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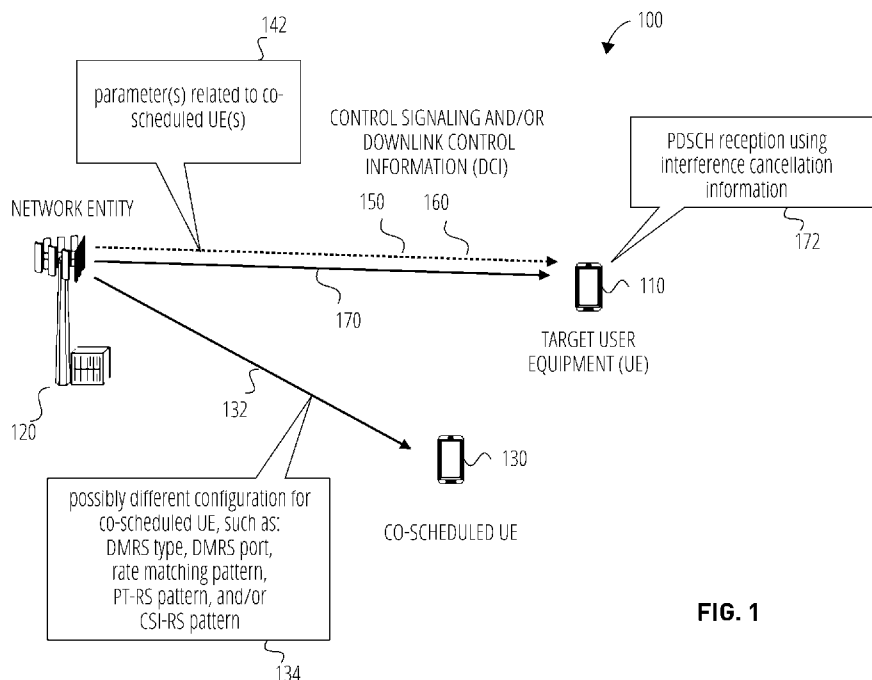


FIG. 1

(57) Abstract: This disclosure provides systems, methods and apparatuses to improve interference cancellation and co-scheduling of wireless transmissions. A network entity can transmit a physical downlink shared channel (PDSCH) to a target UE and also concurrently transmit a transmission to a co-scheduled UE. To improve interference cancellation, the network entity 120 can transmit control signaling and/or downlink control information (DCI) to the target UE to inform the target UE regarding the co-scheduled transmission. Using the techniques of this disclosure, the target UE can determine one or more characteristics of the co-scheduled transmission, such as the demodulation reference signal (DMRS) type, DMRS port, rate matching pattern, a phase tracking reference signal (PT-RS) pattern, a channel state information reference signal (CSI-RS) pattern, and/or modulation order configured for the co-scheduled UE, thereby improving the interference cancellation based PDSCH reception by the target UE.

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CONTROL SIGNALING FOR INTERFERENCE CANCELLATION AND DOWNLINK RECEPTION

TECHNICAL FIELD

[0001] This disclosure relates generally to wireless communication and some aspects relate to control signaling to improve interference cancellation for reception of downlink transmissions.

DESCRIPTION OF RELATED TECHNOLOGY

[0002] In 3rd generation partnership project new radio (3GPP NR), a network entity (such as a base station) can communicate downlink transmissions via an orthogonal frequency division multiplexing (OFDM) waveform. To improve reception of the downlink transmission by a user equipment (UE), the network entity includes a demodulation reference signal (DMRS) to be used for decoding the downlink transmission. The DMRS may include different DMRS ports and each DMRS port includes a predetermined sequence and predetermined location. The UE receives its assigned DMRS port to accurately estimate the radio channel. The UE uses the channel estimate to improve signal reception for the physical downlink shared channel (PDSCH) scheduled for the UE. Additionally, the UE may detect and receive other DMRS (or other reference signals) associated with other downlink transmissions scheduled for other UEs. Interference cancellation refers to a technique in which the UE removes interference caused by the other downlink transmissions using signal processing.

[0003] As 3GPP NR evolves to include advanced techniques, including beamforming, massive multiple-input multiple-output (MIMO), and adaptive modulation and coding, the complexity of the DMRS is increasing. For example, newer types of DMRS can support far more DMRS ports and DMRS mapping than previously contemplated. Furthermore, multi-user MIMO (MU-MIMO) enables a network entity to transmit concurrent signals to different UEs within the same resource. For example, the network entity can concurrently transmit a first downlink transmission to a first UE (referred to as a target UE) and a second downlink transmission to a second UE (referred to as a co-scheduled UE) using the same frequency resources. The target UE may be configured to monitor reference signals for the co-scheduled

UE to improve interference cancellation. The co-scheduled UE may be configured with different DMRS ports or even DMRS ports of different DMRS types. Furthermore, the network entity may configure different reference signals for the co-scheduled UE, such as a channel state information reference signal (CSI-RS), phase tracking reference signal (PT-RS), or rate matching pattern. A target UE may use blind detection of the reference signals to improve interference cancellation. However, blind detection of a large number of possible reference signal configurations can add power consumption or processing time.

BRIEF SUMMARY

[0004] The systems, methods, and apparatuses of this disclosure each have several innovative aspects, no single one of which is solely responsible for the desirable attributes disclosed herein.

[0005] One innovative aspect of the subject matter described in this disclosure can be implemented as a method of wireless communication performed by a target user equipment (UE). The method includes receiving control signaling from a network entity. The control signaling configures at least one parameter associated with co-scheduling of downlink transmissions. The method includes receiving downlink control information (DCI) scheduling at least one physical downlink shared channel (PDSCH) for the target UE. The DCI includes a DCI field indicating information for at least one co-scheduled UE based on the at least one parameter. The method includes receiving the at least one PDSCH based on the DCI and the information for the at least one co-scheduled UE.

[0006] Another innovative aspect of the subject matter described in this disclosure can be implemented as a method of wireless communication performed by a network entity. The method includes transmitting control signaling to a target UE, the control signaling configuring at least one parameter associated with co-scheduling of downlink transmissions. The method includes transmitting DCI scheduling at least one PDSCH for the target UE. The DCI including a DCI field indicating information for at least one co-scheduled UE based on the at least one parameter. The method includes transmitting the at least one PDSCH to the target UE in accordance with the DCI and the information for the at least one co-scheduled UE.

[0007] Another innovative aspect of the subject matter described in this disclosure can be implemented as an apparatus. The apparatus includes a communication unit and a processing

system. The processing system is configured to control the communication unit to implement any one of the above-mentioned methods.

[0008] Details of one or more implementations of the subject matter described in this disclosure are set forth in the accompanying drawings and the description below. Other features, aspects, and advantages will become apparent from the description, the drawings, and the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] Like reference numbers and designations in the various drawings indicate like elements. Note that the relative dimensions of the figures may not be drawn to scale. To easily identify the discussion of any particular element or act, the most significant digit or digits in a reference number refer to the figure number in which that element is first introduced.

[0010] FIG. 1 shows an example wireless communication system.

[0011] FIG. 2A shows an example mapping for a demodulation reference signal (DMRS) type 1.

[0012] FIG. 2B shows an example mapping for a DMRS type 2.

[0013] FIG. 2C shows an example mapping for an enhanced DMRS type 1 (eType1).

[0014] FIG. 2D shows an example mapping for an enhanced DMRS type 2 (eType2).

[0015] FIG. 3 shows an example communication flow diagram according to some implementations of this disclosure.

[0016] FIG. 4 shows example operations of a user equipment (UE) according to some implementations of this disclosure.

[0017] FIG. 5 shows example operations of a network entity according to some implementations of this disclosure.

[0018] FIG. 6 shows an example in which a target UE determines the DMRS type of a co-scheduled UE according to some implementations of this disclosure.

[0019] FIG. 7 shows an example in which a target UE determines the rate matching pattern of the co-scheduled UE according to some implementations of this disclosure.

[0020] FIG. 8 shows an example in which a target UE determines the phase tracking reference signal (PT-RS) of the co-scheduled UE according to some implementations of this disclosure.

[0021] FIG. 9A shows a processing delay for reception of a physical downlink shared channel (PDSCH).

[0022] FIG. 9B shows a processing delay for reception of a PDSCH with additional delay for interference cancellation according to some implementations of this disclosure.

[0023] FIG. 10 shows example signaling from a UE and from a network entity to improve interference cancellation according to some implementations of this disclosure.

[0024] FIG. 11 shows example downlink control information (DCI) signaling to indicate interference cancellation information regarding a co-scheduled UE according to some implementations of this disclosure.

[0025] FIG. 12 shows example operations of a UE according to some implementations of this disclosure.

[0026] FIG. 13 shows example operations of a network entity according to some implementations of this disclosure.

[0027] FIG. 14 is a block diagram illustrating example configurations of a network entity and a user equipment.

DETAILED DESCRIPTION

[0028] The following description is directed to certain implementations for the purpose of describing innovative aspects of this disclosure. However, a person having ordinary skill in the art will readily recognize that the teachings herein can be applied in a multitude of different ways. Some of the examples in this disclosure are based on wireless communication according to the 3rd Generation Partnership Project (3GPP) wireless standards, such as the 4th generation (4G) Long Term Evolution (LTE) and 5th generation (5G) New Radio (NR) standards. However, the described implementations can be implemented in any device, system, or network that is capable of transmitting and receiving radio frequency signals according to any of the wireless communication standards, including any of the Institute of Electrical and Electronics Engineers (IEEE) 802.11, 802.15, or 802.16 wireless standards, or other known signals that are used to communicate within a wireless, cellular, or internet of things (IOT) network, such as a system utilizing 3G, 4G, 5G, WiFi or future radio technology.

[0029] This disclosure provides systems, methods and apparatuses to improve interference cancellation and co-scheduling of wireless transmissions. Co-scheduling refers to a technique in which a transmitting device can concurrently transmit different transmissions to multiple receiving devices using the same frequency range. Some examples of this disclosure are based on downlink transmissions from a network entity (such as a base station) to a first user equipment (UE, referred to as a target UE) and a second UE (referred to as a co-scheduled UE). Interference cancellation refers to a technique in which the target UE removes interference caused by downlink transmissions to the co-scheduled UE using signal processing. To improve interference cancellation, it is desirable for a target UE to know the information of reference signals being transmitted to the co-scheduled UE. Examples of reference signals include a demodulation reference signal (DMRS). In addition to the DMRS, the target UE may benefit from knowing other characteristics of downlink transmissions to the co-scheduled UE, such as a rate matching pattern, a phase tracking reference signal (PT-RS) pattern, and/or a channel state information reference signal (CSI-RS) pattern. The rate matching, PT-RS, and CSI-RS occupy various resource elements (REs) of an OFDM waveform, depending on their respective configurations. By knowing the REs that contain these other reference signals, the target UE can properly cancel the interference caused by those signals. In some implementations, the DMRS type and/or DMRS port of the co-scheduled UE may be different from the DMRS type or DMRS port of the target UE.

[0030] In accordance with aspects of this disclosure, the network entity may provide information to the target UE regarding one or more co-scheduled UE(s). The information may be collectively referred to as “interference cancellation information,” “co-scheduling information,” “information of a co-scheduled UE,” or other similar terms. The information may be included in control signaling, such as a radio resource control (RRC) signaling, medium access control (MAC) control element (MAC CE), or downlink control information (DCI). In some aspects, the network entity provides control signaling that either explicitly or implicitly indicates the modulation order, DMRS type, DMRS port, rate matching pattern, PT-RS pattern, and/or CSI-RS pattern of the co-scheduled UE.

[0031] In some aspects, the target UE performs blind detection of downlink signals to co-scheduled UEs for interference cancellation. According to various implementations of this disclosure, the network entity and the target UE can implement predefined rules to limit differences in the DMRS, rate matching, PT-RS, or CSI-RS configurations of the target UE

and the co-scheduled UE(s). The predefined rules enable the UE to reduce the time and power that would otherwise be needed for the target UE to perform blind detection of the transmissions to the co-scheduled UE(s).

[0032] In some aspects, the network entity transmits control signaling (such as RRC, MAC CE, or DCI) to inform the target UE regarding possible configurations of downlink transmissions to co-scheduled UEs. Additionally, the network entity can inform the target UE that the DCI includes a field having co-scheduled UE information. When present, the DCI field for the co-scheduled UE information can indicate whether there are co-scheduled UE(s) or not. In some implementations, the DCI field for co-scheduled UE information can indicate the DMRS sequence and modulation order for the co-scheduled UE(s). Some aspects of this disclosure can reduce overhead associated with the DCI field. For example, the set of possible modulation orders may be limited or may be signaled in RRC signaling ahead of time. Thus, the number of bits needed to indicate the existence of co-scheduled UEs and their respective modulation orders can be less than would otherwise be needed to support a larger set of potential modulation orders.

[0033] Some aspects of this disclosure are related to processing delay for PDSCH reception with interference cancellation. Typically, the UE responds to the PDSCH by transmitting hybrid automatic repeat request (HARQ) via a physical uplink control channel (PUCCH) that is expected to occur at a particular time following the PDSCH. Interference cancellation (including blind detection, when needed) may increase the amount of time needed for the target UE to process the PDSCH. According to aspects of this disclosure, the target UE can indicate processing capabilities or expected additional processing delay. The expected additional processing delay may be associated with the number of DMRS types, DMRS ports, or other information of co-scheduled UE(s) that the target UE will process for interference cancellation. The network entity can adjust the timing for the HARQ feedback based on the expected additional processing delay.

[0034] Particular implementations of the subject matter described in this disclosure can be implemented to realize one or more of the following potential advantages. A target UE can receive reference signals for a co-scheduled UE to tune interference cancellation signal processing. The target UE can improve channel estimation of the wireless channel by removing components that are related to downlink transmissions to a co-scheduled UE, thereby improving reception of the PDSCH scheduled for the target UE. The target UE can

be informed regarding the reference signals to the co-scheduled UE to improve blind detection speed and reduce power consumption/delay associated with blind detection. In some aspects, the pre-defined rules or assumptions regarding limited options for reference signals to a co-scheduled UE can result in faster signal processing and/or improve interference cancellation features in a wireless communication system.

[0035] FIG. 1 shows an example wireless communication system 100. The wireless communication system 100 includes a network entity 120 and two UEs (a target UE 110 and a co-scheduled UE 130). Although illustrated as a smartphones in FIG. 1, the target UE 110 may be implemented as any suitable computing or electronic device, such as a mobile communication device, a modem, cellular phone, gaming device, navigation device, media device, laptop computer, desktop computer, tablet computer, smart appliance, vehicle-based communication system, an Internet-of-things (IoT) device (e.g., sensor node, controller/actuator node, combination thereof), and the like. The network entity 120 supports wireless communication with one or more UEs via radio frequency (RF) signaling using one or more applicable radio access technologies (RATs) as specified by one or more communications protocols or standards. The network entity 120 may employ any of a variety of RATs, such as operating as a NodeB (or base transceiver station (BTS)) for a Universal Mobile Telecommunications System (UMTS) RAT (also known as “3G”), operating as an enhanced NodeB (“eNB”) for a Third Generation Partnership Project (3GPP) Long Term Evolution (LTE) RAT, operating as a 5G node B (“gNB”) for a 3GPP Fifth Generation (5G) New Radio (NR) RAT, and the like. Network entity 120 (e.g., base station, an Evolved Universal Terrestrial Radio Access Network Node B (E-UTRAN Node B), evolved Node B, eNodeB, eNB, Next Generation Node B, gNode B, gNB, ng-eNB, access point, radio head or the like) may be implemented in a macrocell, microcell, small cell, picocell, or the like, or any combination thereof. In some aspects, the functionality, and thus the hardware components, of the network entity 120 may be distributed across multiple network nodes or devices and may be distributed in a manner to perform the functions described herein. As one example, the functionality of network entity 120 may be distributed across a radio unit (RU), distributed unit (DU), or central unit (CU).

[0036] The network entity 120 and the target UE 110 may communicate using wireless links, which may be implemented as any suitable type of wireless link. The wireless links may include one or more wireless links (e.g., radio links) or bearers implemented using any

suitable communication protocol or standard, or combination of communication protocols or standards, such as 3GPP LTE, 5G NR, and so forth. Multiple wireless links may be aggregated in a carrier aggregation to provide a higher data rate for the target UE 110. The network entity 120 may be part of a radio access network (RAN), for example, an Evolved Universal Terrestrial Radio Access Network, E-UTRAN, 5G NR RAN, or NR RAN. The network entity 120 may be connected to a core network (not shown) that provides access to services or other networks. The network entity 120 and target UE 110 may be configured to use multiple-user multiple-input multiple-output (MU-MIMO) communication in which the network entity 120 can transmit multiple downlink transmissions using beam forming and orthogonal frequency division multiplexing (OFDM).

[0037] Communications between network entity 120 and a UE utilize an uplink (UL) transmission path for RF transmissions (referred to as uplink transmissions) from the UE to the network entity 120, and a downlink (DL) transmission path for RF transmissions (referred to as downlink transmissions) from the network entity 120 to the UE. An UL transmission path may include a Physical Uplink Shared Channel (PUSCH), a Physical Uplink Control Channel (PUCCH), and a Physical Random Access Channel (PRACH). The PUSCH is used for the transmission of user data, such as voice data, video data, or text message data from the target UE 110 to network entity 120. Additionally, the PUSCH may be used to transmit control information (e.g., uplink control information (UCI)). The PUSCH may be shared by multiple UEs. The PUCCH is used for transmitting control information (e.g., UCI) from the UE to the network, such as channel quality feedback, scheduling requests, and acknowledgments. The PRACH is used for random access in the uplink direction, enabling the UE to access the system without a prior reservation. The DL transmission path may include one or more of a Physical Downlink Shared Channel (PDSCH), a Physical Downlink Control Channel (PDCCH), a Physical Broadcast Channel (PBCH), or a paging channel. The PDSCH is used for transmission of user data from the network entity to the UE. The PDSCH may be shared by multiple UEs. As with the PUSCH, the data may be any type of information, such as voice data, video data, or text message data. The paging channel is used to notify the UE that there is incoming traffic for it from the network entity 120.

[0038] An OFDM waveform can be used for both uplink and downlink data transmission. A demodulation reference signal (DMRS) associated with physical uplink shared channel (PUSCH) and DMRS associated with physical downlink shared channel (PDSCH) are used

for PUSCH and PDSCH decoding, respectively. The DMRS can be transmitted in front-loaded symbol(s) (such as the third and fourth OFDM symbol in a slot), and some additional symbols in a transmission occasion of PUSCH/PDSCH. In addition to the DMRS, the network entity can enable a phase tracking reference signal (PT-RS) for time-domain phase offset compensation for the OFDM symbols that do not include the DMRS. One PT-RS port should be associated with one DMRS port and the same precoder should be applied for the PT-RS port and DMRS port. The PT-RS is transmitted in the same resource element with the same subcarrier index one resource element of the associated DMRS port, where the associated resource element index is configured by RRC parameter (e.g., *resourceElementOffset* in *PTRS-UplinkConfig* and *PTRS-DownlinkConfig*).

[0039] A detailed description regarding DMRS types and DMRS ports is provided with reference to FIG. 2A, FIG. 2B, FIG. 2C, and FIG. 2D, later in this disclosure. Examples of DMRS types include Type 1 (referred to as Type1), Type 2 (referred to as Type2), enhanced Type 1 (referred to as eType1), and enhanced Type 2 (referred to as eType2). Type1 can support up to 8 ports, Type2 can support up to 12 ports, eType1 can support up to 16 ports, eType2 can support up to 24 ports. The network entity 120 can inform the target UE 110 regarding the DMRS type and DMRS port for the target UE 110 to receive its demodulation reference signal. The network entity can indicate the DMRS ports for the PDSCH for the target UE 110 by the scheduling DCI. The network entity 120 may transmit one or more than one scheduled PDSCHs from one transmission and reception point (TRP) or more than one TRPs. The network entity 120 may schedule PDSCH by one DCI (referred to as single-DCI), and schedule more than one PDSCHs by more than one DCIs (referred to as multi-DCI).

[0040] In addition to the DMRS type and DMRS port, the network entity 120 can configure other reference signals, such as the PT-RS, the CSI-RS, or a rate matching pattern. For example, the network entity 120 can configure the rate matching pattern for the scheduled PDSCH to the target UE 110. The network entity may configure one or more than one rate matching pattern groups by RRC signaling (e.g., *rateMatchPatternGroup1* and *rateMatchPatternGroup2*). The network entity indicates whether the configured one or more than one rate matching pattern groups should be applied for the scheduled PDSCH or not by the scheduling DCI. Each rate matching pattern group configures the resource elements (REs) that are not available for the PDSCH. The other reference signals (such as the PT-RS, the CSI-RS, or the rate matching pattern) occupy particular REs in the OFDM symbol(s) and the

locations of the REs for various reference signals are associated with the configuration of the reference signals.

[0041] Shown in FIG. 1, the network entity 120 can transmit a PDSCH 170 to the target UE 110 and also concurrently transmit a co-scheduled transmission 132 to the co-scheduled UE 130. While the network entity 120 may configure reference signals for the target UE 110, the network entity 120 may configure different reference signals for the co-scheduled UE 130. For example, the network entity 120 may configure, for the co-scheduled UE 130, a different configuration (shown at block 134) for the DMRS type, the DMRS port, rate matching pattern, PT-RS pattern, and/or CSI-RS pattern.

[0042] The target UE 110 receives the PDSCH 170 via an OFDM waveform consisting of multiple symbols. Each symbol spans multiple frequencies (associated with particular subcarriers). For a RE at subcarrier k and symbol l , the UE may obtain the received signal as follows:

$$Y_{k,l} = H_{k,l}W_{k,l}X_{k,l} + \sum_{j=1}^{N_c} H_{k,l}W_{k,l}^{(j)}X_{k,l}^{(j)} + N_{k,l}$$

Where $H_{k,l}$ indicates the frequency domain channel; $W_{k,l}$ indicates the digital precoder for the target UE; $X_{k,l}$ indicates the modulated symbol(s) for the target UE; $W_{k,l}^{(j)}$ indicates the digital precoder for the co-scheduled UE j ; $X_{k,l}^{(j)}$ indicates the modulated symbol(s) for the co-scheduled UE j ; N_c is the number of co-scheduled UEs; $N_{k,l}$ denotes the inter-cell interference plus noise.

[0043] To facilitate the interference cancellation for MU-MIMO operation, the network entity 120 can provide some basic information to the target UE 110 to inform the target UE 110 whether there are co-scheduled UE(s) or not and the DMRS sequence and modulation order for the co-scheduled UE(s). Table 1 illustrates one example for the DCI indication for co-scheduled UEs. Table 1 has 8 entries and each entry can be represented by a different 3 bit value in the DCI. A 3 bit value associated with an entry in the table can indicate whether there is a co-scheduled transmission that at least partially overlaps physical resource block (PRBs) allocated to the target UE.

Table 1: An example for the information for the co-scheduled UEs

DCI field for co-scheduled UE information	Content
0	No co-scheduled UE(s) which has same DMRS sequence as target UE exists
1	In all the PRBs allocated to the target UE, all the co-scheduled UE(s), which has the same DMRS sequence as the target UE, have QPSK scheduled
2	In all the PRBs allocated to the target UE, all the co-scheduled UE(s), which has the same DMRS sequence as the target UE, have 16QAM scheduled
3	In all the PRBs allocated to the target UE, all the co-scheduled UE(s), which has the same DMRS sequence as the target UE, have 64QAM scheduled
4	In all the PRBs allocated to the target UE, all the co-scheduled UE(s), which has the same DMRS sequence as the target UE, have 256QAM scheduled
5	In all the PRBs allocated to the target UE, all the co-scheduled UE(s), which has the same DMRS sequence as the target UE, have 1024QAM scheduled
6	Not covered by cases corresponding to index 0~5. In each individual PRB allocated to the target UE, the following condition is satisfied:

	Only single modulation order is allocated for the co-scheduled UE(s) which has the same DMRS sequence as the target UE, if the co-scheduled UE(s) exist
7	Others or reserved

[0044] For interference cancellation based downlink reception, the target UE 110 may need to perform blind detection of the DMRS for the co-scheduled UE 130. However, as mentioned previously, the DMRS ports could be different or could be DMRS ports from different DMRS types. As the DMRS types are expanded and the quantity of possible DMRS ports increases, blind detection can become exponentially more complex. If the target UE 110 needs to perform blind detection for the DMRS type, the complexity for the target UE 110 could be so high that it could cause large UE power consumption. Similarly, if the target UE 110 needs to perform blind detection for the DMRS port based on determined DMRS type, the additional complexity for the target UE could also be raised so that it could cause additional UE power consumption.

[0045] Thus, in some aspects of this disclosure, the options for DMRS type and DMRS port for the co-scheduled UE 130 are limited so that the target UE 110 can more easily perform the blind detection for the limited options. In some aspects, the network entity 120 can inform the target UE 110 regarding the DMRS type or the DMRS port for the co-scheduled UE 130. The network entity 120 can provide some information (block 142) to the target UE 110 to inform the target UE 110 about the reference signals to the co-scheduled UE 130. For example, the network entity 120 can transmit control signaling 150 and/or DCI 160 to the target UE 110 to indicate whether there are co-scheduled UE(s) or not and the DMRS sequence and modulation order for the co-scheduled UE(s). For some DMRS ports, the network entity 120 should not schedule the other DMRS ports for another UE. In some implementations, the target UE 110 may interpret the control signaling 150 and/or DCI 160 depending on which DMRS port is assigned to the target UE 110.

[0046] This disclosure proposes techniques in which control signaling 150 and/or DCI 160 can improve interference cancellation based PDSCH reception. For example, the disclosure addresses how control signaling, pre-defined rules, or UE assumption regarding information for the co-scheduled UEs can improve reception of the PDSCH 170. The control signaling

150 and/or DCI 160 can provide information that aids the target UE 110 in knowing the possible configurations of reference signals to the co-scheduled UE 130 or explicit configurations of the reference signal, such as the DMRS type, DMRS port, rate matching group, CSI-RS pattern, PT-RS pattern, and energy per resource element (EPRE) ratio between the PT-RS and the DMRS. For example, control signaling can indicate at least one parameter that limits the options for reference signals that may be transmitted to a co-scheduled UE 130. The control signaling can also indicate whether a DCI will include a DCI field to indicate information about the co-scheduled UE 130. The DCI field may be referred to as a “DCI field for co-scheduled information,” “DCI field for co-scheduled UE information,” “DCI field regarding a co-scheduled UE,” or other similar terms, or may be referred to in this disclosure as the “DCI field” for brevity.

[0047] Absent the techniques of this disclosure, the rate matching pattern for the co-scheduled UE 130 may be unknown to the target UE 110. Then the target UE 110 does not know which REs are actually allocated for the co-scheduled UE 130 so that the target UE 110 cannot determine whether to perform interference cancellation for each RE. Furthermore, absent the techniques of this disclosure, the PT-RS pattern and EPRE for the co-scheduled UE 130 is unknown to the target UE 110. The network entity 120 transmits the PT-RS based on quadrature phase shift key (QPSK) modulation, but the network entity 120 may transmit the data for the co-scheduled UE 130 by another modulation order (e.g., quadrature amplitude modulation with 16 constellation points (referred to as 16QAM)). Then the target UE 110 may use an incorrect modulation order assumption to cancel the interference for the REs with PT-RS for the co-scheduled UE 130, which could cause performance degradation. Moreover, the CSI-RS pattern for the co-scheduled UEs is unknown to the target UE. The network entity transmits the CSI-RS based on QPSK, but it may transmit the data for the co-scheduled UEs by another modulation order (e.g., 16QAM). Then the target UE may use an incorrect modulation order assumption to cancel the interference for the REs with CSI-RS for co-scheduled UEs, which could cause performance degradation. Thus, some aspects of this disclosure enable the network entity 120 to inform the target UE 110 regarding the rate matching pattern, the PT-RS pattern, modulation order, or other information about the downlink signals to the co-scheduled UE 130.

[0048] Some aspects of this disclosure are related to overhead reduction for the DCI field for co-scheduled information. Usually the MU-MIMO operation is used for lower modulation

order. Thus, the 3 bit co-scheduled UE information in the DCI as shown in Table 1 may be modified to use fewer bits (such as 2 bits or 1 bit) to convey the co-scheduled UE information. Doing so can reduce the overhead for the co-scheduled UE information indicator in DCI.

[0049] In some implementations, a network entity 120 may have multiple transmission and reception points (TRPs) and may use multiple TRP (mTRP) operation to transmit downlink transmissions. In mTRP operation, the network entity 120 can use multiple TRPs (not shown) to communicate with the target UE 110 and/or the co-scheduled UE 130. For single-DCI based mTRP operation, a single DCI includes scheduling information for multiple TRPs and is transmitted from a first TRP (or alternatively, the same DCI is transmitted from the multiple TRPs). The single DCI includes a complete set of scheduling information regarding the PDSCHs transmitted from multiple TRPs (mTRP). In multi-DCI mTRP operation, each TRP may transmit a different DCI to schedule respective PDSCHs for that TRP. For mTRP operation, if the network entity 120 schedules multiple PDSCHs with different co-scheduled UE information, it would increase complexity of interference cancellation by the target UE 110, as the target UE 110 may need to consider different modulation orders for different co-scheduled UEs from different TRPs. Thus, some aspects of this disclosure how to reduce the UE complexity for interference cancellation for mTRP operation.

[0050] Another aspect of interference cancellation is the timing of HARQ feedback. Typically, the timing of HARQ feedback (in a PUCCH) is based on a timing offset from the PDSCH. However, interference cancellation may require additional complexity for PDSCH processing. It is desirable for the target UE 110 and the network entity 120 to maintain the same understanding regarding timing of the HARQ feedback. In accordance with aspects of this disclosure, the target UE 110 can indicate UE capability for interference cancellation, expected additional processing delay for interference cancellation, or other indicia to account for the additional complexity for interference cancellation for PDSCH processing. The offset timing for the HARQ feedback can be adjusted based on the UE capability, the expected additional delay or the other indicia. In some implementations, the additional processing delay can depend on how much information the network entity 120 provides to the target UE 110 regarding the reference signal configuration options or explicit configurations for the co-scheduled UE 130.

[0051] FIG. 2A shows an example mapping 200a for a DMRS Type 1. In FIG. 2A, each column is an OFDM symbol spanning multiple subcarriers, and each row is a different

subcarrier. Each box (a subcarrier of an OFDM symbol) represents a different RE. A slot is made up of multiple OFDM symbols as shown in FIG. 2B. In Type1 DMRS, the DMRS occupies symbols 2 and 3 of the slot. Type 1 DMRS supports up to 2 front-loaded DMRS symbols and 2 Code Division Multiplexing (CDM) groups. The CDM groups (CDM group 0 291 and CDM group 1 292) are shown with different grey shadings in FIG. 2A. A length 2 frequency-domain orthogonal cover code (FD-OCC) is applied to every two consecutive subcarriers within a CDM group, and a length 2 time-domain orthogonal cover code (TD-OCC) is applied to the two DMRS symbols.

[0052] Different DMRS ports can occupy different CDM groups, different FD-OCC, or different TD-OCC. A resource element in subcarrier k , symbol l for DMRS port p can be generated as follows:

$$a_{k,l}^p = \beta w_f(k') w_t(l') r(2n + k')$$

$$k' = 0,1$$

$$l = \bar{l} + l'$$

$$n = 0,1,\dots$$

[0053] Where, for DMRS type 1, $k = 4n + 2k' + \Delta$ and for DMRS type 2, $k = 6n + k' + \Delta$; $\bar{l}$ is the first symbols index allocated for DMRS; Δ is the subcarrier offset for current CDM group for port p , $\Delta = 0,1$ for CDM group 1 and 2 respectively for DMRS Type1 and $\Delta = 0,2,4$ for CDM group 1 and 2 respectively for DMRS Type1; $r(\cdot)$ is the base sequence for DMRS, which is generated based on a QPSK sequence as defined in 3GPP technical specification 38.211; w_f is the FD-OCC, and it can be either $[1, 1]$ or $[1, -1]$, which depends on the DMRS port index; w_t is the TD-OCC, and it can be either $[1, 1]$ or $[1, -1]$, which depends on the DMRS port index; $l' = 0,1$ for two front-loaded symbols based DMRS and $l' = 0$ for single front-loaded symbol based DMRS, i.e. TD-OCC is disabled.

[0054] Each DMRS port is associated with a particular combination of the CDM group (2 CDM groups, each having an RE group size of 1), TD-OCC (2 options), and FD-OCC (2 options). The Type1 DMRS can support up to 8 ports (2 x 2 x 2). To simplify the configuration of a DMRS port for a UE, the DMRS ports can be numbered (e.g., {1000, 1001, 1002, ..., 1007}) to refer to a particular DMRS port.

[0055] FIG. 2B shows an example mapping 200b for a DMRS type 2. Type2 DMRS supports up to 2 front-loaded DMRS symbols and 3 CDM groups. The CDM groups (CDM group 0 291, CDM group 1 292, CDM group 2 293) are shown with different grey shadings in FIG. 2B. Type2 DMRS uses a length 2 FD-OCC applied to every two consecutive subcarriers within a CDM group, and a length 2 TD-OCC applied to the two DMRS symbols. As a result, Type 2 DMRS supports up to 12 ports ($3 \times 2 \times 2$).

[0056] FIG. 2C shows an example mapping 200c for an enhanced DMRS type 1 (eType1). In 3GPP NR Release 18, to support higher order MU-MIMO, more DMRS ports are introduced with higher order FD-OCC. Such enhanced DMRS structure can create more orthogonal DMRS ports so as to increase the MU-MIMO order for both PDSCH and PUSCH. In one example, 4 FD-OCC sequences $\{[1, 1, 1, 1], [1, -1, 1, -1], [-1, -1, 1, 1], [1, -1, -1, 1]\}$ can be defined to create 4 orthogonal ports. FIG. 2C illustrates an example for FD-OCC-4 based enhanced DMRS type 1 (referred to as eType1). In the example shown in FIG. 2C, the eType1 DMRS uses two CDM groups (2 options) with a length 2 TD-OCC (2 options) and a length 4 FD-OCC (4 options) applied to each CDM group. As a result, eType1 DMRS supports up to 16 ports ($2 \times 2 \times 4$).

[0057] FIG. 2D shows an example mapping 200d for an enhanced DMRS type 2 (eType2). In the example eType2 DMRS, there are three CDM groups (3 options) with a length 2 TD-OCC (2 options) and a length 4 FD-OCC (4 options) applied to each CDM group. As a result, the example eType2 DMRS supports up to 24 ports ($3 \times 2 \times 4$).

[0058] Although FIG. 2A through FIG. 2D describes example mappings and port options for different DMRS types, other DMRS types having different quantities of ports are possible. Future enhancements to wireless communication technology may result in ever increasing numbers of possible DMRS types and quantities of DMRS ports supported for each DMRS type.

[0059] For MU-MIMO, a network entity can schedule UEs with Type1 and eType1 DMRS or UEs with Type2 and eType2 DMRS or UEs with the same type of DMRS. Therefore, in some implementations, it is possible for the DMRS type for a target UE to be different from the DMRS type configured for a co-scheduled UE. As described with reference to FIG. 6, the DMRS type of a co-scheduled UE may be based on, or limited by, the DMRS type of the target UE using a pre-defined rule. Doing so can reduce the options that the target UE would consider during blind detection. Alternatively, or additionally, a network entity can provide

information to the target UE to implicitly or explicitly indicate the DMRS type used for the co-scheduled UE. Similarly, the DMRS port for the co-scheduled UE can be based on, or limited by, the DMRS port assigned to the target UE. Alternatively, or additionally, the network entity can provide information to the target UE to implicitly or explicitly indicate the DMRS port assigned to the co-scheduled UE.

[0060] FIG. 3 shows an example communication flow diagram 300 according to some implementations of this disclosure. The communication flow diagram 300 shows the communication between the network entity 120 and the target UE 110. In some implementations, the target UE 110 reports (shown as capability message 340) one or more capabilities for supported configurations for the interference cancellation based PDSCH reception. For example, the target UE 110 can indicate one or more of the following elements:

- whether the target UE 110 supports the interference cancellation based PDSCH reception for single-TRP, single-DCI based multi-TRP, and/or multi-DCI based multi-TRP operations;
- the supported DMRS type(s) for the target UE and co-scheduled UE(s);
- whether the target UE 110 supports different DMRS types for the target UE and co-scheduled UE(s);
- supported modulation order for the co-scheduled UE(s);
- supported modulation order for the target UE;
- whether the UE supports CSI-RS transmission for the co-scheduled UE(s);
- whether the UE supports different CSI-RS pattern for the target UE and co-scheduled UE(s);
- whether the UE supports PT-RS transmission for the co-scheduled UE(s);
- whether the UE supports different PT-RS pattern for the target UE and co-scheduled UE(s);
- whether the UE supports different EPRE ratios between the PT-RS and DMRS for the target UE and co-scheduled UE(s); or
- the additional PDSCH processing delay for the interference cancellation.

[0061] The network entity 120 may use this information to determine whether or not to co-schedule a downlink transmission to a co-scheduled UE. Furthermore, the network entity 120 may set parameters for the target UE 110 or the co-scheduled UE based on the UE capabilities

that the network entity 120 receives from both of the UEs. In the example of FIG. 3, the network entity 120 determines that interference cancellation and co-scheduling are supported.

[0062] The network entity 120 transmits control signaling 350 configuring at least one of the parameters: presence of the DCI field for co-scheduled information, candidate modulation order for the co-scheduled UE(s), and/or additional information of the co-scheduled UEs. For example, the additional information may indicate the DMRS type, DMRS port(s) or number of DMRS ports, rate matching pattern, PT-RS pattern, EPRE ratio between PT-RS and DMRS, or CSI-RS pattern of the co-scheduled UE(s). The network entity may transmit the control signaling 350 by an RRC message (e.g., *RRCReconfiguration*). Although described as RRC signaling, the control signaling 350 may be an RRC reconfiguration message from the network entity 120 to the target UE 110, or a system information block (SIB), where the SIB can be an existing SIB (e.g., SIB1) or a new SIB (e.g., SIB *J*, where *J* is an integer above 21) transmitted by network entity 120.

[0063] The network entity 120 schedules one or more PDSCHs by one or more DCI(s) 360. The one or more DCI(s) 360 can indicate the information for the co-scheduled UEs. For example, the one or more DCI(s) 360 can include a DCI field populated with information regarding a co-scheduled UE. In some implementations, the one or more DCI(s) 360 can also indicate the offset between PDSCH and HARQ (e.g., *PDSCH-to-HARQ feedback timing indicator*) based on the minimum PDSCH processing delay and additional processing delay for interference cancellation.

[0064] The target UE 110 receives the scheduled one or more PDSCH(s) 370 with interference cancellation based on the configured information for co-scheduling (as indicated in the control signaling 350 and the one or more DCI(s) 360) and/or pre-defined transmission behavior of the co-scheduled UE. The target UE 110 may transmit the HARQ feedback 380 (such as a HARQ acknowledgement, HARQ-ACK) indicating the results of decoding the scheduled PDSCH.

[0065] FIG. 4 shows example operations 400 of a UE according to some implementations of this disclosure. For example, the example operations 400 can be implemented by a target UE (such as the target UE 110 described herein).

[0066] At block 450, the UE receives control signaling from a network entity, the configuring at least one parameter associated with co-scheduling of downlink transmissions at block 450. The control signaling may contain the information described with reference to

the control signaling 150, 350, or 1050, described with reference to FIG. 1, FIG. 3, and FIG. 10, respectively.

[0067] At block 460, the UE receives DCI scheduling at least one PDSCH for the target UE. The DCI includes including a DCI field indicating information for at least one co-scheduled UE based on the at least one parameter. The DCI may contain information described with reference to the DCI 160, 360, or 1160 described with reference to FIG. 1, FIG. 3, and FIG. 11, respectively.

[0068] At block 470, the UE receives the at least one PDSCH based on the DCI and the information for the at least one co-scheduled UE. The operations in block 470 may include operations described with reference to receiving the one or more PDSCH(s) 370 as described with reference to FIG. 3. Alternatively, or additionally, the receiving the PDSCH can include interference cancellation based on the DMRS type, DMRS port, PT-RS, CSI-RS, or rate matching patterns, as described with reference to FIG. 6, FIG. 7, and FIG. 8, respectively.

[0069] After receiving the PDSCH, the UE may communicate a HARQ feedback, such as the HARQ feedback 380, or HARQ feedback via a PUCCH 980, as described with reference to FIG. 3 and FIG. 9B, respectively.

[0070] **FIG. 5** shows example operations 500 of a network entity according to some implementations of this disclosure. For example, the example operations 500 can be implemented by network entity (such as the network entity 120 described herein).

[0071] At block 550, the network entity transmits control signaling to a target user equipment (UE), the control signaling configuring at least one parameter associated with co-scheduling of downlink transmissions. The control signaling may contain the information described with reference to the control signaling 150, 350, or 1050, described with reference to FIG. 1, FIG. 3, and FIG. 10, respectively.

[0072] At block 560, the network entity transmits DCI scheduling at least one PDSCH for the target UE, the DCI including a DCI field indicating information for at least one co-scheduled UE based on the at least one parameter at block 560. Additionally, the network entity co-schedules a downlink transmission via another PDSCH to a co-scheduled UE. The DCI may contain information described with reference to the DCI 160, 360, or 1160 described with reference to FIG. 1, FIG. 3, and FIG. 11, respectively.

[0073] At block 570, the network entity transmits the at least one PDSCH to the target UE in accordance with the DCI and the information for the at least one co-scheduled UE.

Concurrently, the network entity transmits the scheduled downlink transmission to the co-scheduled UE.

[0074] FIG. 6 shows an example in which a target UE determines the DMRS type of a co-scheduled UE according to some implementations of this disclosure. In FIG. 6, the top OFDM map 691 shows the DMRS type and DMRS ports that may be allocated to the target UE using eType1 DMRS. In the example, the target UE is assigned to one of the DMRS ports (referring to a CDM group, FD-OCC option, and TD-OCC option) in the second CDM group (CDM group 1 292). The target UE may monitor the assigned DMRS port to estimate channel quality for interference cancellation. In addition to the DMRS port that is assigned to the target UE, the target UE may monitor a DMRS port (from the same or different DMRS type) that is assigned to a co-scheduled UE. In the bottom OFDM map 692, the target UE may receive a DMRS port of a Type1 DMRS for a co-scheduled UE.

[0075] This disclosure includes a variety of options for determining the DMRS type and DMRS port of the co-scheduled UE, such as a pre-defined rule, a technique for flexible configuration and indication of the DMRS type, and blind detection. The example of FIG. 6 shows an implementation in which the DMRS type of the co-scheduled UE (e.g., Type1 DMRS) is limited based on a pre-defined rule (e.g., based on the DMRS type of the target UE), but FIG. 6 can also illustrate operations in which the DMRS type is configured or in which the UE performs blind detection.

[0076] The pre-defined rule may enable the network entity and the target UE to determine that the DMRS type (e.g., Type1/Type2/eType1/eType2) for the co-scheduled UEs is based on the DMRS type for the target UE. For example, the network entity and UE may determine the DMRS type for the co-scheduled UEs should be the same as the DMRS type for the target UE. Alternatively, the network entity and UE may determine the DMRS type for the co-scheduled UEs based on a pre-defined DMRS type (e.g., Type1 or Type2). For example, if the target UE is configured with Type1 or eType1 DMRS, the network entity may configure Type1 DMRS for the co-scheduled UE. According to the pre-defined rule, the target UE may assume the co-scheduled UEs be Type1 DMRS if the target UE is configured with a Type1 DMRS or eType1 DMRS. Alternatively, if the target UE is configured with Type2 or eType2 DMRS, the network entity may configure Type2 DMRS for the co-scheduled UE. According to the pre-defined rule, the target UE may assume the co-scheduled UEs be Type2 DMRS if the target UE is configured with a Type2 DMRS or eType2 DMRS.

[0077] In some implementations, the network entity refrains from configuring the presence of the DCI field for co-scheduled UE information or indicates that there are no co-scheduled UEs if the target UE is configured with eType1 or eType2 DMRS. In this example, if the target UE is configured with eType1 or eType2 DMRS, the target UE should not expect the network entity to include the DCI field of co-scheduled UE information in DCI or would receive a DCI field that indicates there is no co-scheduled UE. The network entity may refrain from co-scheduling downlink transmissions when using eType1 or eType2 DMRS for the target UE.

[0078] Some aspects of this disclosure enable the network entity to configure a different DMRS type for the co-scheduled UE and the target UE. The network entity may configure the DMRS type (e.g., Type1/Type2/eType1/eType2) for the co-scheduled UEs by RRC signaling, MAC CE, or DCI. For a target UE configured with Type1 or eType1 DMRS, the network entity may transmit control signaling or DCI to indicate whether the co-scheduled UEs are based on Type1 or eType1 DMRS. In another example, for a UE configured with Type2 or eType2 DMRS, the network entity can indicate whether the co-scheduled UEs are based on Type2 or eType2 DMRS.

[0079] In another example that does not require a pre-defined rule, the target UE may perform blind detection of the DMRS type for the co-scheduled UE. The target UE may report the UE capability indicating whether it supports blind detection of the DMRS type for the co-scheduled UE. The target UE may perform blind detection on the DMRS symbols to determine what DMRS type is used for the co-scheduled UE. In blind detection, the target UE attempts to detect the DMRS sequence for each type of DMRS until the target UE determines the type of DMRS where the DMRS sequence is properly detected. In some implementations, the network entity can transmit control signaling that limits the options for DMRS types so that the target UE has fewer hypotheses to consider during blind detection. In some other implementations, the network entity and target UE may determine the options for DMRS types for the co-scheduled UE based on a predefined rule (e.g., based on the DMRS type for the target UE). For example, if the target UE is scheduled with Type1 or eType1, the options for DMRS types for the co-scheduled UE may be Type1 or eType1; if the target UE is scheduled with Type2 or eType2, the options for DMRS types for the co-scheduled UE may be Type2 or eType2. Because blind detection may add additional processing delay for PDSCH reception using interference cancellation, the target UE may indicate the additional processing

delay (as described with reference to FIG. 10) and may transmit the HARQ feedback after the additional processing delay (as described with reference to FIG. 9B).

[0080] In addition to determining the DMRS type of the co-scheduled UE, the target UE may determine the DMRS port for the co-scheduled UE. Similar to the techniques for determining the DMRS type, this disclosure provides several techniques for the target UE to determine the DMRS port of the co-scheduled UE, such as a pre-defined rule, a technique for flexible configuration and indication of the DMRS port, and blind detection.

[0081] In some aspects, the network entity and target UE determine that the DMRS ports for the co-scheduled UEs (e.g., DMRS port = {1000, 1001, ...}) for the co-scheduled UEs based on a predefined rule. For reference, DMRS ports for Type1 DMRS are numbered from {1000, ..., 1007}. The DMRS ports {1000, 1001, 1004, 1005} are from a first CDM group (CDM group 0), and the DMRS ports {1002, 1003, 1006, 1007} are from a second CDM group (CDM group 1). Similarly, the DMRS ports for Type2 DMRS are numbered from {1000, ..., 1011}. The DMRS ports {1000, 1001, 1006, 1007} are from a first CDM group (CDM group 0), the DMRS ports {1002, 1003, 1008, 1009} are from a second CDM group (CDM group 1), and the DMRS ports {1004, 1005, 1010, 1011} are from a third CDM group (CDM group 2). DMRS ports for eType1 DMRS can be numbered from {1000, ..., 1015}, and DMRS ports for eType2 DMRS can be numbered from {1000, ..., 1023}. As with the Type1 and Type2 port numbering schemes, the DMRS ports for eType1 and eType2 can correspond to particular CDM groups.

[0082] In some implementations, the network entity and target UE first determine the DMRS type (e.g., Type1/Type2/eType1/eType2) for the co-scheduled UEs and then determine DMRS ports for the co-scheduled UEs. The network entity may randomly select DMRS port(s) for the co-scheduled UE different from target UE and the target UE may perform blind detection to determine the DMRS port(s) for the co-scheduled UE. In one example, if the target UE is configured by DMRS port=1000 according to DMRS type 1, the DMRS ports for the co-scheduled UEs can be determined by randomly selecting from DMRS ports {1001, 1002, ..., 1007}. In one example, if the target UE is configured by DMRS port=1000 according to DMRS type 2, the DMRS ports for the co-scheduled UEs can be determined by randomly selecting from DMRS ports {1001, 1002, ..., 1011}. Alternatively, the network entity configures the number of total DMRS ports for the co-scheduled UEs. The target UE determines the DMRS ports for the co-scheduled UEs based on the indicated DMRS ports for

the target UE. In one example, if the target UE is configured by DMRS port 1000 according to DMRS Type1 and the network entity configures the number of total DMRS ports for the co-scheduled UEs is 2, the target UE determines the DMRS ports for the co-scheduled UEs are {1001, 1002}. In some other implementations, the number of total DMRS ports or the maximum number of total DMRS ports for the co-scheduled UEs may be predefined (e.g., 2).

[0083] In some implementations, the network entity and target UE first determine the DMRS type for the co-scheduled UEs and then determine DMRS ports for the co-scheduled UE. The network entity may randomly select DMRS ports in the same CDM group for the co-scheduled UE different from the DMRS port(s) in the same CDM group for the target UE, and the target UE may perform blind detection to determine the DMRS port(s) for the co-scheduled UE from the same CDM group as the DMRS ports for the target UE. In one example, if the target UE is configured by one DMRS port=1000 in CDM group 0 according to DMRS type 1, the DMRS ports for the co-scheduled UEs can be determined by selecting from DMRS ports {1001, 1004, 1005}. In one example, if the target UE is configured by one DMRS port=1000 in CDM group 0 according to DMRS type 2, the DMRS ports for the co-scheduled UEs can be determined by selecting from DMRS ports {1001, 1006, 1007}. Alternatively, the network entity configures the number of DMRS ports for the co-scheduled UEs. The target UE determines the DMRS ports for the co-scheduled UEs based on the indicated DMRS ports and CDM groups for the target UE. In one example, if the target UE is configured by DMRS port 1000 in CDM group 0 according to DMRS Type1 and the network entity configures the number of total DMRS ports for the co-scheduled UEs is 2, the target UE determines the DMRS ports for the co-scheduled UEs are {1001, 1004}, which are also in CDM group 0.

[0084] In some implementations, the network entity and target UE first determine the DMRS type for the co-scheduled UEs and then determine DMRS ports for the co-scheduled UE. The network entity may randomly select DMRS ports in the different CDM group(s) for the co-scheduled UE from the CDM group(s) for the target UE, and the target UE may perform blind detection to determine the DMRS ports in different CDM group(s) for the co-scheduled UE from the CDM group(s) for the target UE. In one example, if the UE is configured by one DMRS port=1000 in CDM group 0 according to DMRS type 1, the DMRS ports for the co-scheduled UEs can be determined by selecting from CDM group 1= {1002, 1003, 1006, 1007}. In one example, if the target UE is configured by one DMRS port=1000 in CDM group 0 according to DMRS type 2, the DMRS ports for the co-scheduled UEs can be determined

by selecting from CDM group 1={1002, 1003, 1008, 1009} or CDM group 2={1004, 1005, 1010, 1011}. Alternatively, the network entity configures the number of DMRS ports for the co-scheduled UEs. The target UE determines the DMRS ports for the co-scheduled UEs based on the indicated DMRS ports, CDM group(s) and total number of CDM groups for the target UE. In one example, if the target UE is configured by DMRS port 1000 according to DMRS Type1 and the network entity configures the number of total DMRS ports for the co-scheduled UEs is 2 and the number of total CDM groups is 2, the target UE determines the DMRS ports for the co-scheduled UEs as port {1002, 1003}.

[0085] In some implementations, the network entity and target UE determine that the DMRS ports for the co-scheduled UEs (e.g., DMRS port = {1000, 1001, ...}) for the co-scheduled UEs by RRC signaling, MAC CE, or DCI.

[0086] In some implementations, the network entity configures a set of candidate DMRS ports for the co-scheduled UEs and the network entity indicates the candidate DMRS port by RRC signaling, MAC CE, or DCI.

[0087] In one example, for a target UE configured with a set of candidate DM-RS ports, the network entity indicates DMRS ports for the co-scheduled UEs by random selecting DMRS ports different from the target UE based on DMRS type (e.g., Type1/Type2/eType1/eType2).

[0088] In one example, for a target UE configured with a set of candidate DM-RS ports, the network entity indicates DMRS ports for the co-scheduled UEs by random selecting DMRS ports from the same or different CDM group different from the UE based on DMRS type (e.g., Type1/Type2/eType1/eType2).

[0089] In some implementations, the target UE may perform blind detection of the DMRS port for the co-scheduled UE. The target UE may report the UE capability indicating whether it supports blind detection of the DMRS port for the co-scheduled UE. In one example, for a target UE configured with DMRS ports, the target UE can perform blind detection of DMRS ports for the co-scheduled UE with or without the determined DMRS type (e.g., Type1/Type2/eType1/eType2). As with blind detection of DMRS type, the blind detection of DMRS port may cause additional processing delay for PDSCH reception. In some implementations, the target UE may indicate the additional processing delay (as described with reference to FIG. 10) and may transmit the HARQ feedback after the additional processing delay (as described with reference to FIG. 9B).

[0090] FIG. 7 shows an example in which a target UE determines the rate matching pattern of the co-scheduled UE according to some implementations of this disclosure. This disclosure includes a variety of options for determining rate matching pattern of the co-scheduled UE, such as a pre-defined rule or a configurable rate matting pattern that is indicated by control signaling or DCI. The example of FIG. 7 shows an implementation in which the rate matching pattern 775 of the target UE occupies the same REs in the top OFDM map 774 for the target UE as the rate matching pattern 777 for the bottom OFDM map 776 for the co-scheduled UE. The target UE may determine the rate matching pattern 777 for the co-scheduled UE based on a predefined rule or based on control signaling or DCI from the network entity.

[0091] The network entity and target UE may determine that the rate matching pattern group(s) for the co-scheduled UE based on a predefined rule. In some implementations, the network entity and UE determine the rate matching pattern group(s) for the co-scheduled UEs should be the same as the rate matching pattern group(s) for the target UE, as shown in FIG. 7. In some other implementations, the network entity and target UE determine the rate matching pattern group(s) for the co-scheduled UEs based on a pre-defined value (e.g., no rate matching pattern group).

[0092] In some implementations, if the target UE is configured with at least one rate matching pattern group, the network entity may refrain from configuring the presence of the DCI field for co-scheduled UE information or may indicate that there are no co-scheduled UEs. For example, the network entity may refrain from co-scheduling a downlink transmission when the target UE is configured with a rate matching pattern.

[0093] In some implementations, the network entity configures the rate matching pattern group(s) for the co-scheduled UEs by RRC signaling, MAC CE, or DCI. For example, the network entity may explicitly configure whether the rate matching pattern group(s) for the co-scheduled UEs. In some other implementations, the network entity configures the rate matching pattern group(s) based on the rate matching pattern group(s) for the target UE. In one example, for a PDSCH with different rate matching pattern group(s) for the target UE, the network entity configures separate rate matching pattern group(s) for the co-scheduled UE.

[0094] FIG. 8 shows an example in which a target UE determines the phase tracking reference signal (PT-RS) of the co-scheduled UE according to some implementations of this disclosure. This disclosure includes a variety of options for determining the PT-RS of the co-

scheduled UE, such as a pre-defined rule, a configurable PT-RS pattern that is indicated by control signaling or DCI, or blind detection. In FIG. 8, the PT-RS 878 of the target UE is shown in the top OFDM map 874 and the PT-RS 879 of the co-scheduled UE is shown in the bottom OFDM map 876. In addition to the being aware of the PT-RS of the co-scheduled UE, the target UE may benefit from awareness of the EPRE ratio between the PT-RS and the DMRS.

[0095] In some implementations, the network entity and target UE determine that the PT-RS pattern and/or the EPRE ratio between the PT-RS and DMRS for the co-scheduled UEs based on a predefined rule. In some implementations, the network entity and target UE determine the PT-RS pattern and/or the EPRE ratio should be based on the same configuration as the target UE (e.g., the same resource block (RB) offset, RE offset, time domain density, and frequency domain density). The network entity and target UE determine the PT-RS for the co-scheduled UE is associated with the DMRS port with lowest index among the DMRS ports for the co-scheduled UE.

[0096] In some other implementations, the network entity and target UE determine the PT-RS pattern for the co-scheduled UEs based on a predefined pattern (e.g., no PT-RS for the co-scheduled UEs), or a PT-RS pattern with a predefined RB offset, RE offset, time domain density, frequency domain density and associated DMRS port. In some other implementations, the network entity and target UE determine the EPRE ratio between the PT-RS and DMRS for the co-scheduled UE based on the number of DMRS ports for the co-scheduled UE and a predefined PT-RS power boosting configuration (e.g., *EPRE-Ratio* configured as 0) or the *EPRE-Ratio* configured for the target UE. In some other implementations, the network entity and target UE determine the EPRE ratio between the PT-RS and DMRS for the co-scheduled UE based on a predefined value (e.g., 0dB).

[0097] In some other implementations, if the network entity enables PT-RS for the target UE, the network entity may refrain from configuring the presence of the DCI field for co-scheduled UE information or may indicate that there are no co-scheduled UEs. For example, the network entity may refrain from co-scheduling a downlink transmission when the target UE is configured with a PT-RS.

[0098] In some implementations, the network entity configures the PT-RS pattern (e.g., RB offset, RE offset, time domain density, and frequency domain density) associated DMRS port

for the co-scheduled UEs by RRC signaling, MAC CE, or DCI. The network entity may configure the EPRE ratio between PT-RS and DMRS by RRC signaling, MAC CE, or DCI.

[0099] In one example, the network entity may configure a set of candidate PT-RS configurations for the co-scheduled UEs and the network entity indicates the candidate PT-RS configuration identifier (ID) by DCI. The network entity can list the PT-RS configurations that may be used for co-scheduled UEs. The network entity can then signal in DCI which option is used. Alternatively, the target UE can use the set of candidate PT-RS configurations as a limit of blind detection options.

[0100] In some implementations, the target UE may perform blind detection of the PT-RS pattern and/or EPRE ratio between the PT-RS and DMRS for the co-scheduled UE. The target UE may report the UE capability indicating whether it supports blind detection of the PT-RS pattern and/or EPRE ratio. In some implementations, the network entity may configure candidate PT-RS patterns, and the target UE can perform the blind detection based on the candidate PT-RS patterns. When using blind detection, the target UE may indicate the additional processing delay (as described with reference to FIG. 10) and may transmit the HARQ feedback after the additional processing delay (as described with reference to FIG. 9B).

[0101] The descriptions of FIG. 6, FIG. 7, and FIG. 8 describe how the target UE can determine the locations of reference signals (such as the DMRS, the PT-RS, and the rate matching pattern) of a co-scheduled UE. Similar techniques can apply to other types of reference signals, such as a CSI-RS, remote interference measurement (RIM) reference signal, and positioning reference signal (PRS).

[0102] The network entity and UE determine that the CSI-RS pattern for the co-scheduled UEs based on a predefined rule. In some implementations, the network entity and target UE determine the CSI-RS pattern should be based on the same configuration as the target UE (e.g., the same resource block (RB) offset, RE offset, time domain density, and frequency domain density). Thus, the network entity and target UE determine that the REs allocated for the PDSCH for the target UE should not be allocated for the CSI-RS for co-scheduled UEs.

[0103] In some implementations, the network entity and the target UE determine the CSI-RS pattern by the lowest or highest CSI-RS resource index among the CSI-RS resources for the co-scheduled UE. In some other implementations, the network entity and target UE determine the CSI-RS pattern for the co-scheduled UEs based on a predefined pattern, such

as no CSI-RS for the co-scheduled UEs or a CSI-RS pattern with a predefined RB offset, RE offset, time domain density, frequency domain density for CSI-RS pattern of the target UE. In some other implementations, if the network entity schedules CSI-RS for the co-scheduled UE in the same slot as the target UE, the network entity may refrain from configuring the presence of the DCI field for co-scheduled UE information or may indicate that there is no co-scheduled UE.

[0104] In some implementations, the network entity configures the CSI-RS pattern (e.g., RB offset, RE offset, time domain density, and frequency domain density) for the co-scheduled UEs by RRC signaling, MAC CE, or DCI. In some implementations, the network entity configures a set of candidate CSI-RS configurations for the co-scheduled UEs and the network entity indicates the candidate CSI-RS configuration identifier (ID) by RRC signaling, MAC CE, or DCI.

[0105] In some implementations, the target UE may perform blind detection of the CSI-RS pattern for the co-scheduled UE(s). The target UE may report the UE capability indicating whether it supports blind detection of the CSI-RS pattern for the co-scheduled UE(s). In some implementations, the network entity may configure candidate CSI-RS patterns, and the target UE can perform the blind detection based on the candidate CSI-RS patterns. When using blind detection, the target UE may indicate the additional processing delay (as described with reference to FIG. 10) and may transmit the HARQ feedback after the additional processing delay (as described with reference to FIG. 9B).

[0106] **FIG. 9A** shows a processing delay for reception of a PDSCH. The network entity transmits DCI in a PDCCH 960 to schedule the PDSCH 970. Typically, the DCI in the PDCCH 960 also indicates the PUCCH 980 resource for HARQ feedback. For example, the DCI may indicate an offset (shown as the first offset 974) between the last symbol of the PDSCH 970 and first symbol of the PUCCH 980, where the first offset 974 should be no less than the minimum PDSCH processing delay 972, $T_{proc,1}$ as defined in 3GPP technical specification (TS) 38.214. The offset is also referred to as parameter K_1 , or the *PDSCH-to-HARQ feedback timing indicator*, in DCI. The *PDSCH-to-HARQ feedback timing indicator* is a value that refers to a lookup table that can be configured by RRC signaling (not shown).

[0107] As described in this disclosure, there may be additional processing delay needed for the target UE to perform interference cancellation and properly decode the PDSCH 970. The

PDSCH processing delay 972 may be insufficient for the target UE to determine whether the PDSCH 970 has been properly received using interference cancellation.

[0108] FIG. 9B shows a processing delay for reception of a PDSCH with additional delay for interference cancellation according to some implementations of this disclosure. Prior to the PDCCH 960, the target UE may report the UE capability indicating the additional processing delay for interference cancellation for PDSCH reception. In some implementations, the target UE reports the additional PDSCH processing delay for one or more types of blind detection used for interference cancellation. For example, the additional PDSCH processing delay for the DMRS type blind detection, DMRS port blind detection, PT-RS blind detection, or CSI-RS blind detection may be a configurable value. Alternatively, or additionally, the additional processing delay for one or more types of blind detection or for interference cancellation, generally, be predefined (e.g., the time associated with 2 or 4 symbols). When reported in a UE capability message, the additional processing delay may be based on an expected additional processing delay that depends on the amount of information that the network entity provides regarding the co-scheduled UE.

[0109] Based on the reported additional processing delay, the network entity can determine the offset value (shown as new first offset 978 in FIG. 9B) between the PDSCH 970 and PUCCH 980 (for HARQ feedback) that is no less than the PDSCH processing delay 972 plus the UE reported additional processing delay 975, if the network entity indicates that there are co-scheduled UEs in the DCI. In one example, the total PDSCH processing delay for interference cancellation is $T_{proc,1} + d_3$, where $T_{proc,1}$ is defined in 3GPP TS 38.214 and d_3 indicates the additional delay reported by the UE capability. Alternatively, the additional processing delay may be predefined.

[0110] In some implementations, the network entity and target UE determine the additional processing delay for interference cancellation based on at least one of the following factors: number of DMRS ports for co-scheduled UE(s); modulation order for co-scheduled UE(s); whether additional information for the co-scheduled UEs, such as DMRS type, CSI-RS pattern, PT-RS pattern, EPRE ratio between PT-RS and DMRS, is known by the target UE.

[0111] In one example, the target UE may report different UE capability indicating the additional delay for different number of DMRS ports for co-scheduled UE(s). In another example, different additional delays may be predefined for different number of DMRS ports for co-scheduled UE(s). In another example, the target UE may report different UE capability

indicating the additional delay for different modulation orders for co-scheduled UE(s). In another example, different additional delays may be predefined for different modulation orders for co-scheduled UE(s).

[0112] FIG. 10 shows example signaling from a UE and from a network entity to improve interference cancellation according to some implementations of this disclosure. The example signaling from UE 1040 may be sent to the network entity to indicate UE capability regarding supported configurations for interference cancellation 1042 as described in capability message 340 of FIG. 3. Additionally, or alternatively, the example signaling from UE 1040 may indicate additional processing delay for interference cancellation 1044 as described with reference to FIG. 9B.

[0113] The example control signaling from network entity 1050 may be transmitted from the network entity to the target UE. The example control signaling may include one or more of the following parameters: DMRS type of co-scheduled UE 1051, rate-matching pattern for co-scheduled UE 1052, PT-RS pattern of co-scheduled UE 1053, CSI-RS pattern for co-scheduled UE 1054, presence of DCI field for co-scheduled UE information 1055. In some implementations, the example control signaling from network entity 1050 may include a limited set of options for co-scheduled reference signals. The DCI (not shown) may include a value that refers to the limited set of options. Alternatively, or additionally, the target UE may use the limited set of options to reduce the burden of blind detection for an unlimited set of reference signal configurations.

[0114] FIG. 11 shows example DCI 1160 to indicate interference cancellation information regarding a co-scheduled UE according to some implementations of this disclosure. The example DCI 1160 may include a DCI field for co-scheduled UE information 1162. The DCI field in combination with the control signaling (such as the example control signaling from network entity 1050 described with reference to FIG. 10) can inform the target UE about the reference signals or possible reference signal options that are used for a co-scheduled UE. In some implementations, the DCI field for co-scheduled UE information 1162 can be a value from a lookup table (such as any of Tables 1-6). The value can inform the target UE whether there is a co-scheduled UE as well as the modulation order or DMRS configuration of the co-scheduled UE.

[0115] As described with reference to Table 1, the DCI field may be a 3 bit value to represent one of the 8 entries in the table. However, some of the options in Table 1 may be unnecessary.

Therefore, there is an opportunity to reduce overhead for the DCI field by limiting the DCI field value options or by pre-configuring some parameters in the control signaling (such as RRC signaling) before the DCI. In some implementations, the network entity configures the candidate modulation orders for the co-scheduled UEs by RRC signaling and the network entity indicates the modulation order for the co-scheduled UEs based on the candidate modulation orders. The network entity may provide a common configuration or separate configuration for DCI format 1_1 and DCI format 1_2.

[0116] In some implementations, the network entity configures the maximum modulation order for the co-scheduled UEs by RRC signaling or MAC CE, and the network entity indicates the modulation order for the co-scheduled UEs based on the modulation orders smaller than or equal to the maximum modulation order. In one example, the network entity configures the maximum modulation order for the co-scheduled UEs as 64QAM, then the network entity indicates the information of co-scheduled UEs by a 2 bit value in DCI. Table 2 shows an example with 4 entries such that a 2 bit value can indicate co-scheduled UE information and modulation order. In some implementations, the UE may report the UE capability indicating the supported maximum modulation order for the co-scheduled UEs.

Table 2: An example for the information for the co-scheduled UEs with maximum modulation order configured as 64QAM

DCI field for co-scheduled UE information	Content
0	No co-scheduled UE(s) which has same DMRS sequence as target UE exists
1	In all the PRBs allocated to the target UE, all the co-scheduled UE(s), which has the same DMRS sequence as the target UE, have QPSK scheduled

2	In all the PRBs allocated to the target UE, all the co-scheduled UE(s), which has the same DMRS sequence as the target UE, have 16QAM scheduled
3	In all the PRBs allocated to the target UE, all the co-scheduled UE(s), which has the same DMRS sequence as the target UE, have 64QAM scheduled

[0117] In some other implementations, the network entity configures a list of candidate modulation orders for the co-scheduled UEs by RRC signaling or MAC CE, and the network entity indicates the modulation order for the co-scheduled UEs based on the configured candidate modulation orders. In one example, the network entity configures the candidate modulation order for the co-scheduled UEs as {16QAM, 64QAM, 256QAM}, then the network entity indicates the information of co-scheduled UEs by a 2 bit value in DCI to represent one of the 4 entries shown in Table 3. In some implementations, the UE may report the UE capability indicating the supported modulation order(s) for the co-scheduled UEs.

Table 3: An example for the information for the co-scheduled UEs with candidate modulation order configured as {16QAM, 64QAM, 256QAM}

DCI field for co-scheduled UE information	Content
0	No co-scheduled UE(s) which has same DMRS sequence as target UE exists
1	In all the PRBs allocated to the target UE, all the co-scheduled UE(s), which has the same DMRS sequence as the target UE, have 16QAM scheduled

2	In all the PRBs allocated to the target UE, all the co-scheduled UE(s), which has the same DMRS sequence as the target UE, have 64QAM scheduled
3	In all the PRBs allocated to the target UE, all the co-scheduled UE(s), which has the same DMRS sequence as the target UE, have 256QAM scheduled

[0118] In some other implementations, the network entity may configure whether the network entity indicates the exact modulation order for the co-scheduled UE(s) or the network entity only indicates whether any of the co-scheduled UEs shares the same modulation order as the target UE or not. The network entity may provide the configuration by RRC signaling. The network entity may provide a common configuration or separate configuration for DCI format 1_1 and DCI format 1_2. Table 4 illustrates one example for the information for the co-scheduled UEs with implicit modulation order indication. Table 4 has 4 entries, which can be represented by a 2 bit value in the DCI.

Table 4: An example for the information for the co-scheduled UEs with implicit modulation order indication

DCI field for co-scheduled UE information	Content
0	No co-scheduled UE(s) which has same DMRS sequence as target UE exists
1	In all the PRBs allocated to the target UE, all the co-scheduled UE(s), which has the same DMRS sequence as the target UE, have the same modulation order scheduled as the target UE

2	In all the PRBs allocated to the target UE, all the co-scheduled UE(s), which has the same DMRS sequence as the target UE, have different modulation order scheduled as the target UE
3	reserved

[0119] Table 5 illustrates another example for the information for the co-scheduled UEs with implicit modulation order indication. Table 5 has 2 entries, which can be represented by a single bit in the DCI.

Table 5: Another example for the information for the co-scheduled UEs with implicit modulation order indication

DCI field for co-scheduled UE information	Content
0	No co-scheduled UE(s) which has same DMRS sequence and the same modulation order as target UE exists
1	In all the PRBs allocated to the target UE, all the co-scheduled UE(s), which has the same DMRS sequence as the target UE, have the same modulation order scheduled as the target UE

[0120] In some other implementations, the target UE may perform blind detection of the modulation order for the co-scheduled UE(s). The target UE may report the UE capability indicating whether it supports blind detection of the modulation order for the co-scheduled UE(s). Then the network entity may configure whether the network entity indicates the exact modulation order for the co-scheduled UE(s) or not. If the network entity configures not to indicate the exact modulation order for the co-scheduled UE(s), the network entity only indicates whether there is co-scheduled UE(s) or co-scheduled UE(s) with the same DMRS sequence as the target UE. The network entity may indicate the co-scheduled UE(s) are based

on a single modulation order. Table 6 illustrates one example for the information for the co-scheduled UEs without modulation order indication. Table 6 has 2 entries, which can be represented by a single bit in the DCI.

Table 6: An example for the information for the co-scheduled UEs with implicit modulation order indication

DCI field for co-scheduled UE information	Content
0	No co-scheduled UE(s) which has same DMRS sequence
1	In all the PRBs allocated to the target UE, all the co-scheduled UE(s), which has the same DMRS sequence as the target UE, have a single modulation order scheduled

[0121] In some implementations, the network entity may configure candidate modulation orders, and the target UE can perform the blind detection of the modulation order based on the candidate modulation orders.

[0122] In some implementations, the network entity may configure candidate modulation orders and a modulation and coding scheme (MCS) table (e.g., the table with maximum modulation as {64QAM,256QAM,1024QAM}) for the co-scheduled UE(s), and the target UE can perform the blind detection with smaller search space based on candidate modulation orders and a MCS table. In one example, the target UE is configured with candidate modulation orders={2,4,6,8,10} and MCS table=64QAM for the co-scheduled UE(s), the target UE can perform the blind detection with smaller candidate modulation orders search space from {2,4,6,8,10} to {2,4,6}.

[0123] In some implementations, the network entity may configure a MCS table, e.g, the table with maximum modulation as {64QAM,256QAM,1024QAM} and indicate DCI field in Table 1 for the co-scheduled UE(s), and the target UE can perform the blind detection with

smaller search space based on the configured MCS table and indicated DCI field. In one example, the target UE is configured with MCS table=64QAM and indicated with DCI field=6 in Table 1 for the co-scheduled UE(s), the target UE can perform the blind detection with smaller candidate modulation orders search space from {2,4,6,8} to {2,4,6}, where assume the maximum supported modulation order for the co-scheduled UE(s) is 8 (256QAM).

[0124] In some implementations, the network entity may configure candidate modulation orders, a MCS table (e.g., the table with maximum modulation as {64QAM,256QAM,1024QAM}), and DCI field in Table 1 for the co-scheduled UE(s), and the target UE can perform the blind detection with smaller search space based on candidate modulation orders and a MCS table with the indicated DCI field. In one example, the target UE is configured with candidate modulation orders={2,4,6,8,10}, MCS table=64QAM, and indicated DCI field=6 in Table 1 for the co-scheduled UE(s), the target UE can perform the blind detection with smaller candidate modulation orders search space from {2,4,6,8,10} to {2,4,6}.

[0125] In some implementations, the target UE may report additional PDSCH processing delay for the blind detection of modulation order for the co-scheduled UE(s). In some other implementations, the PDSCH processing delay for the blind detection of modulation order for the co-scheduled UE(s) may be predefined (e.g., 2 or 4 symbols).

[0126] In some implementations, the network entity configures the presence of DCI field for the co-scheduled UE information indication commonly or separately for different TRPs (e.g., different Control Resource Set (CORESET) pools). In some implementations, the network entity enables the DCI field for the co-scheduled UE information indication for the CORESET for one CORESET pool, but disables the DCI field for the CORESET for another CORESET pool.

[0127] In some other implementations, if the network entity enables the DCI field for the co-scheduled UE information indication for all the TRPs, the network entity refrains from indicating different values for the DCI field for the co-scheduled UE information indication in DCIs scheduling the PDSCH fully or partially overlapped in time domain. Thus, the target UE may expect the same values for the DCI field for the co-scheduled UE information indication in DCIs scheduling the PDSCH fully or partially overlapped in time domain. In some other implementations, the target UE may report the UE capability indicating whether

the target UE supports different values for the DCI field for the co-scheduled UE information indication in DCIs scheduling the PDSCH fully or partially overlapped in time domain.

[0128] In some other implementations, the network entity refrains from configuring the presence of the field for co-scheduled UE information indication in DCI or indicating the co-scheduled UE information other than no co-scheduled UE if the target UE is configured with single-DCI based mTRP operation or multi-DCI based mTRP operation. Thus, the target UE should not expect the network entity configure the presence of the field of co-scheduled UE information in DCI or indicate the co-scheduled UE information other than no co-scheduled UE if the target UE is configured with single-DCI based mTRP operation or multi-DCI based mTRP operation.

[0129] In some implementations, if the network entity indicates the DMRS ports for the target UE that do not support MU-MIMO operation, i.e., the network entity shall not schedule the remaining DMRS ports to another UE, the target UE may ignore the DCI field for co-scheduled UE information indication or expect the DCI field for co-scheduled UE information indication should indicate no co-scheduled UE. If the network entity indicates the DMRS ports for the target UE that do not support MU-MIMO operation, the network entity may refrain from indicating the DCI field for co-scheduled UE information indication with a value other than no co-scheduled UE. Thus, in one example, the target UE may expect the value of the DCI indicator of co-scheduled UE information to be 0.

[0130] In one example, the DMRS ports that do not support MU-MIMO operation may be defined as follows (3GPP TS 38.214 section 5.1.6.2):

For DM-RS configuration type 1,

- if a UE is scheduled with one codeword and assigned with the antenna port mapping with indices of {2, 9, 10, 11 or 30} in Table 7.3.1.2.2-1 and Table 7.3.1.2.2-2 of Clause 7.3.1.2 of [5, TS 38.212], or
 - if a UE is scheduled with one codeword and assigned with the antenna port mapping with indices of {2, 9, 10, 11 or 12} in Table 7.3.1.2.2-1A and {2, 9, 10, 11, 30 or 31} in Table 7.3.1.2.2-2A of Clause 7.3.1.2 of [5, TS 38.212], or
 - if a UE is scheduled with two codewords,
- the UE may assume that all the remaining orthogonal antenna ports are not associated with transmission of PDSCH to another UE.

For DM-RS configuration type 2,

- if a UE is scheduled with one codeword and assigned with the antenna port mapping with indices of {2, 10 or 23} in Table 7.3.1.2.2-3 and Table 7.3.1.2.2-4 of Clause 7.3.1.2 of [5, TS38.212], or
 - if a UE is scheduled with one codeword and assigned with the antenna port mapping with indices of {2, 10, 23 or 24} in Table 7.3.1.2.2-3A and {2, 10, 23 or 58} in Table 7.3.1.2.2-4A of Clause 7.3.1.2 of [5, TS 38.212], or
 - if a UE is scheduled with two codewords,
- the UE may assume that all the remaining orthogonal antenna ports are not associated with transmission of PDSCH to another UE.

[0131] FIG. 12 shows example operations 1200 of a UE according to some implementations of this disclosure. For example, the example operations 400 can be implemented by a target UE (such as the target UE 110 described herein).

[0132] At block 1240, the UE transmits UE capability (340, 1040) regarding supported configurations of interference cancellation for PDSCH reception.

[0133] At block 1250, the UE receives control signaling (150, 350, 450, 1050) configuring at least one of the following parameters: presence of the DCI field for co-scheduled UE(s) information, candidate modulation order for the co-scheduled UE(s), additional information of the co-scheduled UE(s) such as any of: DMRS type, DMRS port(s) or number of DMRS ports for co-scheduled UE(s), CSI-RS pattern for co-scheduled UE(s), rate matching pattern for co-scheduled UE(s), PT-RS pattern, EPRE ratio between PT-RS and DMRS.

[0134] At block 1260, the UE receives one or more DCI(s) (160, 360, 460, 1160) scheduling one or more PDSCH(s) and indicating the information for co-scheduled UE(s) and offset between the PDSCH and HARQ feedback based on PDSCH processing delay with interference cancellation.

[0135] At block 1270, the UE receives the scheduled one or more PDSCH(s) (370, 470, 970) based on the configured and indicated information of the co-scheduled UE(s). At block 1280, the UE transmits HARQ feedback (380, 980) for the scheduled PDSCH(s).

[0136] FIG. 13 shows example operations of a network entity according to some implementations of this disclosure. For example, the example operations 500 can be implemented by network entity (such as the network entity 120 described herein).

[0137] At block 1340, the network entity receives UE capability (340, 1040) regarding supported configurations of interference cancellation for PDSCH reception.

[0138] At block 1350, the network entity transmits control signaling (150, 350, 550, 1050) configuring at least one of the following parameters: presence of the DCI field for co-scheduled UE(s) information, candidate modulation order for the co-scheduled UE(s), additional information of the co-scheduled UE(s) such as any of: DMRS type, DMRS port(s) or number of DMRS ports, CSI-RS pattern, rate matching pattern, PT-RS pattern, EPRE ratio between PT-RS and DMRS.

[0139] At block 1360, the network entity transmits one or more DCI(s) (160, 360, 560, 960, 1160) scheduling one or more PDSCH(s) and indicating the information for co-scheduled UE(s) and offset between the PDSCH and HARQ feedback based on PDSCH processing delay with interference cancellation.

[0140] At block 1370, the network entity transmits the scheduled one or more PDSCH(s) (170, 370, 570, 970) to the target UE and co-scheduled UE(s). At block 1380, the network entity receives HARQ feedback (380, 980) for the scheduled PDSCH(s).

[0141] **FIG. 14** is a block diagram illustrating example configurations of a network entity and a user equipment. Note that the depicted hardware configurations represent the processing components and communication components of a network entity 1420 (such as the network entity 120 described herein) and a UE 1410 (such as the target UE 110 described herein). The depicted hardware configurations may omit certain components well-understood to be frequently implemented in such electronic devices, such as displays, peripherals, power supplies, and the like.

[0142] The UE 1410 includes antennas 1411, a radio frequency front end (RF front end) 1412, and radio-frequency transceivers (e.g., an LTE transceiver 1413 and a 5G NR transceiver 1414) for communicating with network entity 1420 and/or one or more TRPs. The RF front end 1412 includes one or more modems configured for the corresponding RAT(s) employed (for example, 3GPP 5G NR), one or more analog-to-digital converters (ADCs), one or more digital-to-analog converters (DACs), signal processors, and the like. In the example illustrated in FIG. 14, the RF front end 1412 of the UE 1410 may couple or connect the LTE transceiver 1413, and the 5G NR transceiver 1414 to the antennas 1411 to facilitate various types of wireless communication. The RF front end 1412 operates, in effect, as a physical (PHY) transceiver interface to conduct and process signaling between the one or more

processor(s) 1415 and antennas 1411 so as to facilitate various types of wireless communication.

[0143] The antennas 1411 of the UE 1410 may include an array of multiple antennas that may be tuned to one or more frequency bands associated with a corresponding RAT. The antennas 1411 and the RF front end 1412 may be tuned to, and/or be tunable to, one or more frequency bands defined by the 3GPP LTE and 5G NR communication standards and implemented by the LTE transceiver 1413, and/or the 5G NR transceiver 1414. Additionally, the antennas 1411, the RF front end 1412, the LTE transceiver 1413, and/or the 5G NR transceiver 1414 may be configured to support beamforming for the transmission and reception of communications with the network entity 1420 and/or with one or more TRPs. By way of example and not limitation, the antennas 1411 and the RF front end 1412 may be implemented for operation in sub-gigahertz bands, sub-6 GHz bands, and/or above 6 GHz bands that are defined by the 3GPP LTE and 5G NR communication standards.

[0144] The UE 1410 also includes processor(s) 1415 and computer-readable storage media (CRM) 1416. The processor(s) 1415 may include, for example, one or more central processing units, graphics processing units (GPUs), or other application-specific integrated circuits (ASIC), and the like. To illustrate, the processor(s) 1415 may include an application processor (AP) utilized by the UE 1410 to execute an operating system and various user-level software applications, as well as one or more processors utilized by modems or a baseband processor of the RF front end 1412.

[0145] CRM 1416 may include any suitable memory or storage device such as random-access memory (RAM), static RAM (SRAM), dynamic RAM (DRAM), non-volatile RAM (NVRAM), read-only memory (ROM), Flash memory, solid-state drive (SSD) or other mass-storage devices, and the like useable to store one or more sets of executable software instructions and associated data that manipulate the one or more processor(s) 1415 and other components of the UE 1410 to perform the various functions described herein and attributed to the UE 1410. The sets of executable software instructions include, for example, an operating system (OS) and various drivers (not shown), and various software applications (not shown), which are executable by processor(s) 1415 to enable user-plane communication, control-plane signaling, and user interaction with the UE 1410.

[0146] Turning to the hardware configuration of the network entity 1420, it is noted that although FIG. 14 illustrates an implementation of the network entity 1420 as a single network

node (for example, a 5G NR Node B, or “gNB”), the functionality, and thus the hardware components, of the network entity 1420 instead may be distributed across multiple network nodes or devices and may be distributed in a manner to perform the functions described herein. As one example, the functionality of network entity 1420 may be distributed across a radio unit (RU), distributed unit (DU), or central unit (CU).

[0147] The network entity 1420 includes antennas 1421, a radio frequency front end (RF front end) 1422, one or more LTE transceivers 1423, and/or one or more 5G NR transceivers 1424 for communicating with the UE 1410. The RF front end 1422 of the network entity 1420 may couple or connect the LTE transceivers 1423 and the 5G NR transceivers 1424 to the antennas 1421 to facilitate various types of wireless communication. Similar to RF front end 1412, the RF front end 1422 includes one or more modems, one or more ADCs, one or more DACs, and the like. RF front end 1422 receives the one or more RF signals, for example, RF signals from UE 1410, and pre-processes the one or more RF signals to generate data from the RF signals that is provided as input to processes and/or applications executing on network entity 1420. This pre-processing may include, for example, power amplification, conversion of band-pass signaling to baseband signaling, initial analog-to-digital conversion, and the like.

[0148] The antennas 1421 of the network entity 1420 may be configured individually and/or as one or more arrays of multiple antennas. The antennas 1421 and the RF front end 1422 may be tuned to, and/or be tunable to, one or more frequency band defined by the 3GPP LTE and 5G NR communication standards, and implemented by the LTE transceivers 1423, and/or the 5G NR transceivers 1424. Additionally, the antennas 1421, the RF front end 1422, the LTE transceivers 1423, and/or the 5G NR transceivers 1424 may be configured to support beamforming, such as Massive-MIMO, for the transmission and reception of communications with the UE 1410.

[0149] The network entity 1420 also includes processor(s) 1425 and computer-readable storage media (CRM) 1426. The processor(s) 1425 may include, for example, one or more central processing units, graphics processing units (GPUs), or other application-specific integrated circuits (ASIC), and the like. To illustrate, the processor(s) 1425 may include an application processor (AP) utilized by the network entity 1420 to execute an operating system and various user-level software applications, as well as one or more processors utilized by modems or a baseband processor of the RF front end 1422 to enable communication with the UE 1410.

[0150] CRM 1426 may include any suitable memory or storage device such as random-access memory (RAM), static RAM (SRAM), dynamic RAM (DRAM), non-volatile RAM (NVRAM), read-only memory (ROM), or Flash memory usable to store device data of the network entity 1420. CRM 1426 also includes an RF resource manager 1427. In some aspects, the RF resource manager 1427 of the network entity 1420 is implemented to perform various functions associated with allocating physical access (for example, resource blocks) or communication resources for the air interface of the network entity 1420. The air interface of the network entity 1420 may be partitioned or divided into various units (for example, frames, subframes, or slots) of one or more of bandwidth, time, symbols, or spatial layers. For example, within a framework of a 5G NR protocol, the RF resource manager 1427 may allocate bandwidth and time intervals of access in resource blocks, each of which may be allocated in whole, or in part, to one or more channels for communicating with the UE 1410. The channels may include one or more of a PRACH, a PUCCH, a PUSCH, a PDCCH, a PDSCH, a PBCH, or a paging channel. The resource blocks may include multiple subcarriers that each span a portion of a frequency domain of the resource blocks. The subcarriers may be further divided into resource elements, or OFDM symbols, that each span a portion of a time domain of the subcarriers. Consequently, a resource block includes multiple OFDM symbols that may be grouped into subcarriers with other OFDM symbols having a common frequency bandwidth.

[0151] CRM 1426 further includes network entity manager 1428. Alternately or additionally, the network entity manager 1428 may be implemented in whole or part as hardware logic or circuitry integrated with or separate from other components of the network entity 1420. In at least some aspects, the network entity manager 1428 configures the LTE transceivers 1423 and the 5G NR transceivers 1424 for communication with the UE 1410, communication with TRPs via fronthaul interface 1429, as well as communication with a core network. In some aspects, the network entity 1420 includes an inter-network entity station interface 1431, such as an Xn and/or X2 interface, which the network entity manager 1428 configures to exchange user-plane and control-plane data between another network entity, to manage the communication of the network entity 1420 with the UE 1410. The network entity 1420 includes a core network interface 1432 that the network entity manager 1428 configures to exchange user-plane and control-plane data with core network functions and entities.

[0152] FIG. 1 through FIG. 14 and the operations described herein are examples meant to aid in understanding example implementations and should not be used to limit the potential implementations or limit the scope of the claims. Some implementations may perform additional operations, fewer operations, operations in parallel or in a different order, and some operations differently.

[0153] The examples in this disclosure are provided for pedagogical purposes. The described examples are based on a network entity transmitting co-scheduled downlink transmissions to a target UE and at least one co-scheduled UE. However, the disclosed techniques may also apply to co-scheduled uplink transmissions from a UE to multiple base stations, multiple transmission and reception points (TRPs), or multiple peer devices. For example, the UE may transmit uplink control information (UCI) that indicates information regarding co-scheduled uplink transmissions, indication of co-scheduled uplink reference signals, or the existence of a co-scheduled concurrent uplink transmission.

[0154] The foregoing disclosure provides illustration and description but is not intended to be exhaustive or to limit the aspects to the precise form disclosed. Modifications and variations may be made in light of the above disclosure or may be acquired from practice of the aspects. While the aspects of the disclosure have been described in terms of various examples, any combination of aspects from any of the examples is also within the scope of the disclosure. Alternatively, or in addition to the other examples described herein, examples include any combination of the following implementation options (identified as clauses for reference).

[0155] Clauses

[0156] Clause 1. An apparatus, including a processor configured to cause a User Equipment (UE) to: receive the configuration on presence of a “downlink control information (DCI) field” for “co-scheduled UE information” indication including at least the demodulation reference signal (DMRS) sequence and modulation order; receive one or more than one DCIs scheduling one or more than one physical downlink shared channel (PDSCH); receive the scheduled PDSCH(s) based on the indicated co-scheduled UE information and additional information for the co-scheduled UE including at least one of the following: DMRS type; DMRS port information; Channel State Information Reference Signal (CSI-RS) pattern; phase tracking reference signal (PT-RS) pattern; Energy Per Resource Element (EPRE) ratio

between PT-RS and DMRS; rate matching pattern group; transmit Hybrid Automatic Repeat request (HARQ) Acknowledgement (ACK) information for the received PDSCH.

[0157] Clause 2. The apparatus according to clause 1, where the UE transmits the UE capability indicating at least one of the following: whether the UE supports the interference cancellation based PDSCH reception for single transmission and reception point (TRP) and/or single-DCI based multi-TRP and/or multi-DCI based multi-TRP operations; supported DMRS type(s) for the target UE and co-scheduled UE(s); whether the UE supports different DMRS types for the target UE and co-scheduled UE(s); supported modulation order for the co-scheduled UE(s); supported modulation order for the target UE; whether the UE supports PT-RS transmission for the co-scheduled UE(s); whether the UE supports different PT-RS pattern for the target UE and co-scheduled UE(s); whether the UE supports different EPRE ratios between the PT-RS and DMRS for the target UE and co-scheduled UE(s); the additional PDSCH processing delay for the interference cancellation.

[0158] Clause 3. The apparatus according to clause 1, where the UE determines the DMRS type of the co-scheduled UEs based on the DMRS type of the UE.

[0159] Clause 4. The apparatus according to clause 1, where the UE receives the configuration of the DMRS type of the co-scheduled UEs.

[0160] Clause 5. The apparatus according to clause 1, where the UE determines the rate matching pattern group(s) of the co-scheduled UEs based on the rate matching pattern group(s) of the UE.

[0161] Clause 6. The apparatus according to clause 1, where the UE determines the rate matching pattern group(s) of the co-scheduled UEs based on a predefined value.

[0162] Clause 7. The apparatus according to clause 1, where the UE receives the configuration of the rate matching pattern group(s) of the co-scheduled UEs.

[0163] Clause 8. The apparatus according to clause 1, where the UE determines the PT-RS pattern of the co-scheduled UEs based on the PT-RS pattern of the UE.

[0164] Clause 9. The apparatus according to clause 1, where the UE determines the PT-RS pattern of the co-scheduled UEs based on a predefined PT-RS pattern.

[0165] Clause 10. The apparatus according to clause 1, where the UE receives the configuration of the PT-RS pattern of the co-scheduled UEs.

[0166] Clause 11. The apparatus according to clause 1, where the UE determines the EPRE ratio between the PT-RS and DMRS of the co-scheduled UEs based on the EPRE ratio between the PT-RS and DMRS of the UE.

[0167] Clause 12. The apparatus according to clause 1, where the UE determines the EPRE ratio between the PT-RS and DMRS based on a predefined value.

[0168] Clause 13. The apparatus according to clause 1, where the UE receives the configuration of the EPRE ratio between the PT-RS and DMRS of the co-scheduled UEs.

[0169] Clause 14. The apparatus according to clause 1, where the UE receives the configuration for the DCI overhead with one of the following parameters: maximum modulation order for co-scheduled UEs; candidate modulation orders for co-scheduled UEs.

[0170] Clause 15. The apparatus according to clause 14, where the UE determines the payload size for the DCI field for co-scheduled UE information indication based on the received configuration.

[0171] Clause 16. The apparatus according to clause 1, where the UE ignores the DCI field for co-scheduled UE information indication if the indicated DMRS ports indicates other DMRS ports are not used for another UE.

[0172] Clause 17. The apparatus according to clause 1, where the UE determines the PDSCH processing delay based on the indicated co-scheduled UE information.

[0173] Clause 18. The apparatus according to clause 17, where the UE determines additional PDSCH processing delay if the DCI field for co-scheduled UE information indicates a value other than no co-scheduled UE.

[0174] Clause 19. The apparatus according to clause 18, where the UE determines the additional PDSCH processing delay based on at least one of the following factors: number of DMRS ports for co-scheduled UE(s); modulation order for co-scheduled UE(s); whether the additional information for the co-scheduled UE(s) is known by the UE.

[0175] Clause 20. The apparatus according to clause 18, where the additional processing delay is predefined.

[0176] Clause 21. An apparatus, including a processor configured to cause a network entity to: transmit the configuration on presence of a downlink control information (DCI) field for co-scheduled UE information indication including at least the demodulation reference signal (DMRS) sequence and modulation order; transmit one or more than one DCIs scheduling one

or more than one physical downlink shared channels (PDSCH) for a target UE and a co-scheduled UE; transmit the scheduled PDSCH(s) for the target UE and the scheduled PDSCH(s) for the co-scheduled UE based on the indicated co-scheduled UE information and additional information for the co-scheduled UE including at least one of the following: DMRS type; DMRS port information; Channel State Information Reference Signal (CSI-RS) pattern; Physical Tracking Reference Signal (PT-RS) pattern; Energy Per Resource Element (EPRE) ratio between PT-RS and DMRS; rate matching pattern group; receive Hybrid Automatic Repeat request (HARQ) Acknowledgement (ACK) information for the PDSCH(s).

[0177] Clause 22. The apparatus according to clause 21, where the network entity receives the UE capability indicating at least one of the following: whether the UE supports the interference cancellation based PDSCH reception for single transmission and reception point (TRP) and/or single-DCI based multi-TRP and/or multi-DCI based multi-TRP operations; supported DMRS type(s) for the target UE and co-scheduled UE(s); whether the UE supports different DMRS types for the target UE and co-scheduled UE(s); supported modulation order for the co-scheduled UE(s); supported modulation order for the target UE; whether the UE supports PT-RS transmission for the co-scheduled UE(s); whether the UE supports different PT-RS pattern for the target UE and co-scheduled UE(s); whether the UE supports different EPRE ratios between the PT-RS and DMRS for the target UE and co-scheduled UE(s); the additional PDSCH processing delay for the interference cancellation.

[0178] Clause 23. The apparatus according to clause 21, where the network entity transmits the DMRS of the co-scheduled UE based on the DMRS type of the target UE.

[0179] Clause 24. The apparatus according to clause 21, where the network entity transmits the configuration of the DMRS type of the co-scheduled UEs to the target UE.

[0180] Clause 25. The apparatus according to clause 21, where the network entity refrains from configuring DMRS eType1 or eType2 for at least one of the target UE and co-scheduled UE.

[0181] Clause 26. The apparatus according to clause 21, where the network entity transmits the PDSCH of the co-scheduled UE based on the rate matching pattern group(s) of the target UE.

[0182] Clause 27. The apparatus according to clause 21, where the network entity transmits the PDSCH of the co-scheduled UE based on predefined rate matching pattern group(s).

[0183] Clause 28. The apparatus according to clause 21, where the network entity transmits the configuration of the rate matching pattern group(s) of the co-scheduled UEs to the target UE.

[0184] Clause 29. The apparatus according to clause 21, where the network entity transmits the PT-RS of the co-scheduled UE based on the PT-RS pattern of the target UE.

[0185] Clause 30. The apparatus according to clause 21, where the network entity transmits the PT-RS of the co-scheduled UEs based on a predefined PT-RS pattern.

[0186] Clause 31. The apparatus according to clause 21, where the network entity transmits the configuration of the PT-RS pattern of the co-scheduled UEs to the target UE.

[0187] Clause 32. The apparatus according to clause 21, where the network entity transmits the PT-RS of the co-scheduled UE based on the EPRE ratio between the PT-RS and DMRS of the target UE.

[0188] Clause 33. The apparatus according to clause 21, where the network entity transmits the PT-RS of the co-scheduled UE based on a predefined EPRE ratio between the PT-RS and DMRS.

[0189] Clause 34. The apparatus according to clause 21, where the network entity transmits the configuration of the EPRE ratio between the PT-RS and DMRS of the co-scheduled UEs to the target UE.

[0190] Clause 35. The apparatus according to clause 21, where the network entity refrains from configuring PT-RS for at least one of the target UE and co-scheduled UE.

[0191] Clause 36. The apparatus according to clause 21, where the network entity refrains from configuring PDSCH based on single-DCI based multi-TRP or multi-DCI based multi-TRP operation for at least one of the target UE and co-scheduled UE.

[0192] Clause 37. The apparatus according to clause 21, where the network entity transmits the configuration for the DCI overhead with one of the following parameters: maximum modulation order for co-scheduled UEs; candidate modulation orders for co-scheduled UEs.

[0193] Clause 38. The apparatus according to clause 37, where the network entity determines the payload size for the DCI field for co-scheduled UE information indication based on the received configuration.

[0194] Clause 39. The apparatus according to clause 21, where the network entity refrains from indicating the DCI field for co-scheduled UE information indication with a value other

than no co-scheduled UE if the indicated DMRS ports indicates other DMRS ports are not used for another UE.

[0195] Clause 40. The apparatus according to clause 21, where the network entity determines the PDSCH processing delay based on the indicated co-scheduled UE information.

[0196] Clause 41. The apparatus according to clause 40, where the network entity determines additional PDSCH processing delay if the DCI field for co-scheduled UE information indicates a value other than no co-scheduled UE.

[0197] Clause 42. The apparatus according to clause 41, where the network entity determines the additional PDSCH processing delay based on at least one of the following factors: number of DMRS ports for co-scheduled UE(s); modulation order for co-scheduled UE(s); whether the additional information for the co-scheduled UE(s) is known by the UE.

[0198] Clause 43. The apparatus according to clause 41, where the additional processing delay is predefined.

[0199] Another innovative aspect of the subject matter described in this disclosure can be implemented as a computer-readable medium having stored therein instructions which, when executed by a processor, causes the processor to perform any one of the above-mentioned functionalities.

[0200] Another innovative aspect of the subject matter described in this disclosure can be implemented as a system having means for implementing any one of the above-mentioned functionalities.

[0201] Another innovative aspect of the subject matter described in this disclosure can be implemented as an apparatus having one or more processors configured to perform one or more operations implementing any one of the above-mentioned functionalities.

[0202] As used herein, the terms “component” and “module” are intended to be broadly construed as hardware, firmware, or a combination of hardware and software. As used herein, a processor is implemented in hardware, firmware, or a combination of hardware and software. As used herein, the phrase “based on” is intended to be broadly construed to mean “based at least in part on.”

[0203] As used herein, a phrase referring to “at least one of” or “one or more of” a list of items refers to any combination of those items, including single members. For example, “at least one of: a, b, or c” is intended to cover the possibilities of: a only, b only, c only, a

combination of a and b, a combination of a and c, a combination of b and c, and a combination of a and b and c.

[0204] In this disclosure, the term "can" indicates a capability, or alternatively indicates a possible implementation option. The term "may" indicates a permission or a possible implementation option.

[0205] The various illustrative components, logic, logical blocks, modules, circuits, operations and algorithm processes described in connection with the implementations disclosed herein may be implemented as electronic hardware, firmware, software, or combinations of hardware, firmware or software, including the structures disclosed in this specification and the structural equivalents thereof. The interchangeability of hardware, firmware and software has been described generally, in terms of functionality, and illustrated in the various illustrative components, blocks, modules, circuits and processes described above. Whether such functionality is implemented in hardware, firmware or software depends upon the particular application and design constraints imposed on the overall system.

[0206] The hardware and data processing apparatus used to implement the various illustrative components, logics, logical blocks, modules and circuits described in connection with the aspects disclosed herein may be implemented or performed with a general purpose single- or multi-chip 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, or any conventional processor, controller, microcontroller, or state machine. A processor also may be implemented as a combination of computing devices, for example, a combination of a DSP and a microprocessor, multiple microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration. In some implementations, particular processes, operations and methods may be performed by circuitry that is specific to a given function.

[0207] As described above, some aspects of the subject matter described in this specification can be implemented as software. For example, various functions of components disclosed herein, or various blocks or steps of a method, operation, process or algorithm disclosed herein can be implemented as one or more modules of one or more computer programs. Such computer programs can include non-transitory processor-executable or computer-executable

instructions encoded on one or more tangible processor-readable or computer-readable storage media for execution by, or to control the operation of, a data processing apparatus including the components of the devices described herein. By way of example, and not limitation, such storage media may include RAM, ROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium that may be used to store program code in the form of instructions or data structures. Combinations of the above should also be included within the scope of storage media.

[0208] As used herein, the terms “user device”, “user equipment” (for example, UE 110), “wireless communication device”, “mobile communication device”, “communication device”, or “mobile device” refer to any one or all of cellular telephones, smartphones, portable computing devices, personal or mobile multi-media players, laptop computers, tablet computers, smartbooks, Internet-of-Things (IoT) devices, palm-top computers, wireless electronic mail receivers, multimedia Internet enabled cellular telephones, wireless gaming controllers, display sub-systems, driver assistance systems, vehicle controllers, vehicle system controllers, vehicle communication system, infotainment systems, vehicle telematics systems or subsystems, vehicle display systems or subsystems, vehicle data controllers, point-of-sale (POS) terminals, health monitoring devices, drones, cameras, media-streaming dongles or another personal media devices, wearable devices such as smartwatches, wireless hotspots, femtocells, broadband routers or other types of routers, and similar electronic devices which include a programmable processor and memory and circuitry configured to perform operations as described herein. Further, the user device in some cases may be embedded in an electronic system such as the head unit of a vehicle or an advanced driver assistance system (ADAS). Still further, a mobile-internet device (MID). Depending on the type, the user device can include one or more general-purpose processors, a computer-readable memory, a user interface, one or more network interfaces, one or more sensors, etc.

[0209] Various modifications to the implementations described in this disclosure may be readily apparent to persons having ordinary skill in the art, and the generic principles defined herein may be applied to other implementations without departing from the scope of this disclosure. Thus, the claims are not intended to be limited to the implementations shown herein but are to be accorded the widest scope consistent with this disclosure, the principles and the novel features disclosed herein.

[0210] Additionally, various features that are described in this specification in the context of separate implementations also can be implemented in combination in a single implementation. Conversely, various features that are described in the context of a single implementation also can be implemented in multiple implementations separately or in any suitable subcombination. As such, although features may be described above as acting in particular combinations, and even initially claimed as such, one or more features from a claimed combination can in some cases be excised from the combination, and the claimed combination may be directed to a subcombination or variation of a subcombination.

[0211] Similarly, while operations are depicted in the drawings 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. Further, the drawings may schematically depict one or more example processes in the form of a flowchart or flow diagram. However, other operations that are not depicted can be incorporated in the example processes that are schematically illustrated. For example, one or more additional operations can be performed before, after, simultaneously, or between any of the illustrated operations. In some circumstances, multitasking and parallel processing may be advantageous. Moreover, the separation of various system components in the implementations described above should not be understood as requiring such separation in all implementations, and it should be understood that the described program components and systems can generally be integrated together in a single software product or packaged into multiple software products. Additionally, other implementations are within the scope of the following claims. In some cases, the actions recited in the claims can be performed in a different order and still achieve desirable results.

[0212] The foregoing disclosure provides illustration and description but is not intended to be exhaustive or to limit the aspects to the precise form disclosed. Modifications and variations may be made in light of the above disclosure or may be acquired from practice of the aspects. While the aspects of the disclosure have been described in terms of various examples, any combination of aspects from any of the examples is also within the scope of the disclosure.

CLAIMS

What is claimed is:

1. A method of wireless communication performed by a target user equipment (UE) (110), comprising:

receiving control signaling (150, 350, 450, 1050, 1250) from a network entity (120), the control signaling configuring at least one parameter associated with co-scheduling of downlink transmissions;

receiving downlink control information (DCI) (160, 360, 460, 960, 1160, 1260) scheduling at least one physical downlink shared channel (PDSCH) for the target UE, the DCI including a DCI field indicating information for at least one co-scheduled UE based on the at least one parameter; and

receiving the at least one PDSCH (170, 370, 470, 970, 1270), based on the DCI and the information for the at least one co-scheduled UE.

2. The method of claim 1, wherein the at least one parameter indicates whether the DCI field is present in the DCI.

3. The method of claim 1, wherein the DCI field indicates for the at least one co-scheduled UE at least one of:

modulation order,

demodulation reference signal (DMRS) sequence,

DMRS type,

DMRS port,

channel state information reference signal (CSI-RS) pattern,

phase tracking reference signal (PT-RS) pattern,

energy per resource element (EPRE) ratio between PT-RS and DMRS, or

rate matching pattern group.

4. The method of claim 3, further comprising at least one of:

determining the DMRS type or DMRS port of the at least one co-scheduled UE based on a DMRS type or DMRS port of the target UE;

receiving the DMRS type or DMRS port of the at least one co-scheduled UE via the control signaling or DCI; or

performing blind detection for the DMRS type or DMRS port from among a limited set of DMRS types or DMRS ports.

5. The method of any one of claims 1 to 4, further comprising:

determining one or more properties of downlink transmissions scheduled for the at least one co-scheduled UE; and

receiving the at least one PDSCH using interference cancellation based on the one or more properties of the downlink transmissions scheduled for the at least one co-scheduled UE.

6. The method of claim 5,

wherein the one or more properties of the downlink transmissions scheduled for the at least one co-scheduled UE include at least one of: a rate matching pattern, a phase tracking reference signal (PT-RS) pattern, or an energy per resource element (EPRE) ratio between the PT-RS and demodulation reference signal (DMRS) of the at least one co-scheduled UE, and

wherein the determining the one or more properties is based on at least one of: a corresponding property of downlink transmissions to the target UE, a predefined value, or a configuration in the control signaling.

7. The method of any one of claims 1 to 6, wherein the at least one parameter includes a configuration of at least one of: a maximum modulation order for the at least one co-scheduled UE or candidate modulation orders for the at least one co-scheduled UE, the method further comprising:

determining a payload size for the DCI field based on the configuration.

8. The method of any one of claims 1 to 7, further comprising:

receiving, via the DCI, an offset between the at least one PDSCH and hybrid automatic repeat request (HARQ) feedback, wherein the offset is based, at least in part, on a PDSCH processing delay and an additional PDSCH processing delay for interference cancellation; and

transmitting HARQ feedback information (380, 980, 1280) to the network entity (120) based on the offset.

9. The method of claim 8, wherein the additional PDSCH processing delay is based on at least one of:

- a number of demodulation reference signal (DMRS) ports for the at least one co-scheduled UE,
- a modulation order for the at least one co-scheduled UE, or
- an amount of information for the at least one co-scheduled UE provided to the target UE.

10. The method of any one of claims 1 to 9, further comprising:

- transmitting a UE capability (340, 1040, 1240) indicating at least one of:
 - whether the target UE supports PDSCH reception using interference cancellation for single transmission and reception point (TRP) operation, single-DCI based multi-TRP operation, or multi-DCI based multi-TRP operation;
 - supported DMRS types for the target UE and the at least one co-scheduled UE;
 - whether the target UE supports different DMRS types for the target UE and the at least one co-scheduled UE;
 - supported modulation order for the at least one co-scheduled UE;
 - supported modulation order for the target UE;
 - whether the target UE can process a phase tracking reference signal (PT-RS) for the at least one co-scheduled UE;
 - whether the target UE supports different PT-RS patterns for the target UE and the at least one co-scheduled UE;
 - whether the target UE supports different energy per resource element (EPRE) ratios between the PT-RS and DMRS for the target UE and the at least one co-scheduled UE; or
 - an additional PDSCH processing delay for the interference cancellation.

11. A method of wireless communication performed by a network entity (120), comprising:

transmitting control signaling (150, 350, 550, 1350) to a target user equipment (UE) (110), the control signaling configuring at least one parameter associated with co-scheduling of downlink transmissions;

transmitting downlink control information (DCI) (160, 360, 560, 960, 1160, 1360) scheduling at least one physical downlink shared channel (PDSCH) for the target UE, the DCI including a DCI field indicating information for at least one co-scheduled UE based on the at least one parameter; and

transmitting the at least one PDSCH (170, 370, 570, 970, 1370) to the target UE in accordance with the DCI and the information for the at least one co-scheduled UE.

12. The method of claim 11, wherein the at least one parameter indicates whether the DCI field is present in the DCI.

13. The method of claim 11 or 12, wherein the DCI field indicates for the at least one co-scheduled UE at least one of:

- modulation order,
- demodulation reference signal (DMRS) sequence,
- DMRS type,
- DMRS port,
- channel state information reference signal (CSI-RS) pattern,
- phase tracking reference signal (PT-RS) pattern,
- energy per resource element (EPRE) ratio between PT-RS and DMRS, or
- rate matching pattern group.

14. The method of any one of claims 11 to 13, further comprising:

- receiving a UE capability (340, 1340, 1040, 1340) indicating at least one of:

- whether the target UE supports PDSCH reception using interference cancellation for single transmission and reception point (TRP) operation, single-DCI based multi-TRP operation, or multi-DCI based multi-TRP operation,

- supported DMRS types for the target UE and the at least one co-scheduled UE,

- whether the target UE supports different DMRS types for the target UE and the at least one co-scheduled UE,

- supported modulation order for the at least one co-scheduled UE,

supported modulation order for the target UE,
 whether the target UE can process a phase tracking reference signal (PT-RS) for the at least one co-scheduled UE,
 whether the target UE supports different PT-RS patterns for the target UE and the at least one co-scheduled UE,
 whether the target UE supports different energy per resource element (EPRE) ratios between the PT-RS and DMRS for the target UE and the at least one co-scheduled UE, or
 an estimated additional PDSCH processing delay for the interference cancellation.

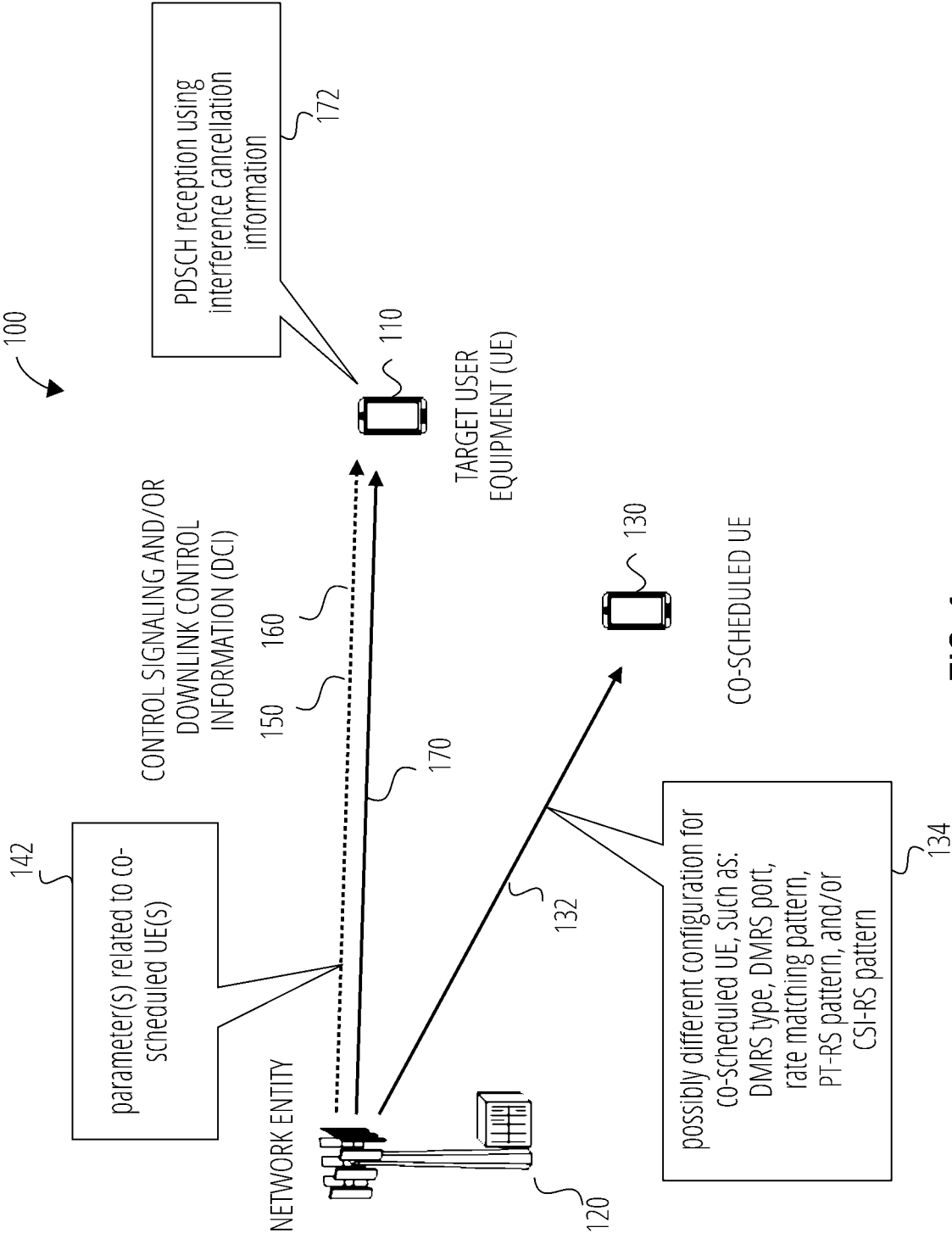
15. The method of any one of claims 11 to 14, further comprising:

refraining from co-scheduling a downlink transmission concurrent with the at least one PDSCH based on at least one of:

the target UE being configured with enhanced Type1 (eType1) or enhanced Type2 (eType2) based demodulation reference signal (DMRS),
 the target UE being configured with at least one rate matching pattern group,
 the target UE being configured with a phase tracking reference signal (PT-RS),
 the target UE and the at least one co-scheduled UE being configured with a same channel state information reference signal (CSI-RS),
 the target UE being configured with single-DCI based multiple transmit receive point (mTRP) operation or multi-DCI based mTRP operation, or
 the target UE being configured with one or more DMRS ports that do not support multi-user multiple-input multiple-output (MU-MIMO) operation.

16. An apparatus, comprising:

a communication unit; and
 a processing system configured to control the communication unit to implement any one of the methods of any one of claims 1 to 15.



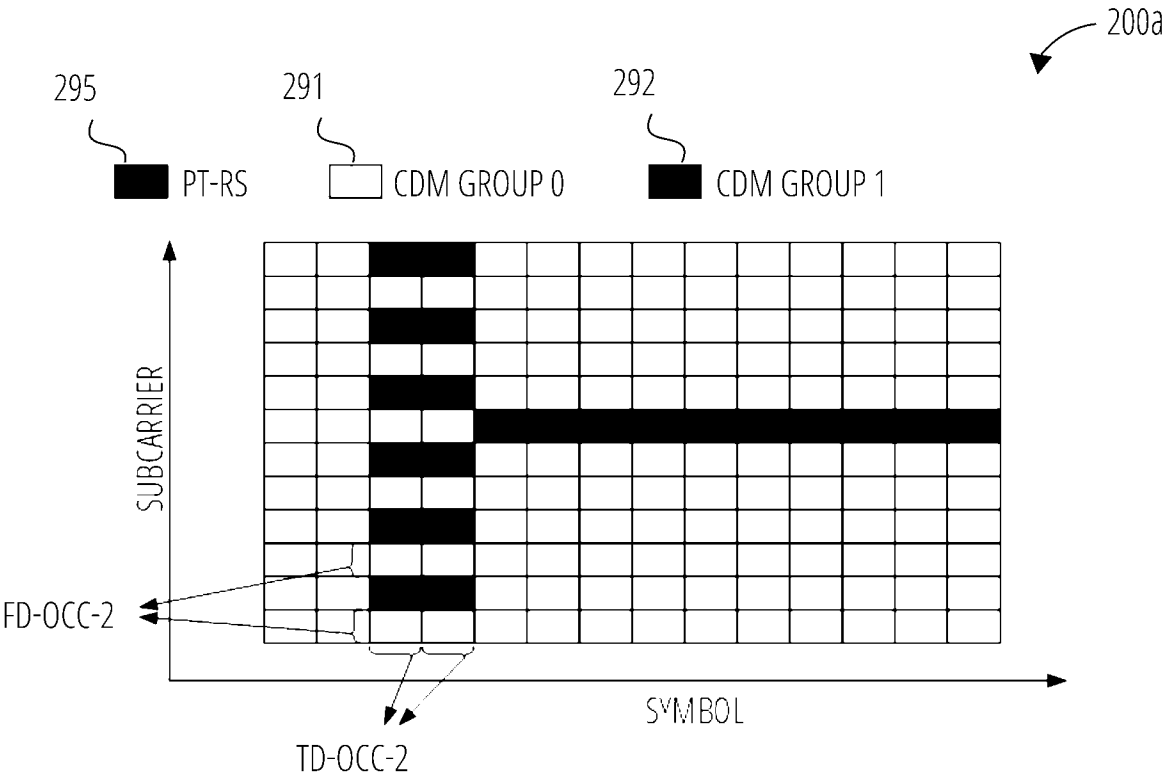


FIG. 2A

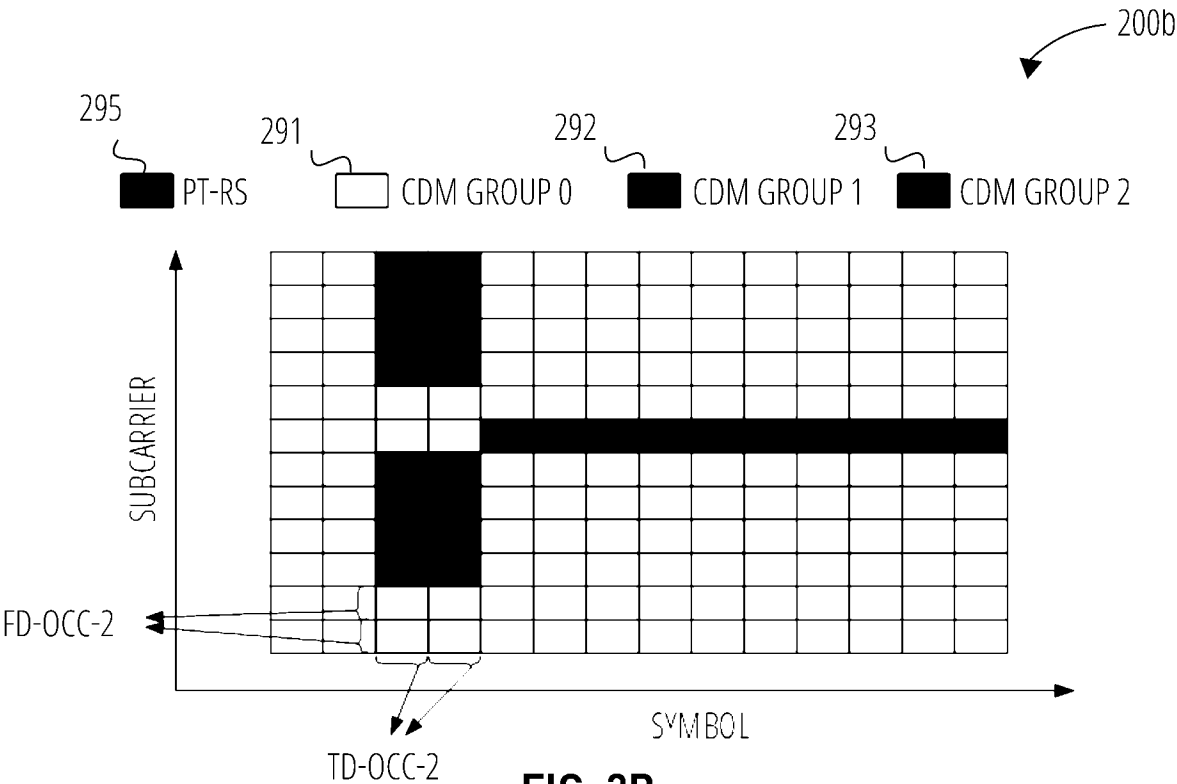
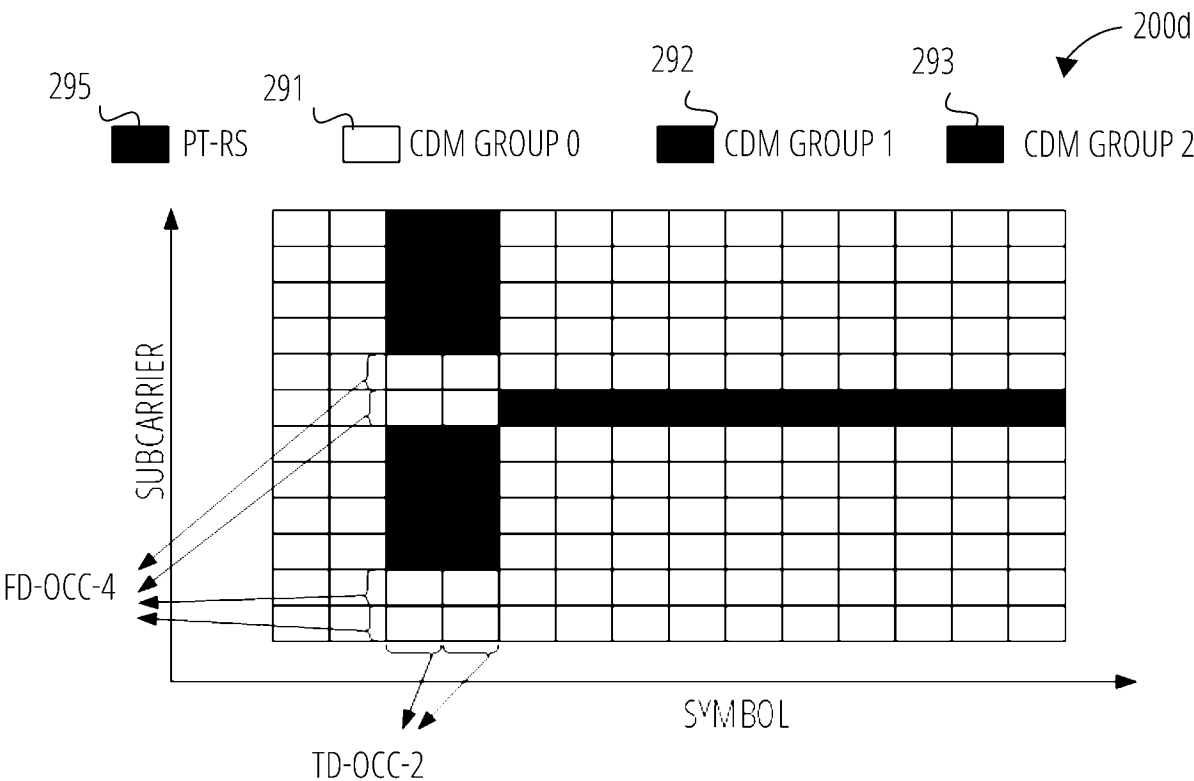
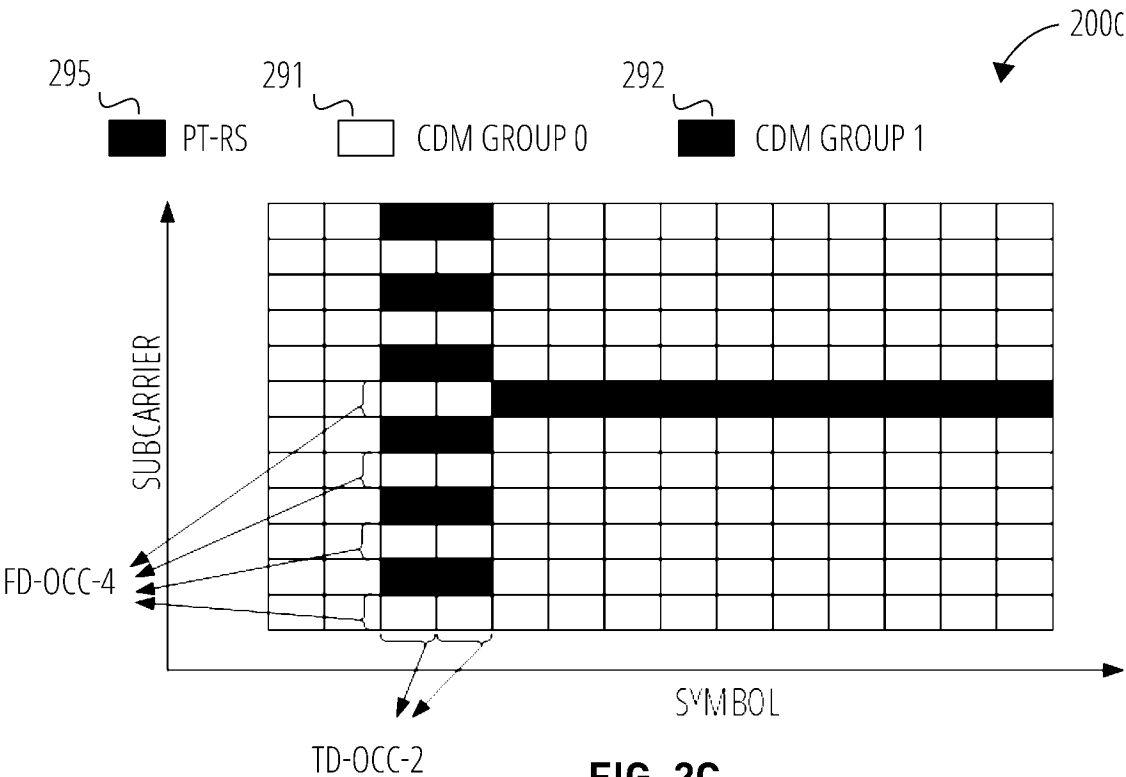


FIG. 2B



4/13

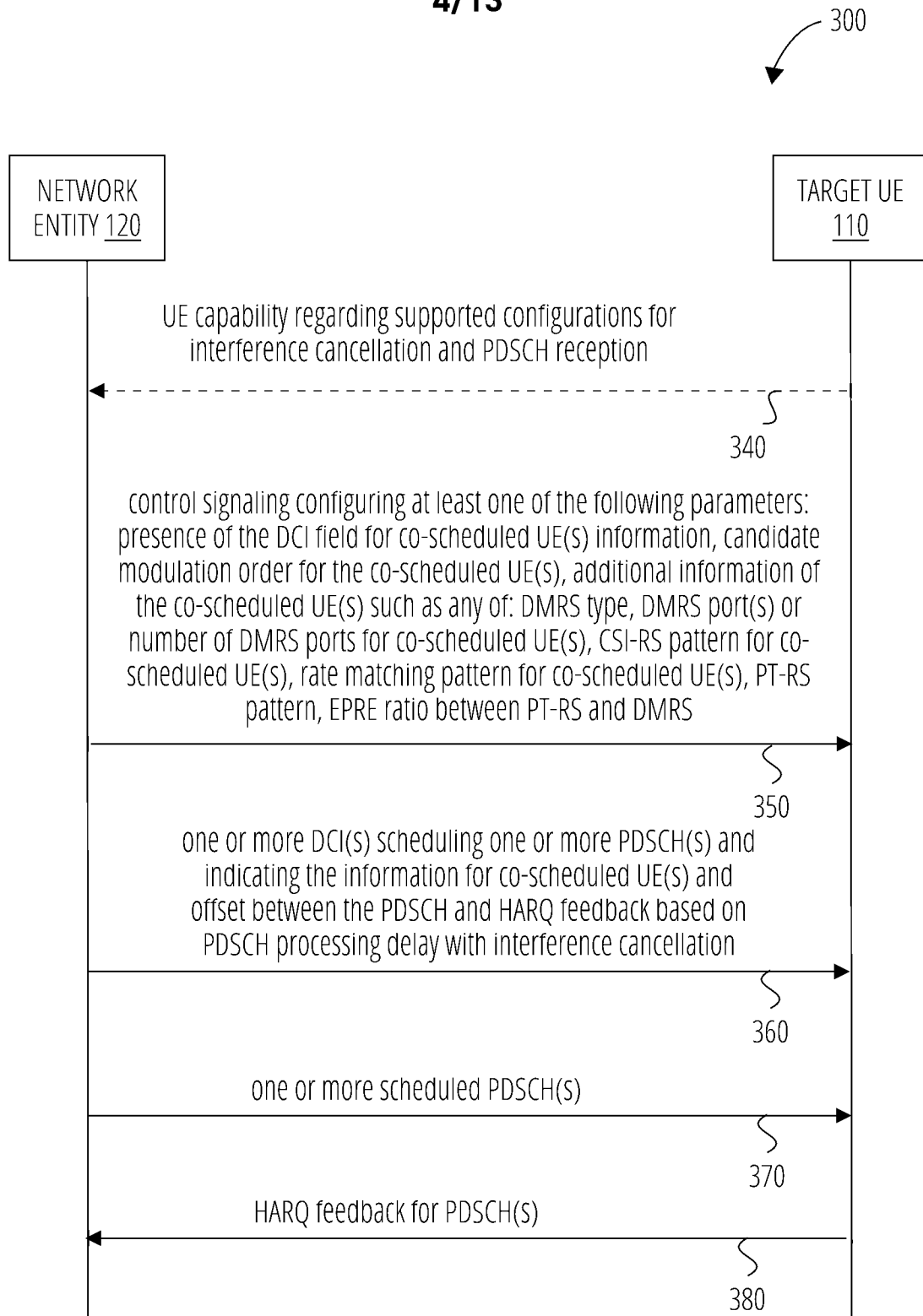


FIG. 3

5/13

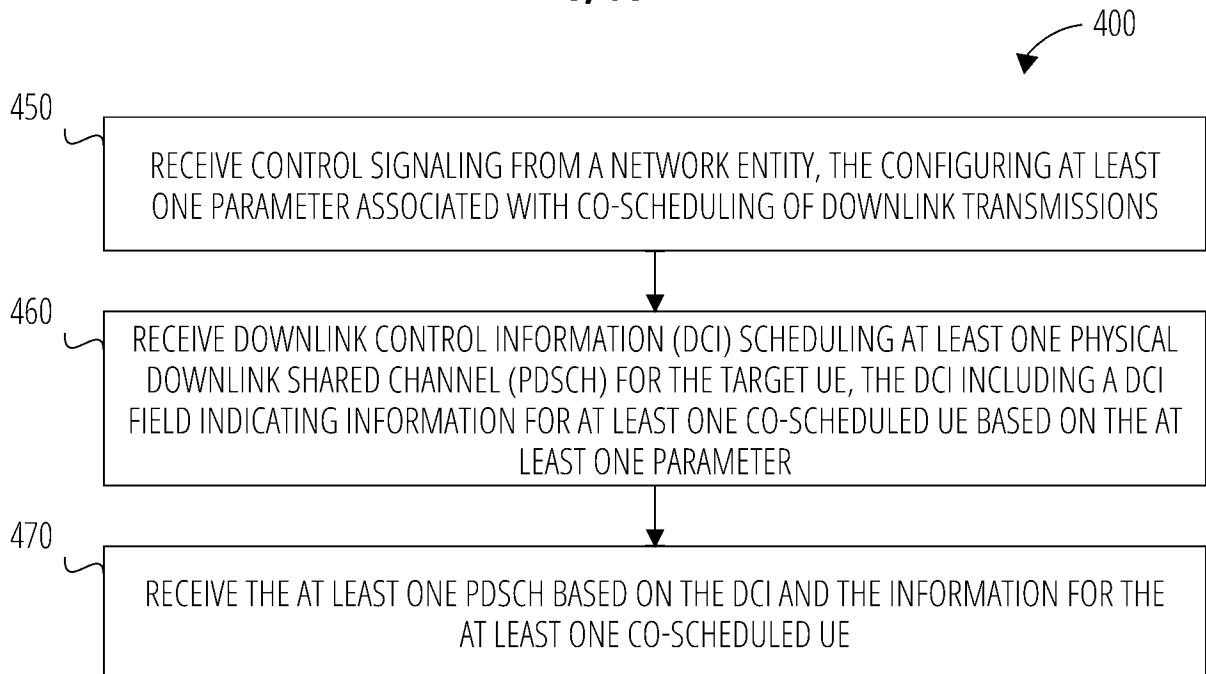


FIG. 4

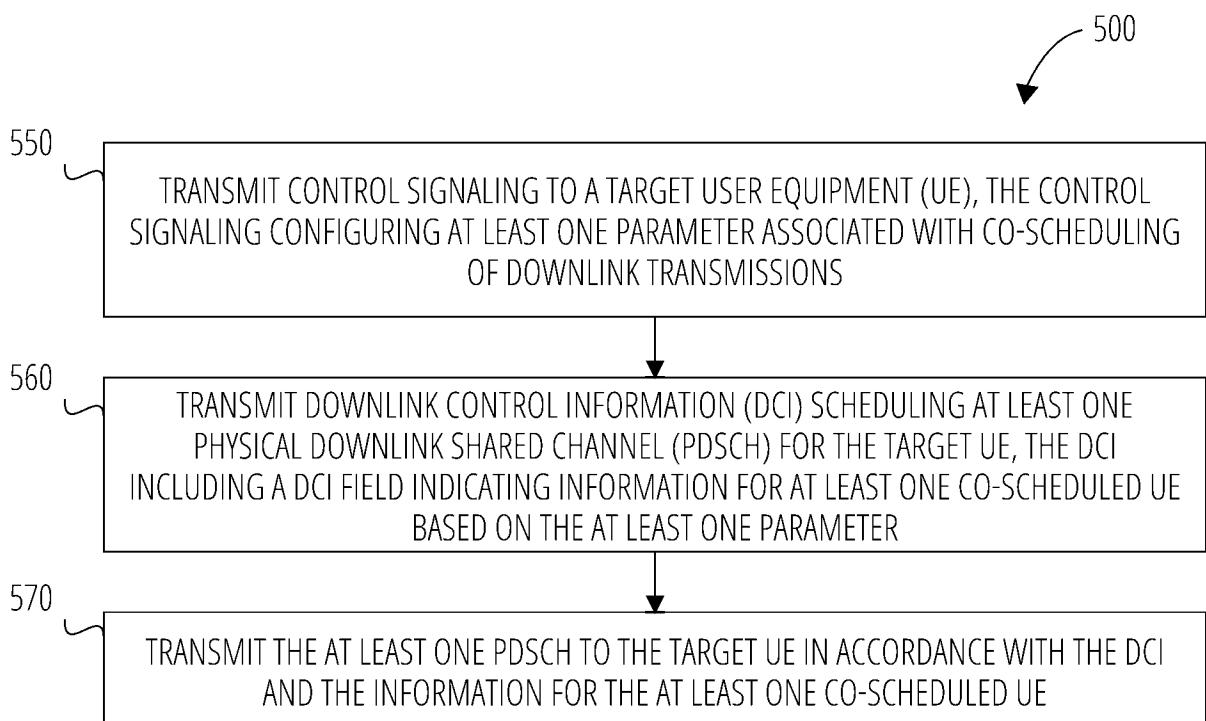


FIG. 5

6/13

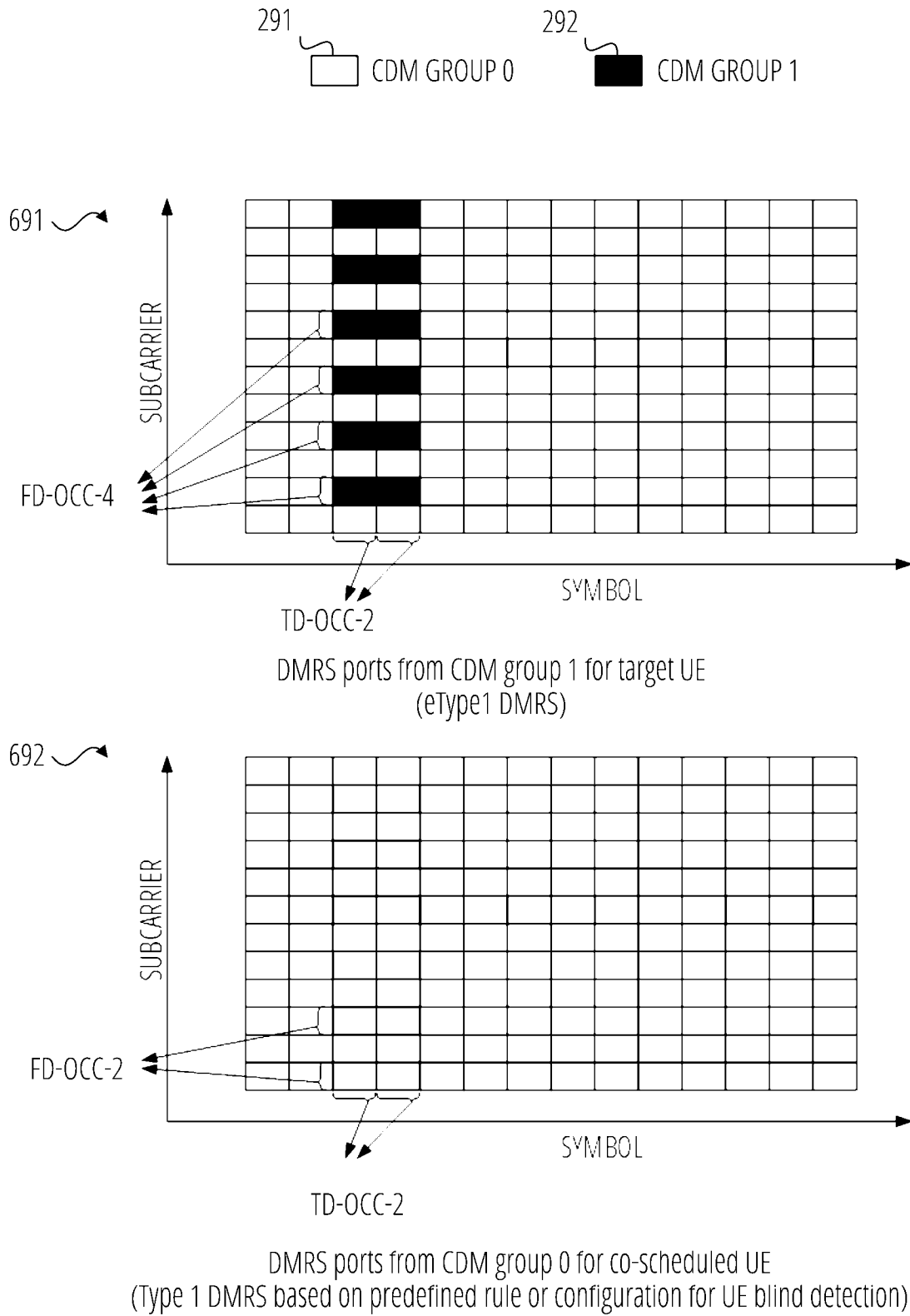
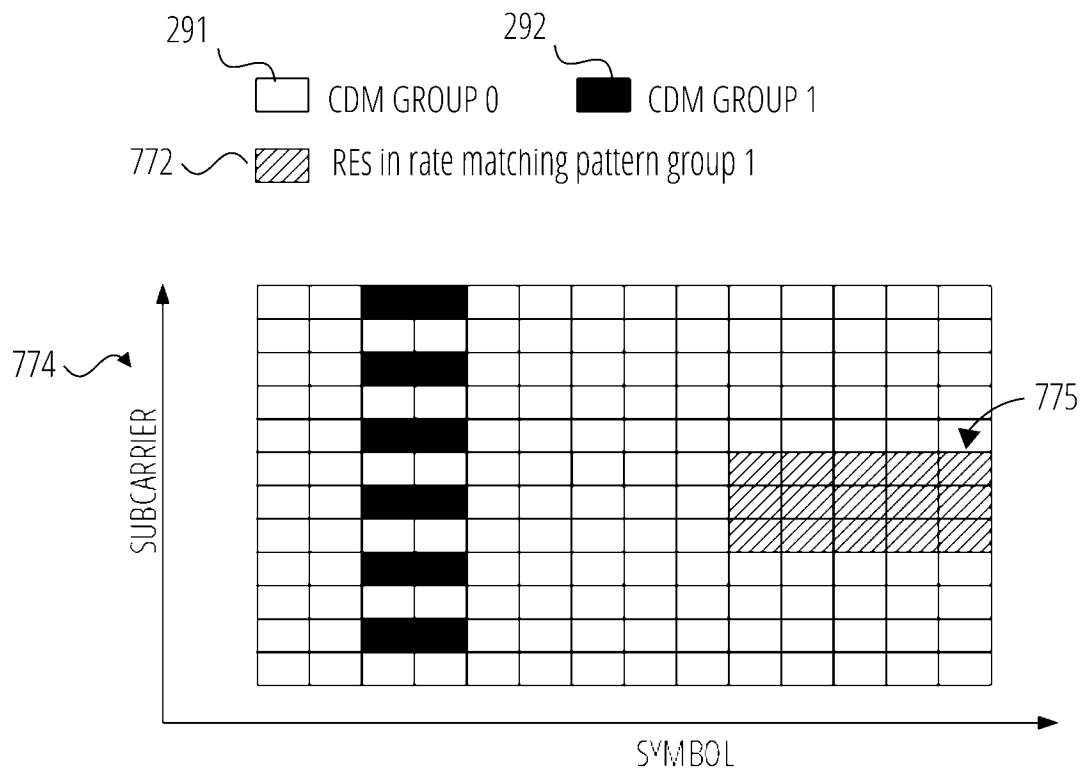
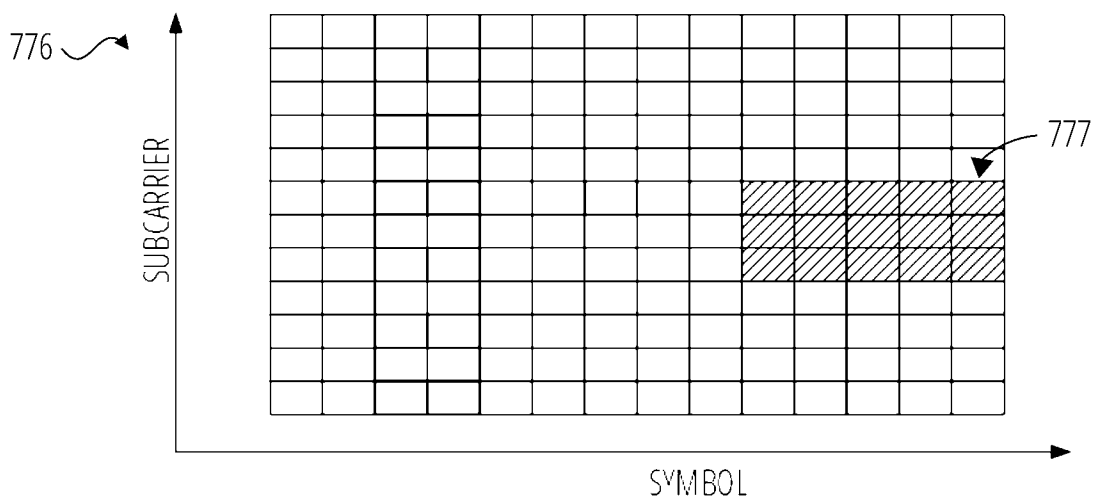


FIG. 6

7/13



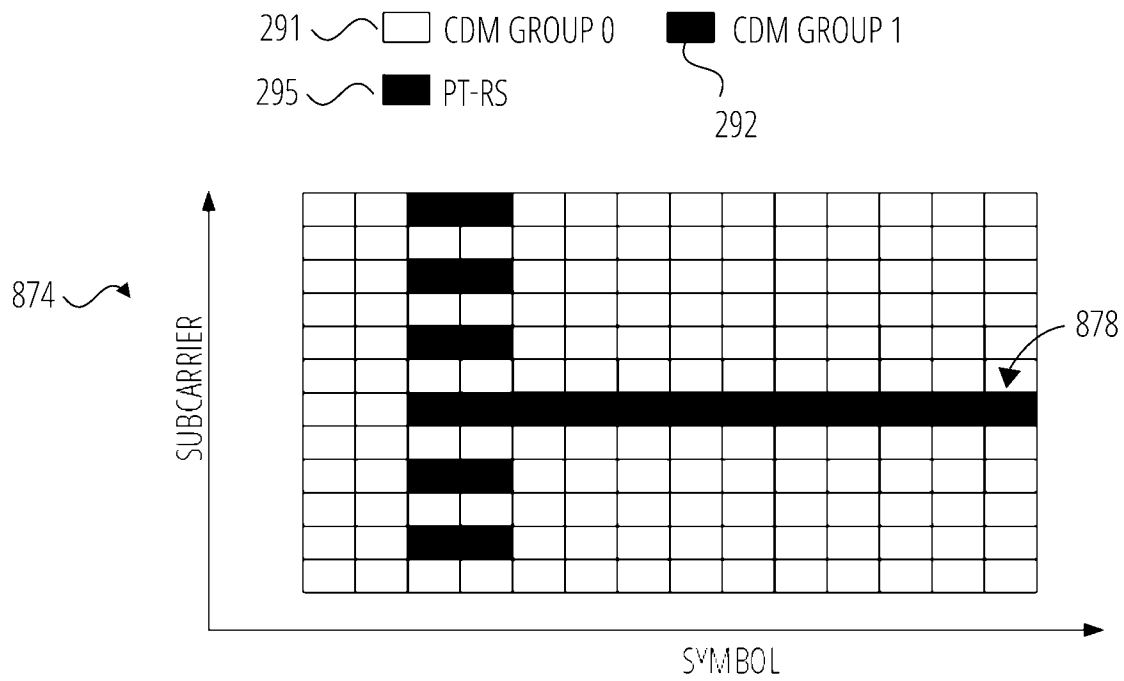
DMRS and rate matching pattern for target UE
Rate matching pattern group 1 is configured for target UE



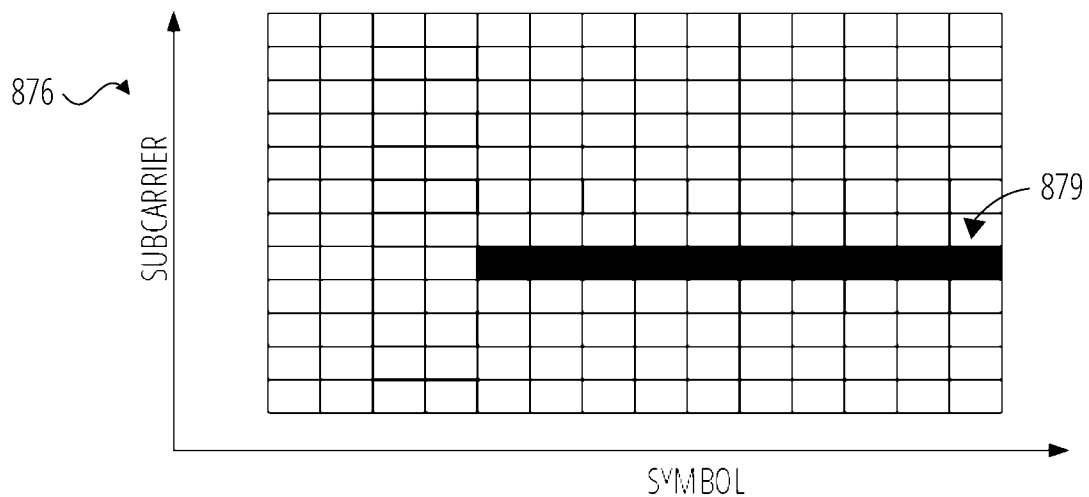
DMRS and rate matching pattern for co-scheduled UE
The same rate matching pattern group 1 as the target UE or
the network entity indicates the rate matching pattern group of the co-scheduled UE

FIG. 7

8/13



DMRS and PT-RS pattern for target UE



DMRS and PT-RS pattern for co-scheduled UE

PT-RS pattern is based on same RB/RE offset and time/freq offset density of target UE, or configured by network entity, or blindly detected by the UE

FIG. 8

9/13

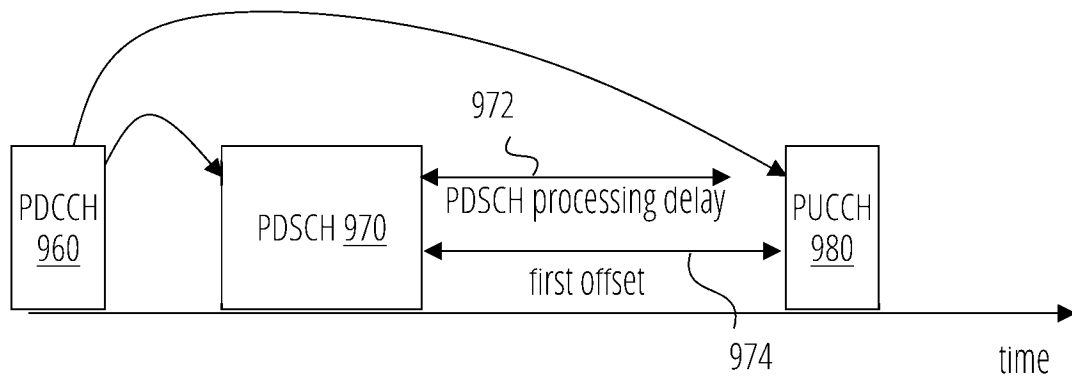


FIG. 9A

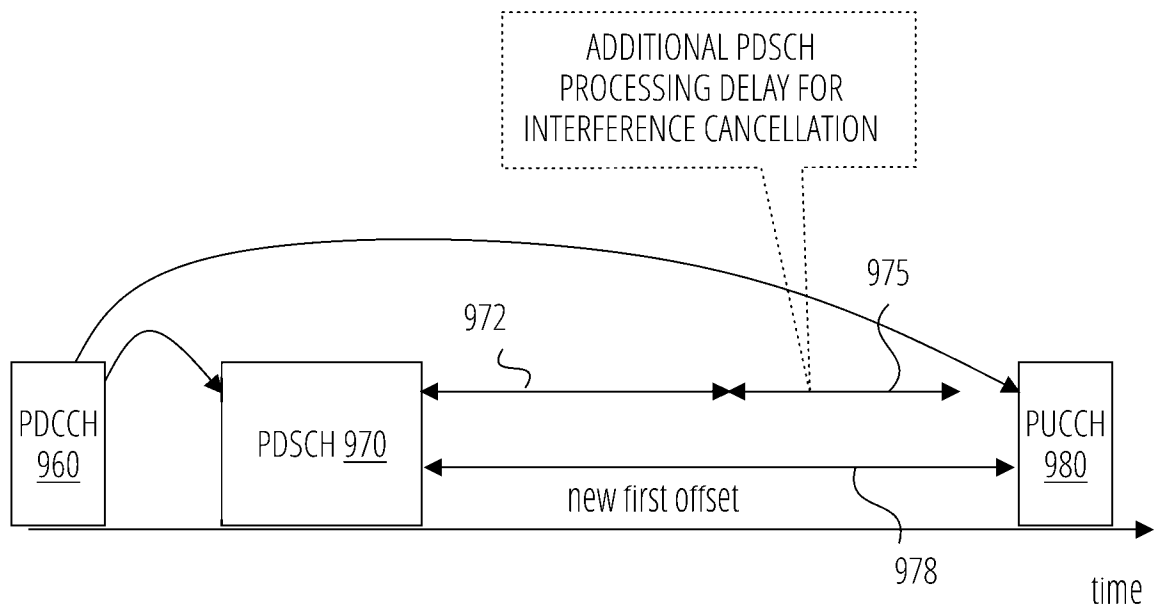


FIG. 9B

10/13

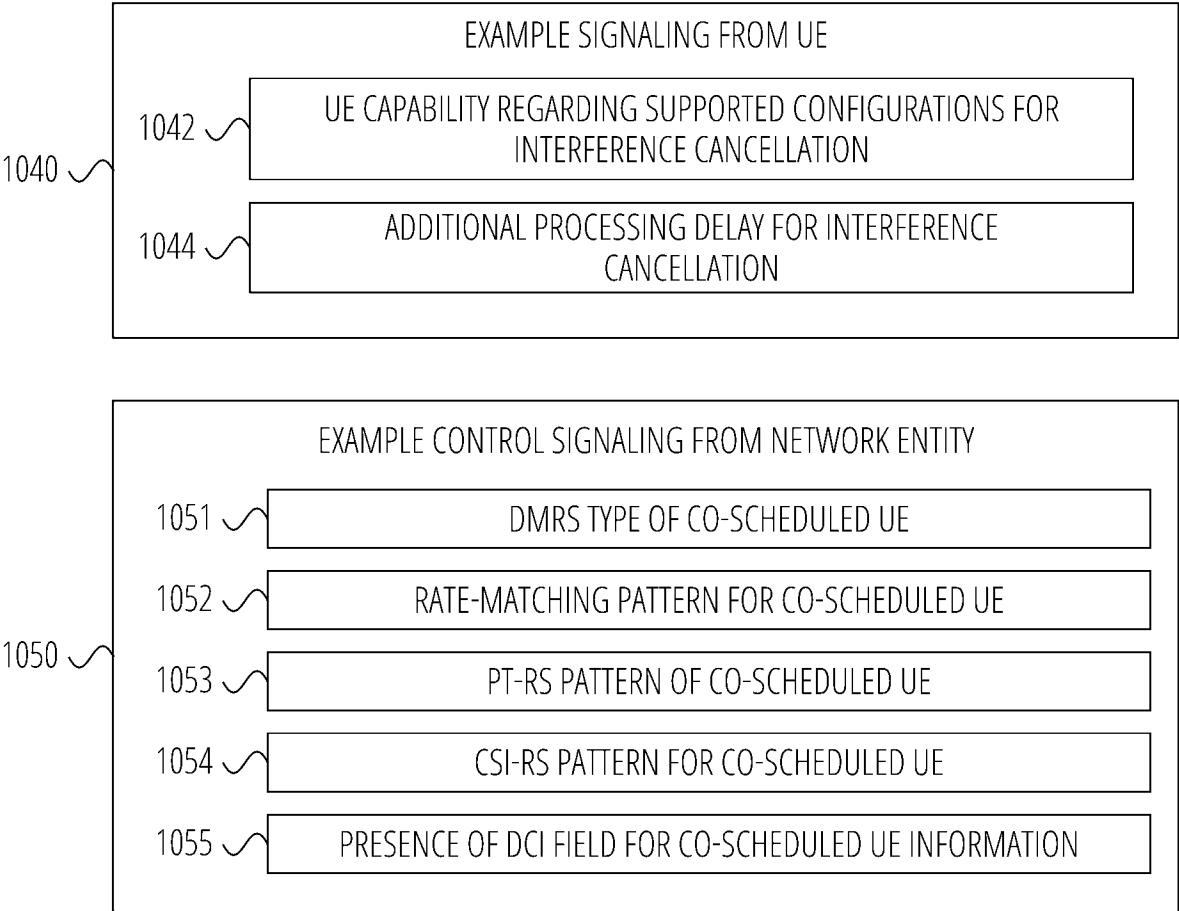


FIG. 10

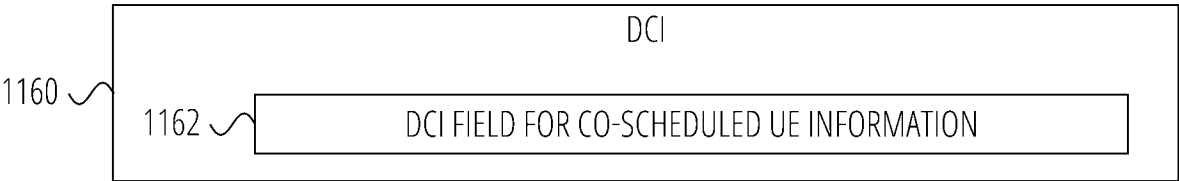


FIG. 11

11/13

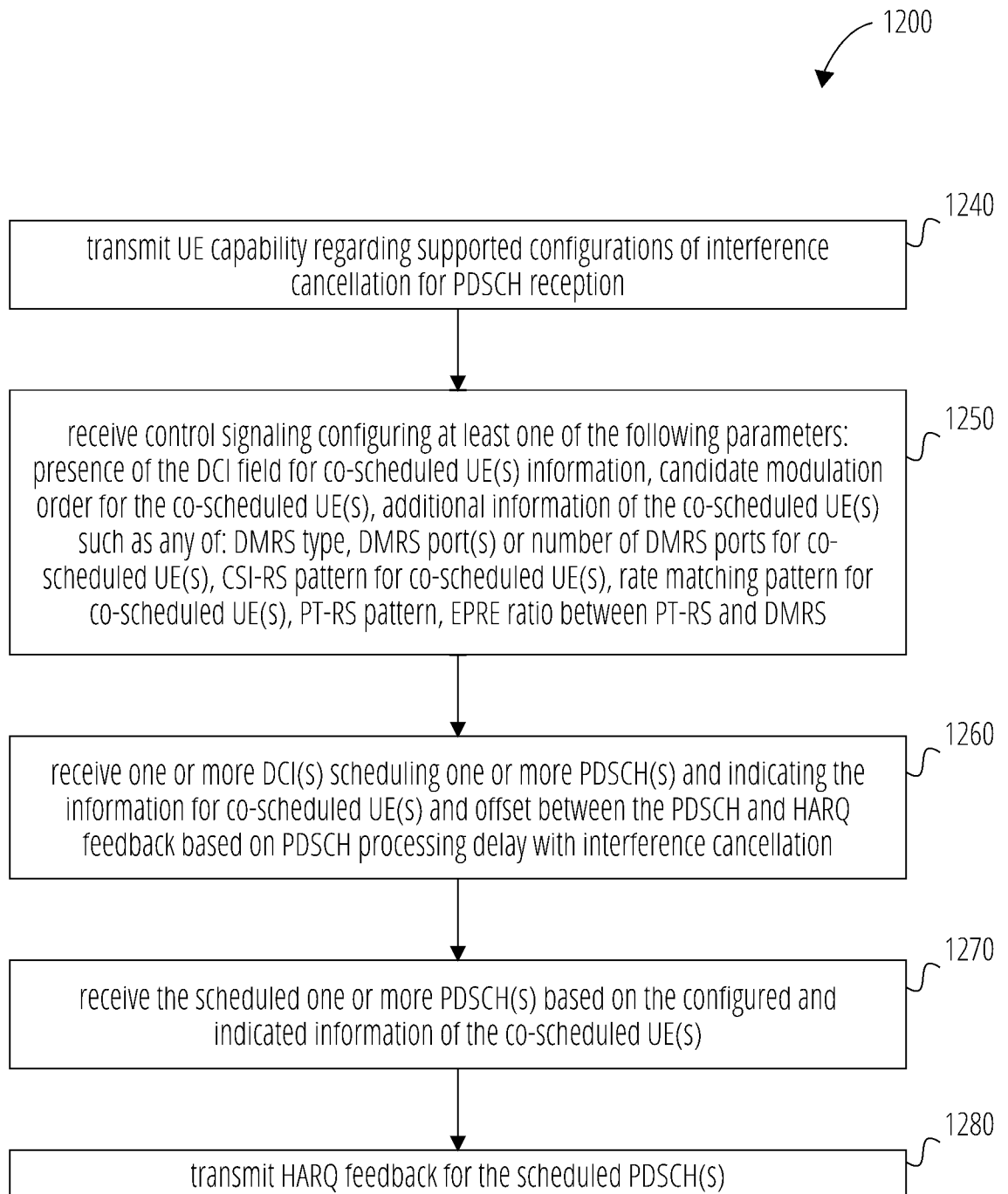


FIG. 12

12/13

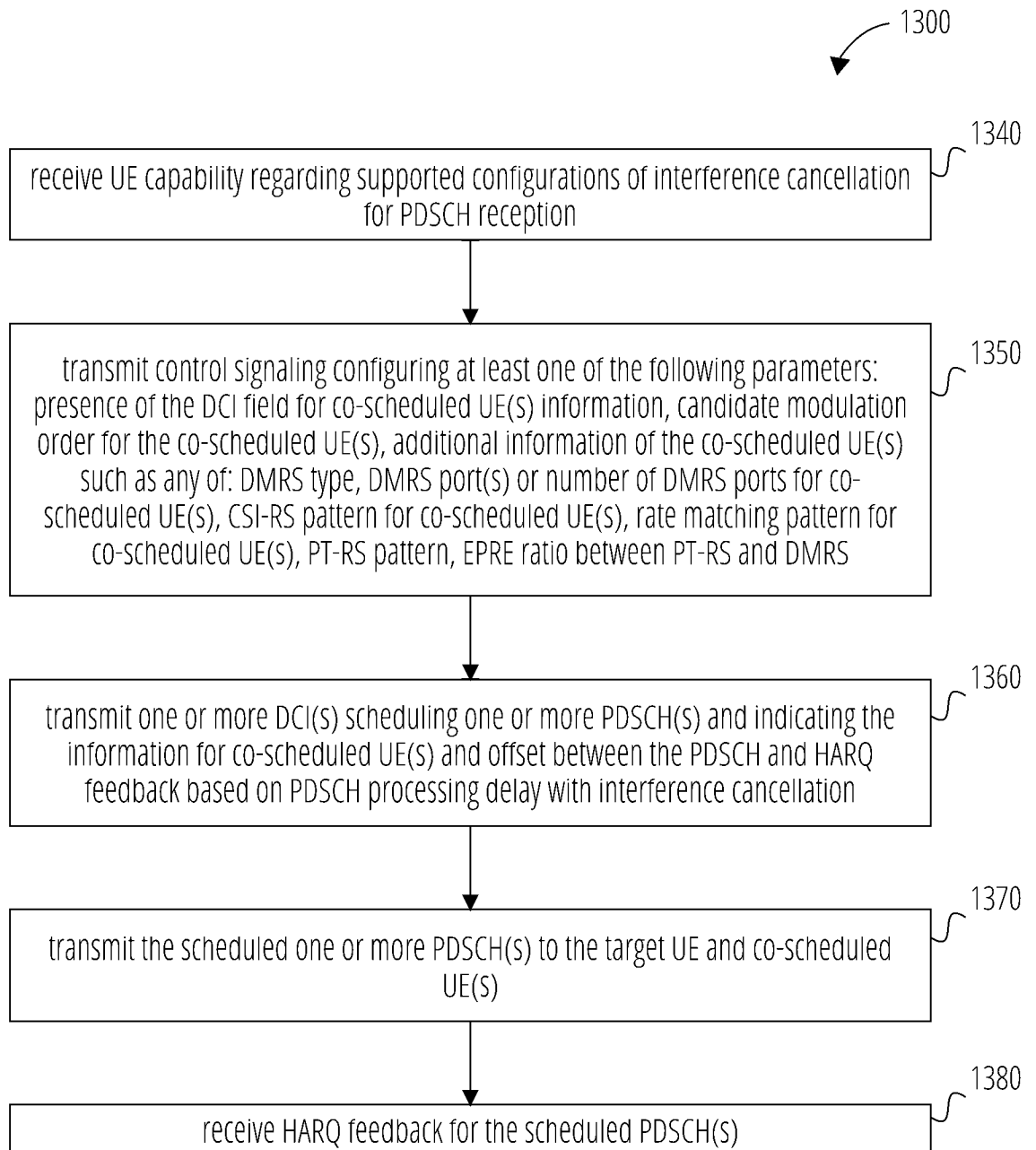


FIG. 13

13/13

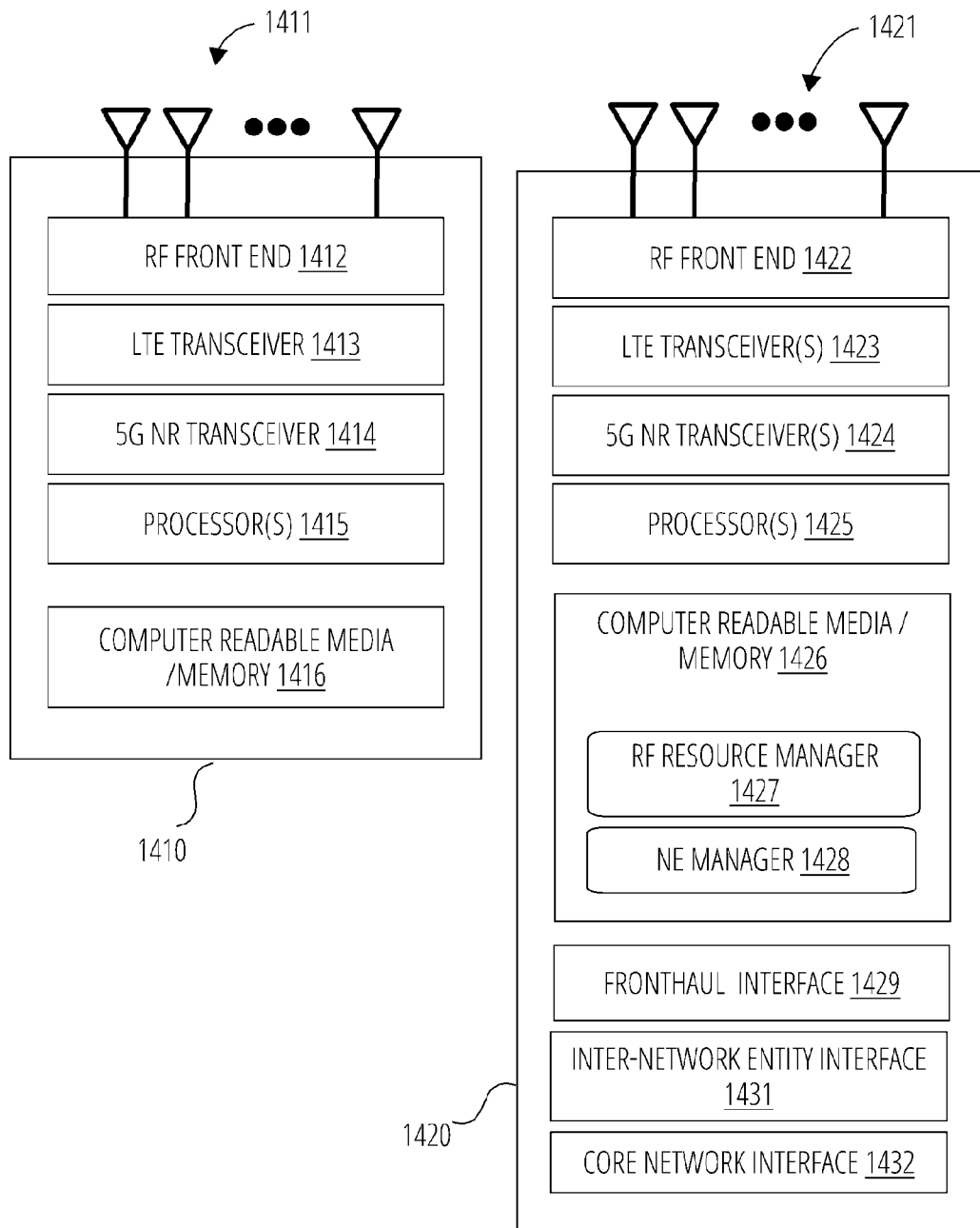


FIG. 14

INTERNATIONAL SEARCH REPORT

International application No

PCT/CN2023/112563

A. CLASSIFICATION OF SUBJECT MATTER

INV. H04L5/00 H04W72/23 H04J11/00
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04L H04W H04J

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2018/124708 A1 (DAVYDOV ALEXEI [RU] ET AL) 3 May 2018 (2018-05-03) paragraph [0035] - paragraph [0041]; figure 5 -----	1-16
A	WO 2020/002662 A1 (ERICSSON TELEFON AB L M [SE]) 2 January 2020 (2020-01-02) figure 8 -----	1-16
A	US 2022/085939 A1 (MONDAL BISHWARUP [US] ET AL) 17 March 2022 (2022-03-17) paragraph [0004] - paragraph [0085] -----	1-16



Further documents are listed in the continuation of Box C.



See patent family annex.

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"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

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"&" document member of the same patent family

Date of the actual completion of the international search

2 February 2024

Date of mailing of the international search report

19/02/2024

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Authorized officer

de Paz Alberola, R

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/CN2023/112563

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