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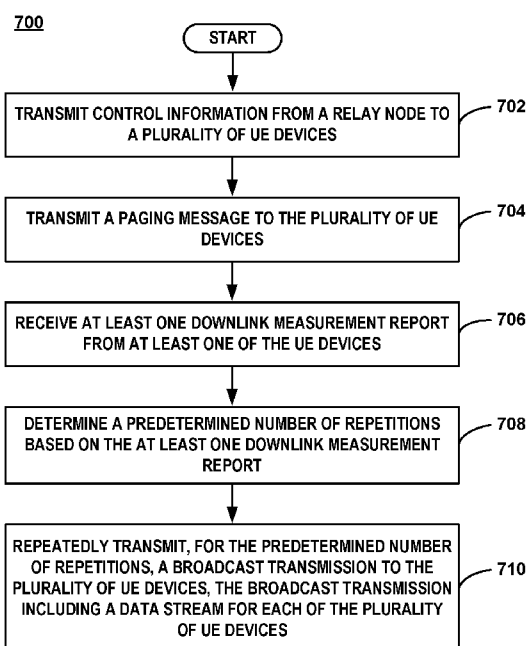


FIG. 7

(57) Abstract: A relay node receives a data block containing multiplexed data streams intended for multiple user equipment (UE) devices being served by the relay node. The relay node extracts the data streams from the data block and allocates them each to a separate narrowband channel that is associated with a particular UE device. The relay node repeatedly transmits the narrowband channels to the UE devices in a broadcast transmission that is transmitted for a predetermined number of repetitions. Each UE device decodes their own respective narrowband channel to obtain the data stream intended for the UE device associated with a particular narrowband channel. A feedback mechanism is utilized by the relay node to determine whether to retransmit a data packet or a new data packet in subsequent broadcast transmissions.

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- *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*
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METHOD OF DETERMINING NUMBER OF REPETITIONS FOR MULTIUSER BROADCAST IN IOT DEPLOYMENTS

CLAIM OF PRIORITY

5 **[0001]** The present application claims the benefit of priority to Provisional Application No. 62/661,253, entitled "BROADCAST BASED RELAYING TO THE IOT DEVICES", docket number TPRO 00321 US, filed April 23, 2018, Provisional Application No. 62/682,081, entitled "CONTROL INFORMATION FROM MICROCELL TO NODE, MAPPING BLOCKS TO UE ID", docket number TPRO 00322 filed June 7, 2018, 10 Provisional Application No. 62/682,090, entitled "MULTIUSER BROADCAST TRANSMISSION NODE", docket number TPRO 00323 filed June 7, 2018, and Provisional Application No. 62/682,095, entitled "METHOD OF DETERMINING NUMBER OF REPETITIONS FOR MULTIUSER BROADCAST IN IOT DEPLOYMENTS", docket number TPRO 00324 filed June 7, 2018, all of which are 15 assigned to the assignee hereof and hereby expressly incorporated by reference in their entirety.

FIELD

20 **[0002]** This invention generally relates to wireless communications and more particularly to relaying signals between wireless communication stations.

BACKGROUND

25 **[0003]** The Internet of things (IoT) is the extension of Internet connectivity into physical devices and everyday objects. Embedded with electronics, Internet connectivity, and other forms of hardware (e.g., such as sensors), IoT devices can (1) communicate and interact with other devices over the Internet, and (2) be remotely monitored and controlled. The definition of IoT has evolved due to the convergence of multiple technologies, real-time analytics, machine learning, commodity sensors, and embedded systems. Traditional fields of embedded systems, wireless sensor networks,

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control systems, automation (including home and building automation), and others all contribute to enabling the Internet of things.

[0004] In some cases, IoT devices operate in deep coverage areas where the downlink received signal strength is very poor. In extreme scenarios, the received
5 signal strength at the IoT device receiver could have a signal-to-noise ratio (SNR) as low as $\text{SNR} = -14$ dB. In such situations, relay nodes are deployed for transmissions to the hard-to-reach IoT devices. However, the relay nodes improve the received signal strength at the expense of higher complexity. The increase in complexity is a result of interference management (e.g., in-band relays) and the control signaling required to
10 manage the base station-relay node downlink transmission and scheduling of the relay node-IoT device links.

SUMMARY

[0005] A relay node receives a data block containing multiplexed data streams
15 intended for multiple user equipment (UE) devices being served by the relay node. The relay node extracts the data streams from the data block and allocates them each to a separate narrowband channel that is associated with a particular UE device. The relay node repeatedly transmits the narrowband channels to the UE devices in a broadcast transmission that is transmitted for a predetermined number of repetitions. Each UE
20 device decodes their own respective narrowband channel to obtain the data stream intended for the UE device associated with a particular narrowband channel. A feedback mechanism is utilized by the relay node to determine whether to retransmit a data packet or a new data packet in subsequent broadcast transmissions.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] FIG. 1 is a block diagram of a communication system for an example in which a relay node is used to broadcast data streams to a plurality of user equipment (UE) devices.

[0007] FIG. 2A is a block diagram of an example of the base station shown in FIG. 1.

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[0008] FIG. 2B is a block diagram of an example of the relay node shown in FIG. 1.

[0009] FIG. 2C is a block diagram of an example of the UE devices shown in FIG. 1.

[0010] FIG. 2D is a block diagram of an example of the circuitry utilized within the relay node shown in FIG. 1.

5 **[0011]** FIG. 3 is a messaging diagram of an example of the messages exchanged between the relay node and UE devices when determining a predetermined number of repetitions to transmit the broadcast transmission to the UE devices.

[0012] FIG. 4 is a block diagram of an example of a data packet with embedded feedback process information.

10 **[0013]** FIG. 5 is a messaging diagram of an example of the messages exchanged between the relay node and UE devices when utilizing a default predetermined number of repetitions to transmit the broadcast transmission to the UE devices.

[0014] FIG. 6 is a flowchart of an example of a method in which a relay node uses control information to extract, from a block of data, a data stream for each of a plurality
15 of UE devices and transmits, to the plurality of UE devices via a broadcast transmission, the data stream for each of the plurality of UE devices.

[0015] FIG. 7 is a flowchart of an example of a method in which a relay node repeatedly transmits, for a predetermined number of repetitions, a broadcast
20 transmission to a plurality of UE devices. The broadcast transmission includes a data stream for each of the plurality of UE devices.

[0016] FIG. 8 is a flowchart of an example of a method in which a relay node transmits control information to a plurality of UE devices and transmits, to the plurality of UE devices via a broadcast transmission, a data stream for each of the plurality of UE devices.

25 **[0017]** FIG. 9 is a flowchart of an example of a method in which a relay node transmits a broadcast transmission to a plurality of UE devices and receives a feedback message from each of the plurality of UE devices regarding their respective data streams.

DETAILED DESCRIPTION

[0018] The examples described herein utilize a Multiuser Broadcast Transmission (MBT) to serve the IoT devices. For example, a small cell node (e.g., relay node) uses MBT to transmit data to the IoT devices that are out of the reach of a macrocell node (e.g., base station). The MBT is a single broadcast transmission to a plurality of user equipment (UE) devices that contains data for each of the plurality of UE devices.

[0019] The MBT advantageously reduces the amount of control signaling required since the relay node does not, in some examples, utilize any channel-aware scheduling or channel quality feedback from the UE devices for the downlink transmissions. The reduced amount of control signaling and scheduler complexity results in a low-cost solution for both the small cell transmitter (e.g., relay node transmitter) and the UE device receivers. The small cell node performs Long-Term Evolution (LTE) Release-8 paging and IDLE mode procedures for the IoT UE devices such as transmitting the primary synchronization signal (PSS) and secondary synchronization signal (SSS) channels, physical broadcast shared channel (PBSCCH), Paging, and System Information Block (SIB) messaging.

[0020] In other examples, a UE device may act as a relay node for other UE devices. The network (e.g., base station) may select the UE device that acts as the relay node, or the UE device may volunteer to act as the relay node for other UE devices.

[0021] In still other examples, dual-connectivity (DC) could be used with the macrocell base station as the primary cell and the small cell node as the secondary cell. In the DC example, the macrocell node (e.g., base station) handles the basic paging and IDLE mode operations, and when ready, the UE devices switch to CONNECTED mode to transmit/receive data on the secondary cell, which is provided by the small cell node. Although MBT is feasible in the DC mode, the majority of the examples described herein will refer to the small cell node as the relay node.

[0022] FIG. 1 is a block diagram of a communication system for an example in which a relay node is used to broadcast data streams to a plurality of user equipment (UE) devices. Communication system 100 is part of a radio access network (not shown) that provides various wireless services to UE devices that are located within the respective

service areas of the various base stations that are part of the radio access network. For the examples herein, communication system 100 operates in accordance with at least one revision of the 3rd Generation Partnership Project Long Term Evolution (3GPP LTE) communication specification.

5 **[0023]** In the interest of clarity and brevity, communication system 100 is shown as having only base station 102. However, in other examples, communication system 100 could have any suitable number of base stations. Base station 102, sometimes referred to as eNodeB or eNB, communicates with user equipment (UE) devices 106, 108, 110 via relay node 104. For example, base station 102 transmits data to relay node 104 via
10 downlink signal 112, and relay node 104 broadcasts the data to UE devices 106, 108, 110 via signal 114. UE devices 106, 108, 110 are any wireless communication devices such as a mobile phone, a transceiver modem, a personal digital assistant (PDA), or a tablet, for example. Although not explicitly shown in FIG. 1, base station 102 may also receive uplink signals from relay node 104 and/or from UE devices 106, 108, 110.

15 **[0024]** Base station 102 is connected to the network through a backhaul (not shown) in accordance with known techniques. As shown in FIG. 2A, base station 102 comprises controller 204, transmitter 206, and receiver 208, as well as other electronics, hardware, and code. Base station 102 is any fixed, mobile, or portable equipment that performs the functions described herein. The various functions and operations of the
20 blocks described with reference to base station 102 may be implemented in any number of devices, circuits, or elements. Two or more of the functional blocks may be integrated in a single device, and the functions described as performed in any single device may be implemented over several devices.

25 **[0025]** For the example shown in FIG. 2A, base station 102 may be a fixed device or apparatus that is installed at a particular location at the time of system deployment. Examples of such equipment include fixed base stations or fixed transceiver stations. In some situations, base station 102 may be mobile equipment that is temporarily installed at a particular location. Some examples of such equipment include mobile transceiver stations that may include power generating equipment such as electric generators, solar
30 panels, and/or batteries. Larger and heavier versions of such equipment may be

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transported by trailer. In still other situations, base station 102 may be a portable device that is not fixed to any particular location. Accordingly, base station 102 may be a portable user device such as a UE device in some circumstances.

[0026] Controller 204 includes any combination of hardware, software, and/or

5 firmware for executing the functions described herein as well as facilitating the overall functionality of base station 102. An example of a suitable controller 204 includes code running on a microprocessor or processor arrangement connected to memory.

Transmitter 206 includes electronics configured to transmit wireless signals. In some situations, transmitter 206 may include multiple transmitters. Receiver 208 includes

10 electronics configured to receive wireless signals. In some situations, receiver 208 may include multiple receivers. Receiver 208 and transmitter 206 receive and transmit signals, respectively, through antenna 210. Antenna 210 may include separate transmit and receive antennas. In some circumstances, antenna 210 may include multiple transmit and receive antennas.

15 **[0027]** Transmitter 206 and receiver 208 in the example of FIG. 2A perform radio frequency (RF) processing including modulation and demodulation. Receiver 208, therefore, may include components such as low noise amplifiers (LNAs) and filters.

Transmitter 206 may include filters and amplifiers. Other components may include isolators, matching circuits, and other RF components. These components in

20 combination or cooperation with other components perform the base station functions. The required components may depend on the particular functionality required by the base station.

[0028] Transmitter 206 includes a modulator (not shown), and receiver 208 includes a demodulator (not shown). The modulator modulates the signals to be transmitted as

25 part of the downlink signal 112 and can apply any one of a plurality of modulation orders. The demodulator demodulates any uplink signals received at base station 102 in accordance with one of a plurality of modulation orders.

[0029] As mentioned above, base station 102 provides various wireless services to UE devices 106, 108, 110 via relay node 104. For example, base station 102 transmits

30 data to relay node 104 via downlink signal 112, and relay node 104 broadcasts the data

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to UE devices 106, 108, 110 via signal 114. The relay node 104 is sometimes referred to as a relay or as a small cell node.

[0030] As shown in FIG. 2B, relay node 104 comprises controller 216, transmitter 218, and receiver 214, as well as other electronics, hardware, and code. Relay node 104 is any fixed, mobile, or portable equipment that performs the functions described herein. The various functions and operations of the blocks described with reference to relay node 104 may be implemented in any number of devices, circuits, or elements. Two or more of the functional blocks may be integrated in a single device, and the functions described as performed in any single device may be implemented over several devices.

[0031] For the example shown in FIG. 2B, relay node 104 may be a fixed device or apparatus that is installed at a particular location at the time of system deployment. Examples of such equipment include fixed base stations or fixed transceiver stations. In some situations, relay node 104 may be mobile equipment that is temporarily installed at a particular location. Some examples of such equipment include mobile transceiver stations that may include power generating equipment such as electric generators, solar panels, and/or batteries. Larger and heavier versions of such equipment may be transported by trailer. In still other situations, relay node 104 may be a portable device that is not fixed to any particular location. Accordingly, relay node 104 may be a portable user device such as a UE device in some circumstances.

[0032] Controller 216 includes any combination of hardware, software, and/or firmware for executing the functions described herein as well as facilitating the overall functionality of relay node 104. An example of a suitable controller 216 includes code running on a microprocessor or processor arrangement connected to memory.

Transmitter 218 includes electronics configured to transmit wireless signals. In some situations, transmitter 218 may include multiple transmitters. Receiver 214 includes electronics configured to receive wireless signals. In some situations, receiver 214 may include multiple receivers. Receiver 214 and transmitter 218 receive and transmit signals, respectively, through antenna 212. Antenna 212 may include separate transmit

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and receive antennas. In some circumstances, antenna 212 may include multiple transmit and receive antennas.

[0033] Transmitter 218 and receiver 214 in the example of FIG. 2B perform radio frequency (RF) processing including modulation and demodulation. Receiver 214, therefore, may include components such as low noise amplifiers (LNAs) and filters. Transmitter 218 may include filters and amplifiers. Other components may include isolators, matching circuits, and other RF components. These components in combination or cooperation with other components perform the base station functions. The required components may depend on the particular functionality required by the base station.

[0034] Transmitter 218 includes a modulator (not shown), and receiver 214 includes a demodulator (not shown). The modulator modulates the signals to be transmitted as part of the broadcast signal 114 and can apply any one of a plurality of modulation orders. The demodulator demodulates any uplink signals received at relay node 104 in accordance with one of a plurality of modulation orders.

[0035] As shown in FIG. 2C, UE devices 106, 108, 110 utilize their respective antennas 220 and receivers 222 to receive downlink signals 114 from relay node 104. Besides antenna 220 and receiver 222, UE device 106 (UE1) further comprises controller 224 and transmitter 226, as well as other electronics, hardware, and code.

Although FIG. 2C specifically depicts the circuitry and configuration of UE device 106, the same UE device circuitry and configuration is utilized for UE devices 108, 110 in communication system 100. UE device 106 is any fixed, mobile, or portable equipment that performs the functions described herein. The various functions and operations of the blocks described with reference to UE device 106 may be implemented in any number of devices, circuits, or elements. Two or more of the functional blocks may be integrated in a single device, and the functions described as performed in any single device may be implemented over several devices.

[0036] Controller 224 includes any combination of hardware, software, and/or firmware for executing the functions described herein as well as facilitating the overall functionality of a UE device. An example of a suitable controller 224 includes code

running on a microprocessor or processor arrangement connected to memory.

Transmitter 226 includes electronics configured to transmit wireless signals. In some situations, the transmitter 226 may include multiple transmitters. Receiver 222 includes electronics configured to receive wireless signals. In some situations, receiver 222 may include multiple receivers. Receiver 222 and transmitter 226 receive and transmit signals, respectively, through antenna 220. Antenna 220 may include separate transmit and receive antennas. In some circumstances, antenna 220 may include multiple transmit and receive antennas.

[0037] Transmitter 226 and receiver 222 in the example of FIG. 2C perform radio

frequency (RF) processing including modulation and demodulation. Receiver 222, therefore, may include components such as low noise amplifiers (LNAs) and filters.

Transmitter 226 may include filters and amplifiers. Other components may include isolators, matching circuits, and other RF components. These components in combination or cooperation with other components perform the UE device functions.

The required components may depend on the particular functionality required by the UE device.

[0038] Transmitter 226 includes a modulator (not shown), and receiver 222 includes a demodulator (not shown). The modulator can apply any one of a plurality of

modulation orders to modulate the signals to be transmitted as uplink signals (not shown). The demodulator demodulates the downlink signals 114 in accordance with one of a plurality of modulation orders.

[0039] In operation, base station 102 transmits, via transmitter 206 and antenna 210, downlink signal 112 to relay node 104. Downlink signal 112 contains control information and a block of data assigned to UE devices 106, 108, 110. In the example shown in FIG. 1, the block of data includes data intended for UE devices 106, 108, 110 that is multiplexed (e.g., combined) together to form a single signal 112. In some examples, the control information is a bitmap.

[0040] Relay node 104 receives downlink signal 112 via antenna 212 and receiver 214. The control information helps relay node 104 identify UE devices 106, 108, 110

and match them to their respective data streams. More specifically, relay node 104

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uses the control information to (1) extract the data stream for each of UE devices 106, 108, 110 from the block of data contained in downlink signal 112, and (2) assign each data stream to a narrowband channel, resulting in a frequency-division multiplexing (FDM)-based resource allocation.

5 **[0041]** For example, as shown in FIG. 2D, relay node 104 includes demultiplexer 228, which is used in combination with receiver 214 of relay node 104 and the control information received from base station 102, to (1) separate the multiplexed block of data contained in downlink signal 112 into separate data streams intended for each of UE devices 106, 108, 110, and (2) match each of the separated (e.g. extracted) data
10 streams to a particular UE device. As shown in FIG. 2D, the product of demultiplexer 228 is first data stream 230 that is matched to UE1 106, second data stream 232 that is matched to UE2 108, and third data stream 234 that is matched to UE3 110. The functionality of demultiplexer 228 is performed by controller 216 in the example shown in FIG. 2D. However, in other examples, the functionality of demultiplexer 228 may be
15 performed by any other suitable circuitry.

[0042] The separated data streams 230, 232, 234 are sent to resource mapper 236, which maps (e.g., assigns) each of the separated data streams 230, 232, 234 to a narrowband channel. In order to serve UE devices 106, 108, 110, relay node 104 splits the downlink bandwidth of signal 114 into a number of narrowband channels, for
20 example, each consisting of six resource blocks in the frequency domain, as specified in LTE-Machine Type Communication (LTE-M) Release-12. In some examples, space-division multiplexing (SDM) and/or frequency-hopping schemes on top of FDM can be applied to each narrowband signal. In other examples, time-division multiplexing (TDM) or code-division multiplexing (CDM) may be used instead of SDM. At the physical layer
25 level, each UE-specific narrowband channel is allocated (e.g., assigned) a set of subcarriers within the portion of downlink channel bandwidth.

[0043] Relay node 104 transmits, via transmitter 218 and antenna 212, control information to UE devices 106, 108, 110, which are configured to use the control information to receive their respective data streams. In the examples described herein,
30 there are two methods to deliver the downlink control information (DCI) to UE devices

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106, 108, 110. The DCI parameters common to all UE devices 106, 108, 110 are delivered using the Common Search Space Machine-Type Communication Physical Downlink Control Channel (CSS-MPDCCH) or SIB messaging. The second method is to send the DCI using the UE-specific search space (USS) MPDCCH or to embed the DCI within a data packet in broadcast transmission 114.

[0044] The resource allocation (e.g., assignment) information, the modulation and coding scheme (MCS), and the transmission mode information for the multiuser broadcast transmission 114 are semi-static and can be announced to all targeted UE devices 106, 108, 110 before beginning data transmission since these parameters are kept the same during the transmission of multiple data blocks. For example, after receiving the block of data from base station 102 and determining N_{rep} , relay node 104 transmits control information regarding the resource assignment information, the MCS, the N_{rep} , and the transmission mode information (e.g., transmit diversity parameters, etc.) to UE devices 106, 108, and 110 using the CSS-MPDCCH or SIB messaging.

[0045] As mentioned above, the control information transmitted to UE devices 106, 108, 110 may include, for example, one or more of the following: a predetermined number of repetitions (e.g., times) that the broadcast transmission 114 will be transmitted, a modulation and coding scheme, resource allocation (e.g., assignment) information, transmission mode information, and feedback process information. In some examples, the control information is transmitted in a System Information Block (SIB) message. In other examples, the control information is transmitted on a Common Search Space Machine-Type Communication Physical Downlink Control Channel (CSS-MPDCCH). For example, UE devices 106, 108, 110 are informed about the resource assignment information (e.g., which narrowband channel contains the data stream for which UE device and/or which subcarriers are associated with each narrowband channel) via control information signaling (e.g. MPDCCH).

[0046] Once UE devices 106, 108, 110 are informed about the resource assignment information and/or other control information, relay node 104 transmits a broadcast transmission 114 to UE devices 106, 108, 110 via transmitter 218 and antenna 212.

The broadcast transmission 114 contains the data stream for each of UE devices 106,

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108, 110 in a separate narrowband channel. Although each of UE devices 106, 108, 110 will receive the same multiuser broadcast transmission (MBT) 114 from relay node 104, each UE device 106, 108, 110 will use its own respective narrowband receiver, which may be integrated into receiver 222, to access (e.g., receive and decode) the
5 portion of the received downlink signal 114 that contains the narrowband channel that has been assigned to that particular UE device.

[0047] To achieve robustness, relay node 104 transmits broadcast transmission 114 for a predetermined number of repetitions using multi-subframe repetition, as defined in LTE-M Release-12. In IoT deployments, the data is repeatedly transmitted over
10 multiple subframes to achieve robustness at the expense of higher latency. In some examples, the predetermined number of repetitions is a default number of repetitions. In other examples, the predetermined number of repetitions is determined.

[0048] FIG. 3 is a messaging diagram of an example of the messages exchanged between relay node 104 and UE devices 106, 108, 110 when determining a
15 predetermined number of repetitions, N_{rep} , to transmit broadcast transmission 114 to UE devices 106, 108, 110. In some examples, the predetermined number of repetitions, N_{rep} , is computed based on the worst received signal strength reported by UE devices 106, 108, 110. As shown in FIG. 3, relay node 104 transmits, via transmitter 218 and antenna 212, paging message 302 to all UE devices 106, 108, 110 listed in the block of
20 data received from base station 102. In the example shown in FIG. 3, relay node 104 uses the common search space (CSS) MPDCCH to page UE devices 106, 108, 110. In other examples, the UE devices 106, 108, 110 periodically monitor the downlink signal 114 and may receive data at a predetermined subframe (e.g., in polling scheduler deployments).

[0049] In some examples, paging message 302 includes a request for UE devices 106, 108, 110 to each submit downlink measurement reports to relay node 104, based on their respectively measured received signal strength of broadcast transmission 114. In other examples, paging message 302 includes a request for UE devices 106, 108, 110 to each submit downlink measurement reports to relay node 104, if their received
25 signal strength measurement value γ , is below a threshold value γ_t . In response to
30

paging message 302, one or more of UE devices 106, 108, 110 transmit their respective page response 304 using their assigned Physical Uplink Control Channel (PUCCH) resources.

[0050] In some examples, one or more of the page responses 304 may include a
5 downlink measurement report. In order to obtain exactness in some examples, UE
devices 106, 108, 110 include a quantized worseness of the received signal strength
compared to one or more threshold values, γ_t , in the downlink measurement report. For
example, if a UE device is experiencing received signal strength below a first threshold
10 value, γ_{t1} , then the UE device reports back a threshold index value of '1', and if the
received signal strength is below first and second threshold values, γ_{t1} and γ_{t2} , then the
UE device reports a threshold index value of '2' and so on. Alternatively, if a UE device
is experiencing received signal strength up to 0.5 dB (e.g., within a first range) below γ_t ,
then the UE device reports back a range index value of '1', and if the received signal
15 strength is between 1 dB and 0.5 dB (e.g., within a second range) below γ_t , then the UE
device reports a range index value of '2' and so on.

[0051] Thus, in light of the foregoing, the downlink measurement report may include
one or more of the following: a received signal strength measurement value, γ ; a first
threshold index value that indicates that a received signal strength measurement value,
 γ , is below a first threshold value; a second threshold index value that indicates that a
20 received signal strength measurement value, γ , is below a first threshold value and a
second threshold value; a first range index value that indicates that a received signal
strength measurement value, γ , is within a first range of values below a first threshold
value; and a second range index value that indicates that a received signal strength
measurement value, γ , is within a second range of values below a first threshold value.

25 **[0052]** Based on the number of UE devices 106, 108, 110 that report back the
condition $\gamma < \gamma_t$ and their reported index value, relay node 104 utilizes controller 216 to
determine the value of N_{rep} . With this approach, the value of N_{rep} becomes a function of
the number of UE devices 106, 108, 110 reporting $\gamma < \gamma_t$ and their respective reported
index values.

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[0053] After the value of N_{rep} is decided (e.g., by default or determined by relay node 104), relay node 104 transmits control information 306 to be used for the multiuser broadcast transmissions 114 to all UE devices 106, 108, 110. As mentioned above, this control information 306 may include, for example, one or more of the following: a
5 predetermined number of repetitions (e.g., N_{rep}) that the broadcast transmission 114 will be transmitted, a modulation and coding scheme, resource allocation (e.g., assignment) information, transmission mode information, and feedback process information. In some examples, the control information is transmitted in a System Information Block (SIB) message. In other examples, the control information is transmitted on a Common
10 Search Space Machine-Type Communication Physical Downlink Control Channel (CSS-MPDCCH). In still other examples, the control information is transmitted in a data packet of broadcast transmission 114. In further examples, the control information is transmitted on a UE-specific Search Space Machine-Type Communication Physical Downlink Control Channel (USS-MPDCCH). The resource allocation information and
15 the value of N_{rep} can be transmitted semi-statically to UE devices 106, 108, 110 and are not required to be transmitted again until there is a change in the resource allocation or the predetermined number of repetitions.

[0054] Regardless of the manner in which the predetermined number of repetitions is determined, relay node 104 transmits, via transmitter 218 and antenna 212, broadcast
20 transmission 114 (e.g., signal 308) for the predetermined number of repetitions, N_{rep} . UE devices 106, 108, 110 utilize the control information 306 to receive the repeated broadcast transmissions 114 and combine the energy received in each subframe to achieve a higher energy per bit, resulting in a higher successful detection rate. After receiving all N_{rep} subframes of data, each UE device 106, 108, 110 transmits feedback
25 message 310 to relay node 104 using a Physical Uplink Control Channel (PUCCH) or a Physical Uplink Shared Channel (PUSCH). Relay node 104 receives feedback message 310 via antenna 212 and receiver 214. In the example shown in FIG. 3, feedback message 310 is either an ACK or a NACK signal.

[0055] In some examples, Hybrid Automatic Repeat Request (HARQ) feedback is
30 used in connection with the multiuser broadcast transmissions 114 to achieve higher

detection performance. To handle the HARQ processes assigned to a particular UE device, HARQ process information 404 such as a HARQ Process Identifier (ID) (HPI), a New Data Indicator (NDI), and a Redundancy Version (RV) is embedded in the data packet 402 itself, as shown in FIG. 4. After receiving the narrowband channel data packet, each UE device 106, 108, 110 decodes the HARQ process information 404 before decoding the data in the data packet 402. This allows each UE device 106, 108, 110 to monitor and track its own respective HARQ process information.

[0056] In some examples, the UE device waits to receive all the repetitions (e.g., N_{rep}) of the broadcast transmission 114 before attempting to decode the packet. In other examples, the UE device may attempt to decode the packet after receiving any number of repetitions or after receiving each repetition. Depending on the decoding success, the UE device sends either an ACK or a NACK feedback message to relay node 104. If the UE device is successfully able to decode the packet before receiving all of the repetitions, the UE device could send an early termination ACK. If the feedback message is an ACK, relay node 104 transmits a new data packet (and a New Data Indicator) in the next transmission. If the feedback message is a NACK, relay node 104 transmits a next Redundancy Version packet (and an associated Redundancy Version (RV) value) in the next transmission. As a consequence of using this HARQ process for different UE devices 106, 108, 110 within the same multiuser broadcast transmission 114, the RV of the data packets addressed to different UE devices 106, 108, 110 could be different. Thus, relay node 104 is responsible for managing the HARQ processes for each of UE devices 106, 108, 110.

[0057] Since multiple UE devices 106, 108, 110 are served with the multiuser broadcast transmission 114, the PUCCH capacity may not be enough to transmit the large number of ACK/NACK feedback messages. Thus, in some examples, UE devices 106, 108, 110 are allowed to transmit their ACK/NACK feedback messages on PUSCH resources. In some examples, the amount of feedback signaling can be reduced if the UE devices 106, 108, 110 only transmit a NACK if they are unable to decode the data packet after receiving all of the repetitions (e.g., N_{rep}).

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[0058] FIG. 5 shows the signaling flows when a default MCS and a default N_{rep} are used for the multiuser broadcast transmission 114. The use of a default MCS and a default N_{rep} for the multiuser broadcast transmission 114 reduces the amount of control signaling required. For example, relay node 104 announces the default MCS value and the default N_{rep} value periodically to all UE devices 106, 108, 110 using SIB messaging (e.g., control information 502). After the block of data is received from base station 102, relay node 104 allocates (e.g., assigns) the narrowband channels to UE devices 106, 108, 110 and transmits those assignments to the respective UE devices 106, 108, 110 in the page messages 504 transmitted to UE devices 106, 108, 110. UE devices 106, 108, 110 transmit page responses 506 on granted PUSCH resources. In other examples, the page messages 504 are not required if UE devices 106, 108, 110 are already periodically scheduled (e.g., by a polling scheduler) to monitor the data channel 114 to receive the narrowband channel assignments.

[0059] Relay node 104 transmits broadcast transmission 508 for the default number of repetitions, N_{rep} . UE devices 106, 108, 110 transmit feedback messages 514 to relay node 104 on granted PUSCH resources. Based on the received feedback messages 514, relay node 104 places either a new data packet or a next Redundancy Version packet on the assigned narrowband channel for each UE device 106, 108, 110. Unless one or more UE devices 106, 108, 110 report back a worse channel condition $\gamma < \gamma_t$, relay node 104 avoids transmitting the MPDCCH. The MPDCCH is only transmitted to provide the new non-default values of the MCS and/or N_{rep} .

[0060] There are several advantages to the examples described herein. For example, as mentioned above, the examples described herein do not require a complex channel-aware scheduler and do not require frequent individual Channel State Information (CSI) feedback from the UE devices 106, 108, 110. This significantly reduces the complexity of relay node 104 and reduces the control signaling overhead. In addition, the multiuser broadcast transmissions 114 from the near-located relay node 104 allow for a reduced number of required repetitions, N_{rep} , achieving further efficiency.

[0061] FIG. 6 is a flowchart of an example of a method in which a relay node uses control information to extract, from a block of data, a data stream for each of a plurality

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of UE devices and transmits, to the plurality of UE devices via a broadcast transmission, the data stream for each of the plurality of UE devices. The method 600 begins at step 602 with receiving, at relay node 104, a block of data and control information. At step 604, relay node 104 uses the control information to extract a data stream, from the
5 block of data, for each of UE devices 106, 108, 110. At step 606, relay node 104 assigns each data stream to one of a plurality of narrowband channels. At step 608, relay node 104 allocates a set of subcarriers to each of the plurality of narrowband channels. At step 610, relay node 104 transmits, to UE devices 106, 108, 110, resource assignment information. At step 612, relay node 104 transmits, to UE devices 106, 108,
10 110, a paging message. At step 614, relay node 104 transmits, to UE devices 106, 108, 110 via a broadcast transmission 114, the data stream for each of UE devices 106, 108, 110.

[0062] FIG. 7 is a flowchart of an example of a method in which a relay node repeatedly transmits, for a predetermined number of repetitions, a broadcast
15 transmission to a plurality of UE devices. The broadcast transmission includes a data stream for each of the plurality of UE devices. The method 700 begins at step 702 with transmitting control information from relay node 104 to UE devices 106, 108, 110. At step 704, relay node 104 transmits a paging message to UE devices 106, 108, 110. At step 706, relay node 104 receives at least one downlink measurement report from at
20 least one of UE devices 106, 108, 110. At step 708, relay node 104 determines a predetermined number of repetitions based on at least one downlink measurement report. At step 710, relay node 104 repeatedly transmits, for the predetermined number of repetitions, a broadcast transmission 114 to UE devices 106, 108, 110. The
25 broadcast transmission 114 includes a data stream for each of UE devices 106, 108, 110.

[0063] FIG. 8 is a flowchart of an example of a method in which a relay node transmits control information to a plurality of UE devices and transmits, to the plurality of UE devices via a broadcast transmission, a data stream for each of the plurality of UE
30 devices. The method 800 begins at step 802 with receiving, at relay node 104, a block of data containing a data stream for each of UE devices 106, 108, 110. At step 804,

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relay node 104 assigns each data stream to one of a plurality of narrowband channels. At step 806, relay node 104 allocates a set of subcarriers to each of the plurality of narrowband channels. At step 808, relay node 104 transmits control information to UE devices 106, 108, 110. At step 810, relay node 104 transmits a broadcast transmission 114 to UE devices 106, 108, 110. The broadcast transmission 114 includes a data stream for each of UE devices 106, 108, 110.

[0064] FIG. 9 is a flowchart of an example of a method in which a relay node transmits a broadcast transmission to a plurality of UE devices and receives a feedback message from each of the plurality of UE devices regarding their respective data streams. The method 900 begins at step 902 with transmitting control information from relay node 104 to UE devices 106, 108, 110. At step 904, relay node 104 transmits a broadcast transmission 114 to UE devices 106, 108, 110. The broadcast transmission 114 includes a data stream for each of UE devices 106, 108, 110. At step 906, relay node 104 receives a feedback message from each of UE devices 106, 108, 110 regarding their respective data streams. At step 908, if the feedback message is an ACK signal, relay node 104 transmits a new data packet in the next transmission to the UE device that sent the ACK signal. At step 910, if the feedback message is a NACK signal, relay node 104 transmits a next Redundancy Version data packet in the next transmission to the UE device that sent the NACK signal.

[0065] Clearly, other embodiments and modifications of this invention will occur readily to those of ordinary skill in the art in view of these teachings. The above description is illustrative and not restrictive. This invention is to be limited only by the following claims, which include all such embodiments and modifications when viewed in conjunction with the above specification and accompanying drawings. The scope of the invention should, therefore, be determined not with reference to the above description, but instead should be determined with reference to the appended claims along with their full scope of equivalents.

CLAIMS

1. A method comprising:
transmitting control information from a relay node to a plurality of user equipment
5 (UE) devices; and
repeatedly transmitting, for a predetermined number of repetitions, a broadcast
transmission from the relay node to the plurality of UE devices, the broadcast
transmission including a data stream for each of the plurality of UE devices, each of the
plurality of UE devices configured to use the control information to receive their
10 respective data streams.
2. The method of claim 1, wherein the control information comprises at least one of
the following: the predetermined number of repetitions, a modulation and coding
scheme, resource allocation information, transmission mode information, and feedback
15 process information.
3. The method of claim 1, wherein transmitting control information comprises at
least one of the following: transmitting control information in a System Information Block
(SIB) message, and transmitting control information on a Common Search Space
20 Machine-Type Communication Physical Downlink Control Channel (CSS-MPDCCH).
4. The method of claim 1, wherein the predetermined number of repetitions is a
default number of repetitions.
- 25 5. The method of claim 1, further comprising:
determining the predetermined number of repetitions.

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6. The method of claim 5, further comprising:

receiving at least one downlink measurement report from at least one of the plurality of UE devices; and

5 determining the predetermined number of repetitions based on the at least one downlink measurement report.

7. The method of claim 6, wherein the at least one downlink measurement report comprises:

10 a first index value that indicates that a received signal strength measurement value is below a first threshold value.

8. The method of claim 6, wherein the at least one downlink measurement report comprises:

15 a second index value that indicates that a received signal strength measurement value is below a first threshold value and below a second threshold value.

9. The method of claim 5, further comprising:

transmitting a paging message to the plurality of UE devices; and

20 receiving at least one downlink measurement report from at least one of the plurality of UE devices, the at least one downlink measurement report being transmitted in response to the paging message.

10. The method of claim 9, wherein the paging message includes a request for the at
25 least one downlink measurement report if a received signal strength measurement value is below a first threshold value.

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11. A relay node comprising:
a transmitter configured to:
transmit control information to a plurality of user equipment (UE) devices;
and

5 repeatedly transmit, for a predetermined number of repetitions, a
broadcast transmission to the plurality of UE devices, the broadcast transmission
including a data stream for each of the plurality of UE devices, each of the
plurality of UE devices configured to use the control information to receive their
respective data streams.

10 12. The relay node of claim 11, wherein the control information comprises at least
one of the following: the predetermined number of repetitions, a modulation and coding
scheme, resource allocation information, transmission mode information, and feedback
process information.

15 13. The relay node of claim 11, wherein the transmitter is further configured to
transmit control information in a System Information Block (SIB) message.

20 14. The relay node of claim 11, wherein the transmitter is further configured to
transmit control information on a Common Search Space Machine-Type
Communication Physical Downlink Control Channel (CSS-MPDCCH).

25 15. The relay node of claim 11, wherein the predetermined number of repetitions is a
default number of repetitions.

16. The relay node of claim 11, further comprising:
a controller configured to determine the predetermined number of repetitions.

17. The relay node of claim 16, further comprising:

a receiver configured to receive at least one downlink measurement report from at least one of the plurality of UE devices,

5 the controller further configured to determine the predetermined number of repetitions based on the at least one downlink measurement report.

18. The relay node of claim 17, wherein the at least one downlink measurement report comprises:

10 a first index value that indicates that a received signal strength measurement value is below a first threshold value.

19. The relay node of claim 17, wherein the at least one downlink measurement report comprises:

15 a second index value that indicates that a received signal strength measurement value is below a first threshold value and below a second threshold value.

20. The relay node of claim 16, wherein the transmitter is further configured to transmit a paging message to the plurality of UE devices, the relay node further

20 comprising:

a receiver configured to receive at least one downlink measurement report from at least one of the plurality of UE devices, the at least one downlink measurement report being transmitted in response to the paging message.

25 21. The relay node of claim 20, wherein the paging message includes a request for the at least one downlink measurement report if a received signal strength measurement value is below a first threshold value.

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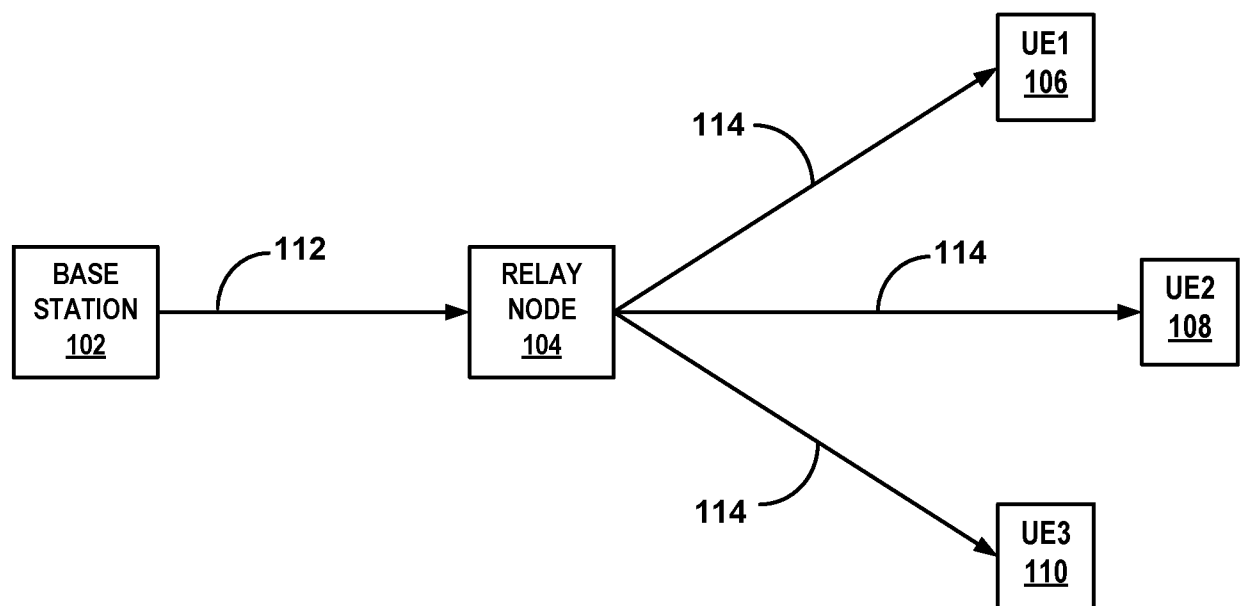
100

FIG. 1

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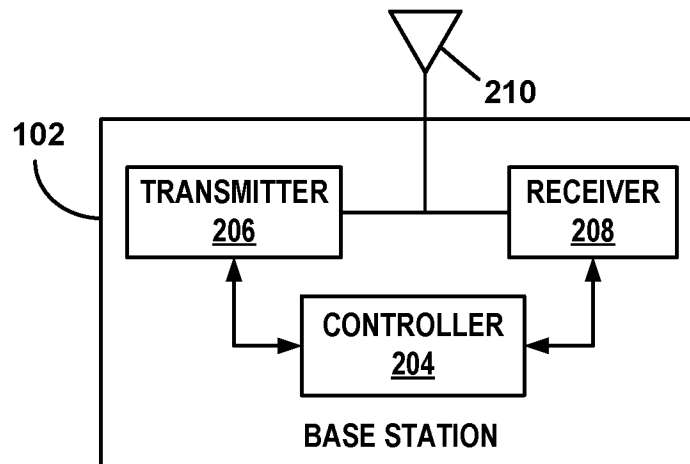


FIG. 2A

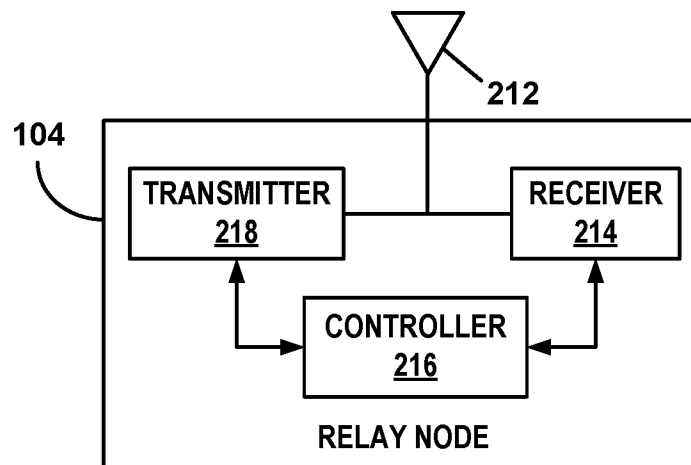


FIG. 2B

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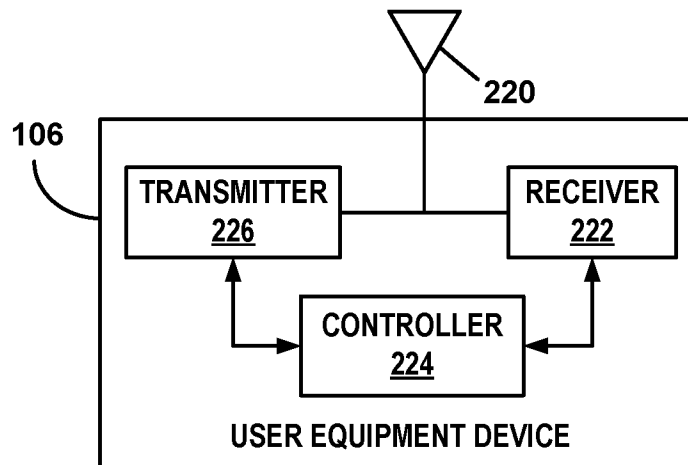


FIG. 2C

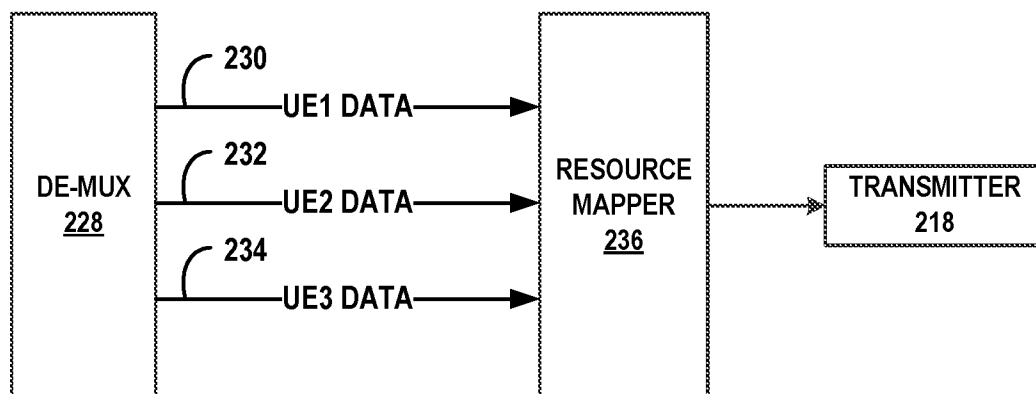


FIG. 2D

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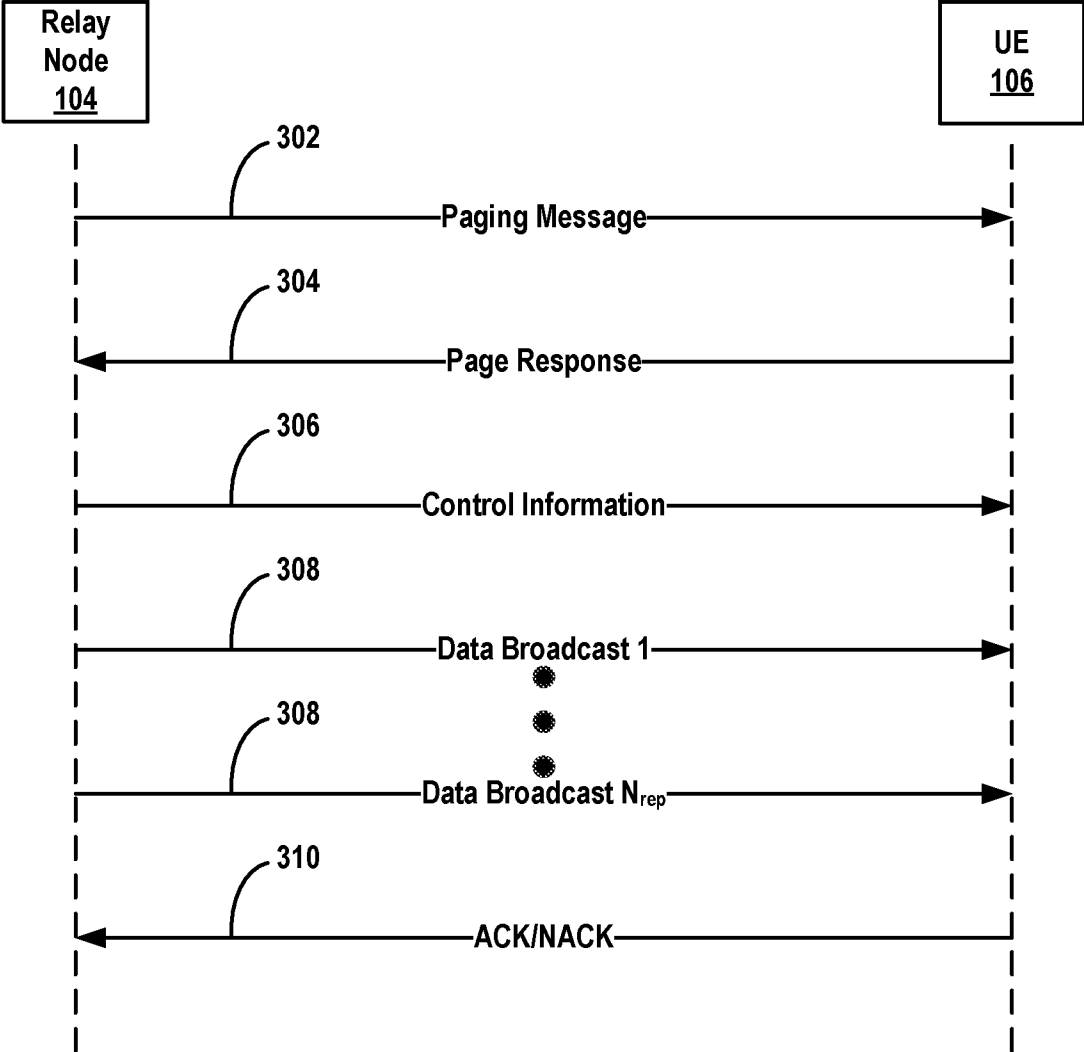


FIG. 3

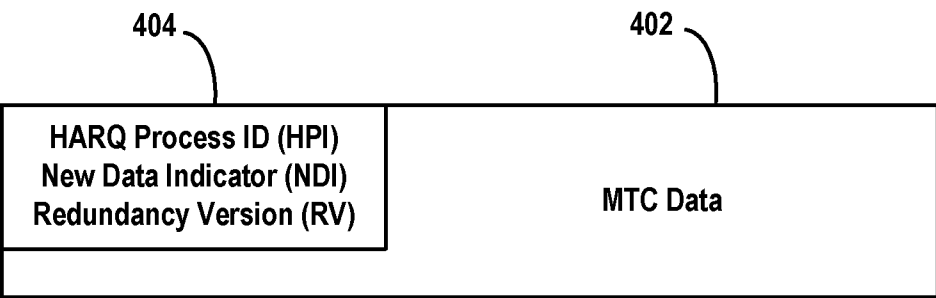


FIG. 4

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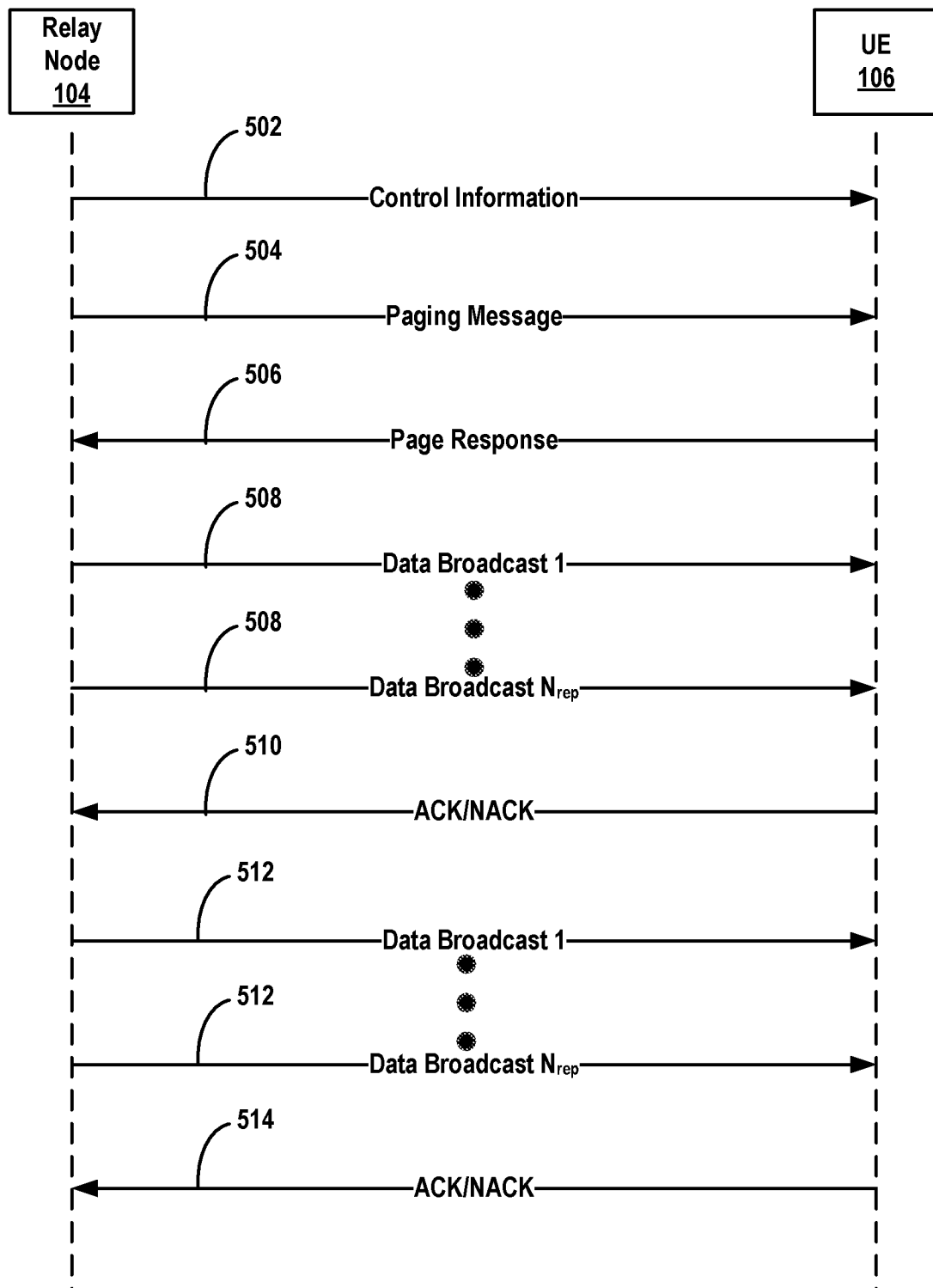
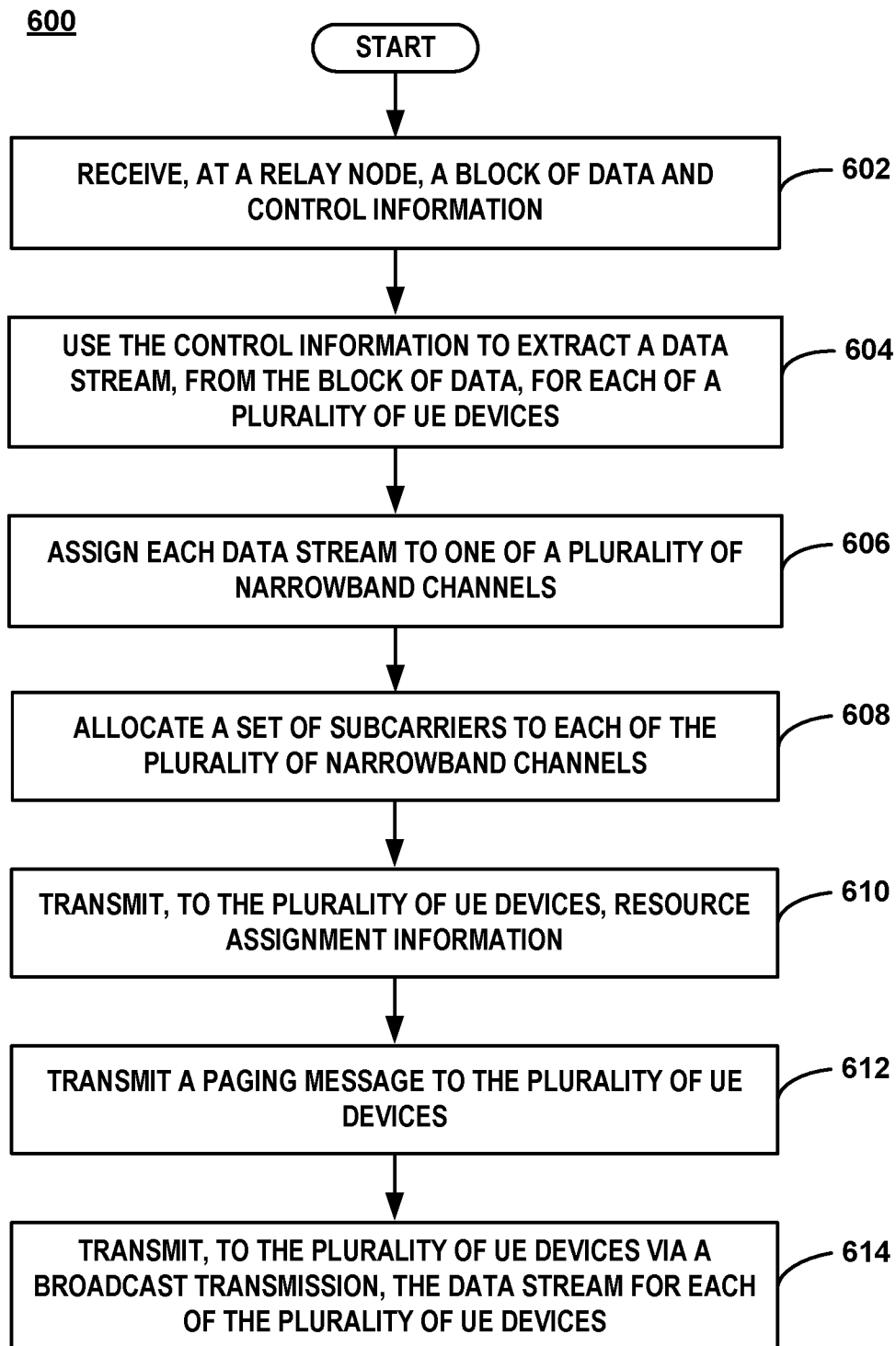


FIG. 5

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**FIG. 6**

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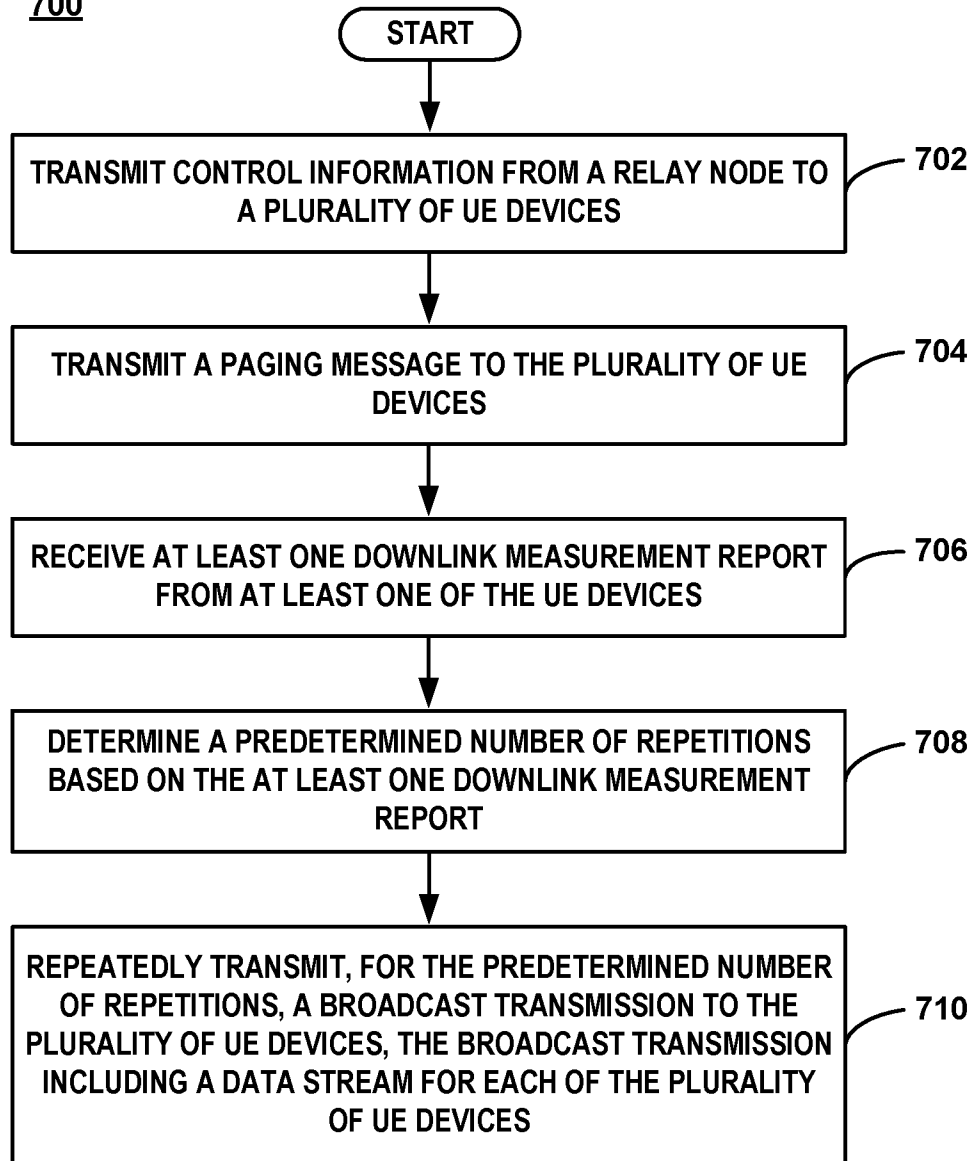
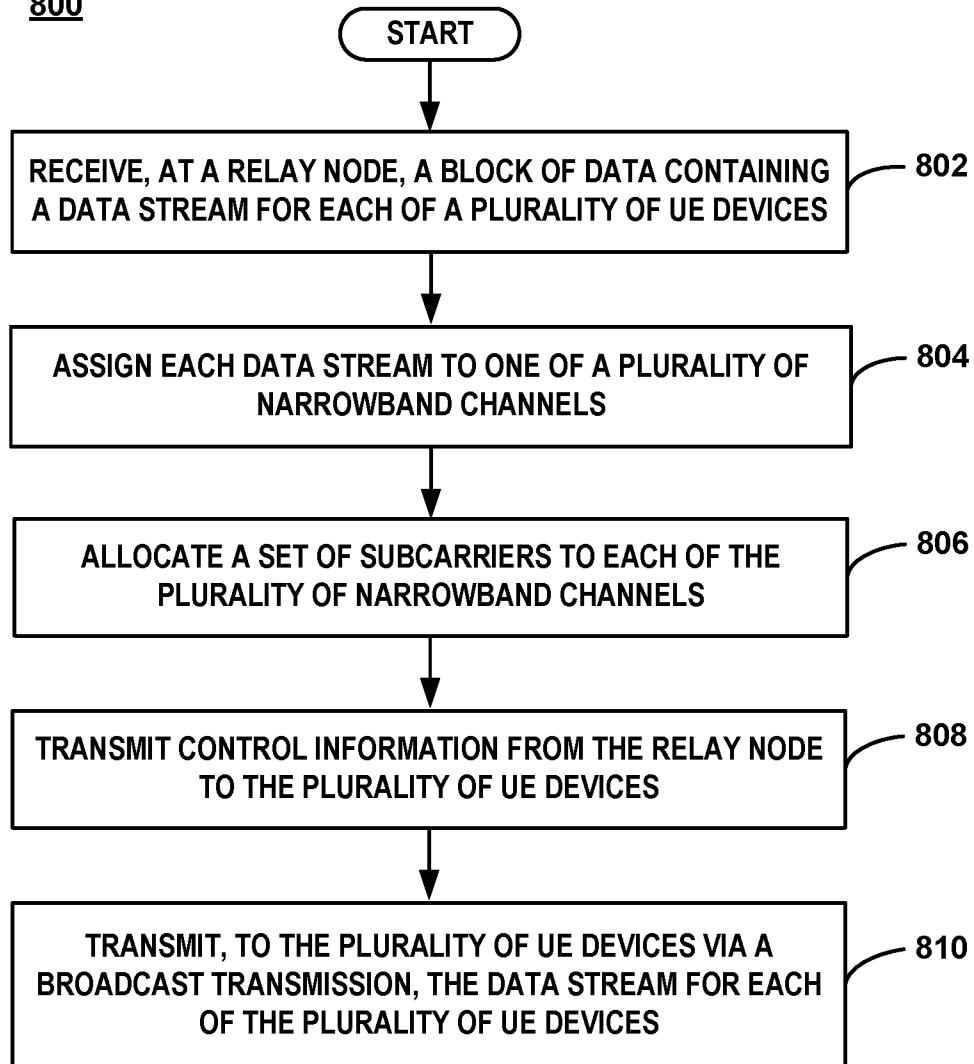
700

FIG. 7

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800**FIG. 8**

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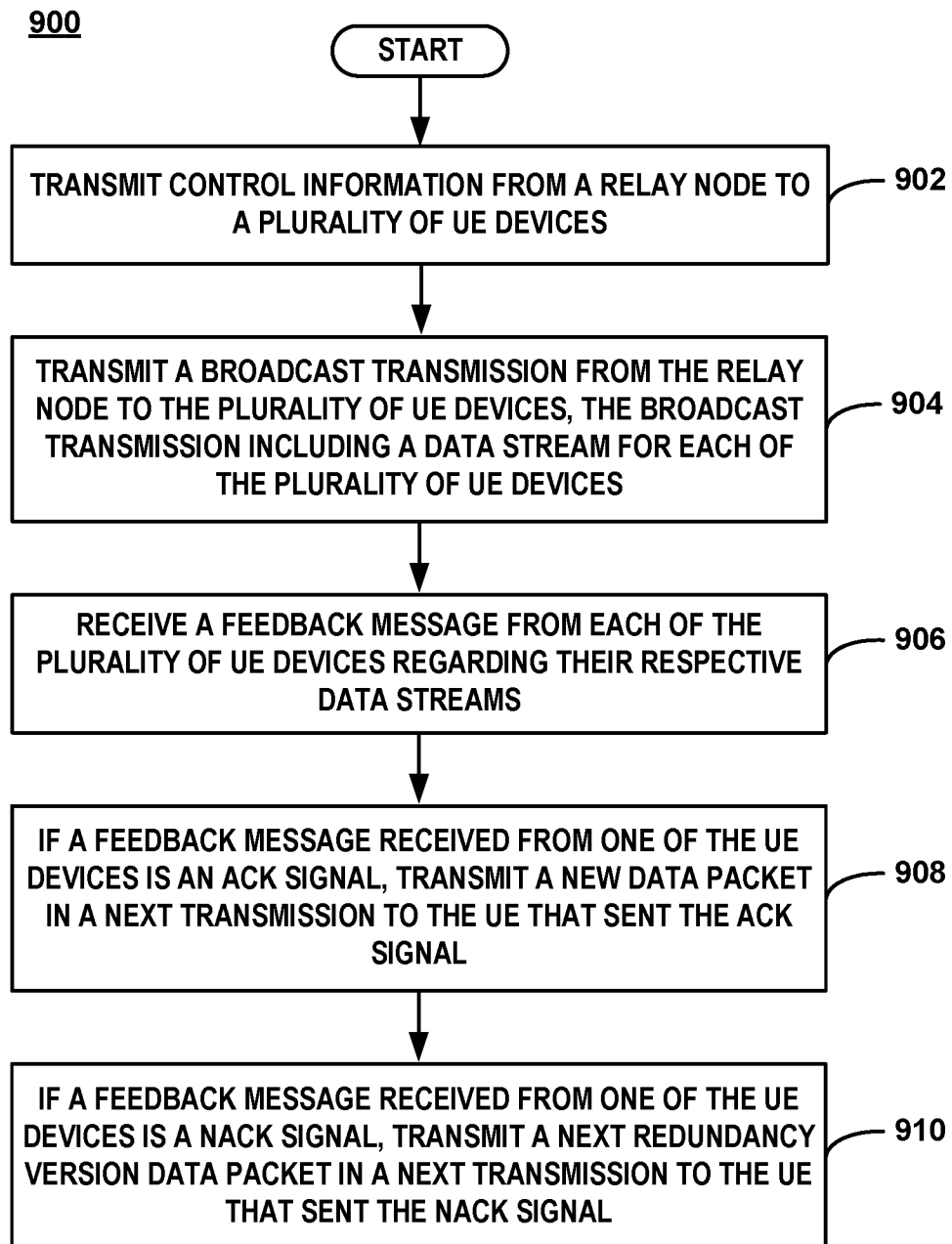


FIG. 9

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2019/028644**A. CLASSIFICATION OF SUBJECT MATTER****H04L 12/18(2006.01)i, H04L 1/08(2006.01)i, H04L 5/00(2006.01)i, H04W 72/12(2009.01)i, H04W 24/10(2009.01)i, H04L 1/00(2006.01)i**

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)

H04L 12/18; H04J 1/16; H04L 1/00; H04L 1/08; H04W 16/26; H04W 72/04; H04L 5/00; H04W 72/12; H04W 24/10

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: relay node, UE device, control information, repetition, broadcast transmission, data stream

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2017-078603 A1 (TELEFONAKTIEBOLAGET LM ERICSSON (PUBL)) 11 May 2017 See paragraph [0072]; claims 31-32; and figure 7.	1-21
Y	US 2016-0345300 A1 (INDUSTRY-UNIVERSITY COOPERATION FOUNDATION HANYANG UNIVERSITY) 24 November 2016 See paragraphs [0052], [0130]; claims 1-2; and figure 6.	1-21
Y	US 2010-0182919 A1 (YOUNG-DAE LEE et al.) 22 July 2010 See paragraph [0029]; and figure 4.	9-10, 20-21
A	US 2018-0109358 A1 (CHINA ACADEMY OF TELECOMMUNICATIONS TECHNOLOGY) 19 April 2018 See paragraph [0054]; and figure 4.	1-21
A	US 2017-0181009 A1 (ALCATEL LUCENT) 22 June 2017 See claims 1-11.	1-21



Further documents are listed in the continuation of Box C.



See patent family annex.

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"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

11 September 2019 (11.09.2019)

Date of mailing of the international search report

11 September 2019 (11.09.2019)

Name and mailing address of the ISA/KR

International Application Division

Korean Intellectual Property Office

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2019/028644

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