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(54) **Title:** METHOD FOR CHANNEL STATE INFORMATION, USER EQUIPMENT, AND BASE STATION

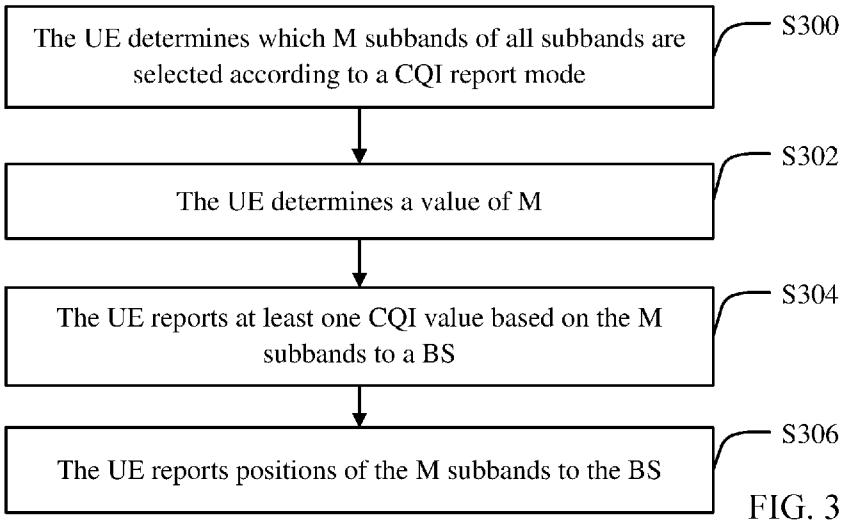


FIG. 3

(57) **Abstract:** A method for channel state information (CSI) executable in a user equipment (UE) includes: determining which M subbands of all subbands are selected according to a CQI report mode, wherein each of the subbands includes at least one physical resource block (PRB); determining a value of M; reporting at least one CQI value based on the M subbands to a base station (BS); and reporting positions of the M subbands to the BS.

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METHOD FOR CHANNEL STATE INFORMATION, USER EQUIPMENT, AND BASE STATION

Technical Field

[0001] The present disclosure relates to the field of communication systems, and more particularly, to a method for channel state information (CSI), a user equipment, and a base station.

Background Art

[0002] Wireless communication systems and networks have developed towards being a broadband and mobile system. In cellular wireless communication systems, user equipment (UE) is connected by a wireless link to a radio access network (RAN). The RAN comprises a set of base stations (BSs) which provide wireless links to the UEs located in cells covered by the base station, and an interface to a core network (CN) which provides overall network control. As will be appreciated the RAN and CN each conduct respective functions in relation to the overall network. The 3rd Generation Partnership Project (3GPP) has developed the so-called Long Term Evolution (LTE) system, namely, an Evolved Universal Mobile Telecommunication System Territorial Radio Access Network, (E-UTRAN), for a mobile access network where one or more macro-cells are supported by a base station known as an eNodeB or eNB (evolved NodeB). More recently, LTE is evolving further towards the so-called 5G or NR (new radio) systems where one or more cells are supported by a base station known as a gNB.

[0003] Ultra-reliable low-latency communication (URLLC), is one of several different types of use cases supported by the 5G NR standard, as stipulated by 3GPP Release 15. URLLC is a communication service for successfully delivering packets with stringent requirements, particularly in terms of availability, latency, and reliability. URLLC is developed to support the emerging applications and services, such as wireless control and automation in industrial factory environments, inter-vehicular communications for improved safety and efficiency, and the tactile internet. Thus, URLLC is important for 5G as it supports verticals bringing new business to the whole telecommunication industry.

[0004] One of the key features of URLLC is low latency which is the key point to make autonomous vehicle and remote surgeries possible. Low latency allows a network to be optimized for processing incredibly large amounts of data with minimal delay or latency. URLLC requires a quality of service (QoS) totally different from mobile broadband services.

[0005] URLLC guarantees latency to be 1ms or less. Time-sensitive networking (TSN) is another component of the 5G URLLC. All devices along a URLLC connection have to synchronize on the same time-base. Enabling technologies for URLLC, for example, include: integrated frame structure, incredibly fast turnaround, efficient control and data resource sharing, grant-free based uplink transmission, and advanced channel coding schemes.

Technical Problem

[0006] Channel state information (CSI) feedback enhancements in 3GPP Release 17 URLLC/Industrial Internet of Things (IIoT) WI can select more accurate modulation and coding schemes (MCS). In addition, to fulfil the requirements of low latency for URLLC services, subband CSI reporting enhancements and reduction of CSI reporting complexity are required.

Technical Solution

[0007] An object of the present disclosure is to propose a method for channel state information (CSI), a user equipment, and a base station.

[0008] A first aspect of the present disclosure provides a method for channel state information (CSI) executable in a user equipment (UE), including: determining which M subbands of all subbands are selected according to a CQI

report mode, wherein each of the subbands includes at least one physical resource block (PRB); determining a value of M; reporting at least one CQI value based on the M subbands to a base station (BS); and reporting positions of the M subbands to the BS.

[0009] In one embodiment of the present disclosure, each of the M subbands has a CQI value, and the determining which M subbands of all the subbands are selected includes: sorting the CQI values of all of the subbands; and selecting the M subbands having the worst M CQI values.

[0010] In one embodiment of the present disclosure, the M subbands of the subbands are selected randomly.

[0011] In one embodiment of the present disclosure, M is configured by downlink control information (DCI), higher layer parameters, or radio resource control (RRC) parameters.

[0012] In one embodiment of the present disclosure, M is determined by a size of a bandwidth part (BWP).

[0013] In one embodiment of the present disclosure, M is one-to-one correlation with a subband size.

[0014] In one embodiment of the present disclosure, the reporting the at least one CQI value based on the M subbands to the base station (BS) includes: reporting the CQI values of the M subbands to the BS.

[0015] In one embodiment of the present disclosure, the reporting the at least one CQI value based on the M subbands to the base station (BS) includes: reporting a statistic CQI value to the BS.

[0016] In one embodiment of the present disclosure, the statistic CQI value includes an average of the CQI values of the M subbands and a CQI variance of the M subbands.

[0017] In one embodiment of the present disclosure, a maximum or minimum one of the CQI values of the M subbands is reported with the statistic CQI value.

[0018] In one embodiment of the present disclosure, a size of a bitmap to express the positions of the M subbands is $\lceil log_2(\mathrm{N}) \rceil$, and N is a total number of the subbands.

[0019] In one embodiment of the present disclosure, only the at least one CQI value is reported to the BS based on setting of a higher layer parameter reportQuantity.

[0020] In one embodiment of the present disclosure, a signal to interference plus noise ratio (SINR) is reported to the BS with the at least one CQI value based on setting of a higher layer parameter reportQuantity.

[0021] In one embodiment of the present disclosure, a subband Offset level (s) of each of the M subbands is defined as: subband offset level (s) = subband CQI index (s) - benchmark CQI index; a subband differential CQI value each of the M subbands is acquired according to the subband Offset level (s) of each of the M subbands; wherein the reporting at least one CQI value to the base station (BS) includes: reporting the subband differential CQI value each of the M subbands to the BS.

[0022] In one embodiment of the present disclosure, the benchmark CQI index is an average of the CQI values of all of the subbands.

[0023] In one embodiment of the present disclosure, the benchmark CQI index is one of the subbands having the best CQI value.

[0024] In one embodiment of the present disclosure, the benchmark CQI index is one of the subbands having the worst CQI value.

[0025] In one embodiment of the present disclosure, at least one reporting strategy for the reporting the at least one CQI value based on the M subbands to the base station (BS) is determined based on a size of a bandwidth part (BWP).

[0026] In one embodiment of the present disclosure, at least one reporting strategy for the reporting the at least one

CQI value based on the M subbands to the base station (BS) is determined based on a number of the subbands.

[0027] In one embodiment of the present disclosure, a priority of a CSI report to the BS is associated with an ultra-reliable low-latency communication (URLLC) service.

[0028] In one embodiment of the present disclosure, a priority of a CSI report to the BS is associated with an enhanced mobile broadband (eMBB) service.

[0029] In one embodiment of the present disclosure, a priority of a CSI report to the BS is associated with an aperiodic CSI (A-CSI) report to be carried on a physical uplink control channel (PUCCH).

[0030] In one embodiment of the present disclosure, a priority of a CSI report to the BS is associated with an aperiodic CSI (A-CSI) report to be carried on a physical uplink shared channel (PUSCH).

[0031] In one embodiment of the present disclosure, a priority of the reporting the at least one CQI value based on the M subbands to the base station (BS) is associated with one of an ultra-reliable low-latency communication (URLLC) service and an enhanced mobile broadband (eMBB) service and one of an aperiodic CSI (A-CSI) report to be carried on a physical uplink control channel (PUCCH), an aperiodic CSI (A-CSI) report to be carried on a physical uplink shared channel (PUSCH), a semi-persistent CSI report to be carried on a physical uplink control channel (PUCCH), a semi-persistent CSI report to be carried on a physical uplink shared channel (PUSCH), and a periodic CSI report to be carried on a physical uplink control channel (PUCCH).

[0032] A second aspect of the present disclosure provides a method for channel state information (CSI) executable in a base station (BS), including: receiving at least one CQI value from a user equipment (UE), wherein the at least one CQI value is based on M subbands of all subbands, and each of the subbands includes at least one physical resource block (PRB); receiving positions of the M subbands from the UE; and selecting, according to the at least one CQI value and the positions of the M subbands, a modulation and coding scheme (MCS) for the UE.

[0033] In one embodiment of the present disclosure, M is configured by downlink control information (DCI), higher layer parameters, or radio resource control (RRC) parameters.

[0034] In one embodiment of the present disclosure, M is configured by higher layer parameters.

[0035] In one embodiment of the present disclosure, the higher layer parameters are radio resource control (RRC) parameters.

[0036] In one embodiment of the present disclosure, M is determined by a size of a bandwidth part (BWP).

[0037] In one embodiment of the present disclosure, M is one-to-one correlation with a subband size.

[0038] In one embodiment of the present disclosure, only the at least one CQI value is received based on setting of a higher layer parameter reportQuantity.

[0039] In one embodiment of the present disclosure, a signal to interference plus noise ratio (SINR) is received with the at least one CQI value based on setting of a higher layer parameter reportQuantity.

[0040] A third aspect of the present disclosure provides a user equipment including a transceiver and a processor connected with the transceiver. The processor is configured to execute the following steps including: determining which M subbands of all subbands are selected according to a CQI report mode, wherein each of the subbands includes at least one physical resource block (PRB); determining a value of M; reporting at least one CQI value based on the M subbands to a base station (BS); and reporting positions of the M subbands to the BS.

[0041] In one embodiment of the present disclosure, each of the M subbands has a CQI value, and the determining which M subbands of all the subbands are selected includes: sorting the CQI values of all of the subbands; and

selecting the M subbands having the worst M CQI values.

[0042] In one embodiment of the present disclosure, the M subbands of the subbands are selected randomly.

[0043] In one embodiment of the present disclosure, M is configured by downlink control information (DCI), higher layer parameters, or radio resource control (RRC) parameters.

[0044] In one embodiment of the present disclosure, M is determined by a size of a bandwidth part (BWP).

[0045] In one embodiment of the present disclosure, M is one-to-one correlation with a subband size.

[0046] In one embodiment of the present disclosure, the reporting the at least one CQI value based on the M subbands to the base station (BS) includes: reporting the CQI values of the M subbands to the BS.

[0047] In one embodiment of the present disclosure, the reporting the at least one CQI value based on the M subbands to the base station (BS) includes: reporting a statistic CQI value to the BS.

[0048] In one embodiment of the present disclosure, the statistic CQI value includes an average of the CQI values of the M subbands and a CQI variance of the M subbands.

[0049] In one embodiment of the present disclosure, a maximum or minimum one of the CQI values of the M subbands is reported with the statistic CQI value.

[0050] In one embodiment of the present disclosure, a size of a bitmap to express the positions of the M subbands is $\lceil log_2(N) \rceil$, and N is a total number of the subbands.

[0051] In one embodiment of the present disclosure, only the at least one CQI value is reported to the BS based on setting of a higher layer parameter reportQuantity.

[0052] In one embodiment of the present disclosure, a signal to interference plus noise ratio (SINR) is reported to the BS with the at least one CQI value based on setting of a higher layer parameter reportQuantity.

[0053] In one embodiment of the present disclosure, a subband Offset level (s) of each of the M subbands is defined as: subband offset level (s) = subband CQI index (s) - benchmark CQI index; a subband differential CQI value each of the M subbands is acquired according to the subband Offset level (s) of each of the M subbands; wherein the reporting at least one CQI value to the base station (BS) includes: reporting the subband differential CQI value each of the M subbands to the BS.

[0054] In one embodiment of the present disclosure, the benchmark CQI index is an average of the CQI values of all of the subbands.

[0055] In one embodiment of the present disclosure, the benchmark CQI index is one of the subbands having the best CQI value.

[0056] In one embodiment of the present disclosure, the benchmark CQI index is one of the subbands having the worst CQI value.

[0057] In one embodiment of the present disclosure, at least one reporting strategy for the reporting the at least one CQI value based on the M subbands to the base station (BS) is determined based on a size of a bandwidth part (BWP).

[0058] In one embodiment of the present disclosure, at least one reporting strategy for the reporting the at least one CQI value based on the M subbands to the base station (BS) is determined based on a number of the subbands.

[0059] In one embodiment of the present disclosure, a priority of a CSI report to the BS is associated with an ultra-reliable low-latency communication (URLLC) service.

[0060] In one embodiment of the present disclosure, a priority of a CSI report to the BS is associated with an enhanced mobile broadband (eMBB) service.

[0061] In one embodiment of the present disclosure, a priority of a CSI report to the BS is associated with an aperiodic CSI (A-CSI) report to be carried on a physical uplink control channel (PUCCH).

[0062] In one embodiment of the present disclosure, a priority of a CSI report to the BS is associated with an aperiodic CSI (A-CSI) report to be carried on a physical uplink shared channel (PUSCH).

[0063] In one embodiment of the present disclosure, a priority of a CSI report to the BS is associated with one of an ultra-reliable low-latency communication (URLLC) service and an enhanced mobile broadband (eMBB) service and one of an aperiodic CSI (A-CSI) report to be carried on a physical uplink control channel (PUCCH), an aperiodic CSI (A-CSI) report to be carried on a physical uplink shared channel (PUSCH), a semi-persistent CSI report to be carried on a physical uplink control channel (PUCCH), a semi-persistent CSI report to be carried on a physical uplink shared channel (PUSCH), and a periodic CSI report to be carried on a physical uplink control channel (PUCCH).

[0064] A fourth aspect of the present disclosure provides a base station including a transceiver and a processor connected with the transceiver. The processor is configured to execute the following steps including: receiving at least one CQI value from a user equipment (UE), wherein the at least one CQI value is based on M subbands of all subbands, and each of the subbands includes at least one physical resource block (PRB); receiving positions of the M subbands from the UE; and selecting, according to the at least one CQI value and the positions of the M subbands, a modulation and coding scheme (MCS) for the UE.

[0065] In one embodiment of the present disclosure, M is configured by downlink control information (DCI), higher layer parameters, or radio resource control (RRC) parameters.

[0066] In one embodiment of the present disclosure, M is determined by a size of a bandwidth part (BWP).

[0067] In one embodiment of the present disclosure, M is one-to-one correlation with a subband size.

[0068] In one embodiment of the present disclosure, only the at least one CQI value is received based on setting of a higher layer parameter reportQuantity.

[0069] In one embodiment of the present disclosure, a signal to interference plus noise ratio (SINR) is received with the at least one CQI value based on setting of a higher layer parameter reportQuantity.

[0070] The disclosed method may be implemented in a chip. The chip may include a processor, configured to call and run a computer program stored in a memory, to cause a device in which the chip is installed to execute the disclosed method.

[0071] The disclosed method may be programmed as computer executable instructions stored in non-transitory computer readable medium. The non-transitory computer readable medium, when loaded to a computer, directs a processor of the computer to execute the disclosed method.

[0072] The non-transitory computer readable medium may include at least one from a group consisting of: a hard disk, a CD-ROM, an optical storage device, a magnetic storage device, a Read Only Memory, a Programmable Read Only Memory, an Erasable Programmable Read Only Memory, EPROM, an Electrically Erasable Programmable Read Only Memory and a Flash memory.

[0073] The disclosed method may be programmed as computer program product, that causes a computer to execute the disclosed method.

[0074] The disclosed method may be programmed as computer program, that causes a computer to execute the disclosed method.

Advantageous Effects

[0075] This present disclosure proposes a UE selected sub-band feedback mechanism to improve the performance of CSI report especially for URLLC. The present disclosure can improve the resource utilization efficiency and the accuracy of CSI report and reduce the complexity of CSI report and the CSI feedback latency.

[0076] Furthermore, the enhanced CSI report mechanism is also provided for more accurate MCS selection. The present disclosure can ensure that the CSI value can accurately express the current channel status and reduce the signalling overhead of CSI reporting.

[0077] Furthermore, to adapt with different use cases or different traffic type, the present disclosure also provides alternative designs for sub-band CSI report strategy. The current sub-band CSI feedback is based on differential feedback for overhead reduction, and a 2-bit delta CQI index over the wideband CQI is reported. However, this leads to a large granularity and inaccuracy of the CSI report, especially in frequency selective channel conditions. To this issue, several enhanced sub-band feedback methods are introduced in the present disclosure to improve the current differential sub-Band CSI report. In addition, several CQI reporting strategies are also proposed to enable more accurate CSI feedback and result in high spectrum efficiency or a reliable transmission.

[0078] Furthermore, the present disclosure also provides enhanced priority rules for CSI reports to guarantee the CSI report of URLLC traffic service. Because the existing priority rules are not friendly to URLLC services, for example, P/SP-CSI report on PUCCH is regarded as lowest priority even if it is targeted for URLLC traffic link adaptation. Therefore, in order to ensure high-reliability transmission of URLLC services and to adapt with potential new features in Release-17, existing priority rules need improvements.

Description of Drawings

[0079] In order to more clearly illustrate the embodiments of the present disclosure or related art, the following figures will be described in the embodiments are briefly introduced. It is obvious that the drawings are merely some embodiments of the present disclosure, a person having ordinary skill in this field can obtain other figures according to these figures without paying the premise.

[0080] FIG. 1 is a schematic diagram showing a telecommunication system.

[0081] FIG. 2 is a schematic diagram showing a CRAN with a baseband unit pool, remote radio heads, and UEs.

[0082] FIG. 3 is a schematic diagram showing a method for channel state information executed at user equipment (UE) side according to an embodiment of the present disclosure.

[0083] FIG. 4 is a schematic diagram showing the disclosed method executed at a base station (BS) side according to an embodiment of the present disclosure.

[0084] FIG. 5 is a block diagram of a system for wireless communication according to an embodiment of the present disclosure.

DETAILED DESCRIPTION OF EMBODIMENTS

[0085] Embodiments of the present disclosure are described in detail with the technical matters, structural features, achieved objects, and effects with reference to the accompanying drawings as follows. Specifically, the terminologies in the embodiments of the present disclosure are merely for describing the purpose of the certain embodiment, but not to limit the present disclosure.

[0086] With reference to FIG. 1, a telecommunication system including a group 100a of a plurality of UEs, a base station (BS) 200a, and a network entity device 300 executes the disclosed method according to an embodiment of the present disclosure. The group 100a of a plurality of UEs may include a UE 10a, a UE 10b, and other UEs. FIG. 1 is shown for illustrative not limiting, and the system may include more UEs, BSs, and CN entities. Connections between

devices and device components are shown as lines and arrows in the figure. Connections between devices may be realized by wireless connections. Connections between device components may be realized by wirelines, buses, traces, cables or optical fabrics. The UE 10a may include a processor 11a, a memory 12a, and a transceiver 13a. The UE 10b may include a processor 11b, a memory 12b, and a transceiver 13b. The base station 200a may include a baseband unit (BBU) 204a. The base band unit 204a may include a processor 201a, a memory 202a, and a transceiver 203a. The network entity device 300 may include a processor 301, a memory 302, and a transceiver 303. Each of the processors 11a, 11b, 201a, and 301 may be configured to implement proposed functions, procedures and/or methods described in the description. Layers of radio interface protocol may be implemented in the processors 11a, 11b, 201a, and 301. Each of the memories 12a, 12b, 202a, and 302 operatively stores a variety of programs and information to operate a connected processor. Each of the transceivers 13a, 13b, 203a, and 303 is operatively coupled with a connected processor, transmits and/or receives radio signals or wireline signals. The UE 10a may be in communication with the UE 10b through a sidelink. The base station 200a may be an eNB, a gNB, or one of other types of radio nodes.

[0087] Each of the processors 11a, 11b, 201a, and 301 may include a central processing unit (CPU), an application-specific integrated circuits (ASICs), other chipsets, logic circuits and/or data processing devices. Each of the memories 12a, 12b, 202a, and 302 may include a read-only memory (ROM), a random access memory (RAM), a flash memory, a memory card, a storage medium and/or other storage devices. Each of the transceivers 13a, 13b, 203a, and 303 may include baseband circuitry and radio frequency (RF) circuitry to process radio frequency signals. When the embodiments are implemented in software, the techniques described herein can be implemented with modules, units, procedures, functions, entities and so on, that perform the functions described herein. The modules can be stored in a memory and executed by the processors. The memory can be implemented within a processor or external to the processor, in which those can be communicatively coupled to the processor via various means are known in the art.

[0088] The network entity device 300 may be a node in a CN. CN may include LTE CN or 5G core (5GC) which includes user plane function (UPF), session management function (SMF), mobility management function (AMF), unified data management (UDM), policy control function (PCF), control plane (CP)/user plane (UP) separation (CUPS), authentication server (AUSF), network slice selection function (NSSF), and network exposure function (NEF).

[0089] With reference to FIG. 2, a base station 200b is an embodiment of the base station 200a and includes a central controller (CC) 210, access points 211-1, 211-2, ...and 211-M. M is a positive integer. The central controller 210 may be implemented into a central unit (CU), and may include a BBU, such as BBU 204a, in connection with the access points (APs) 211-1, 211-2, ...and 211-M. Each of the access points 211-1, 211-2, ...and 211-M may be implemented into a radio node, a remote unit (RU), or a remote radio head (RRH), and may include a transmission and reception point (TRP). The access points 211-1, 211-2, ...and 211-M may be located in different locations.

[0090] The central controller 210 receives wireless signals from a group 100b of V user equipments (UEs) through a group of M distributed radio nodes. V is a positive integer. The group of V user equipments includes UEs 10-1, 10-2, 10-3, and ...10-V. The UEs 10-1, 10-2, 10-3, and ...10-V may be located in different locations.

[0091] The considered technical problem falls in the area of high density connectivity and non-orthogonal multiple access (NOMA) in CRAN systems. In an example, a CRAN network operating in a time division duplex (TDD) mode where channel estimation is performed through uplink pilot transmission.

[0092] Each coherence slot is divided between two instances of uplink training using orthogonal uplink pilots, uplink and downlink data transmission. An embodiment of the present disclosure processes uplinks from V UEs to M single antenna access points (APs). At each time slot, each AP performs uplink channel estimation independently.

[0093] The APs 211-1, 211-2, ...and 211-M are distributed within a coverage area and are managed by the central controller 210 that contains a centralized baseband unit (BBU) pool and handles operations of a physical layer and a medium access control (MAC) layer, such as data decoding and encoding, scheduling, and power allocation. The APs 211-1, 211-2, ...and 211-M are linked to the central controller 210 through high performance transport links known as fronthaul. Fronthaul may be implemented by optical cables or high bandwidth wireless channels. The system in FIG. 2 including the base station 200b and the UEs 10-1, 10-2, 10-3, and ...10-V. The UEs 10-1, 10-2, 10-3, and ...10-V is a simplified example of a CRAN. The APs 211-1, 211-2, ...and 211-M perform channel estimation and the link level transmission chain until equalization. The central controller 210 performs signal decoding, encoding, modulation, demodulation, scheduling and MAC layer operations.

[0094] Uplink (UL) transmission of a control signal or data may be a transmission operation from a UE to a base station. Downlink (DL) transmission of a control signal or data may be a transmission operation from a base station to a UE.

[0095] Regarding the CSI report mechanism in 3GPP release 16, as specified in 38.214 section 5.2.1.1:

The time domain behavior of the CSI-ReportConfig is indicated by the higher layer parameter reportConfigType and can be set to 'aperiodic', 'semiPersistentOnPUCCH', 'semiPersistentOnPUSCH', or 'periodic'. For periodic and semiPersistentOnPUCCH/semiPersistentOnPUSCH CSI reporting, the configured periodicity and slot offset applies in the numerology of the UL BWP in which the CSI report is configured to be transmitted on. The higher layer parameter reportQuantity indicates the CSI-related, L1-RSRP-related or L1-SINR-related quantities to report. The reportFreqConfiguration indicates the reporting granularity in the frequency domain, including the CSI reporting band and if PMI/CQI reporting is wideband or subband. The timeRestrictionForChannelMeasurements parameter in CSI-ReportConfig can be configured to enable time domain restriction for channel measurements and timeRestrictionForInterferenceMeasurements can be configured to enable time domain restriction for interference measurements. The CSI-ReportConfig can also contain CodebookConfig, which contains configuration parameters for Type-I, Type II or Enhanced Type II CSI including codebook subset restriction, and configurations of group based reporting.

[0096] A method of a subband division is introduced in Table 1 below (TS 38.214):

For CSI reporting, a UE can be configured via higher layer signaling with one out of two possible subband sizes, where a subband is defined as N_{PRB}^{SB} *contiguous PRBs and depends on the total number of PRBs in the bandwidth part according to Table 5.2.1.4-2.*

Table 1

Bandwidth part (PRBs)	Subband size (PRBs)
24 – 72	4, 8
73 – 144	8, 16
145 – 275	16, 32

[0097] The CSI report in a frequency domain can be a wideband report or a subband report and determined by the higher layer parameter *reportFreqConfiguration*. A subband partition is based on the size of the bandwidth part (BWP). Considering the stringent requirements on latency and reliability for URLLC services, the conventional report mechanism is not sufficient, especially the conventional low-latency CSI is limited to the wideband report. For a more accurate MCS selection mechanism and improve the QoS requirements of URLLC, the existing CSI reporting scheme needs improvements.

[0098] In an LTE system, there are two subband CQI reporting modes: higher layer configured subband feedback and UE selected subband feedback. In the higher layer configured subband feedback, the subband partition is determined by the size of BWP, and a UE reports a wideband CQI value and a subband offset level of each subband to a base station. In the UE selected subband feedback, a UE may select M preferred subbands of size k and report an average of CQI values of the M subbands and indexes of the M subbands to a base station. The value of M is related to the system bandwidth. It is beneficial to introduce the UE selected subband feedback for URLLC services in NR, since the UE selected subband feedback can bring more flexibility for the CSI report. Moreover, if the UE can select M subbands that can better characterize the current channel quality, it is also beneficial for the base station to select a more accurate MCS selection. Since the CSI reporting is more likely to be used for retransmission. To ensure the stability of the data transmission, the scheduling configuration of retransmission information is more important. Therefore, the UE selected subband feedback mechanism can be a baseline, the present disclosure provides an enhanced UE selected subband feedback for more accurate MCS selections.

[0099] With reference to FIG. 3, a UE, such as one of the UE 10a or UE 10b, executes a method for channel state information (CSI).

[0100] In operation S300, the UE determines which M subbands of all subbands are selected according to a CQI report mode. The CQI report mode is configured to indicate a rule for selecting the M subbands. Each of the subbands includes at least one physical resource block (PRB).

[0101] Each of the subbands has a CQI value. In one embodiment, the UE determines to select the M subbands having best M CQI values. In detail, the UE sorts the CQI values of all of the subbands and selects the M subbands having the best M CQI values. The present embodiment can directly follow the LTE approach, which has less impact on the standard.

[0102] In another embodiment, the UE determines to select the M subbands having worst M CQI values. In detail, the UE sorts the CQI values of all of the subbands and selects the M subbands having the worst M CQI values. The present embodiment can still be applied to the retransmission (assisting to adjust the MCS selection), the repetition (assisting to adjust the power allocation), or the transmission of the next physical downlink shared channel (PDSCH) (for example, when a large packet is split into several codewords (CWs)) carried on sequential PDSCHs, or to protect a new packet in the next PDSCH if survival time is permitted). In the present embodiment, to guarantee the reliability of retransmission especially for URLLC services, it should be more conservative to report the M subbands having the worst M CQI values.

[0103] In yet another embodiment, the UE randomly selects the M subbands or selects, according to a predefined algorithm, the M subbands which can reflect status of a current channel.

[0104] Any combinations of the above three embodiments can be possible. That is, to adapt with different scenarios, the above three embodiments can be supported simultaneously, the parameter is a CQI report mode (*CQIReportMode*). For example, when *CQIReportMode* = 0, it represents that the M subbands having the best M CQI values are selected. When *CQIReportMode* = 1, it represents that the M subbands having the worst M CQI values are selected. When *CQIReportMode* = 2, it represents that the UE selects the M subbands. *CQIReportMode* can be configured by DCI or higher layer parameters.

[0105] In operation S302, the UE determines a value of M.

[0106] In one embodiment, M is configured by downlink control information (DCI) or higher layer parameters. The higher layer parameters may be but is not limited to radio resource control (RRC) parameters. The present embodiment has less impact on the standard, but it also introduces extra signalling overhead.

[0107] To avoid the extra signaling overhead, in another embodiment, the value of M can be determined by the size of a BWP. The mapping table of subband size and BWP can add another dimension, the value of M, as specified in Table 2:

Table 2

Bandwidth part (PRBs)	Subband size (PRBs)	M
24 – 72	4, 8	X1
73 – 144	8, 16	X2
145 – 275	16, 32	X3

[0108] It can be assumed that only three kinds of value (X1, X2 and X3) are supported for M for each subband size level. The values of X1, X2 and X3 can be configurable or pre-configured in the UE.

[0109] In yet another embodiment, the value of M is one-to-one correlation with subband size, as specified in Table 3. In the subband size configuration, the BWP range of each level corresponds to two subband sizes, and the specific subband size is configured through higher layer parameter *subbandSize* (configured in RRC IE *CSI-ReportConfig*). Therefore, the higher layer parameter *subbandSize* can also be used for the determination of the value of M. For example, if *subbandSize* configures the subband size as 4, and the BWP size is 30, the corresponding M value is Y1. For another example, if the subband size is configured as 16, and the BWP size is 100, the value of M is Y4. It is noted that the value of M is an integer and no less than 1.

Table 3

Bandwidth part (PRBs)	Subband size (PRBs)	M
24 – 72	4, 8	Y1, Y2
73 – 144	8, 16	Y3, Y4
145 – 275	16, 32	Y5, Y6

[0110] Optionally, the determination of the value of M could also be configured by another higher layer parameter or configured by DCI, which means the value of M and subband size don't use the same parameter *subbandSize*. Then a new parameter *ReportSubbandNum* should be introduced. *ReportSubbandNum* is a 1-bit parameter. When

ReportSubbandNum = 0, it represents the previous value is selected (e.g. Y1 or Y3 or Y5). When *ReportSubbandNum* = 1, it represents the latter value is selected (e.g. Y2 or Y4 or Y6).

[0111] In operation S304, the UE reports at least one CQI value based on the M subbands to a BS.

[0112] In one embodiment, the UE reports the CQI values of the M subbands to a BS. Comparing with the legacy subband reporting mechanism, the present embodiment can bring significant benefits to the resource efficiency because it is not necessary to report all the CQI values of all subbands, and the CQI values of the M subbands can convey the current channel status.

[0113] In another embodiment, the UE reports an average of the CQI values of the M subbands to a BS. That is, there's only one CQI value reported to the BS. This further reduces the signalling overhead compared with the above-mentioned embodiment. It is also equivalent to processing the reported CQI value on the UE side, so no additional algorithm is needed to process the CQI value for the BS side. The BS can make a MCS selection based on this average of the CQI values of the M subbands.

[0114] In yet another embodiment, the UE reports a statistic CQI value to a BS. For the sporadic traffic, filtering or averaging measurement reports could better combat the interference uncertainties. Therefore, in the present embodiment, the statistic CQI value should be reported to the BS. For instance, the statistic CQI value including the average of the CQI values of the M subbands and CQI variance of the M subbands should be reported. In addition, a maximum or minimum one of the CQI values of the M subbands could be reported with the statistic CQI value optionally.

[0115] In operation S306, the UE reports positions of the M subbands to the BS. Operation S306 can help make decisions on the MCS selection, since this information is unknown to the BS perspective. The original report mechanism for the locations of the M subbands in LTE is combinatorial index report. As shown below, the total number of subbands can be regarded as N, and the number of the selected subbands is M.

[0116] A combinatorial index r defined as:

$$\mathrm{r} = \sum_{i=0}^{M-1} \left\langle {N - s_i \atop M - i} \right\rangle$$

where the set$\{s_i\}_{i=0}^{M-1}, (1 \le s_i \le N, s_i < s_{i+1})$ contains the M sorted subband indices and $\left\langle {x \atop y} \right\rangle = \begin{cases} \binom{x}{y} & x \ge y \\ 0 & x < y \end{cases}$ is the extended binomial coefficient, resulting in unique label $\mathrm{r} \in \{0,1,\ldots,\binom{N}{M} - 1\}$and $\binom{n}{k} = \frac{n!}{k!(n-k)!}$

The number of bits to denote the position of the M selected subbands is $\mathrm{L} = \lceil log_2 \binom{N}{M} \rceil$.

[0117] The above-mentioned method can be reused or regards as a baseline in NR, however, the signalling overhead of this reporting method is very large. At least the number of bits reserved for this combinatorial index is large. According to the current configuration method (as specified in Table 1), the maximum number of subbands is 18. When this method is used for reporting and the number of the selected M subbands exceeds 1 (M>1), the number of bits required for this reporting method has the possibility to exceed $\lceil log_2(18) \rceil$. Therefore, the present disclosure proposes another solution to use bitmap to express the locations of the M subbands. The size of this bitmap is $\lceil log_2(N) \rceil$ for each field in this bitmap represents the status of each subband. For example, this field is set to 1 to indicate this subband is selected for CQI calculation. This field is set to 0 to indicate this subband is not selected.

There are M fields are set to 1 in total in this bitmap. In this case, the reported location information will not exceed $\lceil log_2(N) \rceil$ bit at most. For example, if the current number of the subbands is 18, then at most $\lceil log_2(18) \rceil$ bit is required.

[0118] This present disclosure proposes a UE selected sub-band feedback mechanism to improve the performance of CSI report especially for URLLC. The present disclosure can improve the resource utilization efficiency and the accuracy of CSI report and reduce the complexity of CSI report and the CSI feedback latency.

[0119] Regarding the recent CQI reporting mechanism in Release-16, when the wideband CQI reporting is configured, a wideband CQI value is reported for each codeword for the entire CSI reporting band. When subband CQI reporting is configured, one CQI value for each codeword is reported for each subband in the CSI reporting band. For wideband reporting, it can only express the overall status of the CQI value on the wideband. For the communication environment where the channel or interference fluctuates significantly, the wideband CQI value cannot serve as a reference for the BS. As for the subband, although the respective CQI value is reported for each subband, the signalling overhead is relatively large. For CQI reporting, there is a trade-off between signalling overhead and accurate representation of channel quality. For the above two situations, reporting the CQI statistical value is a compromise solution. The statistic CQI value can be the average of the CQI values and the CQI variance of all the subbands, and optionally the maximum or minimum CQI value can be reported with the statistic CQI value. In this case, at most four CQI values should be reported, and this hugely reduces the complexity of CQI report compared with subband CQI report. Furthermore, this solution can also be combined with the differential CQI report.

[0120] The statistic CQI reporting described above can be another reporting method equivalent to a wideband report or a subband report. It can also be used as assistant information and reported together with the wideband report or subband report.

[0121] In addition, the UE experienced signal to a signal to interference plus noise ratio (SINR) is also highly time-variant due to rapid load fluctuations of the neighbouring cells. That is to say, if the UE performs SINR measurement on a set of the PRBs within a certain period of time, the SINR may vary greatly in another period of time. Therefore, it is a challenge to accurately track the UE experienced SINR, since there is a variety of delays between the UE and the BS, for example, measurement delay, CSI reporting delay, and the processing delays for the BS side. These fast variations of the SINR in both time and frequency domain also impact the CSI report accuracy especially for frequency selective cases. In this case, statistic SINR result can be reported with the corresponding CQI report. From the UE perspective, the calculation of the CQI value is left for UE implementation. However, it does have a mapping relationship with the MCS selection and the SINR, and this SINR could be reported to the BS for the more accurate MCS selection. Alternatively, this SINR could be the one when determining CQI value or the statistic value for example the mean value of SINR and the variance of SINR.

[0122] It should be noted that the reference point for UE measurements (e.g. L1-SINR) in Release-16 is the antenna connector (for FR1). However, the SINR introduced in the present disclosure is for the MCS selection. It is different from the SINR distribution at the antenna connector, which does not account for the number of Rx antennas nor the gains that Rx architecture may provide via combining techniques (e.g. MRC/IRC) and/or channel estimation techniques and/or decoding techniques (linear/nonlinear receivers).

[0123] To reduce the CSI reporting time, especially for URLLC traffic, a simplified CSI report can be supported. For instance, only the CQI value is reported. This is because for some urgent transmissions, it is no need to report all types of CSI, only some critical information is sufficient, which not only reduces the complexity of CSI reporting, but

also reduces the CSI reporting time accordingly. In addition, SINR could be assistance information reported with the CQI report for the more accurate MCS selection. In this case, new parameters should be introduced for the higher layer parameter *reportQuantity*. When the higher layer parameter *reportQuantity* is set to 'CQI', only the CQI value is reported. When the higher layer parameter *reportQuantity* is set to 'CQI-SINR', both the CQI value and the SINR are reported.

[0124] The above-mentioned enhanced CSI report mechanism is also provided for more accurate MCS selection. The present disclosure can ensure that the CSI value can accurately express the current channel status and reduce the signalling overhead of CSI reporting.

[0125] The recent CSI report mechanism for low-latency CSI is more likely be configured to the wideband report. However, many URLLC applications are restricted to small packet transmission and often occupy only one or just a few subbands. Hence subband CSI is more appropriate to use for URLLC service. The current subband CSI feedback is based on differential feedback for overhead reduction, and a 2-bit delta CQI index over the wideband CQI is reported. However, this leads to a large granularity and inaccuracy of the CSI report, especially in frequency selective channel conditions. Suppose the BS would make the MCS selection based on the coarse CSI report, it will either result in low spectrum efficiency or an unreliable transmission. To figure out this issue, an enhanced subband feedback method should be introduced to enable more accurate CSI feedback.

[0126] As configured by the higher layer parameter *cqi-FormatIndicator*. When wideband CQI reporting is configured, a wideband CQI value is reported for each codeword for the entire CSI reporting band. When subband CQI reporting is configured, one CQI value for each codeword is reported for each subband in the CSI reporting band, and for each subband a 2-bit subband differential CQI is defined. Regarding the traffic type with small packet scheduling or occupy only a few subbands, wideband CQI calculation is unnecessary, because the difference between the wideband CQI value and the subband CQI value will not be too large. For transmissions with a large amount of data, the difference between the wideband CQI value and the subband CQI value may be relatively large. If the current CQI offset mapping table is used, the CQI status can only be roughly reflected, since there are only four levels of subband differential CQI values. Therefore, the differential CQI reporting strategy needs to be improved. Having this issue in mind, the present disclosure provides the following solutions.

[0127] First, the basis of the differential CQI calculation and comparison should be modified. It has been analyzed above, if the wideband CQI value is used for comparison, there is no practical significance. The benchmark can be the average CQI value of all the subbands, it can better reflect the overall level of the subband CQI value. For other subband CQI values, the differential CQI is calculated on the basis of this average CQI, and the data distribution will not fluctuate too much and won't bring extra signalling overhead. In this case, for each subband index s, the subband differential CQI is defined as:

$$\text{Subband Offset level (s)} = \text{subband CQI index (s)} - \text{Average CQI index.}$$

[0128] Optionally, this benchmark CQI index can also be the best CQI value of all the subbands or the worst CQI value of all the subbands due to different use cases or application scenarios. In this way, according to different scenarios or configurations, the BS side can better obtain the current subband CQI distribution. The subband differential CQI value is defined as:

$$\text{subband offset level (s)} = \text{subband CQI index (s)} - \text{benchmark CQI index.}$$

[0129] In this case, the Benchmark CQI index is configurable, it could be the average CQI value or best CQI or worst CQI value of all the subbands, and configured by DCI or higher layer parameters.

[0130] Secondly, the current table for mapping subband differential CQI value to offset level is too coarse to accurate CSI report. At least for URLLC, it needs a new mapping table with smaller granularity. As specified in Table 4, D subband differential CQI values should be supported, where D > 4. The value of L and the offset level range for each differential CQI value are configurable.

Table 4

Subband differential CQI value	Offset level
0	O_1~O_2
1	O_3~O_4
…	…
D - 1	O_k~O_{k+1}

[0131] For one embodiment as specified in Table 5, we assume D=8, which means the subband differential CQI value is a 3-bit parameter. The mapping relation between subband differential CQI value and offset level is shown in Table 5 as an example.

Table 5

Subband differential CQI value	Offset level
0	0
1	1
2	2~4
3	4~8
4	≥ 8
5	-1~-4
6	-4~-8
7	≤ -8

[0132] For one embodiment as specified in Table 5, we assume D=8, which means the subband differential CQI value is a 3-bit parameter. The mapping relation between subband differential CQI value and offset level is shown in Table 5 as an example.

[0133] Regarding the subband CQI reporting strategy, there exist limitations if the same strategy is used in all scenarios. One strategy cannot be applicable to all scenarios. Therefore, the strategy can be adaptively changed according to different scenarios to achieve the best performance.

[0134] In one embodiment, the CQI reporting strategy is closely related to the BWP size. When the BWP size is small, the difference between wideband CQI value and subband CQI value is not large. At this time, there's not much benefit of using the differential CQI report based on the wideband CQI value. However, when the BWP size is large, the differential CQI report calculated based on the wideband CQI value can better reflect the overall level of the CQI

value and achieve the purpose of reducing the reported signalling. Therefore, the CQI reporting strategy can be determined by the BWP size, as specified in Table 6, which introduces a mapping relationship between BWP size and the reporting strategy.

Table 6

Bandwidth part (PRBs)	Reporting Strategy
$B_1 \sim B_2$	S_1
$B_2+1 \sim B_3$	S_2
…	…
$B_n+1 \sim B_{n+1}$	S_n

[0135] In Table 6, there are n strategies and expressed as S_i, where $1 \leq i \leq n$, as for the specific strategy represented by S_i can be configured.

[0136] In one embodiment, as specified in Table 7, when n=2, there are only two reporting strategies supported for subband CQI report. When the BWP is below 144 PRBs, differential CQI reporting is not supported, that is, the actual CQI values of the subbands are reported instead of the difference with a benchmark CQI value. When the BWP size is above 144 PRBs, differential CQI report is supported, and the benchmark CQI value is configurable and can be wideband CQI or average CQI or others.

Table 7

Bandwidth part (PRBs)	Reporting Strategy
24 – 144	No differential CQI report
145 – 275	Differential CQI report

[0137] In another embodiment, when n=3, the mapping relationship between BWP size and reporting strategy is specified in Table 8. For this case, when the BWP is below 72 PRBs, differential CQI reporting is not supported. When the BWP is between 73 and 144 PRBs, differential CQI report is supported, and the benchmark CQI value can be any kind of CQI (configured by DCI or higher layers) except the wideband CQI value. When the BWP is above 145 PRBs, differential CQI report based on the wideband CQI value is supported.

Table 8

Bandwidth part (PRBs)	Reporting Strategy
24 – 72	No differential CQI report
73 – 144	Differential CQI report without wideband CQI value
145 – 275	Differential CQI report with wideband CQI value

[0138] In another embodiment, another solution is to determine the reporting strategy based on the number of subbands. In fact, this solution is more intuitive, because, for the case of a small number of subbands, there is less advantage in calculating the differential CQI value based on the wideband CQI value. In the case of larger number of

subbands, the legacy strategy can be used, and the differential CQI report is based on the wideband CQI value. In this case, a threshold is introduced, it can be defined as *SubbandNumThe*. This parameter can be pre-configured (e.g. *SubbandNumThe* = 9) or configured by DCI or higher layer parameter (e.g. RRC). When the number of subbands is below *SubbandNumThe*, differential CQI reporting is not supported, the actual CQI values of the subbands are reported instead of the difference with a benchmark CQI value. When the number of subbands is below *SubbandNumThe*, differential CQI report is supported, and the benchmark CQI value is configurable and can be configured as the wideband CQI value or the average CQI value or others.

[0139] Similarly, it can be more refined, as shown in Table 9, dividing multiple levels for the number of subbands, and configuring corresponding reporting strategies for the number of subbands with different value ranges. Similar to the Table 6, there are n strategies and expressed as S_i, where $1 \leq i \leq n$, as for the specific strategy represented by R_i can be configured.

Table 9

Subband Number	Reporting Strategy
$M_1 \sim M_2$	R_1
$M_2+1 \sim M_3$	R_2
...	...
$M_n+1 \sim M_{n+1}$	R_n

[0140] In one embodiment, when n=3, the mapping relationship between the number of the subbands and reporting strategy is specified in Table 10. For this case, when the number of subbands is below 3, differential CQI reporting is not supported. When the number of subbands is between 4 and 9, differential CQI report is supported, and the benchmark CQI can be any kind of CQI values (configured by DCI or higher layers) except the wideband CQI values. When the number of subbands is above 10, differential CQI report based on wideband CQI is supported.

Table 10

Subband Number	Reporting Strategy
1-3	No differential CQI report
4-9	Differential CQI report without wideband CQI
≥ 10	Differential CQI report with wideband CQI

[0141] The current sub-band CSI feedback is based on differential feedback for overhead reduction, and a 2-bit delta CQI index over the wideband CQI is reported. However, this leads to a large granularity and inaccuracy of the CSI report, especially in frequency selective channel conditions. To this issue, the above-mentioned sub-band CSI report strategies (enhanced sub-band feedback methods) are introduced in the present disclosure to improve the current differential sub-Band CSI report. In addition, the above-mentioned CQI reporting strategies are also proposed to enable more accurate CSI feedback and result in high spectrum efficiency or a reliable transmission.

[0142] The P/SP-CSI on PUCCH has been considered as a lowest priority as compared with other CSI reporting types and no priority index associated with the CSI reporting configuration. Therefore, even if it is targeted for URLLC

traffic link adaptation, it may be dropped if it collides with a higher priority CSI reporting (e.g., A-CSI reporting, SP-CSI on PUSCH) irrespective of whether the higher priority CSI reporting is targeted for eMBB or URLLC. Therefore, the priority rules for CSI reports needs improvement, P/SP-CSI on PUCCH needs to be associated with a priority index.

[0143] Regarding Release-16, the priority definition for CSI reports is shown as below (38.214 section 5.2.5):

CSI reports are associated with a priority value $Pri_{iCSI}(y,k,c,s) = 2 \cdot N_{cells} \cdot M_s \cdot y + N_{cells} \cdot M_s \cdot k + M_s \cdot c + s$ *where*

- $y=0$ *for aperiodic CSI reports to be carried on PUSCH* $y=1$ *for semi-persistent CSI reports to be carried on PUSCH,* $y=2$ *for semi-persistent CSI reports to be carried on PUCCH and* $y=3$ *for periodic CSI reports to be carried on PUCCH;*
- $k=0$ *for CSI reports carrying L1-RSRP or L1-SINR and* $k=1$ *for CSI reports not carrying L1-RSRP or L1-SINR;*
- *c is the serving cell index and* N_{cells} *is the value of the higher layer parameter maxNrofServingCells;*
- *s is the reportConfigID and* M_s *is the value of the higher layer parameter maxNrofCSI-ReportConfigurations.*

A first CSI report is said to have priority over second CSI report if the associated $Pri_{iCSI}(y,k,c,s)$ *value is lower for the first report than for the second report.*

[0144] On the basis of the priority rules in Release-16, the present disclosure provides alternative designs as follows.

[0145] In one embodiment, regarding the recent specification, when P/SP-CSI on PUCCH collides with other UL transmissions, it is always regarded as the lowest priority even though it is URLLC traffic. However, such a rule is unreasonable. Because of the high reliability and low latency of URLLC, when conflicts occur, the transmission of URLLC services should be guaranteed as much as possible. Therefore, to figure out this problem, the present disclosure provides the following priority rules.

[0146] CSI reports are associated with a priority value $Pri_{iCSI}(t.y,k,c,s) = 2 \cdot N_{cells} \cdot M_s \cdot 4 \cdot \mathrm{t} + 2 \cdot N_{cells} \cdot M_s \cdot y + N_{cells} \cdot M_s \cdot k + M_s \cdot c + s$ where

- $t = 0$ for URLLC service
- $t = 1$ for eMBB service.

[0147] In another embodiment, the topic of A-CSI on PUCCH was previously discussed in previous releases, however, due to the time limitation and lack of consensus on the triggering mechanism, this topic was ultimately left out of NR Release-16. The main motivation to introduce A-CSI on PUCCH is to allow more scheduling flexibility for the base station (e.g. gNB), and low signalling overhead. Therefore, CSI priority rules should take A-CSI on PUCCH into account, and considering the A-CSI on PUCCH is most likely used for URLLC service, it should have higher priority, and the following solution is provided.

[0148] CSI reports are associated with a priority value $Pri_{iCSI}(y,k,c,s) = 2 \cdot N_{cells} \cdot M_s \cdot y + N_{cells} \cdot M_s \cdot k + M_s \cdot c + s$ where

- $y = 0$ for aperiodic CSI reports to be carried on PUCCH;
- $y = 1$ for aperiodic CSI reports to be carried on PUSCH;
- $y = 2$ for semi-persistent CSI reports to be carried on PUSCH;
- $y = 3$ for semi-persistent CSI reports to be carried on PUCCH;

- $y = 4$ for periodic CSI reports to be carried on PUCCH.

[0149] In another embodiment, the above two embodiments can also be used in combination. The combined solution is as follows.

[0150] CSI reports are associated with a priority value $Pri_{iCSI}(t, y, k, c, s) = 2 \cdot N_{cells} \cdot M_s \cdot 5 \cdot \mathrm{t} + 2 \cdot N_{cells} \cdot M_s \cdot y + N_{cells} \cdot M_s \cdot k + M_s \cdot c + s$ where

- $t = 0$ for URLLC service.

  $t = 1$ for eMBB service
- $y = 0$ *for aperiodic CSI reports to be carried on PUCCH;*

  $y = 1$ *for aperiodic CSI reports to be carried on PUSCH;*

  $y = 2$ *for semi-persistent CSI reports to be carried on PUSCH;*

  $y = 3$ *for semi-persistent CSI reports to be carried on PUCCH;*

  $y = 4$ *for periodic CSI reports to be carried on PUCCH.*

[0151] The above-mentioned enhanced priority rules for CSI reports can guarantee the CSI report of URLLC traffic service. Because the existing priority rules are not friendly to URLLC services, for example, P/SP-CSI report on PUCCH is regarded as lowest priority even if it is targeted for URLLC traffic link adaptation. Therefore, in order to ensure high-reliability transmission of URLLC services and to adapt with potential new features in Release-17, existing priority rules need improvements.

[0152] With reference to FIG. 4, a BS, such as one of the BS 200a or BS 200b, executes a method for channel state information (CSI).

[0153] In operation S400, the BS receives at least one CQI value from a user equipment (UE), wherein the at least one CQI value is based on M subbands of all subbands, and each of the subbands includes at least one physical resource block (PRB).

[0154] In one embodiment, M is configured by downlink control information (DCI). In another embodiment, M is configured by higher layer parameters. The higher layer parameters are radio resource control (RRC) parameters.

[0155] In one embodiment, M is determined by a size of a bandwidth part (BWP). In another embodiment, M is one-to-one correlation with a subband size.

[0156] In operation S402, the BS receives positions of the M subbands from the UE.

[0157] In one embodiment, only the at least one CQI value is received. In another embodiment, a signal to interference plus noise ratio (SINR) is received with the at least one CQI value.

[0158] In operation S404, the BS selects, according to the at least one CQI value and the positions of the M subbands, a modulation and coding scheme (MCS) for the UE.

[0159] Any combination of the above embodiments may be possible.

[0160] FIG. 5 is a block diagram of an example system 700 for wireless communication according to an embodiment of the present disclosure. Embodiments described herein may be implemented into the system using any suitably configured hardware and/or software. FIG. 5 illustrates the system 700 including a radio frequency (RF) circuitry 710, a baseband circuitry 720, a processing unit 730, a memory/storage 740, a display 750, a camera 760, a sensor 770, and an input/output (I/O) interface 780, coupled with each other as illustrated.

[0161] The processing unit 730 may include a circuitry, such as, but not limited to, one or more single-core or multi-core processors. The processors may include any combinations of general-purpose processors and dedicated

processors, such as graphics processors and application processors. The processors may be coupled with the memory/storage and configured to execute instructions stored in the memory/storage to enable various applications and/or operating systems running on the system.

[0162] The baseband circuitry 720 may include a circuitry, such as, but not limited to, one or more single-core or multi-core processors. The processors may include a baseband processor. The baseband circuitry may handle various radio control functions that enable communication with one or more radio networks via the RF circuitry. The radio control functions may include, but are not limited to, signal modulation, encoding, decoding, radio frequency shifting, etc. In some embodiments, the baseband circuitry may provide for communication compatible with one or more radio technologies. For example, in some embodiments, the baseband circuitry may support communication with 5G NR, LTE, an evolved universal terrestrial radio access network (EUTRAN) and/or other wireless metropolitan area networks (WMAN), a wireless local area network (WLAN), a wireless personal area network (WPAN). Embodiments in which the baseband circuitry is configured to support radio communications of more than one wireless protocol may be referred to as multi-mode baseband circuitry. In various embodiments, the baseband circuitry 720 may include circuitry to operate with signals that are not strictly considered as being in a baseband frequency. For example, in some embodiments, baseband circuitry may include circuitry to operate with signals having an intermediate frequency, which is between a baseband frequency and a radio frequency.

[0163] The RF circuitry 710 may enable communication with wireless networks using modulated electromagnetic radiation through a non-solid medium. In various embodiments, the RF circuitry may include switches, filters, amplifiers, etc. to facilitate the communication with the wireless network. In various embodiments, the RF circuitry 710 may include circuitry to operate with signals that are not strictly considered as being in a radio frequency. For example, in some embodiments, RF circuitry may include circuitry to operate with signals having an intermediate frequency, which is between a baseband frequency and a radio frequency.

[0164] In various embodiments, the transmitter circuitry, control circuitry, or receiver circuitry discussed above with respect to the UE, eNB, or gNB may be embodied in whole or in part in one or more of the RF circuitries, the baseband circuitry, and/or the processing unit. As used herein, "circuitry" may refer to, be part of, or include an Application Specific Integrated Circuit (ASIC), an electronic circuit, a processor (shared, dedicated, or group), and/or a memory (shared, dedicated, or group) that execute one or more software or firmware programs, a combinational logic circuit, and/or other suitable hardware components that provide the described functionality. In some embodiments, the electronic device circuitry may be implemented in, or functions associated with the circuitry may be implemented by, one or more software or firmware modules. In some embodiments, some or all of the constituent components of the baseband circuitry, the processing unit, and/or the memory/storage may be implemented together on a system on a chip (SOC).

[0165] The memory/storage 740 may be used to load and store data and/or instructions, for example, for system. The memory/storage for one embodiment may include any combination of suitable volatile memory, such as dynamic random access memory (DRAM)), and/or non-volatile memory, such as flash memory. In various embodiments, the I/O interface 780 may include one or more user interfaces designed to enable user interaction with the system and/or peripheral component interfaces designed to enable peripheral component interaction with the system. User interfaces may include, but are not limited to a physical keyboard or keypad, a touchpad, a speaker, a microphone, etc. Peripheral component interfaces may include, but are not limited to, a non-volatile memory port, a universal serial bus (USB) port, an audio jack, and a power supply interface.

[0166] In various embodiments, the sensor 770 may include one or more sensing devices to determine environmental conditions and/or location information related to the system. In some embodiments, the sensors may include, but are not limited to, a gyro sensor, an accelerometer, a proximity sensor, an ambient light sensor, and a positioning unit. The positioning unit may also be part of, or interact with, the baseband circuitry and/or RF circuitry to communicate with components of a positioning network, e.g., a global positioning system (GPS) satellite. In various embodiments, the display 750 may include a display, such as a liquid crystal display and a touch screen display. In various embodiments, the system 700 may be a mobile computing device such as, but not limited to, a laptop computing device, a tablet computing device, a netbook, an ultrabook, a smartphone, etc. In various embodiments, system may have more or less components, and/or different architectures. Where appropriate, methods described herein may be implemented as a computer program. The computer program may be stored on a storage medium, such as a non-transitory storage medium.

[0167] The embodiment of the present disclosure is a combination of techniques/processes that can be adopted in 3GPP specification to create an end product.

[0168] A person having ordinary skill in the art understands that each of the units, algorithm, and steps described and disclosed in the embodiments of the present disclosure are realized using electronic hardware or combinations of software for computers and electronic hardware. Whether the functions run in hardware or software depends on the condition of application and design requirement for a technical plan. A person having ordinary skill in the art can use different ways to realize the function for each specific application while such realizations should not go beyond the scope of the present disclosure. It is understood by a person having ordinary skill in the art that he/she can refer to the working processes of the system, device, and unit in the above-mentioned embodiment since the working processes of the above-mentioned system, device, and unit are basically the same. For easy description and simplicity, these working processes will not be detailed.

[0169] It is understood that the disclosed system, device, and method in the embodiments of the present disclosure can be realized with other ways. The above-mentioned embodiments are exemplary only. The division of the units is merely based on logical functions while other divisions exist in realization. It is possible that a plurality of units or components are combined or integrated in another system. It is also possible that some characteristics are omitted or skipped. On the other hand, the displayed or discussed mutual coupling, direct coupling, or communicative coupling operate through some ports, devices, or units whether indirectly or communicatively by ways of electrical, mechanical, or other kinds of forms.

[0170] The units as separating components for explanation are or are not physically separated. The units for display are or are not physical units, that is, located in one place or distributed on a plurality of network units. Some or all of the units are used according to the purposes of the embodiments. Moreover, each of the functional units in each of the embodiments can be integrated in one processing unit, physically independent, or integrated in one processing unit with two or more than two units.

[0171] If the software function unit is realized and used and sold as a product, it can be stored in a readable storage medium in a computer. Based on this understanding, the technical plan proposed by the present disclosure can be essentially or partially realized as the form of a software product. Or, one part of the technical plan beneficial to the conventional technology can be realized as the form of a software product. The software product in the computer is stored in a storage medium, including a plurality of commands for a computational device (such as a personal computer, a server, or a network device) to run all or some of the steps disclosed by the embodiments of the present

disclosure. The storage medium includes a USB disk, a mobile hard disk, a read-only memory (ROM), a random access memory (RAM), a floppy disk, or other kinds of media capable of storing program codes.

[0172] While the present disclosure has been described in connection with what is considered the most practical and preferred embodiments, it is understood that the present disclosure is not limited to the disclosed embodiments but is intended to cover various arrangements made without departing from the scope of the broadest interpretation of the appended claims.

Claims

1. A method for channel state information (CSI) executable in a user equipment (UE), comprising:
determining which M subbands of all subbands are selected according to a CQI report mode, wherein each of the subbands comprises at least one physical resource block (PRB);
determining a value of M;
reporting at least one CQI value based on the M subbands to a base station (BS); and
reporting positions of the M subbands to the BS.

2. The method of claim 1, wherein each of the M subbands has a CQI value, and the determining which M subbands of all the subbands are selected comprises:
sorting the CQI values of all of the subbands; and
selecting the M subbands having the worst M CQI values.

3. The method of claim 1, wherein the M subbands of the subbands are selected randomly.

4. The method of claim 1, wherein M is configured by downlink control information (DCI), higher layer parameters, or radio resource control (RRC) parameters.

5. The method of claim 1, wherein M is determined by a size of a bandwidth part (BWP).

6. The method of claim 1, wherein M is one-to-one correlation with a subband size.

7. The method of claim 1, wherein the reporting the at least one CQI value based on the M subbands to the base station (BS) comprises:
reporting the CQI values of the M subbands to the BS.

8. The method of claim 1, wherein the reporting the at least one CQI value based on the M subbands to the base station (BS) comprises:
reporting a statistic CQI value to the BS.

9. The method of claim 8, wherein the statistic CQI value comprises an average of the CQI values of the M subbands and a CQI variance of the M subbands.

10. The method of claim 9, wherein a maximum or minimum one of the CQI values of the M subbands is reported with the statistic CQI value.

11. The method of claim 1, wherein a size of a bitmap to express the positions of the M subbands is $\lceil log_2(N) \rceil$, and N is a total number of the subbands.

12. The method of claim 1, wherein only the at least one CQI value is reported to the BS based on setting of a higher layer parameter reportQuantity.

13. The method of claim 1, wherein a signal to interference plus noise ratio (SINR) is reported to the BS with the at least one CQI value based on setting of a higher layer parameter reportQuantity.

14. The method of claim 1, wherein a subband Offset level (s) of each of the M subbands is defined as:
subband offset level (s) = subband CQI index (s) - benchmark CQI index;
a subband differential CQI value each of the M subbands is acquired according to the subband Offset level (s) of each of the M subbands;
wherein the reporting at least one CQI value to the base station (BS) comprises:
reporting the subband differential CQI value each of the M subbands to the BS.

15. The method of claim 14, wherein the benchmark CQI index is an average of the CQI values of all of the subbands.

16. The method of claim 14, wherein the benchmark CQI index is one of the subbands having the best CQI value.

17. The method of claim 14, wherein the benchmark CQI index is one of the subbands having the worst CQI value.

18. The method of claim 14, wherein at least one reporting strategy for the reporting the at least one CQI value based on the M subbands to the base station (BS) is determined based on a size of a bandwidth part (BWP).

19. The method of claim 14, wherein at least one reporting strategy for the reporting the at least one CQI value based on the M subbands to the base station (BS) is determined based on a number of the subbands.

20. The method of claim 1, wherein a priority of a CSI report to the BS is associated with an ultra-reliable low-latency communication (URLLC) service.

21. The method of claim 1, wherein a priority of a CSI report to the BS is associated with an enhanced mobile broadband (eMBB) service.

22. The method of claim 1, wherein a priority of a CSI report to the BS is associated with an aperiodic CSI (A-CSI) report to be carried on a physical uplink control channel (PUCCH).

23. The method of claim 1, wherein a priority of a CSI report to the BS is associated with an aperiodic CSI (A-CSI) report to be carried on a physical uplink shared channel (PUSCH).

24. The method of claim 1, wherein a priority of a CSI report to the BS is associated with one of an ultra-reliable low-latency communication (URLLC) service and an enhanced mobile broadband (eMBB) service and one of an aperiodic CSI (A-CSI) report to be carried on a physical uplink control channel (PUCCH), an aperiodic CSI (A-CSI) report to be carried on a physical uplink shared channel (PUSCH), a semi-persistent CSI report to be carried on a physical uplink control channel (PUCCH), a semi-persistent CSI report to be carried on a physical uplink shared channel (PUSCH), and a periodic CSI report to be carried on a physical uplink control channel (PUCCH).

25. A method for channel state information (CSI) executable in a base station (BS), comprising:

receiving at least one CQI value from a user equipment (UE), wherein the at least one CQI value is based on M subbands of all subbands, and each of the subbands comprises at least one physical resource block (PRB);

receiving positions of the M subbands from the UE; and

selecting, according to the at least one CQI value and the positions of the M subbands, a modulation and coding scheme (MCS) for the UE.

26. The method of claim 25, wherein M is configured by downlink control information (DCI), higher layer parameters, or radio resource control (RRC) parameters.

27. The method of claim 25, wherein M is determined by a size of a bandwidth part (BWP).

28. The method of claim 25, wherein M is one-to-one correlation with a subband size.

29. The method of claim 25, wherein only the at least one CQI value is received based on setting of a higher layer parameter reportQuantity.

30. The method of claim 25, wherein a signal to interference plus noise ratio (SINR) is received with the at least one CQI value based on setting of a higher layer parameter reportQuantity.

31. A user equipment (UE) comprising:

a transceiver; and

a processor connected with the transceiver and configured to execute the following steps comprising:

determining which M subbands of all subbands are selected according to a CQI report mode, wherein each of the subbands comprises at least one physical resource block (PRB);

determining a value of M;

reporting at least one CQI value based on the M subbands to a base station (BS); and

reporting positions of the M subbands to the BS.

32. The user equipment of claim 31, wherein each of the M subbands has a CQI value, and the determining which M

subbands of all the subbands are selected comprises:

sorting the CQI values of all of the subbands; and

selecting the M subbands having the worst M CQI values.

33. The user equipment of claim 31, wherein the M subbands of the subbands are selected randomly.

34. The user equipment of claim 31, wherein M is configured by downlink control information (DCI), higher layer parameters, or radio resource control (RRC) parameters.

35. The user equipment of claim 31, wherein M is determined by a size of a bandwidth part (BWP).

36. The user equipment of claim 31, wherein M is one-to-one correlation with a subband size.

37. The user equipment of claim 31, wherein the reporting the at least one CQI value based on the M subbands to the base station (BS) comprises:

reporting the CQI values of the M subbands to the BS.

38. The user equipment of claim 31, wherein the reporting the at least one CQI value based on the M subbands to the base station (BS) comprises:

reporting a statistic CQI value to the BS.

39. The user equipment of claim 38, wherein the statistic CQI value comprises an average of the CQI values of the M subbands and a CQI variance of the M subbands.

40. The user equipment of claim 39, wherein a maximum or minimum one of the CQI values of the M subbands is reported with the statistic CQI value.

41. The user equipment of claim 31, wherein a size of a bitmap to express the positions of the M subbands is $\lceil log_2(N) \rceil$, and N is a total number of the subbands.

42. The user equipment of claim 31, wherein only the at least one CQI value is reported to the BS based on setting of a higher layer parameter reportQuantity.

43. The user equipment of claim 31, wherein a signal to interference plus noise ratio (SINR) is reported to the BS with the at least one CQI value based on setting of a higher layer parameter reportQuantity.

44. The user equipment of claim 31, wherein a subband Offset level (s) of each of the M subbands is defined as:

subband offset level (s) = subband CQI index (s) - benchmark CQI index;

a subband differential CQI value each of the M subbands is acquired according to the subband Offset level (s) of each of the M subbands;

wherein the reporting at least one CQI value to the base station (BS) comprises:

reporting the subband differential CQI value each of the M subbands to the BS.

45. The user equipment of claim 44, wherein the benchmark CQI index is an average of the CQI values of all of the subbands.

46. The user equipment of claim 44, wherein the benchmark CQI index is one of the subbands having the best CQI value.

47. The user equipment of claim 44, wherein the benchmark CQI index is one of the subbands having the worst CQI value.

48. The user equipment of claim 44, wherein at least one reporting strategy for the reporting the at least one CQI value based on the M subbands to the base station (BS) is determined based on a size of a bandwidth part (BWP).

49. The user equipment of claim 44, wherein at least one reporting strategy for the reporting the at least one CQI value based on the M subbands to the base station (BS) is determined based on a number of the subbands.

50. The user equipment of claim 31, wherein a priority of a CSI report to the BS is associated with an ultra-reliable

low-latency communication (URLLC) service.

51. The user equipment of claim 31, wherein a priority of a CSI report to the BS is associated with an enhanced mobile broadband (eMBB) service.

52. The user equipment of claim 31, wherein a priority of a CSI report to the BS is associated with an aperiodic CSI (A-CSI) report to be carried on a physical uplink control channel (PUCCH).

53. The user equipment of claim 31, wherein a priority of a CSI report to the BS is associated with an aperiodic CSI (A-CSI) report to be carried on a physical uplink shared channel (PUSCH).

54. The user equipment of claim 31, wherein a priority of a CSI report to the BS is associated with one of an ultra-reliable low-latency communication (URLLC) service and an enhanced mobile broadband (eMBB) service and one of an aperiodic CSI (A-CSI) report to be carried on a physical uplink control channel (PUCCH), an aperiodic CSI (A-CSI) report to be carried on a physical uplink shared channel (PUSCH), a semi-persistent CSI report to be carried on a physical uplink control channel (PUCCH), a semi-persistent CSI report to be carried on a physical uplink shared channel (PUSCH), and a periodic CSI report to be carried on a physical uplink control channel (PUCCH).

55. A base station, comprising:

a transceiver; and

a processor connected with the transceiver and configured to execute the following steps comprising:

receiving at least one CQI value from a user equipment (UE), wherein the at least one CQI value is based on M subbands of all subbands, and each of the subbands comprises at least one physical resource block (PRB);

receiving positions of the M subbands from the UE; and

selecting, according to the at least one CQI value and the positions of the M subbands, a modulation and coding scheme (MCS) for the UE.

56. The base station of claim 55, wherein M is configured by downlink control information (DCI), higher layer parameters, or radio resource control (RRC) parameters.

57. The base station of claim 55, wherein M is determined by a size of a bandwidth part (BWP).

58. The base station of claim 55, wherein M is one-to-one correlation with a subband size.

59. The base station of claim 55, wherein only the at least one CQI value is received based on setting of a higher layer parameter reportQuantity.

60. The base station of claim 55, wherein a signal to interference plus noise ratio (SINR) is received with the at least one CQI value based on setting of a higher layer parameter reportQuantity.

61. A chip, comprising:

a processor, configured to call and run a computer program stored in a memory, to cause a device in which the chip is installed to execute any of the methods of claims 1 to 24.

62. A chip, comprising:

a processor, configured to call and run a computer program stored in a memory, to cause a device in which the chip is installed to execute any of the methods of claims 25 to 30.

63. A computer readable storage medium, in which a computer program is stored, wherein the computer program causes a computer to execute any of the methods of claims 1 to 24.

64. A computer readable storage medium, in which a computer program is stored, wherein the computer program causes a computer to execute any of the methods of claims 25 to 30.

65. A computer program product, comprising a computer program, wherein the computer program causes a computer to execute any of the methods of claims 1 to 24.

66. A computer program product, comprising a computer program, wherein the computer program causes a computer to execute any of the methods of claims 25 to 30.

67. A computer program, wherein the computer program causes a computer to execute any of the methods of claims 1 to 24.

68. A computer program, wherein the computer program causes a computer to execute any of the methods of claims 25 to 30.

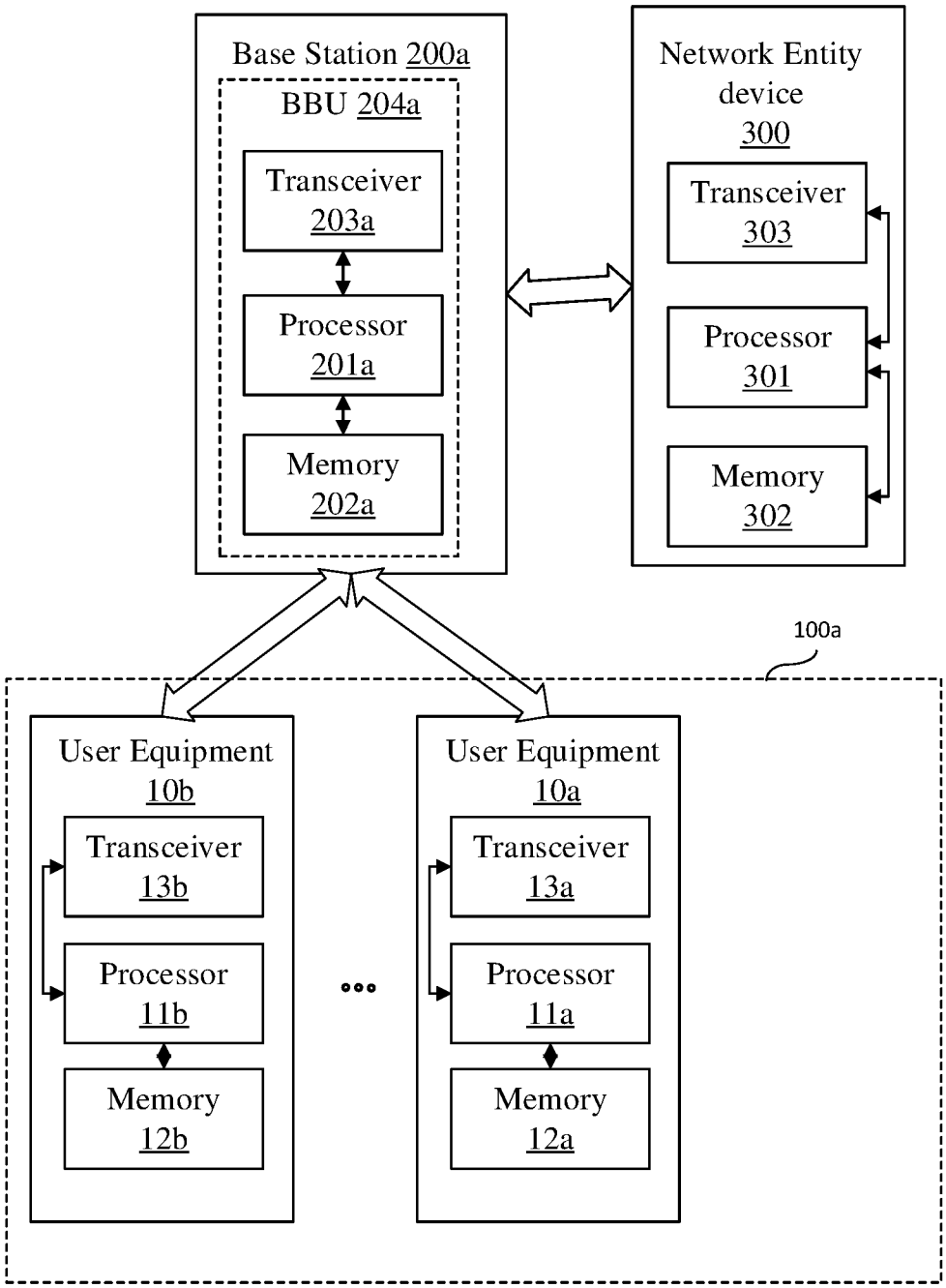

Base Station 200a
BBU 204a
Transceiver 203a
Processor 201a
Memory 202a
Network Entity device 300
Transceiver 303
Processor 301
Memory 302
100a
User Equipment 10b
Transceiver 13b
Processor 11b
Memory 12b
User Equipment 10a
Transceiver 13a
Processor 11a
Memory 12a

FIG. 1

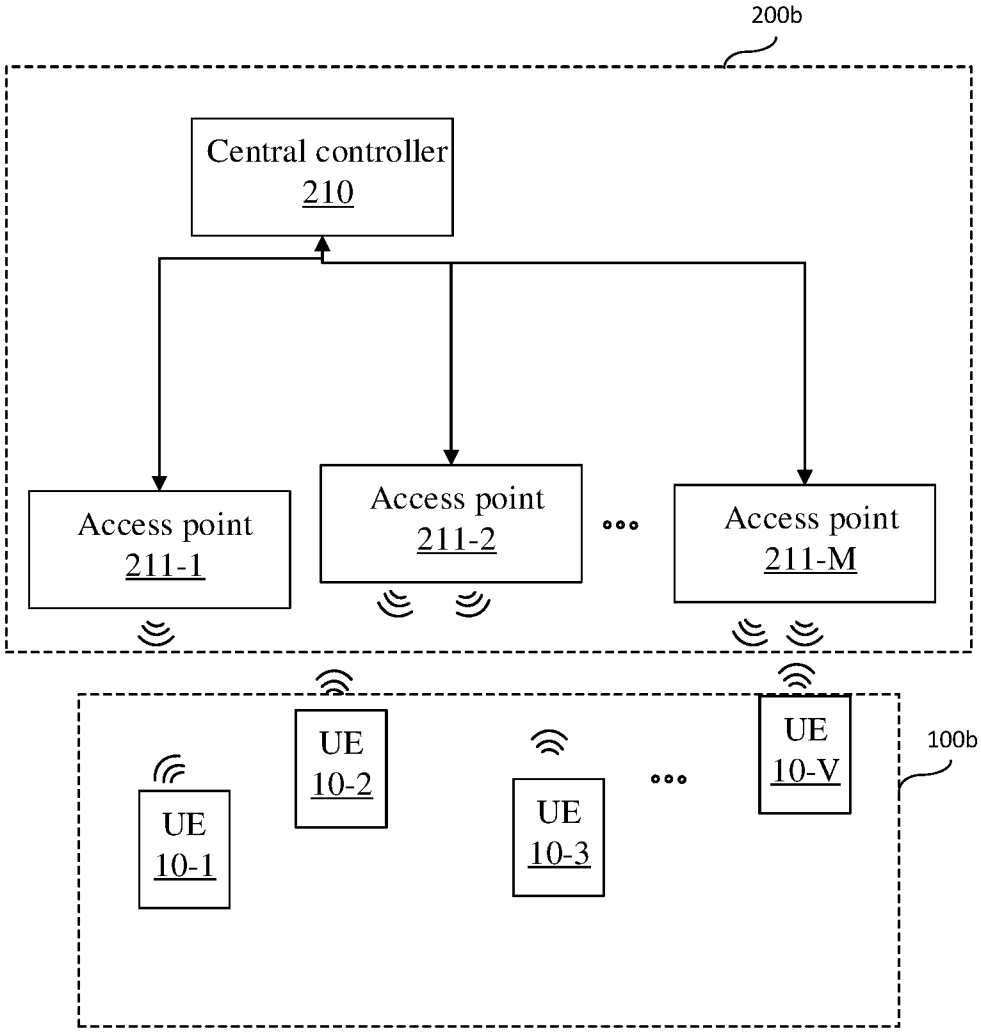

200b
Central controller
210
Access point
211-1
Access point
211-2
Access point
211-M
UE
10-1
UE
10-2
UE
10-3
UE
10-V
100b

FIG. 2

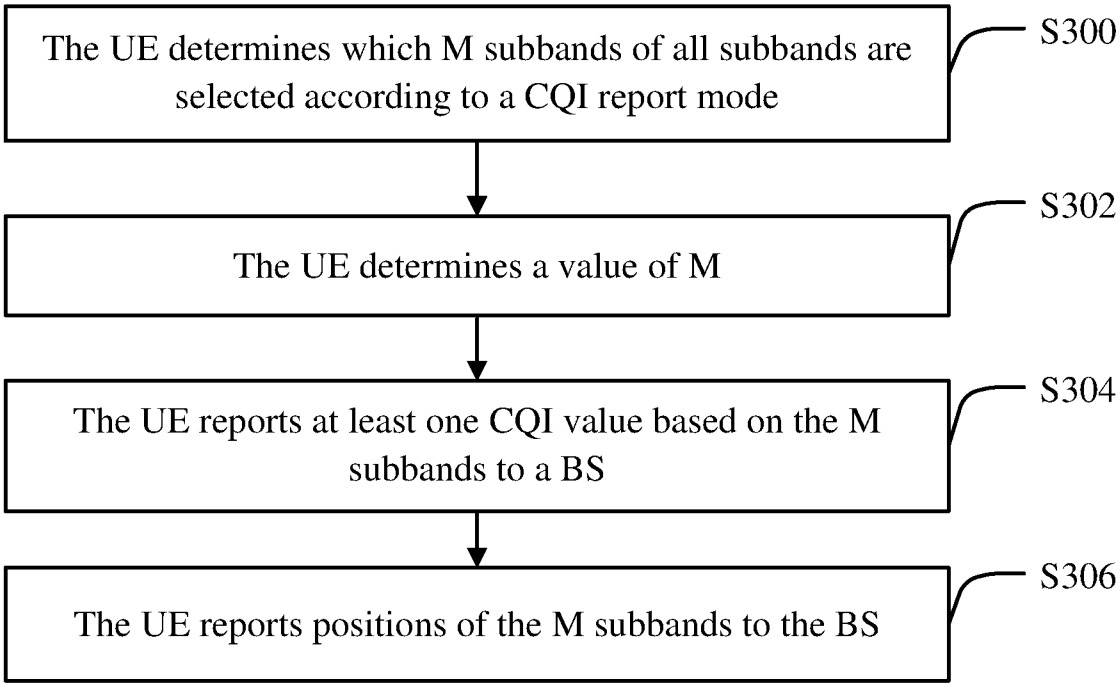

The UE determines which M subbands of all subbands are selected according to a CQI report mode
S300
The UE determines a value of M
S302
The UE reports at least one CQI value based on the M subbands to a BS
S304
The UE reports positions of the M subbands to the BS
S306

FIG. 3

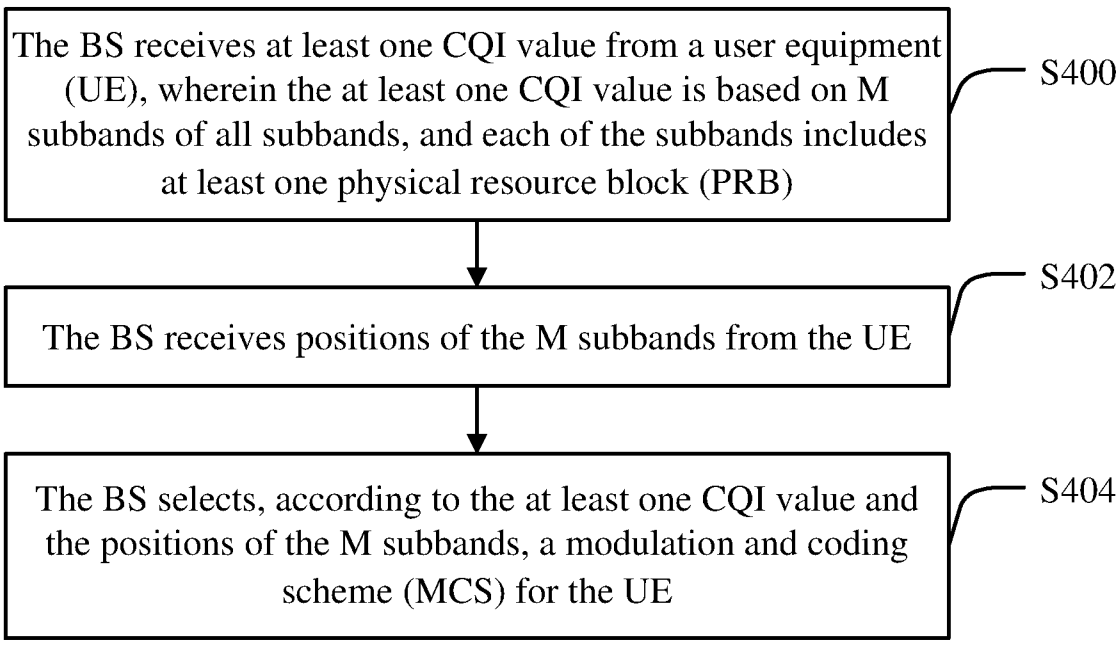

The BS receives at least one CQI value from a user equipment (UE), wherein the at least one CQI value is based on M subbands of all subbands, and each of the subbands includes at least one physical resource block (PRB)
S400
The BS receives positions of the M subbands from the UE
S402
The BS selects, according to the at least one CQI value and the positions of the M subbands, a modulation and coding scheme (MCS) for the UE
S404

FIG. 4

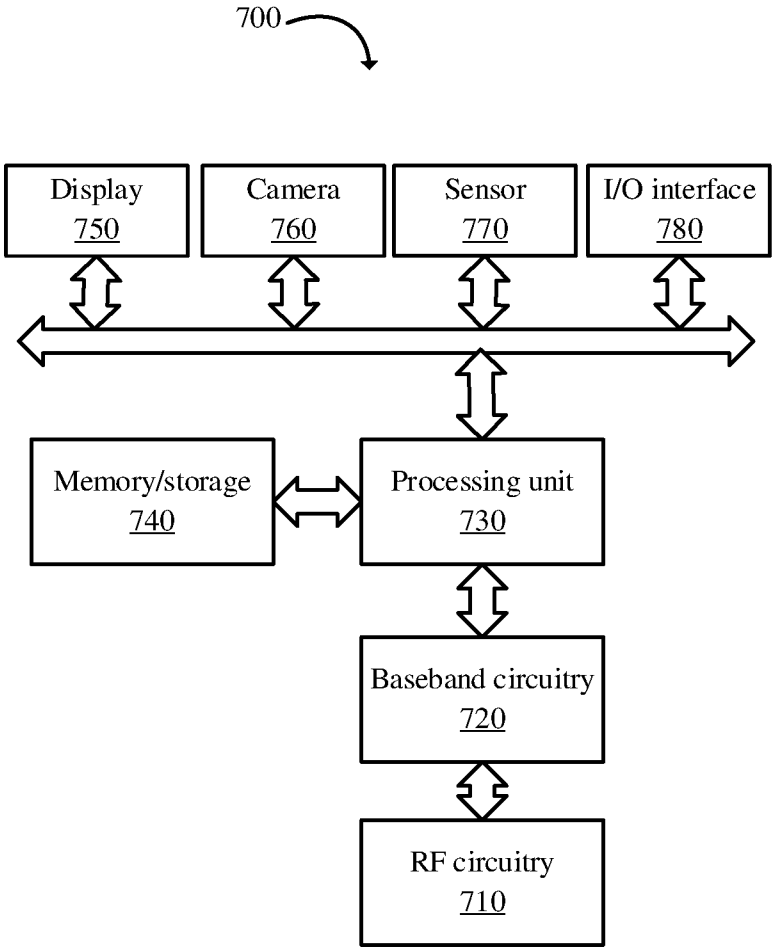

700
Display
750
Camera
760
Sensor
770
I/O interface
780
Memory/storage
740
Processing unit
730
Baseband circuitry
720
RF circuitry
710

FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2020/121166

A. CLASSIFICATION OF SUBJECT MATTER

H04W 72/12(2009.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04W; H04Q; H04L

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

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

CNKI,IEEE,VEN,CNABS,CNTXT,USTXT,EPTXT,WOTXT,3GPP:channel,state,information,CSI, CQI, physical resource block,PRB, bandwidth, part, BWP,coding,scheme,MCS, downlink control information, DCI,index,interference,plus, noise, ratio. SINR

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 102355338 A (CHINA ACADEMY OF TELECOMM TECH) 15 February 2012 (2012-02-15) see description, paragraphs [0060]-[0120]	1-68
A	CN 101911753 A (NTT DOCOMO INC) 08 December 2010 (2010-12-08) the whole document	1-68
A	WO 2020151760 A1 (QUALCOMM INC et al.) 30 July 2020 (2020-07-30) the whole document	1-68
A	US 2016344488 A1 (HONG KONG APPLIED SCIENCE & TECH RESEARCH INST CO LTD) 24 November 2016 (2016-11-24) the whole document	1-68
A	CN 112088561 A (KT CORP) 15 December 2020 (2020-12-15) the whole document	1-68

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
14 June 2021	**25 June 2021**
Name and mailing address of the ISA/CN **National Intellectual Property Administration, PRC** **6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088** **China** Facsimile No. **(86-10)62019451**	Authorized officer **TANG,Mingming** Telephone No. **86-010-62089396**

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2020/121166

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
CN	102355338	A	15 February 2012	CN	102355338	B	02 April 2014
CN	101911753	A	08 December 2010	JP	5202544	B2	05 June 2013
				JP	WO2009087924	A1	26 May 2011
				US	2011009139	A1	13 January 2011
				KR	20100106437	A	01 October 2010
				CN	101911753	B	11 September 2013
				US	8548512	B2	01 October 2013
				WO	2009087924	A1	16 July 2009
				EP	2242301	A1	20 October 2010
WO	2020151760	A1	30 July 2020	WO	2020150940	A1	30 July 2020
US	2016344488	A1	24 November 2016	US	9722758	B2	01 August 2017
CN	112088561	A	15 December 2020	KR	20200018310	A	19 February 2020