic grant even if the original transmission was based on a configured grant. Therefore, URLLC transmissions would need to use to different power control loops; one for the original transmission and one for retransmissions. Another problem is when both URLLC and eMBB transmissions are based on dynamic grants. In this case, the same power control loop is applied to both the URLLC and eMBB transmission. A third problem is that current signaling scheme to configure the power control loops does not support differentiated power control for URLLC. That is, the power control signaling under the current standard does not allow an indication of separate power control for the URLLC service.

SUMMARY

One aspect of the present disclosure comprises methods and apparatus for configuring and enabling separate power control for URLLC service or other services. The UE is configured with a separate power control process for URLLC. The UE can then be signaled to use the separate power control process for URLLC services. The indication of the power control process can be signaled implicitly or explicitly. In one embodiment, the base station sends to the UE an uplink grant containing a service-specific identifier that is linked to or associated with a separate power control process. In another embodiment, the base station sends to the UE an uplink grant assigning a modulation and coding scheme (MCS) that has been linked to the separate power control process. In still another embodiment, the base station sends to the UE an uplink grant containing an error detection code that is linked to or associated with a separate power control process. In one embodiment, an explicit indication of the service-specific power control process can be included in configuration information sent by the base station to the user equipment.

One aspect of the disclosure comprises power control methods performed by a UE. The UE may optionally receive, from the base station, configuration information for configuring service-specific power control on the uplink shared channel. As one example, service-specific power control may be configured for URLLC on the PUSCH, while general power control is used for other services (e.g., eMBB). With the service-specific power control configured, the UE receives, from a base station, an indication to use the service-specific power control process for a data transmission on the shared uplink channel (e.g., PUSCH). Responsive to the indication, the UE applies the service-specific power control process to control the transmit power of the data transmission.

Another aspect of the disclosure comprises a UE configured to perform the methods of the preceding paragraph. In one embodiment, the UE comprises a

communication circuit for communicating with a base station in a wireless communication network, and a processing circuit. The processing circuit is configured to receive, from a base station, an indication to use the service-specific power control process for a data transmission on the shared uplink channel (e.g., PUSCH). The processing circuit is further configured to, responsive to the indication, apply the service-specific power control process to control the transmit power of the data transmission.

Another aspect of the disclosure comprises a computer program containing executable instructions that when executed by a processing circuit in a UE, causes the UE to perform the above described method.

Another aspect of the disclosure comprises a method performed by a base station in a wireless communication network. The base station sends configuration information to a user equipment to configure a service-specific power control process for an uplink shared channel. Once the UE is configured to use service -specific power control, the base station sends the user equipment an indication to use the service-specific power control process for a data transmission on the shared uplink channel. In some embodiments, he base station further applies the service-specific power control process to control a transmit power of the data transmission.

Another aspect of the disclosure comprises a base station configured to perform the methods of the preceding paragraph. In one embodiment, the base station comprises a communication circuit for communicating with a UE, and a processing circuit. The processing circuit is configured to send configuration information to a user equipment to configure a service-specific power control process for an uplink shared channel. The processing circuit is further configured to send the user equipment an indication to use the service-specific power control process for a data transmission on the shared uplink channel, and to apply the service-specific power control process to control a transmit power of the data transmission.

Another aspect of the disclosure comprises a computer program containing executable instructions that when executed by a processing circuit in a base station, causes the base station to perform the above described method.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates an exemplary communication network according to an embodiment.

Figure 2 illustrates a power control method implemented by a UE.

Figure 3 illustrates a method implemented by a base station of configuring power control for uplink transmissions by a UE.

Figure 4 is a schematic block diagram of an exemplary UE configured to implement power control as herein described.

Figure 5 is a schematic block diagram of an exemplary base station adapted to configure power control for a UE on an uplink shared channel.

Figure 6 is a functional block diagram of a wireless terminal that can be configured as a UE or base station.

Figure 7 illustrates the main functional elements of a processing circuit for a UE as herein described.

Figure 8 illustrates the main functional elements of a processing circuit for a UE as herein described.

Figure 9 illustrates an exemplary wireless network according to an embodiment.

Figure 10 illustrates an exemplary UE according to an embodiment.

Figure 11 illustrates an exemplary virtualization environment according to an embodiment.

Figure 12 illustrates an exemplary telecommunication network connected via an intermediate network to a host computer according to an embodiment.

Figure 13 illustrates an exemplary host computer communicating via a base station with a user equipment over a partially wireless connection according to an embodiment.

Figures 14-17 illustrate an exemplary methods implemented in a communication system, according to an embodiment.

DETAILED DESCRIPTION

Referring now to the drawings, various embodiments of the disclosure will be described in the context of a NR wireless communication network. The exemplary embodiments herein described focus on how to apply service-specific uplink power control for URLLC service. These solutions are also applicable to other cases to achieve service-specific power control for other services. Also, those skilled in the art will appreciate that the methods and apparatus herein described are not limited to use in NR networks, but may also be used in wireless communication networks operating according to other standards

Figure 1 illustrates a wireless communication network 10 according to the NR standard currently being developed by Third Generation Partnership Project (3GPP). The wireless communication network 10 comprises one or more base stations 100 providing service to user equipment (UEs) 200 in respective cells 20 of the wireless communication network 10. The base stations 100 are also referred to as Evolved NodesBs (eNBs) and gNodeBs (gNBs) in 3GPP standards. Although only one cell 20 and one base station 100 are shown in Figure 1, those skilled in the art will appreciate that a typical wireless communication network 10 comprises many cells 20 served by many base stations 100.

The UEs 200 may comprise any type of equipment capable of communicating with the base stations 100 over a wireless communication channel. For example, the

UEs 200 may comprise cellular telephones, smart phones, laptop computers, notebook computers, tablets, machine-to-machine (M2M) devices (also known as machine type communication (MTC) devices), embedded devices, wireless sensors, or other types of wireless end user devices capable of communicating over wireless communication networks 10.

NR systems use Orthogonal Frequency Division Multiplexing (OFDM) in the downlink (DL). Both OFDM and Single Carrier Frequency -Division Multiple Access (SC-FDMA) can be used in the UL. The physical resources used for communications can be viewed as a time frequency grid. Generally, the time frequency grid is divided into OFDM or SC-FDMA symbols in the time domain and subcarriers in the frequency domain. The basic resource used for communication, referred to as a resource element, comprises one symbol in the time domain and one subcarrier in the frequency domain.

In LTE systems, the symbol duration of a symbol is fixed at 66.67 µs and the subcarrier spacing (SCS) is 15 kHz. In NR systems, the subcarrier spacing and symbol duration is variable depending on the numerology. This enables the radio resources to the utilized more efficiently to support different services. When different numerologies are used, the symbol duration is inversely proportional to the subcarrier spacing with a normal cyclic prefix length. For example, for a subcarrier spacing of 15kHz, the symbol duration is 66.67 µs, the same as LTE. For a subcarrier spacing of 30kHz, the symbol duration is 33.33 µs.

The time domain is divided into radio frames of 10 milliseconds each. One radio frame comprises ten subframes of one millisecond each. Each subframe includes one or more slots defined as 14 OFDM or SC-FDMA symbols. There can be 1, 2, 4, 8 or 16 slots in a subframe. Additionally, NR systems include a time unit referred to as a mini-slot. A mini-slot may comprise 2, 4 or 7 symbols and is used to adapt to different transmission durations for different services to fulfill transmission delay requirements.

Because the symbol duration in NR varies depending on the subcarrier spacing, it follows therefore that the duration of a slot or mini-slot also varies depending on the subcarrier spacing assuming the same number of symbols. For example, a slot comprising 14 symbols will have a different duration depending on whether a subcarrier spacing of 15 kHz or 30 kHz is used. Also, the number of slots in a subframe varies depending on the subcarrier spacing. For example, with 15kz subcarrier spacing, the subframe will have only one slot. With a subcarrier spacing of 60 kHz, each subframe comprises 4 slots.

The UE 200 uses the PUSCH to transmit data on the uplink to the base station 100. A new Modulation and Coding Scheme (MCS) table has been proposed for URLLC transmission on the PUSCH. For grant-based URLLC transmission, a new Radio Resource Control (RRC) parameter is introduced for configuring a new Radio Network Temporary Identifier (RNTI) for URLLC. When the new RNRTI is not configured, the existing RRC parameter *mcs-table* is extended to select from 3 MCS tables (existing 64QAM MCS table, existing 256QAM MCS table, new 64QAM MCS table). When the new RNTI is configured via RRC, RNTI scrambling of the Downlink Control Information (DCI) Cyclic Redundancy Check (CRC) is used to choose the MCS table. If the DCI CRC is scrambled with the new RNTI, the new 64QAM MCS table is used; otherwise, existing behavior under the current standard is followed. With this newly introduced RNTI, the base station 100 can signal the UE 200 of the selected MCS table for URLLC.

NR systems use power control on the PUSCH, which may be either open-loop or closed-loop to control the transmit power of the UE 200. In open-loop power control, the UE 200 measures the strength of the signals received on the downlink and adjusts its transmit power based on the measurements. Generally, the transmit power is increased if the received signal strength decreases, and the transmit power is decreased if the received signal strength increases. With closed loop power control, the base station 100 serving the UE 200 sends transmit power control (TPC) commands to instruct the UE 200 to increase or decrease its power depending on the strength of the received signal at the base station 100. The TPC commands comprises a single bit used to indicate whether the UE 200 should increase or decrease its transmit power. A "0" indicates that the UE 200 should reduce its transmit power by one step and a "1" indicates that the UE 200 should increase its transmit power by one step. The frequency of the TPC commands in NR, referred to herein as the power control frequency, is dependent on the subcarrier spacing. Generally, the power control frequency increases as the subcarrier spacing increases and symbol duration decreases. For instance, with a subcarrier spacing of 15kHz, the maximum power control frequency is 1000 times per second. For mini-slots with only two OFDM symbols, the power control frequency can be up to 7000 times per second.

One aspect of the disclosure is to enable service-specific power control for uplink transmissions on the PUSCH. In one example, separate power control for the URLLC is enabled so the URLLC transmission can be boosted relative to other services, such as eMBB. Boosting the URLLC transmission increases the likelihood that the signal will be received at the base station 100 and reduces latency. Those skilled in the art will appreciate that service-specific power control could be used for other purposes.

Release 15 (Rel-15) of the NR standard, allows separate power control loops for a configured grant and dynamic grant on the uplink in the same cell. The *PUSCH PowerControl* Information Element (IE), shown below, is used to configure UE-specific power control for the PUSCH. The *PUSCH PowerControl* Information Element allows multiple P0-PUSCH and AlphaSets to be configured for the PUSCH in one cell.

```
PUSCH-PowerControl ::=                      SEQUENCE {

    tpc-Accumulation    ENUMERATED { disabled }                     OPTIONAL, -- Need R
    msg3-Alpha  Alpha                                               OPTIONAL, -- Need S
    p0-NominalWithoutGrant  INTEGER (-202..24)                      OPTIONAL, -- Need M,
    p0-AlphaSets    SEQUENCE (SIZE (1..maxNrofP0-PUSCH-AlphaSets)) OF P0-PUSCH-AlphaSet
                                                                    OPTIONAL, -- Need M,
    pathlossReferenceRSToAddModList     SEQUENCE (SIZE (1..maxNrofPUSCH-
PathlossReferenceRSs)) OF PUSCH-PathlossReferenceRS                 OPTIONAL, -- Need N
    pathlossReferenceRSToReleaseList    SEQUENCE (SIZE (1..maxNrofPUSCH-
PathlossReferenceRSs)) OF PUSCH-PathlossReferenceRS-Id              OPTIONAL, -- Need N
    twoPUSCH-PC-AdjustmentStates            ENUMERATED {twoStates}  OPTIONAL, -- Need S
    deltaMCS        ENUMERATED {enabled}                            OPTIONAL, -- Need S
    sri-PUSCH-MappingToAddModList       SEQUENCE (SIZE (1..maxNrofSRI-PUSCH-Mappings)) OF
SRI-PUSCH-PowerControl                                              OPTIONAL, -- Need M
    sri-PUSCH-MappingToReleaseList          SEQUENCE (SIZE (1..maxNrofSRI-PUSCH-
Mappings)) OF SRI-PUSCH-PowerControlId                              OPTIONAL, -- Need M
```

Separate power control for a configured grant can be configured using the *PowerControlLoopToUse* parameter in the *ConfiguredGrantConfig* Information Element specified in the 3GPP TS 38.331-f10 specification.

Separate power control for the configured grant could potentially be used to enable separate power control for URLLC in limited circumstances. For example, if the URLLC transmissions map to the configured grant and the eMBB transmission map to the dynamic grant, it is possible to implement separate power control for URLLC transmissions.

The current standard, however, does not provide necessary support for service-specific power control. One problem is that retransmissions only use a dynamic grant even if the original transmission was based on a configured grant. Therefore, URLLC transmissions would need to use to different power control loops; one for the original transmission and one for retransmissions. Another problem is when both URLLC and eMBB transmissions are based on dynamic grants. In this case, the same power control loop is applied to both the URLLC and eMBB transmission. A third problem is that current signaling scheme to configure the power control loops does not support differentiated power control for URLLC. That is, the power control signaling under the current standard does not allow an indication of separate power control for the URLLC service.

In exemplary embodiments of this disclosure, the base station 100 configures a UE 200 with a separate power control process for URLLC via Radio Resource Control (RRC) signaling, referred to herein as the URLLC power control process. The base station 100 can then signal the UE 200 to use the separate power control process for URLLC services. The separate power control process can be signaled implicitly or explicitly. In some embodiments, implicit signaling of the power control process is achieved by configuring an association between downlink control information (DCI) used to schedule a data transmission on the PUSCH and the service-specific power control process. Thus, DCI is in effect reused in these embodiments to implicitly signal to the UE 200 to use the service-specific power control process.

In the embodiments described below, it is assumed that a service specific power control process has been configured for URLLC service and that a general power control process is used for other data transmissions (e.g., eMBB) on the PUSCH. The base station 100 may configure the UE 200 to use the separate, service-specific power control process via RRC signaling.

In a first embodiment, it is assumed that the network 10 has configured an additional RNTI for URLLC via RRC signaling for a UE 200. In this embodiment, the RNTI is linked with a separate service-specific power control process for URLLC services. When the UE 200 receives DCI indicating an uplink grant addressed to the configured RNTI for URLLC, the UE 200 applies the URLLC power control process for the corresponding data transmission. Otherwise, the UE 200 uses the general (non-URLLC) power control process for the data transmission on the PUSCH.

In a second embodiment, a new MCS table configured for a URLLC data transmission is used to indicate whether the UE 200 should use the URLLC power control process for the PUSCH transmission. In this embodiment, the MCS table for URLLC transmissions is linked with a separate, service-specific power control process for URLLC services. The base station 100 uses the RRC parameter *mcs-table* to indicate what MCS table is selected for a data transmission on the PUSCH by the UE 200. The UE 200 may receive the *mcs-table* parameter via either RRC signaling or PDCCH. When an existing MCS table is chosen for a data transmission, the UE 200 can multiplex the data from eMBB logical channel (LCH) with the data from the URLLC LCH. In this case, it is sufficient for the UE 200 to use the general (non-URLLC) power control process, i.e., no power boosting for the data transmission. When the new MCS table for URLLC is selected for the data transmission, the UE 200 uses the URLLC-specific power control process for the data transmission.

In a third embodiment, the URLLC service is configured with a longer CRC sequence than other services to reduce the false detection ratio. In this embodiment, the longer CRC sequence is linked with a separate power control process for URLLC services. In this embodiment, the CRC sequence (for PDCCH or PUSCH) is reused to indicate the power control process for different services. As one example, a PUSCH/UL grant configured with a long CRC sequence indicates to the UE 200 that it should use the service-specific power control process for URLLC services, while a PUSCH/UL grant configured with shorter CRC sequence indicates to the UE 200 that it should use the general power control process for other services.

In a fourth embodiment, a new RRC parameter is used to explicitly signal the UE 200 to use the service-specific power control process. In the case of URLLC, a new parameter named *urllc-P0-PUSCH-AlphaSetId* is added to the *PUSCH-PowerControl* IE to explicitly indicate a power control process that is associated with URLLC. The UE 200 selects the appropriate power control process/configuration for URLLC when the UE 200 decides to use the service-specific power control for URLLC data transmission.

Although URLLC service has been used as a specific example in this embodiment, those skilled in the art will recognize that the same techniques can be used to link a power control process with any specific service. More generally, a new parameter named *priorty-P0-PUSCH-AlphaSetId* may be added to the *PUSCH-PowerControl* IE to associate a specific power control process with a specific service.

Figure 2 illustrates an exemplary power control method 300 performed by a UE 200 according to an embodiment. The UE 200 may optionally receive, from the base station 100, configuration information for configuring service-specific power control on the uplink shared channel (block 310). The service-specific power control process may comprise an open-loop or closed-loop power control process. It is assumed that the service-specific power control process is in addition to the power control processes used for other services. As one example, service-specific power control may be configured for URLLC on the PUSCH, while a general power control process is used for other services (e.g., eMBB). In one embodiment, the base station 100 may send the parameters *P0-PUSCH* and *Alpha* in the *PUSCH-PowerControl* IE or other RRC signaling to configure the service-specific power control process (e.g., open-loop process) for URLLC or other service. In some embodiments, configuring the service-specific power control process includes configuring an association between DCI information used to schedule a data transmission and the service-specific power control process to enable the base station 100 to implicitly signal to the UE 200 when to use the service-specific power control process as hereinafter described. In other embodiments, the base station 100 sends a new parameter called *priorty-P0-PUSCH-AlphaSetId* in the *PUSCH-PowerControl* IE or other RRC signaling to associate a specific power control process with a specific service.

With the service-specific power control configured, the UE 200 receives, from a base station 10, an indication to use the service-specific power control process for a data transmission on the shared uplink channel (e.g., PUSCH) (block 320). The indication may be implicit or explicit. Responsive to the indication, the UE 200 applies the service-specific power control process to control the transmit power of the data transmission (block 330).

In some embodiments of the method 300, receiving an indication to use the service-specific power control process for a data transmission comprises receiving an uplink grant for the data transmission addressed to a service-specific identifier. The service-specific identifier may, for example, comprises a new RNTI associated with a specific service. In this embodiment, the UE 200 may receive configuration information or other signaling from the base station 100 to configure an association between the new RNTI for a specific service (e.g., URLLC) and a separate, service-specific power control process for that service.

In some embodiments of the method 300, receiving an indication to use the service-specific power control process for a scheduled data transmission comprises receiving an uplink grant for the data transmission including an indication to use a predetermined MCS scheme table for the data transmission. In this embodiment, the UE 200 may receive configuration information or other signaling from the base station 100 to configure an association between the MCS table for a specific service (e.g., URLLC) and a separate, service-specific power control process for that service.

In some embodiments of the method 300, receiving an indication to use the service-specific power control process for a data transmission comprises receiving an uplink grant for the data transmission, said uplink grant including a predetermined error detection sequence. The predetermined error detection sequence may, for example, comprise a long CRC sequence. In this embodiment, the UE 200 may receive configuration information or other signaling from the base station 100 to configure an association between the CRC sequence for a specific service (e.g., URLLC) and a separate, service-specific power control process for that service.

In some embodiments of the method 300, receiving an indication to use the service-specific power control process for a data transmission comprises receiving a power control identifier associated with the service-specific power control process. For example, the power control identifier may be sent in a power control information element via RRC signaling.

In some embodiments of the method 300, the configuration information for configuring the service-specific power control is received via RRC signaling.

In some embodiments of the method 300, the service-specific power control is configured for ultra-reliable, low latency communication data transmissions.

Figure 3 illustrates an exemplary power control method 400 performed by a base station 100. The base station 100 sends configuration information to a UE 200 to configure a service-specific power control process for an uplink shared channel (block 410). The service-specific power control process may comprise an open-loop or closed-loop power control process. It is assumed that the service-specific power control process is in addition to the power control processes used for other services. As one example, service-specific power control may be configured for URLLC on the PUSCH, while a general power control process is used for other services (e.g., eMBB). In one embodiment, the base station 100 may send the parameters *P0-PUSCH* and *Alpha* in the Power Control Information Element or other RRC signaling to configure the service-specific power control process (e.g., open-loop process) for URLLC or other service. In some embodiments, configuring the service-specific power control process includes configuring an association between DCI information used to schedule a data transmission and the service -specific power control process to enable the base station 100 to implicitly signal to the UE 200 when to use the service-specific power control process as hereinafter described. In another embodiment, the base station 100 sends a new parameter called *priorty-P0-PUSCH-AlphaSetId* in the *PUSCH-PowerControl* IE or other RRC signaling to associate a specific power control process with a specific service.

Once the UE 200 is configured to use service -specific power control, the base station 100 sends the UE 200 an indication to use the service-specific power control process for a data transmission on the shared uplink channel (block 420). In some embodiments, the base station 100 optionally applies the service-specific power control process to control a transmit power of the data transmission (block 430).

In some embodiments of the method 400, sending an indication to use the service-specific power control process for a data transmission comprises sending an uplink grant addressed to a service-specific identifier. For example, the service-specific identifier may comprise an RNTI associated with a specific service. In this embodiment, the UE 200 may receive configuration information or other signaling from the base station 100 to configure an association between the RNTI for a specific service (e.g., URLLC) and a separate, service-specific power control process for that service.

In some embodiments of the method 400, sending an indication to use the service-specific power control process for a data transmission comprises sending an indication to use a predetermined MCS table for the data transmission. In this embodiment, the UE 200 may receive configuration information or other signaling from the base station 100 to configure an association between the MCS table for a specific service (e.g., URLLC) and a separate, service-specific power control process for that service.

In some embodiments of the method 400, sending an indication to use the service-specific power control process for a data transmission comprises sending an uplink grant configured with a predetermined error detection sequence. For example, the predetermined error detection sequence may comprise a long CRC sequence. In this embodiment, the UE 200 may receive configuration information or other signaling from the base station 100 to configure an association between the CRC sequence for a specific service (e.g., URLLC) and a separate, service-specific power control process for that service.

In some embodiments of the method 400, sending an indication to use the service-specific power control process for a data transmission comprises sending a power control identifier associated with the service-specific power control process. In one embodiment, the power control identifier is sent in a power control information element via RRC signaling.

In some embodiments of the method 400, the service-specific power control is configured for ultra-reliable, low latency communication data transmissions.

In some embodiments of the method 400, the service-specific power control is configured via RRC signaling.

An apparatus can perform any of the methods herein described by implementing any functional means, modules, units, or circuitry. In one embodiment, for example, the apparatuses comprise respective circuits or circuitry configured to perform the steps shown in the method figures. The circuits or circuitry in this regard may comprise circuits dedicated to performing certain functional processing and/or one or more microprocessors in conjunction with memory. For instance, the circuitry may include one or more microprocessor or microcontrollers, as well as other digital hardware, which may include Digital Signal Processors (DSPs), special-purpose digital logic, and the like. The processing circuitry may be configured to execute program code stored in memory, which may include one or several types of memory such as read-only memory (ROM), random-access memory, cache memory, flash memory devices, optical storage devices, etc. Program code stored in memory may include program instructions for executing one or more telecommunications and/or data communications protocols as well as instructions for carrying out one or more of the techniques described herein, in several embodiments. In embodiments that employ memory, the memory stores program code that, when executed by the one or more processors, carries out the techniques described herein.

Figure 4 illustrates a UE 200 in accordance with one or more embodiments. The UE 200 comprises one or more antennas 210, a first receiving module 220, and a power control module 230. In some embodiments, the UE 200 may further include a second receiving module 240. The various modules 220, 230, and 240 can be implemented by hardware and/or by software code that is executed by one or more processors or processing circuits. The first receiving module 220 is configured to receive, from a base station 100, an indication to use a service-specific power control process for a data transmission on a shared uplink channel. The service-specific power control process is separate from the power control processes used for other data transmissions on the PUSCH. The power control module 230 is configured to, responsive to the indication, apply the service-specific power control process for the data transmission. If present, the second receiving module 240 is configured to receive, from a base station 100, configuration information for configuring the service-specific power control process for the specific service.

Figure 5 illustrates a base station 100 in accordance with one or more embodiments. The base station 100 comprises one or more antennas 110, a first sending module 120, a second sending module 130, and an optional power control module 140. The various modules 120, 130 and 140 can be implemented by hardware and/or by software code that is executed by a processor or processing circuit. The first sending module 120 is configured to send configuration information to a UE 200 to configure a service-specific power control process for an uplink shared channel. The second sending module 130 is configured to send, to the UE 200, an indication to use the service-specific power control process for a data transmission on the shared uplink channel. The power control module 140, if present, is configured to use the service-specific power control process for controlling the transmit power of the data transmission.

Figure 6 illustrates a radio node 500 according to one embodiment that may be configured to function as a base station 100 or UE 200 as herein described. The radio node 500 comprises one or more antennas 510, a communication circuit 520, a processing circuit 530, and memory 570.

The communication circuit 520 is coupled to the antennas 510 and comprises the radio frequency (RF) circuitry needed for transmitting and receiving signals over a wireless communication channel. In one embodiment, the communication circuit 520 may comprises a transceiver including a transmitter and receiver and configured to operate according to the NR standard. The processing circuit 530 controls the overall operation of the radio node 500 and processes the signals transmitted to or received by the radio node 500. Such processing includes coding and modulation of transmitted data signals, and the demodulation and decoding of received data signals. The processing circuit 530 may comprise one or more microprocessors that execute code stored in memory 570, hardware circuits, firmware, or a combination thereof.

Memory 570 comprises both volatile and non-volatile memory for storing computer program code and data needed by the processing circuit 530 for operation. Memory 570 may comprise any tangible, non-transitory computer-readable storage medium for storing data including electronic, magnetic, optical, electromagnetic, or semiconductor data storage. Memory 570 stores a computer program 580 comprising executable instructions that configure the processing circuit 530 to implement the methods 300 (for a UE 200) or 400 (for a base station 100) according to Figures 2 and 3 as described herein. A computer program 580 in this regard may comprise one or more code modules corresponding to the means or units described above. In general, computer program instructions and configuration information are stored in a non-volatile memory, such as a ROM, erasable programmable read only memory (EPROM) or flash memory. Temporary data generated during operation may be stored in a volatile memory, such as a random access memory (RAM). In some embodiments, computer program 580 for configuring the processing circuit 530 as herein described may be stored in a removable memory, such as a portable compact disc, portable digital video disc, or other removable media. The computer program 580 may also be embodied in a carrier such as an electronic signal, optical signal, radio signal, or computer readable storage medium.

Figure 7 illustrates the main functional elements of the processing circuit 530 in radio node 500 configured as a UE 200. The processing circuit 530 comprises a first receiving unit 535, and a power control unit 540. In some embodiments, the processing circuit 530 may further include a second receiving unit 545. The first receiving unit 535 is configured to receive, from a base station, an indication to use a service-specific power control process for a data transmission on a shared uplink channel. The power control unit 540 is configured to, responsive to the indication, apply the service-specific power control process for the data transmission. The service-specific power control process is separate from the power control processes used for other data transmissions on the PUSCH. If present, the second receiving unit 545 is configured to receive, from a base station, configuration information for configuring the service-specific power control process for the specific service.

Figure 8 illustrates the main functional elements of the processing circuit 530 in radio node 500 configured as a base station 100. The processing circuit 530 comprises a first sending unit 550, a second sending unit 550, and a power control unit 560. The first sending unit 550 is configured to send configuration information to a UE 200 to configure a service-specific power control process for an uplink shared channel. The second sending unit 555 is configured to send, to the UE 200, an indication to use the service-specific power control process for a data transmission on the shared uplink channel. The power control unit 560, if present, is configured to apply the service-specific power control process for controlling the transmit power of the data transmission.

Those skilled in the art will also appreciate that embodiments herein further include corresponding computer programs. A computer program comprises instructions which, when executed on at least one processor of an apparatus, cause the apparatus to carry out any of the respective processing described above. A computer program in this regard may comprise one or more code modules corresponding to the means or units described above.

Embodiments further include a carrier containing such a computer program. This carrier may comprise one of an electronic signal, optical signal, radio signal, or computer readable storage medium.

In this regard, embodiments herein also include a computer program product stored on a non-transitory computer readable (storage or recording) medium and comprising instructions that, when executed by a processor of an apparatus, cause the apparatus to perform as described above.

Embodiments further include a computer program product comprising program code portions for performing the steps of any of the embodiments herein when the computer program product is executed by a computing device. This computer program product may be stored on a computer readable recording medium.

Additional embodiments will now be described. At least some of these embodiments may be described as applicable in certain contexts and/or wireless network types for illustrative purposes, but the embodiments are similarly applicable in other contexts and/or wireless network types not explicitly described.

ADDITIONAL EMBODIMENTS

Although the subject matter described herein may be implemented in any appropriate type of system using any suitable components, the embodiments disclosed herein are described in relation to a wireless network, such as the example wireless network illustrated in Figure 9. For simplicity, the wireless network of Figure 9 only depicts network 1106, network nodes 1160 and 1160b, and WDs 1110, 1110b, and 1110c. In practice, a wireless network may further include any additional elements suitable to support communication between wireless devices or between a wireless device and another communication device, such as a landline telephone, a service provider, or any other network node or end device. Of the illustrated components, network node 1160 and wireless device (WD) 1110 are depicted with additional detail. The wireless network may provide communication and other types of services to one or more wireless devices to facilitate the wireless devices' access to and/or use of the services provided by, or via, the wireless network.

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

Network 1106 may comprise one or more backhaul networks, core networks, IP networks, public switched telephone networks (PSTNs), packet data networks, optical networks, wide-area networks (WANs), local area networks (LANs), wireless local area networks (WLANs), wired networks, wireless networks, metropolitan area networks, and other networks to enable communication between devices.

Network node 1160 and WD 1110 comprise various components described in more detail below. These components work together in order to provide network node and/or wireless device functionality, such as providing wireless connections in a wireless network. In different embodiments, the wireless network may comprise any number of wired or wireless networks, network nodes, base stations, controllers, wireless devices, relay stations, and/or any other components or systems that may facilitate or participate in the communication of data and/or signals whether via wired or wireless connections.

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

In Figure 9, network node 1160 includes processing circuitry 1170, device readable medium 1180, interface 1190, auxiliary equipment 1184, power source 1186, power circuitry 1187, and antenna 1162. Although network node 1160 illustrated in the example wireless network of Figure 9 may represent a device that includes the illustrated combination of hardware components, other embodiments may comprise network nodes with different combinations of components. It is to be understood that a network node comprises any suitable combination of hardware and/or software needed to perform the tasks, features, functions and methods disclosed herein. Moreover, while the components of network node 1160 are depicted as single boxes located within a larger box, or nested within multiple boxes, in practice, a network node may comprise multiple different physical components that make up a single illustrated component (e.g., device readable medium 1180 may comprise multiple separate hard drives as well as multiple RAM modules).

Similarly, network node 1160 may be composed of multiple physically separate components (e.g., a NodeB component and a RNC component, or a BTS component and a BSC component, etc.), which may each have their own respective components. In certain scenarios in which network node 1160 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 NodeB's. In such a scenario, each unique NodeB and RNC pair, may in some instances be considered a single separate network node. In some embodiments, network node 1160 may be configured to support multiple radio access technologies (RATs). In such embodiments, some components may be duplicated (e.g., separate device readable medium 1180 for the different RATs) and some components may be reused (e.g., the same antenna 1162 may be shared by the RATs). Network node 1160 may also include multiple sets of the various illustrated components for different wireless technologies integrated into network node 1160, such as, for example, GSM, WCDMA, LTE, NR, WiFi, or Bluetooth wireless technologies. These wireless technologies may be integrated into the same or different chip or set of chips and other components within network node 1160.

Processing circuitry 1170 is configured to perform any determining, calculating, or similar operations (e.g., certain obtaining operations) described herein as being provided by a network node. These operations performed by processing circuitry 1170 may include processing information obtained by processing circuitry 1170 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.

Processing circuitry 1170 may comprise a combination of one or more of a microprocessor, controller, microcontroller, central processing unit, digital signal processor, application-specific integrated circuit, field programmable gate array, or any other suitable computing device, resource, or combination of hardware, software and/or encoded logic operable to provide, either alone or in conjunction with other network node 1160 components, such as device readable medium 1180, network node 1160 functionality. For example, processing circuitry 1170 may execute instructions stored in device readable medium 1180 or in memory within processing circuitry 1170. Such functionality may include providing any of the various wireless features, functions, or benefits discussed herein. In some embodiments, processing circuitry 1170 may include a system on a chip (SOC).

In some embodiments, processing circuitry 1170 may include one or more of radio frequency (RF) transceiver circuitry 1172 and baseband processing circuitry 1174. In some embodiments, radio frequency (RF) transceiver circuitry 1172 and baseband processing circuitry 1174 may be on separate chips (or sets of chips), boards, or units, such as radio units and digital units. In alternative embodiments, part or all of RF transceiver circuitry 1172 and baseband processing circuitry 1174 may be on the same chip or set of chips, boards, or units

In certain embodiments, some or all of the functionality described herein as being provided by a network node, base station, eNB or other such network device may be performed by processing circuitry 1170 executing instructions stored on device readable medium 1180 or memory within processing circuitry 1170. In alternative embodiments, some or all of the functionality may be provided by processing circuitry 1170 without executing instructions stored on a separate or discrete device readable medium, such as in a hard-wired manner. In any of those embodiments, whether executing instructions stored on a device readable storage medium or not, processing circuitry 1170 can be configured to perform the described functionality. The benefits provided by such functionality are not limited to processing circuitry 1170 alone or to other components of network node 1160, but are enjoyed by network node 1160 as a whole, and/or by end users and the wireless network generally.

Device readable medium 1180 may comprise any form of volatile or non-volatile computer readable memory including, without limitation, persistent storage, solid-state memory, remotely mounted memory, magnetic media, optical media, random access memory (RAM), read-only memory (ROM), mass storage media (for example, a hard disk), removable storage media (for example, a flash drive, a Compact Disk (CD) or a Digital Video Disk (DVD)), and/or any other volatile or non-volatile, non-transitory device readable and/or computer-executable memory devices that store information, data, and/or instructions that may be used by processing circuitry 1170. Device readable medium 1180 may store any suitable instructions, data or information, including a computer program, software, an application including one or more of logic, rules, code, tables, etc. and/or other instructions capable of being executed by processing circuitry 1170 and, utilized by network node 1160. Device readable medium 1180 may be used to store any calculations made by processing circuitry 1170 and/or any data received via interface 1190. In some embodiments, processing circuitry 1170 and device readable medium 1180 may be considered to be integrated.

Interface 1190 is used in the wired or wireless communication of signalling and/or data between network node 1160, network 1106, and/or WDs 1110. As illustrated, interface 1190 comprises port(s)/terminal(s) 1194 to send and receive data, for example to and from network 1106 over a wired connection. Interface 1190 also includes radio front end circuitry 1192 that may be coupled to, or in certain embodiments a part of, antenna 1162. Radio front end circuitry 1192 comprises filters 1198 and amplifiers 1196. Radio front end circuitry 1192 may be connected to antenna 1162 and processing circuitry 1170. Radio front end circuitry may be configured to condition signals communicated between antenna 1162 and processing circuitry 1170. Radio front end circuitry 1192 may receive digital data that is to be sent out to other network nodes or WDs via a wireless connection. Radio front end circuitry 1192 may convert the digital data into a radio signal having the appropriate channel and bandwidth parameters using a combination of filters 1198 and/or amplifiers 1196. The radio signal may then be transmitted via antenna 1162. Similarly, when receiving data, antenna 1162 may collect radio signals which are then converted into digital data by radio front end circuitry 1192. The digital data may be passed to processing circuitry 1170. In other embodiments, the interface may comprise different components and/or different combinations of components.

In certain alternative embodiments, network node 1160 may not include separate radio front end circuitry 1192, instead, processing circuitry 1170 may comprise radio front end circuitry and may be connected to antenna 1162 without separate radio front end circuitry 1192. Similarly, in some embodiments, all or some of RF transceiver circuitry 1172 may be considered a part of interface 1190. In still other embodiments, interface 1190 may include one or more ports or terminals 1194, radio front end circuitry 1192, and RF transceiver circuitry 1172, as part of a radio unit (not shown), and interface 1190 may communicate with baseband processing circuitry 1174, which is part of a digital unit (not shown).

Antenna 1162 may include one or more antennas, or antenna arrays, configured to send and/or receive wireless signals. Antenna 1162 may be coupled to radio front end circuitry 1190 and may be any type of antenna capable of transmitting and receiving data and/or signals wirelessly. In some embodiments, antenna 1162 may comprise one or more omni-directional, sector or panel antennas operable to transmit/receive radio signals between, for example, 2 GHz and 66 GHz. An omni-directional antenna may be used to transmit/receive radio signals in any direction, a sector antenna may be used to transmit/receive radio signals from devices within a particular area, and a panel antenna may be a line of sight antenna used to transmit/receive radio signals in a relatively straight line. In some instances, the use of more than one antenna may be referred to as MIMO. In certain embodiments, antenna 1162 may be separate from network node 1160 and may be connectable to network node 1160 through an interface or port.

Antenna 1162, interface 1190, and/or processing circuitry 1170 may be configured to perform any receiving operations and/or certain obtaining operations described herein as being performed by a network node. Any information, data and/or signals may be received from a wireless device, another network node and/or any other network equipment. Similarly, antenna 1162, interface 1190, and/or processing circuitry 1170 may be configured to perform any transmitting operations described herein as being performed by a network node. Any information, data and/or signals may be transmitted to a wireless device, another network node and/or any other network equipment.

Power circuitry 1187 may comprise, or be coupled to, power management circuitry and is configured to supply the components of network node 1160 with power for performing the functionality described herein. Power circuitry 1187 may receive power from power source 1186. Power source 1186 and/or power circuitry 1187 may be configured to provide power to the various components of network node 1160 in a form suitable for the respective components (e.g., at a voltage and current level needed for each respective component). Power source 1186 may either be included in, or external to, power circuitry 1187 and/or network node 1160. For example, network node 1160 may be connectable to an external power source (e.g., an electricity outlet) via an input circuitry or interface such as an electrical cable, whereby the external power source supplies power to power circuitry 1187. As a further example, power source 1186 may comprise a source of power in the form of a battery or battery pack which is connected to, or integrated in, power circuitry 1187. The battery may provide backup power should the external power source fail. Other types of power sources, such as photovoltaic devices, may also be used.

Alternative embodiments of network node 1160 may include additional components beyond those shown in Figure 9 that may be responsible for providing certain aspects of the network node's functionality, including any of the functionality described herein and/or any functionality necessary to support the subject matter described herein. For example, network node 1160 may include user interface equipment to allow input of information into network node 1160 and to allow output of information from network node 1160. This may allow a user to perform diagnostic, maintenance, repair, and other administrative functions for network node 1160.

As used herein, wireless device (WD) refers to a device capable, configured, arranged and/or operable to communicate wirelessly with network nodes and/or other wireless devices. Unless otherwise noted, the term WD may be used interchangeably herein with user equipment (UE). Communicating wirelessly may involve transmitting and/or receiving wireless signals using electromagnetic waves, radio waves, infrared waves, and/or other types of signals suitable for conveying information through air. In some embodiments, a WD may be configured to transmit and/or receive information without direct human interaction. For instance, a WD may be designed to transmit information to a network on a predetermined schedule, when triggered by an internal or external event, or in response to requests from the network. Examples of a WD include, but are not limited to, a smart phone, a mobile phone, a cell phone, a voice over IP (VoIP) phone, a wireless local loop phone, a desktop computer, a personal digital assistant (PDA), a wireless cameras, a gaming console or device, a music storage device, a playback appliance, a wearable terminal device, a wireless endpoint, a mobile station, a tablet, a laptop, a laptop-embedded equipment (LEE), a laptop-mounted equipment (LME), a smart device, a wireless customer-premise equipment (CPE). A vehicle-mounted wireless terminal device, etc. A WD may support device-to-device (D2D) communication, for example by implementing a 3GPP standard for sidelink communication, vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), vehicle-to-everything (V2X) and may in this case be referred to as a D2D communication device. As yet another specific example, in an Internet of Things (IoT) scenario, a WD may represent a machine or other device that performs monitoring and/or measurements, and transmits the results of such monitoring and/or measurements to another WD and/or a network node. The WD may in this case be a machine-to-machine (M2M) device, which may in a 3GPP context be referred to as an MTC device. As one particular example, the WD may be a UE implementing the 3GPP narrow band internet of things (NB-IoT) standard. Particular examples of such machines or devices are sensors, metering devices such as power meters, industrial machinery, or home or personal appliances (e.g., refrigerators, televisions, etc.) personal wearables (e.g., watches, fitness trackers, etc.). In other scenarios, a WD may represent a vehicle or other equipment that is capable of monitoring and/or reporting on its operational status or other functions associated with its operation. A WD as described above may represent the endpoint of a wireless connection, in which case the device may be referred to as a wireless terminal. Furthermore, a WD as described above may be mobile, in which case it may also be referred to as a mobile device or a mobile terminal.

As illustrated, wireless device 1110 includes antenna 1111, interface 1114, processing circuitry 1120, device readable medium 1130, user interface equipment 1132, auxiliary equipment 1134, power source 1136 and power circuitry 1137. WD 1110 may include multiple sets of one or more of the illustrated components for different wireless technologies supported by WD 1110, such as, for example, GSM, WCDMA, LTE, NR, WiFi, WiMAX, NB-IoT, or Bluetooth wireless technologies, just to mention a few. These wireless technologies may be integrated into the same or different chips or set of chips as other components within WD 1110.

Antenna 1111 may include one or more antennas or antenna arrays, configured to send and/or receive wireless signals, and is connected to interface 1114. In certain alternative embodiments, antenna 1111 may be separate from WD 1110 and be connectable to WD 1110 through an interface or port. Antenna 1111, interface 1114, and/or processing circuitry 1120 may be configured to perform any receiving or transmitting operations described herein as being performed by a WD. Any information, data and/or signals may be received from a network node and/or another WD. In some embodiments, radio front end circuitry and/or antenna 1111 may be considered an interface.

As illustrated, interface 1114 comprises radio front end circuitry 1112 and antenna 1111. Radio front end circuitry 1112 comprise one or more filters 1118 and amplifiers 1116. Radio front end circuitry 1114 is connected to antenna 1111 and processing circuitry 1120, and is configured to condition signals communicated between antenna 1111 and processing circuitry 1120. Radio front end circuitry 1112 may be coupled to or a part of antenna 1111. In some embodiments, WD 1110 may not include separate radio front end circuitry 1112; rather, processing circuitry 1120 may comprise radio front end circuitry and may be connected to antenna 1111. Similarly, in some embodiments, some or all of RF transceiver circuitry 1122 may be considered a part of interface 1114. Radio front end circuitry 1112 may receive digital data that is to be sent out to other network nodes or WDs via a wireless connection. Radio front end circuitry 1112 may convert the digital data into a radio signal having the appropriate channel and bandwidth parameters using a combination of filters 1118 and/or amplifiers 1116. The radio signal may then be transmitted via antenna 1111. Similarly, when receiving data, antenna 1111 may collect radio signals which are then converted into digital data by radio front end circuitry 1112. The digital data may be passed to processing circuitry 1120. In other embodiments, the interface may comprise different components and/or different combinations of components.

Processing circuitry 1120 may comprise a combination of one or more of a microprocessor, controller, microcontroller, central processing unit, digital signal processor, application-specific integrated circuit, field programmable gate array, or any other suitable computing device, resource, or combination of hardware, software, and/or encoded logic operable to provide, either alone or in conjunction with other WD 1110 components, such as device readable medium 1130, WD 1110 functionality. Such functionality may include providing any of the various wireless features or benefits discussed herein. For example, processing circuitry 1120 may execute instructions stored in device readable medium 1130 or in memory within processing circuitry 1120 to provide the functionality disclosed herein.

As illustrated, processing circuitry 1120 includes one or more of RF transceiver circuitry 1122, baseband processing circuitry 1124, and application processing circuitry 1126. In other embodiments, the processing circuitry may comprise different components and/or different combinations of components. In certain embodiments processing circuitry 1120 of WD 1110 may comprise a SOC. In some embodiments, RF transceiver circuitry 1122, baseband processing circuitry 1124, and application processing circuitry 1126 may be on separate chips or sets of chips. In alternative embodiments, part or all of baseband processing circuitry 1124 and application processing circuitry 1126 may be combined into one chip or set of chips, and RF transceiver circuitry 1122 may be on a separate chip or set of chips. In still alternative embodiments, part or all of RF transceiver circuitry 1122 and baseband processing circuitry 1124 may be on the same chip or set of chips, and application processing circuitry 1126 may be on a separate chip or set of chips. In yet other alternative embodiments, part or all of RF transceiver circuitry 1122, baseband processing circuitry 1124, and application processing circuitry 1126 may be combined in the same chip or set of chips. In some embodiments, RF transceiver circuitry 1122 may be a part of interface 1114. RF transceiver circuitry 1122 may condition RF signals for processing circuitry 1120.

In certain embodiments, some or all of the functionality described herein as being performed by a WD may be provided by processing circuitry 1120 executing instructions stored on device readable medium 1130, which in certain embodiments may be a computer-readable storage medium. In alternative embodiments, some or all of the functionality may be provided by processing circuitry 1120 without executing instructions stored on a separate or discrete device readable storage medium, such as in a hard-wired manner. In any of those particular embodiments, whether executing instructions stored on a device readable storage medium or not, processing circuitry 1120 can be configured to perform the described functionality. The benefits provided by such functionality are not limited to processing circuitry 1120 alone or to other components of WD 1110, but are enjoyed by WD 1110 as a whole, and/or by end users and the wireless network generally.

Processing circuitry 1120 may be configured to perform any determining, calculating, or similar operations (e.g., certain obtaining operations) described herein as being performed by a WD. These operations, as performed by processing circuitry 1120, may include processing information obtained by processing circuitry 1120 by, for example, converting the obtained information into other information, comparing the obtained information or converted information to information stored by WD 1110, 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.

Device readable medium 1130 may be operable to store a computer program, software, an application including one or more of logic, rules, code, tables, etc. and/or other instructions capable of being executed by processing circuitry 1120. Device readable medium 1130 may include computer memory (e.g., Random Access Memory (RAM) or Read Only Memory (ROM)), mass storage media (e.g., a hard disk), removable storage media (e.g., a Compact Disk (CD) or a Digital Video Disk (DVD)), and/or any other volatile or non-volatile, non-transitory device readable and/or computer executable memory devices that store information, data, and/or instructions that may be used by processing circuitry 1120. In some embodiments, processing circuitry 1120 and device readable medium 1130 may be considered to be integrated.

User interface equipment 1132 may provide components that allow for a human user to interact with WD 1110. Such interaction may be of many forms, such as visual, audial, tactile, etc. User interface equipment 1132 may be operable to produce output to the user and to allow the user to provide input to WD 1110. The type of interaction may vary depending on the type of user interface equipment 1132 installed in WD 1110. For example, if WD 1110 is a smart phone, the interaction may be via a touch screen; if WD 1110 is a smart meter, the interaction may be through a screen that provides usage (e.g., the number of gallons used) or a speaker that provides an audible alert (e.g., if smoke is detected). User interface equipment 1132 may include input interfaces, devices and circuits, and output interfaces, devices and circuits. User interface equipment 1132 is configured to allow input of information into WD 1110, and is connected to processing circuitry 1120 to allow processing circuitry 1120 to process the input information. User interface equipment 1132 may include, for example, a microphone, a proximity or other sensor, keys/buttons, a touch display, one or more cameras, a USB port, or other input circuitry. User interface equipment 1132 is also configured to allow output of information from WD 1110, and to allow processing circuitry

1120 to output information from WD 1110. User interface equipment 1132 may include, for example, a speaker, a display, vibrating circuitry, a USB port, a headphone interface, or other output circuitry. Using one or more input and output interfaces, devices, and circuits, of user interface equipment 1132, WD 1110 may communicate with end users and/or the wireless network, and allow them to benefit from the functionality described herein.

Auxiliary equipment 1134 is operable to provide more specific functionality which may not be generally performed by WDs. This may comprise specialized sensors for doing measurements for various purposes, interfaces for additional types of communication such as wired communications etc. The inclusion and type of components of auxiliary equipment 1134 may vary depending on the embodiment and/or scenario.

Power source 1136 may, in some embodiments, be in the form of a battery or battery pack. Other types of power sources, such as an external power source (e.g., an electricity outlet), photovoltaic devices or power cells, may also be used. WD 1110 may further comprise power circuitry 1137 for delivering power from power source 1136 to the various parts of WD 1110 which need power from power source 1136 to carry out any functionality described or indicated herein. Power circuitry 1137 may in certain embodiments comprise power management circuitry. Power circuitry 1137 may additionally or alternatively be operable to receive power from an external power source; in which case WD 1110 may be connectable to the external power source (such as an electricity outlet) via input circuitry or an interface such as an electrical power cable. Power circuitry 1137 may also in certain embodiments be operable to deliver power from an external power source to power source 1136. This may be, for example, for the charging of power source 1136. Power circuitry 1137 may perform any formatting, converting, or other modification to the power from power source 1136 to make the power suitable for the respective components of WD 1110 to which power is supplied.

Figure 10 illustrates one embodiment of a UE in accordance with various aspects described herein. As used herein, a user equipment or UE may not necessarily have a user in the sense of a human user who owns and/or operates the relevant device. Instead, a UE may represent a device that is intended for sale to, or operation by, a human user but which may not, or which may not initially, be associated with a specific human user (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). UE 12200 may be any UE identified by the 3rd Generation Partnership Project (3GPP), including a NB-IoT UE, a machine type communication (MTC) UE, and/or an enhanced MTC (eMTC) UE. UE 1200, as illustrated in Figure 10, is one example of a WD configured for communication in accordance with one or more communication standards promulgated by the 3rd Generation Partnership Project (3GPP), such as 3GPP's GSM, UMTS, LTE, and/or 5G standards. As mentioned previously, the term WD and UE may be used interchangeable. Accordingly, although Figure 10 is a UE, the components discussed herein are equally applicable to a WD, and vice-versa.

In Figure 10, UE 1200 includes processing circuitry 1201 that is operatively coupled to input/output interface 1205, radio frequency (RF) interface 1209, network connection interface 1211, memory 1215 including random access memory (RAM) 1217, read-only memory (ROM) 1219, and storage medium 1221 or the like, communication subsystem 1231, power source 1233, and/or any other component, or any combination thereof. Storage medium 1221 includes operating system 1223, application program 1225, and data 1227. In other embodiments, storage medium 1221 may include other similar types of information. Certain UEs may utilize all of the components shown in

Figure 10, or only a subset of the components. The level of integration between the components may vary from one UE to another UE. Further, certain UEs may contain multiple instances of a component, such as multiple processors, memories, transceivers, transmitters, receivers, etc.

In Figure 10, processing circuitry 1201 may be configured to process computer instructions and data. Processing circuitry 1201 may be configured to implement any sequential state machine operative to execute machine instructions stored as machine-readable computer programs in the memory, such as one or more hardware-implemented state machines (e.g., in discrete logic, FPGA, ASIC, etc.); programmable logic together with appropriate firmware; one or more stored program, general-purpose processors, such as a microprocessor or Digital Signal Processor (DSP), together with appropriate software; or any combination of the above. For example, the processing circuitry 1201 may include two central processing units (CPUs). Data may be information in a form suitable for use by a computer.

In the depicted embodiment, input/output interface 1205 may be configured to provide a communication interface to an input device, output device, or input and output device. UE 1200 may be configured to use an output device via input/output interface 1205. An output device may use the same type of interface port as an input device. For example, a USB port may be used to provide input to and output from UE 1200. The output device may be a speaker, a sound card, a video card, a display, a monitor, a printer, an actuator, an emitter, a smartcard, another output device, or any combination thereof. UE 1200 may be configured to use an input device via input/output interface 1205 to allow a user to capture information into UE 1200. The input device may include a touch-sensitive or presence-sensitive display, a camera (e.g., a digital camera, a digital video camera, a web camera, etc.), a microphone, a sensor, a mouse, a trackball, a directional pad, a trackpad, a scroll wheel, a smartcard, and the like. The presence-sensitive display may include a capacitive or resistive touch sensor to sense input from a user. A sensor may be, for instance, an accelerometer, a gyroscope, a tilt sensor, a force sensor, a magnetometer, an optical sensor, a proximity sensor, another like sensor, or any combination thereof. For example, the input device may be an accelerometer, a magnetometer, a digital camera, a microphone, and an optical sensor.

In Figure 10, RF interface 1209 may be configured to provide a communication interface to RF components such as a transmitter, a receiver, and an antenna. Network connection interface 1211 may be configured to provide a communication interface to network 1243a. Network 1243a may encompass wired and/or wireless networks such as a local-area network (LAN), a wide-area network (WAN), a computer network, a wireless network, a telecommunications network, another like network or any combination thereof. For example, network 1243a may comprise a Wi-Fi network. Network connection interface 1211 may be configured to include a receiver and a transmitter interface used to communicate with one or more other devices over a communication network according to one or more communication protocols, such as Ethernet, TCP/IP, SONET, ATM, or the like. Network connection interface 1211 may implement receiver and transmitter functionality appropriate to the communication network links (e.g., optical, electrical, and the like). The transmitter and receiver functions may share circuit components, software or firmware, or alternatively may be implemented separately.

RAM 1217 may be configured to interface via bus 1202 to processing circuitry 1201 to provide storage or caching of data or computer instructions during the execution of software programs such as the operating system, application programs, and device drivers. ROM 1219 may be configured to provide computer instructions or data to processing circuitry 1201. For example, ROM 1219 may be configured to store invariant low-level system code or data for basic system functions such as basic input and output

(I/O), startup, or reception of keystrokes from a keyboard that are stored in a non-volatile memory. Storage medium 1221 may be configured to include memory such as RAM, ROM, programmable read-only memory (PROM), erasable programmable read-only memory (EPROM), electrically erasable programmable read-only memory (EEPROM), magnetic disks, optical disks, floppy disks, hard disks, removable cartridges, or flash drives. In one example, storage medium 1221 may be configured to include operating system 1223, application program 1225 such as a web browser application, a widget or gadget engine or another application, and data file 1227. Storage medium 1221 may store, for use by UE 1200, any of a variety of various operating systems or combinations of operating systems.

Storage medium 1221 may be configured to include a number of physical drive units, such as redundant array of independent disks (RAID), floppy disk drive, 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 random access memory (SDRAM), external micro-DIMM SDRAM, smartcard memory such as a subscriber identity module or a removable user identity (SIM/RUIM) module, other memory, or any combination thereof. Storage medium 1221 may allow UE 1200 to access computer-executable instructions, application programs or the like, stored on transitory or non-transitory memory media, to off-load data, or to upload data. An article of manufacture, such as one utilizing a communication system may be tangibly embodied in storage medium 1221, which may comprise a device readable medium.

In Figure 10, processing circuitry 1201 may be configured to communicate with network 1243b using communication subsystem 1231. Network 1243a and network 1243b may be the same network or networks or different network or networks.

Communication subsystem 1231 may be configured to include one or more transceivers used to communicate with network 1243b. For example, communication subsystem 1231 may be configured to include one or more transceivers used to communicate with one or more remote transceivers of another device capable of wireless communication such as another WD, UE, or base station of a radio access network (RAN) according to one or more communication protocols, such as IEEE 802.10, CDMA, WCDMA, GSM, LTE, UTRAN, WiMax, or the like. Each transceiver may include transmitter 1233 and/or receiver 1235 to implement transmitter or receiver functionality, respectively, appropriate to the RAN links (e.g., frequency allocations and the like). Further, transmitter 1233 and receiver 1235 of each transceiver may share circuit components, software or firmware, or alternatively may be implemented separately.

In the illustrated embodiment, the communication functions of communication subsystem 1231 may include data communication, voice communication, multimedia communication, short-range communications such as Bluetooth, near-field communication, location-based communication such as the use of the global positioning system (GPS) to determine a location, another like communication function, or any combination thereof. For example, communication subsystem 1231 may include cellular communication, Wi-Fi communication, Bluetooth communication, and GPS communication. Network 1243b may encompass wired and/or wireless networks such as a local-area network (LAN), a wide-area network (WAN), a computer network, a wireless network, a telecommunications network, another like network or any combination thereof. For example, network 1243b may be a cellular network, a Wi-Fi network, and/or a near-field network. Power source 1213 may be configured to provide alternating current (AC) or direct current (DC) power to components of UE 1200.

The features, benefits and/or functions described herein may be implemented in one of the components of UE 1200 or partitioned across multiple components of UE

1200. Further, the features, benefits, and/or functions described herein may be implemented in any combination of hardware, software or firmware. In one example, communication subsystem 1231 may be configured to include any of the components described herein. Further, processing circuitry 1201 may be configured to communicate with any of such components over bus 1202. In another example, any of such components may be represented by program instructions stored in memory that when executed by processing circuitry 1201 perform the corresponding functions described herein. In another example, the functionality of any of such components may be partitioned between processing circuitry 1201 and communication subsystem 1231. In another example, the non-computationally intensive functions of any of such components may be implemented in software or firmware and the computationally intensive functions may be implemented in hardware.

Figure 11 is a schematic block diagram illustrating a virtualization environment 1300 in which functions implemented by some embodiments may be virtualized. In the present context, virtualizing means creating virtual versions of apparatuses or devices which may include virtualizing hardware platforms, storage devices and networking resources. As used herein, virtualization can be applied to a node (e.g., a virtualized base station or a virtualized radio access node) or to a device (e.g., a UE, a wireless device or any other type of communication device) or components thereof and relates to an implementation in which at least a portion of the functionality is implemented as one or more virtual components (e.g., via one or more applications, components, functions, virtual machines or containers executing on one or more physical processing nodes in one or more networks).

In some embodiments, some or all of the functions described herein may be implemented as virtual components executed by one or more virtual machines implemented in one or more virtual environments 1300 hosted by one or more of hardware nodes 1330. Further, in embodiments in which the virtual node is not a radio access node or does not require radio connectivity (e.g., a core network node), then the network node may be entirely virtualized.

The functions may be implemented by one or more applications 1320 (which may alternatively be called software instances, virtual appliances, network functions, virtual nodes, virtual network functions, etc.) operative to implement some of the features, functions, and/or benefits of some of the embodiments disclosed herein. Applications 1320 are run in virtualization environment 1300 which provides hardware 1330 comprising processing circuitry 1360 and memory 1390. Memory 1390 contains instructions 1395 executable by processing circuitry 1360 whereby application 1320 is operative to provide one or more of the features, benefits, and/or functions disclosed herein.

Virtualization environment 1300, comprises general-purpose or special-purpose network hardware devices 1330 comprising a set of one or more processors or processing circuitry 1360, which may be commercial off-the-shelf (COTS) processors, dedicated Application Specific Integrated Circuits (ASICs), or any other type of processing circuitry including digital or analog hardware components or special purpose processors. Each hardware device may comprise memory 1390-1 which may be non-persistent memory for temporarily storing instructions 1395 or software executed by processing circuitry 1360. Each hardware device may comprise one or more network interface controllers (NICs) 1370, also known as network interface cards, which include physical network interface 1380. Each hardware device may also include non-transitory, persistent, machine-readable storage media 1390-2 having stored therein software 1395 and/or instructions executable by processing circuitry 1360. Software 1395 may include any type of software including software for instantiating one or more virtualization layers 1350 (also referred to as hypervisors), software to execute virtual machines 1340 as well as software allowing it to execute functions, features and/or benefits described in relation with some embodiments described herein.

Virtual machines 1340, comprise virtual processing, virtual memory, virtual networking or interface and virtual storage, and may be run by a corresponding virtualization layer 1350 or hypervisor. Different embodiments of the instance of virtual appliance 1320 may be implemented on one or more of virtual machines 1340, and the implementations may be made in different ways.

During operation, processing circuitry 1360 executes software 1395 to instantiate the hypervisor or virtualization layer 1350, which may sometimes be referred to as a virtual machine monitor (VMM). Virtualization layer 1350 may present a virtual operating platform that appears like networking hardware to virtual machine 1340.

As shown in Figure 11, hardware 1330 may be a standalone network node with generic or specific components. Hardware 1330 may comprise antenna 13225 and may implement some functions via virtualization. Alternatively, hardware 1330 may be part of a larger cluster of hardware (e.g., such as in a data center or customer premise equipment (CPE)) where many hardware nodes work together and are managed via management and orchestration (MANO) 13100, which, among others, oversees lifecycle management of applications 1320.

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.

In the context of NFV, virtual machine 1340 may be a software implementation of a physical machine that runs programs as if they were executing on a physical, non-virtualized machine. Each of virtual machines 1340, and that part of hardware 1330 that executes that virtual machine, be it hardware dedicated to that virtual machine and/or hardware shared by that virtual machine with others of the virtual machines 1340, forms a separate virtual network elements (VNE).

Still in the context of NFV, Virtual Network Function (VNF) is responsible for handling specific network functions that run in one or more virtual machines 1340 on top of hardware networking infrastructure 1330 and corresponds to application 1320 in Figure 11.

In some embodiments, one or more radio units 13200 that each include one or more transmitters 13220 and one or more receivers 13210 may be coupled to one or more antennas 13225. Radio units 13200 may communicate directly with hardware nodes 1330 via one or more appropriate network interfaces and may be used in combination with the virtual components to provide a virtual node with radio capabilities, such as a radio access node or a base station.

In some embodiments, some signalling can be effected with the use of control system 13230 which may alternatively be used for communication between the hardware nodes 1330 and radio units 13200.

Figure 12 illustrates a telecommunication network connected via an intermediate network to a host computer in accordance with some embodiments. In particular, with reference to FIGURE 12, in accordance with an embodiment, a communication system includes telecommunication network 1410, such as a 3GPP-type cellular network, which comprises access network 1411, such as a radio access network, and core network 1414. Access network 1411 comprises a plurality of base stations 1412a, 1412b, 1412c, such as NBs, eNBs, gNBs or other types of wireless access points, each defining a corresponding coverage area 1413a, 1413b, 1413c. Each base station 1412a, 1412b, 1412c is connectable to core network 1414 over a wired or wireless connection 1415. A first UE 1491 located in coverage area 1413c is configured to wirelessly connect to, or be paged by, the corresponding base station 1412c. A second UE 1492 in coverage area 1413a is wirelessly connectable to the corresponding base station 1412a. While a plurality of UEs 1491, 1492 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 1412.

Telecommunication network 1410 is itself connected to host computer 1430, which may be embodied in the hardware and/or software of a standalone server, a cloud-implemented server, a distributed server or as processing resources in a server farm. Host computer 1430 may be under the ownership or control of a service provider, or may be operated by the service provider or on behalf of the service provider. Connections 1421 and 1422 between telecommunication network 1410 and host computer 1430 may extend directly from core network 1414 to host computer 1430 or may go via an optional intermediate network 1420. Intermediate network 1420 may be one of, or a combination of more than one of, a public, private or hosted network; intermediate network 1420, if any, may be a backbone network or the Internet; in particular, intermediate network 1420 may comprise two or more sub-networks (not shown).

The communication system of Figure 12 as a whole enables connectivity between the connected UEs 1491, 1492 and host computer 1430. The connectivity may be described as an over-the-top (OTT) connection 1450. Host computer 1430 and the connected UEs 1491, 1492 are configured to communicate data and/or signaling via OTT connection 1450, using access network 1411, core network 1414, any intermediate network 1420 and possible further infrastructure (not shown) as intermediaries. OTT connection 1450 may be transparent in the sense that the participating communication devices through which OTT connection 1450 passes are unaware of routing of uplink and downlink communications. For example, base station 1412 may not or need not be informed about the past routing of an incoming downlink communication with data originating from host computer 1430 to be forwarded (e.g., handed over) to a connected UE 1491. Similarly, base station 1412 need not be aware of the future routing of an outgoing uplink communication originating from the UE 1491 towards the host computer 1430.

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 13. Figure 13 illustrates host computer communicating via a base station with a user equipment over a partially wireless connection in accordance with some embodiments In communication system 1500, host computer 1510 comprises hardware 1515 including communication interface 1516 configured to set up and maintain a wired or wireless connection with an interface of a different communication device of communication system 1500. Host computer 1510 further comprises processing circuitry 1518, which may have storage and/or processing capabilities. In particular, processing circuitry 1518 may comprise one or more programmable processors, application-specific integrated circuits, field programmable gate arrays or combinations of these (not shown) adapted to execute instructions. Host computer 1510 further comprises software 1511, which is stored in or accessible by host computer 1510 and executable by processing circuitry 1518. Software 1511 includes host application 1512. Host application 1512 may be operable to provide a service to a remote user, such as UE 1530 connecting via OTT connection 1550 terminating at UE 1530 and host computer 1510. In providing the service to the remote user, host application 1512 may provide user data which is transmitted using OTT connection 1550.

Communication system 1500 further includes base station 1520 provided in a telecommunication system and comprising hardware 1525 enabling it to communicate with host computer 1510 and with UE 1530. Hardware 1525 may include communication interface 1526 for setting up and maintaining a wired or wireless connection with an interface of a different communication device of communication system 1500, as well as radio interface 1527 for setting up and maintaining at least wireless connection 1570 with UE 1530 located in a coverage area (not shown in Figure 13) served by base station 1520. Communication interface 1526 may be configured to facilitate connection 1560 to host computer 1510. Connection 1560 may be direct or it may pass through a core network (not shown in Figure 13) of the telecommunication system and/or through one or more intermediate networks outside the telecommunication system. In the embodiment shown, hardware 1525 of base station 1520 further includes processing circuitry 1528, which may comprise one or more programmable processors, application-specific integrated circuits, field programmable gate arrays or combinations of these (not shown) adapted to execute instructions. Base station 1520 further has software 1521 stored internally or accessible via an external connection.

Communication system 1500 further includes UE 1530 already referred to. Its hardware 1535 may include radio interface 1537 configured to set up and maintain wireless connection 1570 with a base station serving a coverage area in which UE 1530 is currently located. Hardware 1535 of UE 1530 further includes processing circuitry 1538, which may comprise one or more programmable processors, application-specific integrated circuits, field programmable gate arrays or combinations of these (not shown) adapted to execute instructions. UE 1530 further comprises software 1531, which is stored in or accessible by UE 1530 and executable by processing circuitry 1538. Software 1531 includes client application 1532. Client application 1532 may be operable to provide a service to a human or non-human user via UE 1530, with the support of host computer 1510. In host computer 1510, an executing host application 1512 may communicate with the executing client application 1532 via OTT connection 1550 terminating at UE 1530 and host computer 1510. In providing the service to the user, client application 1532 may receive request data from host application 1512 and provide user data in response to the request data. OTT connection 1550 may transfer both the request data and the user data. Client application 1532 may interact with the user to generate the user data that it provides.

It is noted that host computer 1510, base station 1520 and UE 1530 illustrated in Figure 13 may be similar or identical to host computer 1430, one of base stations 1412a, 1412b, 1412c and one of UEs 1491, 1492 of Figure 12, respectively. This is to say, the inner workings of these entities may be as shown in Figure 13 and independently, the surrounding network topology may be that of Figure 12.

In Figure 13, OTT connection 1550 has been drawn abstractly to illustrate the communication between host computer 1510 and UE 1530 via base station 1520, without explicit reference to any intermediary devices and the precise routing of messages via these devices. Network infrastructure may determine the routing, which it may be configured to hide from UE 1530 or from the service provider operating host computer 1510, or both. While OTT connection 1550 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).

Wireless connection 1570 between UE 1530 and base station 1520 is in accordance with the teachings of the embodiments described throughout this disclosure. One or more of the various embodiments improve the performance of OTT services provided to UE 1530 using OTT connection 1550, in which wireless connection 1570 forms the last segment. More precisely, the teachings of these embodiments may improve reliability and latency of data transmissions and thereby provide benefits such as faster data communication and improved user experience.

A measurement procedure may be provided for the purpose of monitoring data rate, latency and other factors on which the one or more embodiments improve. There may further be an optional network functionality for reconfiguring OTT connection 1550 between host computer 1510 and UE 1530, in response to variations in the measurement results. The measurement procedure and/or the network functionality for reconfiguring OTT connection 1550 may be implemented in software 1511 and hardware 1515 of host computer 1510 or in software 1531 and hardware 1535 of UE 1530, or both. In embodiments, sensors (not shown) may be deployed in or in association with communication devices through which OTT connection 1550 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 1511, 1531 may compute or estimate the monitored quantities. The reconfiguring of OTT connection 1550 may include message format, retransmission settings, preferred routing etc.; the reconfiguring need not affect base station 1520, and it may be unknown or imperceptible to base station 1520. Such procedures and functionalities may be known and practiced in the art. In certain embodiments, measurements may involve proprietary UE signaling facilitating host computer 1510's measurements of throughput, propagation times, latency and the like. The measurements may be implemented in that software 1511 and 1531 causes messages to be transmitted, in particular empty or 'dummy' messages, using OTT connection 1550 while it monitors propagation times, errors etc.

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 and a UE which may be those described with reference to Figures 12 and 13. For simplicity of the present disclosure, only drawing references to Figure 14 will be included in this section. In step 1610, the host computer provides user data. In substep 1611 (which may be optional) of step 1610, the host computer provides the user data by executing a host application. In step 1620, the host computer initiates a transmission carrying the user data to the UE. In step 1630 (which may be optional), the base station transmits to the UE the user data which was carried in the transmission that the host computer initiated, in accordance with the teachings of the embodiments described throughout this disclosure. In step 1640 (which may also be optional), the UE executes a client application associated with the host application executed by the host computer.

Figure 15 is a flowchart illustrating a method implemented in a communication system, in accordance with one embodiment. The communication system includes a host computer, a base station and a UE which may be those described with reference to Figures 12 and 13. For simplicity of the present disclosure, only drawing references to Figure 15 will be included in this section. In step 1710 of the method, the host computer provides user data. In an optional substep (not shown) the host computer provides the user data by executing a host application. In step 1720, the host computer initiates a transmission carrying the user data to the UE. The transmission may pass via the base station, in accordance with the teachings of the embodiments described throughout this disclosure. In step 1730 (which may be optional), the UE receives the user data carried in the transmission.

Figure 16 is a flowchart illustrating a method implemented in a communication system, in accordance with one embodiment. The communication system includes a host computer, a base station and a UE which may be those described with reference to Figures 12 and 13. For simplicity of the present disclosure, only drawing references to Figure 16 will be included in this section. In step 1810 (which may be optional), the UE receives input data provided by the host computer. Additionally or alternatively, in step 1820, the UE provides user data. In substep 1821 (which may be optional) of step 1820, the UE provides the user data by executing a client application. In substep 1811 (which may be optional) of step 1810, the UE executes a client application which provides the user data in reaction to the received input data provided by the host computer. In providing the user data, the executed client application may further consider user input received from the user. Regardless of the specific manner in which the user data was provided, the UE initiates, in substep 1830 (which may be optional), transmission of the user data to the host computer. In step 1840 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 17 is a flowchart illustrating a method implemented in a communication system, in accordance with one embodiment. The communication system includes a host computer, a base station and a UE which may be those described with reference to Figures 12 and 13. For simplicity of the present disclosure, only drawing references to Figure 17 will be included in this section. In step 1910 (which may be optional), in accordance with the teachings of the embodiments described throughout this disclosure, the base station receives user data from the UE. In step 1920 (which may be optional), the base station initiates transmission of the received user data to the host computer. In step 1930 (which may be optional), the host computer receives the user data carried in the transmission initiated by the base station.

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

Generally, all terms used herein are to be interpreted according to their ordinary meaning in the relevant technical field, unless a different meaning is clearly given and/or is implied from the context in which it is used. All references to a/an/the element, apparatus, component, means, step, etc. are to be interpreted openly as referring to at least one instance of the element, apparatus, component, means, step, etc., unless explicitly stated otherwise. The steps of any methods disclosed herein do not have to be performed in the exact order disclosed, unless a step is explicitly described as following or preceding another step and/or where it is implicit that a step must follow or precede another step. Any feature of any of the embodiments disclosed herein may be applied to any other embodiment, wherever appropriate. Likewise, any advantage of any of the embodiments may apply to any other embodiments, and vice versa. Other objectives, features and advantages of the enclosed embodiments will be apparent from the description.

The term unit may have conventional meaning in the field of electronics, electrical devices and/or electronic devices and may include, for example, electrical and/or electronic circuitry, devices, modules, processors, memories, logic solid state and/or discrete devices, computer programs or instructions for carrying out respective tasks, procedures, computations, outputs, and/or displaying functions, and so on, as such as those that are described herein.

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

CLAIMS

What is claimed is:

1. A method implemented by a user equipment in a wireless communication network, said method comprising:

receiving, from a base station, an indication to use a service-specific power control process for a data transmission on a shared uplink channel; and

responsive to the indication, applying the service-specific power control process to control a transmit power of the data transmission.

2. The method of claim 1, wherein receiving an indication to use the service-specific power control process for a data transmission comprises receiving an uplink grant for the data transmission addressed to a service-specific identifier.

3. The method of claim 2, wherein the service-specific identifier comprises a radio network temporary identifier associated with a specific service.

4. The method of claim 1, wherein receiving an indication to use the service-specific power control process for a scheduled data transmission comprises receiving an uplink grant for the data transmission including an indication to use a predetermined modulation and coding scheme table for the data transmission.

5. The method of claim 1 wherein receiving an indication to use the service-specific power control process for a data transmission comprises receiving an uplink grant for the data transmission, said uplink grant including a predetermined error detection sequence.

6. The method of claim 5, wherein the predetermined error detection sequence comprises a long cyclic redundancy check code.

7. The method of claim 1, wherein receiving an indication to use the service-specific power control process for a data transmission comprises receiving a power control identifier associated with the service-specific power control process.

8. The method of claim 7, wherein the power control identifier is sent in a power control information element via radio resource control signaling.

9. The method of any one of claims 1 – 8, further comprising:
receiving, from a base station, configuration information for configuring the service-specific power control on the uplink shared channel.

10. The method of any one of claims 1 – 9, wherein receiving configuration information from the base station comprises receiving the configuration information via radio resource control (RRC) signaling.

11. The method of any one of claims 1 – 10, wherein the service-specific power control is configured for ultra-reliable, low latency communication data transmissions.

12. A method implemented by a base station in a serving cell of the wireless communication network, said method comprising:

sending configuration information to a user equipment to configure a service-specific power control process for an uplink shared channel; and sending, to the user equipment, an indication to use the service-specific power control process for a data transmission on the shared uplink channel.

13. The method of claim 12, wherein sending an indication to use the service-specific power control process for a data transmission comprises sending an uplink grant addressed to a service-specific identifier.

14. The method of claim 13, wherein the serviced-specific identifier comprises a radio network temporary identifier associated with a specific service.

15. The method of claim 12, wherein sending an indication to use the service-specific power control process for a data transmission comprises sending an indication to use a predetermined modulation and coding scheme table for the data transmission.

16. The method of claim 12, wherein sending an indication to use the service-specific power control process for a data transmission comprises sending an uplink grant configured with a predetermined error detection sequence.

17. The method of claim 16, wherein the predetermined error detection sequence comprises a long cyclic redundancy check code.

18. The method of claim 12, wherein sending an indication to use the service-specific power control process for a data transmission comprises sending a power control identifier associated with the service-specific power control process.

19. The method of claim 18, wherein the power control identifier is sent in a power control information element via radio resource control signaling.

20. The method of any one of claims 12 – 19, wherein the service-specific power control is configured for ultra-reliable, low latency communication data transmissions.

21. The method of any one of claims 12 – 20, further comprising, applying the service-specific power control process for the data transmission.

22. A user equipment in a wireless communication network, said user equipment comprising:

a communication circuit configured for communication with one or more serving cells the wireless communication network; and

a processing circuit configured to:

receive, from a base station, an indication to use a service-specific power control process for a data transmission on a shared uplink channel; and

responsive to the indication, apply the service-specific power control process to control a transmit power of the data transmission.

23. The user equipment of claim 22, wherein the processing circuit is further configured to receive, as said indication, an uplink grant for the data transmission addressed to a service-specific identifier.

24. The user equipment of claim 23, wherein the service-specific identifier comprises a radio network temporary identifier associated with a specific service.

25. The user equipment of claim 22, wherein the processing circuit is further configured to receive, as said indication, an uplink grant for the data transmission including an indication to use a predetermined modulation and coding scheme table for the data transmission.

26. The user equipment of claim 22, wherein the processing circuit is further configured to receive, as said indication, an uplink grant for the data transmission, said uplink grant including a predetermined error detection sequence.

27. The user equipment of claim 26, wherein the predetermined error detection sequence comprises a long cyclic redundancy check code.

28. The user equipment of claim 22, wherein the processing circuit is further configured to receive, as said indication, a power control identifier associated with the service-specific power control process.

29. The user equipment of claim 28, wherein the power control identifier is received in a power control information element via radio resource control signaling.

30. The user equipment of any one of claims 22 – 29, wherein, the processing circuit is further configured to:

receive, from a base station, configuration information for configuring the service-specific power control on the uplink shared channel.

31. The user equipment of any one of claims 22 – 30, wherein the processing circuit is further configured to receive the configuration information via radio resource control (RRC) signaling.

32. The user equipment of any one of claims 22 – 31, wherein the service-specific power control is configured for ultra-reliable, low latency communication data transmissions.

33. A non-transitory computer-readable storage medium containing a computer program comprising executable instructions that, when executed by a processing circuit in a user equipment in a wireless communication network causes the user equipment to:

receive, from a base station, an indication to use a service-specific power control process for a data transmission on a shared uplink channel; and

responsive to the indication, apply the service-specific power control process to control a transmit power of the data transmission.

34. A base station in a serving cell of the wireless communication network, said base station comprising:

a communication circuit configured for communication with one or more serving cells the wireless communication network; and

a processing circuit configured to:

send configuration information to a user equipment to configure a service-specific power control process for an uplink shared channel; and

send, to the user equipment, an indication to use the service-specific power control process for a data transmission on the shared uplink channel; and apply the service-specific power control process to control a transmit power of the data transmission.

35. The base station of claim 34, wherein the processing circuit is further configured to send, as the indication, an uplink grant addressed to a service-specific identifier.

36. The base station of claim 35, wherein, the serviced-specific identifier comprises a radio network temporary identifier associated with a specific service.

37. The base station of claim 34, wherein the processing circuit is further configured to send, as the indication, an indication to use a predetermined modulation and coding scheme table for the data transmission.

38. The base station of claim 34, wherein the processing circuit is further configured to send, as the indication, an uplink grant configured with a predetermined error detection sequence.

39. The base station of claim 38 wherein the predetermined error detection sequence comprises a long cyclic redundancy check code.

40. The base station of claim 34, wherein the processing circuit is further configured to send, as the indication, a power control identifier associated with the service-specific power control process.

41. The base station of claim 40 wherein the power control identifier is sent in a power control information element via radio resource control signaling.

42. The base station of any one of claims 34 – 41, wherein the service-specific power control is configured for ultra-reliable, low latency communication data transmissions.

43. A non-transitory computer-readable storage medium containing a computer program comprising executable instructions that, when executed by a processing circuit in a base station in a wireless communication network causes the base station to:

send configuration information to a user equipment to configure a service-specific power control process for an uplink shared channel; and

send, to the user equipment, an indication to use the service-specific power control process for a data transmission on the shared uplink channel; and

apply the service-specific power control process to control a transmit power of the data transmission.

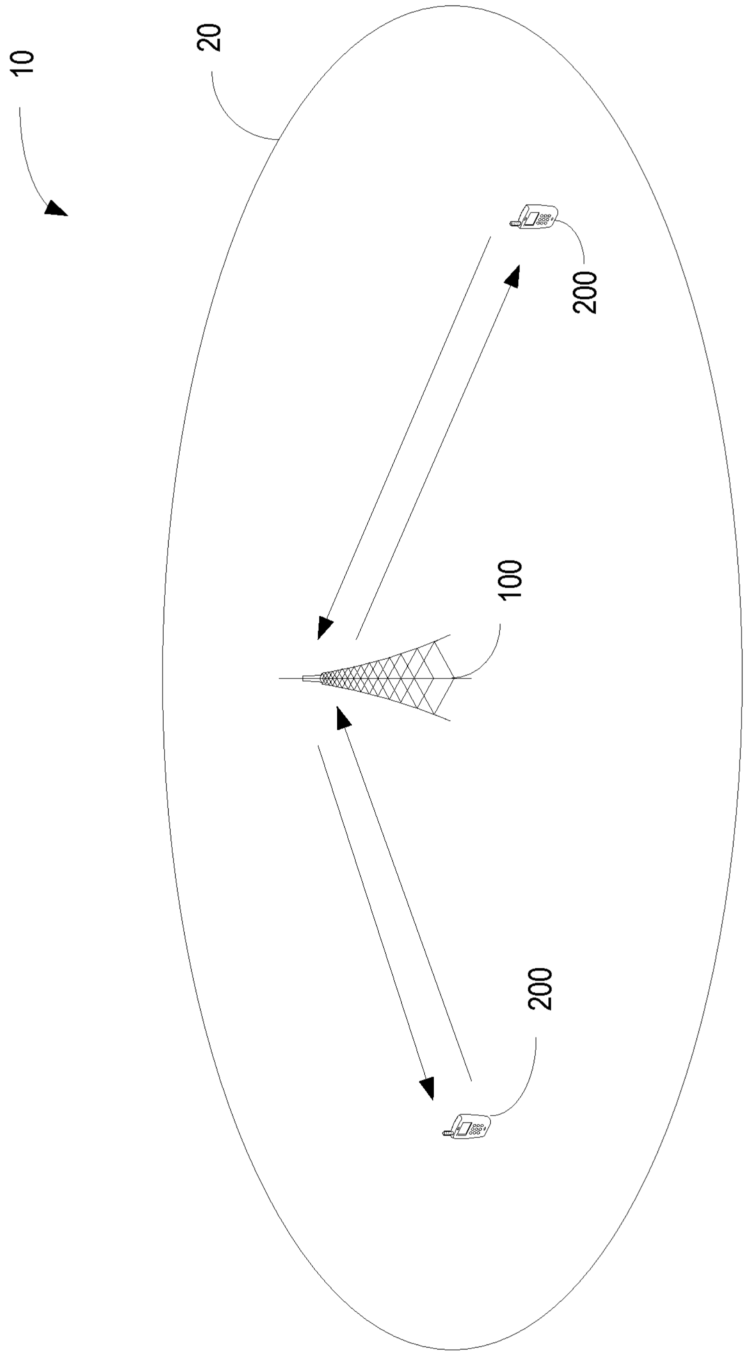


FIG. 1

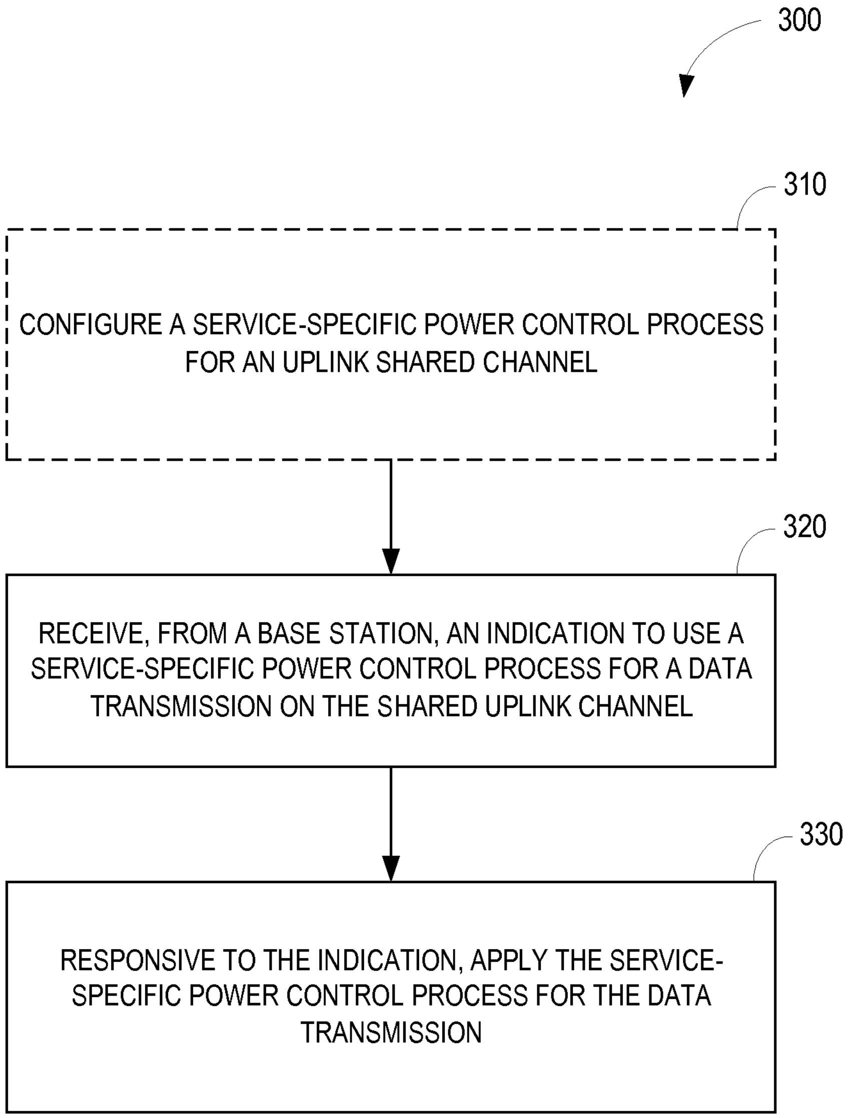

300
310
CONFIGURE A SERVICE-SPECIFIC POWER CONTROL PROCESS FOR AN UPLINK SHARED CHANNEL
320
RECEIVE, FROM A BASE STATION, AN INDICATION TO USE A SERVICE-SPECIFIC POWER CONTROL PROCESS FOR A DATA TRANSMISSION ON THE SHARED UPLINK CHANNEL
330
RESPONSIVE TO THE INDICATION, APPLY THE SERVICE-SPECIFIC POWER CONTROL PROCESS FOR THE DATA TRANSMISSION

FIG. 2

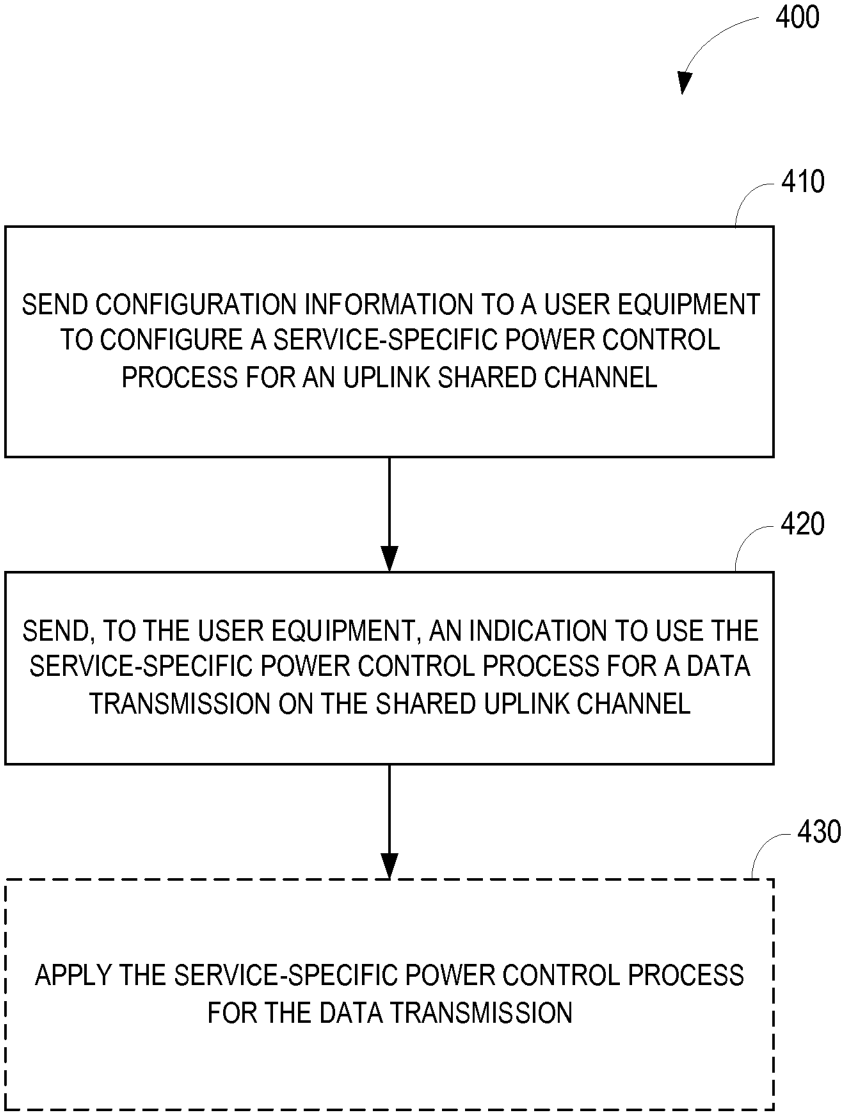

400
410
SEND CONFIGURATION INFORMATION TO A USER EQUIPMENT TO CONFIGURE A SERVICE-SPECIFIC POWER CONTROL PROCESS FOR AN UPLINK SHARED CHANNEL
420
SEND, TO THE USER EQUIPMENT, AN INDICATION TO USE THE SERVICE-SPECIFIC POWER CONTROL PROCESS FOR A DATA TRANSMISSION ON THE SHARED UPLINK CHANNEL
430
APPLY THE SERVICE-SPECIFIC POWER CONTROL PROCESS FOR THE DATA TRANSMISSION

FIG. 3

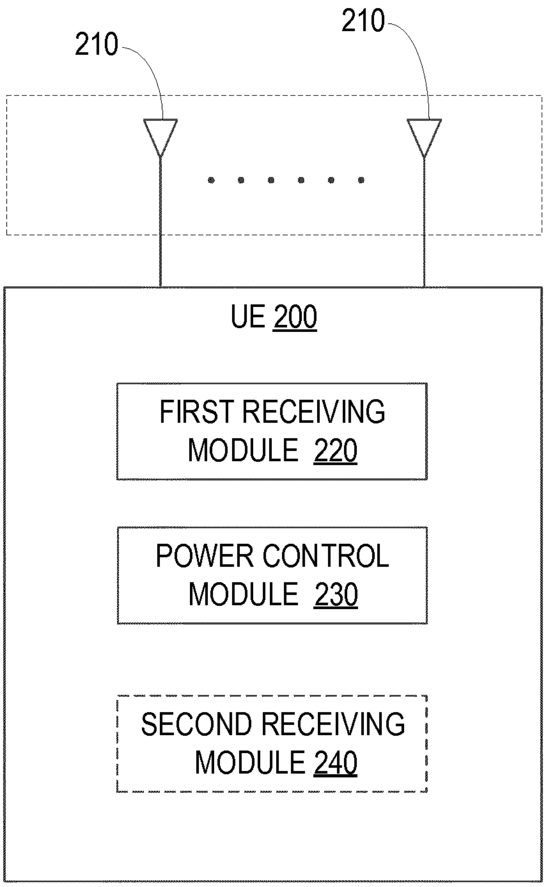

210
210
UE 200
FIRST RECEIVING MODULE 220
POWER CONTROL MODULE 230
SECOND RECEIVING MODULE 240

FIG. 4

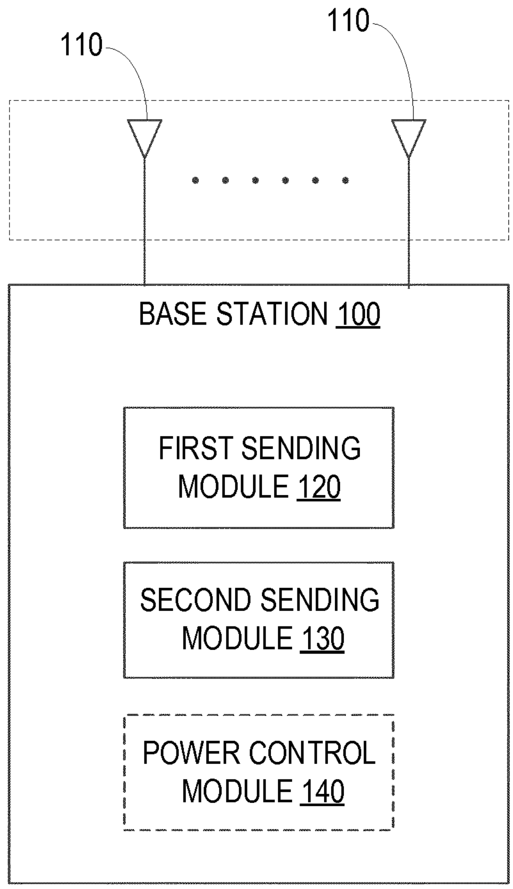

110
110
BASE STATION 100
FIRST SENDING MODULE 120
SECOND SENDING MODULE 130
POWER CONTROL MODULE 140

FIG. 5

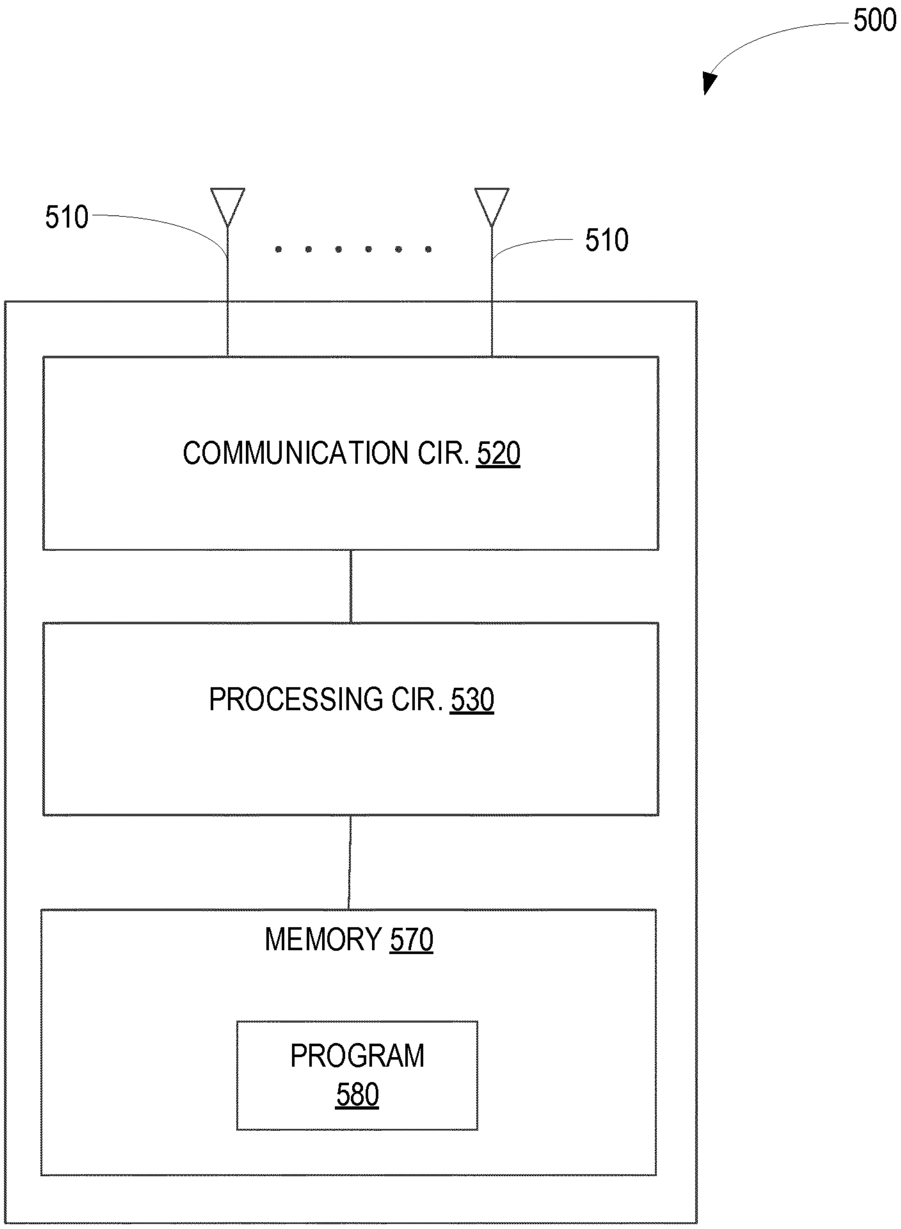

500
510
510
COMMUNICATION CIR. 520
PROCESSING CIR. 530
MEMORY 570
PROGRAM
580

FIG. 6

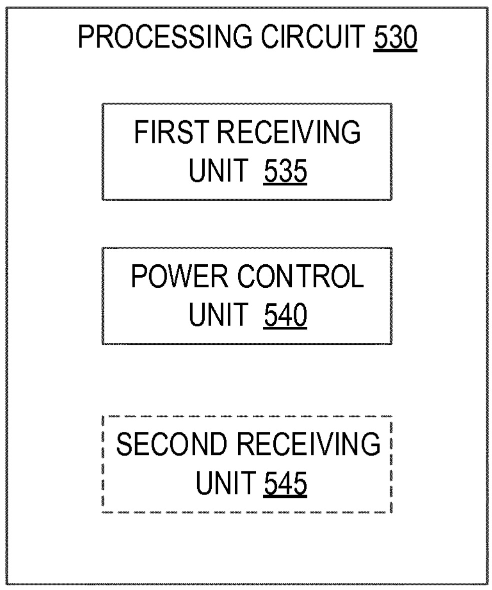

PROCESSING CIRCUIT 530
FIRST RECEIVING UNIT 535
POWER CONTROL UNIT 540
SECOND RECEIVING UNIT 545

FIG. 7

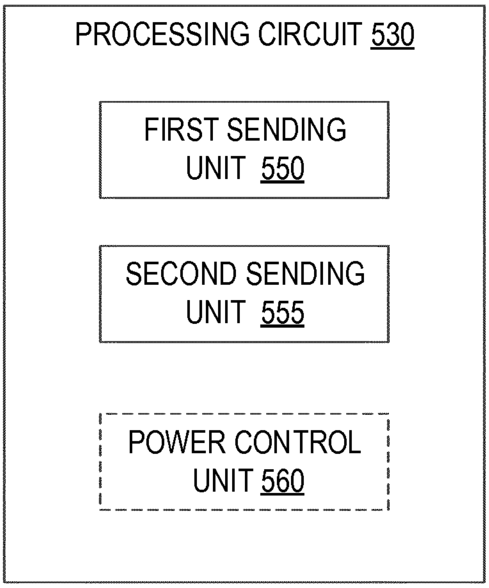

PROCESSING CIRCUIT 530
FIRST SENDING UNIT 550
SECOND SENDING UNIT 555
POWER CONTROL UNIT 560

FIG. 8

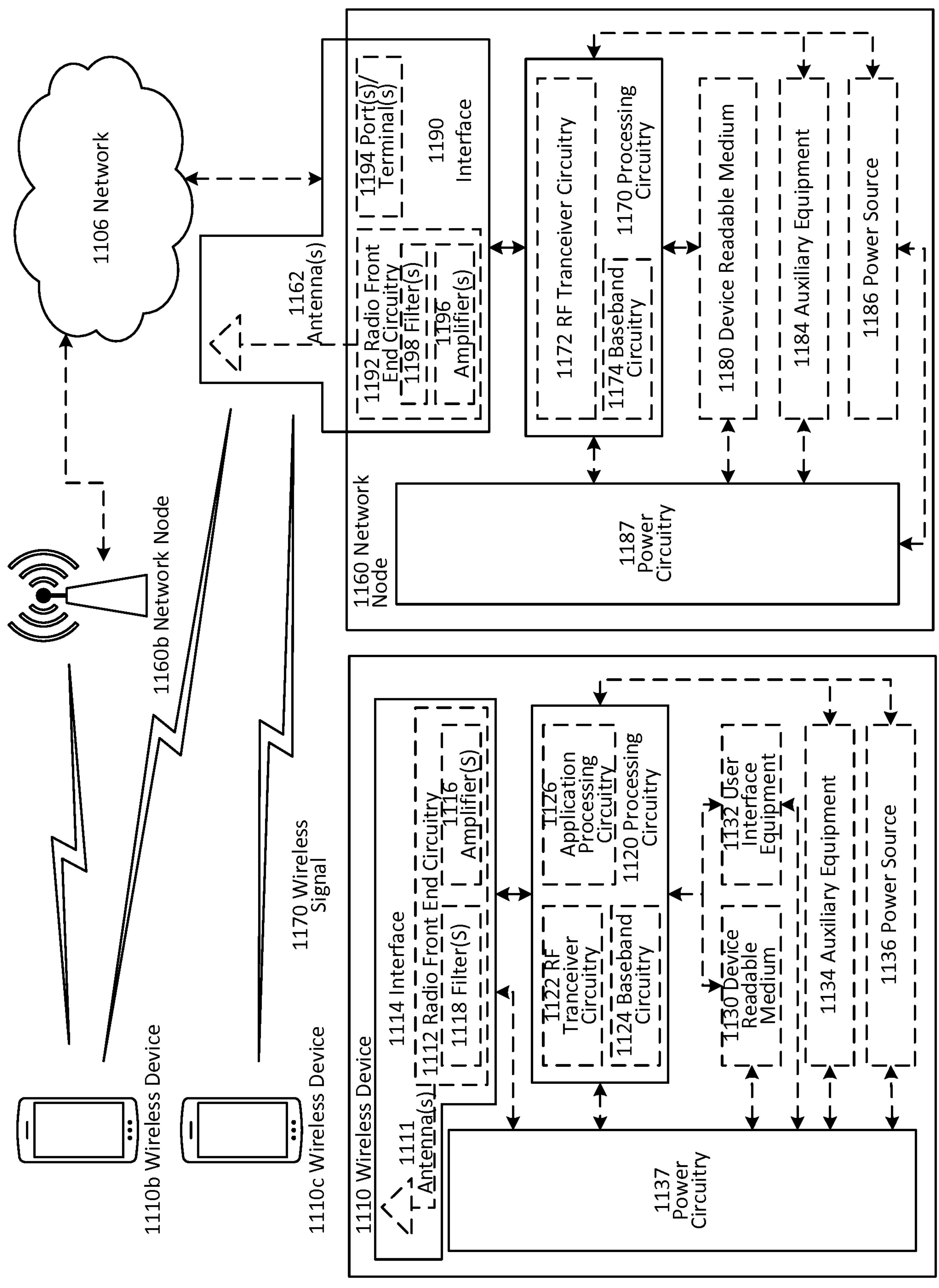

1106 Network
1160b Network Node
1110b Wireless Device
1110c Wireless Device
1170 Wireless Signal
1160 Network Node
1162 Antenna(s)
1192 Radio Front End Circuitry
1198 Filter(s)
1196 Amplifier(s)
1194 Port(s)/ Terminal(s)
1190 Interface
1172 RF Tranceiver Circuitry
1174 Baseband Circuitry
1170 Processing Circuitry
1180 Device Readable Medium
1184 Auxiliary Equipment
1186 Power Source
1187 Power Circuitry
1110 Wireless Device
1111 Antenna(s)
1114 Interface
1112 Radio Front End Circuitry
1118 Filter(S)
1116 Amplifier(S)
1122 RF Tranceiver Circuitry
1124 Baseband Circuitry
1126 Application Processing Circuitry
1120 Processing Circuitry
1130 Device Readable Medium
1132 User Interface Equipment
1134 Auxiliary Equipment
1136 Power Source
1137 Power Circuitry

FIG. 9

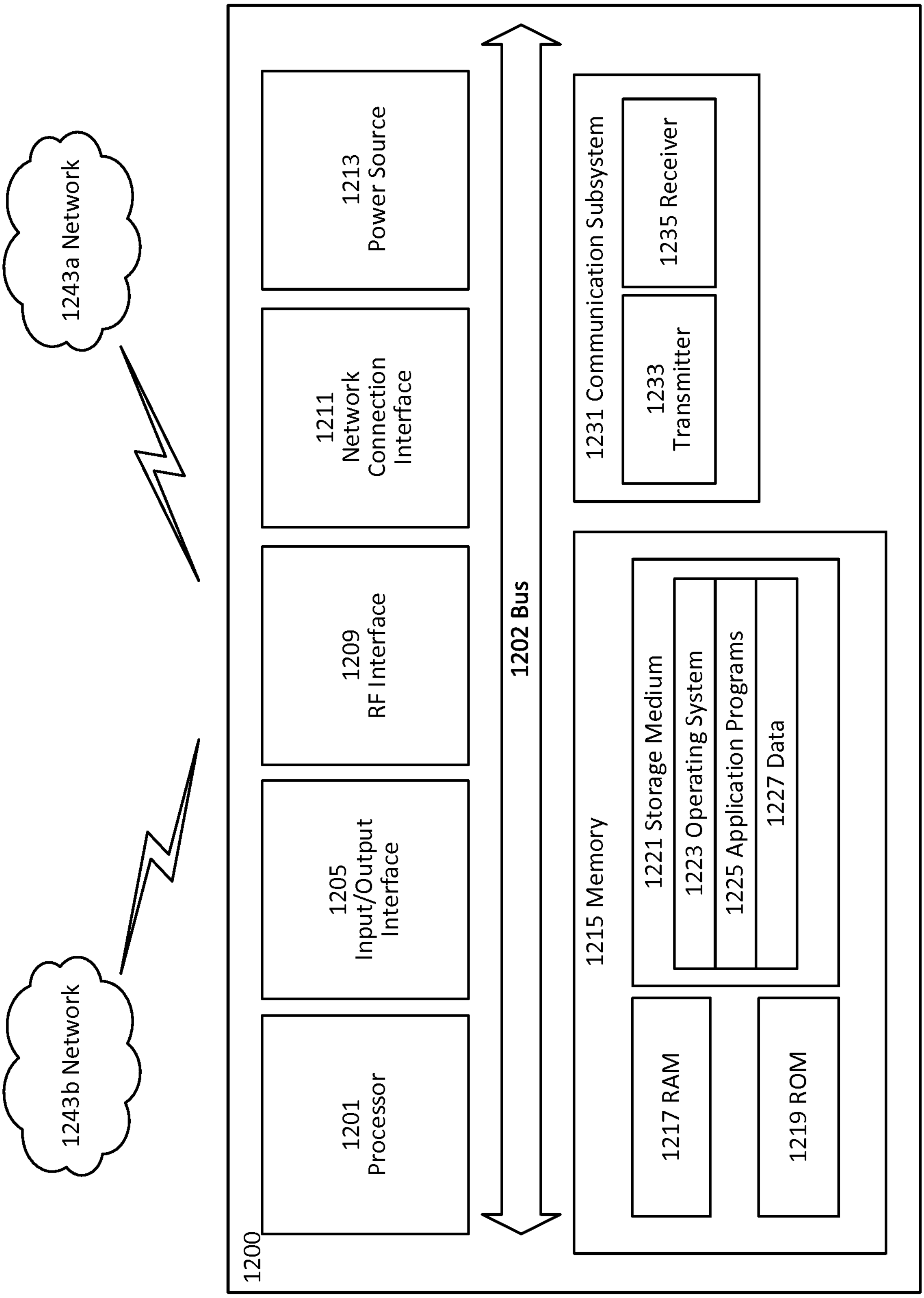

1243a Network
1243b Network
1200
1201 Processor
1205 Input/Output Interface
1209 RF Interface
1211 Network Connection Interface
1213 Power Source
1202 Bus
1215 Memory
1217 RAM
1219 ROM
1221 Storage Medium
1223 Operating System
1225 Application Programs
1227 Data
1231 Communication Subsystem
1233 Transmitter
1235 Receiver

FIG. 10

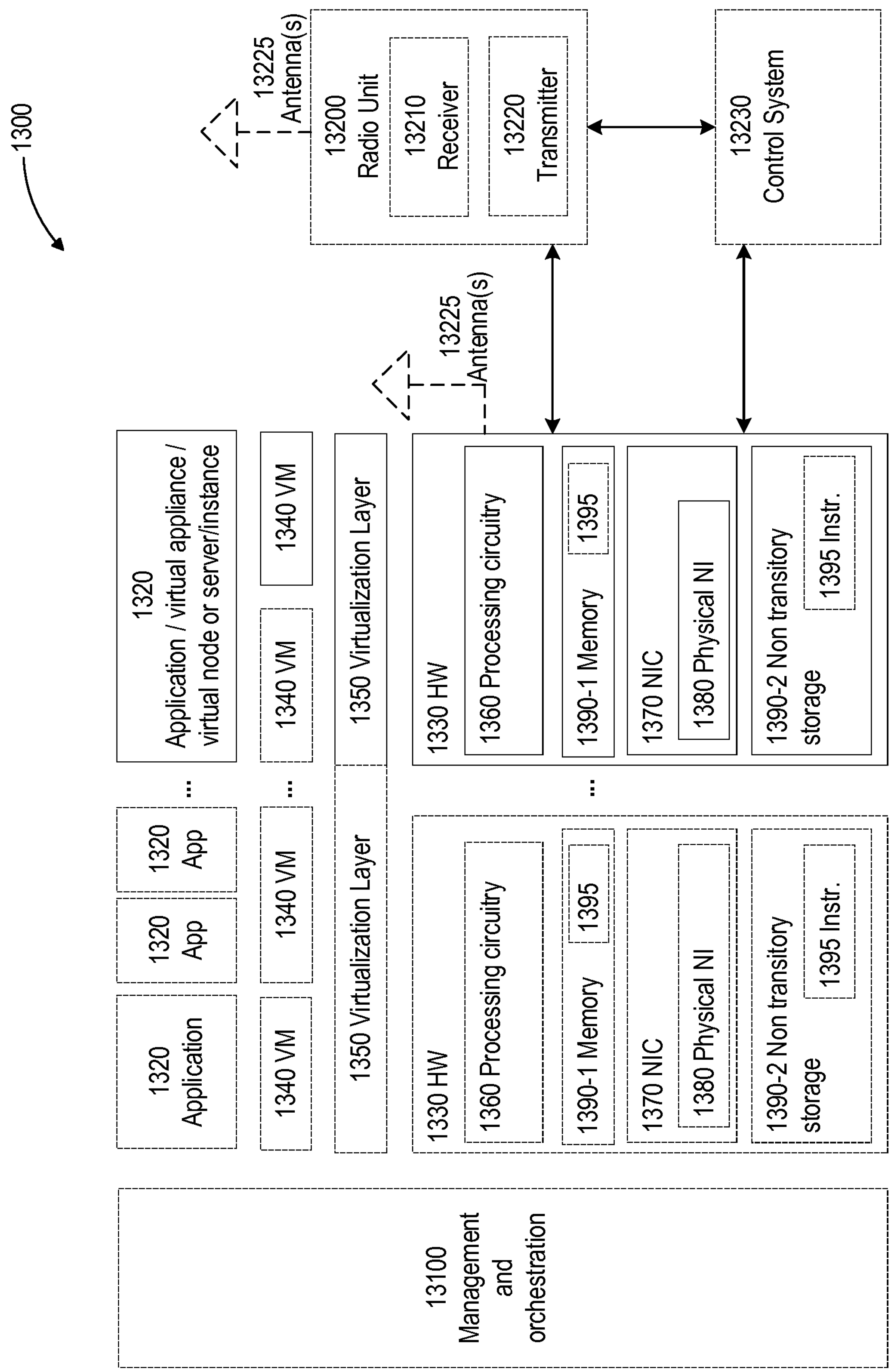

1300
13225 Antenna(s)
13200 Radio Unit
13210 Receiver
13220 Transmitter
13230 Control System
13225 Antenna(s)
1320 Application / virtual appliance / virtual node or server/instance
1340 VM
1340 VM
1350 Virtualization Layer
1330 HW
1360 Processing circuitry
1390-1 Memory
1395
1370 NIC
1380 Physical NI
1390-2 Non transitory storage
1395 Instr.
1320 App
1320 App
1320 Application
1340 VM
1340 VM
1350 Virtualization Layer
1330 HW
1360 Processing circuitry
1390-1 Memory
1395
1370 NIC
1380 Physical NI
1390-2 Non transitory storage
1395 Instr.
13100 Management and orchestration

FIG. 11

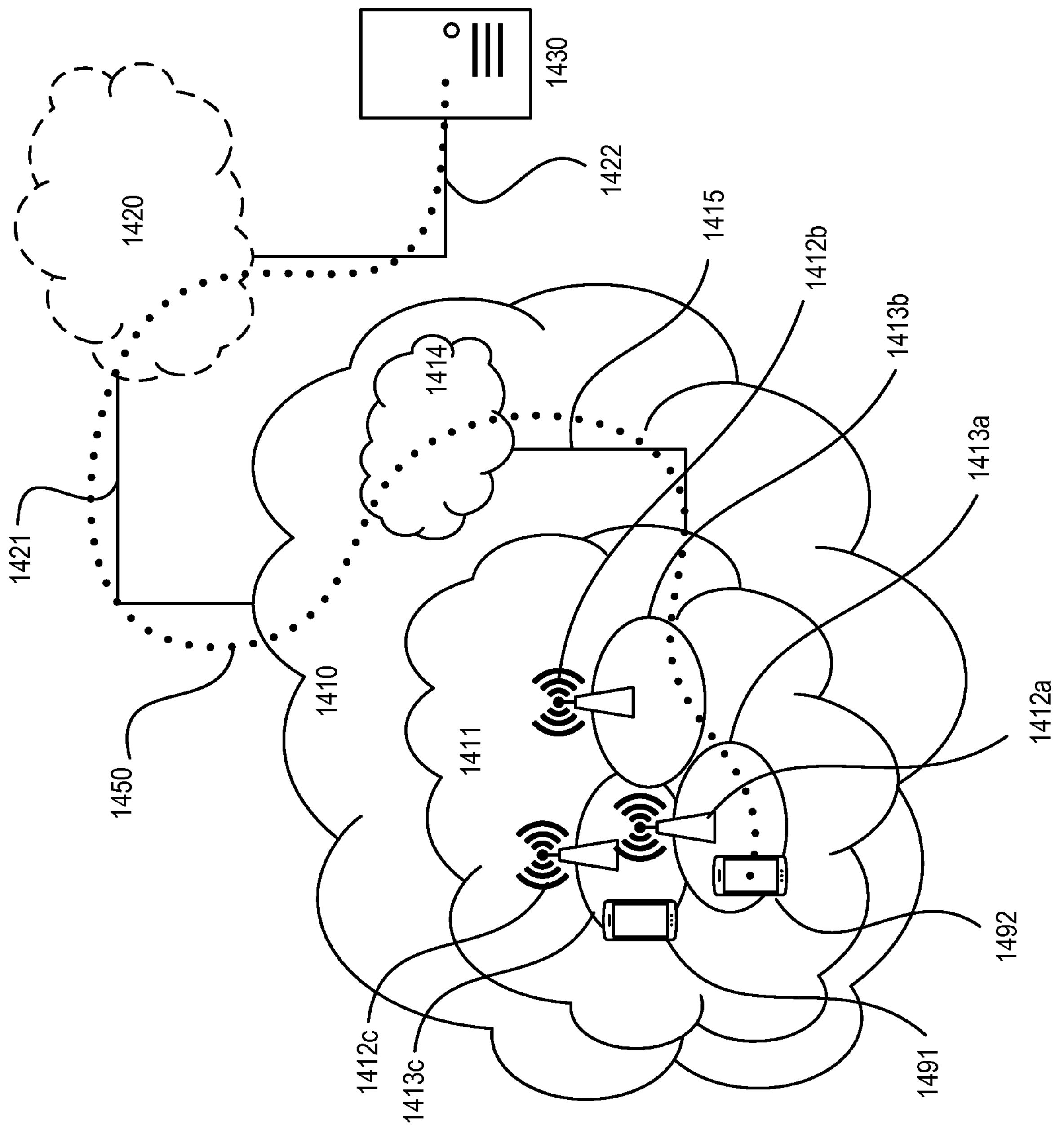
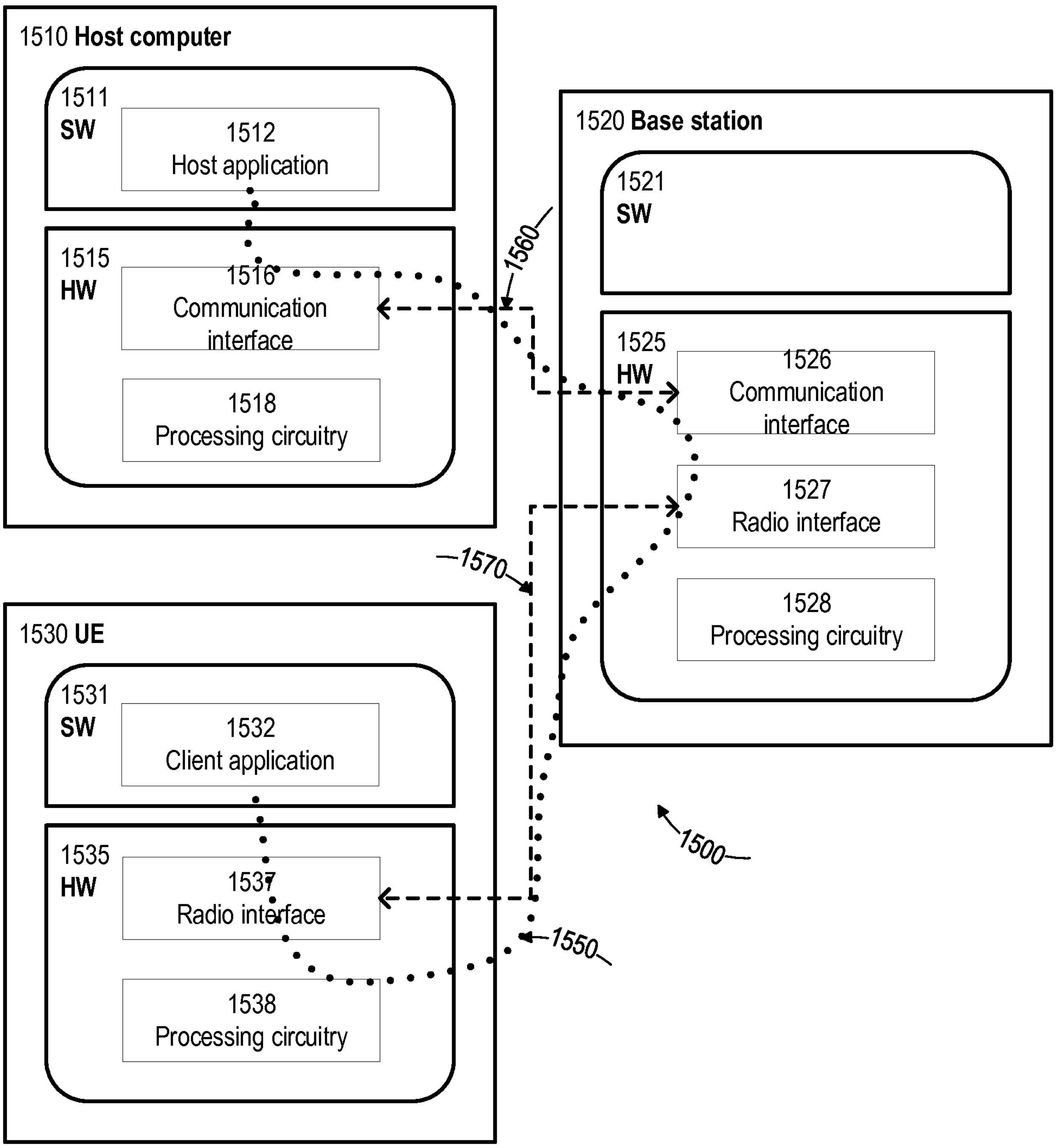

1420
1430
1422
1415
1412b
1413b
1414
1413a
1421
1410
1450
1411
1412a
1492
1412c
1413c
1491

FIG. 12



1510 Host computer
1511
SW
1512
Host application
1515
HW
1516
Communication interface
1518
Processing circuitry
1520 Base station
1521
SW
1525
HW
1526
Communication interface
1527
Radio interface
1528
Processing circuitry
1560
1570
1530 UE
1531
SW
1532
Client application
1535
HW
1537
Radio interface
1538
Processing circuitry
1550
1500

FIG. 13

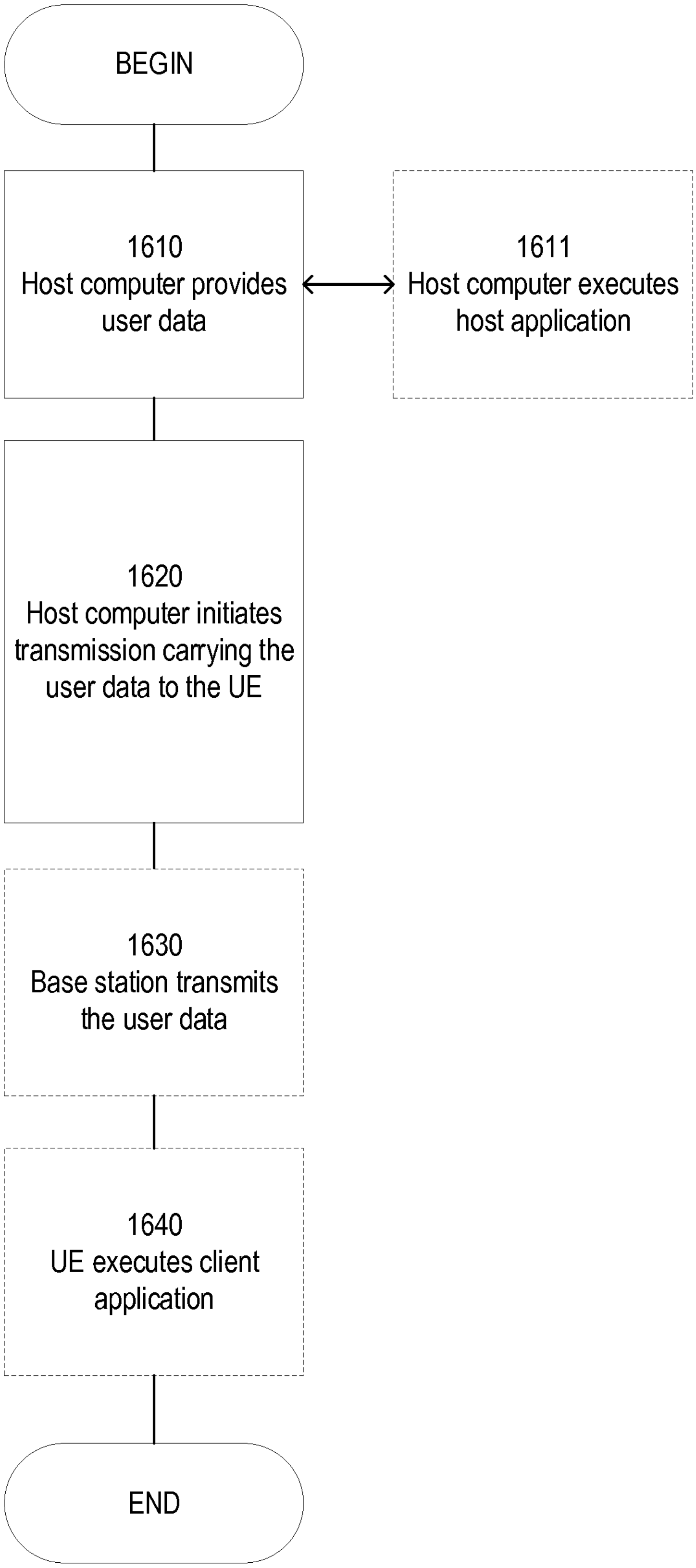

BEGIN
1610
Host computer provides user data
1611
Host computer executes host application
1620
Host computer initiates transmission carrying the user data to the UE
1630
Base station transmits the user data
1640
UE executes client application
END

FIG. 14

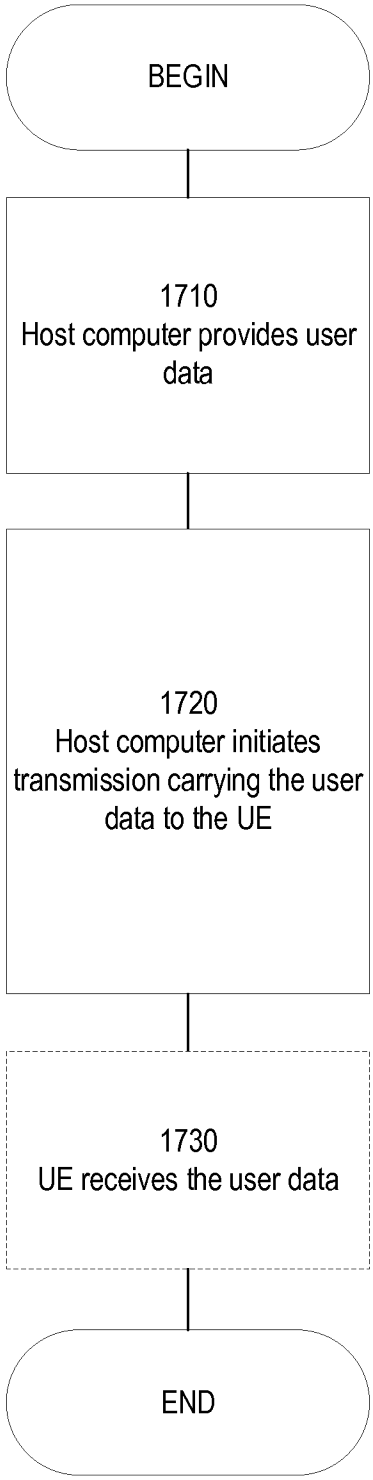

BEGIN
1710
Host computer provides user data
1720
Host computer initiates transmission carrying the user data to the UE
1730
UE receives the user data
END

FIG. 15

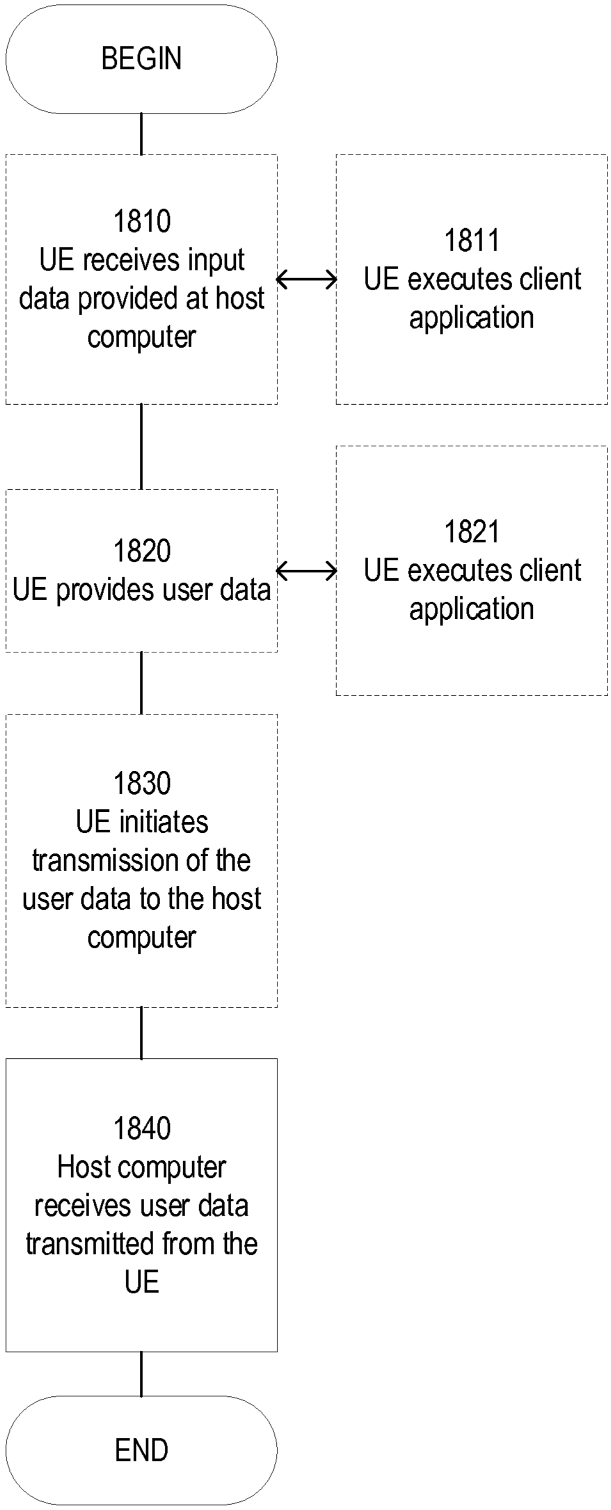

BEGIN
1810
UE receives input data provided at host computer
1811
UE executes client application
1820
UE provides user data
1821
UE executes client application
1830
UE initiates transmission of the user data to the host computer
1840
Host computer receives user data transmitted from the UE
END

FIG. 16

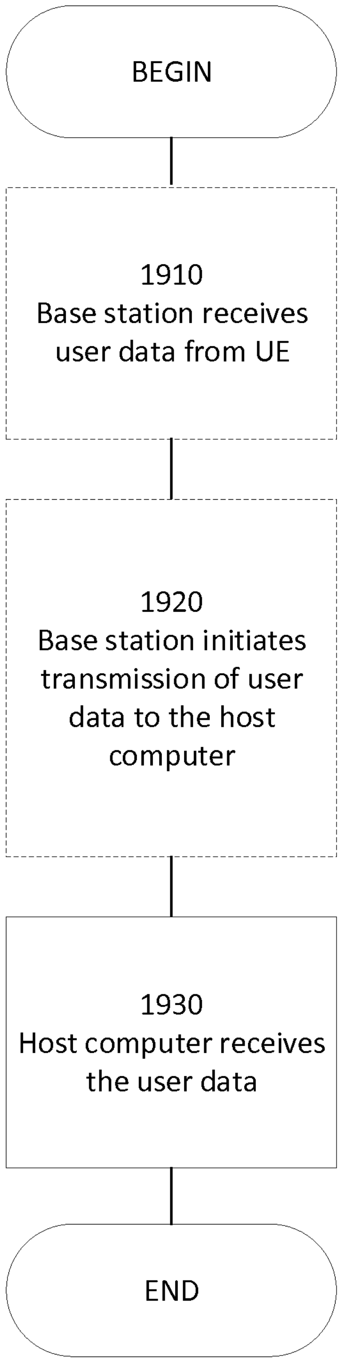

BEGIN
1910
Base station receives user data from UE
1920
Base station initiates transmission of user data to the host computer
1930
Host computer receives the user data
END

FIG. 17

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2019/064931

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04W52/14 H04W52/26
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)
H04W

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, 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	PANASONIC: "Discussion on uplink power control for NR URLLC", 3GPP DRAFT; R1-1806179, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG1, no. Busan, Korea; 20180521 - 20180525 20 May 2018 (2018-05-20), XP051441389, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/Meetings%5F3GPP%5FSYNC/RAN1/Docs/ [retrieved on 2018-05-20]	1-3, 5-14, 16-24, 26-36, 38-43
Y	page 1, line 7 - line 15 page 1, line 27 - line 33 -----	4,15,25, 37

-/--

[X] 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	Date of mailing of the international search report
2 September 2019	09/09/2019

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Riposati, Benedetto

1

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2019/064931

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	ERICSSON: "Offline Discussion on Support of Separate CQI and MCS table(s) for URLLC", 3GPP DRAFT; R1-1807823_SUMMARY_URLLC_CQI_MCS_THU_PM_V2, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE, vol. RAN WG1, no. Busan, Korea; 20180521 - 20180525 29 May 2018 (2018-05-29), XP051463506, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/tsg%5Fran/WG1%5FRL1/TSGR1%5F93/Docs [retrieved on 2018-05-29]	4,15,25, 37
A	section 1 section 2.1	1-3, 5-14, 16-24, 26-36, 38-43
A	QUALCOMM INCORPORATED: "Considerations on differentiating eMBB and URLLC", 3GPP DRAFT; R1-1807367 CONSIDERATIONS ON DIFFERENTIATING EMBB AND URLLC, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX, vol. RAN WG1, no. Busan, Korea; 20180521 - 20180525 20 May 2018 (2018-05-20), XP051442559, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/Meetings%5F3GPP%5FSYNC/RAN1/Docs/ [retrieved on 2018-05-20] section 2	1-43
A	"3rd Generation Partnership Project; Technical Specification Group Radio Access Network; NR; Physical layer procedures for control (Release 15)", 3GPP STANDARD; TECHNICAL SPECIFICATION; 3GPP TS 38.213, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE, vol. RAN WG1, no. V15.1.0, 8 April 2018 (2018-04-08), pages 1-77, XP051451088, [retrieved on 2018-04-08] page 13, line 1 - page 14, line 16	1-43

1