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(54) Title: CONFIGURABLE CHANNEL QUALITY INDICATOR (CQI) REPORTING FOR WIRELESS NETWORKS

(57) Abstract: A technique is provided for determining, by a base station, a channel quality for a wireless channel between the base station and a user device, selecting a channel quality indicator (CQI) configuration of a plurality of CQI configurations based on either the channel quality or a property of the user device, the selected CQI configuration being associated with a set of CQI values and a number of information bits used to indicate a CQI value within the set of CQI values, and transmitting, by the base station to the user device, information identifying the selected CQI configuration to be used for transmitting CQI values from the user device to the base station.

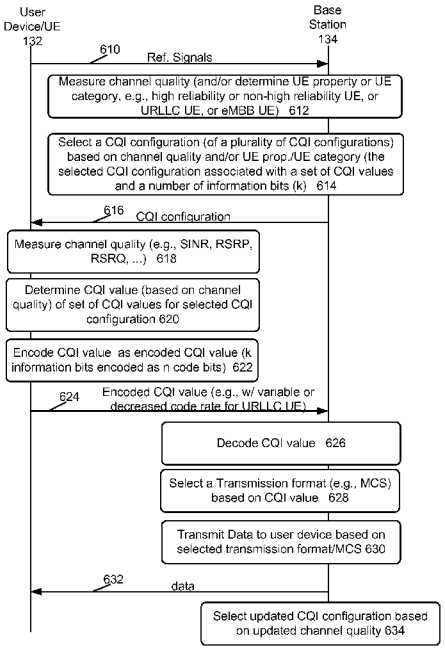

FIG. 6

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Configurable Channel Quality Indicator (CQI) Reporting for Wireless Networks

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TECHNICAL FIELD

[0001] This description relates to communications, and in particular, to a configurable channel quality indicator (CQI) reporting for wireless networks.

BACKGROUND

[0002] A communication system may be a facility that enables communication between two or more nodes or devices, such as fixed or mobile communication devices. Signals can be carried on wired or wireless carriers.

[0003] An example of a cellular communication system is an architecture that is being standardized by the 3rd Generation Partnership Project (3GPP). A recent development in this field is often referred to as the long-term evolution (LTE) of the Universal Mobile Telecommunications System (UMTS) radio-access technology. E-UTRA (evolved UMTS Terrestrial Radio Access) is the air interface of 3GPP's Long Term Evolution (LTE) upgrade path for mobile networks. In LTE, base stations or access points (APs), which are referred to as enhanced Node AP (eNBs), provide wireless access within a coverage area or cell. In LTE, mobile devices, user devices or mobile stations are referred to as user equipments (UEs).

[0004] A base station may select a transmission format (e.g., modulation and coding scheme/MCS) for transmitting data to the user device based on a channel quality indicator (CQI) value received from the user device.

SUMMARY

[0005] According to an example implementation, a method includes determining,

by a base station, a channel quality for a wireless channel between the base station and a user device; selecting a channel quality indicator (CQI) configuration of a plurality of CQI configurations based on either the channel quality or a property of the user device, the selected CQI configuration being associated with a set of CQI values and a number of information bits used to indicate a CQI value within the set of CQI values; and transmitting, by the base station to the user device, information identifying the selected CQI configuration to be used for transmitting CQI values from the user device to the base station.

[0006] According to an example implementation, an apparatus includes at least one processor and at least one memory including computer instructions, when executed by the at least one processor, cause the apparatus to: determine, by a base station, a channel quality for a wireless channel between the base station and a user device; select a channel quality indicator (CQI) configuration of a plurality of CQI configurations based on either the channel quality or a property of the user device, the selected CQI configuration being associated with a set of CQI values and a number of information bits used to indicate a CQI value within the set of CQI values; and transmit, by the base station to the user device, information identifying the selected CQI configuration to be used for transmitting CQI values from the user device to the base station.

[0007] According to an example implementation, an apparatus includes means for determining, by a base station, a channel quality for a wireless channel between the base station and a user device; means for selecting a channel quality indicator (CQI) configuration of a plurality of CQI configurations based on either the channel quality or a property of the user device, the selected CQI configuration being associated with a set of CQI values and a number of information bits used to indicate a CQI value within the set of CQI values; and means for transmitting, by the base station to the user device, information identifying the selected CQI configuration to be used for transmitting CQI values from the user device to the base station.

[0008] According to an example implementation, a computer program product includes a non-transitory computer-readable storage medium and storing executable code that, when executed by at least one data processing apparatus, is configured to cause the at least one data processing apparatus to perform a method including: determining, by a

base station, a channel quality for a wireless channel between the base station and a user device; selecting a channel quality indicator (CQI) configuration of a plurality of CQI configurations based on either the channel quality or a property of the user device, the selected CQI configuration being associated with a set of CQI values and a number of information bits used to indicate a CQI value within the set of CQI values; and transmitting, by the base station to the user device, information identifying the selected CQI configuration to be used for transmitting CQI values from the user device to the base station.

[0009] According to an example implementation, a method includes determining, by a base station, whether a user device is within a specific category of user devices; allocating, by the base station, a first size of uplink resources to the user device for the transmission of a channel quality indicator (CQI) if the user device is not within the specific category of user devices; otherwise, allocating a second size of uplink resources, which is greater than the first size of uplink resources, to the user device for the transmission of a channel quality indicator (CQI) if the user device is within the specific category of user devices so that a lower coding rate will be used by the user device to encode a CQI value for transmission to the base station.

[0010] According to an example implementation, an apparatus includes at least one processor and at least one memory including computer instructions, when executed by the at least one processor, cause the apparatus to: determine, by a base station, whether a user device is within a specific category of user devices; allocate, by the base station, a first size of uplink resources to the user device for the transmission of a channel quality indicator (CQI) if the user device is not within the specific category of user devices; otherwise, allocate a second size of uplink resources, which is greater than the first size of uplink resources, to the user device for the transmission of a channel quality indicator (CQI) if the user device is within the specific category of user devices so that a lower coding rate will be used by the user device to encode a CQI value for transmission to the base station.

[0011] According to an example implementation, an apparatus includes means for determining, by a base station, whether a user device is within a specific category of user devices; means for allocating, by the base station, a first size of uplink resources to the

user device for the transmission of a channel quality indicator (CQI) if the user device is not within the specific category of user devices; means for otherwise, allocating a second size of uplink resources, which is greater than the first size of uplink resources, to the user device for the transmission of a channel quality indicator (CQI) if the user device is within the specific category of user devices so that a lower coding rate will be used by the user device to encode a CQI value for transmission to the base station.

[0012] According to an example implementation, a computer program product includes a non-transitory computer-readable storage medium and storing executable code that, when executed by at least one data processing apparatus, is configured to cause the at least one data processing apparatus to perform a method including: determining, by a base station, whether a user device is within a specific category of user devices; allocating, by the base station, a first size of uplink resources to the user device for the transmission of a channel quality indicator (CQI) if the user device is not within the specific category of user devices; otherwise, allocating a second size of uplink resources, which is greater than the first size of uplink resources, to the user device for the transmission of a channel quality indicator (CQI) if the user device is within the specific category of user devices so that a lower coding rate will be used by the user device to encode a CQI value for transmission to the base station.

[0013] According to an example implementation, a method includes receiving, by a user device from a base station, information identifying a selected channel quality indicator (CQI) configuration, of a plurality of CQI configurations, to be used to transmit a CQI value, the selected CQI configuration associated with a set of CQI values and a number of information bits used to indicate a CQI value within the set of CQI values; determining, by the user device, a channel quality of a user device-base station wireless channel; determining, by the user device based on the channel quality, a CQI value of a set of CQI values associated with the selected CQI configuration; encoding, by the user device, the CQI value; and transmitting, by the user device to the base station, the encoded CQI value.

[0014] According to an example implementation, an apparatus includes at least one processor and at least one memory including computer instructions, when executed by the at least one processor, cause the apparatus to: receive, by a user device from a base

station, information identifying a selected channel quality indicator (CQI) configuration, of a plurality of CQI configurations, to be used to transmit a CQI value, the selected CQI configuration associated with a set of CQI values and a number of information bits used to indicate a CQI value within the set of CQI values; determine, by the user device, a channel quality of a user device-base station wireless channel; determine, by the user device based on the channel quality, a CQI value of a set of CQI values associated with the selected CQI configuration; encoding, by the user device, the CQI value; and transmitting, by the user device to the base station, the encoded CQI value.

[0015] According to an example implementation, an apparatus includes means for receiving, by a user device from a base station, information identifying a selected channel quality indicator (CQI) configuration, of a plurality of CQI configurations, to be used to transmit a CQI value, the selected CQI configuration associated with a set of CQI values and a number of information bits used to indicate a CQI value within the set of CQI values; means for determining, by the user device, a channel quality of a user device-base station wireless channel; means for determining, by the user device based on the channel quality, a CQI value of a set of CQI values associated with the selected CQI configuration; means for encoding, by the user device, the CQI value; and means for transmitting, by the user device to the base station, the encoded CQI value.

[0016] According to an example implementation, a computer program product includes a non-transitory computer-readable storage medium and storing executable code that, when executed by at least one data processing apparatus, is configured to cause the at least one data processing apparatus to perform a method including: receiving, by a user device from a base station, information identifying a selected channel quality indicator (CQI) configuration, of a plurality of CQI configurations, to be used to transmit a CQI value, the selected CQI configuration associated with a set of CQI values and a number of information bits used to indicate a CQI value within the set of CQI values; determining, by the user device, a channel quality of a user device-base station wireless channel; determining, by the user device based on the channel quality, a CQI value of a set of CQI values associated with the selected CQI configuration; encoding, by the user device, the CQI value; and transmitting, by the user device to the base station, the encoded CQI value.

[0017] According to an example implementation, a method includes determining, by a base station, whether a user device is within a specific category of user devices; decoding a CQI value, using a fixed or default channel quality indicator (CQI) configuration if the user device is not within the specific category of user devices; and otherwise, performing the following if the user device is within the specific category of user devices: selecting a variable channel quality indicator (CQI) configuration of a plurality of CQI configurations based on a measured channel quality, the selected CQI configuration being associated with a set of CQI values and a number of information bits used to indicate a CQI value within the set of CQI values; and transmitting, by the base station to the user device, information identifying the selected CQI configuration to be used for transmitting CQI values from the user device to the base station.

[0018] According to an example implementation, an apparatus includes at least one processor and at least one memory including computer instructions, when executed by the at least one processor, cause the apparatus to: determine, by a base station, whether a user device is within a specific category of user devices; decode a CQI value, using a fixed or default channel quality indicator (CQI) configuration if the user device is not within the specific category of user devices; and otherwise, perform the following if the user device is within the specific category of user devices: select a variable channel quality indicator (CQI) configuration of a plurality of CQI configurations based on a measured channel quality, the selected CQI configuration being associated with a set of CQI values and a number of information bits used to indicate a CQI value within the set of CQI values; and transmit, by the base station to the user device, information identifying the selected CQI configuration to be used for transmitting CQI values from the user device to the base station.

[0019] According to an example implementation, an apparatus includes means for determining, by a base station, whether a user device is within a specific category of user devices; means for decoding a CQI value, using a fixed or default channel quality indicator (CQI) configuration if the user device is not within the specific category of user devices; and means for otherwise, performing the following if the user device is within the specific category of user devices, including: means for selecting a variable channel quality indicator (CQI) configuration of a plurality of CQI configurations based on a

measured channel quality, the selected CQI configuration being associated with a set of CQI values and a number of information bits used to indicate a CQI value within the set of CQI values; and means for transmitting, by the base station to the user device, information identifying the selected CQI configuration to be used for transmitting CQI values from the user device to the base station.

[0020] According to an example implementation, a computer program product includes a non-transitory computer-readable storage medium and storing executable code that, when executed by at least one data processing apparatus, is configured to cause the at least one data processing apparatus to perform a method including: determining, by a base station, whether a user device is within a specific category of user devices; decoding a CQI value, using a fixed or default channel quality indicator (CQI) configuration if the user device is not within the specific category of user devices; and otherwise, performing the following if the user device is within the specific category of user devices: selecting a variable channel quality indicator (CQI) configuration of a plurality of CQI configurations based on a measured channel quality, the selected CQI configuration being associated with a set of CQI values and a number of information bits used to indicate a CQI value within the set of CQI values; and transmitting, by the base station to the user device, information identifying the selected CQI configuration to be used for transmitting CQI values from the user device to the base station.

[0021] The details of one or more examples of implementations are set forth in the accompanying drawings and the description below. Other features will be apparent from the description and drawings, and from the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] FIG. 1 is a block diagram of a wireless network according to an example implementation.

[0023] FIG. 2 is a flow chart illustrating operation of a base station according to an example implementation.

[0024] FIG. 3 is a flow chart illustrating operation of a base station according to an example implementation.

[0025] FIGs. 4 is a flow chart illustrating operation of a user device according to

an example implementation.

[0026] FIG. 5 is a flow chart illustrating operation of a base station according to an example implementation.

[0027] FIG. 6 is a diagram illustrating operation of a network according to an example implementation.

[0028] FIG. 7 is a diagram illustrating operation of a network according to an example implementation.

[0029] FIG. 8 is a block diagram of a node or wireless station (e.g., network device, base station/access point or mobile station/user device/UE) according to an example implementation.

DETAILED DESCRIPTION

[0030] FIG. 1 is a block diagram of a wireless network 130 according to an example implementation. In the wireless network 130 of FIG. 1, user devices 131, 132, 133 and 135, which may also be referred to as mobile stations (MSs) or user equipment (UEs), may be connected (and in communication) with a base station (BS) 134, which may also be referred to as an access point (AP), an enhanced Node B (eNB) or a network node. At least part of the functionalities of an access point (AP), base station (BS) or (e)Node B (eNB) may be also be carried out by any node, server or host which may be operably coupled to a transceiver, such as a remote radio head. BS (or AP) 134 provides wireless coverage within a cell 136, including to user devices 131, 132, 133 and 135. Although only four user devices are shown as being connected or attached to BS 134, any number of user devices may be provided. BS 134 is also connected to a core network 150 via a S1 interface 151. This is merely one simple example of a wireless network, and others may be used.

[0031] A user device (user terminal, user equipment (UE) or mobile station) may refer to a portable computing device that includes wireless mobile communication devices operating with or without a subscriber identification module (SIM), including, but not limited to, the following types of devices: a mobile station (MS), a mobile phone, a cell phone, a smartphone, a personal digital assistant (PDA), a handset, a device using a wireless modem (alarm or measurement device, etc.), a laptop and/or touch screen

computer, a tablet, a phablet, a game console, a notebook, and a multimedia device, as examples. It should be appreciated that a user device may also be a nearly exclusive uplink only device, of which an example is a camera or video camera loading images or video clips to a network.

[0032] By way of illustrative example, the various example implementations or techniques described herein may be applied to various user devices, such as machine type communication (MTC) user devices, enhanced machine type communication (eMTC) user devices, Internet of Things (IoT) user devices, and/or narrowband IoT user devices. IoT may refer to an ever-growing group of objects that may have Internet or network connectivity, so that these objects may send information to and receive information from other network devices. For example, many sensor type applications or devices may monitor a physical condition or a status, and may send a report to a server or other network device, e.g., when an event occurs. Machine Type Communications (MTC, or Machine to Machine communications) may, for example, be characterized by fully automatic data generation, exchange, processing and actuation among intelligent machines, with or without intervention of humans.

[0033] Also, in an example implementation, a user device or UE may be a UE/user device with ultra reliable low latency communications (URLLC) applications. A cell (or cells) may include a number of user devices connected to the cell, including user devices of different types or different categories, e.g., including the categories of MTC, NB-IoT, URLLC, or other UE category.

[0034] In LTE (as an example), core network 150 may be referred to as Evolved Packet Core (EPC), which may include a mobility management entity (MME) which may handle or assist with mobility/handover of user devices between BSs, one or more gateways that may forward data and control signals between the BSs and packet data networks or the Internet, and other control functions or blocks.

[0035] The various example implementations may be applied to a wide variety of wireless technologies or wireless networks, such as LTE, LTE-A, 5G, cmWave, and/or mmWave band networks, IoT, MTC, eMTC, URLLC, etc., or any other wireless network or wireless technology. These example networks or technologies are provided only as illustrative examples, and the various example implementations may be applied to any

wireless technology/wireless network.

[0036] Different categories (or different types) of user devices/UEs may have different requirements for reliability and latency. According to an example implementation, it may be useful to, at least in some cases, treat different types of user devices differently, e.g., in order to attempt to accommodate or meet their different reliability and/or latency requirements.

[0037] Some user devices or UEs may require high reliability services, and thus, may be referred to as high reliability UEs, since these UEs may have one or more applications running thereon that may require a reliability that is greater than standard or non-high reliability UEs/applications. For example, a UE that has two applications running thereon, including: 1) a first application (e.g., an autonomous or self-driving car related application that requires high reliability, such as a much lower block error rate) that requires high reliability services and 2) a second application (e.g., web browser, email application, social media application, where standard reliability is sufficient) that does not require high reliability services, may be considered as a high reliability UE, for example. Thus, for example, a high reliability UE/user device may include a UE that has mixed traffic, e.g., including high reliability traffic and non-high reliability traffic.

[0038] For example, ultra-reliable and low-latency communications (URLLC) (or URLLC UE) is a new usage scenario, which is considered for 5G systems. This enables emerging new applications and services from various verticals on top of regular cellular communication, such as industrial automations, autonomous driving, vehicular safety, e-health services, and so on. 3GPP targets in providing connectivity with reliability corresponding to block error rate (BLER) of 10^{-5} and up to 1 ms U-Plane (user/data plane) latency. Thus, for example, URLLC user devices/UEs may require a significantly lower block error rate than other types of user devices/UEs. Thus, for example, a URLLC UE may include a UE that requires a URLLC service, and/or a UE that has at least some URLLC traffic, including a UE that has (e.g., receives and/or transmits) mixed traffic (data) including both URLLC traffic and non-URLLC traffic. Different types of traffic may be transmitted and/or received by different applications, for example.

[0039] High reliability UEs, such as URLLC UEs, may have relatively strict requirements for reliability and/or latency. For example, the URLLC UEs may require

that a payload should be delivered with high success probability with a limited number of transmission attempts, e.g., which may include a maximum of one retransmission round can be realized for each payload to meet 1 ms latency considering transmission time interval of 0.125 ms. This is merely an illustrative example, and others may be used to illustrate a high reliability and/or low latency UE. According to an example implementation, achieving a relatively high level of reliability with a limited number of transmission attempts may, for example, require accurate selection of the employed transmission format (which may include a selected modulation and coding scheme (MCS)) for data transmissions. For downlink transmissions, a user device or user equipment (UE) may trigger the MCS selection by the BS with reporting channel measurements, e.g., by reporting channel quality indicator (CQI) value in a channel status report, e.g., where the reported CQI may be based on a measured channel quality (e.g., SINR, RSRP, RSRQ, …). Failure at the BS in decoding the channel status report or CQI value can cause, at least in some cases, the BS to select a MCS (for downlink data transmission) that may be higher than what the downlink channel can support while still meeting the required reliability/block error rate for that type of UE. Thus, for example, in such a case, transmitting data from the BS to the UE using a MCS that is too high may cause a failure at the user device/UE in decoding the data message due to an incorrectly (or erroneously) selected MCS scheme. Thus, to maintain high reliability performance of a URLLC or other high reliability UE, it may be useful to improve the reliability of CQI value reporting.

[0040] A base station may select a transmission format (e.g., modulation and coding scheme/MCS) for transmitting data to the user device based on a channel quality indicator (CQI) value received from the user device. For example, a user device or UE may measure a downlink channel quality (e.g., signal-to-interference plus noise ratio or SINR, reference signal received power or RSRP, reference signal received quality or RSRQ, …) based on reference signals received from a BS. In an example implementation, the user device may select a channel quality indicator (CQI) value, out of a set of CQI values, that, for example, may represent a highest modulation and coding scheme (MCS) that may be used to transmit downlink data on the UE-BS wireless/radio channel that would be received with a target block error rate (e.g., 10% BLER for non-

URLLC UEs, and 1% for URLLC UEs, for example).

[0041] By way of illustrative example, in LTE, a user device/UE measures the received reference signal (RS) to estimate the downlink channel quality. The UE then maps the estimated channel quality to one of a plurality of CQI values and reports the selected CQI value back to the base station (BS). As an example in current LTE, the CQI reporting is performed over physical uplink control channel (PUCCH) with format 2, 2a, and 2b. There are 16 different CQI values which can be represented by 4 bits. The selected CQI value is encoded into 20 bits to add redundancy, allow for error detection and correction, and/or overall improve the robustness of the transmitted CQI against noise and interference. In general, k information bits may be encoded to an n-bit encoded CQI value (k code bits). The received CQI value is then decoded and used by the BS to determine a MCS that will be used by the BS for downlink data transmissions to the user device/UE. For example, in a case where the BS decodes the CQI value incorrectly as a higher value (corresponding to a higher MCS), the BS would perform data transmissions to the UE with a higher data rate (higher MCS), which may typically cause a reduced transmission reliability. This problem can be severe for URLLC devices as the limited number of transmission rounds provides marginal soft combining gain.

[0042] Therefore, various example implementations are described to allow improved reliability for a transmission of a channel status (CQI) value from the user device/UE to the BS. By improving the reliability of CQI transmission, this may decrease the likelihood that a received CQI value will be mis-decoded (or incorrectly decoded) into a wrong or incorrect CQI value, e.g., which could result in an incorrect choice of MCS for downlink transmission from the BS to the UE. According to an example implementation, reliability of a CQI transmission may be improved by decreasing a code rate for a transmitted CQI value. A code rate for the CQI value may be determined as, for example:

[0043] Code rate = k/n, where k is the number of information bits of the unencoded CQI value, and n is the number of code bits of the encoded CQI value, e.g., 4/20. According to an example implementations, the code rate for the transmitted CQI value may be decreased, e.g., for high reliability UEs or URLLC UEs, or for lower channel qualities, by either: 1) decreasing k, the number of information bits for the

unencoded CQI value, or 2) increasing n, the number of code bits for the reported CQI value. In both cases, the CQI value code rate may be decreased by increasing the redundancy bits/information for the encoded CQI value. Either or both of these techniques may be used to increase the reliability of CQI reporting.

[0044] Thus, according to an example implementation, in a first method or technique, a CQI code rate may be decreased (e.g., in order to improve CQI transmission reliability) by decreasing the number (k) of information bits of the unencoded CQI value. According to an example implementation, a plurality of CQI configurations may be available, where each CQI configuration may be associated with a number (k) of information bits used to indicate a CQI value and a set of CQI values. A BS may select one of the plurality of CQI configurations based on either a channel quality or a UE property (e.g., based on the category or type of UE, such as whether the UE is a high reliability UE or a URLLC UE or not). For example, a CQI configuration, having fewer number (k) of information bits for a CQI value, may be selected for high reliability or URLLC UEs and/or for lower channel qualities, e.g., so as to provide a decreased CQI code rate for those situations, for example. By decreasing the CQI value code rate, e.g., from 4/20 to 3/20, as an example, this may improve CQI transmission reliability, e.g., in such cases of a CQI transmission from a high reliability UE or URLLC UE and/or for a low or lower (e.g., less than a threshold) channel quality. Therefore, according to an example implementation, a flexible CQI reporting format may be provided for high reliability UEs or URLLC UEs in which a selected CQI configuration (including an associated set of CQI values) can be UE-specific.

[0045] Thus, in the first method or technique, the granularity of CQI reporting (e.g., using fewer CQI values in the CQI configuration and/or fewer CQI information bits) may be decreased or reduced, which decreases the CQI coding rate. In this way, the CQI value is chosen from a set with fewer elements (fewer CQI values, which may be represented with fewer CQI information bits). For instance, different CQI configurations (each CQI configuration having an associated set of CQI values) can be formed, e.g., with sizes of 2, 4, 8, and 16 CQI values, which can be represented by 1, 2, 3, and 4 bits, respectively.

[0046] Thus, according the first method or technique, the BS may configure a

reduced set of CQI values to be used by the UE (decreasing k) in order to decrease the CQI value code rate. According to an example implementation, the UEs with good (or better than a threshold) channel qualities may use a normal or standard (or default) CQI configuration that includes, for example, a set of 16 different CQI values for reporting the channel measurements (CQI value), while UEs with bad (or less than the threshold channel quality) channel qualities may use a selected one of a plurality of (variable) CQI configurations with reduced sizes (reduced number of CQI values as compared to the standard or default numbers of CQI values). In an example implementation, all non high reliability (e.g., eMBB) UEs may then use the regular or standard CQI report format, and high reliability UEs or URLLC UEs may use a selected CQI configuration of a plurality of CQI configurations that have a reduced set of CQI values, e.g., where one of the CQI configurations may be selected based on a channel quality. In this way, the resources (number of encoded bits n) occupied by non-high reliability (e.g., eMBB) CQI report and high reliability or URLLC CQI report may be the same (n resource blocks or n bits), but the high reliability UE or URLLC UE CQI report will have more redundancy (based on smaller set of CQI values and thus a smaller number k of CQI information bits), and thus, a better performance in terms of reliability. A reduced CQI set (a CQI configuration having fewer CQI values) can be allocated separately for each UE or jointly for a group of UEs. The separate CQI set enables employing the MCS according to the UE characteristics, such as link quality and data traffic.

[0047] Alternatively, in a second method or technique, a CQI code rate may be decreased (e.g., in order to improve CQI transmission reliability for high reliability UEs or URLLC UEs) by increasing n, the number of code bits available to encode the transmitted CQI value. For example, the number (n) of code bits for the encoded CQI value may be increased by providing a larger set of resources (e.g., 2n, or 3n bits or resources) that may be used by the UE to transmit the encoded CQI value to the BS for the high reliability or URLLC UEs, while providing a smaller (or standard) set of resources (e.g., n bits) to allow a non high reliability or non-URLLC UE to transmit an encoded CQI value. Thus, in this manner, different sized resources may be used for different categories or different types of UEs, e.g., to allow different CQI code rates to be used for non-high reliability UEs (or non-URLLC UEs) as compared to high reliability

UEs or URLLC UEs. An example of a non high reliability UE may be an eMBB (enhanced mobile broadband) UE.

[0048] Thus, according to the second method or technique, more redundancy may be used or employed by the UE for coding the CQI values (e.g., by increasing n, the number of code bits for the reported CQI value). This approach requires allocating more radio resources for CQI reporting, e.g., by, for example, increasing the resources for PUCCH (physical uplink control channel) for CQI reporting. For instance, the BS can assign, for a high reliability UE or URLLC UE, resources of a multiple CQI reporting resources, e.g., that may ordinarily be used (by a non high reliability or non-URLLC UE) to report two (or three or four) CQI reports for a single UE. Thus, if n resources (e.g., n bits) are typically allocated for a non-high reliability UE or non-URLLC UE to report a CQI value, then the BS may allocate 2n or 3n bits or resources to a high reliability UE or URLLC UE to allow the high reliability or URLLC UE to report a CQI value with a decreased code rate and enhanced CQI reporting reliability. In this case, the CQI resources used or occupied for high reliability or URLLC CQI report may be integer multiple of the resource occupied by non high reliability/non-URLLC UE (e.g., eMBB UE) CQI report. Alternatively, rather than making the resource size a multiple of standard CQI reporting size, the BS may allocate a dedicated resource to a high reliability UE or URLLC UE for reporting a CQI value for, where the dedicated resource may be any size, not limited to multiple of standard CQI reporting resource size, for example.

[0049] Further example details will be described for the first method or technique (in which CQI coding rate is decreased by decreasing k), according to an illustrative example implementation.

[0050] According to an illustrative example implementation, several different CQI configurations may be provided for high reliability UEs or URLLC UEs, where each CQI configuration may be associated with a set of CQI values (or a CQI set) and a number (k) of CQI information bits, in which a same number of code bits (n) or physical resources needed for transmitting CQI value/report is the same as that required or used by non high reliability UEs. In this way, it is easier to multiplex CQI reports from high reliability (or URLLC UEs) and non high reliability UEs.

[0051] An example of deriving a CQI set (or a CQI configuration) with a set of

CQI values having a reduced number of CQI values/elements. For example, it may be assumed that the original or standard CQI set (same as LTE) is $S = \{0,1,2,\dots,15\}$. A reduced set of CQI values can be formed, by way of example, by defining 1) the number of elements/CQI values represented by 2^k where k is the number of CQI information bits and 2) the maximum CQI value that is denoted by $M \in S$. The reduced set can be presented as $S' = \left\{ \left\lfloor i\frac{M+1}{2^k} \right\rfloor \middle| i = 0,\dots,2^k - 1 \right\}$. Table 1 provides an example of new CQI sets that can be formed. Thus, Table 1 illustrates a plurality of possible CQI configurations, with each CQI configuration associated with a set of CQI values and a number (k) of CQI information bits.

Table 1. Example of CQI sets.

k	M	CQI set
4	15	$S = \{0,1,2,\dots,15\}$ (Original CQI set)
3	15	$S' = \{0,2,4,6,8,10,12,14\}$
2	15	$S' = \{0,4,8,12\}$
1	15	$S' = \{0,8\}$
3	7	$S' = \{0,1,2,\dots,7\}$
2	7	$S' = \{0,2,4,6\}$
1	7	$S' = \{0,4\}$

[0052] In addition, this scheme gives the flexibility of adjusting the reliability, granularity, and accuracy for CQI reporting. For instance, the BS can configure a UE with poor channel quality to report CQI with less than 4 bits, as it is utilized for normal reporting.

[0053] The BS can further adjust the maximum reporting value for CQI according to the typical data size that UE needs to send. Considering the minimum physical resource unit, the BS can limit the maximum value for the CQI report if the UE only needs to send a small amount of data. In this way, the UE would be scheduled according to the MCSs lower than the maximum CQI report. This limitation does not affect the

transmission performance for small data packet transmissions, as at least one physical resource block should be assigned for each payload transmission. For example, for transmitting 40 bytes of data, one resource block is assigned for MCSs between 10 and 15, for example. That is to say, the occupied resource does not depend on the CQI value once the reported CQI is higher than 10.

[0054] FIG. 2 is a flow chart illustrating operation of a base station according to an example implementation. Operation 210 includes determining, by a base station, a channel quality for a wireless channel between the base station and a user device. Operation 220 includes selecting a channel quality indicator (CQI) configuration of a plurality of CQI configurations based on either the channel quality or a property of the user device, the selected CQI configuration being associated with a set of CQI values and a number of information bits used to indicate a CQI value within the set of CQI values. And, operation 230 includes transmitting, by the base station to the user device, information identifying the selected CQI configuration to be used for transmitting CQI values from the user device to the base station.

[0055] According to an example implementation of the method of FIG. 2, the property of the user device includes determining whether or not the user device requires high reliability communication.

[0056] According to an example implementation of the method of FIG. 2, the property of the user device comprises determining whether or not the user device is an ultra-reliable, low latency user device or the user device requires ultra-reliable, low latency communications or service.

[0057] According to an example implementation of the method of FIG. 2, the method further including receiving, by the base station from the user device, an encoded CQI value that is one CQI value within the set of CQI values associated with the selected CQI configuration; decoding, by the base station, the CQI value; selecting, by the base station, a transmission format based on the CQI value; and transmitting, by the base station to the user device, data based on the selected MCS.

[0058] According to an example implementation of the method of FIG. 2, the selecting a transmission format includes selecting a modulation and coding scheme (MCS) based on the CQI value.

[0059] According to an example implementation of the method of FIG. 2, the determining, by a base station, a channel quality for a wireless channel between the base station and a user device includes at least one of the following: receiving, by the base station from the user device, channel quality information for a downlink channel between the base station and the user device; and measuring, by the base station based on received reference signals, a channel quality of an uplink channel between the user device and the base station.

[0060] According to an example implementation of the method of FIG. 2, the selecting a CQI configuration includes: selecting a channel quality indicator (CQI) configuration of a plurality of CQI configurations based on the channel quality, wherein a first CQI configuration associated with a greater number of information bits is selected for a higher quality channel, and wherein a second CQI configuration associated with a fewer number of information bits is selected for a lower quality channel.

[0061] According to an example implementation of the method of FIG. 2, wherein a lower coding rate is associated with a CQI value, received by the base station from the user device, for a lower channel quality based on fewer information bits for the CQI value; and a higher coding rate is associated with a CQI value, received by the base station from the user device, for a higher channel quality based on greater information bits for the CQI value.

[0062] According to an example implementation of the method of FIG. 2, a lower coding rate is associated with a CQI value received by the base station from the user device based on fewer information bits for the CQI value, where the user device requires high reliability communications; and a higher coding rate is associated with a CQI value received by the base station from the user device based on greater information bits for the CQI value, where the user device does not require high reliability communications.

[0063] According to an example implementation of the method of FIG. 2, a CQI configuration, having fewer information bits for each CQI value within the set of CQI values of the CQI configuration, is selected for a high reliability user device that requires high reliability communications to thereby provide a decreased code rate for a CQI value transmitted by a high reliability user device; and a CQI configuration, having greater

information bits for each CQI value within the set of CQI values of the CQI configuration, is selected for a non-high reliability user device that does not require high reliability communications to thereby provide an increased code rate for a CQI value transmitted by a non-high reliability user device.

[0064] According to an example implementation of the method of FIG. 2, a first set of CQI values uses a first number of information bits for each CQI value within the first set of CQI values are used for a channel quality that is greater than a threshold, and a second set of CQI values having a second number of information bits, which are less than the first number of information bits, are used for a channel quality that is greater than a threshold.

[0065] According to an example implementation of the method of FIG. 2, and further including: determining whether the channel quality is less than a threshold; wherein the selecting a CQI configuration includes selecting, by the base station, if the channel quality is not less than the threshold, a first CQI configuration associated with a first set of CQI values having a first number of CQI values; and selecting, by the base station, if the channel quality is less than the threshold, a second CQI configuration associated with a second set of CQI values having a second number of CQI values that is less than the first number of CQI values.

[0066] According to an example implementation, an apparatus includes at least one processor and at least one memory including computer instructions, when executed by the at least one processor, cause the apparatus to perform a method of determining, by a base station, a channel quality for a wireless channel between the base station and a user device; selecting a channel quality indicator (CQI) configuration of a plurality of CQI configurations based on either the channel quality or a property of the user device, the selected CQI configuration being associated with a set of CQI values and a number of information bits used to indicate a CQI value within the set of CQI values; and transmitting, by the base station to the user device, information identifying the selected CQI configuration to be used for transmitting CQI values from the user device to the base station.

[0067] According to an example implementation, an apparatus includes means (e.g., 802A/802B and/or 804, FIG. 8) for determining, by a base station, a channel quality

for a wireless channel between the base station and a user device; means (e.g., 802A/802B and/or 804, FIG. 8) for selecting a channel quality indicator (CQI) configuration of a plurality of CQI configurations based on either the channel quality or a property of the user device, the selected CQI configuration being associated with a set of CQI values and a number of information bits used to indicate a CQI value within the set of CQI values; and, means (e.g., 802A/802B and/or 804, FIG. 8) for transmitting, by the base station to the user device, information identifying the selected CQI configuration to be used for transmitting CQI values from the user device to the base station.

[0068] According to an example implementation of the apparatus, the property of the user device includes determining whether or not the user device requires high reliability communication.

[0069] According to an example implementation of the apparatus, the property of the user device comprises determining whether or not the user device is an ultra-reliable, low latency user device or the user device requires ultra-reliable, low latency communications or service.

[0070] According to an example implementation of the apparatus, further including means (e.g., 802A/802B and/or 804, FIG. 8) for receiving, by the base station from the user device, an encoded CQI value that is one CQI value within the set of CQI values associated with the selected CQI configuration; means (e.g., 802A/802B and/or 804, FIG. 8) for decoding, by the base station, the CQI value; selecting, by the base station, a transmission format based on the CQI value; and means (e.g., 802A/802B and/or 804, FIG. 8) for transmitting, by the base station to the user device, data based on the selected transmission format.

[0071] According to an example implementation of the apparatus, the means for selecting a transmission format includes means (e.g., 802A/802B and/or 804, FIG. 8) for selecting a modulation and coding scheme (MCS) based on the CQI value.

[0072] According to an example implementation of the apparatus, the means for determining, by a base station, a channel quality for a wireless channel between the base station and a user device includes at least one of the following: means (e.g., 802A/802B and/or 804, FIG. 8) for receiving, by the base station from the user device, channel quality information for a downlink channel between the base station and the user device;

and means (e.g., 802A/802B and/or 804, FIG. 8) for measuring, by the base station based on received reference signals, a channel quality of an uplink channel between the user device and the base station.

[0073] According to an example implementation of the apparatus, the means for selecting a CQI configuration includes: means (e.g., 802A/802B and/or 804, FIG. 8) for selecting a channel quality indicator (CQI) configuration of a plurality of CQI configurations based on the channel quality, wherein a first CQI configuration associated with a greater number of information bits is selected for a higher quality channel, and wherein a second CQI configuration associated with a fewer number of information bits is selected for a lower quality channel.

[0074] According to an example implementation of the apparatus, wherein a lower coding rate is associated with a CQI value, received by the base station from the user device, for a lower channel quality based on fewer information bits for the CQI value; and a higher coding rate is associated with a CQI value, received by the base station from the user device, for a higher channel quality based on greater information bits for the CQI value.

[0075] According to an example implementation of the apparatus,

a lower coding rate is associated with a CQI value received by the base station from the user device based on fewer information bits for the CQI value, where the user device requires high reliability communications; and a higher coding rate is associated with a CQI value received by the base station from the user device based on greater information bits for the CQI value, where the user device does not require high reliability communications.

[0076] According to an example implementation of the apparatus, a CQI configuration, having fewer information bits for each CQI value within the set of CQI values of the CQI configuration, is selected for a high reliability user device that requires high reliability communications to thereby provide a decreased code rate for a CQI value transmitted by a high reliability user device; and a CQI configuration, having greater information bits for each CQI value within the set of CQI values of the CQI configuration, is selected for a non-high reliability user device that does not require high reliability communications to thereby provide an increased code rate for a CQI value

transmitted by a non-high reliability user device.

[0077] According to an example implementation of the apparatus, a first set of CQI values uses a first number of information bits for each CQI value within the first set of CQI values are used for a channel quality that is greater than a threshold, and a second set of CQI values having a second number of information bits, which are less than the first number of information bits, are used for a channel quality that is greater than a threshold.

[0078] According to an example implementation of the apparatus, and further including: means (e.g., 802A/802B and/or 804, FIG. 8) for determining whether the channel quality is less than a threshold; wherein the means for selecting a CQI configuration includes means (e.g., 802A/802B and/or 804, FIG. 8) for selecting, by the base station, if the channel quality is not less than the threshold, a first CQI configuration associated with a first set of CQI values having a first number of CQI values; and means (e.g., 802A/802B and/or 804, FIG. 8) for selecting, by the base station, if the channel quality is less than the threshold, a second CQI configuration associated with a second set of CQI values having a second number of CQI values that is less than the first number of CQI values.

[0079] FIG. 3 is a flow chart illustrating operation of a base station according to an example implementation. Operation 310 includes determining, by a base station, whether a user device is within a specific category of user devices. Operation 320 includes allocating, by the base station, a first size of uplink resources to the user device for the transmission of a channel quality indicator (CQI) if the user device is not within the specific category of user devices. Operation 330 includes otherwise, allocating a second size of uplink resources, which is greater than the first size of uplink resources, to the user device for the transmission of a channel quality indicator (CQI) if the user device is within the specific category of user devices so that a lower coding rate will be used by the user device to encode a CQI value for transmission to the base station.

[0080] According to an example implementation of the method of FIG. 3, the specific category of user devices includes user devices that require an ultra-reliable, low-latency communications or services.

[0081] According to an example implementation of the method of FIG. 3, the

second size of uplink resources is greater than the first size of uplink resources.

[0082] According to an example implementation of the method of FIG. 3, the second size of uplink resources is greater than, and a multiple of, the first size of uplink resources.

[0083] According to an example implementation, an apparatus includes at least one processor and at least one memory including computer instructions, when executed by the at least one processor, cause the apparatus to perform a method of determining, by a base station, whether a user device is within a specific category of user devices; allocating, by the base station, a first size of uplink resources to the user device for the transmission of a channel quality indicator (CQI) if the user device is not within the specific category of user device; and, otherwise, allocating a second size of uplink resources, which is greater than the first size of uplink resources, to the user device for the transmission of a channel quality indicator (CQI) if the user device is within the specific category of user devices so that a lower coding rate will be used by the user device to encode a CQI value for transmission to the base station.

[0084] According to an example implementation, an apparatus includes means (e.g., 802A/802B and/or 804, FIG. 8) for determining, by a base station, whether a user device is within a specific category of user devices; means (e.g., 802A/802B and/or 804, FIG. 8) allocating, by the base station, a first size of uplink resources to the user device for the transmission of a channel quality indicator (CQI) if the user device is not within the specific category of user device; otherwise, allocating a second size of uplink resources, which is greater than the first size of uplink resources, to the user device for the transmission of a channel quality indicator (CQI) if the user device is within the specific category of user devices so that a lower coding rate will be used by the user device to encode a CQI value for transmission to the base station.

[0085] FIG. 4 is a flow chart illustrating operation of a user device according to an example implementation. Operation 410 includes receiving, by a user device from a base station, information identifying a selected channel quality indicator (CQI) configuration, of a plurality of CQI configurations, to be used to transmit a CQI value, the selected CQI configuration associated with a set of CQI values and a number of information bits used to indicate a CQI value within the set of CQI values. Operation

420 includes determining, by the user device, a channel quality of a user device-base station wireless channel. Operation 430 includes determining, by the user device based on the channel quality, a CQI value of a set of CQI values associated with the selected CQI configuration. Operation 440 includes encoding, by the user device, the CQI value. And, operation 450 includes transmitting, by the user device to the base station, the encoded CQI value.

[0086] According to an example implementation, an apparatus includes at least one processor and at least one memory including computer instructions, when executed by the at least one processor, cause the apparatus to perform a method of receiving, by a user device from a base station, information identifying a selected channel quality indicator (CQI) configuration, of a plurality of CQI configurations, to be used to transmit a CQI value, the selected CQI configuration associated with a set of CQI values and a number of information bits used to indicate a CQI value within the set of CQI values; determining, by the user device, a channel quality of a user device-base station wireless channel; determining, by the user device based on the channel quality, a CQI value of a set of CQI values associated with the selected CQI configuration; encoding, by the user device, the CQI value; And, transmitting, by the user device to the base station, the encoded CQI value.

[0087] According to an example implementation, an apparatus includes means (e.g., 802A/802B and/or 804, FIG. 8) for receiving, by a user device from a base station, information identifying a selected channel quality indicator (CQI) configuration, of a plurality of CQI configurations, to be used to transmit a CQI value, the selected CQI configuration associated with a set of CQI values and a number of information bits used to indicate a CQI value within the set of CQI values; means (e.g., 802A/802B and/or 804, FIG. 8) for determining, by the user device, a channel quality of a user device-base station wireless channel; means (e.g., 802A/802B and/or 804, FIG. 8) for determining, by the user device based on the channel quality, a CQI value of a set of CQI values associated with the selected CQI configuration; means (e.g., 802A/802B and/or 804, FIG. 8) for encoding, by the user device, the CQI value; and, means (e.g., 802A/802B and/or 804, FIG. 8) for transmitting, by the user device to the base station, the encoded CQI value.

[0088] FIG. 5 is a flow chart illustrating operation of a base station according to an example implementation. Operation 510 includes determining, by a base station, whether a user device is within a specific category of user devices. Operation 520 includes decoding a CQI value, using a fixed or default channel quality indicator (CQI) configuration if the user device is not within the specific category of user devices. Operation 530 includes otherwise, performing the following (operations 540, 550) if the user device is within the specific category of user devices. Operation 540 includes selecting a variable channel quality indicator (CQI) configuration of a plurality of CQI configurations based on a measured channel quality, the selected CQI configuration being associated with a set of CQI values and a number of information bits used to indicate a CQI value within the set of CQI values. And, operation 550 includes transmitting, by the base station to the user device, information identifying the selected CQI configuration to be used for transmitting CQI values from the user device to the base station.

[0089] According to an example implementation of the method of FIG. 5, the specific category of user devices may include user devices that require ultra-reliable, low-latency communications.

[0090] According to an example implementation of the method of FIG. 5, further including performing the following if the user device is within the specific category of user devices: receiving, by the base station from the user device, an encoded CQI value that is one CQI value within the set of CQI values associated with the selected CQI configuration; decoding, by the base station, the CQI value; selecting, by the base station, a transmission format (e.g., a modulation and coding scheme or MCS) based on the CQI value; and transmitting, by the base station to the user device, data based on the selected transmission format (e.g., a selected MCS).

[0091] According to an example implementation, an apparatus includes at least one processor and at least one memory including computer instructions, when executed by the at least one processor, cause the apparatus to perform a method of determining, by a base station, whether a user device is within a specific category of user devices; decoding a CQI value, using a fixed or default channel quality indicator (CQI) configuration if the user device is not within the specific category of user devices; otherwise, performing the following (operations 540, 550) if the user device is within the

specific category of user devices, including selecting a variable channel quality indicator (CQI) configuration of a plurality of CQI configurations based on a measured channel quality, the selected CQI configuration being associated with a set of CQI values and a number of information bits used to indicate a CQI value within the set of CQI values, and transmitting, by the base station to the user device, information identifying the selected CQI configuration to be used for transmitting CQI values from the user device to the base station.

[0092] According to an example implementation, an apparatus includes means (e.g., 802A/802B and/or 804, FIG. 8) for determining, by a base station, whether a user device is within a specific category of user devices; means (e.g., 802A/802B and/or 804, FIG. 8) for decoding a CQI value, using a fixed or default channel quality indicator (CQI) configuration if the user device is not within the specific category of user devices; means (e.g., 802A/802B and/or 804, FIG. 8) for otherwise, performing the following (operations 540, 550) if the user device is within the specific category of user devices, including means (e.g., 802A/802B and/or 804, FIG. 8) for selecting a variable channel quality indicator (CQI) configuration of a plurality of CQI configurations based on a measured channel quality, the selected CQI configuration being associated with a set of CQI values and a number of information bits used to indicate a CQI value within the set of CQI values, and means (e.g., 802A/802B and/or 804, FIG. 8) for transmitting, by the base station to the user device, information identifying the selected CQI configuration to be used for transmitting CQI values from the user device to the base station.

[0093] FIG. 6 is a diagram illustrating operation of a network according to an example implementation. A user device (or UE) 132 may be in communication with BS 134. At 610, user device 132 may send reference signals, or other control signals, to BS 134. At 612, BS 134 may measure a channel quality, and/or determine a UE property (such as a UE type, or UE category of UE 134, such as whether or not the UE 132 is a high reliability UE or URLLC UE or not).

[0094] At 614, the BS 134 may select a CQI configuration, out of a plurality of CQI configurations, based on the measured channel quality or the UE property (e.g., UE category) for UE 132. Each CQI configuration may be associated with a set of CQI values and a number (k) of CQI information bits. The BS 134 may receive signals from

user device 132, e.g., indicating capabilities of the UE, such as via or during random access or other communication message from the user device 132, which may indicate one or more UE properties, e.g., indicating whether the user device 132 is a high reliability or URLLC UE, or not.

[0095] At 616, the BS 134 may send or transmit to the user device 132 information identifying the selected CQI configuration.

[0096] At 618, the user device 132 may measure a channel quality (e.g., SINR, RSRP, RSRQ, …)

[0097] At 620, the user device 132 may determine a CQI value of the set of CQI values associated with the selected CQI configuration.

[0098] At 622, the user device 132 may encode the CQI value, e.g., based on the channel quality measured by the user device 132. Thus, the user device 132 may encode the k bit CQI value (which may be fewer bits than the standard CQI value used for non URLLC UEs, for example, or used for normal or standard quality channels) into an n bit encoded CQI value.

[0099] At 624, the user device 132 may transmit the encoded CQI value (e.g., with a lower or variable code rate, based on the lower number of CQI information bits for the CQI value) to the BS 134.

[00100] At 626, the BS 134 may decode the received CQI value. At 628, the BS 134 may select a transmission format, e.g., MCS, to be used to transmit data to the user device 132.

[00101] At 630 and 632, the BS 134 transmits data to the user device 132 based on the selected transmission format. At 634, the BS 134 may measure or determine an updated channel quality, and if the channel quality has changed or changed by more than a threshold, then a new CQI configuration may be determined, and then information identifying the updated or new CQI configuration to the user device 132, and the operations shown in FIG. 6 may repeat for the updated or new CQI configuration.

[00102] FIG. 7 is a diagram illustrating operation of a network according to another example implementation. A user device (or UE) 132 may be in communication with BS 134.

[00103] At 710, the user device 132 may send or transmit information to the BS

134 that indicates a UE property (e.g., UE category, which may indicate whether the user device 132 is a high reliability UE or URLLC UE, or not).

[00104] At 712, the BS 134 may determine the UE property of the user device 132, e.g., determine whether the user device 132 is a high reliability UE or URLLC UE.

[00105] At 714, if the user device 132 is a non-high reliability or a non-URLLC UE, then 1) the user device 132 may use a fixed(or default or standard or non-high reliability CQI configuration) CQI configuration to select and encode a CQI value for transmission to the BS 134, and 2) the BS 134 may use the fixed or default CQI configuration to decode the CQI value received from user device 132.

[00106] At 716, otherwise, operations 614, 616, 618, 620 and 622 are performed if user device 132 is a high reliability UE or URLLC UE, which may include selecting a variable CQI configuration based on a channel quality, and then having the user device 132 use the selected CQI configuration to encode a CQI value for transmission for high reliability or URLLC UE.

[00107] Continuing in FIG. 7, at 624, the user device 132 may then transmit the encoded CQI value to the BS 134.

[00108] At 626, the BS 134 decodes the received encoded CQI value.

[00109] At 628, the BS 134 selects a transmission format, e.g., MCS, based on the received and decoded CQI value.

[00110] At 630 and 632, the BS 134 transmits (based on modulating and coding) data to the user device 132 based on the selected transmission format/MCS.

[00111] FIG. 8 is a block diagram of a wireless station (e.g., AP, BS, eNB (macro or micro), UE or user device) 800 according to an example implementation. The wireless station 800 may include, for example, one or two RF (radio frequency) or wireless transceivers 802A, 802B, where each wireless transceiver includes a transmitter to transmit signals and a receiver to receive signals. The wireless station also includes a processor or control unit/entity (controller) 804 to execute instructions or software and control transmission and receptions of signals, and a memory 806 to store data and/or instructions.

[00112] Processor 804 may also make decisions or determinations, generate frames, packets or messages for transmission, decode received frames or messages for

further processing, and other tasks or functions described herein. Processor 804, which may be a baseband processor, for example, may generate messages, packets, frames or other signals for transmission via wireless transceiver 802 (802A or 802B). Processor 804 may control transmission of signals or messages over a wireless network, and may control the reception of signals or messages, etc., via a wireless network (e.g., after being down-converted by wireless transceiver 802, for example). Processor 804 may be programmable and capable of executing software or other instructions stored in memory or on other computer media to perform the various tasks and functions described above, such as one or more of the tasks or methods described above. Processor 804 may be (or may include), for example, hardware, programmable logic, a programmable processor that executes software or firmware, and/or any combination of these. Using other terminology, processor 804 and transceiver 802 together may be considered as a wireless transmitter/receiver system, for example.

[00113] In addition, referring to FIG. 8, a controller (or processor) 808 may execute software and instructions, and may provide overall control for the station 800, and may provide control for other systems not shown in FIG. 8, such as controlling input/output devices (e.g., display, keypad), and/or may execute software for one or more applications that may be provided on wireless station 800, such as, for example, an email program, audio/video applications, a word processor, a Voice over IP application, or other application or software.

[00114] In addition, a storage medium may be provided that includes stored instructions, which when executed by a controller or processor may result in the processor 804, or other controller or processor, performing one or more of the functions or tasks described above.

[00115] According to another example implementation, RF or wireless transceiver(s) 802A/802B may receive signals or data and/or transmit or send signals or data. Processor 804 (and possibly transceivers 802A/802B) may control the RF or wireless transceiver 802A or 802B to receive, send, broadcast or transmit signals or data.

[00116] The embodiments are not, however, restricted to the system that is given as an example, but a person skilled in the art may apply the solution to other communication systems. Another example of a suitable communications system is the 5G

concept. It is assumed that network architecture in 5G will be quite similar to that of the LTE-advanced. 5G is likely to use multiple input – multiple output (MIMO) antennas, many more base stations or nodes than the LTE (a so-called small cell concept), including macro sites operating in co-operation with smaller stations and perhaps also employing a variety of radio technologies for better coverage and enhanced data rates.

[00117] It should be appreciated that future networks will most probably utilize network functions virtualization (NFV) which is a network architecture concept that proposes virtualizing network node functions into "building blocks" or entities that may be operationally connected or linked together to provide services. A virtualized network function (VNF) may comprise one or more virtual machines running computer program codes using standard or general type servers instead of customized hardware. Cloud computing or data storage may also be utilized. In radio communications this may mean node operations may be carried out, at least partly, in a server, host or node operationally coupled to a remote radio head. It is also possible that node operations will be distributed among a plurality of servers, nodes or hosts. It should also be understood that the distribution of labor between core network operations and base station operations may differ from that of the LTE or even be non-existent.

[00118] Implementations of the various techniques described herein may be implemented in digital electronic circuitry, or in computer hardware, firmware, software, or in combinations of them. Implementations may be implemented as a computer program product, i.e., a computer program tangibly embodied in an information carrier, e.g., in a machine-readable storage device or in a propagated signal, for execution by, or to control the operation of, a data processing apparatus, e.g., a programmable processor, a computer, or multiple computers. Implementations may also be provided on a computer readable medium or computer readable storage medium, which may be a non-transitory medium. Implementations of the various techniques may also include implementations provided via transitory signals or media, and/or programs and/or software implementations that are downloadable via the Internet or other network(s), either wired networks and/or wireless networks. In addition, implementations may be provided via machine type communications (MTC), and also via an Internet of Things (IOT).

[00119] The computer program may be in source code form, object code form, or

in some intermediate form, and it may be stored in some sort of carrier, distribution medium, or computer readable medium, which may be any entity or device capable of carrying the program. Such carriers include a record medium, computer memory, read-only memory, photoelectrical and/or electrical carrier signal, telecommunications signal, and software distribution package, for example. Depending on the processing power needed, the computer program may be executed in a single electronic digital computer or it may be distributed amongst a number of computers.

[00120] Furthermore, implementations of the various techniques described herein may use a cyber-physical system (CPS) (a system of collaborating computational elements controlling physical entities). CPS may enable the implementation and exploitation of massive amounts of interconnected ICT devices (sensors, actuators, processors microcontrollers,...) embedded in physical objects at different locations. Mobile cyber physical systems, in which the physical system in question has inherent mobility, are a subcategory of cyber-physical systems. Examples of mobile physical systems include mobile robotics and electronics transported by humans or animals. The rise in popularity of smartphones has increased interest in the area of mobile cyber-physical systems. Therefore, various implementations of techniques described herein may be provided via one or more of these technologies.

[00121] A computer program, such as the computer program(s) described above, can be written in any form of programming language, including compiled or interpreted languages, and can be deployed in any form, including as a stand-alone program or as a module, component, subroutine, or other unit or part of it suitable for use in a computing environment. A computer program can be deployed to be executed on one computer or on multiple computers at one site or distributed across multiple sites and interconnected by a communication network.

[00122] Method steps may be performed by one or more programmable processors executing a computer program or computer program portions to perform functions by operating on input data and generating output. Method steps also may be performed by, and an apparatus may be implemented as, special purpose logic circuitry, e.g., an FPGA (field programmable gate array) or an ASIC (application-specific integrated circuit).

[00123] Processors suitable for the execution of a computer program include, by

way of example, both general and special purpose microprocessors, and any one or more processors of any kind of digital computer, chip or chipset. Generally, a processor will receive instructions and data from a read-only memory or a random access memory or both. Elements of a computer may include at least one processor for executing instructions and one or more memory devices for storing instructions and data. Generally, a computer also may include, or be operatively coupled to receive data from or transfer data to, or both, one or more mass storage devices for storing data, e.g., magnetic, magneto-optical disks, or optical disks. Information carriers suitable for embodying computer program instructions and data include all forms of non-volatile memory, including by way of example semiconductor memory devices, e.g., EPROM, EEPROM, and flash memory devices; magnetic disks, e.g., internal hard disks or removable disks; magneto-optical disks; and CD-ROM and DVD-ROM disks. The processor and the memory may be supplemented by, or incorporated in, special purpose logic circuitry.

[00124] To provide for interaction with a user, implementations may be implemented on a computer having a display device, e.g., a cathode ray tube (CRT) or liquid crystal display (LCD) monitor, for displaying information to the user and a user interface, such as a keyboard and a pointing device, e.g., a mouse or a trackball, by which the user can provide input to the computer. Other kinds of devices can be used to provide for interaction with a user as well; for example, feedback provided to the user can be any form of sensory feedback, e.g., visual feedback, auditory feedback, or tactile feedback; and input from the user can be received in any form, including acoustic, speech, or tactile input.

[00125] Implementations may be implemented in a computing system that includes a back-end component, e.g., as a data server, or that includes a middleware component, e.g., an application server, or that includes a front-end component, e.g., a client computer having a graphical user interface or a Web browser through which a user can interact with an implementation, or any combination of such back-end, middleware, or front-end components. Components may be interconnected by any form or medium of digital data communication, e.g., a communication network. Examples of communication networks include a local area network (LAN) and a wide area network (WAN), e.g., the Internet.

[00126] While certain features of the described implementations have been illustrated as described herein, many modifications, substitutions, changes and equivalents will now occur to those skilled in the art. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit of the various embodiments.

WHAT IS CLAIMED IS:

1. A method comprising:

determining, by a base station, a channel quality for a wireless channel between the base station and a user device;

selecting a channel quality indicator (CQI) configuration of a plurality of CQI configurations based on either the channel quality or a property of the user device, the selected CQI configuration being associated with a set of CQI values and a number of information bits used to indicate a CQI value within the set of CQI values; and

transmitting, by the base station to the user device, information identifying the selected CQI configuration to be used for transmitting CQI values from the user device to the base station.

2. The method of claim 1 wherein the property of the user device comprises determining whether or not the user device requires high reliability communication.

3. The method of any of claims 1-2 wherein the property of the user device comprises determining whether or not the user device is an ultra-reliable, low latency user device or the user device requires ultra-reliable, low latency communications or service.

4. The method of any of claims 1-3 and further comprising:

receiving, by the base station from the user device, an encoded CQI value that is one CQI value within the set of CQI values associated with the selected CQI configuration;

decoding, by the base station, the CQI value;

selecting, by the base station, a transmission format based on the CQI value; and

transmitting, by the base station to the user device, data based on the selected transmission format.

5. The method of claim 4 wherein the selecting a transmission format comprises selecting a modulation and coding scheme (MCS) based on the CQI value.

6. The method of any of claims 1-5 wherein the determining, by a base station, a channel quality for a wireless channel between the base station and a user device comprises at least one of the following:

receiving, by the base station from the user device, channel quality information for a downlink channel between the base station and the user device; and

measuring, by the base station based on received reference signals, a channel quality of an uplink channel between the user device and the base station.

7. The method of any of claims 1-6 wherein the selecting a CQI configuration comprises:

selecting a channel quality indicator (CQI) configuration of a plurality of CQI configurations based on the channel quality, wherein a first CQI configuration associated with a greater number of information bits is selected for a higher quality channel, and wherein a second CQI configuration associated with a fewer number of information bits is selected for a lower quality channel.

8. The method of any of claims 1-7 wherein:

a lower coding rate is associated with a CQI value, received by the base station from the user device, for a lower channel quality based on fewer information bits for the CQI value; and

a higher coding rate is associated with a CQI value, received by the base station from the user device, for a higher channel quality based on greater information bits for the CQI value.

9. The method of any of claims 1-8 wherein:

a lower coding rate is associated with a CQI value received by the base station from the user device based on fewer information bits for the CQI value, where the user device requires high reliability communications; and

a higher coding rate is associated with a CQI value received by the base station from the user device based on greater information bits for the CQI value, where the user device does not require high reliability communications.

10. The method of any of claims 1-9 wherein:

a CQI configuration, having fewer information bits for each CQI value within the set of CQI values of the CQI configuration, is selected for a high reliability user device that requires high reliability communications to thereby provide a decreased code rate for a CQI value transmitted by a high reliability user device; and

a CQI configuration, having greater information bits for each CQI value within the set of CQI values of the CQI configuration, is selected for a non-high reliability user device that does not require high reliability communications to thereby provide an increased code rate for a CQI value transmitted by a non-high reliability user device.

11. The method of any of claims 1-10 wherein a first set of CQI values uses a first number of information bits for each CQI value within the first set of CQI values are used for a channel quality that is greater than a threshold, and a second set of CQI values having a second number of information bits, which are less than the first number of information bits, are used for a channel quality that is greater than a threshold.

12. The method of any of claims 1-11 and further comprising:

determining whether the channel quality is less than a threshold;

wherein the selecting a CQI configuration comprises:

selecting, by the base station, if the channel quality is not less than the threshold, a first CQI configuration associated with a first set of CQI values having a first number of CQI values; and

selecting, by the base station, if the channel quality is worse than the threshold, a second CQI configuration associated with a second set of CQI values having a second number of CQI values that is less than the first number of CQI values.

13. An apparatus comprising means for performing the method of any of claims 1-12.

14. An apparatus comprising at least one processor and at least one memory including computer instructions, when executed by the at least one processor, cause the apparatus to perform a method of any of claims 1-12.

15. A method comprising:

determining, by a base station, whether a user device is within a specific category of user devices;

allocating, by the base station, a first size of uplink resources to the user device for the transmission of a channel quality indicator (CQI) if the user device is not within the specific category of user devices;

otherwise, allocating a second size of uplink resources, which is greater than the first size of uplink resources, to the user device for the transmission of a channel quality indicator (CQI) if the user device is within the specific category of user devices so that a lower coding rate will be used by the user device to encode a CQI value for transmission to the base station.

16. The method of claim 15 wherein the specific category of user devices comprises user devices that require an ultra-reliable, low-latency communications.

17. The method of any of claims 15-16 wherein the second size of uplink resources is greater than the first size of uplink resources.

18. An apparatus comprising means for performing the method of any of claims 15-17.

19. An apparatus comprising at least one processor and at least one memory including computer instructions, when executed by the at least one processor, cause the apparatus to perform a method of any of claims 15-17.

20. A method comprising:

receiving, by a user device from a base station, information identifying a selected channel quality indicator (CQI) configuration, of a plurality of CQI configurations, to be used to transmit a CQI value, the selected CQI configuration associated with a set of CQI values and a number of information bits used to indicate a CQI value within the set of CQI values;

determining, by the user device, a channel quality of a user device-base station wireless channel;

determining, by the user device based on the channel quality, a CQI value of a set of CQI values associated with the selected CQI configuration;

encoding, by the user device, the CQI value; and

transmitting, by the user device to the base station, the encoded CQI value.

21. An apparatus comprising means for performing the method of claim 20.

22. An apparatus comprising at least one processor and at least one memory including computer instructions, when executed by the at least one processor, cause the apparatus to perform a method of claim 20.

23. A method comprising:

determining, by a base station, whether a user device is within a specific category of user devices;

decoding a CQI value, using a fixed or default channel quality indicator (CQI) configuration if the user device is not within the specific category of user devices; and

otherwise, performing the following if the user device is within the specific category of user devices:

selecting a variable channel quality indicator (CQI) configuration of a plurality of CQI configurations based on a measured channel quality, the selected CQI configuration being associated with a set of CQI values and a number of information bits used to indicate a CQI value within the set of CQI values; and

transmitting, by the base station to the user device, information identifying the selected CQI configuration to be used for transmitting CQI values from the user device to the base station.

24. The method of claim 23 wherein the specific category of user devices comprises user devices that require high reliability communications.

25. The method of any of claims 23-24 wherein the specific category of user devices comprises user devices that require ultra-reliable, low-latency communications.

26. The method of any of claims 23-25 and further comprising performing the following if the user device is within the specific category of user devices:

receiving, by the base station from the user device, an encoded CQI value that is one CQI value within the set of CQI values associated with the selected CQI configuration;

decoding, by the base station, the CQI value;

selecting, by the base station, a transmission format based on the CQI value;

transmitting, by the base station to the user device, data based on the selected transmission format.

27. An apparatus comprising means for performing the method of any of claims 23-26.

28. An apparatus comprising at least one processor and at least one memory including computer instructions, when executed by the at least one processor, cause the apparatus to perform a method of any of claims 23-26.

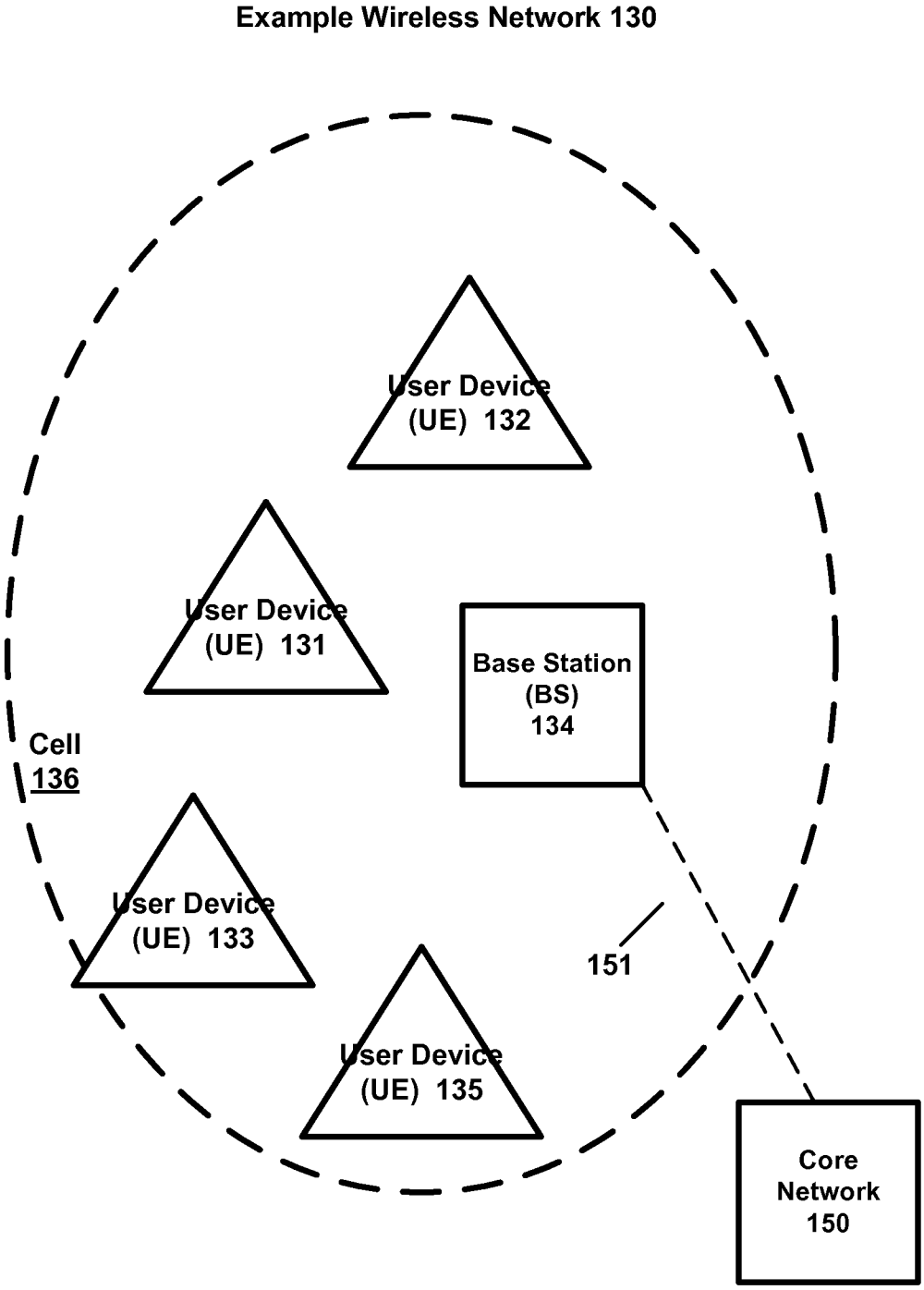
Example Wireless Network 130
User Device
(UE) 132
User Device
(UE) 131
Base Station
(BS)
134
Cell
136
User Device
(UE) 133
151
User Device
(UE) 135
Core
Network
150

FIG. 1

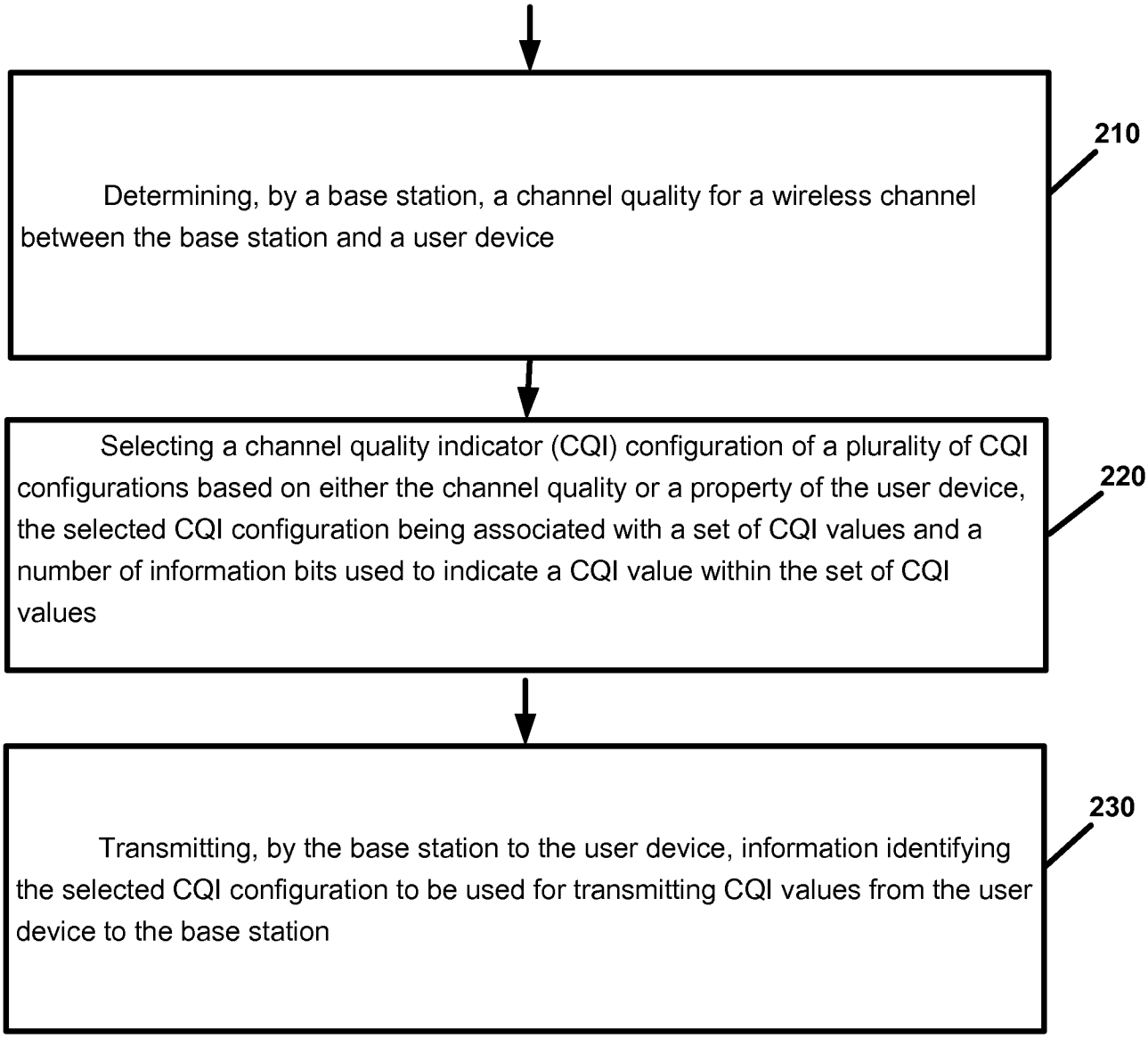
Determining, by a base station, a channel quality for a wireless channel between the base station and a user device
210
Selecting a channel quality indicator (CQI) configuration of a plurality of CQI configurations based on either the channel quality or a property of the user device, the selected CQI configuration being associated with a set of CQI values and a number of information bits used to indicate a CQI value within the set of CQI values
220
Transmitting, by the base station to the user device, information identifying the selected CQI configuration to be used for transmitting CQI values from the user device to the base station
230

FIG. 2

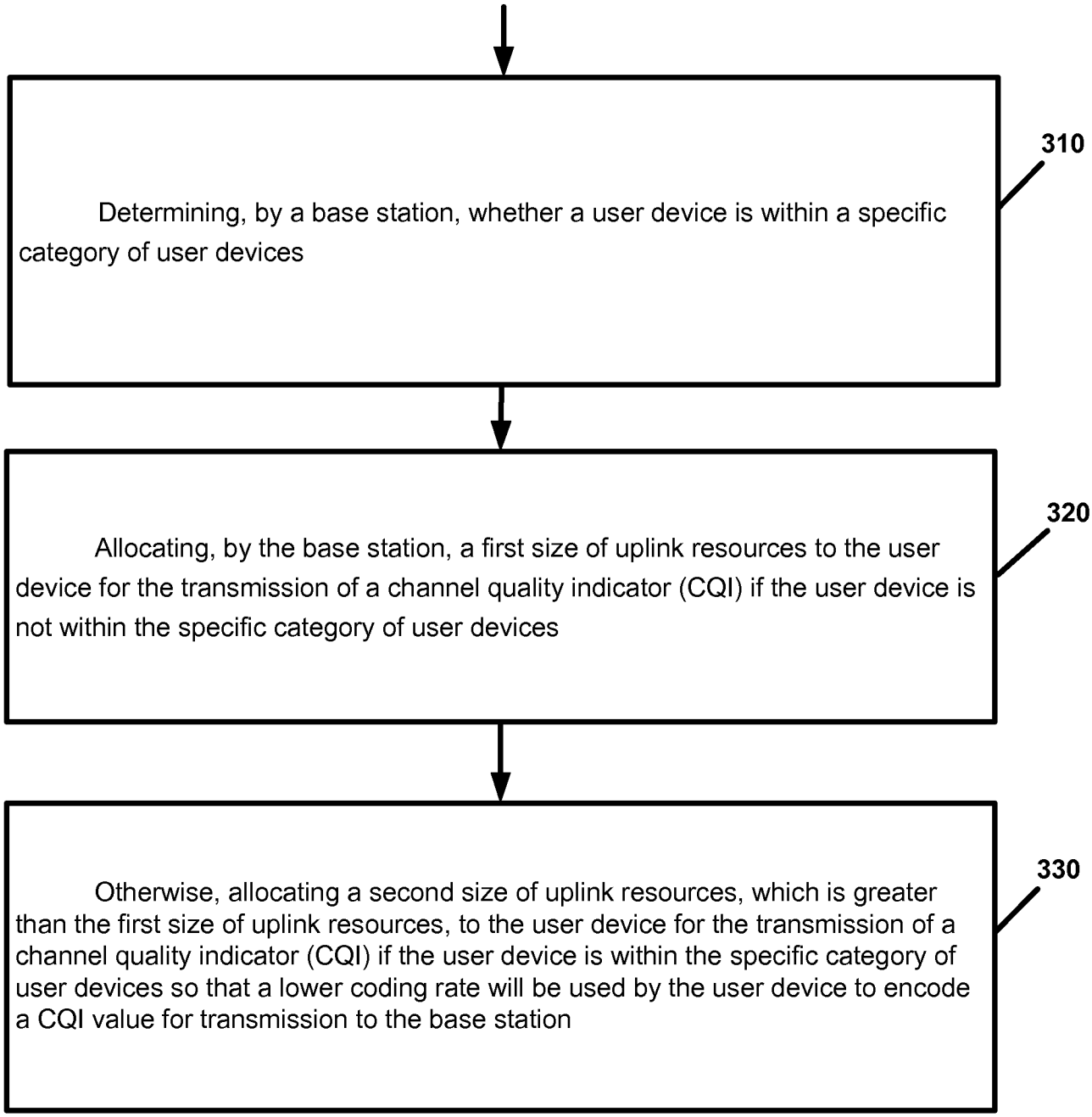
Determining, by a base station, whether a user device is within a specific category of user devices
310
Allocating, by the base station, a first size of uplink resources to the user device for the transmission of a channel quality indicator (CQI) if the user device is not within the specific category of user devices
320
Otherwise, allocating a second size of uplink resources, which is greater than the first size of uplink resources, to the user device for the transmission of a channel quality indicator (CQI) if the user device is within the specific category of user devices so that a lower coding rate will be used by the user device to encode a CQI value for transmission to the base station
330

FIG. 3

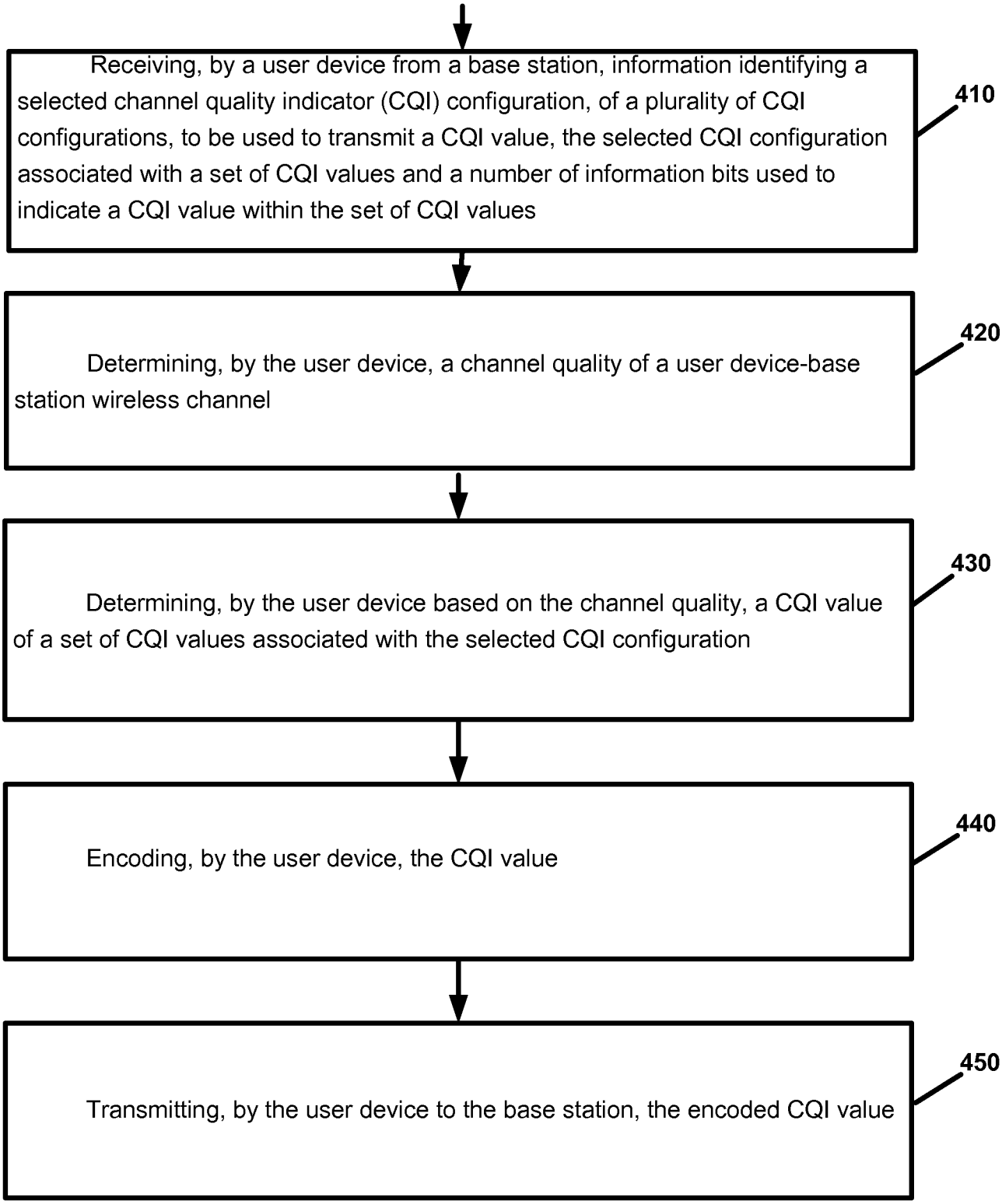
Receiving, by a user device from a base station, information identifying a selected channel quality indicator (CQI) configuration, of a plurality of CQI configurations, to be used to transmit a CQI value, the selected CQI configuration associated with a set of CQI values and a number of information bits used to indicate a CQI value within the set of CQI values
410
Determining, by the user device, a channel quality of a user device-base station wireless channel
420
Determining, by the user device based on the channel quality, a CQI value of a set of CQI values associated with the selected CQI configuration
430
Encoding, by the user device, the CQI value
440
Transmitting, by the user device to the base station, the encoded CQI value
450

FIG. 4

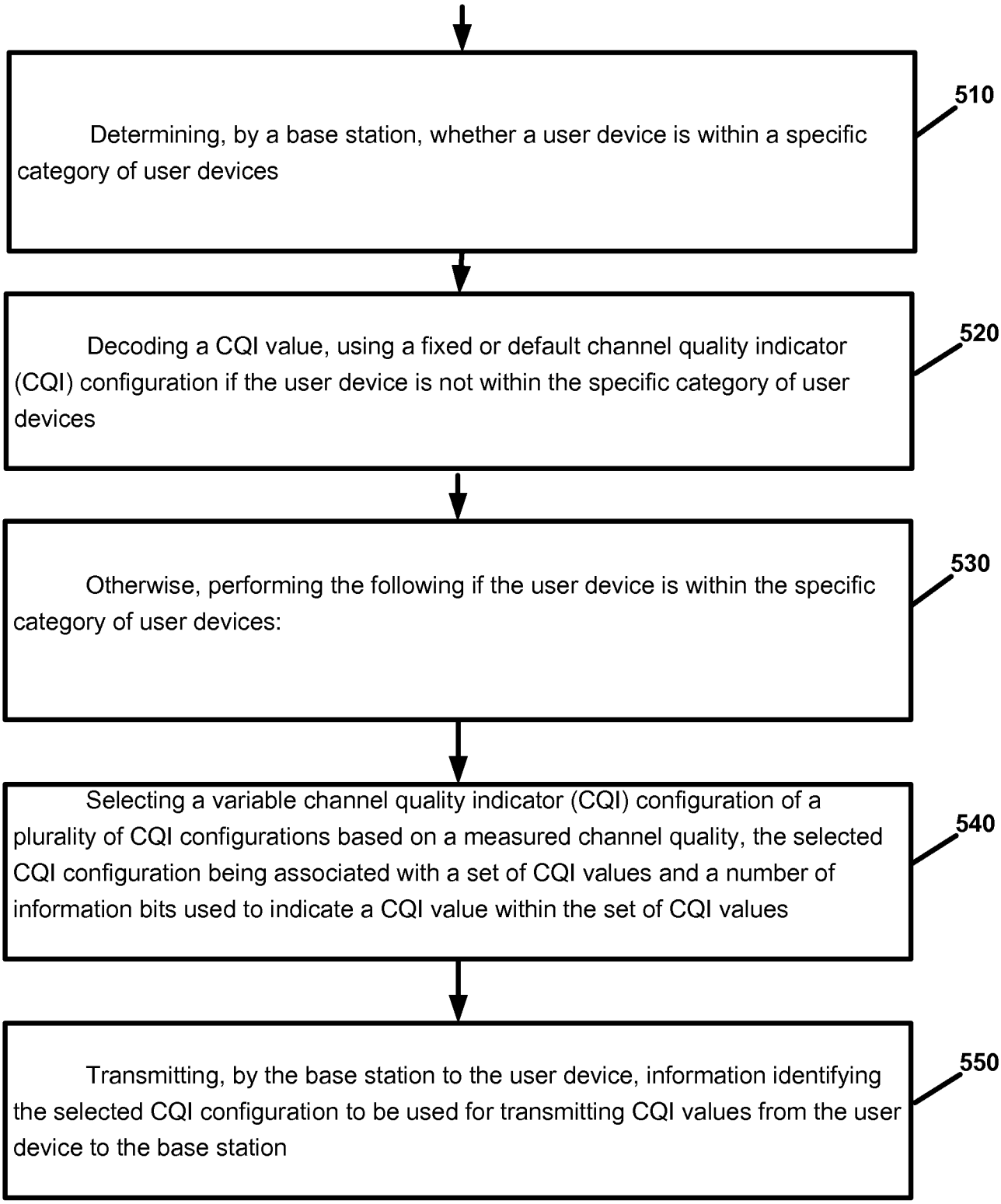
Determining, by a base station, whether a user device is within a specific category of user devices
510
Decoding a CQI value, using a fixed or default channel quality indicator (CQI) configuration if the user device is not within the specific category of user devices
520
Otherwise, performing the following if the user device is within the specific category of user devices:
530
Selecting a variable channel quality indicator (CQI) configuration of a plurality of CQI configurations based on a measured channel quality, the selected CQI configuration being associated with a set of CQI values and a number of information bits used to indicate a CQI value within the set of CQI values
540
Transmitting, by the base station to the user device, information identifying the selected CQI configuration to be used for transmitting CQI values from the user device to the base station
550

FIG. 5

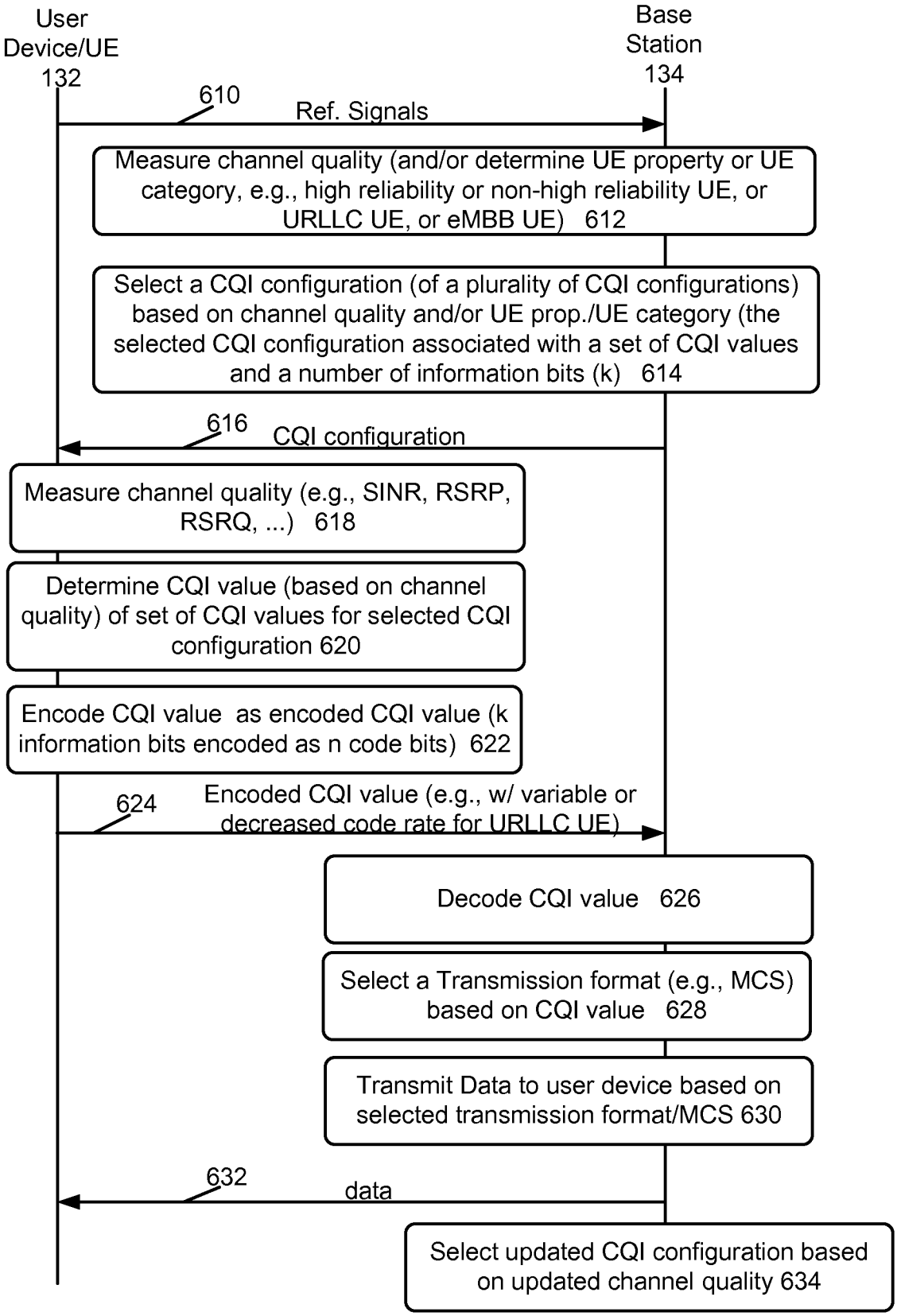
User Device/UE 132
Base Station 134
610
Ref. Signals
Measure channel quality (and/or determine UE property or UE category, e.g., high reliability or non-high reliability UE, or URLLC UE, or eMBB UE) 612
Select a CQI configuration (of a plurality of CQI configurations) based on channel quality and/or UE prop./UE category (the selected CQI configuration associated with a set of CQI values and a number of information bits (k) 614
616
CQI configuration
Measure channel quality (e.g., SINR, RSRP, RSRQ, ...) 618
Determine CQI value (based on channel quality) of set of CQI values for selected CQI configuration 620
Encode CQI value as encoded CQI value (k information bits encoded as n code bits) 622
624
Encoded CQI value (e.g., w/ variable or decreased code rate for URLLC UE)
Decode CQI value 626
Select a Transmission format (e.g., MCS) based on CQI value 628
Transmit Data to user device based on selected transmission format/MCS 630
632
data
Select updated CQI configuration based on updated channel quality 634

FIG. 6

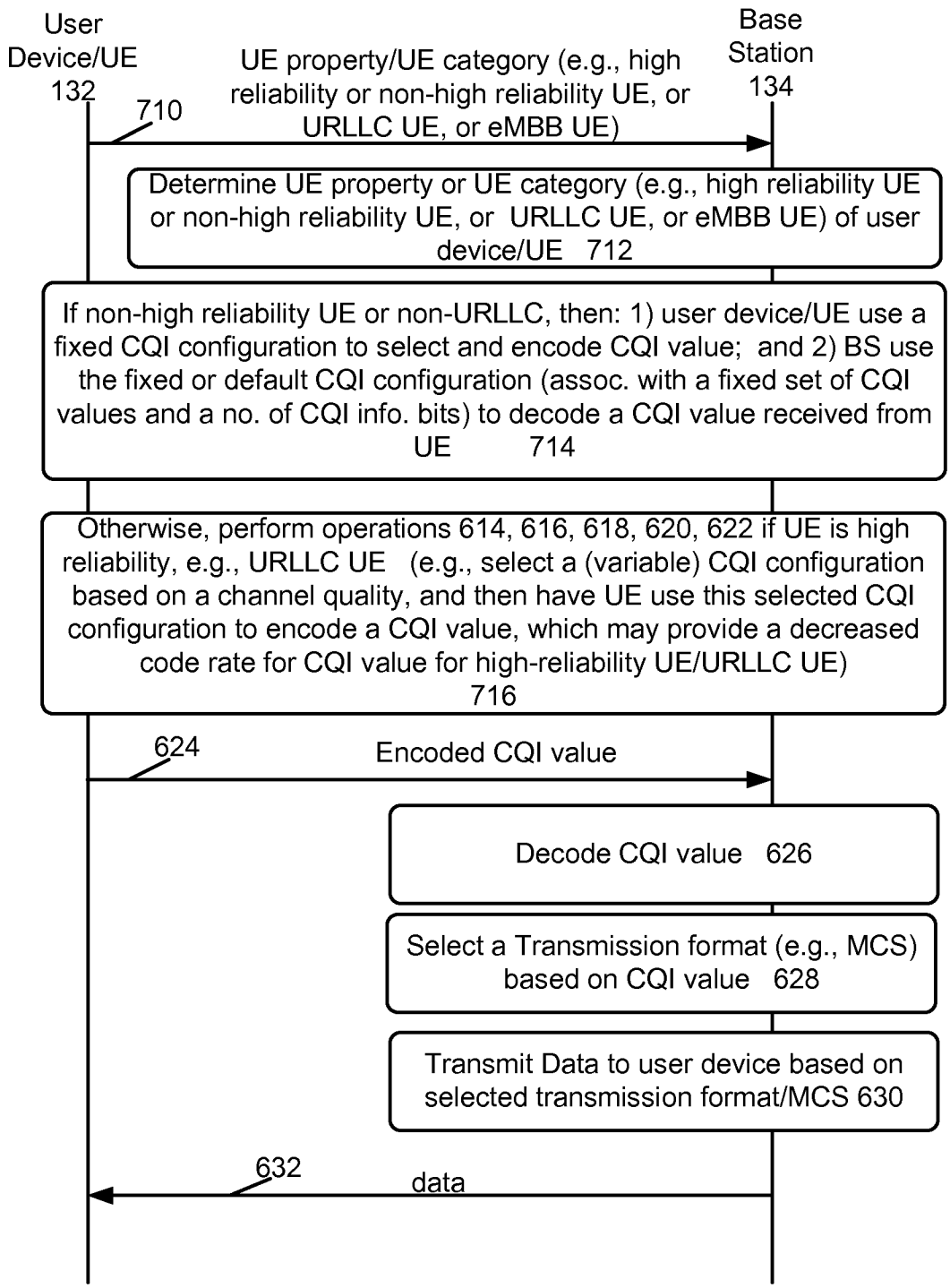
User Device/UE 132
Base Station 134
710
UE property/UE category (e.g., high reliability or non-high reliability UE, or URLLC UE, or eMBB UE)
Determine UE property or UE category (e.g., high reliability UE or non-high reliability UE, or URLLC UE, or eMBB UE) of user device/UE 712
If non-high reliability UE or non-URLLC, then: 1) user device/UE use a fixed CQI configuration to select and encode CQI value; and 2) BS use the fixed or default CQI configuration (assoc. with a fixed set of CQI values and a no. of CQI info. bits) to decode a CQI value received from UE 714
Otherwise, perform operations 614, 616, 618, 620, 622 if UE is high reliability, e.g., URLLC UE (e.g., select a (variable) CQI configuration based on a channel quality, and then have UE use this selected CQI configuration to encode a CQI value, which may provide a decreased code rate for CQI value for high-reliability UE/URLLC UE) 716
624
Encoded CQI value
Decode CQI value 626
Select a Transmission format (e.g., MCS) based on CQI value 628
Transmit Data to user device based on selected transmission format/MCS 630
632
data

FIG. 7

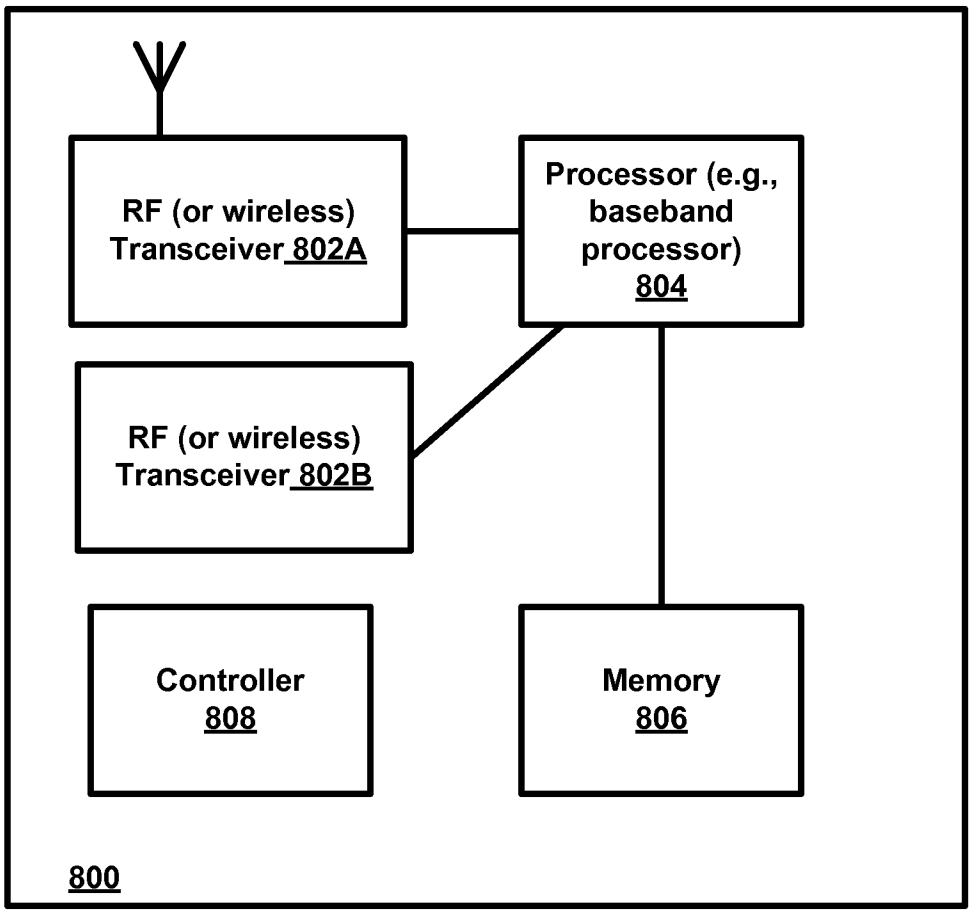
RF (or wireless) Transceiver 802A
Processor (e.g., baseband processor) 804
RF (or wireless) Transceiver 802B
Controller 808
Memory 806
800

FIG. 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/077725

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04L1/00
ADD. H04W84/10

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 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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2016/122380 A1 (ERICSSON TELEFON AB L M [SE]) 4 August 2016 (2016-08-04)	1,4-6, 13,14, 20-23, 26-28
Y	page 1, line 5 - page 5, line 23 page 9, line 11 - page 24, line 18 page 26, line 21 - page 27, line 21 tables 1,2,4 figures 3,4	2,3, 7-12, 15-19, 24,25

Y	US 2007/058676 A1 (LIM CHI-WOO [KR] ET AL) 15 March 2007 (2007-03-15)	2,3, 7-12, 15-19, 24,25
A	paragraphs [0028] - [0067]	1,4-6, 13,14, 20-23, 26-28

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[X] Further documents are listed in the continuation of Box C.

[X] 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
7 August 2017	18/08/2017

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	Papanikolaou, Eleni

2

Form PCT/ISA/210 (second sheet) (April 2005)

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	SAMSUNG: "Discussions on service specific CSI for NR", 3GPP DRAFT; R1-1612508 SERVICE SPECIFIC CSI FOR NR, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG1, no. Reno, USA; 20161114 - 20161118 4 November 2016 (2016-11-04), XP051189384, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_87/Docs/ [retrieved on 2016-11-04] the whole document -----	1-28

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2016/077725

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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