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(54) **Title:** CHANNEL STATE INFORMATION FEEDBACK FOR HIGHER RANK EXTENSION

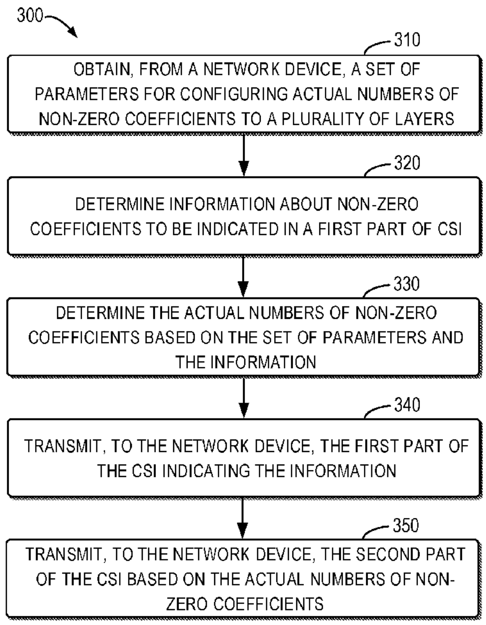

FIG. 3

(57) **Abstract:** Embodiments of the present disclosure relate to methods, devices, apparatuses and computer readable storage media for Channel State Information (CSI) feedback. A terminal device obtains, from a network device, a set of parameters for configuring actual numbers of non-zero coefficients to a plurality of layers of a channel. The terminal device determines information about non-zero coefficients to be indicated in a first part of CSI. The terminal device determines the actual numbers of non-zero coefficients based on the set of parameters and the information. The terminal device transmits, to the network device, the first part of the CSI indicating the information and transmits, to the network device, the second part of the CSI based on the actual numbers of non-zero coefficients. As such, the total payload of CSI feedback for a higher rank can maintain comparable to that for a lower rank.

WO 2020/199045 A1

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CHANNEL STATE INFORMATION FEEDBACK FOR HIGHER RANK EXTENSION

FIELD

[0001] Embodiments of the present disclosure generally relate to the field of telecommunication and in particular, to methods, devices, apparatuses and computer readable storage media for Channel State Information (CSI) feedback.

BACKGROUND

[0002] In the latest 3GPP specifications (that is, Release 16), it has been agreed that Type II CSI feedback (which is designed for a lower rank, such as, Rank Indication (RI) is 1 or 2) can be extended to a higher rank (such as, RI is 3 or 4), so as to support more data streams per user equipment (UE) for Single-User Multiple-Input Multiple-Output (SU-MIMO) or Multi-User Multiple-Input Multiple-Output (MU-MIMO) transmissions. The rank may indicate the number of independent transmission layers supported in a communication channel. That is, the overhead of CSI feedback will be significantly increased due to the addition of more layers for the rank extension. In this event, it would be desirable to maintain the total payload of CSI feedback for a higher rank (such as, RI is 3 or 4) comparable to that for a lower rank (such as, RI is 2).

SUMMARY

[0003] In general, example embodiments of the present disclosure provide a solution for CSI feedback.

[0004] In a first aspect, there is provided a device. The device comprises at least one processor; and at least one memory including computer program codes; the at least one memory and the computer program codes are configured to, with the at least one processor, cause the device to: obtain, at a terminal device and from a network device, a set of parameters for configuring actual numbers of non-zero coefficients to a plurality of layers of a channel between the terminal device and the network device; determine information about non-zero coefficients to be indicated in a first part of channel state information; determine the actual numbers of non-zero coefficients based on the set of parameters and the information, the actual numbers of non-zero coefficients being associated with a second part of the channel state information; transmit, to the network device, the first part of the channel state information indicating the information; and transmit, to the network device, the second part of the channel state information based on the actual numbers of non-zero coefficients.

[0005] In a second aspect, there is provided a device. The device comprises at least one processor; and at least one memory including computer program codes; the at least one memory and the computer program codes are configured to, with the at least one processor, cause the device to: indicate, from a network device to a terminal device, a set of parameters for configuring actual numbers of non-zero coefficients to a plurality of layers of a channel between the network device and the terminal device; receive a first part of channel state information from the terminal device, the first part of the channel state information indicating information about non-zero coefficients to be used across the plurality of layers; determine the actual numbers of non-zero coefficients based on the information and the set of parameters; and receive, from the terminal device, a second part of the channel state information based on the actual numbers of non-zero coefficients.

[0006] In a third aspect, there is provided a method. The method comprises: obtaining, at a terminal device and from a network device, a set of parameters for configuring actual numbers of non-zero coefficients to a plurality of layers of a channel between the terminal device and the network device; determining information about non-zero coefficients to be indicated in a first part of channel state information; determining the actual numbers of non-zero coefficients based on the set of parameters and the information, the actual numbers of non-zero coefficients being associated with a second part of the channel state information; transmitting, to the network device, the first part of the channel state information indicating the information; and transmitting, to the network device, the second part of the channel state information based on the actual numbers of non-zero coefficients.

[0007] In a fourth aspect, there is provided a method. The method comprises: indicating, from a network device to a terminal device, a set of parameters for configuring actual numbers of non-zero coefficients to a plurality of layers of a channel between the network device and the terminal device; receiving a first part of channel state information from the terminal device, the first part of the channel state information indicating information about non-zero coefficients to be used across the plurality of layers; determining the actual numbers of non-zero coefficients based on the information and the set of parameters; and receiving, from the terminal device, a second part of the channel state information based on the actual numbers of non-zero coefficients.

[0008] In a fifth aspect, there is provided an apparatus comprising: means for obtaining, at a terminal device and from a network device, a set of parameters for configuring actual numbers of non-zero coefficients to a plurality of layers of a channel between the terminal device and the network device; means for determining information about non-zero coefficients to be indicated in a first part of channel state information; means for determining the actual numbers of non-zero coefficients based on the set of parameters and the information, the actual numbers of non-zero coefficients being associated with a second part of the channel state information; means for transmitting, to the network device, the first part of the channel state information indicating the information; and means for transmitting, to the network device, the second part of the channel state information based on the actual numbers of non-zero coefficients.

[0009] In a sixth aspect, there is provided an apparatus comprising: means for indicating, from a network device to a terminal device, a set of parameters for configuring actual numbers of non-zero coefficients to a plurality of layers of a channel between the network device and the terminal device; means for receiving a first part of channel state information from the terminal device, the first part of the channel state information indicating information about non-zero coefficients to be used across the plurality of layers; means for determining the actual numbers of non-zero coefficients based on the information and the set of parameters; and means for receiving, from the terminal device, a second part of the channel state information based on the actual numbers of non-zero coefficients.

[0010] In a seventh aspect, there is provided a non-transitory computer readable medium comprising program instructions for causing an apparatus to perform at least the method according to the third or fourth aspect.

[0011] It is to be understood that the summary section is not intended to identify key or essential features of embodiments of the present disclosure, nor is it intended to be used to limit the scope of the present disclosure. Other features of the present disclosure will become easily comprehensible through the following description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] Some example embodiments will now be described with reference to the accompanying drawings, where:

[0013] FIG. 1 illustrates an example communication network in which example embodiments of the present disclosure may be implemented;

[0014] FIG. 2 illustrates a schematic diagram illustrating a process for CSI feedback according to example embodiments of the present disclosure;

[0015] FIG. 3 illustrates a flowchart of a method implemented at a terminal device according to example embodiments of the present disclosure;

[0016] FIG. 4 illustrates a flowchart of a method implemented at a network device according to example embodiments of the present disclosure;

[0017] FIG. 5 illustrates a simplified block diagram of an apparatus that is suitable for implementing example embodiments of the present disclosure; and

[0018] FIG. 6 illustrates a block diagram of an example computer readable medium in accordance with example embodiments of the present disclosure.

[0019] Throughout the drawings, the same or similar reference numerals represent the same or similar element.

DETAILED DESCRIPTION

[0020] Principle of the present disclosure will now be described with reference to some example embodiments. It is to be understood that these embodiments are described only for the purpose of illustration and help those skilled in the art to understand and implement the present disclosure, without suggesting any limitation as to the scope of the disclosure. The disclosure described herein can be implemented in various manners other than the ones described below.

[0021] In the following description and claims, unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skills in the art to which this disclosure belongs.

[0022] References in the present disclosure to "one embodiment," "an embodiment," "an example embodiment," and the like indicate that the embodiment described may include a particular feature, structure, or characteristic, but it is not necessary that every embodiment includes the particular feature, structure, or characteristic. Moreover, such phrases are not necessarily referring to the same embodiment. Further, when a particular feature, structure, or characteristic is described in connection with an embodiment, it is submitted that it is within the knowledge of one skilled in the art to affect such feature, structure, or characteristic in connection with other embodiments whether or not explicitly described.

[0023] It shall be understood that although the terms “first” and “second” etc. may be used herein to describe various elements, these elements should not be limited by these terms. These terms are only used to distinguish one element from another. For example, a first element could be termed a second element, and similarly, a second element could be termed a first element, without departing from the scope of example embodiments. As used herein, the term “and/or” includes any and all combinations of one or more of the listed terms.

[0024] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of example embodiments. As used herein, the singular forms “a”, “an” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms “comprises”, “comprising”, “has”, “having”, “includes” and/or “including”, when used herein, specify the presence of stated features, elements, and/or components etc., but do not preclude the presence or addition of one or more other features, elements, components and/ or combinations thereof.

[0025] As used in this application, the term “circuitry” may refer to one or more or all of the following:

(a) hardware-only circuit implementations (such as implementations in only analog and/or digital circuitry) and

(b) combinations of hardware circuits and software, such as (as applicable):

(i) a combination of analog and/or digital hardware circuit(s) with software/firmware and

(ii) any portions of hardware processor(s) with software (including digital signal processor(s)), software, and memory(ies) that work together to cause an apparatus, such as a mobile phone or server, to perform various functions) and

(c) hardware circuit(s) and or processor(s), such as a microprocessor(s) or a portion of a microprocessor(s), that requires software (e.g., firmware) for operation, but the software may not be present when it is not needed for operation.

[0026] This definition of circuitry applies to all uses of this term in this application, including in any claims. As a further example, as used in this application, the term circuitry also covers an implementation of merely a hardware circuit or processor (or multiple processors) or portion of a hardware circuit or processor and its (or their) accompanying software and/or firmware. The term circuitry also covers, for example and if applicable to the particular claim element, a baseband integrated circuit or processor integrated circuit for a mobile device or a similar integrated circuit in server, a cellular network device, or other computing or network device.

[0027] As used herein, the term "communication network" refers to a network following any suitable communication standards, such as Long Term Evolution (LTE), LTE-Advanced (LTE-A), Wideband Code Division Multiple Access (WCDMA), High-Speed Packet Access (HSPA), Narrow Band Internet of Things (NB-IoT) and so on. Furthermore, the communications between a terminal device and a network device in the communication network may be performed according to any suitable generation communication protocols, including, but not limited to, the first generation (1G), the second generation (2G), 2.5G, 2.75G, the third generation (3G), the fourth generation (4G), 4.5G, the future fifth generation (5G) communication protocols, and/or any other protocols either currently known or to be developed in the future. Embodiments of the present disclosure may be applied in various communication systems. Given the rapid development in communications, there will of course also be future type communication technologies and systems with which the present disclosure may be embodied. It should not be seen as limiting the scope of the present disclosure to only the aforementioned system.

[0028] As used herein, the term "network device" refers to a node in a communication network via which a terminal device accesses the network and receives services therefrom. The network device may refer to a base station (BS) or an access point (AP), for example, a node B (NodeB or NB), an evolved NodeB (eNodeB or eNB), a NR NB (also referred to as a gNB), a Remote Radio Unit (RRU), a radio header (RH), a remote radio head (RRH), a relay, a low power node such as a femto, a pico, and so forth, depending on the applied terminology and technology.

[0029] The term "terminal device" refers to any end device that may be capable of wireless communication. By way of example rather than limitation, a terminal device may also be referred to as a communication device, user equipment (UE), a Subscriber Station (SS), a Portable Subscriber Station, a Mobile Station (MS), or an Access Terminal (AT). The terminal device may include, but not limited to, a mobile phone, a cellular phone, a smart phone, voice over IP (VoIP) phones, wireless local loop phones, a tablet, a wearable terminal device, a personal digital assistant (PDA), portable computers, desktop computer, image capture terminal devices such as digital cameras, gaming terminal devices, music storage and playback appliances, vehicle-mounted wireless terminal devices, wireless endpoints, mobile stations, laptop-embedded equipment (LEE), laptop-mounted equipment (LME), USB dongles, smart devices, wireless customer-premises equipment (CPE), an Internet of Things (loT) device, a watch or other wearable, a head-mounted display (HMD), a vehicle, a drone, a medical device and applications (e.g., remote surgery), an industrial device and applications (e.g., a robot and/or other wireless devices operating in an industrial and/or an automated processing chain contexts), a consumer electronics device, a device operating on commercial and/or industrial wireless networks, and the like. In the following description, the terms “terminal device”, “communication device”, “terminal”, “user equipment” and “UE” may be used interchangeably.

[0030] As described above, in the latest 3GPP specifications (that is, Release 16), it has been agreed that Type II CSI feedback (which is designed for a lower rank, such as, RI is 1 or 2) can be extended to a higher rank (such as, RI is 3 or 4), so as to support more data streams per UE for SU-MIMO or MU-MIMO transmissions. However, the overhead of CSI feedback will be significantly increased due to the addition of more layers for higher rank extension. In this event, it would be desirable to maintain the total payload of CSI feedback for a higher rank comparable to that for a lower rank.

[0031] Some traditional solutions control and restrict the payload of CSI feedback in different layers for different RIs. For example, for different RIs, spatial domain parameters and frequency domain basis parameters may be configured for different layers. Besides, since the total number of non-zero coefficients among different layers may have dominant impact on the total payload of linear combination coefficient (LCC) quantization for different RIs, some traditional solutions set a maximum number of non-zero coefficients (K_0) to constrain the maximum feedback overhead for higher rank extension. However, these solutions cannot ensure that the total payload of CSI feedback for a higher rank is comparable to that for a lower rank.

[0032] Embodiments of the present disclosure provide a solution for CSI feedback, so as to at least in part solve the above and other potential problems. Some example embodiments of the present disclosure will be described below with reference to the figures. However, those skilled in the art would readily appreciate that the detailed description given herein with respect to these figures is for explanatory purpose as the present disclosure extends beyond theses limited embodiments.

[0033] FIG. 1 shows an example communication network 100 in which implementations of the present disclosure can be implemented. The communication network 100 includes a network device 110 and terminal devices 120-1, 120-2 . . . and 120-N, which can be collectively or individually referred to as "terminal device(s)" 120. The network 100 can provide one or more cells 102 to serve the terminal device 120. It is to be understood that the number of network devices, terminal devices and/or cells is given for the purpose of illustration without suggesting any limitations to the present disclosure. The communication network 100 may include any suitable number of network devices, terminal devices and/or cells adapted for implementing implementations of the present disclosure.

[0034] In the communication network 100, the network device 110 can communicate data and control information to the terminal device 120 and the terminal device 120 can also communication data and control information to the network device 110. A link from the network device 110 to the terminal device 120 is referred to as a downlink (DL), while a link from the terminal device 120 to the network device 110 is referred to as an uplink (UL).

[0035] The communications in the network 100 may conform to any suitable standards including, but not limited to, Global System for Mobile Communications (GSM), Long Term Evolution (LTE), LTE-Evolution, LTE-Advanced (LTE-A), Wideband Code Division Multiple Access (WCDMA), Code Division Multiple Access (CDMA), GSM EDGE Radio Access Network (GERAN), and the like. Furthermore, the communications may be performed according to any generation communication protocols either currently known or to be developed in the future. Examples of the communication protocols include, but not limited to, the first generation (1G), the second generation (2G), 2.5G, 2.75G, the third generation (3G), the fourth generation (4G), 4.5G, the fifth generation (5G) communication protocols.

[0036] In order to obtain CSI of a communication channel between the network device 110 and the terminal device 120, the network device 110 may transmit a Channel State Information-reference signal (CSI-RS) to the terminal device 120. The terminal device 120 may receive the CSI-RS from the network device 110, and obtain channel information by measuring the CSI-RS. The terminal device 120 may then determine the CSI of the communication channel based on the obtained channel information and a corresponding codebook. For example, the obtained channel information can be quantized into the CSI based on the corresponding codebook. The terminal device 120 may report the CSI to the network device 110. The process for reporting the CSI is also called as "CSI feedback". The CSI may ensure reliability of the wireless communication between the network device 110 and the terminal device 120.

[0037] FIG. 2 shows a schematic diagram of a process 200 for CSI feedback according to example embodiments of the present disclosure. For the purpose of discussion, the process 200 will be described with reference to FIG. 1. The process 200 may involve the terminal device 120 and the network devices 110 as illustrated in FIG. 1.

[0038] As shown in FIG. 2, the terminal device may obtain 210 a set of parameters (such as, γ_0, γ_1, α, β_3 and/or β_4 as described below) for configuring actual numbers of non-zero coefficients to a plurality of layers of a channel between the terminal device 120 and the network device 110. In some embodiments, the set of parameters may be determined by the network device 110 and indicated 210 to the terminal device 120 via Radio Resource Control signaling.

[0039] The terminal device 120 may determine 220 information about non-zero coefficients to be indicated in a first part of CSI. In some embodiments, for example, the terminal device 120 may measure the channel according to CSI-RS transmitted from the network device 110 and perform channel quantization. The terminal device 120 may then determine the value of RI as well as the information about non-zero coefficients to be indicated in a first part of the Channel State Information.

[0040] In response to obtaining the set of parameters and determining the information to be indicated in the first part of the CSI, the terminal device 120 may determine 230, based on the information indicated in the first part of CSI and the set of parameters, the actual numbers of non-zero coefficients for the plurality of layers.

[0041] In some embodiments, for different RIs (such as, RI is 1, 2, 3 or 4), the information in the first part of the CSI may indicate a total number of non-zero coefficients to be used across the plurality of layers of the channel. For example, the total number of non-zero coefficients indicated in the first part of the CSI may be represented as K_{NZ}, where $0 < K_{NZ} \leq 2K_0$ and K_0 represents the predefined maximum number of non-zero coefficients per layer. That is, for different RIs, the number of bits used for reporting the first part of CSI is always $\lceil log_2(2K_0)\rceil$.

[0042] In some embodiments, for RI=3 (that is, three independent layers are supported in a communication channel), the actual numbers of non-zero coefficients for the three layers may be represented as $K_{NZ,0}^{R3}$, $K_{NZ,1}^{R3}$, and $K_{NZ,2}^{R3}$ respectively. In some embodiments, for example, $K_{NZ,0}^{R3}$, $K_{NZ,1}^{R3}$, and $K_{NZ,2}^{R3}$ can be determined as below:

$$K_{NZ,0}^{R3} = \left\lceil \gamma_0 \times \frac{\beta_3 K_{NZ}}{2} \right\rceil \quad (1)$$

$$K_{NZ,1}^{R3} = \left\lceil \gamma_1 \times \frac{\beta_3 K_{NZ}}{2} \right\rceil \quad (2)$$

$$K_{NZ,2}^{R3} = \beta_3 K_{NZ} - \left\lceil \gamma_0 \times \frac{\beta_3 K_{NZ}}{2} \right\rceil - \left\lceil \gamma_1 \times \frac{\beta_3 K_{NZ}}{2} \right\rceil \quad (3)$$

where $1 > \gamma_0 \geq \gamma_1 > 0.5$ and $\beta_3 \geq 1$. Since $K_{NZ,0}^{R3} + K_{NZ,1}^{R3} + K_{NZ,2}^{R3} = \beta_3 K_{NZ}$, that is, the sum of the actual numbers of non-zero coefficients for RI = 3 is equal to or greater than that for RI = 2.

[0043] In some embodiments, for RI =4 (that is, four independent layers are supported in a communication channel), the actual numbers of non-zero coefficients of the four layers may be represented as $K_{NZ,0}^{R4}$, $K_{NZ,1}^{R4}$, $K_{NZ,2}^{R4}$ and $K_{NZ,3}^{R4}$ respectively. In some embodiments, for example, $K_{NZ,0}^{R4}$, $K_{NZ,1}^{R4}$, $K_{NZ,2}^{R4}$ and $K_{NZ,3}^{R4}$ can be determined as below:

$$K_{NZ,0}^{R4} = \left\lceil \gamma_0 \times \frac{\beta_4 K_{NZ}}{2} \right\rceil \quad (4)$$

$$K_{NZ,1}^{R4} = \left\lceil \gamma_1 \times \frac{\beta_4 K_{NZ}}{2} \right\rceil \quad (5)$$

$$K_{NZ,2}^{R4} = \left\lceil \alpha \times \left(\beta_4 K_{NZ} - \left\lceil \gamma_0 \times \frac{\beta_4 K_{NZ}}{2} \right\rceil - \left\lceil \gamma_1 \times \frac{\beta_4 K_{NZ}}{2} \right\rceil \right) \right\rceil \quad (6)$$

$$K_{NZ,3}^{R4} = \beta_4 K_{NZ} - \left\lceil \gamma_0 \times \frac{\beta_4 K_{NZ}}{2} \right\rceil - \left\lceil \gamma_1 \times \frac{\beta_4 K_{NZ}}{2} \right\rceil - \left\lceil \alpha \times \left(\beta_4 K_{NZ} - \left\lceil \gamma_0 \times \frac{\beta_4 K_{NZ}}{2} \right\rceil - \left\lceil \gamma_1 \times \frac{\beta_4 K_{NZ}}{2} \right\rceil \right) \right\rceil \quad (7)$$

where $1 > \gamma_0 \geq \gamma_1 > 0.5$, $1 > \alpha > 0.5$ and $\beta_4 \geq \beta_3 \geq 1$. Since $K_{NZ,0}^{R4} + K_{NZ,1}^{R4} + K_{NZ,2}^{R4} + K_{NZ,3}^{R4} = \beta_4 K_{NZ}$, that is, the sum of the actual numbers of non-zero coefficients for RI = 4 is equal to or greater than that for RI = 2.

[0044] In some embodiments, for RI = 2 (that is, two independent layers are supported in a communication channel), the actual numbers of non-zero coefficients of the two layers may be represented as $K_{NZ,0}$ and $K_{NZ,1}$ respectively. In some embodiments, for example,

$K_{NZ,0}$ and $K_{NZ,1}$ can be determined as below:

$$K_{NZ,0} = \frac{K_{NZ}}{2} \quad (8)$$

$$K_{NZ,1} = \frac{K_{NZ}}{2} \quad (9)$$

[0045] In some embodiments, for RI = 1 (that is, a single layer is supported in a communication channel), the actual number of non-zero coefficients of the single layer may be represented as $K_{NZ,0}$, where $K_{NZ,0} = K_{NZ}$.

[0046] Alternatively, in some embodiments, for different RIs (such as, RI is 1, 2, 3 or 4), the information in the first part of the CSI may indicate two numbers, which are represented as $K_{NZ,0}$ and $K_{NZ,1}$, where $0 < K_{NZ,0} \leq K_0$ and $0 < K_{NZ,1} \leq K_0$ and where K_0 represents the predefined maximum number of non-zero coefficients per layer. That is, for different RIs, the number of bits used for reporting the first part of CSI is always $2 \cdot \lceil log_2(K_0) \rceil$. In some embodiments, $K_{NZ,0}$ and $K_{NZ,1}$ may be determined by assuming RI=2. Assuming that RI is 2, two independent layers may be supported in a channel between the terminal device 120 and the network device 110. In some embodiments, $K_{NZ,0}$ indicated in the first part of the CSI may represent a first number of non-zero coefficients to be used at a first layer of the two layers, and $K_{NZ,1}$ indicated in the first part of the CSI may represent a second number of non-zero coefficients to be used at a second layer of the two layers. For example, $K_{NZ,0}$ and $K_{NZ,1}$ may be common to different RIs (such as, 2, 3 or 4), and they may correspond to the first two layers in the channel when RI > 2. In some embodiments, if RI is 1, $K_{NZ,1}$ may be regarded as 0, although it may be reported as a different value.

[0047] In some embodiments, for RI =3 (that is, three independent layers are supported in a communication channel), the actual numbers of non-zero coefficients of the three layers may be represented as $K_{NZ,0}^{R3}$, $K_{NZ,1}^{R3}$, and $K_{NZ,2}^{R3}$ respectively. In some embodiments, for example, $K_{NZ,0}^{R3}$, $K_{NZ,1}^{R3}$, and $K_{NZ,2}^{R3}$ can be determined as below:

$$K_{NZ,0}^{R3} = \lceil \gamma_0 \times \beta_3 K_{NZ,0} \rceil \quad (10)$$

$$K_{NZ,1}^{R3} = \lceil \gamma_1 \times \beta_3 K_{NZ,1} \rceil \quad (11)$$

$$K_{NZ,2}^{R3} = \beta_3 (K_{NZ,0} + K_{NZ,1}) - \lceil \gamma_0 \times \beta_3 K_{NZ,0} \rceil - \lceil \gamma_1 \times \beta_3 K_{NZ,1} \rceil \quad (12)$$

where $1 > \gamma_0 \geq \gamma_1 > 0.5$ and $\beta_3 \geq 1$. It can be seen that, $K_{NZ,0}^{R3} + K_{NZ,1}^{R3} + K_{NZ,2}^{R3} =$

$\beta_3(K_{NZ,0} + K_{NZ,1})$. That is, the sum of the actual numbers of non-zero coefficients for RI = 3 is equal to or greater than that for RI = 2.

[0048] In some embodiments, for RI =4 (that is, four independent layers are supported in a communication channel), the actual numbers of non-zero coefficients of the four layers may be represented as $K_{NZ,0}^{R4}$, $K_{NZ,1}^{R4}$, $K_{NZ,2}^{R4}$ and $K_{NZ,3}^{R4}$ respectively. In some embodiments, for example, $K_{NZ,0}^{R4}$, $K_{NZ,1}^{R4}$, $K_{NZ,2}^{R4}$ and $K_{NZ,3}^{R4}$ can be determined as below:

$$K_{NZ,0}^{R4} = \lceil \gamma_0 \times \beta_4 K_{NZ,0} \rceil \tag{13}$$

$$K_{NZ,1}^{R4} = \lceil \gamma_1 \times \beta_4 K_{NZ,1} \rceil \tag{14}$$

$$K_{NZ,2}^{R4} = \lceil \alpha \times (\beta_4(K_{NZ,0} + K_{NZ,1}) - \lceil \gamma_0 \times \beta_4 K_{NZ,0} \rceil - \lceil \gamma_1 \times \beta_4 K_{NZ,1} \rceil) \rceil \tag{15}$$

$$K_{NZ,3}^{R4} = \beta_4(K_{NZ,0} + K_{NZ,1}) - \lceil \gamma_0 \times \beta_4 K_{NZ,0} \rceil - \lceil \gamma_1 \times \beta_4 K_{NZ,1} \rceil - \lceil \alpha \times (\beta_4(K_{NZ,0} + K_{NZ,1}) - \lceil \gamma_0 \times \beta_4 K_{NZ,0} \rceil - \lceil \gamma_1 \times \beta_4 K_{NZ,1} \rceil) \rceil \tag{16}$$

where $1 > \gamma_0 \geq \gamma_1 > 0.5$, $1 > \alpha > 0.5$ and $\beta_4 \geq \beta_3 \geq 1$. It can be seen that, $K_{NZ,0}^{R4} + K_{NZ,1}^{R4} + K_{NZ,2}^{R4} + K_{NZ,3}^{R4} = \beta_4(K_{NZ,0} + K_{NZ,1})$. That is, the sum of the actual numbers of non-zero coefficients for RI = 4 is equal to or greater than that for RI = 2.

[0049] In some embodiments, as described above, the set of parameters including at least one of γ_0, γ_1, α, β_3 and β_4 may be indicated 210 from the network device 110 to the terminal device 120 via RRC signaling. Regarding the parameters γ_0, γ_1 and α, in some embodiments, three different values may be indicated via RRC signaling, such as $\{\gamma_0, \gamma_1, \alpha\}$. Alternatively, in some embodiments, two different values may be indicated via RRC signaling, such as $\{\gamma, \alpha\}$, where $\gamma_0 = \gamma_1 = \gamma$. Alternatively, in some embodiments, only a single value may be indicated via RRC signaling, such as $\{\alpha\}$, where $\gamma_0 = \gamma_1 = \alpha$. Regarding the parameters β_3 and β_4, in some embodiments, two different values may be indicated via RRC signaling, such as $\{\beta_3, \beta_4\}$. Alternatively, in some embodiments, only a single value may be indicated via RRC signaling, such as $\{\beta\}$, where $\beta_3 = \beta_4 = \beta$. Alternatively, in some embodiments, if no value regarding the parameters β_3 and β_4 is indicated via RRC signaling, the terminal device 120 may assume that both of β_3 and β_4 equal to 1.

[0050] As shown in FIG.2, the terminal device 120 may transmit 240 the first part of CSI indicating the information about non-zero coefficients to the network device 110. In response to receiving the first part of CSI from the terminal device 120, the network device 110 may determine 250, based on the information indicated in the first part of CSI and the set of parameters, the actual numbers of non-zero coefficients for the plurality of layers. In some embodiments, for example, the network device 110 may determine the actual numbers of non-zero coefficients for the plurality of layers in a same way as the terminal device 120 as described, which will not be repeated herein.

[0051] Then, the network device 110 may determine, based on the actual numbers of non-zero coefficients for the plurality of layers, a payload size of a second part of the CSI. In response to determining the payload size of the second part of the CSI, the network device 110 may properly receive 260 the second part of the CSI from the terminal device 120.

[0052] In some embodiments, if the total number of non-zero coefficients K_{NZ} is indicated in the first part of the CSI, according to the agreed LCC quantization method, the total payload sizes for different RIs (such as, 2, 3 or 4) are shown as Table 1:

Table 1. The payload size of 2-part CSI for different RIs

RI	Part-I CSI (bits)	Part-II CSI (bits)
2	$\lceil log_2(2K_0)\rceil$	$7 \times K_{NZ} + \lceil log_2(K_{NZ,0})\rceil + \lceil log_2(K_{NZ,1})\rceil + 4LM - 6$
3	$\lceil log_2(2K_0)\rceil$	$7 \times \beta_3 K_{NZ} + \lceil log_2(K_{NZ,0}^{R3})\rceil + \lceil log_2(K_{NZ,1}^{R3})\rceil + \lceil log_2(K_{NZ,2}^{R3})\rceil + 6LM - 9$
4	$\lceil log_2(2K_0)\rceil$	$7 \times \beta_4 K_{NZ} + \lceil log_2(K_{NZ,0}^{R4})\rceil + \lceil log_2(K_{NZ,1}^{R4})\rceil + \lceil log_2(K_{NZ,2}^{R4})\rceil + \lceil log_2(K_{NZ,3}^{R4})\rceil + 8LM - 12$

In Table 1, it is assumed that the number of spatial domain (SD) beams is 2L and the number of frequency domain (FD) beams is M. It can be seen from Table 1 that, if $\beta_3 = 1$, the linear sum (that is, $7 \times \beta_3 K_{NZ}$) of quantization bit length of non-zero coefficients for RI = 3 is the same as that for RI =2 (that is, $7 \times K_{NZ}$). If $\beta_3>1$, the linear sum of quantization bit length of non-zero coefficients for RI = 3 is still comparable to that for RI =2. If $\beta_4 = 1$, the linear sum (that is, $7 \times \beta_4 K_{NZ}$) of quantization bit length of non-zero coefficients for RI = 4 is the same as that for RI =2 (that is, $7 \times K_{NZ}$). If $\beta_4>1$, the linear sum of quantization bit length of non-zero coefficients for RI = 4 is still comparable to that for RI =2. Although the log-domain sum of numbers of non-zero coefficients and the product of the number of SD beams and the number of FD beams are different for different RIs, they have limited effect on the total CSI payload of LCC quantization compared with the linear sum. That is, embodiments of the present disclosure enable the total payload of CSI feedback for a higher rank to be comparable to that for RI=2.

[0053] In some embodiments, if the two numbers $K_{NZ,0}$ and $K_{NZ,1}$ are indicated in the first part of the CSI, according to the agreed LCC quantization method, the total payload sizes for different RIs (such as, RI is 2, 3 or 4) are shown as Table 2:

Table 2. The payload size of 2-part CSI for different RIs

RI	Part-I CSI (bits)	Part-II CSI (bits)
2	$2 \times \lceil log_2(K_0) \rceil$	$7 \times (K_{NZ,0} + K_{NZ,1}) + \lceil log_2(K_{NZ,0}) \rceil + \lceil log_2(K_{NZ,1}) \rceil + 4LM - 6$
3	$2 \times \lceil log_2(K_0) \rceil$	$7 \times \beta_3(K_{NZ,0} + K_{NZ,1}) + \lceil log_2(K_{NZ,0}^{R3}) \rceil + \lceil log_2(K_{NZ,1}^{R3}) \rceil + \lceil log_2(K_{NZ,2}^{R3}) \rceil + 6LM - 9$
4	$2 \times \lceil log_2(K_0) \rceil$	$7 \times \beta_4(K_{NZ,0} + K_{NZ,1}) + \lceil log_2(K_{NZ,0}^{R4}) \rceil + \lceil log_2(K_{NZ,1}^{R4}) \rceil + \lceil log_2(K_{NZ,2}^{R4}) \rceil + \lceil log_2(K_{NZ,3}^{R4}) \rceil + 8LM - 12$

In Table 2, it is also assumed that the number of SD beams is 2L and the number of FD beams is M. It can be seen from Table 2 that, if $\beta_3 = 1$, the linear sum (that is, $7 \times \beta_3(K_{NZ,0} + K_{NZ,1})$) of quantization bit length of non-zero coefficients for RI = 3 is the same as that for RI =2 (that is, $7 \times (K_{NZ,0} + K_{NZ,1})$). If $\beta_3>1$, the linear sum of quantization bit length of non-zero coefficients for RI = 3 is still comparable to that for RI =2. If $\beta_4 = 1$, the linear sum (that is, $7 \times \beta_4(K_{NZ,0} + K_{NZ,1})$) of quantization bit length of non-zero coefficients for RI = 4 is the same as that for RI =2 (that is, $7 \times K_{NZ}$). If $\beta_4>1$, the linear sum of quantization bit length of non-zero coefficients for RI = 4 is still comparable to that for RI =2. Although the log-domain sum of numbers of non-zero coefficients and the product of the number of SD beams and the number of FD beams are different for different RIs, they have limited effect on the total CSI payload of LCC quantization compared with the linear sum. That is, embodiments of the present disclosure enable the total payload of CSI feedback for a higher rank to be comparable to that for RI=2.

[0054] FIG. 3 shows a flowchart of an example method 300 implemented at a terminal device in accordance with some embodiments of the present disclosure. For the purpose of discussion, the method 300 will be described from the perspective of the terminal device 120 with reference to FIG. 1. It is to be understood that method 300 may further include additional blocks not shown and/or omit some shown blocks, and the scope of the present disclosure is not limited in this regard.

[0055] At block 310, the terminal device 120 obtains, from a network device, a set of parameters for configuring actual numbers of non-zero coefficients to a plurality of layers of a channel between the terminal device and the network device.

[0056] In some embodiments, the terminal device 120 may obtain the set of parameters by: receiving, from the network device, a configuration about the set of parameters via Radio Resource Control signaling; and determining, based on the configuration, the set of parameters.

[0057] In some embodiments, the set of parameters may comprise a single parameter.

[0058] In some embodiments, the set of parameters may comprise two or more different parameters.

[0059] At block 320, the terminal device 120 determines information about non-zero coefficients to be indicated in a first part of Channel State Information.

[0060] At block 330, the terminal device 120 determines the actual numbers of non-zero coefficients based on the set of parameters and the information, the actual numbers of non-zero coefficients being associated with a second part of the Channel State Information.

[0061] In some embodiments, the information may indicate a total number of non-zero coefficients to be used across the plurality of layers of the channel.

[0062] In some embodiments, the terminal device 120 may determine the actual numbers of non-zero coefficients, such that a sum of the actual numbers of non-zero coefficients has a correspondence with the total number of non-zero coefficients indicated by the information.

[0063] In some embodiments, the terminal device 120 may determine the actual numbers of non-zero coefficients, such that the sum of the actual numbers of non-zero coefficients equals to the total number of non-zero coefficients indicated by the information.

[0064] In some embodiments, the plurality of layers may comprise more than two layers. The information may indicate a first number of non-zero coefficients to be used at a first layer in the plurality of layers and a second number of non-zero coefficients to be used at a second layer in the plurality of layers.

[0065] In some embodiments, the terminal device 120 may determine the actual numbers of non-zero coefficients, such that a sum of the actual numbers of non-zero coefficients has a correspondence with a sum of the first number and the second number.

[0066] In some embodiments, the terminal device 120 may determine the actual numbers of non-zero coefficients, such that the sum of the actual numbers of non-zero coefficients equals to the sum of the first number and the second number.

[0067] At block 340, the terminal device 120 transmits, to the network device, the first part of the Channel State Information indicating the information.

[0068] At block 350, the terminal device 120 transmits, to the network device, the second part of the Channel State Information based on the actual numbers of non-zero coefficients.

[0069] FIG. 4 shows a flowchart of an example method 400 implemented at a network device in accordance with some embodiments of the present disclosure. For the purpose of discussion, the method 400 will be described from the perspective of the network device 110 with reference to FIG. 1. It is to be understood that method 400 may further include additional blocks not shown and/or omit some shown blocks, and the scope of the present disclosure is not limited in this regard.

[0070] At block 410, the network device 110 indicates, to a terminal device, a set of parameters for configuring actual numbers of non-zero coefficients to a plurality of layers of a channel between the network device and the terminal device.

[0071] In some embodiments, the network device 110 may transmit, to the terminal device, a configuration about the set of parameters via Radio Resource Control signaling.

[0072] At block 420, the network device 110 receives a first part of Channel State Information from the terminal device, the first part of the Channel State Information indicating information about non-zero coefficients to be used across the plurality of layers.

[0073] At block 430, the network device 110 determines the actual numbers of non-zero coefficients based on the information and the set of parameters.

[0074] In some embodiments, the information may indicate a total number of non-zero coefficients to be used across the plurality of layers of the channel.

[0075] In some embodiments, the network device 110 may determine the actual numbers of non-zero coefficients, such that a sum of the actual numbers of non-zero coefficients has a correspondence with the total number of non-zero coefficients indicated by the information.

[0076] In some embodiments, the network device 110 may determine the actual numbers of non-zero coefficients, such that the sum of the actual numbers of non-zero coefficients equals to the total number of non-zero coefficients indicated by the information.

[0077] In some embodiments, the plurality of layers may comprise more than two layers. The information may indicate a first number of non-zero coefficients to be used at a first layer in the plurality of layers and a second number of non-zero coefficients to be used at a second layer in the plurality of layers.

[0078] In some embodiments, the network device 110 may determine the actual numbers of non-zero coefficients, such that a sum of the actual numbers of non-zero coefficients has a correspondence with a sum of the first number and the second number.

[0079] In some embodiments, the network device 110 may determine the actual numbers of non-zero coefficients, such that the sum of the actual numbers of non-zero coefficients equals to the sum of the first number and the second number.

[0080] At block 440, the network device 110 receives, from the terminal device, a second part of the Channel State Information based on the actual numbers of non-zero coefficients.

[0081] In some embodiments, the network device 110 may determine, based on the actual number of non-zero coefficients, a size of the second part of the Channel State Information. The network device 110 may receive, based on the determined size, the second part of the Channel State Information from the terminal device.

[0082] In some embodiments, an apparatus capable of performing the method 300 (for example, the terminal device 120) may comprise means for performing the respective steps of the method 300. The means may be implemented in any suitable form. For example, the means may be implemented in a circuitry or software module.

[0083] In some embodiments, the apparatus comprises: means for obtaining, at a terminal device and from a network device, a set of parameters for configuring actual numbers of non-zero coefficients to a plurality of layers of a channel between the terminal device and the network device; means for determining information about non-zero coefficients to be indicated in a first part of Channel State Information; means for determining the actual numbers of non-zero coefficients based on the set of parameters and the information, the actual numbers of non-zero coefficients being associated with a second part of the Channel State Information; means for transmitting, to the network device, the first part of the Channel State Information indicating the information; and means for transmitting, to the network device, the second part of the Channel State Information based on the actual numbers of non-zero coefficients.

[0084] In some embodiments, the apparatus further comprises means for performing other steps in some embodiments of the method 300. In some embodiments, the means comprises at least one processor; and at least one memory including computer program code, the at least one memory and computer program code configured to, with the at least one processor, cause the performance of the apparatus.

[0085] In some embodiments, an apparatus capable of performing the method 400 (for example, the network device 110) may comprise means for performing the respective steps of the method 400. The means may be implemented in any suitable form. For example, the means may be implemented in a circuitry or software module.

[0086] In some embodiments, the apparatus comprises: means for indicating, from a network device to a terminal device, a set of parameters for configuring actual numbers of non-zero coefficients to a plurality of layers of a channel between the network device and the terminal device; means for receiving a first part of Channel State Information from the terminal device, the first part of the Channel State Information indicating information about non-zero coefficients to be used across the plurality of layers; means for determining the actual numbers of non-zero coefficients based on the information and the set of parameters; and means for receiving, from the terminal device, a second part of the Channel State Information based on the actual numbers of non-zero coefficients.

[0087] In some embodiments, the apparatus further comprises means for performing other steps in some embodiments of the method 400. In some embodiments, the means comprises at least one processor; and at least one memory including computer program code, the at least one memory and computer program code configured to, with the at least one processor, cause the performance of the apparatus.

[0088] FIG. 5 is a simplified block diagram of a device 500 that is suitable for implementing embodiments of the present disclosure. The device 500 may be provided to implement the communication device, for example the terminal device 120 or the network device 110 as shown in FIG. 1. As shown, the device 500 includes one or more processors 510, one or more memories 520 coupled to the processor 510, and one or more communication modules 540 (such as, transmitters and/or receivers) coupled to the processor 510.

[0089] The communication module 540 is for bidirectional communications. The communication module 540 has at least one antenna to facilitate communication. The communication interface may represent any interface that is necessary for communication with other network elements.

[0090] The processor 510 may be of any type suitable to the local technical network and may include one or more of the following: general purpose computers, special purpose computers, microprocessors, digital signal processors (DSPs) and processors based on multicore processor architecture, as non-limiting examples. The device 500 may have multiple processors, such as an application specific integrated circuit chip that is slaved in time to a clock which synchronizes the main processor.

[0091] The memory 520 may include one or more non-volatile memories and one or more volatile memories. Examples of the non-volatile memories include, but are not limited to, a Read Only Memory (ROM) 524, an electrically programmable read only memory (EPROM), a flash memory, a hard disk, a compact disc (CD), a digital video disk (DVD), and other magnetic storage and/or optical storage. Examples of the volatile memories include, but are not limited to, a random access memory (RAM) 522 and other volatile memories that will not last in the power-down duration.

[0092] A computer program 530 includes computer executable instructions that are executed by the associated processor 510. The program 530 may be stored in the ROM 524. The processor 510 may perform any suitable actions and processing by loading the program 530 into the RAM 522.

[0093] The embodiments of the present disclosure may be implemented by means of the program 530 so that the device 500 may perform any process of the disclosure as discussed with reference to FIGs. 2 to 4. The embodiments of the present disclosure may also be implemented by hardware or by a combination of software and hardware.

[0094] In some embodiments, the program 530 may be tangibly contained in a computer readable medium which may be included in the device 500 (such as in the memory 520) or other storage devices that are accessible by the device 500. The device 500 may load the program 530 from the computer readable medium to the RAM 522 for execution. The computer readable medium may include any types of tangible non-volatile storage, such as ROM, EPROM, a flash memory, a hard disk, CD, DVD, and the like. FIG. 6 shows an example of the computer readable medium 600 in form of CD or DVD. The computer readable medium has the program 530 stored thereon.

[0095] Generally, various embodiments of the present disclosure may be implemented in hardware or special purpose circuits, software, logic or any combination thereof. Some aspects may be implemented in hardware, while other aspects may be implemented in firmware or software which may be executed by a controller, microprocessor or other computing device. While various aspects of embodiments of the present disclosure are illustrated and described as block diagrams, flowcharts, or using some other pictorial representations, it is to be understood that the block, apparatus, system, technique or method described herein may be implemented in, as non-limiting examples, hardware, software, firmware, special purpose circuits or logic, general purpose hardware or controller or other computing devices, or some combination thereof.

[0096] The present disclosure also provides at least one computer program product tangibly stored on a non-transitory computer readable storage medium. The computer program product includes computer-executable instructions, such as those included in program modules, being executed in a device on a target real or virtual processor, to carry out the method 300 as described above with reference to FIG. 3 and/or the method 400 as described above with reference to FIG. 4. Generally, program modules include routines, programs, libraries, objects, classes, components, data structures, or the like that perform particular tasks or implement particular abstract data types. The functionality of the program modules may be combined or split between program modules as desired in various embodiments. Machine-executable instructions for program modules may be executed within a local or distributed device. In a distributed device, program modules may be located in both local and remote storage media.

[0097] Program code for carrying out methods of the present disclosure may be written in any combination of one or more programming languages. These program codes may be provided to a processor or controller of a general purpose computer, special purpose computer, or other programmable data processing apparatus, such that the program codes, when executed by the processor or controller, cause the functions/operations specified in the flowcharts and/or block diagrams to be implemented. The program code may execute entirely on a machine, partly on the machine, as a stand-alone software package, partly on the machine and partly on a remote machine or entirely on the remote machine or server.

[0098] In the context of the present disclosure, the computer program codes or related data may be carried by any suitable carrier to enable the device, apparatus or processor to perform various processes and operations as described above. Examples of the carrier include a signal, computer readable medium, and the like.

[0099] The computer readable medium may be a computer readable signal medium or a computer readable storage medium. A computer readable medium may include but not limited to an electronic, magnetic, optical, electromagnetic, infrared, or semiconductor system, apparatus, or device, or any suitable combination of the foregoing. More specific examples of the computer readable storage medium would include an electrical connection having one or more wires, a portable computer diskette, a hard disk, a random access memory (RAM), a read-only memory (ROM), an erasable programmable read-only memory (EPROM or Flash memory), an optical fiber, a portable compact disc read-only memory (CD-ROM), an optical storage device, a magnetic storage device, or any suitable combination of the foregoing.

[00100] Further, while operations are depicted in a particular order, this should not be understood as requiring that such operations be performed in the particular order shown or in sequential order, or that all illustrated operations be performed, to achieve desirable results. In certain circumstances, multitasking and parallel processing may be advantageous. Likewise, while several specific implementation details are contained in the above discussions, these should not be construed as limitations on the scope of the present disclosure, but rather as descriptions of features that may be specific to particular embodiments. Certain features that are described in the context of separate embodiments may also be implemented in combination in a single embodiment. Conversely, various features that are described in the context of a single embodiment may also be implemented in multiple embodiments separately or in any suitable sub-combination.

[00101] Although the present disclosure has been described in languages specific to structural features and/or methodological acts, it is to be understood that the present disclosure defined in the appended claims is not necessarily limited to the specific features or acts described above. Rather, the specific features and acts described above are disclosed as example forms of implementing the claims.

WHAT IS CLAIMED IS:

1. A device, comprising:

at least one processor; and

at least one memory including computer program codes;

the at least one memory and the computer program codes are configured to, with the at least one processor, cause the device to:

obtain, at a terminal device and from a network device, a set of parameters for configuring actual numbers of non-zero coefficients to a plurality of layers of a channel between the terminal device and the network device;

determine information about non-zero coefficients to be indicated in a first part of channel state information;

determine the actual numbers of non-zero coefficients based on the set of parameters and the information, the actual numbers of non-zero coefficients being associated with a second part of the channel state information;

transmit, to the network device, the first part of the channel state information indicating the information; and

transmit, to the network device, the second part of the channel state information based on the actual numbers of non-zero coefficients.

2. The device of claim 1, wherein the device is caused to obtain the set of parameters by:

receiving, from the network device, a configuration about the set of parameters via radio resource control signaling; and

determining, based on the configuration, the set of parameters.

3. The device of claim 1, wherein the information indicates a total number of non-zero coefficients to be used across the plurality of layers of the channel, and wherein the device is caused to:

determine the actual numbers of non-zero coefficients, such that a sum of the actual numbers of non-zero coefficients has a correspondence with the total number of non-zero coefficients indicated by the information.

4. The device of claim 3, wherein the device is caused to:

determine the actual numbers of non-zero coefficients, such that the sum of the actual numbers of non-zero coefficients equals to the total number of non-zero coefficients indicated by the information.

5. The device of claim 1, wherein the plurality of layers comprise more than two layers, the information indicates a first number of non-zero coefficients to be used at a first layer in the plurality of layers and a second number of non-zero coefficients to be used at a second layer in the plurality of layers, and wherein the device is caused to:

determine the actual numbers of non-zero coefficients, such that a sum of the actual numbers of non-zero coefficients has a correspondence with a sum of the first number and the second number.

6. The device of claim 5, wherein the device is caused to:

determine the actual numbers of non-zero coefficients, such that the sum of the actual numbers of non-zero coefficients equals to the sum of the first number and the second number.

7. The device of claim 1, wherein the set of parameters comprise a single parameter.

8. The device of claim 1, wherein the set of parameters comprise two or more different parameters.

9. A device, comprising:

at least one processor; and

at least one memory including computer program codes;

the at least one memory and the computer program codes are configured to, with the at least one processor, cause the device to:

indicate, from a network device to a terminal device, a set of parameters for configuring actual numbers of non-zero coefficients to a plurality of layers of a channel between the network device and the terminal device;

receive a first part of channel State Information from the terminal device, the first part of the channel State Information indicating information about non-zero coefficients to be used across the plurality of layers;

determine the actual numbers of non-zero coefficients based on the information and the set of parameters; and

receive, from the terminal device, a second part of the channel State Information based on the actual numbers of non-zero coefficients.

10. The device of claim 9, wherein the device is caused to indicate the set of parameters by:

transmitting, to the terminal device, a configuration about the set of parameters via radio resource control signaling.

11. The device of claim 9, wherein the device is caused to receive the second part of the channel State Information by:

determining, based on the actual number of non-zero coefficients, a size of the second part of the channel State Information; and

receiving, based on the determined size, the second part of the channel State Information from the terminal device.

12. The device of claim 9, wherein the information indicates a total number of non-zero coefficients to be used across the plurality of layers of the channel, and wherein the device is caused to:

determine the actual numbers of non-zero coefficients, such that a sum of the actual numbers of non-zero coefficients has a correspondence with the total number of non-zero coefficients indicated by the information.

13. The device of claim 12, wherein the device is caused to:

determine the actual numbers of non-zero coefficients, such that the sum of the actual numbers of non-zero coefficients equals to the total number of non-zero coefficients indicated by the information.

14. The device of claim 9, wherein the plurality of layers comprise more than two layers, the information indicates a first number of non-zero coefficients to be used at a first layer in the plurality of layers and a second number of non-zero coefficients to be used at a second layer in the plurality of layers, and wherein the device is caused to:

determine the actual numbers of non-zero coefficients, such that a sum of the actual numbers of non-zero coefficients has a correspondence with a sum of the first number and the second number.

15. The device of claim 14, wherein the device is caused to:

determine the actual numbers of non-zero coefficients, such that the sum of the actual numbers of non-zero coefficients equals to the sum of the first number and the second number.

16. The device of claim 9, wherein the set of parameters comprise a single parameter.

17. The device of claim 9, wherein the set of parameters comprise two or more different parameters.

18. A method comprising:

obtaining, at a terminal device and from a network device, a set of parameters for configuring actual numbers of non-zero coefficients to a plurality of layers of a channel between the terminal device and the network device;

determining information about non-zero coefficients to be indicated in a first part of channel state information;

determining the actual numbers of non-zero coefficients based on the set of parameters and the information, the actual numbers of non-zero coefficients being associated with a second part of the channel state information;

transmitting, to the network device, the first part of the channel state information indicating the information; and

transmitting, to the network device, the second part of the channel state information based on the actual numbers of non-zero coefficients.

19. A method comprising:

indicating, from a network device to a terminal device, a set of parameters for configuring actual numbers of non-zero coefficients to a plurality of layers of a channel between the network device and the terminal device;

receiving a first part of channel state information from the terminal device, the first part of the channel state information indicating information about non-zero coefficients to be used across the plurality of layers;

determining the actual numbers of non-zero coefficients based on the information and the set of parameters; and

receiving, from the terminal device, a second part of the channel state information based on the actual numbers of non-zero coefficients.

20. An apparatus, comprising:

means for obtaining, at a terminal device and from a network device, a set of parameters for configuring actual numbers of non-zero coefficients to a plurality of layers of a channel between the terminal device and the network device;

means for determining information about non-zero coefficients to be indicated in a first part of channel state information;

means for determining the actual numbers of non-zero coefficients based on the set of parameters and the information, the actual numbers of non-zero coefficients being associated with a second part of the channel state information;

means for transmitting, to the network device, the first part of the channel state information indicating the information; and

means for transmitting, to the network device, the second part of the channel state information based on the actual numbers of non-zero coefficients.

21. An apparatus, comprising:

means for indicating, from a network device to a terminal device, a set of parameters for configuring actual numbers of non-zero coefficients to a plurality of layers of a channel between the network device and the terminal device;

means for receiving a first part of channel state information from the terminal device, the first part of the channel state information indicating information about non-zero coefficients to be used across the plurality of layers;

means for determining the actual numbers of non-zero coefficients based on the information and the set of parameters; and

means for receiving, from the terminal device, a second part of the channel state information based on the actual numbers of non-zero coefficients.

22. A non-transitory computer readable medium comprising program instructions for causing an apparatus to perform at least the method of claim 18 or 19.

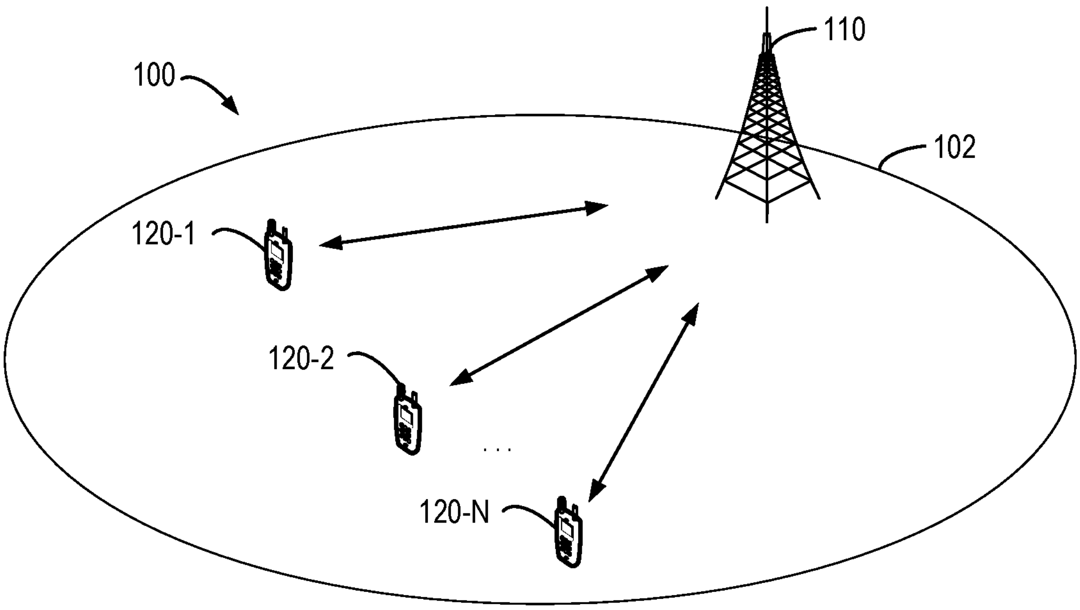
110
100
102
120-1
120-2
...
120-N

FIG. 1

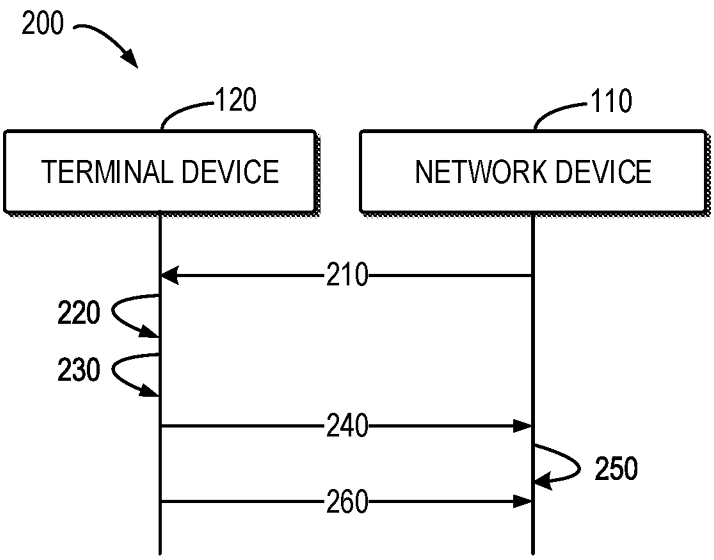
200
120
110
TERMINAL DEVICE
NETWORK DEVICE
210
220
230
240
250
260

FIG. 2

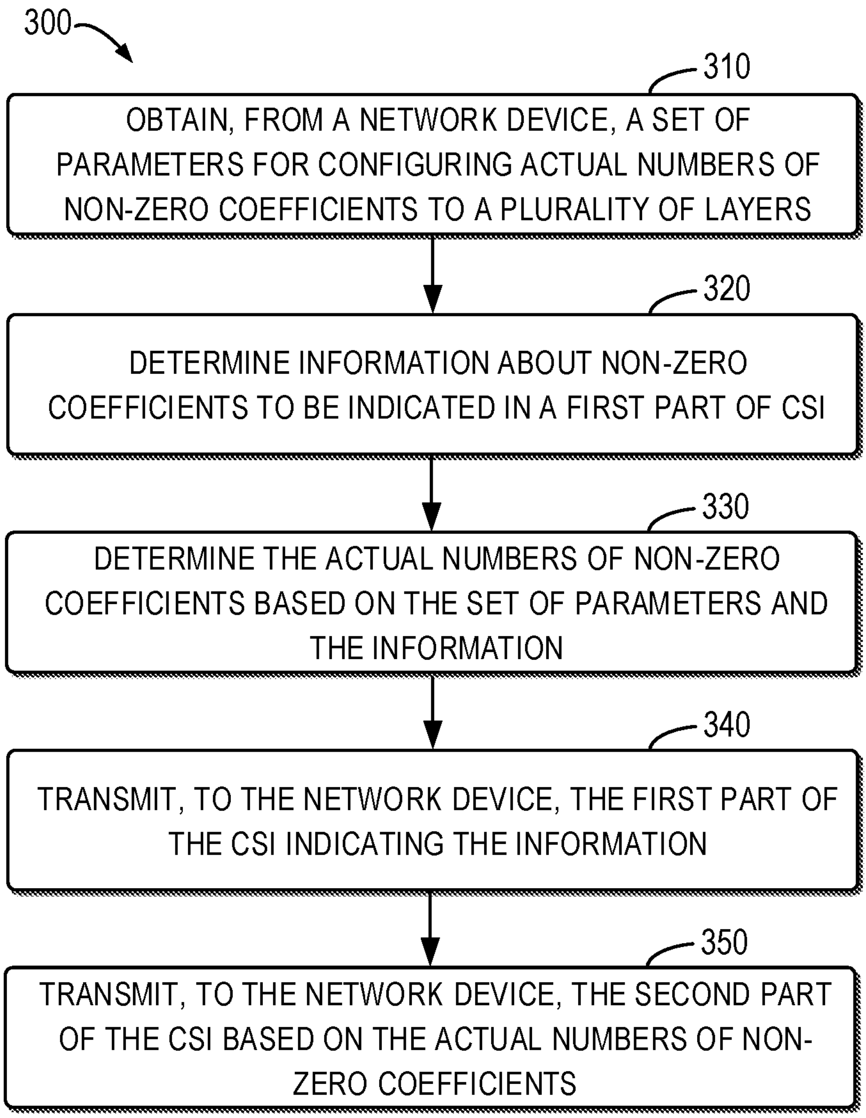
300
310
OBTAIN, FROM A NETWORK DEVICE, A SET OF PARAMETERS FOR CONFIGURING ACTUAL NUMBERS OF NON-ZERO COEFFICIENTS TO A PLURALITY OF LAYERS
320
DETERMINE INFORMATION ABOUT NON-ZERO COEFFICIENTS TO BE INDICATED IN A FIRST PART OF CSI
330
DETERMINE THE ACTUAL NUMBERS OF NON-ZERO COEFFICIENTS BASED ON THE SET OF PARAMETERS AND THE INFORMATION
340
TRANSMIT, TO THE NETWORK DEVICE, THE FIRST PART OF THE CSI INDICATING THE INFORMATION
350
TRANSMIT, TO THE NETWORK DEVICE, THE SECOND PART OF THE CSI BASED ON THE ACTUAL NUMBERS OF NON-ZERO COEFFICIENTS

FIG. 3

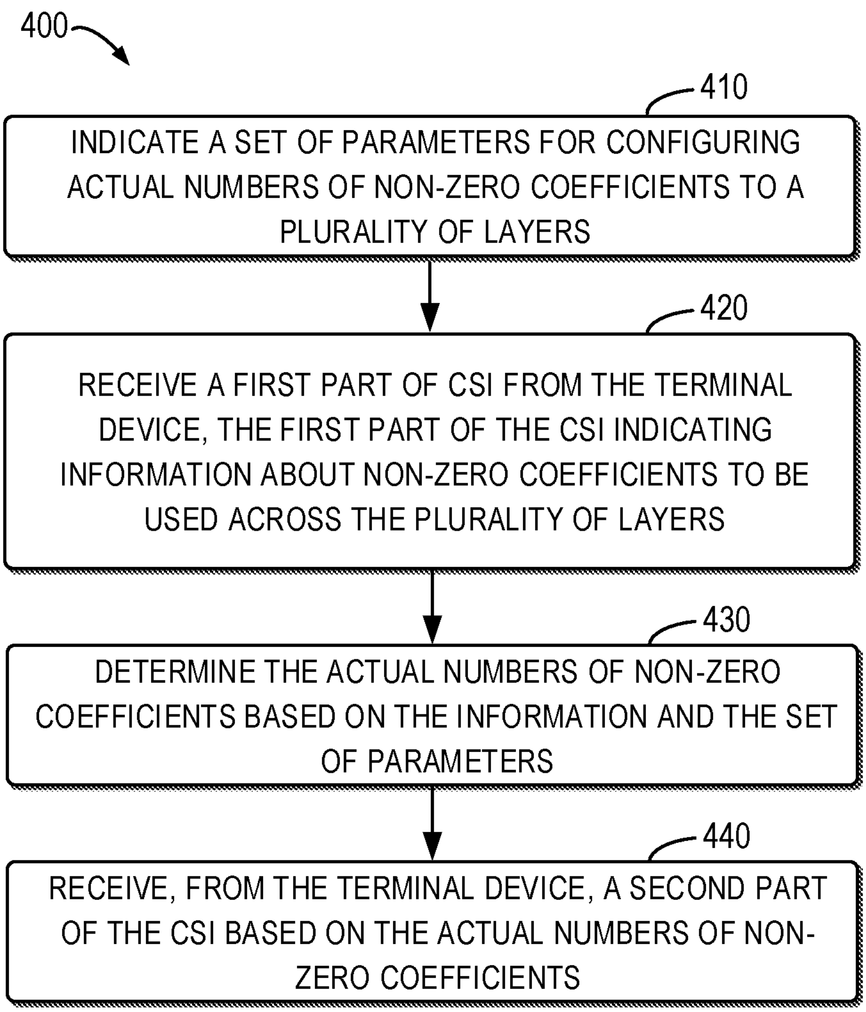
400
410
INDICATE A SET OF PARAMETERS FOR CONFIGURING ACTUAL NUMBERS OF NON-ZERO COEFFICIENTS TO A PLURALITY OF LAYERS
420
RECEIVE A FIRST PART OF CSI FROM THE TERMINAL DEVICE, THE FIRST PART OF THE CSI INDICATING INFORMATION ABOUT NON-ZERO COEFFICIENTS TO BE USED ACROSS THE PLURALITY OF LAYERS
430
DETERMINE THE ACTUAL NUMBERS OF NON-ZERO COEFFICIENTS BASED ON THE INFORMATION AND THE SET OF PARAMETERS
440
RECEIVE, FROM THE TERMINAL DEVICE, A SECOND PART OF THE CSI BASED ON THE ACTUAL NUMBERS OF NON-ZERO COEFFICIENTS

FIG. 4

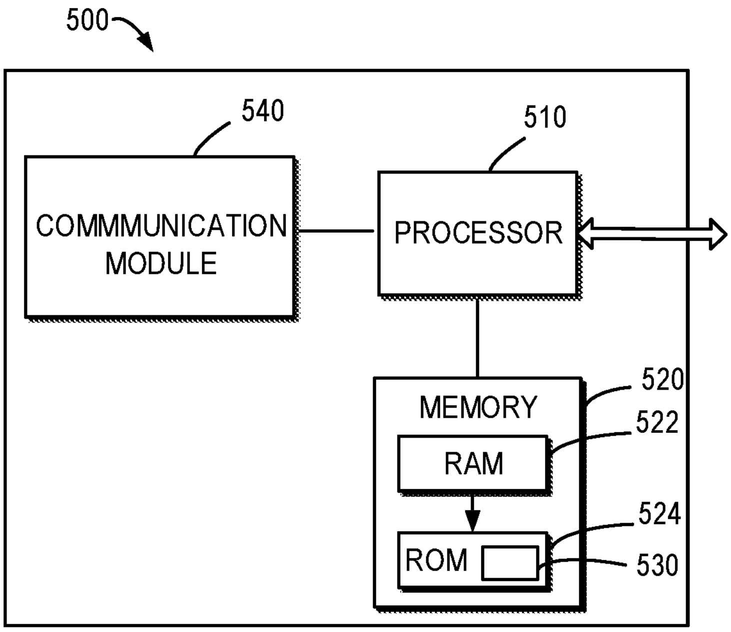
500
540
510
COMMMUNICATION
MODULE
PROCESSOR
MEMORY
520
522
RAM
524
ROM
530

FIG. 5

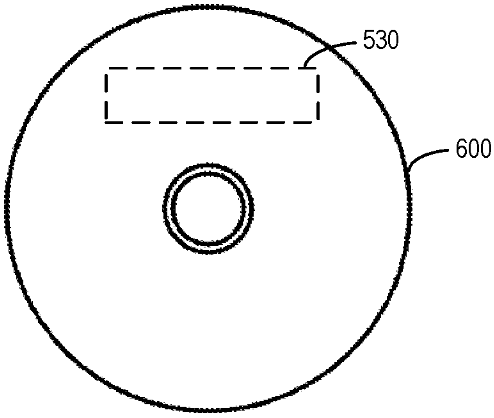
530
600

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2019/080675

A. CLASSIFICATION OF SUBJECT MATTER

H04L 1/00(2006.01)i； H04B 7/06(2006.01)n

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, H04B, H04W, H04Q7/-

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)

CNABS, CNTXT, CNKI, VEN, WOTXT, USTXT, EPTXT, 3GPP： CSI, channel state information, rank, RI, part, first, second, NZ, non-zero, coefficient, number, layer, parameter

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN 109510654 A (CHINA ACAD TELECOM TECHNOLOGY MII) 22 March 2019 (2019-03-22) description， paragraphs [0074]-[0173] and figures 2 to 7	1-22
A	Samsung. "Summary of Tuesday Offline Session on MU-MIMO CSI." *3GPP TSG RAN WG1 96， R1-1903500.*, 27 February 2019 (2019-02-27), the whole document	1-22
A	WO 2019050159 A1 (LG ELECTRONICS INC) 14 March 2019 (2019-03-14) the whole document	1-22

☐ 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
23 July 2019	**31 July 2019**

Name and mailing address of the ISA/CN	Authorized officer
National Intellectual Property Administration, PRC **6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088** **China**	**LU,Jing**
Facsimile No. **(86-10)62019451**	Telephone No. **86-(010)-62412158**

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2019/080675

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
CN	109510654	A	22 March 2019	None			
WO	2019050159	A1	14 March 2019	EP	3480970	A1	08 May 2019
				KR	20190028351	A	18 March 2019
				CN	109757127	A	14 May 2019
				US	2019081678	A1	14 March 2019