



US 20250254008A1

(19) **United States**

(12) **Patent Application Publication**
HAO et al.

(10) **Pub. No.: US 2025/0254008 A1**

(43) **Pub. Date: Aug. 7, 2025**

(54) **CPU, RESOURCE, AND PORT OCCUPATION
FOR MULTI-TRP CSI**

Publication Classification

(71) Applicant: **QUALCOMM Incorporated**, San
Diego, CA (US)

(51) **Int. Cl.**
H04L 5/00 (2006.01)
H04W 24/08 (2009.01)

(72) Inventors: **Chenxi HAO**, Beijing (CN); **Yu
ZHANG**, San Diego, CA (US); **Chao
WEI**, Beijing (CN); **Liangming WU**,
Beijing (CN); **Qiaoyu LI**, Beijing (CN);
Hao XU, Beijing (CN); **Parisa
CHERAGHI**, Cambridge (GB); **Lei
XIAO**, San Jose, CA (US); **Mostafa
KHOSHNEVISAN**, San Diego, CA
(US); **Xiaoxia ZHANG**, San Diego, CA
(US)

(52) **U.S. Cl.**
CPC **H04L 5/0057** (2013.01); **H04L 5/0035**
(2013.01); **H04L 5/0091** (2013.01); **H04W
24/08** (2013.01)

(57) **ABSTRACT**

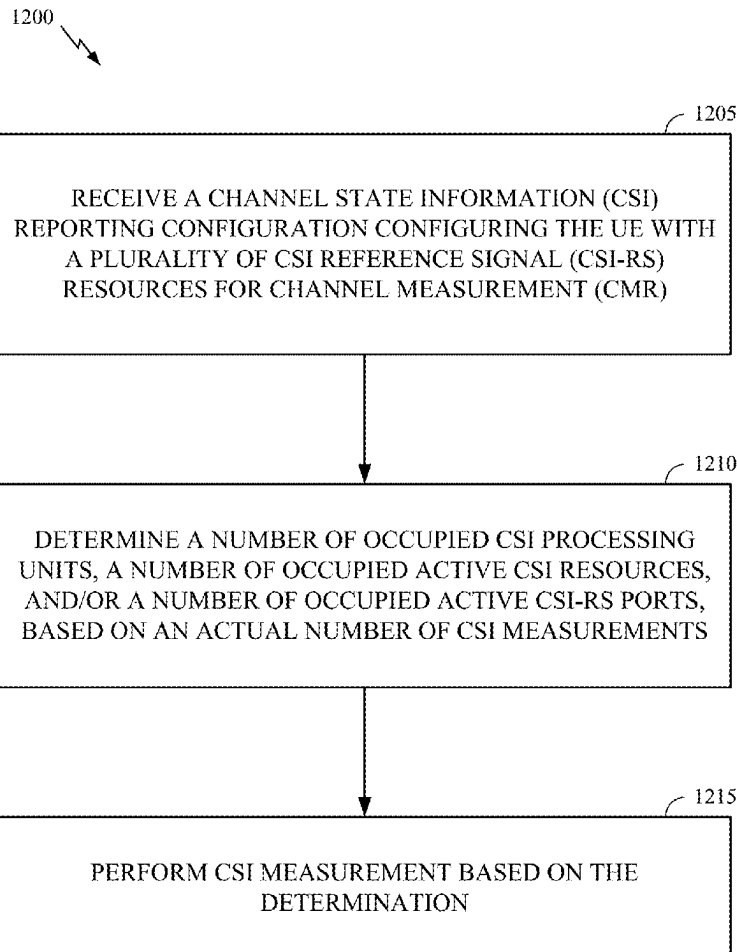
Certain aspects of the present disclosure provide techniques for channel state information (CSI) processing occupation determination that can be used even in multiple transmission reception point (mTRP) scenarios. A method that may be performed by a user equipment (UE) includes receiving a channel state information (CSI) reporting configuration configuring the UE with a plurality of CSI reference signal (CSI-RS) resources for channel measurement (CMRs). The method includes determining a number of occupied CSI processing units, a number of occupied active CSI resources, and/or a number of occupied active CSI-RS ports based on an actual number of CSI measurements. The method includes performing CSI measurement based on the determination.

(21) Appl. No.: **19/186,039**

(22) Filed: **Apr. 22, 2025**

Related U.S. Application Data

(63) Continuation of application No. 17/759,258, filed on Jul. 21, 2022, now Pat. No. 12,316,575, filed as application No. PCT/CN2020/074182 on Feb. 3, 2020.



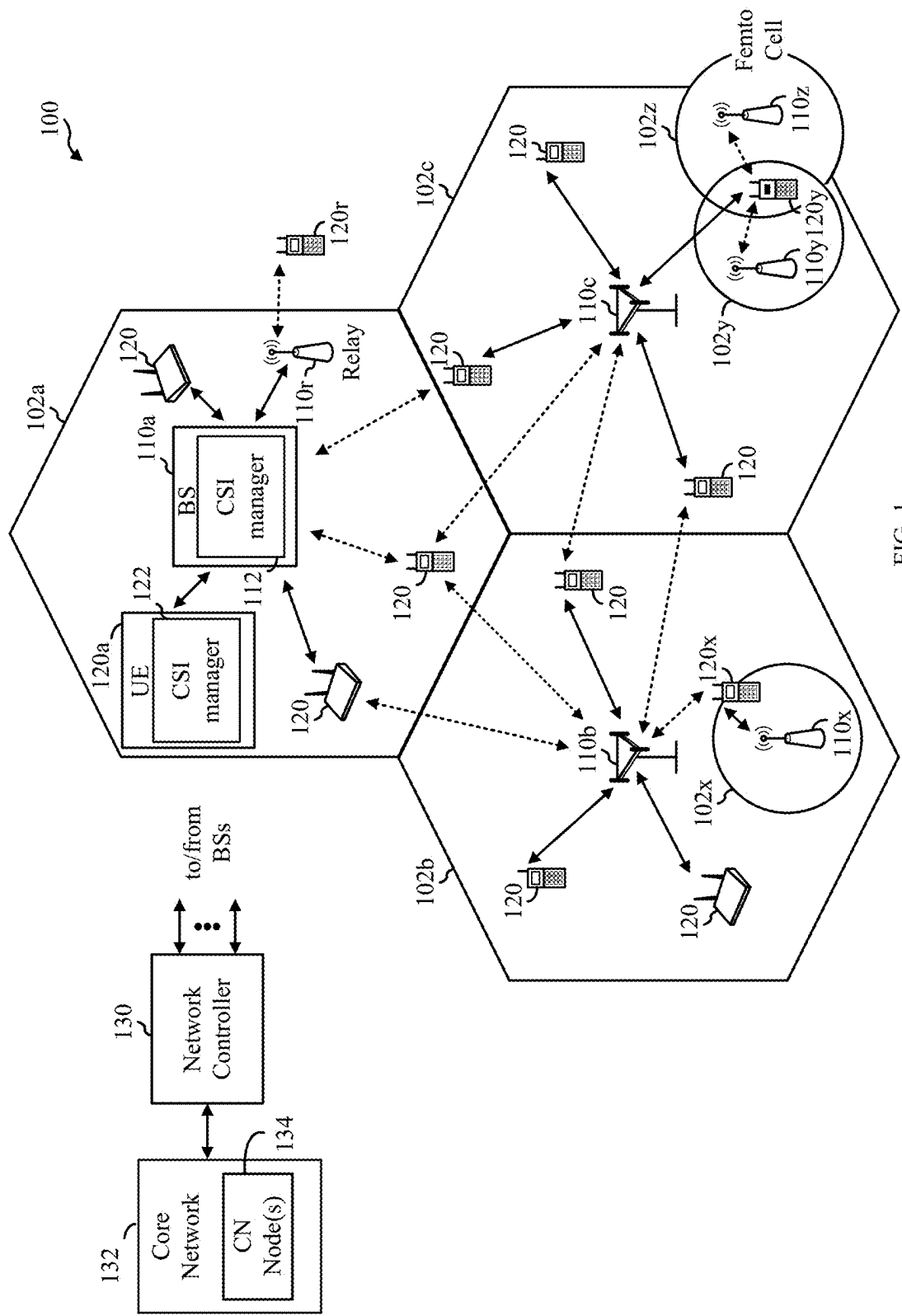


FIG. 1

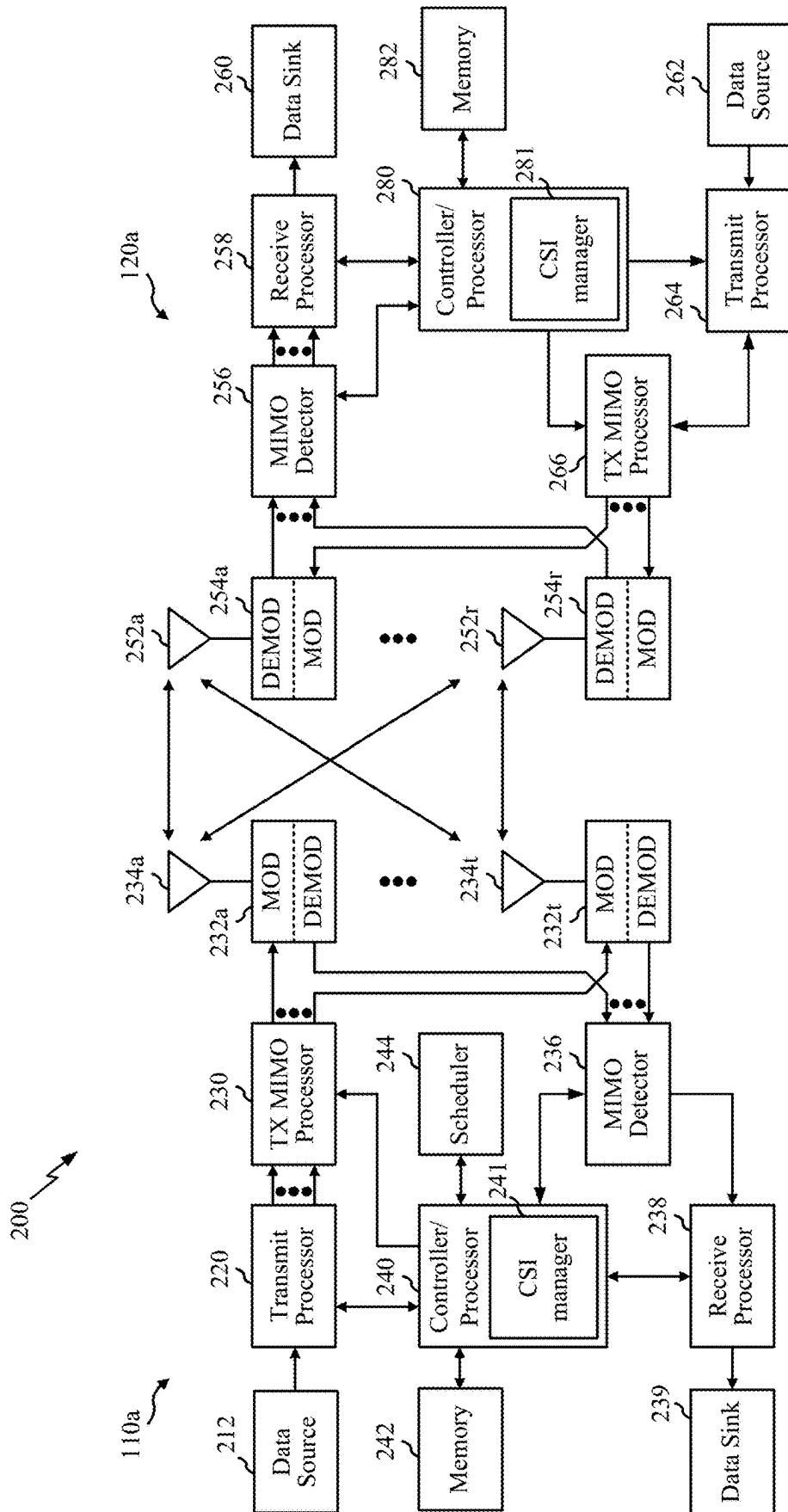


FIG. 2

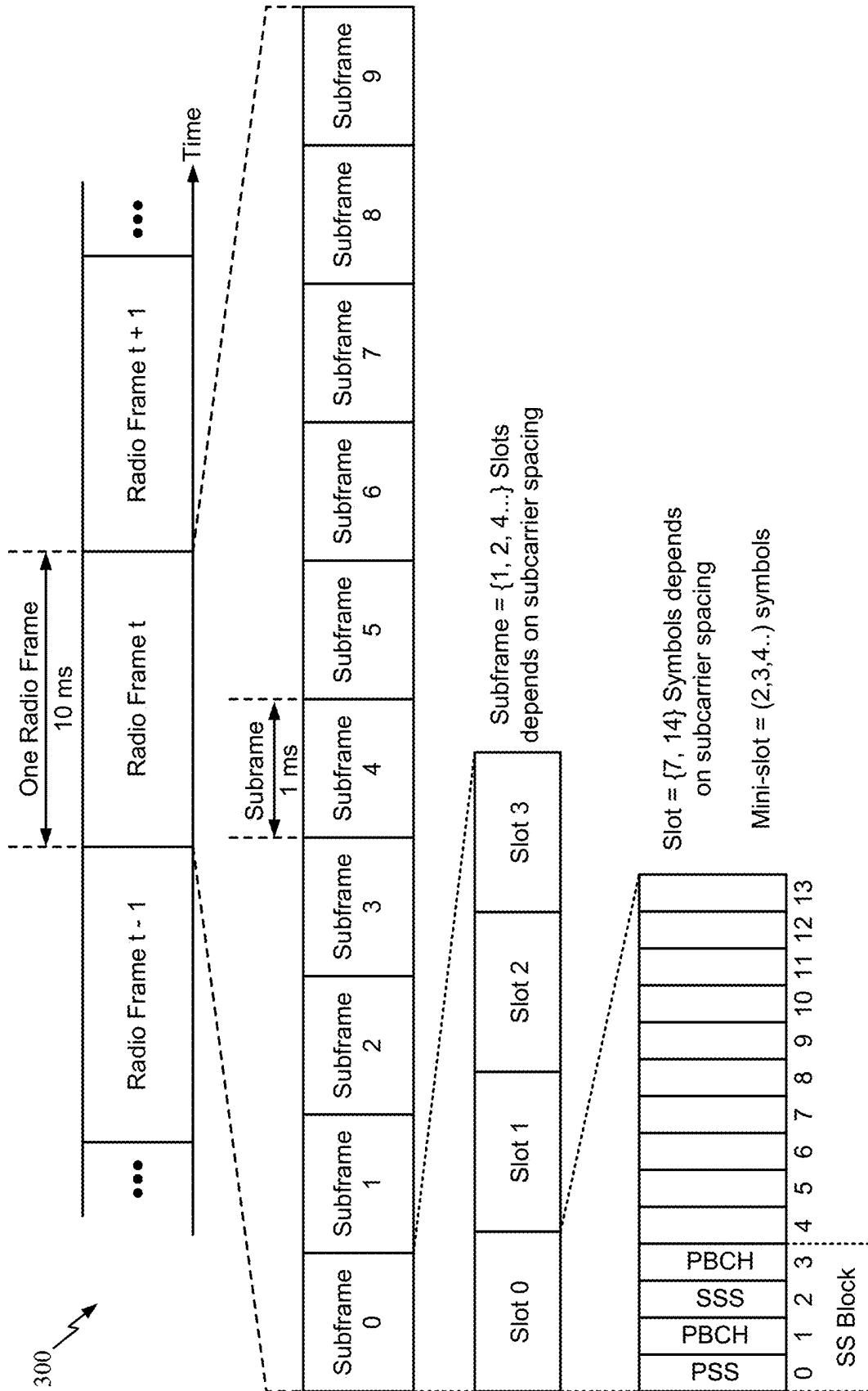


FIG. 3

| | | | | |
|------------------------|---|---|---|---|
| CRI | 0 | 1 | 2 | |
| CSI-RS resource for CM | 0 | 1 | 0 | 1 |

FIG. 4

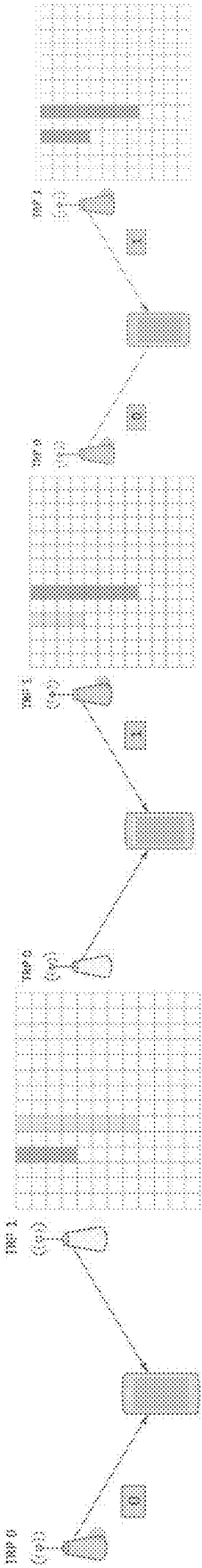


FIG. 5A

FIG. 5B

FIG. 5C

| | | | |
|------------------------|---|---|---|
| CRI | 0 | 1 | 2 |
| CSI-RS resource for CM | 0 | 1 | 2 |

FIG. 6

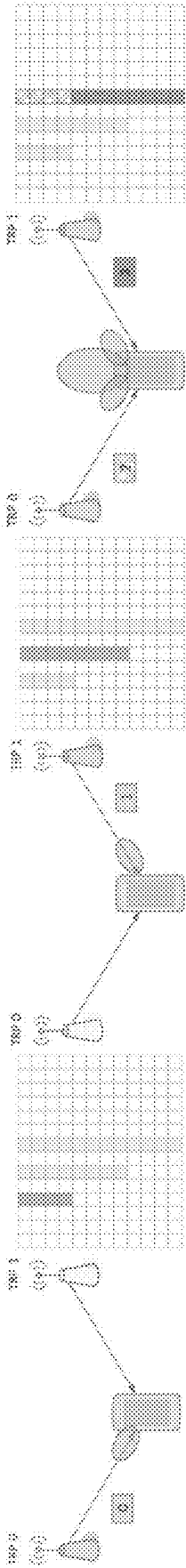


FIG. 7A

FIG. 7B

FIG. 7C

| | | | |
|------------------------|----------------|----------------|----------------------|
| CRI | 0 | 0 | 0 |
| RI-pair | {RI0>0, RI1=0} | {RI0=0, RI1>0} | {RI0>0, RI1>0} |
| CSI-RS resource for CM | Res 0, group 0 | Res 0, group 1 | Res 0, group 0 and 1 |

FIG. 8

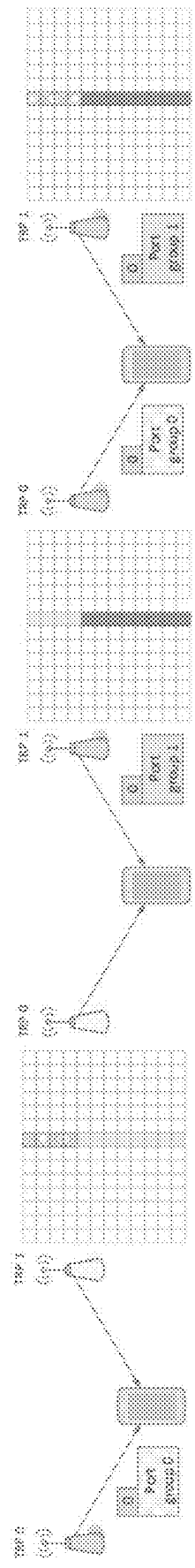


FIG. 9A

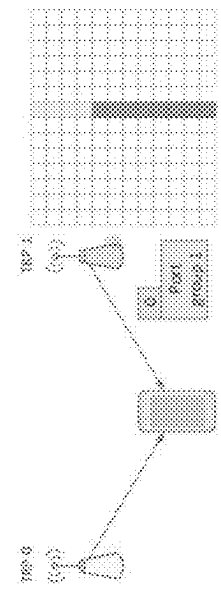


FIG. 9B

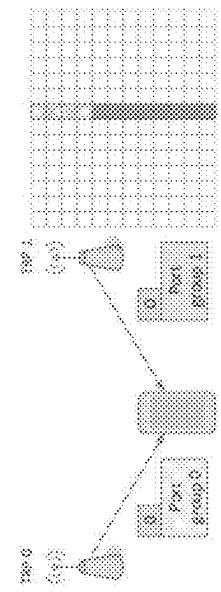


FIG. 9C

| | | | |
|------------------------|---|---|---|
| CRI | 0 | 1 | 2 |
| CSI-RS resource for CM | 0 | 1 | 2 |

FIG. 10



FIG. 11A

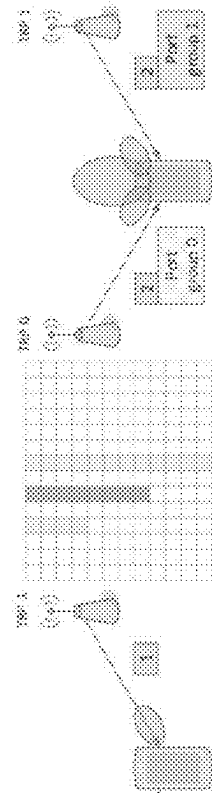


FIG. 11B

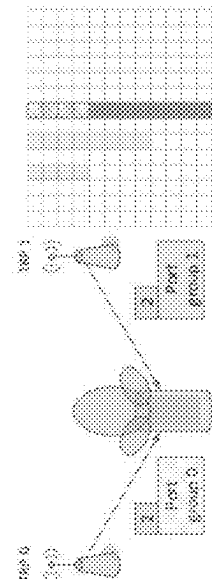


FIG. 11C

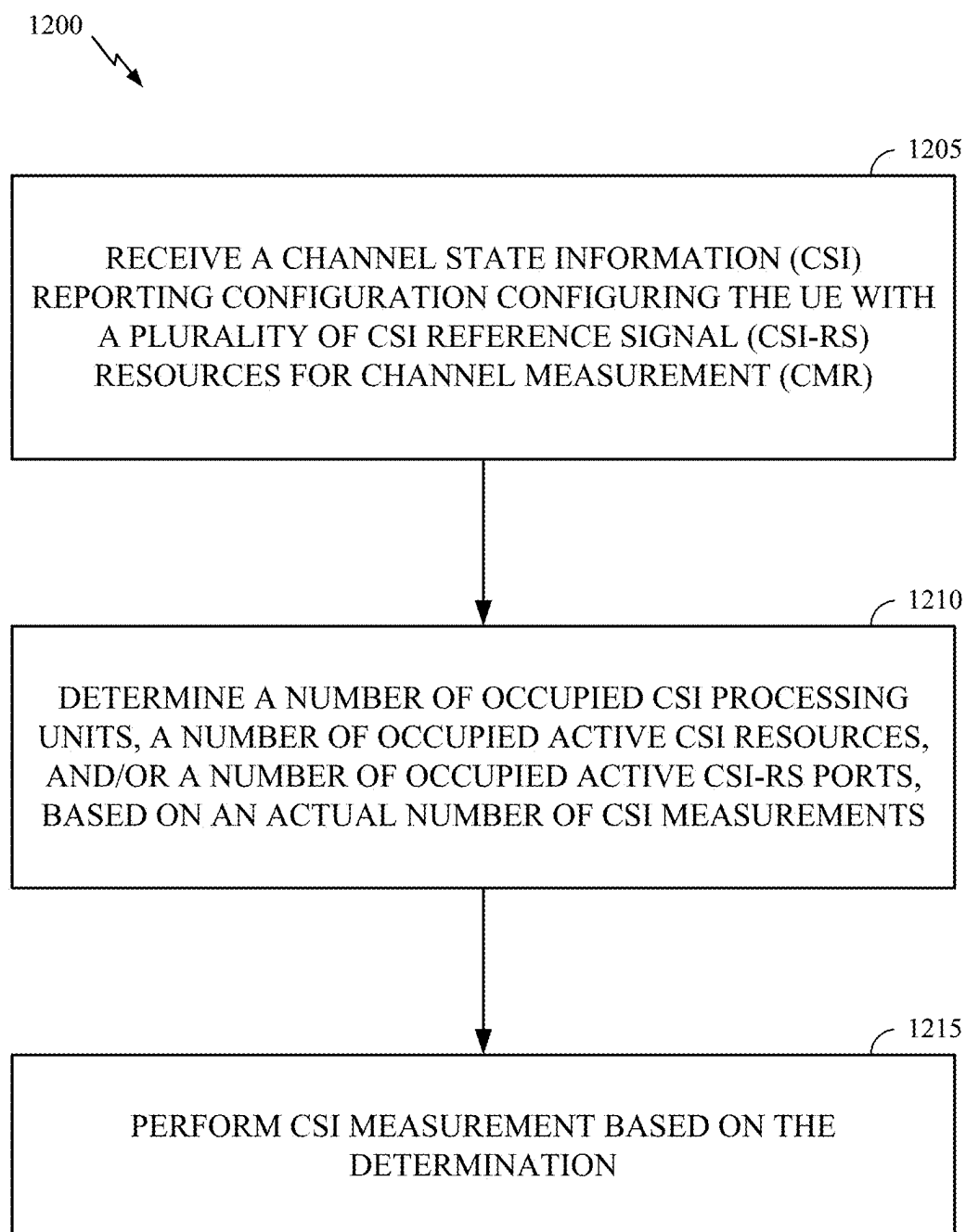


FIG. 12

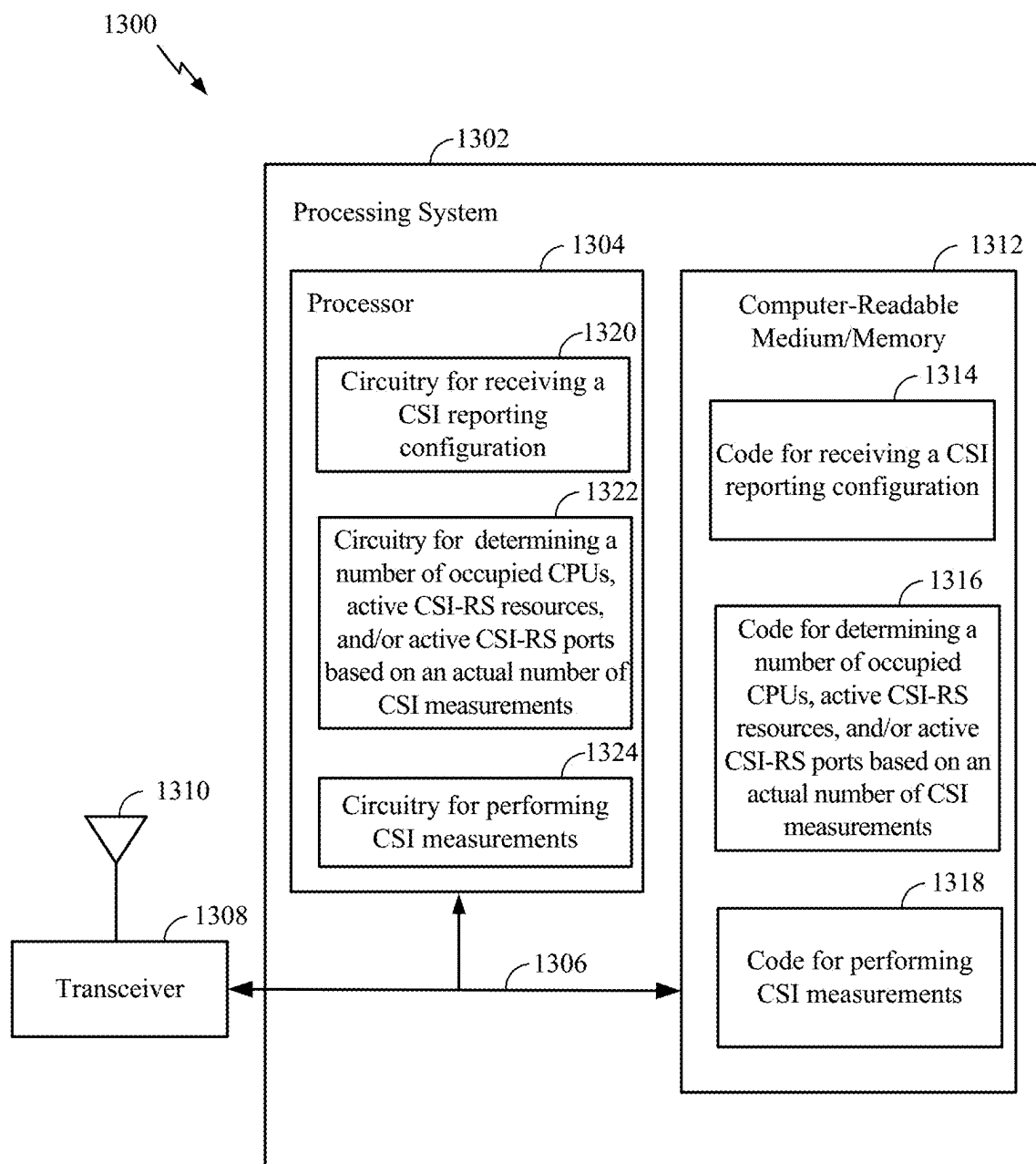


FIG. 13

CPU, RESOURCE, AND PORT OCCUPATION FOR MULTI-TRP CSI

CROSS-REFERENCE TO RELATED APPLICATION(S)

[0001] This application is a continuation of U.S. application Ser. No. 17/759,258, filed Jul. 21, 2022, which is a national stage application under 35 U.S.C. 371 of International Application No. PCT/CN2020/074182, filed Feb. 3, 2020, each of which is hereby assigned to the assignee hereof, and hereby expressly incorporated by reference herein in its entirety as if fully set forth below and for all applicable purposes.

BACKGROUND

Field of the Disclosure

[0002] Aspects of the present disclosure relate to wireless communications, and more particularly, to techniques for determining occupied channel state information (CSI) processing even in multiple transmission reception point (mTRP) scenarios.

Description of Related Art

[0003] Wireless communication systems are widely deployed to provide various telecommunication services such as telephony, video, data, messaging, broadcasts, etc. These wireless communication systems may employ multiple-access technologies capable of supporting communication with multiple users by sharing available system resources (e.g., bandwidth, transmit power, etc.). Examples of such multiple-access systems include 3rd Generation Partnership Project (3GPP) Long Term Evolution (LTE) systems, LTE Advanced (LTE-A) systems, code division multiple access (CDMA) systems, time division multiple access (TDMA) systems, frequency division multiple access (FDMA) systems, orthogonal frequency division multiple access (OFDMA) systems, single-carrier frequency division multiple access (SC-FDMA) systems, and time division synchronous code division multiple access (TD-SCDMA) systems, to name a few.

[0004] These multiple access technologies have been adopted in various telecommunication standards to provide a common protocol that enables different wireless devices to communicate on a municipal, national, regional, and even global level. New radio (e.g., 5G NR) is an example of an emerging telecommunication standard. NR is a set of enhancements to the LTE mobile standard promulgated by 3GPP. NR is designed to better support mobile broadband Internet access by improving spectral efficiency, lowering costs, improving services, making use of new spectrum, and better integrating with other open standards using OFDMA with a cyclic prefix (CP) on the downlink (DL) and on the uplink (UL). To these ends, NR supports beamforming, multiple-input multiple-output (MIMO) antenna technology, and carrier aggregation.

[0005] However, as the demand for mobile broadband access continues to increase, there exists a need for further improvements in NR and LTE technology. Preferably, these improvements should be applicable to other multi-access technologies and the telecommunication standards that employ these technologies.

SUMMARY

[0006] The systems, methods, and devices of the disclosure each have several aspects, no single one of which is solely responsible for its desirable attributes. Without limiting the scope of this disclosure as expressed by the claims which follow, some features will now be discussed briefly. After considering this discussion, and particularly after reading the section entitled “Detailed Description” one will understand how the features of this disclosure provide advantages that include improved channel state information (CSI) processing occupation determination, that can be used even in multiple transmission reception point (mTRP) scenarios

[0007] Certain aspects of the subject matter described in this disclosure can be implemented in a method for wireless communication by a user equipment (UE). The method generally includes receiving a CSI reporting configuration configuring the UE with a plurality of CSI reference signal (CSI-RS) resources for channel measurement (CMRs). The method generally includes determining at least one of: a number of occupied CSI processing units, a number of occupied active CSI resources, or a number of occupied active CSI-RS ports based on an actual number of CSI measurements. The method generally includes performing CSI measurement based on the determination.

[0008] Certain aspects of the subject matter described in this disclosure can be implemented in a method for wireless communication by a base station (BS). The method generally includes sending a UE a CSI reporting configuration configuring the UE with a plurality of CMRs. The method generally includes determining at least one of: a number of occupied CSI processing units, a number of occupied active CSI resources, or a number of occupied active CSI-RS ports based on an actual number of CSI measurements. The method generally includes receiving a CSI report based on the determination

[0009] Aspects of the present disclosure provide means for, apparatus, processors, and computer-readable mediums for performing the methods described herein.

[0010] To the accomplishment of the foregoing and related ends, the one or more aspects comprise the features hereinafter fully described and particularly pointed out in the claims. The following description and the appended drawings set forth in detail certain illustrative features of the one or more aspects. These features are indicative, however, of but a few of the various ways in which the principles of various aspects may be employed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] So that the manner in which the above-recited features of the present disclosure can be understood in detail, a more particular description, briefly summarized above, may be had by reference to aspects, some of which are illustrated in the drawings. It is to be noted, however, that the appended drawings illustrate only certain typical aspects of this disclosure and are therefore not to be considered limiting of its scope, for the description may admit to other equally effective aspects.

[0012] FIG. 1 is a block diagram conceptually illustrating an example telecommunications system, in accordance with certain aspects of the present disclosure.

[0013] FIG. 2 is a block diagram conceptually illustrating a design of an example a base station (BS) and user equipment (UE), in accordance with certain aspects of the present disclosure.

[0014] FIG. 3 is an example frame format for new radio (NR), in accordance with certain aspects of the present disclosure.

[0015] FIG. 4 is a table showing example mapping of channel state information resource indicator (CRI) to CSI reference signal (CSI-RS) resources for channel measurement (CMR) with multiple resource selection with each CSI-RS associated with a single transmission configuration indicator (TCI) state, in accordance with aspects of the present disclosure.

[0016] FIG. 5A is an example of a first CMR selection, in accordance with aspects of the present disclosure.

[0017] FIG. 5B is an example of a second CMR selection, in accordance with aspects of the present disclosure.

[0018] FIG. 5C is an example of multiple CMR selection, in accordance with aspects of the present disclosure.

[0019] FIG. 6 is a table showing an example mapping of CRI to CMR port group with multiple resource selection with each CSI-RS associated with a single TCI state, in accordance with aspects of the present disclosure.

[0020] FIG. 7A is an example of a first CMR selection, in accordance with aspects of the present disclosure.

[0021] FIG. 7B is an example of a second CMR selection, in accordance with aspects of the present disclosure.

[0022] FIG. 7C is an example of multiple CMR selection, in accordance with aspects of the present disclosure.

[0023] FIG. 8 is a table showing an example mapping of CRI/rank indicator (RI)-pair to CMR port group with single resource selection with each CSI-RS associated with multiple TCI states, in accordance with aspects of the present disclosure.

[0024] FIG. 9A is an example of a first CMR port group selection, in accordance with aspects of the present disclosure.

[0025] FIG. 9B is an example of a second CMR port group selection, in accordance with aspects of the present disclosure.

[0026] FIG. 9C is an example of multiple port group of the CMR selection, in accordance with aspects of the present disclosure.

[0027] FIG. 10 is a table showing an example mapping of CRI to CMR port group with single resource selection with each CSI-RS associated with multiple TCI states, in accordance with aspects of the present disclosure.

[0028] FIG. 11A is an example of a first CMR port group selection, in accordance with aspects of the present disclosure.

[0029] FIG. 11B is an example of a second CMR port group selection, in accordance with aspects of the present disclosure.

[0030] FIG. 11C is an example of multiple port group of the CMR selection, in accordance with aspects of the present disclosure.

[0031] FIG. 12 is a flow diagram illustrating example operations for wireless communication by a UE, in accordance with certain aspects of the present disclosure.

[0032] FIG. 13 illustrates a communications device that may include various components configured to perform operations for the techniques disclosed herein in accordance with aspects of the present disclosure.

[0033] To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements that are common to the figures. It is contemplated that elements disclosed in one aspect may be beneficially utilized on other aspects without specific recitation.

DETAILED DESCRIPTION

[0034] Aspects of the present disclosure provide apparatus, methods, processing systems, and computer readable mediums for channel state information (CSI) processing resource occupation determination.

[0035] In certain systems (e.g., Release 17 systems), CSI may support dynamic channel measurement and/or interference measurement for multiple transmission reception point (mTRP) transmission.

[0036] Aspects of the present disclosure provide for determination of occupied CSI processing resources based on an actual number CSI measurements. For example, the number of occupied CSI processing units (CPUs), the number of occupied active CSI reference signal (CSI-RS) resources, and/or the number of occupied active CSI ports may be determined based on the number of CSIs calculated for a corresponding CSI-RS resource. In some examples, the occupied resources may be determined for the corresponding CSI-RS resource based on the occurrences of the CSI-RS resource across all CSI resource indicator (CRI) code-points.

[0037] The following description provides examples of CSI processing resource occupation determination in communication systems, and is not limiting of the scope, applicability, or examples set forth in the claims. Changes may be made in the function and arrangement of elements discussed without departing from the scope of the disclosure. Various examples may omit, substitute, or add various procedures or components as appropriate. For instance, the methods described may be performed in an order different from that described, and various steps may be added, omitted, or combined. Also, features described with respect to some examples may be combined in some other examples. For example, an apparatus may be implemented or a method may be practiced using any number of the aspects set forth herein. In addition, the scope of the disclosure is intended to cover such an apparatus or method which is practiced using other structure, functionality, or structure and functionality in addition to, or other than, the various aspects of the disclosure set forth herein. It should be understood that any aspect of the disclosure disclosed herein may be embodied by one or more elements of a claim. The word “exemplary” is used herein to mean “serving as an example, instance, or illustration.” Any aspect described herein as “exemplary” is not necessarily to be construed as preferred or advantageous over other aspects.

[0038] In general, any number of wireless networks may be deployed in a given geographic area. Each wireless network may support a particular radio access technology (RAT) and may operate on one or more frequencies. A RAT may also be referred to as a radio technology, an air interface, etc. A frequency may also be referred to as a carrier, a subcarrier, a frequency channel, a tone, a subband, etc. Each frequency may support a single RAT in a given geographic area in order to avoid interference between wireless networks of different RATs.

[0039] The techniques described herein may be used for various wireless networks and radio technologies. While aspects may be described herein using terminology commonly associated with 3G, 4G, and/or new radio (e.g., 5G NR) wireless technologies, aspects of the present disclosure can be applied in other generation-based communication systems.

[0040] NR access may support various wireless communication services, such as enhanced mobile broadband (eMBB) targeting wide bandwidth (e.g., 80 MHz or beyond), millimeter wave (mmW) targeting high carrier frequency (e.g., 25 GHz or beyond), massive machine type communications MTC (mMTC) targeting non-backward compatible MTC techniques, and/or mission critical targeting ultra-reliable low-latency communications (URLLC). These services may include latency and reliability requirements. These services may also have different transmission time intervals (TTI) to meet respective quality of service (QoS) requirements. In addition, these services may co-exist in the same subframe. NR supports beamforming and beam direction may be dynamically configured. MIMO transmissions with precoding may also be supported. MIMO configurations in the DL may support up to 8 transmit antennas with multi-layer DL transmissions up to 8 streams and up to 2 streams per UE. Multi-layer transmissions with up to 2 streams per UE may be supported. Aggregation of multiple cells may be supported with up to 8 serving cells.

[0041] FIG. 1 illustrates an example wireless communication network 100 in which aspects of the present disclosure may be performed. For example, the wireless communication network 100 may be an NR system (e.g., a 5G NR network). As shown in FIG. 1 the wireless communication network 100 may be in communication with a core network 132. The core network 132 may be in communication with one or more base station (BSs) 110 and/or user equipment (UE) 120 in the wireless communication network 100 via one or more interfaces.

[0042] As illustrated in FIG. 1 the wireless communication network 100 may include a number of BSs 110a-z (each also individually referred to herein as BS 110 or collectively as BSs 110) and other network entities. A BS 110 may provide communication coverage for a particular geographic area, sometimes referred to as a “cell”, which may be stationary or may move according to the location of a mobile BS 110. In some examples, the BSs 110 may be interconnected to one another and/or to one or more other BSs or network nodes (not shown) in wireless communication network 100 through various types of backhaul interfaces (e.g., a direct physical connection, a wireless connection, a virtual network, or the like) using any suitable transport network. In the example shown in FIG. 1 the BSs 110a, 110b and 110c may be macro BSs for the macro cells 102a, 102b and 102c, respectively. The BS 110x may be a pico BS for a pico cell 102x. The BSs 110y and 110z may be femto BSs for the femto cells 102y and 102z, respectively. A BS may support one or multiple cells. A network controller 130 may couple to a set of BSs 110 and provide coordination and control for these BSs 110 (e.g., via a backhaul).

[0043] The BSs 110 communicate with UEs 120a-y (each also individually referred to herein as UE 120 or collectively as UEs 120) in the wireless communication network 100. The UEs 120 (e.g., 120x, 120y, etc.) may be dispersed throughout the wireless communication network 100, and each UE 120 may be stationary or mobile. Wireless com-

munication network 100 may also include relay stations (e.g., relay station 110r), also referred to as relays or the like, that receive a transmission of data and/or other information from an upstream station (e.g., a BS 110a or a UE 120r) and sends a transmission of the data and/or other information to a downstream station (e.g., a UE 120 or a BS 110), or that relays transmissions between UEs 120, to facilitate communication between devices.

[0044] According to certain aspects, the BSs 110 and UEs 120 may be configured for CPU, resource, and port occupation for mTRP. As shown in FIG. 1 the BS 110a includes a CSI manager 112 and the UE 120a includes a CSI manager 122. The CSI manager 112 and/or the CSI manager 122 may be configured to determine a number of occupied CPUs, CSI-RS resources, and/or CSI ports, based on an actual number CSI measurements, in accordance with aspects of the present disclosure.

[0045] FIG. 2 illustrates example components of BS 110a and UE 120a (e.g., in the wireless communication network 100 of FIG. 1), which may be used to implement aspects of the present disclosure.

[0046] At the BS 110a, a transmit processor 220 may receive data from a data source 212 and control information from a controller/processor 240. The control information may be for the physical broadcast channel (PBCH), physical control format indicator channel (PCFICH), physical hybrid ARQ indicator channel (PHICH), physical downlink control channel (PDCCH), group common PDCCH (GC PDCCH), etc. The data may be for the physical downlink shared channel (PDSCH), etc. A medium access control (MAC)-control element (MAC-CE) is a MAC layer communication structure that may be used for control command exchange between wireless nodes. The MAC-CE may be carried in a shared channel such as a physical downlink shared channel (PDSCH), a physical uplink shared channel (PUSCH), or a physical sidelink shared channel (PSSCH).

[0047] The processor 220 may process (e.g., encode and symbol map) the data and control information to obtain data symbols and control symbols, respectively. The transmit processor 220 may also generate reference symbols, such as for the primary synchronization signal (PSS), secondary synchronization signal (SSS), and channel state information reference signal (CSI-RS). A transmit (TX) multiple-input multiple-output (MIMO) processor 230 may perform spatial processing (e.g., precoding) on the data symbols, the control symbols, and/or the reference symbols, if applicable, and may provide output symbol streams to the modulators (MODs) 232a-232t. Each modulator 232 may process a respective output symbol stream (e.g., for OFDM, etc.) to obtain an output sample stream. Each modulator may further process (e.g., convert to analog, amplify, filter, and upconvert) the output sample stream to obtain a downlink signal. Downlink signals from modulators 232a-232t may be transmitted via the antennas 234a-234t, respectively.

[0048] At the UE 120a, the antennas 252a-252r may receive the downlink signals from the BS 110a and may provide received signals to the demodulators (DEMODs) in transceivers 254a-254r, respectively. Each demodulator 254 may condition (e.g., filter, amplify, downconvert, and digitize) a respective received signal to obtain input samples. Each demodulator may further process the input samples (e.g., for OFDM, etc.) to obtain received symbols. A MIMO detector 256 may obtain received symbols from all the demodulators 254a-254r, perform MIMO detection on the

received symbols if applicable, and provide detected symbols. A receive processor **258** may process (e.g., demodulate, deinterleave, and decode) the detected symbols, provide decoded data for the UE **120a** to a data sink **260**, and provide decoded control information to a controller/processor **280**.

[0049] On the uplink, at UE **120a**, a transmit processor **264** may receive and process data (e.g., for the physical uplink shared channel (PUSCH)) from a data source **262** and control information (e.g., for the physical uplink control channel (PUCCH)) from the controller/processor **280**. The transmit processor **264** may also generate reference symbols for a reference signal (e.g., for the sounding reference signal (SRS)). The symbols from the transmit processor **264** may be precoded by a TX MIMO processor **266** if applicable, further processed by the modulators in transceivers **254a-254r** (e.g., for SC-FDM, etc.), and transmitted to the BS **110a**. At the BS **110a**, the uplink signals from the UE **120a** may be received by the antennas **234**, processed by the modulators **232**, detected by a MIMO detector **236** if applicable, and further processed by a receive processor **238** to obtain decoded data and control information sent by the UE **120a**. The receive processor **238** may provide the decoded data to a data sink **239** and the decoded control information to the controller/processor **240**.

[0050] The memories **242** and **282** may store data and program codes for BS **110a** and UE **120a**, respectively. A scheduler **244** may schedule UEs for data transmission on the downlink and/or uplink.

[0051] Antennas **252**, processors **266**, **258**, **264**, and/or controller/processor **280** of the UE **120a** and/or antennas **234**, processors **220**, **230**, **238**, and/or controller/processor **240** of the BS **110a** may be used to perform the various techniques and methods described herein. For example, as shown in FIG. 2 the controller/processor **240** of the BS **110a** has a CSI manager **241** and the controller/processor **280** of the UE **120a** has a CSI manager **281**. The CSI manager **241** and/or the CSI manager **281** may be configured for determine a number of occupied CPUs, CSI-RS resources, and/or CSI ports, based on an actual number CSI measurements, in accordance with aspects of the present disclosure. Although shown at the controller/processor, other components of the UE **120a** and BS **110a** may be used to perform the operations described herein.

[0052] NR may utilize orthogonal frequency division multiplexing (OFDM) with a cyclic prefix (CP) on the uplink and downlink. NR may support half-duplex operation using time division duplexing (TDD). OFDM and single-carrier frequency division multiplexing (SC-FDM) partition the system bandwidth into multiple orthogonal subcarriers, which are also commonly referred to as tones, bins, etc. Each subcarrier may be modulated with data. Modulation symbols may be sent in the frequency domain with OFDM and in the time domain with SC-FDM. The spacing between adjacent subcarriers may be fixed, and the total number of subcarriers may be dependent on the system bandwidth. The minimum resource allocation, called a resource block (RB), may be 12 consecutive subcarriers. The system bandwidth may also be partitioned into subbands. For example, a subband may cover multiple RBs. NR may support a base subcarrier spacing (SCS) of 15 KHz and other SCS may be defined with respect to the base SCS (e.g., 30 KHz, 60 KHz, 120 KHz, 240 KHz, etc.).

[0053] FIG. 3 is a diagram showing an example of a frame format **300** for NR. The transmission timeline for each of the downlink and uplink may be partitioned into units of radio frames. Each radio frame may have a predetermined duration (e.g., 10 ms) and may be partitioned into 10 subframes, each of 1 ms, with indices of 0 through 9. Each subframe may include a variable number of slots (e.g., 1, 2, 4, 8, 16, . . . slots) depending on the SCS. Each slot may include a variable number of symbol periods (e.g., 7 or 14 symbols) depending on the SCS. The symbol periods in each slot may be assigned indices. A mini-slot, which may be referred to as a sub-slot structure, refers to a transmit time interval having a duration less than a slot (e.g., 2, 3, or 4 symbols). Each symbol in a slot may indicate a link direction (e.g., DL, UL, or flexible) for data transmission and the link direction for each subframe may be dynamically switched. The link directions may be based on the slot format. Each slot may include DL/UL data as well as DL/UL control information.

Example CSI Feedback Configuration

[0054] CSI may refer to channel properties of a communication link. The CSI may represent the combined effects of, for example, scattering, fading, and power decay with distance between a transmitter and receiver. Channel estimation using pilots, such as CSI reference signals (CSI-RS), may be performed to determine these effects on the channel. CSI may be used to adapt transmissions based on the current channel conditions, which is useful for achieving reliable communication, in particular, with high data rates in multi-antenna systems. CSI is typically estimated at the receiver, quantized, and fed back to the transmitter.

[0055] A UE (e.g., such as a UE **120a**) may be configured by a BS (e.g., such as a BS **110**) for CSI reporting. The BS may configure the UE with a CSI reporting configuration or with multiple CSI report configurations. The BS may provide the CSI reporting configuration to the UE via higher layer signaling, such as radio resource control (RRC) signaling (e.g., via a CSI-ReportConfig information element (IE)).

[0056] Each CSI report configuration may be associated with a single downlink bandwidth part (BWP). The CSI report setting configuration may define a CSI reporting band as a subset of subbands of the BWP. The associated DL BWP may indicated by a higher layer parameter (e.g., bwp-Id) in the CSI report configuration for channel measurement and contains parameter(s) for one CSI reporting band, such as codebook configuration, time-domain behavior, frequency granularity for CSI, measurement restriction configurations, and the CSI-related quantities to be reported by the UE. Each CSI resource setting may be located in the DL BWP identified by the higher layer parameter, and all CSI resource settings may be linked to a CSI report setting have the same DL BWP.

[0057] The CSI report configuration may configure the time and frequency resources used by the UE to report CSI. For example, the CSI report configuration may be associated with CSI-RS resources for channel measurement (CM), interference measurement (IM), or both. The CSI report configuration may configure CSI-RS resources for measurement (e.g., via a CSI-ResourceConfig IE). The CSI-RS resources provide the UE with the configuration of CSI-RS ports, or CSI-RS port groups, mapped to time and frequency resources (e.g., resource elements (REs)). CSI-RS resources can be zero power (ZP) or non-zero power (NZP) resources.

At least one NZP CSI-RS resource may be configured for CM. For interference measurement, it can be NZP CSI-RS or zero power CSI-RS, which is known as CSI-IM (note, if NZP CSI-RS, it is called NZP CSI-RS for interference measurement, if zero power, it is called CSI-IM)

[0058] The CSI report configuration may configure the UE for aperiodic, periodic, or semi-persistent CSI reporting. For periodic CSI, the UE may be configured with periodic CSI-RS resources. Periodic CSI and semi-persistent CSI report on physical uplink control channel (PUCCH) may be triggered via RRC or a medium access control (MAC) control element (CE). For aperiodic and semi-persistent CSI on the physical uplink shared channel (PUSCH), the BS may signal the UE a CSI report trigger indicating for the UE to send a CSI report for one or more CSI-RS resources, or configuring the CSI-RS report trigger state (e.g., CSI-AperiodicTriggerStateList and CSI-SemiPersistentOnPUSCH-TriggerStateList). The CSI report trigger for aperiodic CSI and semi-persistent CSI on PUSCH may be provided via downlink control information (DCI). The CSI-RS trigger may be signaling indicating to the UE that CSI-RS will be transmitted for the CSI-RS resource. The UE may report the CSI feedback based on the CSI report configuration and the CSI report trigger. For example, the UE may measure the channel associated with CSI for the triggered CSI-RS resources. Based on the measurements, the UE may select a preferred CSI-RS resource. The UE reports the CSI feedback for the selected CSI-RS resource.

[0059] The CSI report configuration can also configure the CSI parameters (sometimes referred to as quantities) to be reported. Codebooks may include Type I single panel, Type I multi-panel, and Type II single panel. Regardless which codebook is used, the CSI report may include at least the channel quality indicator (CQI), precoding matrix indicator (PMI), CSI-RS resource indicator (CRI), and rank indicator (RI). The structure of the PMI may vary based on the codebook. The CRI, RI, and CQI may be in a first part (Part I) and the PMI may be in a second part (Part II) of the CSI report.

[0060] For the Type I single panel codebook, the PMI may include a W_1 matrix (e.g., subset of beams) and a W_2 matrix (e.g., phase for cross polarization combination and beam selection). For the Type I multi-panel codebook, compared to type I single panel codebook, the PMI further comprises a phase for cross panel combination. The BS may have a plurality of transmit (TX) beams. The UE can feed back to the BS an index of a preferred beam, or beams, of the candidate beams. For example, the UE may feed back the precoding vector w for the l -th layer:

$$w_l = \begin{pmatrix} b_{+45\text{pol}} \\ \varphi \cdot b_{-45\text{pol}} \end{pmatrix},$$

where b represents the oversampled beam (e.g., discrete Fourier transform (DFT) beam), for both polarizations, and φ is the co-phasing.

[0061] For the Type II codebook (e.g., which may be designed for single panel), the PMI is a linear combination of beams; it has a subset of orthogonal beams to be used for linear combination and has per layer, per polarization, amplitude and phase for each beam. The preferred precoder for a layer can be a combination of beams and associated

quantized coefficients, and the UE can feedback the selected beams and the coefficients to the BS.

[0062] The UE may report the CSI feedback based on the CSI report configuration and the CSI report trigger. For example, the UE may measure the channel associated with CSI for the triggered CSI-RS resources. Based on the measurements, the UE may select a preferred CSI-RS resource. The UE reports the CSI feedback for the selected CSI-RS resource. LI may be calculated conditioned on the reported CQI, PMI, RI and CRI; CQI may be calculated conditioned on the reported PMI, RI and CRI; PMI may be calculated conditioned on the reported RI and CRI; and RI may be calculated conditioned on the reported CRI.

Example SD Compressed CSI Feedback

[0063] In certain systems (e.g., Release 15 5G NR), the UE may be configured to report at least a Type II precoder across configured frequency domain (FD) units. The UE may report wideband (WB) PMI and/or subband (SB) PMI as configured.

[0064] For a layer l , its precoder across N_3 FD units (also referred to as PMI subbands) may be given by a size- $N_t \times N_3$ matrix W_l as follows:

$$W_l = W_1 \times W_{2,l},$$

where W_1 and $W_{2,l}$ are as described in the following table:

| Notation | size | description | Comment |
|-----------|-----------------|---|-----------------|
| W_1 | $N_t \times 2L$ | SD basis; same SD bases are applied to both polarizations | Layer-common |
| $W_{2,l}$ | $2L \times N_3$ | Coefficient matrix: | Layer-specific; |

Note:

L value is rank-common and layer-common

[0065] The two matrices can be written as:

$$W_1 = \begin{bmatrix} v_{m_1^{(0)}, m_2^{(0)}}, & & 0 \\ v_{m_1^{(1)}, m_2^{(1)}}, \dots, v_{m_1^{(L-1)}, m_2^{(L-1)}} & & 0 \\ & 0 & v_{m_1^{(0)}, m_2^{(0)}}, \\ & & v_{m_1^{(1)}, m_2^{(1)}}, \dots, v_{m_1^{(L-1)}, m_2^{(L-1)}} \end{bmatrix},$$

where the SD bases are DFT based and the SD basis with index $m_1^{(i)}$ and $m_2^{(i)}$ is written as

$$v_{m_1^{(i)}, m_2^{(i)}} = \begin{bmatrix} u_{m_2^{(i)}} e^{\frac{j2\pi m_1^{(i)}}{O_1 N_1}} & \dots & e^{\frac{j2\pi m_1^{(i)}(N_1-1)}{O_1 N_1}} u_{m_2^{(i)}} \end{bmatrix}^T,$$

$$u_{m_2^{(i)}} = \begin{bmatrix} 1 & e^{\frac{j2\pi m_2^{(i)}}{O_2 N_2}} & \dots & e^{\frac{j2\pi m_2^{(i)}(N_2-1)}{O_2 N_2}} \end{bmatrix}$$

and where the coefficient matrix may be written as

$$W_{2,l} = \begin{bmatrix} p_{0,l,0}^{(1)} p_{0,l,0}^{(2)} e^{j\phi_{0,l,0}} & p_{0,l,1}^{(1)} p_{0,l,1}^{(2)} e^{j\phi_{0,l,1}} & \dots & p_{0,l,M-1}^{(1)} p_{0,l,M-1}^{(2)} e^{j\phi_{0,l,M-1}} \\ p_{1,l,0}^{(1)} p_{1,l,0}^{(2)} e^{j\phi_{1,l,0}} & p_{1,l,1}^{(1)} p_{1,l,1}^{(2)} e^{j\phi_{1,l,1}} & \dots & p_{1,l,M-1}^{(1)} p_{1,l,M-1}^{(2)} e^{j\phi_{1,l,M-1}} \\ \vdots & \vdots & \ddots & \vdots \\ p_{L-1,l,0}^{(1)} p_{L-1,l,0}^{(2)} e^{j\phi_{L-1,l,0}} & p_{L-1,l,1}^{(1)} p_{L-1,l,1}^{(2)} e^{j\phi_{L-1,l,1}} & \dots & p_{L-1,l,M-1}^{(1)} p_{L-1,l,M-1}^{(2)} e^{j\phi_{L-1,l,M-1}} \\ p_{L,l,0}^{(1)} p_{L,l,0}^{(2)} e^{j\phi_{L,l,0}} & p_{L,l,1}^{(1)} p_{L,l,1}^{(2)} e^{j\phi_{L,l,1}} & \dots & p_{L,l,M-1}^{(1)} p_{L,l,M-1}^{(2)} e^{j\phi_{L,l,M-1}} \\ p_{L+1,l,0}^{(1)} p_{L+1,l,0}^{(2)} e^{j\phi_{L+1,l,0}} & p_{L+1,l,1}^{(1)} p_{L+1,l,1}^{(2)} e^{j\phi_{L+1,l,1}} & \dots & p_{L+1,l,M-1}^{(1)} p_{L+1,l,M-1}^{(2)} e^{j\phi_{L+1,l,M-1}} \\ \vdots & \vdots & \ddots & \vdots \\ p_{2L-1,l,0}^{(1)} p_{2L-1,l,0}^{(2)} e^{j\phi_{2L-1,l,0}} & p_{2L-1,l,1}^{(1)} p_{2L-1,l,1}^{(2)} e^{j\phi_{2L-1,l,1}} & \dots & p_{2L-1,l,M-1}^{(1)} p_{2L-1,l,M-1}^{(2)} e^{j\phi_{2L-1,l,M-1}} \end{bmatrix}$$

[0066] In some cases, a common (P1) value may apply to all $p_{i,m,l}^{(1)}$ coefficients (or simply P1 coefficients) in one row. In such cases, given 2L rows in the matrix, the P1 value is row-specific and there might be 2L different values for these coefficients. The coefficients $p_{i,m,l}^{(1)}$, $p_{i,m,l}^{(2)}$ and $\phi_{i,m,l}$ are described as follows:

| Notation | description | Alphabet |
|---|---|---|
| $p_{i,m,l}^{(1)}$ | Reference amplitude beam for i of the 1 st polarization. | $\{1, \sqrt{1/2}\sqrt{1/2}, \sqrt{1/4}\sqrt{1/2}, \sqrt{1/8}\sqrt{1/2}, \sqrt{1/16}\sqrt{1/2}, \sqrt{1/32}\sqrt{1/2}, \sqrt{1/64}\sqrt{1/2}, 0\}$ |
| $p_{i+L,m,l}^{(1)}$ | Reference amplitude for the 2 nd polarization. | $\{1, \sqrt{1/2}\sqrt{1/2}, \sqrt{1/4}\sqrt{1/2}, \sqrt{1/8}\sqrt{1/2}, \sqrt{1/16}\sqrt{1/2}, \sqrt{1/32}\sqrt{1/2}, \sqrt{1/64}\sqrt{1/2}, 0\}$ |
| $p_{i,m,l}^{(2)}$ and $p_{i+L,m,l}^{(2)}$ | Differential amplitude for each individual coefficient | $\{1, \sqrt{0.5}\}$ |
| $\phi_{i,m,l}$ and $\phi_{i+L,m,l}$ | Phase of each individual coefficient | N-PSK, N = 4 or 8 |

[0067] More precisely, the linear combination representation may be written as:

$$W_l = \begin{pmatrix} \sum_{i=0}^{L-1} v_{m_1^{(i)}, m_2^{(i)}} p_{i,m,l}^{(1)} p_{i,m,l}^{(2)} \varphi_{i,m,l} \\ \sum_{i=0}^{L-1} v_{m_1^{(i)}, m_2^{(i)}} p_{i,m,l}^{(1)} p_{i,m,l}^{(2)} \varphi_{i,m,l} \end{pmatrix}$$

[0068] For linear combination of spatial beams B, the UE may report the linear combination coefficients $x_{i,k}^{(l)}$ for each layer l and each subband i, according to the precoding vector w:

$$W_i^{(l)} = \begin{pmatrix} B & 0 \\ 0 & B \end{pmatrix} \times x_i^{(l)} = \begin{pmatrix} \sum_{k=0}^{L-1} b_k \cdot x_{i,k}^{(l)} \\ \sum_{k=0}^{L-1} b_k \cdot x_{i+L,k}^{(l)} \end{pmatrix}$$

[0069] The precoder matrix W is based on the spatial domain (SD) compression of a matrix W_1 matrix and the W_2

matrix for reporting (for cross-polarization) the linear combination coefficients for the selected beams (2L) across the configured FD units.

[0070] For port selection in certain systems (e.g., Rel-15 NR port selection), the BS (e.g., a gNB) may use a beam in $v_{m_1^{(i)}, m_2^{(i)}}$ as the precoder for CSI-RS. The precoder for a layer on a subband is given by:

$$\left(\sum_{i=0}^{L-1} v_{i_{11}d+i} \cdot p_i^{(1)} \cdot p_i^{(2)} \cdot \phi_i \right),$$

where $v_{i_{11}d+i}$ is a vector. In this case, the UE selects the CSI-RS ports, for example, instead of selecting the beam. Thus, using this codebook, if the $(i_{11}d+i)$ -th entry is equal to 1 and the rest are 0s, this means that the $(i_{11}d+i)$ -th port is selected. With this codebook, there are P ports, where the first half of the ports are for polarization 1 and the other half of the ports are for polarization 2, and the same L ports are applied to both polarization. The UE reports the preferred candidate L ports via i_{11} , where the candidates are candidate L ports is 0 . . . L-1, and candidate L ports d . . . d+L-1. The last candidate L ports is

$$\left\lceil \frac{P}{2d} \right\rceil d, \dots, \text{mod}\left(\left\lceil \frac{P}{2d} \right\rceil d + L - 1, \frac{P}{2}\right).$$

In this case, the UE may be restricted to select L consecutive ports (e.g., port $i_{11}d, \dots, i_{11}d+L-1$) and the maximum number ports may be 32, which may be insufficient and should accommodate FD basis.

Example SD and F D Compressed CSI Feedback

[0071] In certain systems (e.g., Rel-16 5G NR), the UE may be configured to report frequency domain (FD) compressed precoder feedback to reduce overhead of the CSI report. With codebook operation with FD compression, for a layer 1, its precoder across N_3 FD units (e.g., PMI subbands) is given by a size- $N_f \times N_3$ matrix W_l as follows:

$$W_l = W_1 \times \tilde{W}_{2,l} \times W_{f,l}^H,$$

where W_1 , \tilde{W}_2 and W_f are as follows:

| Notation | size | description | Comment |
|-------------------|-----------------|---|-----------------|
| W_1 | $N_f \times 2L$ | SD basis; same SD bases are applied to both polarizations | Layer-common |
| $\tilde{W}_{2,l}$ | $2L \times M$ | Coefficient matrix: Consist of max K_0 NZC per-layer; Consist of max $2K_0$ NZC across all layers | Layer-specific; |
| $W_{f,l}$ | $M \times N_3$ | FD basis; same M FD bases are applied to both polarizations | Layer-specific; |

Note:

L value is rank-common and layer-common

M value is rank-group specific and layer-common.

$M = M_{1,2}$ for $RI = \{1, 2\}$ and $M = M_{3,4} \leq M_{1,2}$ for $RI = \{3, 4\}$

[0072] The precoder matrix ($W_{f,i}$) for layer i with $i=0,1$ may use an FD compression $W_{f,i}^H$ matrix to compress the precoder matrix into $\tilde{W}_{2,i}$ matrix size to $2L \times M$ (where M is network configured and communicated in the CSI configuration message via RRC or DCI, and $M < N_3$) given as:

$$W_i = W_1 \tilde{W}_{2,i} W_{f,i}^H,$$

where the precoder matrix W_i (not shown) has $P=2N_1N_2$ rows (spatial domain, number of ports) and N_3 columns (frequency-domain compression unit containing RBs or reporting sub-bands), and where M bases are selected for each of layer 0 and layer 1 independently. The $\tilde{W}_{2,0}$ matrix consists of the linear combination coefficients (amplitude and co-phasing), where each element represents the coefficient of a tap for a beam. The $\tilde{W}_{2,0}$ matrix may be defined by size $2L \times M$, where one row corresponds to one spatial beam in W_1 (not shown) of size $P \times 2L$ (where L is network configured via RRC), and one entry therein represents the coefficient of one tap for this spatial beam.

[0073] The UE may be configured to report (e.g., CSI report) a subset $K_0 < 2LM$ of the linear combination coefficients of the $\tilde{W}_{2,0}$ matrix. For example, the UE may report $K_{NZ,i} < K_0$ coefficients (where $K_{NZ,i}$ corresponds to a maximum number of non-zero coefficients for layer- i with $i=0$ or 1, and K_0 is network configured via RRC) illustrated as shaded squares (unreported coefficients are set to zero). In some configurations, an entry in the $\tilde{W}_{2,0}$ matrix corresponds to a row of W_1 matrix. In the example shown, both the $\tilde{W}_{2,0}$ matrix at layer 0 and the $W_{2,0}$ matrix at layer 1 are $2L \times M$.

[0074] The $W_{f,0}^H$ matrix is composed of the basis vectors (each row is a basis vector) used to perform compression in frequency domain. In the example shown, both the $W_{f,0}^H$ matrix at layer 0 and the $W_{f,1}^H$ matrix at layer 1 include $M=4$ FD basis from N_3 candidate DFT basis. In some configurations, the UE may report a subset of selected basis of the $W_{f,i}^H$ matrix via CSI report. The M bases specifically selected at layer 0 and layer 1. That is, the M bases selected at layer 0 can be same/partially-overlapped/non-overlapped with the M bases selected at layer 1.

[0075] The precoder may be written as:

$$W^{(l)} = \left(\sum_{k=0}^{L-1} \sum_{m=0}^{M-1} b_k \cdot x_{m,k}^{(l)} \cdot f_{m,l}^H \right)$$

[0076] As discussed above, the Type II CSI with FD compression may compress N_3 subbands via M FD bases. The FD bases are selected/reported layer-specific. For each layer, the UE reports a subset of the total $2LM$ coefficients, where the coefficient selection may be layer specific, and the UE may use a size- $2LM$ bitmap to indicate the selected non-zero coefficients (NZC) and report each the NZC after quantization. In some examples, the UE may report up to K_0 coefficients per layer, where $K_{NZ,i} \leq K_0$. In some examples, the UE may report up to $2K_0$ coefficients across all layers, where $\sum_{i=0}^{R-1} K_{NZ,i} \leq 2K_0$. Unreported are set to zeros.

[0077] The UE may report the CSI in uplink control information (UCI). In some examples, the CSI is reported in a two-part UCI. In some examples, in the UCI part one the

UE may transmit RI, CQI, the number of non-zero coefficients (NNZC). In some examples, in the UCI part two the UE may transmit for the supported layers (e.g., layers 0 to RI-1) the SD beam selection, FD basis selection, coefficient selection, strongest coefficient indication (SCI), and/or coefficient quantization. The SD beam selection may indicate the selected beams (e.g., the subset of $2L$ beams).

Example mTRP and NCJT

[0078] In certain system, transmissions may be via multiple transmission configuration indicator (TCI) states. In some examples, a TCI-state is associated with a beam pair, antenna panel, antenna ports, antenna port groups, a quasi-colocation (QCL) relation, and/or a transmission reception point (TRP). Thus, multi-TCI state transmission may be associated with multiple beam pairs, multiple antenna panels, and/or multiple QCL relations which may be associated with one or more multiple TRPs (mTRP).

[0079] In some examples, the TCI state may generally indicate to the UE an association between a downlink reference signal to a corresponding QCL type which may allow the UE to determine the receive beam to use for receiving a transmission. The QCL-type may be associated with a combination (e.g., set) of QCL parameters. In some examples, a QCL-TypeA indicates the ports are QCL'd with respect to Doppler shift, Doppler spread, average delay, and delay spread; QCL-TypeB indicates the ports are QCL'd with respect to Doppler shift, and Doppler spread; QCL-TypeC indicates the ports are QCL'd with respect to average delay and Doppler shift; and QCL-TypeD indicates the ports are QCL'd with respect to Spatial Rx parameter. Different groups of ports can share different sets of QCL parameters.

[0080] In some examples, for a multi-TCI state scenario, the same TB/CB (e.g., same information bits but can be different coded bits) is transmitted from multiple TCI states, such as two or more TRPs in multi-TRP scenario. The UE considers the transmissions from both TCI states and jointly decodes the transmissions. In some examples, the transmissions from the TCI states is at the same time (e.g., in the same slot, mini-slot, and/or in the same symbols), but across different RBs and/or different layers. The number of layers and/or the modulation order from each TCI state can be the same or different. In some examples, the transmissions from the TCI states can be at different times (e.g., in two consecutive mini-slots or slots). In some examples, the transmissions from the TRPs can be a combination of the above.

[0081] In certain wireless communication networks (e.g., new radio), non-coherent joint transmissions (NCJTs) may be used to provide multiple-input multiple-output (MIMO), multiple-user (MU) MIMO, and/or coordinated multi-point (CoMP) communications. The NCJTs may be from multiple transmission-reception points (multi-TRP), multiple panels (multi-panel) of a TRP, or a combination thereof. Coherent joint transmission requires synchronization among transmission reception points (TRPs). However, for distributed TRPs, the precoders cannot be jointly designed and, therefore, the TRPs are not synchronized. Instead, each TRP derives the precoder independently, without knowledge of the precoders used by the other TRPs. Thus, the joint transmission is non-coherent. Using NCJT, TRPs can transmit the same data to a UE to improve the transmission reliability/coverage. Also, using NCJT the TRPs can transmit different data streams to the UE to improve throughput. For NCJT, the UE can select multiple CSI reference signal (CSI-RS) resources, or a CSI-RS with multiple ports, for

CSI reporting. Thus, the UE may be configured to report CRI indicating the selected resources along with CSI including RI, PMI, and CQI for each of the selected resources and/or port groups.

[0082] A CSI report configuration occupies resources at the UE. In certain systems (e.g., Release 15/16 systems), the total number of CSI reports configured by the network is limited (e.g., TS 38.214 Section 5.2.1.6 provides example CSI processing criteria). For example, the total number of configured CSI reports can be limited based on associated CSI processing including the total number of CSI processing units (CPUs), the total number of active CSI-RS resources, and/or the total number of active CSI-RS ports, used by the UE for the CSI reporting.

[0083] In any slot, the UE is not expected to have more active CSI-RS ports or active CSI-RS resources than reported as capability. NZP CSI-RS resource is active in a duration of time defined as follows. For aperiodic CSI-RS, the NZP CSI-RS resource is active in the duration starting from the end of the PDCCH containing the request and ending at the end of the PUSCH containing the report associated with this aperiodic CSI-RS. For semi-persistent CSI-RS, the NZP CSI-RS resource is active in the duration starting from the end of when the activation command is applied, and ending at the end of when the deactivation command is applied. For periodic CSI-RS, the NZP CSI-RS resource is active in the duration starting when the periodic CSI-RS is configured by higher layer signalling, and ending when the periodic CSI-RS configuration is released. If a CSI-RS resource is referred by N CSI reporting settings, the CSI-RS resource and the CSI-RS ports within the CSI-RS resource are counted N times.

[0084] In such systems, to determine the CSI processing, the number of CPUs, active CSI-RS resources, and active CSI-RS ports are counted once per configured resource. Thus, for example, if there is only once resource, there is only one occupied CPU. In some examples, the number of occupied CPUs (O_{cpu}) is equal to 0 for a report quantity “none” and a CSI-RS resource set with the higher layer parameter “trs-Info” is configured; $O_{cpu}=1$ for a CSI report quantity “cri-RSRP”, “ssb-Index-RSRP”, or none; $O_{cpu}=N_{cpu}$ (the UE capability for total number of CPUs) for wideband CSI with up to four ports without CRI report configured; otherwise, $O_{cpu}=K_s$ with K_s denoting the number of CMRs. Regarding the CSI-RS resource and CSI ports, in a given slot, the UE may not be expected to have more active CSI-RS resources and/or CSI-RS ports than an amount reported as the UE capability. If a CSI-RS resource is associated with N CSI report configurations, the CSI-RS resource and the ports within the resource are counted N times (once for each CSI report configuration).

[0085] In certain systems (e.g., Release 17 systems), however, CSI may support dynamic channel measurement and/or interference measurement for mTRP transmission.

[0086] In some scenarios, each CSI-RS resource is associated with a single TCI state and the UE selects multiple CSI-RS resources (e.g., one CMR selected for each TRP). FIG. 4 is a table showing an example mapping of CRI codepoints to CMR in the example scenario with each CSI-RS resource associated with a single TCI state and multiple resource selection and FIGS. 5A-C illustrate the corresponding resource selection. The associated resource grids shows the example corresponding resource elements (REs), in shading, to the selected CMR. As shown in the

FIG. 4 and FIGS. 5A-C, the CRI codepoint 2 allows selection of multiple CMRs. In some examples, this may be used for a sub-6 GHz frequency range (FR1).

[0087] FIG. 6 is a table showing another example mapping of CRI codepoints to CMR port groups in the example scenario with each CSI-RS resource associated with a single TCI state and multiple resource selection and FIGS. 7A-C illustrate the corresponding resource selection. In some examples, this may be used for a millimeter wave (mmW) frequency range (FR2). As shown in the FIG. 4 and FIGS. 7A-C, the UE may only have one receive beam or use a specific beam-pair, and in the scenario where the UE encounters receiving beams from both TRP1 and TRP2 (e.g., CRI codepoint 2), the UE uses another two resources (CMRs 2 and 3) and puts them in the same symbol so the UE can use one beam to receive them simultaneously.

[0088] In some scenarios, each CSI-RS resource is associated with multiple TCI states and the UE selects one CSI-RS resource. For example, there may be only one resource (e.g., CMR) that contains multiple (e.g., two) port groups (e.g., one port group selected for each TRP).

[0089] FIG. 8 is a table showing an example mapping of CRI codepoints/rank indicator (RI)-pairs to CMR port groups in the example scenario with one CSI-RS resource associated with multiple TCI states and FIGS. 9A-C illustrate the corresponding resource selection. As shown in the FIG. 8 and FIGS. 9A-C, the CRI codepoint 2 allows selection of multiple port groups of a CMR. In some examples, this may be used for a FR1.

[0090] FIG. 10 is a table showing another example mapping of CRI codepoints to CMR port groups the example scenario with one CSI-RS resource associated with multiple TCI states and FIGS. 11A-C illustrate the corresponding resource selection. In some examples, this may be used for FR2. As shown in the FIG. 10 and FIGS. 11A-C, the CRI codepoint 2 allows selection of multiple port groups of a CMR. The UE may only have one receive beam or use a specific beam-pair, and in the scenario where the UE encounters receiving beams from both TRP1 and TRP2 (e.g., CRI codepoint 2), the UE uses a third resource resources (CMR 2) to put two resources (CMR 0 and CMR 1) in the same symbol so the UE can use one beam to receive them simultaneously.

[0091] What is needed are techniques and apparatus for CPU, resource, and port occupation for CSI reporting for mTRP scenarios.

Example CPU, Resource, and Port Occupation for mTRP CSI

[0092] Aspects of the present disclosure provide for determination of occupied channel state information (CSI) processing resources based on an actual number CSI measurements (e.g., an actual number of precoding matrix indicator (PMI) calculations). For example, the number of occupied CSI processing units (CPUs), the number of occupied active CSI reference signal (CSI-RS) resources, and/or the number of occupied active CSI ports may be determined based on the actual number of CSIs calculated for a corresponding CSI-RS resource. In some examples, the occupied active resources may be determined for the corresponding CSI-RS resource based on the occurrences of the CSI-RS resource across all CSI resource indicator (CRI) codepoints. In some examples, the occupied active resources may be determined

for the corresponding CSI-RS resource based on the number transmission configuration indicator (TCI) states per resource.

[0093] In an illustrative example, a multiple transmission reception point (mTRP) scenario may involve two TRPs, TRP 0 and TRP 1, for example, as shown in the examples in FIGS. 5A-C, 7A-C, 9A-C, and 11A-C. In the illustrative example, TRP 0 may have 4 CSI ports and TRP 1 may have 8 CSI ports. In this example, the UE calculates 4 precoding matrix indicators (PMIs)—one PMI for a first case that a CMR is selected to measure the TRP 0, one PMI for a second case that a CMR is selected to measure the TRP 1, and two PMIs for a third case that two CMRs are selected to measure both the TRP 0 and the TRP 1. The PMI to measure the TRP 0 in the first case may occupy one CPU, one active CSI-RS resource, and four active CSI-RS ports. The PMI to measure the TRP 1 in the second case may occupy one CPU, one active CSI-RS resource, and eight active CSI-RS ports. The two PMIs to measure the TRP 0 and the TRP 1 in the third case may occupy two CPUs (one for the TRP 0 and one for the TRP 1), two active CSI-RS resources (one for the TRP 0 and one for the TRP 1), and twelve active CSI-RS ports (four for the TRP 0 and eight for the TRP 1). Thus, the total resource occupation for the four PMIs is 4 active CPUs, 4 active CSI-RS resources, and 24 active CSI ports.

[0094] As discussed above with respect to the examples in FIGS. 4, 5A-C, 6, and 7A-C, multiple CSI-RS resources may be selected for channel measurement (CMRs) and each CMR may be associated with a single transmission configuration indicator (TCI) state. According to certain aspects, the CSI processing resources (e.g., the number of occupied active CPUs, the number of occupied active CSI-RS resources, and/or the number of occupied active CSI-RS ports) can be determined for each CMR based on the number of occurrences, N_1 , of the CMR across all CRI codepoints. For example, each port is counted N_1 times, wherein N_1 is the number of occurrences.

[0095] For the example shown in FIGS. 4 and 5A-C for FR1, the CSI processing resources occupied for a CMR may be counted N_1 times. In the example in FIGS. 4 and 5A-C (and with the TRP 0 having 4 ports and the TRP 1 having 8 ports in the illustrative example used herein), the CMR 0 occurs in the codepoints CRI0 and CRI2 and, thus, is counted twice ($N_1=2$). In this example, for CMR 0 (associated with TRP 0), the total number of occupied active CPUs is 2, the total number of occupied active CSI-RS resources is 2, and the total number of occupied active CSI-RS ports is 8. The occupied processing resources for CMR 1 (associated with TRP 1) can be counted similarly. The CMR 1 occurs in the codepoints CRI1 and CRI2 and the total number of occupied active CPUs is 1, the total number of occupied active CSI-RS resources is 2, and the total number of occupied active CSI-RS ports is 16.

[0096] For the example shown in FIGS. 6 and 7A-C for FR2, the CSI processing resources occupied for a CMR may be counted N_1 times. In the example in FIGS. 6 and 7A-C (and with the TRP 0 having 4 ports and the TRP 1 having 8 ports in the illustrative example used herein), the CMR 0 occurs only in the codepoint CRI0 and, thus, is counted once ($N_1=1$). In this example, for CMR 0 (associated with TRP 0), the total number of occupied active CPUs is 1, the total number of occupied active CSI-RS resources is 1, and the total number of occupied active CSI-RS ports is 4. The occupied processing resources for CMR 1 (associated with

TRP 1) can be counted similarly. The CMR 1 occurs in only the codepoint CRI1 and the total number of occupied active CPUs is 1, the total number of occupied active CSI-RS resources is 1, and the total number of occupied active CSI-RS ports is 8. The CMR 2 (associated with TRP 0) and the CMR 3 (associated with TRP 1) are each associated only with the CRI2 and are each counted also once (e.g., occupied active CSI processing resources by CMR 2=1 CPU, 1 CSI-RS resource, 4 CSI-RS ports and by CMR 3=1 CPU, 1 CSI-RS resource, 8 CSI-RS port).

[0097] As discussed above with respect to the examples in FIGS. 8, 9A-C, 10, and 11A-C, a single CMR may be selected and the CMR may be associated with a multiple TCI states. According to certain aspects, the CSI processing resources (e.g., the number of occupied active CPUs, the number of occupied active CSI-RS resources, and/or the number of occupied active CSI-RS ports) can be determined for each CMR based on the number of TCI states and port groups per resource, N_2 .

[0098] For each resource, there are N_2 TCI states and thus N_2 TRPs. For a single TRP, there may be N_2 different channel hypotheses corresponding to N_2 different PMIs. For the case of two transmitting TRPs in an mTRP transmission, there are two out of N_2 different options. For each TRP pair, there are 2 PMI calculations. So the total number of CPU and resource occupation may be equal to

$$2 \times \binom{N_2}{2} = N_2(N_2 - 1).$$

[0099] For the example shown in FIGS. 8 and 9A-C for FR1, the number of occupied active CPUs and the number of occupied active CSI-RS resources for a CMR may be counted as a summation of N_2

$$(\text{if a single port group is selected}) + 2 \times \binom{N_2}{2}$$

(if a port group-pair is selected). The number of occupied active CSI-RS ports may be counted N_2 times. In the example in FIGS. 8 and 9A-C (and with the TRP 0 having 4 ports and the TRP 1 having 8 ports in the illustrative example used herein), for a single CMR with 2 TCI states (port group 0 and port group 1), the number of occupied active CPUs is 4, the number of occupied active CSI-RS resources is 4, and the number occupied active CSI-RS ports is 24.

[0100] For the example shown in FIGS. 10 and 11A-C for FR2, the number of occupied active CPUs and the number of occupied active CSI-RS resources for a CMR may be counted N_2 times and the number of occupied active CSI-RS ports may be counted once. In the example in FIGS. 10 and 11A-C (and with the TRP 0 having 4 ports and the TRP 1 having 8 ports in the illustrative example used herein), for a single CMR with 2 TCI states (port group 0 and port group 1): for CMR port group/TCI state associated with the TRP 0 (CRI0), the number of occupied active CPUs is 1, the number of occupied active CSI-RS resources is 1, and the number occupied active CSI-RS ports is 4; for the CMR port group/TCI state associated with the TRP 1 (CRI1), the number of occupied active CPUs is 1, the number of occupied active CSI-RS resources is 1, and the

number occupied active CSI-RS ports is 8; and for the two CMR port groups/TCI states associated with both the TRP 0 and the TRP 1 (CRI2), the number of occupied active CPUs is 2, the number of occupied active CSI-RS resources is 2, and the number occupied active CSI-RS ports is 12.

[0101] FIG. 12 is a flow diagram illustrating example operations 1200 for wireless communication, in accordance with certain aspects of the present disclosure. The operations 1200 may be performed, for example, by UE (e.g., such as a UE 120a in the wireless communication network 100). Operations 1200 may be implemented as software components that are executed and run on one or more processors (e.g., controller/processor 280 of FIG. 2). Further, the transmission and reception of signals by the UE in operations 1200 may be enabled, for example, by one or more antennas (e.g., antennas 252 of FIG. 2). In certain aspects, the transmission and/or reception of signals by the UE may be implemented via a bus interface of one or more processors (e.g., controller/processor 280) obtaining and/or outputting signals.

[0102] The operations 1200 may begin, at 1205, by receiving a CSI reporting configuration configuring the UE with a plurality of CMRs.

[0103] At 1210, the UE determines a number of occupied CPUs, a number of occupied active CSI resources, and/or a number of occupied active CSI-RS ports, based on an actual number of CSI measurements.

[0104] In some examples, the UE determines a first number of occupied CSI processing units, a first number of occupied active CSI resources, and/or a first number of occupied active CSI-RS ports when the UE operates in a first frequency range (e.g., FR1) and the UE determines a second number of occupied active CSI processing units, a second number of occupied active CSI resources, and/or a second number of occupied active CSI-RS ports when the UE operates in a second frequency range (e.g., FR2).

[0105] According to certain aspects, the UE determines the actual number of CSI measurements based on an indicator. For example, a codepoint of the indicator is associated with one or more CMRs, and a CMR is associated with one or more codepoints of the indicator. In some examples, the indicator is a CRI or a RI-pair.

[0106] In some examples, the UE determines, for a CMR of the plurality of CMRs, its number of occupied CPUs, number of occupied active CSI-RS resources, and/or number of occupied active CSI-RS ports based, at least in part, on the number of codepoints that the CMR is associated with.

[0107] In some examples, the UE determines the actual number of CSI measurements based on the number of CSI-RS port groups and the number of TCI states, N, associated with each of the CMRs. For example, each CMR is associated with a number of occupied CSI processing units, a number of occupied active CSI resources, and a number of occupied active CSI-RS ports.

[0108] In some examples, the UE determines, for a CMR of the plurality of the CMRs, its number of occupied CPUs is equal to a summation of the number of CSI-RS port groups and the number of CSI-RS port-group-pairs; its number of occupied active CSI-RS resources is equal to summation of the number of CSI-RS port groups and the number of CSI-RS port-group-pairs; and its number of occupied active CSI-RS ports is equal to the number of CSI-RS port groups.

[0109] At 1215, the UE performs CSI measurement based on the determination.

[0110] FIG. 13 illustrates a communications device 1300 that may include various components (e.g., corresponding to means-plus-function components) configured to perform operations for the techniques disclosed herein, such as the operations illustrated in FIG. 12. The communications device 1300 includes a processing system 1302 coupled to a transceiver 1308 (e.g., a transmitter and/or a receiver). The transceiver 1308 is configured to transmit and receive signals for the communications device 1300 via an antenna 1310, such as the various signals as described herein. The processing system 1302 may be configured to perform processing functions for the communications device 1300, including processing signals received and/or to be transmitted by the communications device 1300.

[0111] The processing system 1302 includes a processor 1304 coupled to a computer-readable medium/memory 1312 via a bus 1306. In certain aspects, the computer-readable medium/memory 1312 is configured to store instructions (e.g., computer-executable code) that when executed by the processor 1304, cause the processor 1304 to perform the operations illustrated in FIG. 12 or other operations for performing the various techniques discussed herein. In certain aspects, computer-readable medium/memory 1312 stores code 1314 for receiving a CSI reporting configuration configuring the UE with a plurality of CMRs; code 1316 for determining a number of occupied CPUs, a number of occupied active CSI resources, and/or a number of occupied active CSI-RS ports, based on an actual number of CSI measurements; and/or code 1318 for performing CSI measurement based on the determination, in accordance with aspects of the disclosure. In certain aspects, the processor 1304 has circuitry configured to implement the code stored in the computer-readable medium/memory 1312. The processor 1304 includes circuitry 1320 for receiving a CSI reporting configuration configuring the UE with a plurality of CMRs; circuitry 1322 for determining a number of occupied CPUs, a number of occupied active CSI resources, and/or a number of occupied active CSI-RS ports, based on an actual number of CSI measurements; and/or circuitry 1324 for performing CSI measurement based on the determination, in accordance with aspects of the disclosure.

[0112] The techniques described herein may be used for various wireless communication technologies, such as NR (e.g., 5G NR), 3GPP Long Term Evolution (LTE), LTE-Advanced (LTE-A), code division multiple access (CDMA), time division multiple access (TDMA), frequency division multiple access (FDMA), orthogonal frequency division multiple access (OFDMA), single-carrier frequency division multiple access (SC-FDMA), time division synchronous code division multiple access (TD-SCDMA), and other networks. The terms “network” and “system” are often used interchangeably. A CDMA network may implement a radio technology such as Universal Terrestrial Radio Access (UTRA), cdma2000, etc. UTRA includes Wideband CDMA (WCDMA) and other variants of CDMA. cdma2000 covers IS-2000, IS-95 and IS-856 standards. A TDMA network may implement a radio technology such as Global System for Mobile Communications (GSM). An OFDMA network may implement a radio technology such as NR (e.g., 5G RA), Evolved UTRA (E-UTRA), Ultra Mobile Broadband (UMB), IEEE 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.20, Flash-OFDMA, etc. UTRA and E-UTRA are

part of Universal Mobile Telecommunication System (UMTS). LTE and LTE-A are releases of UMTS that use E-UTRA. UTRA, E-UTRA, UMTS, LTE, LTE-A and GSM are described in documents from an organization named “3rd Generation Partnership Project” (3GPP). cdma2000 and UMB are described in documents from an organization named “3rd Generation Partnership Project 2” (3GPP2). NR is an emerging wireless communications technology under development.

[0113] In 3GPP, the term “cell” can refer to a coverage area of a Node B (NB) and/or a NB subsystem serving this coverage area, depending on the context in which the term is used. In NR systems, the term “cell” and BS, next generation NodeB (gNB or gNodeB), access point (AP), distributed unit (DU), carrier, or transmission reception point (TRP) may be used interchangeably. A BS may provide communication coverage for a macro cell, a pico cell, a femto cell, and/or other types of cells. A macro cell may cover a relatively large geographic area (e.g., several kilometers in radius) and may allow unrestricted access by UEs with service subscription. A pico cell may cover a relatively small geographic area and may allow unrestricted access by UEs with service subscription. A femto cell may cover a relatively small geographic area (e.g., a home) and may allow restricted access by UEs having an association with the femto cell (e.g., UEs in a Closed Subscriber Group (CSG), UEs for users in the home, etc.). A BS for a macro cell may be referred to as a macro BS. A BS for a pico cell may be referred to as a pico BS. A BS for a femto cell may be referred to as a femto BS or a home BS.

[0114] A UE may also be referred to as a mobile station, a terminal, an access terminal, a subscriber unit, a station, a Customer Premises Equipment (CPE), a cellular phone, a smart phone, a personal digital assistant (PDA), a wireless modem, a wireless communication device, a handheld device, a laptop computer, a cordless phone, a wireless local loop (WLL) station, a tablet computer, a camera, a gaming device, a netbook, a smartbook, an ultrabook, an appliance, a medical device or medical equipment, a biometric sensor/device, a wearable device such as a smart watch, smart clothing, smart glasses, a smart wrist band, smart jewelry (e.g., a smart ring, a smart bracelet, etc.), an entertainment device (e.g., a music device, a video device, a satellite radio, etc.), a vehicular component or sensor, a smart meter/sensor, industrial manufacturing equipment, a global positioning system device, or any other suitable device that is configured to communicate via a wireless or wired medium. Some UEs may be considered machine-type communication (MTC) devices or evolved MTC (eMTC) devices. MTC and eMTC UEs include, for example, robots, drones, remote devices, sensors, meters, monitors, location tags, etc., that may communicate with a BS, another device (e.g., remote device), or some other entity. A wireless node may provide, for example, connectivity for or to a network (e.g., a wide area network such as Internet or a cellular network) via a wired or wireless communication link. Some UEs may be considered Internet-of-Things (IoT) devices, which may be narrowband IoT (NB-IoT) devices.

[0115] In some examples, access to the air interface may be scheduled. A scheduling entity (e.g., a BS) allocates resources for communication among some or all devices and equipment within its service area or cell. The scheduling entity may be responsible for scheduling, assigning, reconfiguring, and releasing resources for one or more subordi-

nate entities. That is, for scheduled communication, subordinate entities utilize resources allocated by the scheduling entity. Base stations are not the only entities that may function as a scheduling entity. In some examples, a UE may function as a scheduling entity and may schedule resources for one or more subordinate entities (e.g., one or more other UEs), and the other UEs may utilize the resources scheduled by the UE for wireless communication. In some examples, a UE may function as a scheduling entity in a peer-to-peer (P2P) network, and/or in a mesh network. In a mesh network example, UEs may communicate directly with one another in addition to communicating with a scheduling entity.

[0116] The methods disclosed herein comprise one or more steps or actions for achieving the methods. The method steps and/or actions may be interchanged with one another without departing from the scope of the claims. In other words, unless a specific order of steps or actions is specified, the order and/or use of specific steps and/or actions may be modified without departing from the scope of the claims.

[0117] As used herein, a phrase referring to “at least one of” a list of items refers to any combination of those items, including single members. As an example, “at least one of: a, b, or c” is intended to cover a, b, c, a-b, a-c, b-c, and a-b-c, as well as any combination with multiples of the same element (e.g., a-a, a-a-a, a-a-b, a-a-c, a-b-b, a-C-c, b-b, b-b-b, b-b-c, c-c, and c-c-c or any other ordering of a, b, and c).

[0118] As used herein, the term “determining” encompasses a wide variety of actions. For example, “determining” may include calculating, computing, processing, deriving, investigating, looking up (e.g., looking up in a table, a database or another data structure), ascertaining and the like. Also, “determining” may include receiving (e.g., receiving information), accessing (e.g., accessing data in a memory) and the like. Also, “determining” may include resolving, selecting, choosing, establishing and the like.

[0119] The previous description is provided to enable any person skilled in the art to practice the various aspects described herein. Various modifications to these aspects will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other aspects. Thus, the claims are not intended to be limited to the aspects shown herein, but is to be accorded the full scope consistent with the language of the claims, wherein reference to an element in the singular is not intended to mean “one and only one” unless specifically so stated, but rather “one or more.” Unless specifically stated otherwise, the term “some” refers to one or more. All structural and functional equivalents to the elements of the various aspects described throughout this disclosure that are known or later come to be known to those of ordinary skill in the art are expressly incorporated herein by reference and are intended to be encompassed by the claims. Moreover, nothing disclosed herein is intended to be dedicated to the public regardless of whether such disclosure is explicitly recited in the claims. No claim element is to be construed under the provisions of 35 U.S.C. § 112(f) unless the element is expressly recited using the phrase “means for” or, in the case of a method claim, the element is recited using the phrase “step for.”

[0120] The various operations of methods described above may be performed by any suitable means capable of performing the corresponding functions. The means may include various hardware and/or software component(s) and/or module(s), including, but not limited to a circuit, an

application specific integrated circuit (ASIC), or processor. Generally, where there are operations illustrated in figures, those operations may have corresponding counterpart means-plus-function components with similar numbering.

[0121] The various illustrative logical blocks, modules and circuits described in connection with the present disclosure may be implemented or performed with a general purpose processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable logic device (PLD), discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general-purpose processor may be a microprocessor, but in the alternative, the processor may be any commercially available processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices, e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

[0122] If implemented in hardware, an example hardware configuration may comprise a processing system in a wireless node. The processing system may be implemented with a bus architecture. The bus may include any number of interconnecting buses and bridges depending on the specific application of the processing system and the overall design constraints. The bus may link together various circuits including a processor, machine-readable media, and a bus interface. The bus interface may be used to connect a network adapter, among other things, to the processing system via the bus. The network adapter may be used to implement the signal processing functions of the PHY layer. In the case of a user terminal (see FIG. 1), a user interface (e.g., keypad, display, mouse, joystick, etc.) may also be connected to the bus. The bus may also link various other circuits such as timing sources, peripherals, voltage regulators, power management circuits, and the like, which are well known in the art, and therefore, will not be described any further. The processor may be implemented with one or more general-purpose and/or special-purpose processors. Examples include microprocessors, microcontrollers, DSP processors, and other circuitry that can execute software. Those skilled in the art will recognize how best to implement the described functionality for the processing system depending on the particular application and the overall design constraints imposed on the overall system.

[0123] If implemented in software, the functions may be stored or transmitted over as one or more instructions or code on a computer readable medium. Software shall be construed broadly to mean instructions, data, or any combination thereof, whether referred to as software, firmware, middleware, microcode, hardware description language, or otherwise. Computer-readable media include both computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. The processor may be responsible for managing the bus and general processing, including the execution of software modules stored on the machine-readable storage media. A computer-readable storage medium may be coupled to a processor such that the processor can read information from, and write information to, the storage medium. In the alternative, the storage medium may be integral to the processor. By way of

example, the machine-readable media may include a transmission line, a carrier wave modulated by data, and/or a computer readable storage medium with instructions stored thereon separate from the wireless node, all of which may be accessed by the processor through the bus interface. Alternatively, or in addition, the machine-readable media, or any portion thereof, may be integrated into the processor, such as the case may be with cache and/or general register files. Examples of machine-readable storage media may include, by way of example, RAM (Random Access Memory), flash memory, ROM (Read Only Memory), PROM (Programmable Read-Only Memory), EPROM (Erasable Programmable Read-Only Memory), EEPROM (Electrically Erasable Programmable Read-Only Memory), registers, magnetic disks, optical disks, hard drives, or any other suitable storage medium, or any combination thereof. The machine-readable media may be embodied in a computer-program product.

[0124] A software module may comprise a single instruction, or many instructions, and may be distributed over several different code segments, among different programs, and across multiple storage media. The computer-readable media may comprise a number of software modules. The software modules include instructions that, when executed by an apparatus such as a processor, cause the processing system to perform various functions. The software modules may include a transmission module and a receiving module. Each software module may reside in a single storage device or be distributed across multiple storage devices. By way of example, a software module may be loaded into RAM from a hard drive when a triggering event occurs. During execution of the software module, the processor may load some of the instructions into cache to increase access speed. One or more cache lines may then be loaded into a general register file for execution by the processor. When referring to the functionality of a software module below, it will be understood that such functionality is implemented by the processor when executing instructions from that software module.

[0125] Also, any connection is properly termed a computer-readable medium. For example, if the software is transmitted from a website, server, or other remote source using a coaxial cable, fiber optic cable, twisted pair, digital subscriber line (DSL), or wireless technologies such as infrared (IR), radio, and microwave, then the coaxial cable, fiber optic cable, twisted pair, DSL, or wireless technologies such as infrared, radio, and microwave are included in the definition of medium. Disk and disc, as used herein, include compact disc (CD), laser disc, optical disc, digital versatile disc (DVD), floppy disk, and Blu-ray® disc where disks usually reproduce data magnetically, while discs reproduce data optically with lasers. Thus, in some aspects computer-readable media may comprise non-transitory computer-readable media (e.g., tangible media). In addition, for other aspects computer-readable media may comprise transitory computer-readable media (e.g., a signal). Combinations of the above should also be included within the scope of computer-readable media.

[0126] Thus, certain aspects may comprise a computer program product for performing the operations presented herein. For example, such a computer program product may comprise a computer-readable medium having instructions stored (and/or encoded) thereon, the instructions being executable by one or more processors to perform the opera-

tions described herein, for example, instructions for performing the operations described herein and illustrated in FIG. 12.

[0127] Further, it should be appreciated that modules and/or other appropriate means for performing the methods and techniques described herein can be downloaded and/or otherwise obtained by a user terminal and/or base station as applicable. For example, such a device can be coupled to a server to facilitate the transfer of means for performing the methods described herein. Alternatively, various methods described herein can be provided via storage means (e.g., RAM, ROM, a physical storage medium such as a compact disc (CD) or floppy disk, etc.), such that a user terminal and/or base station can obtain the various methods upon coupling or providing the storage means to the device. Moreover, any other suitable technique for providing the methods and techniques described herein to a device can be utilized.

[0128] It is to be understood that the claims are not limited to the precise configuration and components illustrated above. Various modifications, changes and variations may be made in the arrangement, operation and details of the methods and apparatus described above without departing from the scope of the claims.

1. A method for wireless communication by a user equipment (UE), comprising:

receiving a channel state information (CSI) reporting configuration configuring the UE with a plurality of CSI reference signal (CSI-RS) resources for channel measurement (CMRs);

determining at least one of: a number of occupied CSI processing units, a number of occupied active CSI resources, or a number of occupied active CSI-RS ports based on an actual number of CSI measurements; and performing CSI measurement based on the determination.

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